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Design and Development of a Smart Café System Utilizing IoT for Real-Time Remote Monitoring and Updates

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Abstract *– Currently, cafés are a popular place for community activity. In addition to enjoying drinks and food, the café is also a place that is used for discussions, for learning/study, and as a meeting point for various groups, including students. A good café is one with comfortable and safe conditions. One way to ensure the comfort of a café is to monitor and control the body temperature, air quality, room temperature and humidity, the number of visitors, cleanliness, and the temperature in the kitchen. In this research, an IoT-based monitoring and control tool was developed. The goal of this tool is to monitor and control café conditions automatically, in real-time, and touchless. The sensors used collect data and read the conditions of parameters to be evaluated. Among the evaluations performed by this tool are the number of visitors (dine-in or take-away), control of temperature and humidity in the café, attendance tag cards for employees and café security, compliance with health protocols before entering the café, and measurement of a person's body temperature using infrared. In addition, if there is an anomaly in the café (temperature exceedance), the manager receives a notification in real-time of what is going on in the café. Cooling fans and humidifiers are activated when the air quality is abnormal, that is, when the temperature is more than 33°C and the humidity is not between 45% - 65% Relative Humidity. When the temperature in the kitchen is more than 38°C, the alarm is activated.*

Keywords – *Smart Café System; IoT-based Monitoring; Real-Time Control; Environmental Sensors; Automated Café Management.*

I. Introduction

SINCE mid-2019 until mid-2021, Indonesia has been striving to prevent the emergence of new clusters due to Covid-19. According to the Decree of the Minister of Health of the Republic of Indonesia (2020) Number HK.01.07/MENKES/382/2020 [1] concerning health protocols for the community, especially for building owners and visitors, it is necessary to measure body temperature, maintain air quality by optimizing room air circulation, and manage social distancing during transactions.

In an effort to implement the Minister's Decree, it is necessary to monitor the number and condition of visitors to a building while adhering to health protocols to prevent virus transmission. As we know, buildings are places for various user activities. A good building is one that is safe, comfortable, and well-controlled. Buildings E, F, and G are within the Faculty of Industrial Technology, Trisakti University. These buildings are used for various activities, including lectures, administration, laboratories, discussions, and more. One of the rooms in the Faculty of Industrial Technology is the Student Lounge, which is a place where students discuss assignments or general matters. In this room, there is a café frequently visited by students.

A well-controlled café system should implement a smart system. This requires monitoring visitor arrivals, measuring body temperature, and monitoring and controlling air quality.

On the other hand, advancements in data transmission technology, with increased speed, compactness, and efficiency, enable near-lossless data transmission from sender to receiver. Additionally, with the Internet of Things (IoT), everything can communicate with each other, from machine to machine, extending to everything, facilitated by the internet. IoT significantly eases human tasks in monitoring and controlling public spaces, requiring limits on the number of guests, body temperature, room temperature, and humidity.

IoT platforms are developing and available as IoT

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solutions, forming the most critical component of the IoT ecosystem [2]. These platforms include (a) Google Cloud Platform, enabling developers to code, test, and deploy scalable applications with reliable infrastructure handled by Google. Developers focus on code while Google manages infrastructure, computing power, and data storage. (b) Thinger.io, a cloud IoT platform comprising the IoT backend (actual server) and web-based frontend simplifying work with various features using computers or smartphones. (c) ThingWorx, a software platform supporting the creation of smart applications like Smart Cities, Smart Agriculture, Smart Buildings, Smart Grids, and Telematics. (d) ThingSpeak, an IoT platform helping users build applications based on data collected by sensors.

Several studies utilize IoT as the main device in monitoring and controlling buildings. In studies [3, 4], Arduino as a single-board controller has its own IDE (Integrated Development Environment) program. Arduino is also an open-source programmable board easily used for writing and running application programs. Arduino Boards are physical programmable boards used for flexible programming, adaptable signal types, and easy adaptation.

Room temperature comfort is a crucial factor supporting all activities inside, whether for work or study. According to research [5], room temperature comfort is achieved at temperatures ranging from 27°C to 29°C, with the highest comfort level observed from 06.00 to 09.00 WIB at an average temperature of 27.75°C.

