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PAPER

RFID Attendance System with Contagious Disease Prevention Module using Internet-of-Things Technology

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ABSTRACT

This paper presents the development and implementation of an innovative Internet of Things (IoT)-based RFID attendance system integrated with a module focused on curbing the spread of contagious diseases in densely populated settings, such as schools and workplaces. Recognizing the limitations of existing radio frequency identification (RFID) attendance systems, an extensive analysis of prior works was conducted to identify crucial functionalities necessary for an effective solution. Leveraging the IoT paradigm, we devised a 3-layer architecture encompassing thermometer sensors, RFID technology, Arduino microcontrollers, Wi-Fi connectivity, and the message queuing telemetry transport (MQTT) protocol to facilitate seamless data transmission and storage. The resulting prototype enables real-time monitoring of feverish symptoms, serving as an early warning system for potential contagious illnesses while streamlining attendance management. Data collected from the IoT devices is securely stored in a centralized database and accessed through an intuitive information system embedded within the IoT application. Users can effortlessly view and manage attendance data, while administrators gain access to health-related metrics, enabling timely responses to health concerns. User evaluations of the developed system resulted in an outstanding "A" rating, validating its reliability, functionality, and user satisfaction. Future improvements involve real-world testing, scalability assurance, integration with health authorities for comprehensive data management, and automated alerts for potential disease outbreaks.

KEYWORDS

Internet of Things (IoT), pandemic disease prevention, radio frequency identification (RFID) attendance system

1 INTRODUCTION

Nowadays, we have encountered many types of contagious diseases, such as COVID-19, mpox, and hand, foot, and mouth disease (HFMD). One of the common symptoms is fever, where the body temperature of those with fever will increase

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above 37.5 °C [1–4]. During the COVID-19 pandemic, work from home (WFH) was allowed in most companies in various countries. This hybrid method, however, increases disease cases in the workplace. In 2022, most countries declared that the COVID-19 status had changed to the endemic phase [5]. At the same time, most companies have a very comprehensive debate on WFH issues. Some opinions stated that the WFH would reduce the productivity of its resources [6] [7]. Many companies have started revising their policies and strategies to prevent the contagious disease from spreading. The strategies include the implementation of prevention methods for contagious diseases [8].

On the other hand, Internet of Things (IoT) technology has been widely used in various applications to increase workflow efficiency. IoT application development requires 3 layers of IoT architecture, which are the physical layer, network layer, and application layer [2]. The physical layer refers to devices such as radio frequency identification (RFID) and sensors that collect input data from any environment [9] [10]. The collected data will be transferred to the application layer to be processed through the network layer. In the application layer, cloud and database technology and platforms can be used to ensure the collected data can be accessed and managed efficiently from anywhere.

In previous works, many attendance systems have been proposed, but most of them did not consider contagious virus prevention modules. Furthermore, some of the work did not apply comprehensive IoT technology, thus reducing workflow efficiency. The stated related works will be elaborated in Section II. Based on the problem stated in the previous works, we have designed and developed a new attendance system using IoT technology for the spreading of contagious diseases module. As most contagious diseases show identical symptoms, the patient will have high fever symptoms and a body temperature higher than 37.5 °C. In the developed system, an infrared thermometer and RFID tag are included and considered the IoT devices in the physical layer that can collect user data and temperature. To ensure the system's efficiency, we made sure that the system applies IoT requirements, and data transmission between IoT layers is well integrated.

Section III discusses the research methodology of the developed system, including design and development methods. In Section IV, we have discussed the testing process to validate the functionality of the developed system. The paper is concluded in Section V, with a summary of the paper and future challenges.

2 LITERATURE REVIEW

In this section, we have analyzed previous works on RFID system attendance systems, as summarized in Table 1. The analysis will determine the required modules and functions that need to be embedded in the proposed system. Table 1 shows a summary of previous works that have used RFID in the attendance system. RFID has three different segments, which are tags, antennas, and readers. The tags are used to track the system with enhanced chip and radio waves and have their own unique ID [16]. RFID is well used in various applications due to its promising characteristics, such as higher security, longer distance detection, reusableness, and more extensive data storage [4].

