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Real-Time Attendance and Security Monitoring System Using IoT-RFID-Webserver-Android: A Low-Cost Solution

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***Abstract*—The integration of the Internet of Things (IoT) and information technology (IT) fosters intelligent operations within small and medium enterprises (SMEs). This article aims to develop a real-time attendance and security monitoring system utilizing IoT, RFID, webserver, and Android technology with open-source components. Open-source technology is more operationally cost-effective. The monitoring system is designed with four kinds of functions and one analytical framework. (1) The attendance and security device function. (2) The monitoring function oversees attendance and body temperature using a web server and Android notifications. (3) The message notification function detects human motion, and the fire uses the Telegram platform. (4) The remote control function for electric sockets uses the Blynk platform. (5) The analysis of attendance performance uses a Fuzzy Logic method. The results indicate that the functions in parts 1 through 4 are functioning correctly. It has an impact on effective, efficient, and responsive operations. Because the attendance and security monitoring activities operate in real-time, autonomously, and remotely within SMEs. Then, the Fuzzy-Logic analysis provides a clearer and quantifiable measure of employee attendance. This system design leverages open-source technology for low-cost operations among SMEs. If SMEs need future enhancements for scalability, consider the cost implications of enhancing the system. Consider improving the system's scalability by utilizing paid services. Speed up the employee attendance analysis time using a Fuzzy-Logic, Machine Learning embedding system into the microcontroller. Then, optimize the processing workflow of the system networks by incorporating edge computing technology for enhanced big data storage and extended operating times.**

***Keywords*—Industry 4.0; low-cost technologies; small-medium enterprises; real-time attendance; security monitoring system.**

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I. INTRODUCTION

The Fourth Industrial Revolution (Industry 4.0) is intrinsically linked to the application of the Internet of Things (IoT) and information technology (IT). These technologies have a profound impact on human resource management. Various research findings indicate that the Internet of Things (IoT) and Information Technology (IT) offer substantial benefits in the realm of human resource management. Such research results [1]. The combination of IoT and IT can create a smart and automated attendance system. Then, according to [2], IoT and IT have brought about a transformation of management in human resources development (HRD). Because it can help reduce time consumption, facilitate HRD work, and improve employee performance. Furthermore [3]The implementation of IoT and IT technologies for attendance tracking has facilitated the accurate recording of working hours and overtime, while also increasing worker discipline and productivity.

IoT is a smart object tool with the ability to connect objects, devices, and information via the internet [4]. According to [5], IoT is a solution to connecting physical objects using communication networks, sensors, electronics, and software. IoT's smart object capability characteristic is the ability to connect, identify, and monitor objects in real-time [6]. According to [7], the application of IoT will bring innovation in small and medium enterprises (SMEs). Then, accompanied by the development of human resources who master IoT technology. According to [8], the application of IoT can increase productivity in SMEs, including improved product quality, internal communication, safety, and reduced errors. However, according to [9], there are challenges that SMEs face in implementing IoT. It concerns the availability and cost of information and computer technology (ICT) infrastructure. Then, it involves the organizational culture's ability to accept and adapt to ICT.

The article aims to apply IoT and IT by creating an IoT-RFID-Webserver-Android-based attendance and security system. The attendance monitoring system is designed with an automatic database and real-time capabilities. According to [3], an attendance monitoring system with automation and real-time capabilities will foster worker discipline and productivity. Data will be recorded in real-time and automatically stored on the database server. Processes maintain worker discipline by ensuring the attendance system can guarantee a match between working hours and wages due. Then, the proposed system is designed to allow business leaders to monitor through real-time notifications on mobile devices. In response to the aftermath of the COVID-19 pandemic. The system employs RFID technology to enable contactless attendance. It is equipped with a body temperature sensor to prevent the spread of COVID-19. Besides the attendance system, it is integrated with an environmental security system for fire and theft detection. The security system is designed to monitor in real-time and can be remotely controlled by a handphone.

The proposed system's design differs from that of previous research. It uniquely integrates attendance and security monitoring functions into a real-time, automated system. This system combines IoT, RFID, webserver, and Android technologies. Furthermore, the technology employed is open source. This helps reduce operational costs for SMEs. While previous research employed a system design that does not integrate the aforementioned technology. Such as research [10], [11] designed an attendance system using an IoT-based fingerprint. Research [12], [13] made an attendance system with IoT-based RFID. Furthermore, research [1], [14] made an attendance system using blockchain and IoT. [15], [16] designed an attendance system using an IoT-based smartphone.

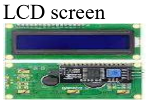
II. Materials and Method

A. Materials

The materials for the attendance and security monitoring system include electronic components, program applications, middleware, cables, and device casing. These materials can be categorized into two groups: the attendance system and the security system. The electronic components comprise Arduino Uno R3 and NodeMCU Esp8266 V3 microcontrollers, various sensors (RFID RC522, Temperature Sensor MLX90614, HC-SR04 Sensor Ultrasonic, HC-SR501 Pir Motion sensor, Flame sensor), and actuators (Relay 2 channel, Buzzer active 5v, LED light, LED screen, Push button). The application programs utilize Arduino Integrated Development Environment (Arduino IDE), XAMPP, and Android Studio. The middleware employs Firebase Cloud Messaging, Cloud Blynk, and Telegram Instant Message Bot. All of these technologies are open source. Considerations in selecting hardware components include being tested, offering affordable prices, and being trusted by researchers. Such as Arduino Uno V3, NodeMCU Esp8266 V3, RFID RC522 used by [12], [13], [17]. Next, considering Firebase Cloud Messaging, Cloud Blynk, and Telegram Instant Message Bot as middleware options, these are open-source solutions.

Details are provided in Table 1, which lists the materials/components, their functions, and their locations within the system. The area is explained based on the process flow diagram of the system presented in Figure 1. Namely, (1) attendance-body temperature, and security-socket devices function; (2) monitoring function of attendance-body temperature data; (3) notification message function of human movement and fire detection; (4) remote control function for electric sockets.

TABLE I
Components and Functionality of IoT-RFID-Webserver-Android-Based Attendance and Security Monitoring Systems

Components	**Unit**	**Functionality of components**	**Location in the system**
Attendance System			
Attendance device casing 	1	Place for the attendance tool container	The location is in the attendance and body temperature device.
Arduino Uno R3 	1	Operate and control the body temperature sensor, ultrasonic sensor, push button, buzzer, and LCD screen..	
NodeMCU Esp8266 V3 	1	Operate and control the RFID reader-tag, LED light.	
Reader-Tag RFID RC522  	1	Reader RFID to identification of the chip number on the RFID Tag (RFID Card).	
Infrared Temperature Sensor MLX90614 	1	Detects body temperature.	
HC-SR04 Sensor Ultrasonic 	1	Detects the distance from the body part that will trigger the body temperature sensor.	
Push Button tactile switch 12x12 mm with cap 	1	The button changes the attendance time mode: In, Break, Return, and Go Home.	
Buzzer active 5v 	1	Sound indicator when the body temperature is more than 37^{0}C.	
LED light 	1	The indicator showed the light turned on to indicate the success of absence activities.	
LCD screen 	1	Screen to display data of employee name, body temperature, and attendance mode.	
Breadboard 	1	A place to plug in sensors and actuators.	
Male-female jumper cable	30	Male-female type cable is used as a circuit connector between components.	

Components	Unit	Functionality of components	Location in the system
 Female-female jumper cable 	20	Female-female type cable is used as a circuit connector between components.	
Adapter 5V + micro USB cable 	1	Power source connector for a microcontroller with a 5V voltage source.	
Arduino IDE application	1	Program application to embed attendance and body temperature systems into microcontrollers.	
Xampp application	1	An application for creating a MySQL Database and a Web server for attendance websites.	The Location is in the server database MySQL on the attendance and body temperature device.
MySQL database	1	An application acts as middleware for storing attendance data and as a connector between the attendance IoT device and the attendance website.	
Android Studio application	1	An application for creating an Android application.	The location is in the computer.
Firebase Cloud Messaging	1	An application such as middleware from Google's cloud-based messaging service for attendance message notification systems and handphones.	The location is in Google's cloud-based messaging service.
Attendance website 	1	The website application features attendance functions: card scanning, attendance recap, Employee table, and Home.	The location is displayed on the server computer.
Security System			
Security device casing 	1	Place for the security tool container.	The location is in the security device.
NodeMCU Esp8266 V3 	1	Operate and control sensors (motion, fire), LED lights, 2-channel relay, buzzer on security device.	
HC-SR501 Pir Motion Sensor 	1	A human motion sensor to detect the movement of a human within a distance is less than 6 meters.	
Pir Motion sensor casing 	1	Casing as a protector for the Pir Motion sensor.	
Flame sensor 3-pin 	1	The sensor detects the presence of fire.	
Relay 2 channel 	1	Actuator to trigger on/off electric power for 2 electric sockets.	
LED light 	1	The light indicator lights up when there is an internet connection.	
Buzzer active 5V 	1	Sound indicator when detecting human movement and fire.	
One-channel electric socket 	2	Power source plug for the microcontroller of the attendance systems.	
Mini breadboard 	2	A place to plug in components for security and electric socket remote control systems.	
Male-female jumper cable 	8	Male-female type cable is used as a circuit connector between components.	
Female-female jumper cable 	4	Female-female type cable is used as a circuit connector between components.	
Adapter + micro USB cable 	1	Power source connector for a microcontroller with a 5V voltage source.	
Arduino IDE application	1	Program application to embed attendance and body temperature systems into microcontrollers.	The location is in the computer.
Blynk application	1	IoT platform service for Electric Socket Remote Control systems.	The location is in the account of the Blynk application on a smartphone.
Telegram Bot	1	An instant messaging service for human movement and fire detection.	The location is in account the Telegram application on a smartphone.

B. Methods

The research methodology involves an experimental design to develop an attendance and security monitoring system. Subsequently, the quantitative Fuzzy-Logic method is employed to predict the level of worker discipline based on the attendance data. Figure 1 illustrates the flow scheme of the process for the attendance and security monitoring system. The process is divided into five subsystems. The first four subsystems pertain to the tool system's functions, and the fifth is dedicated to data analysis.