Research [6] states that using DHT11 for measuring room temperature and humidity (Web Server) has good accuracy. Testing was conducted with HTC-1 Hygrometer, LCD I2C 16X2, and smartphones. This serves as a reference for measuring temperature and humidity. Meanwhile, in research [7], data from DHT11 compared with thermocouple vernier sensors showed an error value of 1.73%. Research [8] implemented an automatic door security system using RFID MFRC-522 with Solenoid Door Lock output, requiring a Telegram BOT to send notifications to smartphones when tapping e-cards. Meanwhile, research [9] states that a counter with Ultrasonic Sensor has 80% accuracy in reading the number of visitors using the Bayes method. In research [10], ultrasonic sensors were used to detect obstacles and measure their distance accurately, displayed on an LCD screen. Research [11] successfully developed a non-contact human body temperature measuring device based on Arduino using the MIX90614 sensor, with an acceptable uncertainty value of 1 degree Celsius. Research [12] designed a human body temperature measurement system by identifying human faces using image processing techniques. The system achieved an average error rate of 0.72%, resulting in an accuracy rate of 99.28%. Several factors influence the accuracy of infrared thermometers, including measuring distance and thermometer type. Research [13] showed less accurate readings when measuring body temperature at distances exceeding specifications. Additionally, body temperature measurements should use thermometers with an accuracy of ±0.3°C as per ASTM E1965-98.

Based on the idea of utilizing existing technology, this research aims to create a smart café monitoring system combining hardware (microcontroller) and software (smart application) for monitoring and controlling café visitors, body temperature, room temperature, and humidity. It also integrates intelligence for counting café visitors, transaction counting (dine-in or take-away), implementing security door locks, monitoring employee attendance remotely, and sending alarms and notifications via Telegram to café owners using RFID (Radio Frequency Identification Device). RFID RC522 is a software application with an antenna that radiates radio waves to RFID tags. The transmitted radio waves propagate in the surrounding area, allowing data to be transferred wirelessly to RFID tags near the antenna [8, 14, 15].

The goal of these additional features in this research is to track daily transactions and immediately trigger alarms and send notifications to the café owner's Telegram if an unauthorized person tries to enter the café without searching through recordings that take longer.

Sensors will collect data and read conditions daily. Each sensor connects to several outputs to operate automatically. For remote and real-time monitoring and control, an Internet of Things (IoT) platform is needed. Research [16] successfully detected and measured water level distance using IoT (Internet of Things) with the HC-SR04 ultrasonic sensor, monitored remotely.

II. Research Methods

The touchless system for transactions, body temperature measurement of visitors, and social distancing are the foundations of the design to be developed. The Arduino system will be connected to several sensors as inputs, which will then be processed to provide the designed outputs. The generated outputs will correspond to the commands set on the Arduino, depending on the input values read by the sensors. This café system includes RFID for attendance and security, visitor count monitoring, body temperature measurement, room temperature and humidity control, and disinfectant spraying.

Before the café operates, employees and dine-in visitors will measure their body temperature and receive disinfectant. Employees will tap their e-cards on the RFID Absence System & Security, allowing the manager to receive notifications on Telegram for remote attendance monitoring.

Figure 1 shows the flow diagram of the smart café system design. As shown in Figure 1, before operating the smart café system, it is necessary to ensure that the Internet network on WiFi is connected, and the PC can sign in to the open-source IoT website with a known username and password, enabling remote monitoring by the manager/owner working from home. Thus, the smart café system will operate 24 hours as long as the Internet connection is functioning well. In addition to being monitored via CCTV, if there is an abnormal condition, the RFID System will immediately trigger an alarm and send notifications to HRD's Telegram without searching through recordings, which takes longer.

Figure 1: Flow Diagram of the Smart Café System Design

On the other hand, the air quality monitoring system will work 24 hours actively, whether connected to the Internet or not, so the temperature and humidity conditions of the café during operation or non-operation can be monitored at all times. Meanwhile, the visitor counter system is only active when the café is operating. The touchless system measures a person's body temperature before entering the café. If the visitor's body temperature exceeds 36.95°C, the LCD will display that the visitor is not allowed to enter the café, and vice versa. Visitors will receive disinfectant upon entering the café. Then, the ultrasonic sensor will read the number of visitors who have entered the café and display the allowed visitor capacity. The ultrasonic sensor will be placed at the café's entrance and exit doors.

In addition, the transaction counter system operated by the café cashier is active when the café operates. When a visitor wishes to dine in or take away, the cashier will press a button to count the total daily transactions, as not all visitors who enter the café will dine in. With this feature, the owner can monitor the café's crowd.