In the previous works, Arduino Uno was mostly used to collect data from the sensors and transfer data to the upper layer using message queuing telemetry transport (MQTT) and Wi-Fi protocol, which can be considered a low-cost device instead of Raspberry Pi that is used in [15]. MQTT is a lightweight open messaging protocol that is widely used in IoT applications [2]. Most studies have prioritized device portability for communication protocols by choosing Wi-Fi instead of wired Ethernet [13]. For data storage, SD cards, databases, and Arduino memory have been used in previous projects. Regarding the RFID sensor, most of the works used MFRC522 due to its compatibility with Arduino Uno. Another important part is data representation, or how the user can access data. Most of the previous studies used liquid-crystal displays (LCDs) with minimal function.

Table 1. Summary of previous studies on RFID attendance system

Article	Gateway	Media	Storage	Data Representation	Sensor
[11]	Arduino	Wi-Fi	SD Card	Thing-speak, LCD	MFRC522
[12]	Arduino	Wi-Fi	Database	LCD Display	MFRC522
[13]	Arduino	Wired	memory	Microsoft Excel	MFRC522
[14]	LM356950	Wi-Fi	Database	Java GUI Application	TRF7960
[15]	Raspb Pi	Wi-Fi	Database	phpMyAdmin, LCD	MFRC522
[16]	Arduino	W-Fi	SD Card	LCD Display	MFRC522
[17]	Arduino	Wi-Fi	memory	Microsoft Excel, LCD	MFRC522
[18]	Arduino	Wi-Fi	Database	Web Application	MFRC522

Table 2 shows open issues that have been analyzed in the previous studies. From the table, limited storage, incompatible data representation, and a simple database are raised as issues that need to be improved. Furthermore, the previous studies have not considered the pandemic situation, where all the works did not have health or body temperature detection. In this paper, a low-cost new attendance system is developed to fit contagious diseases. The previous attendance systems only included RFID tags to record employee attendance. This newly developed system includes an infrared thermometer with an RFID tag to record employee attendance. As stated earlier, the most common symptom of contagious diseases is having a fever. Most pandemic diseases have high fever symptoms, such as a body temperature higher than 37.5 °C. Hence, the newly developed system will help an organization detect the symptoms of COVID-19 and prevent workers with symptoms from coming to the workplace. In addition to the health-related improvements, the developed system makes significant contributions by introducing an information system equipped with a database and a user-friendly interface. These modules effectively address the issues identified in Table 2 of the current system, providing an overall enhanced solution.

Table 2. Summary of open issues in the current RFID attendance system

Open Issue	Possible Solution	References
Limited storage: The data is kept in limited storage (SD card)/simple excel sheet.	Database that can directly keep the data in a server	[6], [13], [14], [16], [17]
Limited display/dashboard: LCD/tool without an interactive user interface	User-friendly dashboard for monitoring	[12], [14], [17], [19], [15]
No health check monitoring embedded	Module to capture user temperature/health condition	[11]–[19]

3 SYSTEM DESIGN AND IMPLEMENTATION

In this section, design and development steps for the proposed system are discussed. The overall design of the proposed system is shown in Figure 1. The connection from a laptop and ESP8266 is connected wirelessly with a wireless access point through a modem and internet. Thus, this connection allows both devices to get IP addresses and communicate with each other. In addition, it allows all devices that are connected to Arduino to send and receive messages.