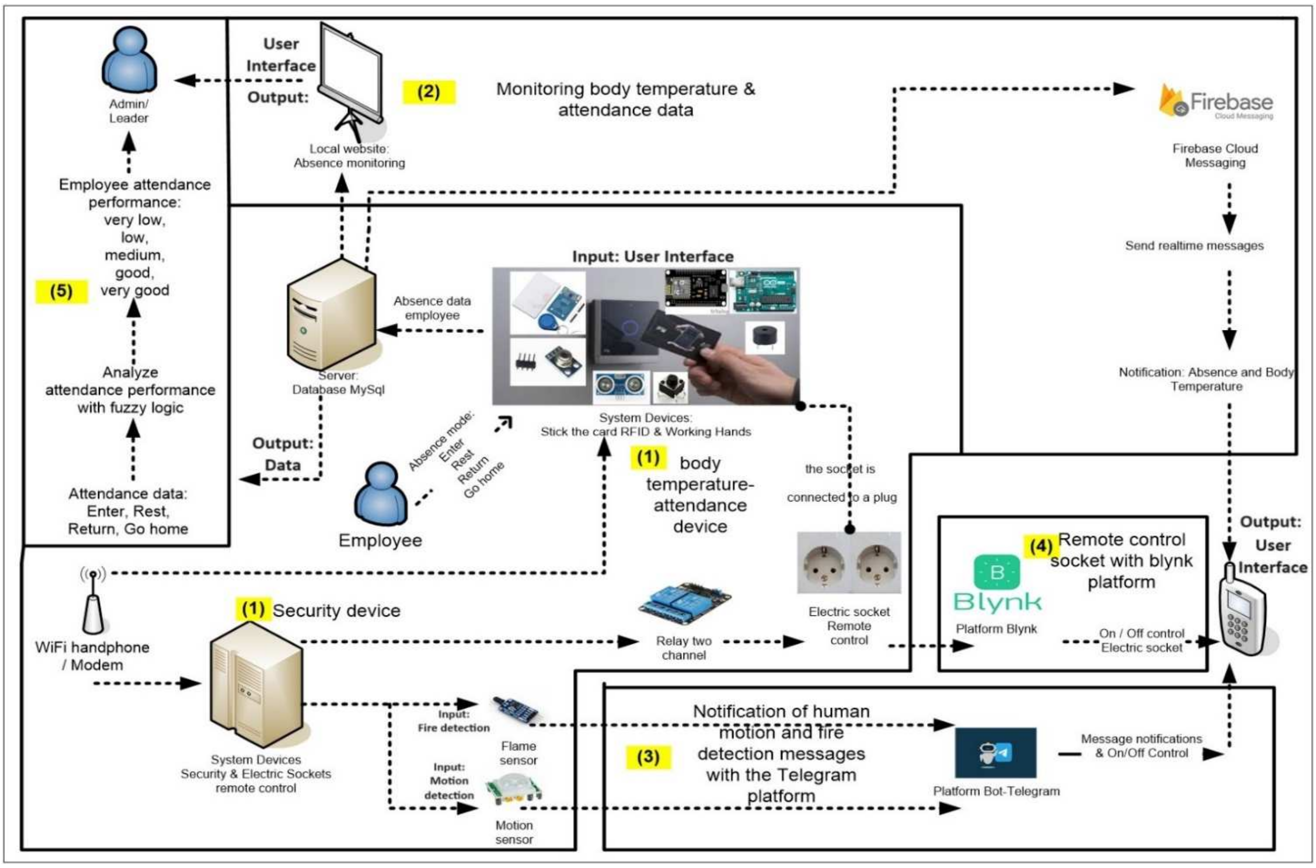


Fig. 1 Schematic flow of the process: attendance and security monitoring system based on IoT-RFID-Webserver-Android

Based on Figure 1, the first subsystem encompasses device functions of attendance, body temperature detection, and security. The operational process in Section 1 is as follows: the administrator adjusts the attendance mode (entry, break, return, or go home) by pressing the button to change the mode. The technical aspects of the attendance system are: (1) recording the employee's RFID card in the database. All employees' RFID card is attached to the RFID reader. It will be connected to the Employee Data Menu website. Next, input the name and address of the employee. (2) Detecting the employee's body temperature by bringing the hand to the ultrasonic proximity sensor at a distance of < 8 cm. Then, the ultrasonic proximity sensor is connected to the body temperature sensor. The worker's body temperature is detected without direct contact. (3) Then, the worker attaches the RFID card to the RFID reader. The RFID card number will be detected and matched with the employee database. In seconds, it will display the employee's identity and body temperature information on the LCD screen. It also sends the information to subsystems 2, 3, and 4.

According to Figure 1, the second subsystem functions to monitor attendance data within the local website application. Additionally, this subsystem monitors attendance and body temperature data through the Android application. The flow process is described as follows: (1) The RFID card number, detected by the attendance device (subsystem 1), contains information such as name, address, and attendance times. These are stored in the MySQL database within the attendance table. (2) This information is transmitted to the website, which features four menus: home, employee data, attendance recapitulation, and card scan. (3) Simultaneously, notification of employee information and body temperature values are transmitted in real-time to the Android application by the Firebase Cloud Messaging as a middleware service. The message notification contains the employee's name, attendance hours, and body temperature.

Based on Figure 1, the third subsystem serves a security function by sending message notifications to the handphone. These messages are transmitted to the handphone via the Telegram Bot Middleware. When the motion sensor detects human movement or the fire sensor detects a fire. Additionally, the motion detection system is designed to be remotely controlled, allowing for the activation or deactivation of the motion sensor by sending an "on/off" message through the Telegram application. During operational hours, the motion sensor is deactivated. Conversely, when operational hours have concluded, the motion sensor is activated.

The fourth subsystem, marked with number 4, has an "on/off" remote control function for the electric sockets. The electric sockets serve as the power source for the attendance device. The remote control function "on/off" is available on the Blynk platform. This makes it easier for managers or administrators to turn on or off the device using a smartphone remotely.

The fifth subsystem, marked with number 5, is the utilization of attendance data to assess employee attendance performance. The performance analysis employs the Fuzzy Logic method. The data variables analyzed include attendance times for entry, breaks, returns, and go-home. A case study was conducted at SMEs Batik in Jombang Regency, East Java.

Data samples were collected in June 2024, amounting to 326 entries.

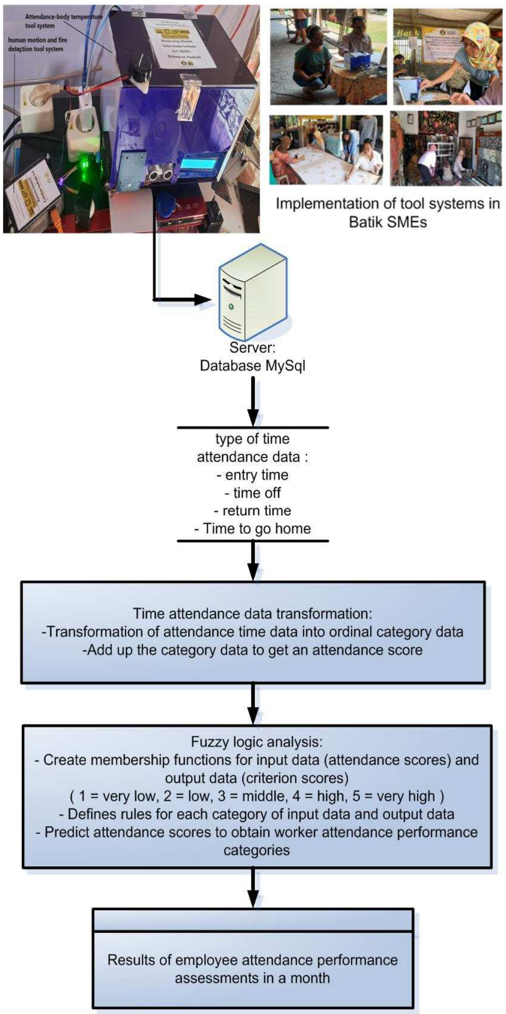


Fig. 2 Gathering attendance data and analysis of employee attendance performance with the fuzzy logic method

Figure 2 illustrates the process of gathering attendance data and analyzing employee attendance performance using the Fuzzy Logic method. The initial stage of analysis involves editing and transforming the attendance data (entry, break, return, and go home) into attendance performance category data using the IBM SPSS application. Furthermore, the process of analyzing worker attendance performance with the Fuzzy Logic method using the Jupyter Notebook application. The following are the steps in processing and transforming attendance data to category data:

a. Retrieve attendance data from the MySQL Database by exporting it in CSV format.
b. Open the IBM SPSS application and import the attendance data file.
c. Perform editing and coding on data variables. Data variables are entry time, break time, return time, and go-home time.
d. The data variables were transformed into time attendance suitability categories.

Next, analyze fuzzy logic to predict worker attendance performance using the Jupyter Notebook application.

a. Define the import library.
b. Define the universe definition of attendance score and criteria.
c. Create membership functions for input data (attendance score) and output data (criteria score).
d. Define rules for each category of input data and output data.
e. Predict workers' attendance performance scores and categories based on attendance scores.

III. Results and Discussion

A. *Results*

The scheme results of the attendance and security monitoring system are shown in Figure 3. It shows the steps of the proposed monitoring system based on IoT-RFID-Webserver-Android technology. Figure 3, number 1 depicts the circuit components diagram of the device. Then, number 2 presents the results of monitoring attendance and body temperature data on the website and Android application. Number 3 displays the monitoring of human motion and fire detection on the Telegram platform. Number 4 shows the monitoring results from the remote control of electric sockets using the Blynk platform. Lastly, number 5 presents the results of employee attendance performance analysis using the Fuzzy Logic method.