Figure 2 shows the block diagram of the designed smart café system. In Figure 2, there are two serial communications between Arduino and NodeMCU ESP8266. The data sent by Arduino includes the Visitor Counter system connected to 2 Ultrasonic Sensors and the Transaction Counter with 6 Push Buttons. This is implemented due to the pin limitations on NodeMCU Amica and NodeMCU Lolin. Then, there is an independent system not connected to the IoT platform but connected to Telegram. This feature is applied to ensure more secure data transmission over the Internet and to send notifications directly to the café HRD manager.

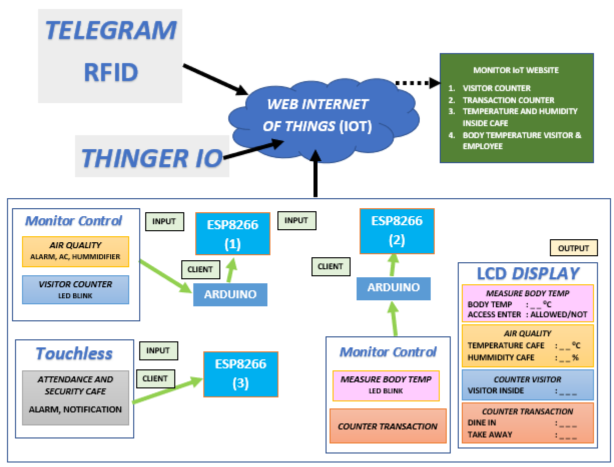

Figure 2: Block Diagram of the Smart Café System

i. Design

In designing the hardware, a contactless body temperature sensor with a wide measurement range from -70°C to +380°C was selected. Infrared radiation is part of the electromagnetic spectrum with wavelengths from 0.7 to 1000 microns. However, only 0.7-14 microns are used for temperature measurement [17, 18]. The selected humidity sensor is a resistive and NTC-based sensor that can be connected to an 8-bit microcontroller, providing fast response, anti-interference, affordability, and good quality.

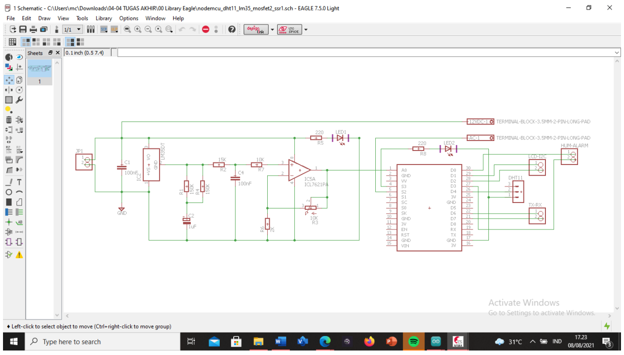

Figure 3: NodeMCU Communication Circuit 1

The café will be connected to the Internet and will collect café condition data to forward to the IoT platform. Temperature and humidity monitoring and control will be applied in the café dining area and kitchen. In the dining area, temperature and humidity data will be collected using the DHT11 sensor. In the kitchen, temperature data will be collected using the LM35 sensor arranged with a Low Pass Filter (LPF). The values of LM35 and DHT11 will be displayed on an LCD Display. The output of DHT11 is Air Conditioning and Humidifier, so if the temperature and humidity conditions are unhealthy, both will activate. The output of LM35 is an alarm, so if the kitchen temperature exceeds 38°C, the alarm will activate, prompting employees to check the kitchen conditions. This facility is used to prevent fires in the café kitchen due to the café's limited staff. LM35 sensor, DHT11 sensor, Air Conditioner (AC), Humidifier, Alarm, WiFi LED, LCD I2C, and TX RX pin D6 D7 NodeMCU will be connected to Serial Communication Circuit 1 (Figure 3). This Serial Communication Circuit will also be connected to Arduino for the Visitor Counter system.

The air quality monitoring system will be active 24 hours, whether connected to the Internet or not, so the café's temperature and humidity conditions can be monitored during operation and non-operation. When the system is connected to the Internet, data is forwarded to the IoT platform to evaluate the café's performance. The café's air circulation can be periodically corrected to prevent the spread of Covid-19. Figure 4 shows the NodeMCU communication circuit for air quality monitoring.