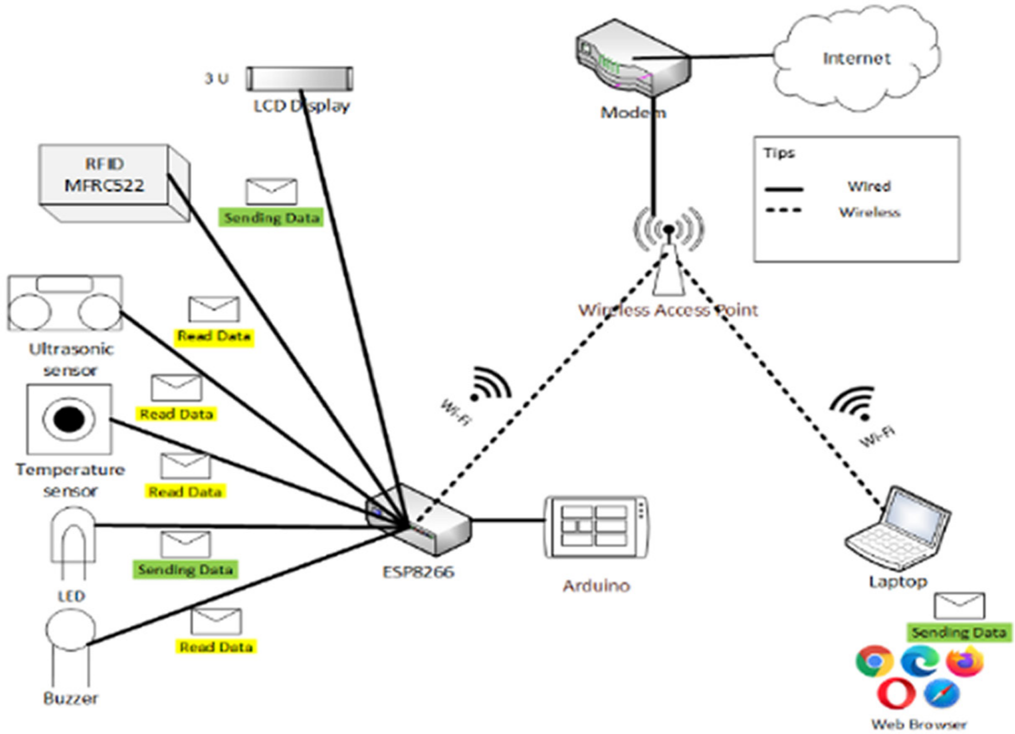

Fig. 1. Physical design of the proposed system

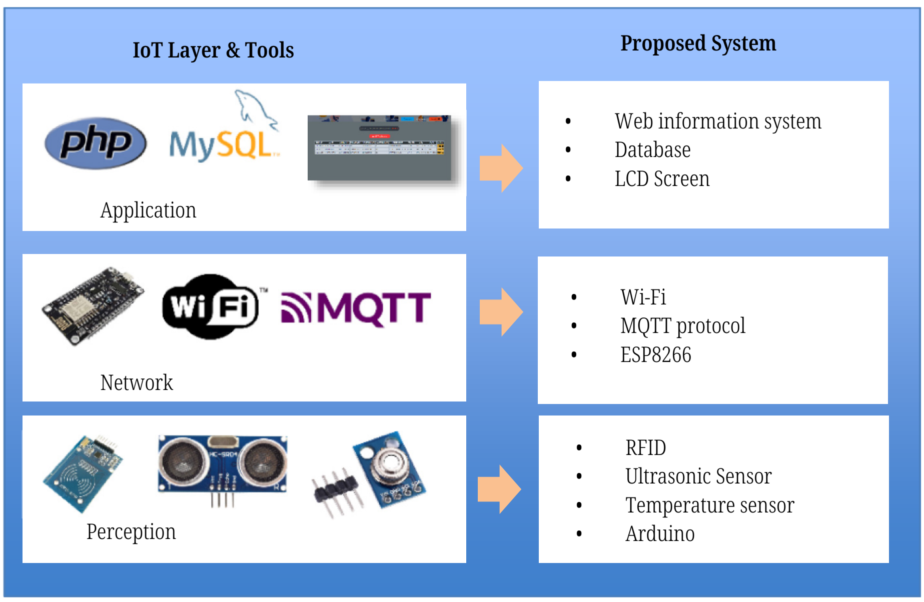

Fig. 2. 3-layer IoT vs proposed system

Figure 2 illustrates the mapping between the IoT layers and the proposed system, along with the applied tools used during the development process. In the perception layer, data collection is accomplished through the utilization of RFID technology and sensors. The gathered data is subsequently transmitted to the network layer via Wi-Fi using ESP8266, which acts as the communication module between IoT devices and the network infrastructure. To integrate IoT devices with the network, the programming tools APIs of Arduino IDE and Node-RED are employed. For efficient communication and message handling, an MQTT broker serves as the central server, receiving messages from clients and appropriately routing them to their destination clients. This facilitates seamless data exchange and synchronization between the IoT devices and the network components. At the application layer, a web-based information system is developed to provide a user-friendly interface for managing and handling the proposed system. This interface assists users in efficiently viewing, monitoring, and controlling the attendance and health-related data collected by the IoT devices, ultimately enhancing the overall system usability and effectiveness.