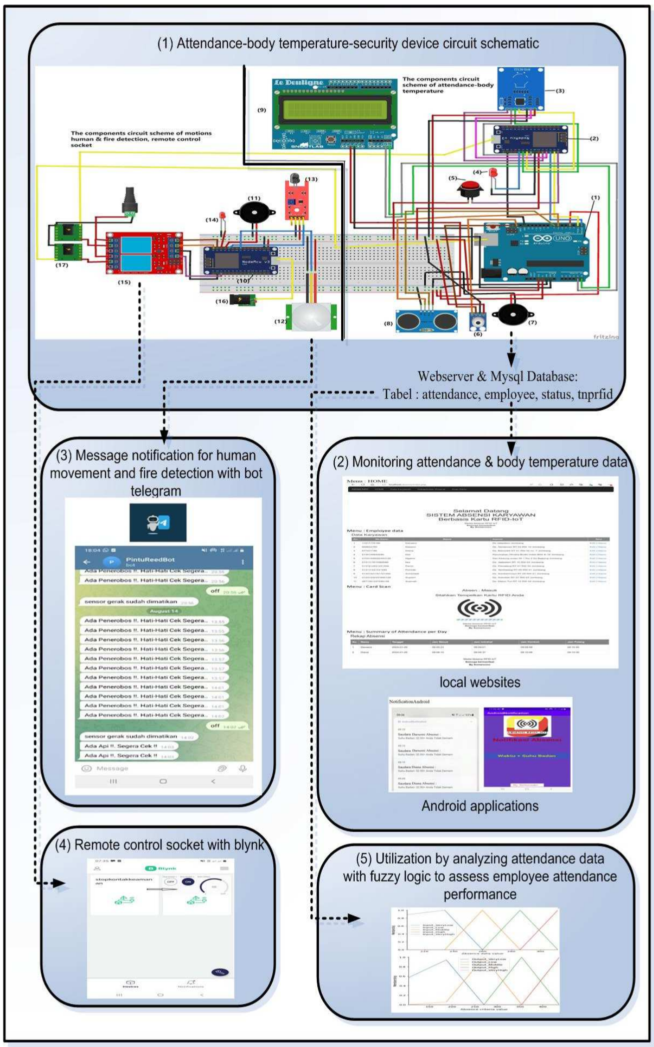


Fig. 3 The scheme of the five subsystems of the attendance and security monitoring system

1) Subsystem 1 – Devices function of attendance, body temperature, and security:

The first subsystem is attendance, body temperature, and security devices function. A diagrammatic illustration of the device making is shown in Figure 4. Figure 4 shows the relationship between components and work program syntax of the attendance and security system. Details about the device making will be explained in Figures 5, 6, and 7. Then on tables 2, 3, and 4.

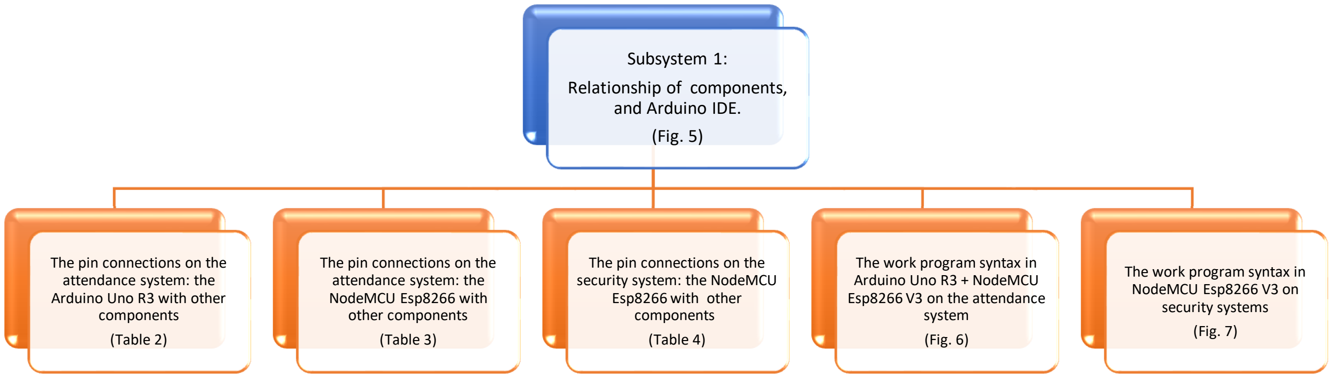


Fig. 4 A diagrammatic illustration of the device making in subsystem 1

Figure 5 illustrates the relationship between the components and *the Arduino Integrated Development Environment* (Arduino IDE) software integrated into subsystem 1. There are two functional parts, namely the attendance and body temperature, and security.

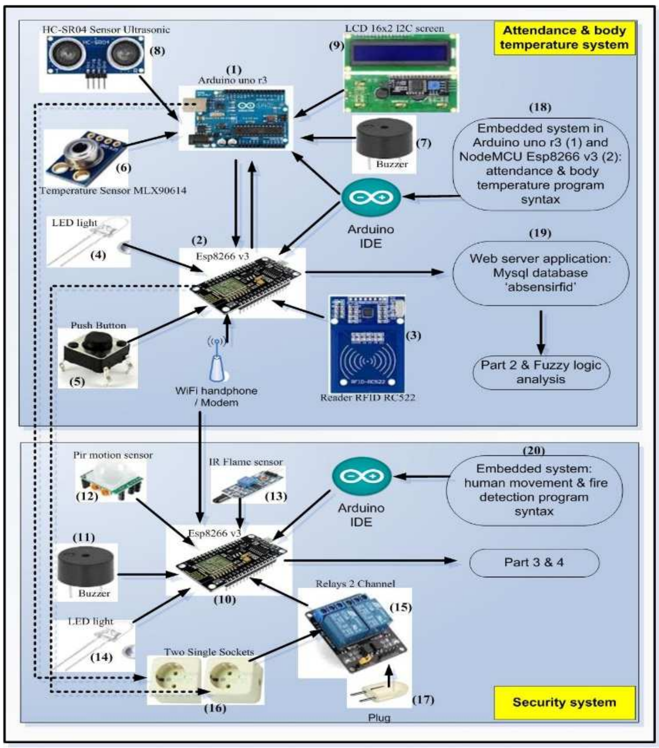


Fig. 5 Relationship between components and Arduino IDE programs in subsystem 1

Based on Figure 5, the attendance and body temperature device utilize the Arduino Uno R3 microcontroller (number 1) to operate and control the body temperature sensors, proximity ultrasonic sensors, LCD screen, and buzzers. The connections of the Arduino Uno R3 with (number 6) the MLX90614 body temperature sensor, (number 8) the HC-SR04 ultrasonic distance sensor, (number 9) the 16x2 I2C LCD screen, and (number 7) the buzzer. Additionally, the Arduino Uno R3 is also connected to the microcontroller (number 2) NodeMCU Esp8266 V3. The connection between the pins of the above components is shown in Table 2.

TABLE II
THE PIN CONNECTIONS OF THE ARDUINO UNO R3 WITH OTHER COMPONENTS IN ATTENDANCE & BODY TEMPERATURE SYSTEMS ON SUBSYSTEM 1

Arduino pin	Temperature sensor pin
3.3 V	3.3 V
Gnd	Gnd
SCL	SCL
SDA	SDA

Arduino pin	I2C LCD pin
5 V	5 V
Gnd	Gnd
A5	SCK
A4	SDA

Arduino pin	Ultrasonic sensor pin
5 V	VCC
D7	Trig
D6	Echo
Gnd	Gnd

Arduino pin	Buzzer pin
D3	+
Gnd	-

Arduino pin	Esp8266 pin
TX	D1
RX	D2

Furthermore, the NodeMCU ESP8266 V3 microcontroller (number 2) has the function of operating and controlling the work of the RFID reader, push buttons, and Wi-Fi networks. The Esp8266 connection to Wi-Fi networks enables attendance and body temperature data can be sent to the Web server database and Android application wirelessly. The pins NodeMCU ESP8266 V3 is connected to: (number 3) RC522 RFID reader, with (number 4) LED light, and (number 5) push button. The connection between the pins of the above components is shown in Table 3.

TABLE III
THE PIN CONNECTIONS OF THE NODEMCU ESP8266 V3 WITH OTHER COMPONENTS IN ATTENDANCE & BODY TEMPERATURE SYSTEMS ON SUBSYSTEM 1

Esp8266 pin	Reader RFID pin
3.3 V	3.3 V
D3	RST
Gnd	Gnd
D6	MISO
D7	MOSI
D5	SCK
D4	SDA

Esp8266 pin	LED Light pin
Gnd	-
D8	+

Esp8266 pin	Push Button pin
3.3 V	Leg 1
D0	Leg 2

Next, in the security function device based on Figure 5. The NodeMCU Esp8266 V3 microcontroller (number 10) is a place to operate and control the work of the Pir Motion sensor, IR Fire Flame sensor, Buzzer, LED light, and two-channel Relays. The NodeMCU Esp8266 V3 is connected to (number 12) Pir Motion sensor, (number 13) IR Fire Flame sensor, (number 11) Buzzer, (number 14) LED light. The Esp8266 is also connected with (number 15) two-channel Relays pin inputs. Then, the Relays' pin outputs are connected to (number 16) the two Sockets. Next, the two Sockets are connected to the plug (number 17). And the plug connected to the Relay pins outputs. The connection between the pins of the above components is shown in Table 4.

TABLE IV
THE PIN CONNECTIONS OF THE NODEMCU ESP8266 V3 WITH OTHER COMPONENTS IN SECURITY FUNCTION ON SUBSYSTEM 1

Esp8266 pin	Pir Motion pin	Esp8266 pin	IR Flame pin
3.3 V	+	3.3 V	VCC
D5	Signal	D4	DO
Gnd	-	Gnd	Gnd
Esp8266 pin	Buzzer pin	Esp8266 pin	LED light pin
D3	+	D2	+
Gnd	-	Gnd	-
Esp8266 Pin	Two-Relay pin (input)	Two Plugs pin	Two-Relay pin (output)
VU	DC +	Plug 1 (+)	COM1
Gnd	DC -	Plug 2 (+)	COM2
D0	IN1	Plug pin	Jack pin
D1	IN2	Negative on Plug 1 & 2 interconnected and connected with	Negative (-)
		Two-Relay pin (output)	Jack pin
		NO1, NO2 pin connected with	Positive (+)

Based on Figure 5, the security function is also designed to remotely control the electric sockets (number 16) as the power source of the attendance device. By a USB cable 5V adapter that connected the microcontrollers 1 (Arduino Uno R3) and 2 (NodeMCU Esp8266 V3) to electric sockets. Next, based on Figure 6 is step involves making the work program syntax for the attendance and body temperature monitoring functions to Arduino Uno R3 and NodeMCU Esp8266 V3 microcontrollers. The work program syntax on microcontrollers will be uploaded with the IDE application.