Figure 3 and Table 3 depict the schematic diagram illustrating the connections between general purpose input output (GPIO) pins and devices. This enhanced implementation includes a body temperature sensor integrated with the low-cost board ESP8266, enabling wireless data transmission to the user application platform. The utilization of this setup represents a notable advancement over previous work, facilitating seamless and cost-effective monitoring of body temperature data and its transmission to the user interface.

In Figure 4, the developed information system is presented, featuring employee records and attendance records. The data displayed in the system is retrieved from the database integrated with the developed prototype. This information system is meticulously designed to facilitate proper user interaction within the IoT application layer, offering seamless access to employee information and attendance data. The PHP language is used to develop the system with a MySQL database.

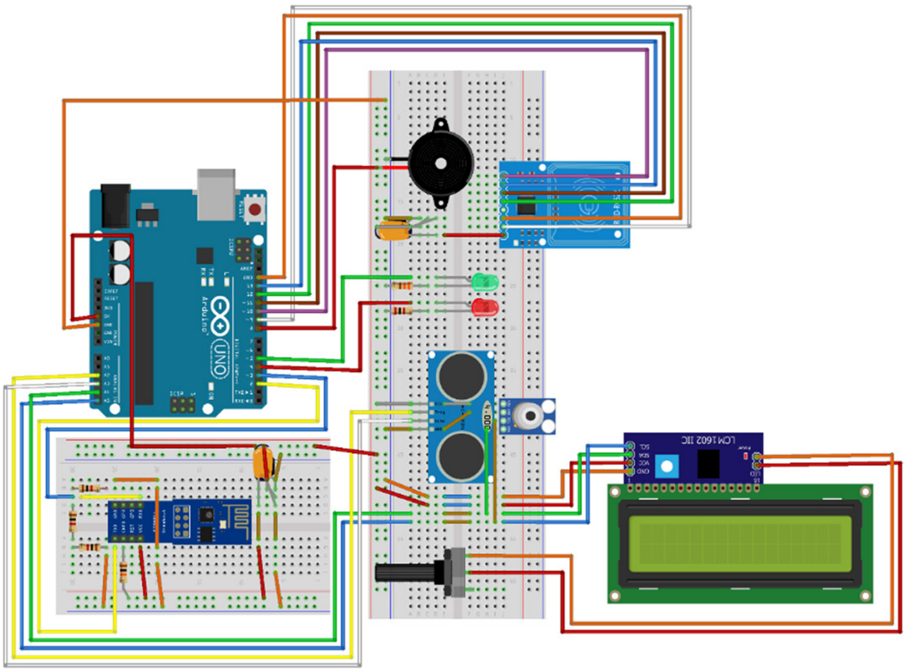

Fig. 3. Schematic diagram for proposed system

Table 3. Sensors pin vs. GPIO pin

Hardware	Wire	Pins
RFID MFRC522	3.3V	3.3V
	RST	9
	MISO	12
	MOSI	11
	SCK	13
	SDA	10
Thermometer MLX-90614	SCL	A5
	SDA	A4
Ultrasonic Sensor	TRIG	A2
	ECHO	A3
ESP8266-ESP01 Wi-Fi Module	VCC	3.3V
	CHPD	3.3V
	TXD	2
	RXD	3
	SDA	A4
	SCL	A5

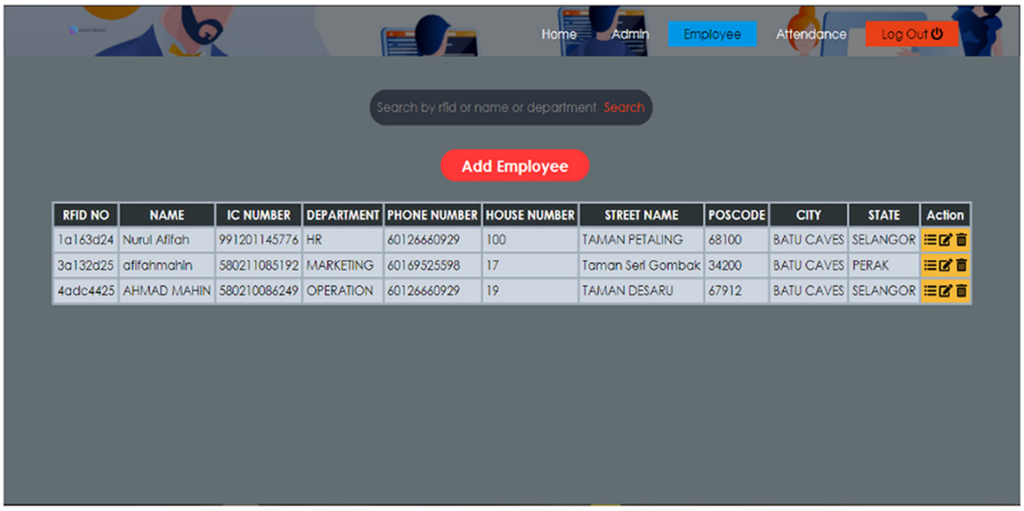

Fig. 4. Attendance record from developed information system

4 RESULT AND DISCUSSION

In this section, we conducted a functionality test to assess the overall completeness of the developed system. The test encompassed various aspects, including temperature detection, RFID detection, ESP8266-ESP01 wireless communication, performance evaluation, and dashboard integration. Additionally, usability testing was performed to validate the effectiveness and user-friendliness of the implemented system. Through these comprehensive tests, we aimed to ensure that all essential functionalities were functioning as intended and to assess the system's practicality and ease of use for end-users.

4.1 Temperature and RFID detection test

The temperature detection test is done based on the testing environment described in Figure 5. Figure 5 illustrates how the body temperature and RFID are detected, and the reading data is displayed on the Arduino's serial monitor.

Fig. 5. Body temperature and RFID detection

4.2 ESP8266-ESP01 wireless communication test

The connectivity test is done to verify the Wi-Fi module is successfully set up between the ESP8266 and Arduino, as shown in Figure 6.

Test	Wireless Communication Test
Purpose	To be able to connect to home network
Object	WPA SSID and password must be identified
Hardware	ESP8266-ESP01 Wi-Fi Module
Result	DHCP IPv4 address will be assign to the device after it connected to the home network

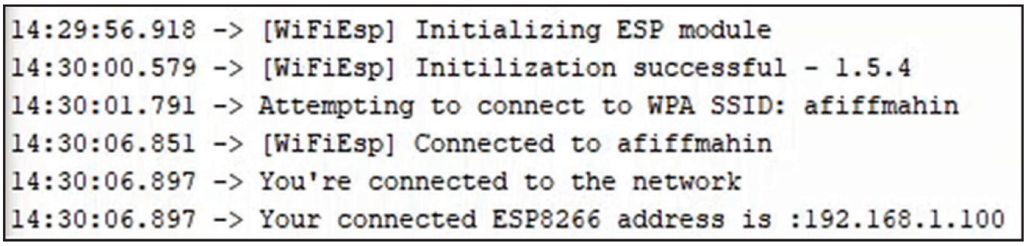

Fig. 6. Successfully connected to home network

4.3 Performance test

The performance test comprises two distinct scenarios: the unregistered RFID case and the high body temperature scenario. The first scenario aims to prevent unauthorized access by intruders, while the second scenario validates the system's ability to detect fever symptoms. In Figure 7, the test results for scenario 1 are presented. When an unregistered RFID tag is scanned, the LCD displays the notification "RFID Does Not Exist," and attendance is not recorded. This module plays a critical role in restricting unauthorized access to restricted areas. Figure 8 illustrates the testing results for scenario 2. During this test, if the detected body temperature exceeds 37.5 °C, attendance will not be recorded, and the LCD will display a notification.

Additionally, a red light-emitting diode (LED) is activated to alert the administrator. These notifications enable the administrator to take necessary measures and prevent potential sick individuals from accessing the area.