The main points of the work program syntax of the attendance and body temperature system are marked in Figure 6, number 18. The looping work program syntax to do work in Arduino Uno R3 is as follows:

a. The work program syntax displays the body temperature and distance sensor values to the serial monitor.
b. The conditional work program syntax to turn off or turn on the buzzer as an alarm for body temperature, which is not a fever or fever status. And the work program syntax displays the body temperature value and status on the I2C LCD screen. If the limb body is detected by the ultrasonic sensor with a distance of < 8 cm, and the body temperature is < 37°C. The buzzer will not sound, and the status "no fever" will be displayed on the LCD screen. But if the body temperature is detected $\geqslant 37^{0}$C. Then the buzzer sounds, and the status "fever" is displayed on the LCD screen.
c. The work program syntax of serial communication between Arduino Uno R3 and NodeMCU Esp8266 V3 . The program syntax content is to read the data request from NodeMCU Esp8266 V3. Then, Arduino Uno R3 will send body temperature and distance data to NodeMCU Esp8266 v3. If the body temperature is detected again. The Arduino Uno R3 sends data again to NodeMCU ESP8266 V3.

Next, based on Figure 6, number 19 is the looping program syntax to do work in NodeMCU Esp8266 V3. The details are as follows:

a. The work program syntax requests, reads, and combines the array data of body temperature and distance. That sent from the Arduino Uno R3.
b. The work program syntax changes the attendance mode, namely entering, resting, returning, and going home mode by pressing the button. When the button is pressed, it will connect to the attendance website database. It will change the attendance mode displayed on the attendance website and tool LCD screen. The first press is the button to enter mode. The second time is breaking mode. The third press is the return mode. Press the fourth time is go into home mode. And the next press will return to enter mode again.
c. The work program syntax reads and sends the RFID card number to the Mysql Database in the “tnprfid” table.
d. A message notification program syntax to the Android application containing the message: attendance time and body temperature value. The message notification process is when the RFID card is attached to the RFID reader. Then it will call the void “sendNotification” program syntax. The message notification will be sent to the handphone.

Next, the work program syntax for the security system is shown in Figure 7, as follows:

a. The conditional program syntax on/off for controlling the motion sensor. If there is an "on" message from the client (handphone). Then the motion sensor will be activated, and the server (Telegram Bot) will send the message "the motion sensor has been activated" to the client's handset. If there is an "off" message from the client's handphone. Then the motion sensor is in an inactive condition and will receive the message "the motion sensor is not active".
b. The conditional program syntax for human motion and fire detection. On the motion sensor, if the condition is active, the motion sensor detects human movement. Then sound the buzzer and send a message "there is a breach, check immediately" to the client's handphone. On the fire sensor, if it detects hot air around the sensor. Then sound the buzzer and send a message "there is a fire, check immediately" to the client's handphone.

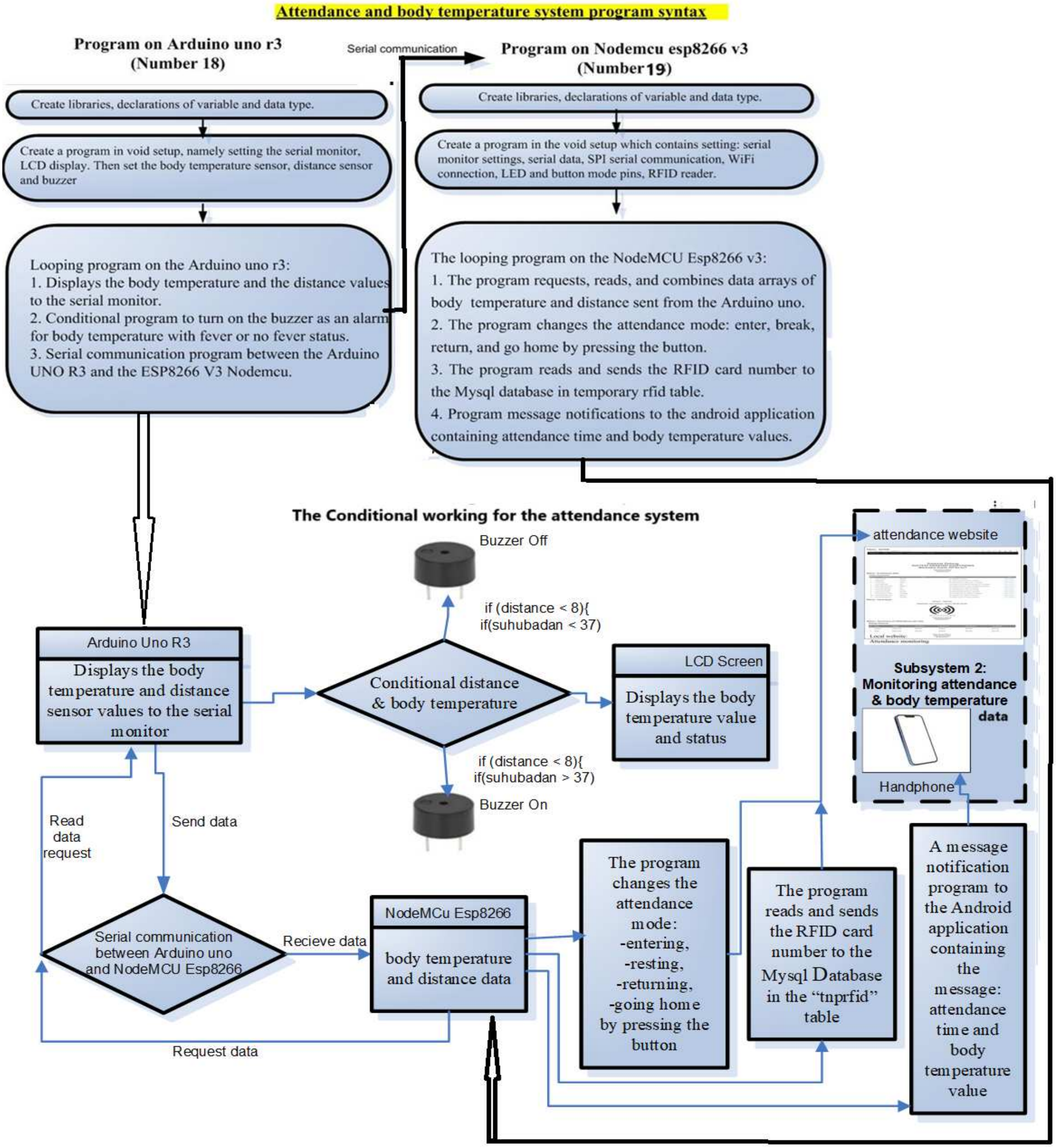


Fig. 6 Illustration of work program syntax in the attendance and body temperature system on subsystem 1

Based on Figure 7, the explanation of the looping program syntax for remote control electric sockets as follows:

a. Set up the Blynk program syntax in void write to connect sockets as variables 1 and 2 with virtual pins V0 and V1 at the Blynk platform.
b. Creates a conditional program syntax, if virtual pin V0 = 1 is activated. Then the relay-1 will be "on" the socket 1. Otherwise, if it is deactivated (V0 = 0). It will be "off" the relay of socket 1. Next, if virtual pin V1 = 1 is activated, the relay-2 will be "on" the socket 2. Conversely, if it is deactivated, it will be "off" the relay of socket 2.
c. Create a recurring work command in the void loop for the remote-control electric sockets by calling the Blynk function "Blynk.run()" and activating the timing function "timer.run()".

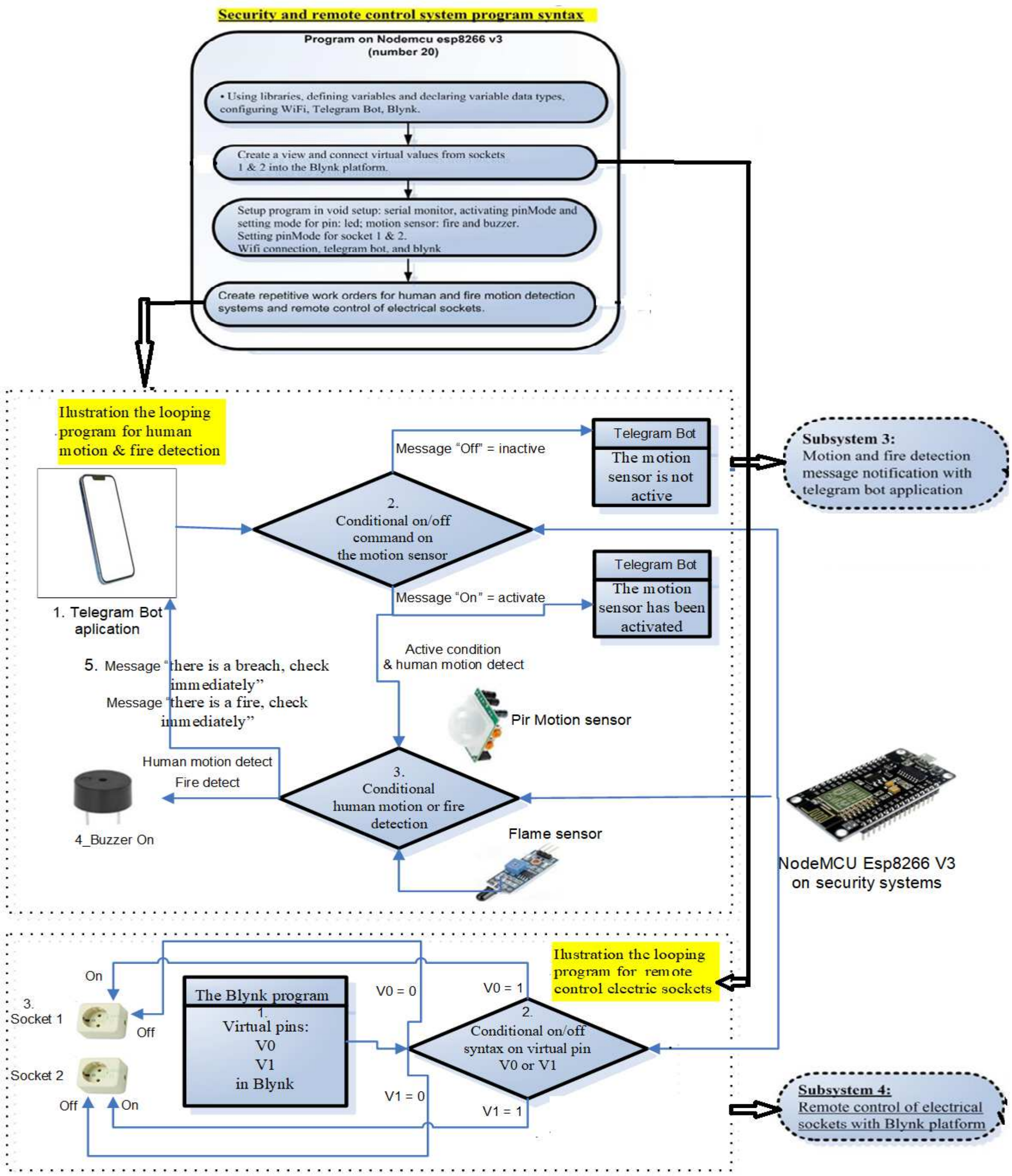


Fig. 7 Illustration of the conditional work syntax program in the security system on subsystem 1

2) Subsystem 2 – Monitoring attendance and body temperature data:

Subsystem 2 contains two applications for monitoring attendance and body temperature data. The first application is a web server-website for monitoring attendance data. The second application is a web server that sends Android message notifications to the handset. The process of creating subsystem 2 is presented in Figure 8.

The attendance data result from the system device subsystem 1. Then stored in the "absensirfid" database webserver. Which contains four tables, namely "attendance", "employee", "status", and "tnprfid". Details of the table contents are as follows:

a. The attendance table contains seven variables, namely sequence number, card number, date, entry time, break time, return time, and go home time. The attendance table functions to store data on attendance hours.
b. The employee table contains four variables, namely sequence number, card number, name, and address. This table stores RFID numbers and employee data.
c. The status table contains attendance modes, namely entry mode (code 1), break mode (code 2), return mode (code 3), go home mode (code 4). This table serves as a choice of attendance mode.
d. The tnprfid table contains RFID card numbers. This table temporarily holds the new employee card number. That will be inputted into the employee table.

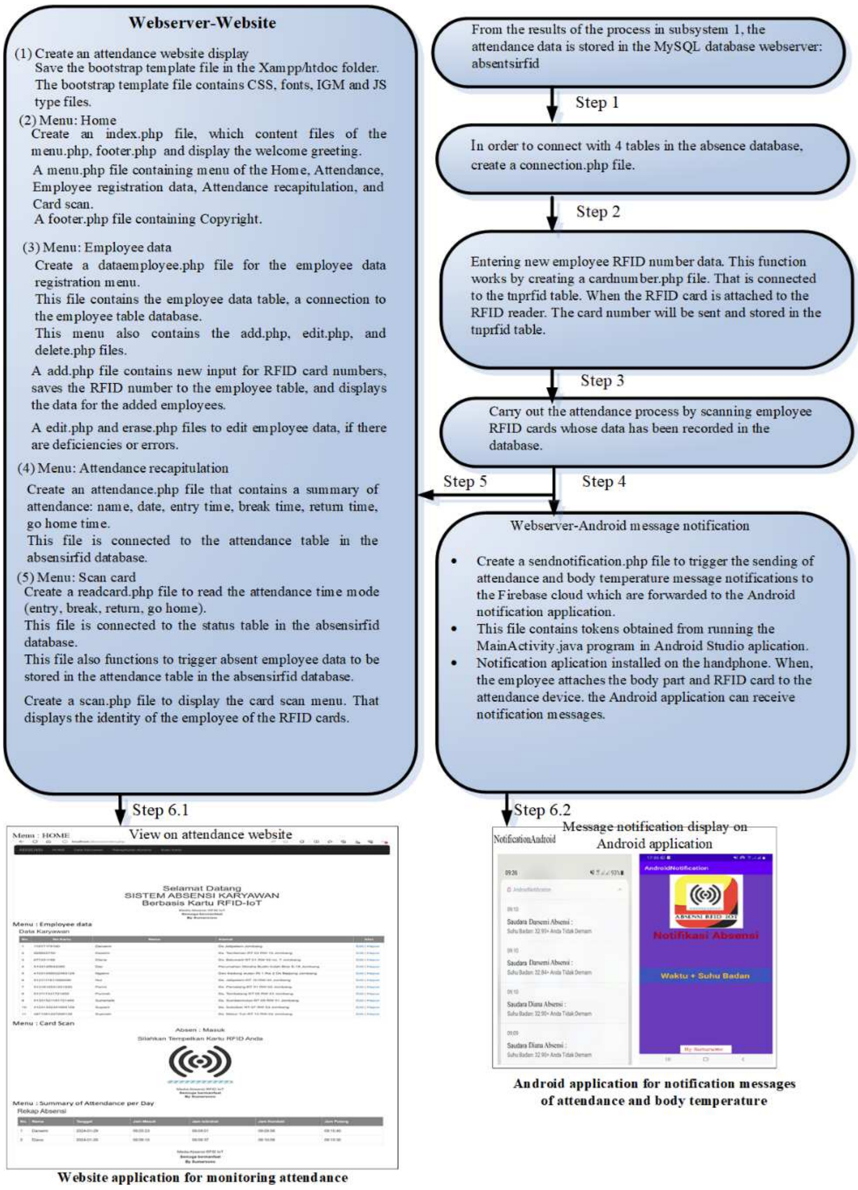


Fig. 8 The creating process and relationships in the subsystem 2

After attendance data is stored in the database. It will be displayed on the attendance Website. The Website contains 4 menus, namely: “Scan Card”, “Absence Recapitulation”, “Employee Data Registration” and “Home” (Figure 8 step 6.1). Furthermore, on the other hand, simultaneously. Attendance and body temperature data are sent to the handphone via message notification (Figure 8 step 6.2).

Based on Figure 8, the working process of the attendance website is summarized as follows:

a. Creating an attendance website using a text editor application with the PHP program language.
b. After the website program coding is made and the part 1 device has been implanted with the attendance system.
c. Then next, the employee data in the form of a RFID card number is attached to the RFID reader. The RFID number will be input automatically into the table in the "absensirfid" database, and also displayed on the attendance Website.
d. As shown in Figure 8, this process can be done. Because there is a connection from the connection.php file (on step 2). It will connect the tables in the "absensirfid" Database with the attendance website.

Next, the building process of the Android application for message notification is summarized as follows:

a. Create an Android Studio project with the name "AndroidNotification".
b. Create an activity mail.xml file for the application display.
c. Connecting the "AndroidNotification" project with Firebase Cloud Messaging.
d. Create a Myservice.java file for the notification application display.
e. Create an AndroidManifest.xml file to connect Myservice.java with Firebase Cloud Messaging for message delivery.
f. Create a MainActivity.java file to generate a token as an IP address for the address to which the message notification is directed. Where the IP address token is

embedded in the website program in the "sendnotification.php" file. So when workers do attendance by attaching RFID cards. Then the "sendNotification.php" file will send a message notification to the handphone.
g. Install the notification Android application on the handphone.

3) Subsystems 3 and 4 – Motion and fire detection with message notification, and remote control of electric sockets:

Figure 9 shows the process in subsystem 3, the notification of motion and fire detection messages with the Telegram bot platform. It also shows the process in subsystem 4, the remote control of the electric sockets with the blynk platform.

Subsystem 3 is an advanced of the work of the security device in subsystem 1. This subsystem's function is user interface to detect the human motion and fire by sending message notifications to the Telegram application on the handphone. For The human motion detection system, the motion sensor can be control "on/off" from the handphone. When people are working, it can be turned "off" motion sensor and vice versa turned "on" when no one is around.

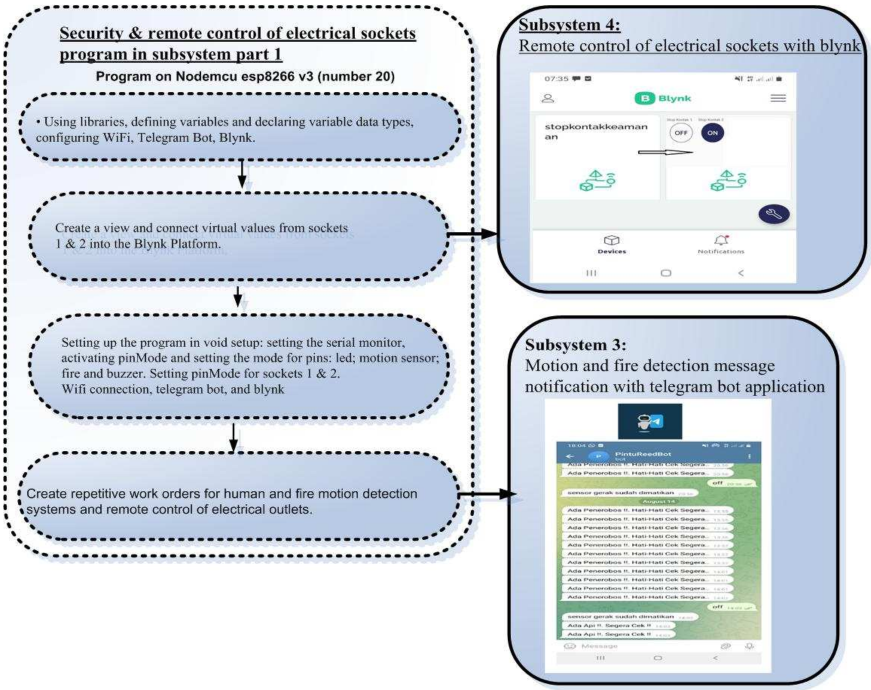


Fig. 9 Processes of subsystems 3 and 4 are associated with subsystem 1

Based on Figure 9 in Subsystem 3. Briefly create a motion and fire detection system configuration in the Telegram application, as follows:

a. Install the Telegram application and create an account on the handphone.
b. Create a Telegram Bot by searching "botfather" and clicking the "start" button.
c. Next, type "/newbot" and "send".
d. Create a unique name for the Telegram Bot.
e. Create a unique name for the username. It will get a Telegram Bot token. This token will be entered into the Telegram authentication program in the Arduino IDE. So that the NodeMCU Esp8266 V3 microcontroller can connect to the Telegram application.
f. Create a "bot ID" by searching "get bot ID" which is the destination address number. The "bot ID" number will be entered in the Arduino IDE program.

An illustration of the process of creating tokens and Bot IDs in the Telegram application is shown in Figure 10.