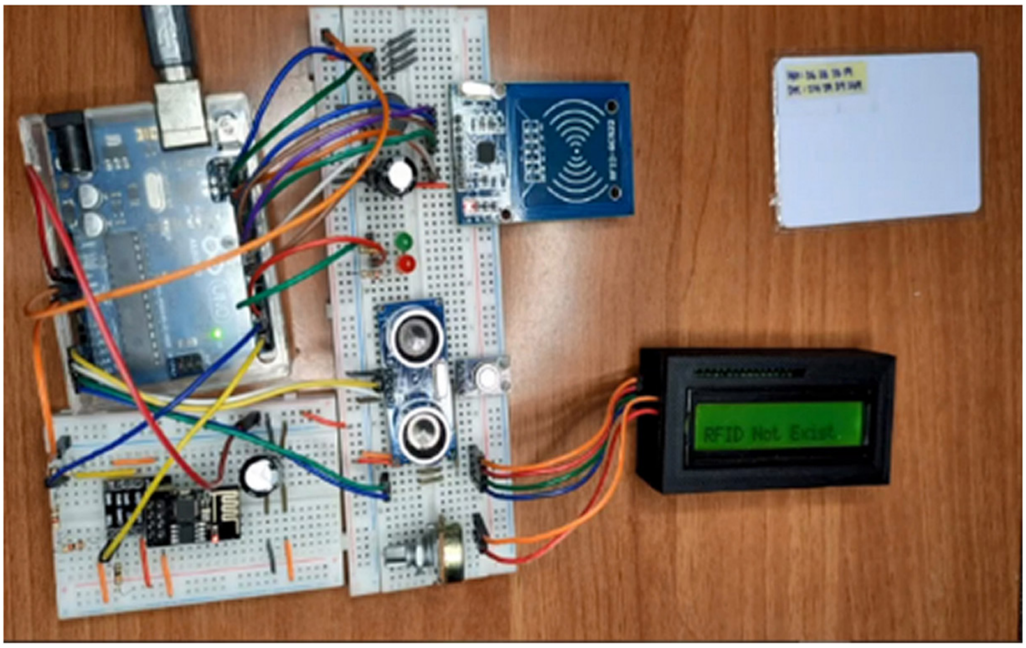

Fig. 7. Testing for scenario 1

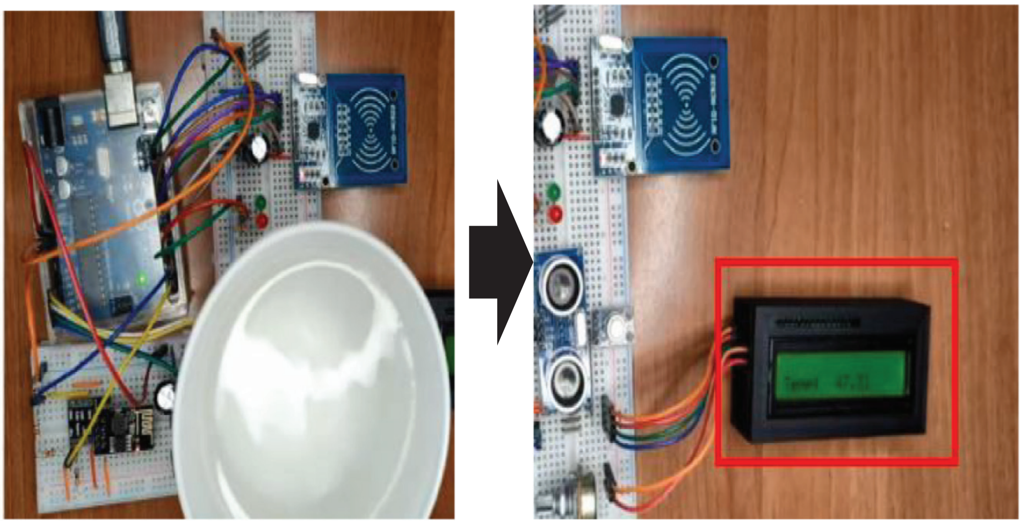

Fig. 8. Testing for scenario 2

4.4 Usability test

For this testing method, feedback from 16 respondents has been taken to evaluate the developed system. The feedback is on two types of testing: the information system and the prototype. The information system test is conducted for admin, security guard, or administration staff, while the prototype is made for employees.