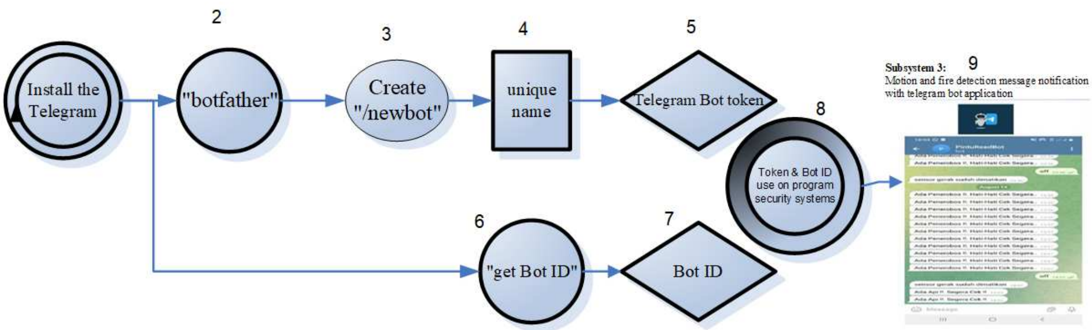


Fig. 10 The process of creating tokens and ID Bot in the Telegram application

Subsystem 4 has a remote control function for the power source of the attendance device. Two electric sockets as a power source plug connected to two-channel relays. Where the relay is controlled on/off by the Blynk application. So that the socket can be controlled "on/off" from a handphone with the user account Blynk. An illustration of the process of creating the configuration of Blynk application is shown in Figure 11.

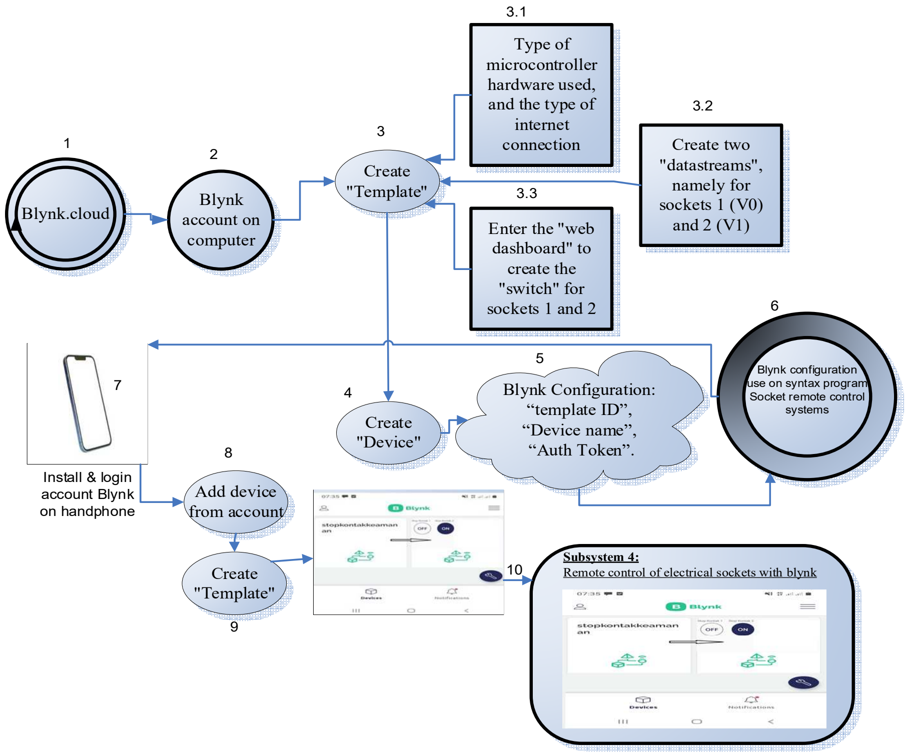


Fig. 11 The process of creating the configuration of Blynk application for remote control of electrical sockets

The process of creating the configuration of the remote control system in the Blynk application is as follows:

a. Create a Blynk account on a computer by opening the website "Blynk.cloud".
b. Open a Blynk account and create templates and devices.
c. Open the template and fill in: the template name, the type of microcontroller hardware used, and the type of internet connection.
d. Create two "datastreams", namely for sockets 1 and 2. Next, select the pins in the datastream with pin V0 for socket 1 and pin V1 for socket 2. Then select the integer data type with the value 0 for "off" and 1 for "on".
e. Then enter the "web dashboard" menu to create a widget display. Select the "switch" type and create two pieces for sockets 1 and 2.
f. Enter the device menu tab. Then give the device name by clicking "new device". Next, the relationship with the previously created template.
g. Get a Firmware Configuration that contains the "template ID", "Device name", and "Auth Token". Auth Token is used as a configuration Blynk to connect with the microcontroller. This makes the socket relay be controlled from a computer or a handphone.
h. Next, it can be accessed from a handphone. Install the Blynk application on the handphone by logging in using the Blynk account that was previously created.
i. Create a "new device" on the device menu tab. Then create two "switch" type widgets for sockets 1 and 2. On sockets 1 and 2 use virtual pins V0 and V1.

4) Analysis of worker attendance performance assessment with the Fuzzy Logic method:

Analysis of worker attendance performance assessment is a stage of monitoring analysis of attendance data generated by the subsystems 1 and 2. The analysis method uses fuzzy logic. The purpose of the analysis is to predict attendance performance based on attendance data, which includes hours of entry, rest, return, and go home.

Before entering the processing of fuzzy logic analysis. The attendance data is transformed into category data and transformed into a score. Attendance data in time format (Hours:Minutes:Second) will be transformed into category data. Where the category level shows suitability in attendance. There are four kinds of attendance data, namely entry, break, return, and go home. Because the assessment is for the entire attendance data. The summation of the four kinds of data is done. The result is the worker attendance suitability score for one day. Furthermore, for the assessment of workers in a one-month period. The attendance score will be multiplied by the number of working days (26 days). So that the worker attendance performance score for one month is obtained. It is a score that still does not have a clear meaning regarding attendance performance. The fuzzy logic method will transform a score as input data into output data. So that the output data will be obtained as clear values and categories related to attendance performance.

Figure 12 shows the results of the prediction analysis of worker attendance performance. For example, the value of the worker attendance score for one month is 330 (input data). The prediction results obtained a score of 409. This value based on the fuzzy membership of the output data is in the very high category. By using the results of fuzzy logic analysis. A worker's attendance performance level for one month is known.

Based on the Fuzzy Logic analysis process in Figure 12. That using the Python program language with the Jupiter Notebook application. The process calculating of the program is as follows:

a. Import libraries: numpy, skfuzzy and control.
b. Determining the membership universe values of the input data and output data. The membership values are grouped into five groups: very low, low, medium, high and very high.
c. The input data is the worker attendance score data for a month. The grouping of input data is calculated from the minimum, maximum, and interval width data. Based on sample data for June 2024. Minimum value = 208, maximum = 338. Class interval width = (338 - 208) / 5 = 26.
d. The output data is the attendance performance criteria score for 1 month. The output data grouping is calculated based on the minimum, maximum, and interval width values.

Minimum data = 1 x 4 x 26 = 104.
Maximum data = 5 x 4 x 26 = 520.
Class interval width = [520 - 104] / 5 = 83.2, where 1 and 5 are the lowest and highest performance scores. The value of 4 is four kinds of absences (entry, break, return, and go home).

The value of 26 is the number of working days for 1 month.

a. Create membership functions of five group categories from the input data and output data. The membership function of each category is based on the width of the class interval.
   The membership function of the input data is:
   Very Low < 234; 234 ≤ Low < 260;
   260 ≤ Middle < 286; 286 ≤ High < 312;
   312 ≤ Very high < 338.
   The membership function of the output data is:
   Very Low < 187.2; 187.2 ≤ Low < 270.4;
   270.4 ≤ Medium < 353.6; 353.6 ≤ High < 436.8;
   436.8 ≤ Very high < 520.
   Defines the function rules of the moment value function to project the membership of the input data on to the membership of the output data.
b. Predict employee attendance performance based on the moment value function that has been defined.
c. Entering attendance score input data and calculating the output score. Based on the output score, the value and category of employee attendance performance are known.

B. Discussion

The article aims to apply IoT and IT technology in SMEs by creating an IoT-RFID-Webserver-Android-based attendance and security monitoring system. The application results show that the monitoring systems are functioning properly. The following discussion outlines each subsystem of the proposed system and provides recommendations for SMEs to enhance the system.

1) Subsystem 1 – Attendance, body temperature, and security devices:

Subsystem 1 is a subsystem that adopts RFID and IoT technology. The program system for detecting attendance, body temperature, human motion, and fire is embedded in the microcontroller. The main components are a microcontroller using Arduino Uno R3 and NodeMCU Esp8266. Then the RFID card-reader, body temperature sensor, ultrasonic distance sensor, motion sensor, fire sensor, LCD, push button, and LED lights. This system design is different from that of other researchers. The difference is in the components used. Like research [10], [18], which uses a Raspberry Pi microprocessor. Where the price is more expensive than the Arduino Uno R3 and NodeMCU Esp8266 V3 microcontrollers. Furthermore, there is a difference in system functions. [13], [19], which are only for attendance functions. They do not embed body temperature detection and security functions.

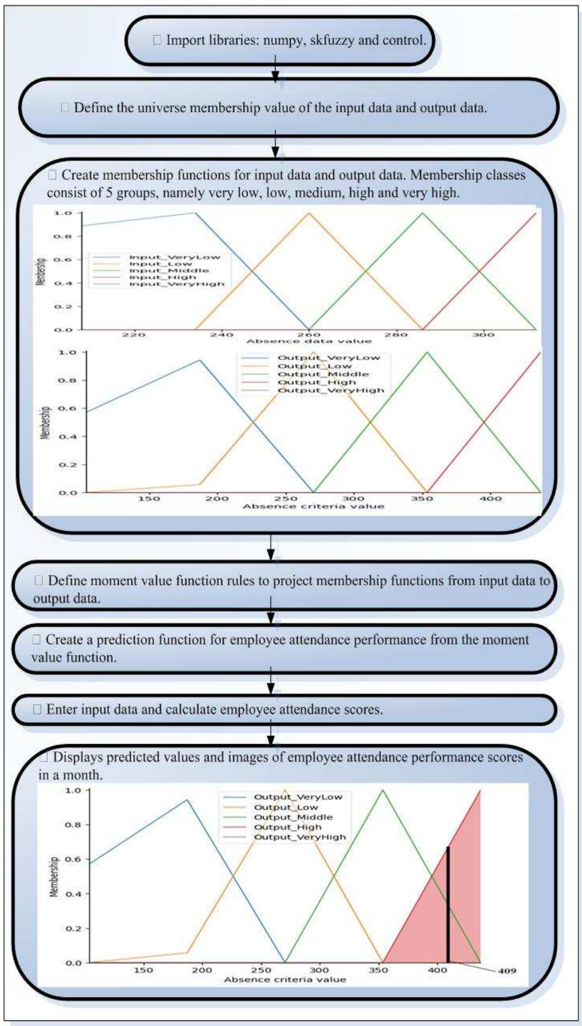


Fig. 12 Fuzzy logic analysis process: worker attendance performance

The devices in subsystem 1 are designed to replace the old ones on the SMEs. The proposed system can efficiently manage employee attendance administration, ensuring accuracy and authenticity. Besides, it is intended to prevent the transmission of COVID-19. The use of RFID technology is the right choice. It prevents direct contact. Then, body temperature detection is added to detect early and prevent further transmission. The proposed system, integrating RFID and body temperature sensors, makes a unique contribution as a worker temperature check and attendance tool. While previous studies only used the RFID function as an attendance tool [8], [12], [17], [20]. The work of subsystem 1 involves bringing the worker's hand closer to the proximity sensor connected to the body temperature sensor. Then the body temperature will be detected. Furthermore, the worker brings the RFID card closer to the RFID reader. This will trigger the transmission of body temperature and worker attendance hours data to the web server database and to the Android smartphone.

The implementation of IoT-RFID-based attendance technology has challenges related to the technical security of the systems and forgery in attendance. The solution to technical security is to provide firewalls and antivirus applications. Next, privacy settings related to important data. Then, for the solution of attendance forgery. According to [21], the solution is to combine good behavior from workers and technical security aspects. Good behavior from workers can be designed with training and education programs.

2) Subsystem 2 – Monitoring attendance and body temperature data:

The second subsystem integrates the technology of the Web server, RFID, and IoT for monitoring of attendance data on the Web server MySQL database, and the Website. The results show that it can automatically acquire and monitor attendance data in real-time. These results align with the research [6], [10], [22]. The IoT and web server MySQL database are effective and efficient technologies for automating process capabilities and improving data services, enabling real-time acquisition and monitoring. Furthermore, a web server MySQL database can be utilized to accommodate various forms of data such as text, numbers, images, and patterns.

The second subsystem also uses Android technology to monitor the body temperature and the RFID cards of the workers. It will send a message notification to the smartphone through Firebase Cloud Messaging (FCM). FCM is a mobile message notification service issued by Google. That is effective, low-cost, and low error [23]. The proposed system demonstrates that message notifications can be delivered quickly and in real-time. The owners or managers will know the hours of attendance and body temperature of workers directly. It can maintain the productivity of the employees' working hours. This finding is in line with research [23]. Integration of FCM and a Web server makes it easier and faster to send messages. Furthermore, according to [20], the FCM platform provides accurate information. Especially integrated in a system that applies RFID technology, each RFID card has a unique number. However, the free FCM platform has limitations in terms of updates and requires maintenance to support the latest version, as well as an end time for the "Firebase Token". Furthermore, according to [24], the FCM service is suitable for services where the amount of data to be sent is limited.

3) Subsystems 3 and 4 – Message notifications of human motion, fire detection, and remote control electrical socket

The third subsystem integrates IoT and instant message platforms, namely Telegram Bot. Telegram Bot is an open-source service for sending or receiving multiplatform instant messages with a client-server architecture [25]. The official clients of Telegram are desktop (Windows, macOS, and Linux), mobile operating systems (Android and iOS), and Web browsers. The third subsystem uses Android for the Telegram operating system. It can monitor and control the detection of human motion and fire in real-time and mobile. Specially designed for human motion detection, it can be remotely controlled with an "on/off" function from a handphone. The telegram bot also uses another researcher, such as [26]. That uses the Telegram platform to serve room security monitoring. Then [27], using a Telegram bot to collect patients' vital signs for remote monitoring and continuity of care. Nevertheless, this platform has limitations on the number of handphones as notification-sending servers and notification-receiving clients. Furthermore, Telegram with a desktop operating system has limitations, which must be properly maintained and updated to support future versions [26].

Next, the fourth Subsystem uses the Blynk platform with free services. Blynk is one of the open-source IoT platforms with free and paid services. That is popularly used for remote monitoring and controlling [28]. It can monitor and control via computer or smartphone in real-time [29]. The proposed system uses free services. However, free services have been able to be used well in systems. But the free services have limitations in scalability. Such as in the number of "Devices", "Templates", and "Widgets". For implementation in SMEs, according to [30], if the user wants to switch from free services to paid services. That needs to study the financial implications.

Furthermore, the fourth subsystem also has a remote control function for the power source of the attendance device. The power source is connected to two electric sockets and two-channel relays. The relays are controlled by NodeMCU Esp8266 V3 microcontroller and connected to the Blynk platform. It made the electric sockets remotely controlled on/off" via a handphone's attendance managers or leaders. These findings confirm that the low-cost IoT platform can help operations in SMEs. This finding is in line with other researchers who use Blynk with free services for some work. Such as [31], controlling and monitoring for biofloc in aquaculture. Then [28] automation of irrigation systems, and [32] generating agricultural data in real-time.

4) The performance assessment of worker attendance with Fuzzy Logic:

Assessment of worker attendance performance using the Fuzzy Logic method. The Fuzzy Logic method transforms qualitative data of vague categories into quantitative data that has a clearer nature [33]. Thus, reducing uncertainty in decision-making is related to the value of worker attendance performance. Furthermore, the results of the analysis are presented in quantitative values within a visual group category, indicating the level of performance. This makes it easier for management or SME owners to make decisions regarding the performance level of worker attendance.

The use of Fuzzy Logic methods in another form is embedded in a microcontroller device system to find a solution to a problem. Such as [34], using fuzzy logic to determine the sustainability performance index of lean systems. [35] Fuzzy-logic methods are embedded in IoT systems for substrate monitoring in mushroom cultivation. Then, a Fuzzy Logic controller to withstand and safeguard against the effects of voltage fluctuations [36]. Furthermore, Fuzzy Logic controllers for smart agriculture systems [37], [38], and smart greenhouse systems [39].

5) Recommendations for SMEs for Enhancing the System:

The proposed attendance system has adequate functionality. The recommendations for SMEs to enhance the attendance system include speeding up the performance analysis time by embedding Fuzzy Logic or Machine Learning into the microcontroller. And optimize the processing workflow networks of the systems by adding edge computing to IoT systems. According to [40], the central element of edge-computing is critical to optimizing the processing workflow networks from the IoT device layer to the middleware node layer and to the output layer on the computer server. It serves efficiently as a big data collector from the IoT devices. For the implementation of edge computing in an IoT system. First, the IoT system is embedding Fuzzy-Logic or Machine-Learning methods in the Arduino Nano 33 BLE Sense microcontroller. According to [41], this microcontroller can deploy a Tiny Machine Learning model. This will make the attendance performance prediction process collaborative. Second, to optimize the processing workflow, networks between layers should be optimized. A lighter communication protocol is needed. Such as Message Queuing Telemetry Transport (MQTT) [40]. Third, it requires a server computer that operates continuously. Such as Raspberry Pi 4B [40]. It will enhance the effectiveness of attendance performance reports and the durability of systems. However, its implementation would require higher costs compared to the proposed attendance system. Previously, it was necessary to study the cost implications of enhancing the attendance system.

The proposed security system has adequate functionality. Recommendations for enhancing the scalability of the security system include considering paid services for the Blynk and Telegram platforms. The free service of Blynk has limitations of scalability [30]. Such as the use limitation of “Widget” features, the number of "Devices", and "Template". Then, the free service of Telegram has limitations [26]. Such as the number of sending servers, receiving clients, needs to be properly maintained, and updated to support future versions. Nevertheless, if a switch to paid services. It needs to study the financial implications.

IV. Conclusion

The implementation of an IoT-RFID-Webserver-Android-based attendance and security monitoring system in SMEs enables managers to monitor worker attendance and environmental security in real-time. The attendance monitoring systems provide performance information to SME managers. Then make informed decisions regarding worker recognition or coaching based on attendance performance. Next, the security monitoring system can detect human movement and fires in real-time by sending notification messages directly to handphones. The system also features a remote control that can be turned on or off by a handphone. This function controls the electric power source of the attendance device. It allows managers to turn off the device's power during working hours remotely. Then, remotely turn on if no one works.

The implementation results demonstrate that each part of the monitoring system functions correctly. The first subsystem comprises devices for attendance, body temperature, and security. This system is designed to replace inefficient traditional methods and to mitigate the transmission of COVID-19. This section includes a work syntax program for detecting attendance, body temperature, human movement, and fire. It is all embedded in a microcontroller. The main components are microcontrollers utilizing Arduino Uno R3 and NodeMCU Esp8266 V3. Other components include an RFID card reader, a body temperature sensor, an ultrasonic distance sensor, a motion sensor, a fire sensor, an LCD screen, a push button, and LED lights. All of these components are affordable and widely available on the market. The second subsystem is responsible for monitoring attendance data within the Web server database and the Website. Also utilizes an Android application to monitor attendance hours and body temperature, with message notifications sent to handphones. The third subsystem monitors and detects human motion and fire for security purposes. This section utilizes an instant messaging platform, a Telegram Bot, to control message notifications on the smartphone. Notably, human motion detection can be controlled remotely on or off from the Telegram bot platform using a smartphone. Furthermore, the fourth subsystem serves as a remote control for the electrical power source of the attendance device, utilizing the Blynk platform. This capability enables users to control devices from their handphones easily. Next, the results of worker attendance performance using Fuzzy Logic methods are discussed. Fuzzy Logic converts qualitative data from vague categories into quantitative data with clearer properties. This thereby reduces uncertainty in decision-making related to assessing worker attendance performance. This approach enables SMEs managers to make more accurate decisions regarding the evaluation of worker attendance performance.

The recommendations for SMEs to enhance the proposed attendance system include speeding up the performance analysis time by embedding the system into the microcontroller. Optimize the processing workflow networks of the systems by integrating edge computing into them. The next recommendations for enhancing the scalability of the proposed security system are to consider using paid services for the Blynk and Telegram platforms. Previously, it was necessary to study the cost implications of enhancing the system.