Figure 9 shows system usability test result of the system that we created. R represents the respondent, *Qx* represents questionnaire number, where $x = 1 \ldots 10$ [19].

The respondents ranked the developed system from 1 to 5. The scale is formulated as follows:

- For each of the odd-numbered questions, subtract 1 from the score.
- For each of the even-numbered questions, subtract their value from 5.
- Take these new values that you have found and add them up to the total score. Then multiply this by 2.5.

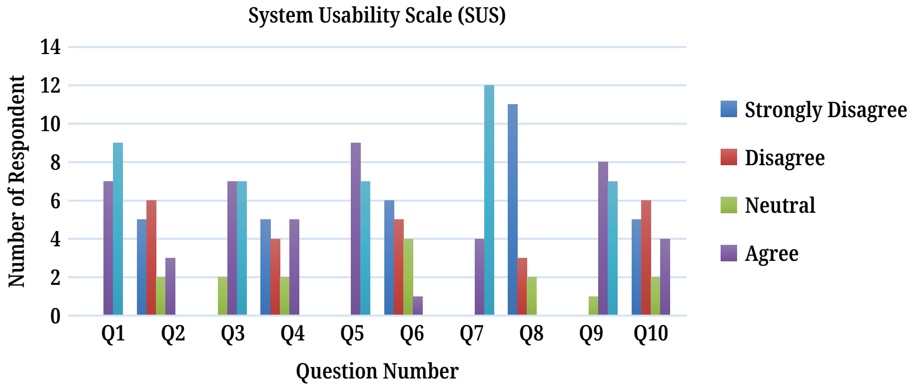

Fig. 9. System usability test for developed system

Table 4 presents the analysis of system usability scale (SUS) data from the respondents. We have collected data from 16 respondents, which is sufficient for the SUS test [13]. In the table, each respondent is represented by 'R,' each question by 'Q,' the raw score by 'RS,' and the final score by 'FS.' The developed system achieved a ranking of A with a score of 80.47% in the test.

Table 4. Data collection from SUS test

R	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	RS (%)	FS (%)
1	4	3	3	4	4	4	5	1	4	2	26	65
2	5	1	3	1	5	1	5	1	5	1	38	95
3	4	2	4	2	4	2	5	1	4	2	32	80
4	5	2	5	2	5	2	5	1	5	4	34	85
5	5	4	5	4	4	3	5	3	5	3	27	67.5
6	4	2	4	1	4	2	4	2	4	2	31	77.5
7	4	3	4	4	4	3	4	2	3	3	24	60
8	4	1	4	1	4	1	4	1	4	1	35	87.5
9	5	1	5	1	5	1	5	1	5	1	40	100
10	4	2	4	2	4	2	4	2	4	1	31	77.5
11	4	4	4	4	4	3	5	3	5	4	24	60
12	5	2	5	3	5	2	5	1	5	2	35	87.5
13	5	2	5	4	5	1	5	1	4	4	32	80
14	5	4	4	1	5	3	5	1	4	2	32	80
15	5	1	5	3	4	1	5	1	4	1	36	90
16	5	1	5	2	5	1	5	1	5	2	38	95
AVERAGE SCORE												80.47

5 CONCLUSION

To prevent the spreading of contagious diseases in community places, such as schools and workplaces, an attendance system with a contagious disease prevention module has been developed using IoT technology. From the analysis of previous works, we have identified that the current RFID attendance system needs to be embedded with an infrared thermometer to prevent contagious diseases from spreading. The developed prototype uses a low-cost Arduino Uno microcontroller with a database system. The functionality of the proposed prototype is validated when the transmitted data is successfully received and viewed on both the Arduino and LCD, and all data is saved in the database and can be viewed and managed in the developed information system. The information system provides an interactive user interface for managing the attendance history. The developed system's satisfaction rate, effectiveness, and efficiency have been validated through the SUS test, resulting in an A grade and a score of 80.47%.

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