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References

[1] V. T. D. Huynh, "A blockchain-based IoT system for secure attendance management," *Lect. Notes Data Eng. Commun. Technol.*, vol. 188, pp. 294-306, 2023, doi: 10.1007/978-3-031-46749-3_28.

[2] X. Niu, "Exploration on human resource management and prediction model of data-driven information security in Internet of Things," *Heliyon*, vol. 10, no. 9, 2024, doi:10.1016/j.heliyon.2024.e29582.

[3] S. Cay et al., "The effect of fingerprint attendance and work motivation on employee discipline on CV Story of Copyright," *J. Off.*, vol. 7, no. 2, 2022, doi: 10.26858/jo.v7i2.31369.

[4] S. Sumarsono, N. Muflihah, and F. A. A. N. Farida, "IoT based multiple sensors agriculture for soil parameters monitoring using Thinger platform," in *AIP Conf. Proc.*, vol. 2991, 2024, doi:10.1063/5.0198607.

[5] E. E. Alahi et al., "Integration of IoT-enabled technologies and artificial advancements and future trends," *Sensors*, vol. 23, no. 11, 2023, doi: 10.3390/s23115206.

[6] S. Sumarsono, F. A. N. Farida Afiatna, and N. Muflihah, "The monitoring system of soil pH factor using IoT-webserver-android and machine learning: A case study," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 14, no. 1, pp. 118-130, Feb. 2024, doi:10.18517/ijaseit.14.1.18745.

[7] A. D. S. Vodă, A. I. M. Tudor, and I. B. Chițu, "IoT technologies as instruments for SMEs' innovation and sustainable growth," *Sustainability*, vol. 13, no. 11, 2021, doi:10.3390/su13116357.

[8] Q. A. Abdulaziz et al., "Developing an IoT framework for Industry 4.0 in Malaysian SMEs: An analysis of current status, practices, and challenges," *Appl. Sci.*, vol. 13, no. 6, 2023, doi:10.3390/app13063658.

[9] A. Costa et al., "SMEs and open innovation: Challenges and costs of engagement," *Technol. Forecast. Soc. Change*, vol. 194, Jun. 2023, doi: 10.1016/j.techfore.2023.122731.

[10] V. D. Nguyen et al., "Internet of Things-based intelligent attendance system: Framework, practice implementation, and application," *Electronics*, vol. 11, no. 19, 2022, doi:10.3390/electronics11193151.

[11] M. Idhom et al., "IoT-based portable fingerprint attendance system using the minutiae based algorithm," in *Proc. IEEE 7th Inf. Technol. Int. Semin. (ITIS)*, 2021, pp. 1-6, doi:10.1109/ITIS53497.2021.9791575.

[12] G. M. Kumar et al., "Attendance system using RFID tag," in *AIP Conf. Proc.*, vol. 2393, 2022, doi: 10.1063/5.0081796.

[13] A. Shrivastava et al., "IoT based RFID attendance monitoring system of students using Arduino ESP8266 & Adafruit.io on defined area," *Cybern. Syst.*, vol. 56, no. 1, pp. 21-32, Jan. 2025, doi:10.1080/01969722.2023.2166243.

[14] S. U. Abidemi et al., "Attendance system via Internet of Things, blockchain and artificial intelligence technology: Literature review," *Lect. Notes Netw. Syst.*, vol. 655, pp. 321-330, 2023, doi:10.1007/978-3-031-28694-0_30.

[15] M. A. A. E. Yousef and V. Dattana, "Auto attendance smartphones application based on the global positioning system (GPS)," *Adv. Intell. Syst. Comput.*, vol. 1363, pp. 917-934, 2021, doi: 10.1007/978-3-030-73100-7_63.

[16] T. W. Chiang et al., "Development and evaluation of an attendance tracking system using smartphones with GPS and NFC," *Appl. Artif. Intell.*, vol. 36, no. 1, 2022, doi: 10.1080/08839514.2022.2083796.

[17] K. Aravindhan et al., "Design of attendance monitoring system using RFID," in *Proc. 7th Int. Conf. Adv. Comput. Commun. Syst. (ICACCS)*, 2021, pp. 1628-1631, doi: 10.1109/ICACCS51430.2021.9441704.

[18] A. S. Nadhan et al., "Smart attendance monitoring technology for Industry 4.0," *J. Nanomater.*, vol. 2022, 2022, doi:10.1155/2022/4899768.

[19] N. F. J. Rabbany, "Smart attendance for lecture with physical distancing based on the Internet of Things (IoT)," in *Proc. Int. Conf. Elect. Eng., Comput. Sci. Inform. (EECSI)*, 2022, pp. 210-214, doi:10.23919/eecsi56542.2022.9946589.

[20] L. Karunarathne et al., "Business during COVID: An IoT based automated sand truck management," *Comput. Sci. Inf. Technol.*, vol. 13, no. 10, pp. 63-82, 2023, doi: 10.5121/csit.2023.131006.

[21] S. Furnell, K. Millet, and M. Papadaki, "Fifteen years of phishing: Can technology save us?," *Comput. Fraud Secur.*, vol. 2019, no. 7, pp. 11-16, Jul. 2019, doi: 10.1016/S1361-3723(19)30074-0.

[22] F. A. J. Vaz et al., "Smart attendance system using RFID and Raspberry Pi," in *Proc. 2nd Int. Conf. Electron. Renew. Syst. (ICEARS)*, 2023, pp. 1450-1455, doi:10.1109/icears56392.2023.10085186.

[23] W.-T. Sung, I. G. Tofik Isa, and S.-J. Hsiao, "An IoT-based aquaculture monitoring system using Firebase," *Comput. Mater. Contin.*, vol. 76, no. 2, pp. 2179-2200, 2023, doi:10.32604/cmc.2023.041022.

[24] G. Albertengo et al., "On the performance of web services, Google Cloud Messaging and Firebase Cloud Messaging," *Digit. Commun. Netw.*, vol. 6, no. 1, pp. 31-37, Feb. 2020, doi:10.1016/j.dcan.2019.02.002.

[25] P. Fernández-Álvarez and R. J. Rodríguez, "Extraction and analysis of retrievable memory artifacts from Windows Telegram Desktop application," *Forensic Sci. Int. Digit. Investig.*, vol. 40, 2022, doi:10.1016/j.fsidi.2022.301342.

[26] M. Fajar and M. Dwi, "IoT implementation for server room security monitoring using Telegram API," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 12, no. 5, pp. 1931-1937, Oct. 2022, doi:10.18517/ijaseit.12.5.13922.

[27] J. P. Y. Tan et al., "mHealth app to facilitate remote care for patients with COVID-19: Rapid development of the DrCovid+ app," *JMIR Form. Res.*, vol. 7, 2023, doi: 10.2196/38555.

[28] M. G. Kibria and M. T. A. Seman, "Internet of Things based automated agriculture system for irrigating soil," *Bull. Electr. Eng. Inform.*, vol. 11, no. 3, pp. 1752-1764, Jun. 2022, doi: 10.11591/eei.v11i3.3554.

[29] R. Eka et al., "Monitoring and controlling system of smart mini greenhouse based on Internet of Things (IoT) for spinach plant (Amaranthus sp.)," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 14, no. 1, pp. 131-136, Feb. 2024, doi: 10.18517/ijaseit.14.1.18408.

[30] H. J. El-Khozondar et al., "A smart energy monitoring system using ESP32 microcontroller," *e-Prime - Adv. Electr. Eng. Electron. Energy*, vol. 9, Mar. 2024, doi: 10.1016/j.prime.2024.100666.

[31] R. Al Mamun, M. Ashik-e-rabbani, and M. Haque, "IoT-based real-time biofloc monitoring and controlling system for smart agriculture," *Smart Agric. Technol.*, vol. 9, Sep. 2024, doi:10.1016/j.atech.2024.100598.

[32] N. N. Thilakarathne et al., "Towards making the fields talk: A real-time cloud enabled IoT crop management platform for smart agriculture," *Front. Plant Sci.*, vol. 13, 2023, doi:10.3389/fpls.2022.1030168.

[33] P. Flores and E. Mendoza, "A fuzzy logic technique for the environmental impact assessment of marine renewable energy power plants," *Energies*, vol. 18, no. 2, 2025, doi: 10.3390/en18020272.

[34] V. Gopi and S. P. G., "Modelling the inhibitors of integrated sustainable lean manufacturing system in the South Indian SMEs using fuzzy logic," *J. Model. Manag.*, vol. 18, no. 5, pp. 1-22, 2023, doi:10.1108/JM2-05-2023-0107.

[35] F. Irwanto et al., "IoT and fuzzy logic integration for improved substrate environment management in mushroom cultivation," *Smart Agric. Technol.*, vol. 7, 2024, doi: 10.1016/j.atech.2024.100427.

[36] I. Diahovchenko, P. Korzh, and M. Kolcun, "A fuzzy-logic-based method for maintenance prioritization of high-voltage SF6 circuit breakers, considering uneven wear," *Results Eng.*, vol. 16, Sep. 2022, doi: 10.1016/j.rineng.2022.100788.

[37] J. Tian, "IoT smart agriculture and agricultural product income insurance participant behavior based on fuzzy neural network," *Comput. Intell. Neurosci.*, vol. 2022, 2022, doi:10.1155/2022/4778975.

[38] L. Bin et al., "Sustainable smart agriculture farming for cotton crop: A fuzzy logic rule based methodology," *Sustainability*, vol. 15, no. 18, 2023, doi: 10.3390/su151813874.

[39] V. Thomopoulos et al., "Application of fuzzy logic and IoT in a small-scale smart greenhouse system," *Smart Agric. Technol.*, vol. 8, Mar. 2024, doi: 10.1016/j.atech.2024.100446.

[40] M. Katsigiannis and K. Mykoniatis, "Enhancing industrial IoT with edge computing and computer vision: An analog gauge visual digitization approach," *Manuf. Lett.*, vol. 41, pp. 1264-1273, 2024, doi:10.1016/j.mfglet.2024.09.153.

[41] V. Tsoukas et al., "A gas leakage detection device based on the technology of TinyML," *Technologies*, vol. 11, no. 2, 2023, doi:10.3390/technologies11020045.