The Visitor Counter system is only active when the café operates. The touchless application measures

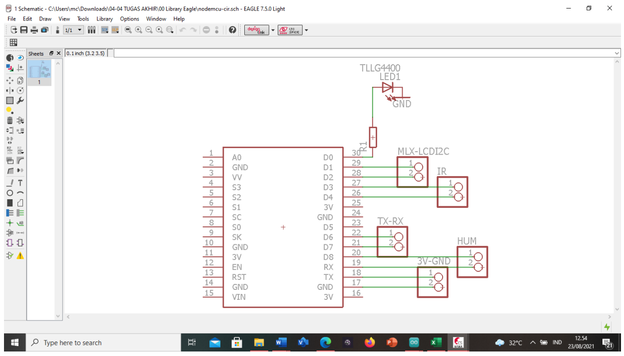

Figure 4: NodeMCU Communication Circuit 2

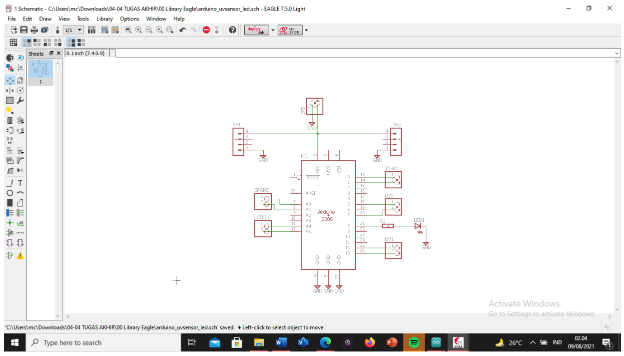

Figure 5: Arduino Communication Circuit 1

a person's body temperature before entering the café. If the visitor's body temperature exceeds 36.95°C, the LCD will display that the visitor is not allowed to enter the café, and vice versa. Visitors will receive disinfectant upon entering the café. Then, the ultrasonic sensor will read the number of visitors who have entered the café and display the allowed visitor capacity. The ultrasonic sensor will be placed at the café's entrance and exit doors. Figures 5 and 6 show the Arduino communication circuits for the Visitor Counter system connected to 2 Ultrasonic Sensors and the Transaction Counter with 6 Push Buttons.

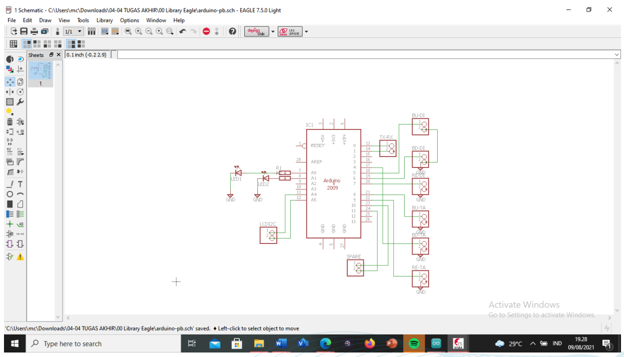

Figure 6: Arduino Communication Circuit 2

Additionally, the transaction counter system operated by the café cashier is active when the café operates. When a visitor wishes to dine in or take away, the cashier will press a button to count the total daily transactions, as not all visitors who enter the café will dine in. With this feature, the owner can monitor the café's crowd.

The software/application design uses Arduino Uno, IoT Platforms (ThingSpeak and Thinger.io), and Telegram applications. Through the Arduino application, the code will be compiled and implemented on the Smart Café system. The IoT Platform and Telegram will be used for remote monitoring in real-time to facilitate café management evaluations.

ii. Testing

Testing is conducted to ensure that the tool functions/operates correctly as desired. Several tests include evaluating the system's performance when sensors read the obtained data and compare it with actual conditions, testing the components' performance in the system by activating alarms on several sensors at predetermined values, testing the IoT Webserver Platform, and testing the overall system performance.

iii. Testing Parameters

The parameters monitored and controlled in the smart café system are as follows: 1. Air humidity. Air quality is also influenced by air humidity. Indoor air humidity levels change more easily than outdoor air. According to [19], the normal indoor air humidity level is 45% - 65% as the ideal level. If the humidity level is below 45%, airways and mucous membranes will dry out, and the influenza virus can survive longer. Conversely, if the humidity level is above 65%, it will trigger allergies for asthma sufferers. 2. Air temperature anomalies. According to the Indonesian Minister of Health (2011) on indoor air health guidelines, air quality requirements include particulate matter, air temperature, lighting, humidity, and ventilation rates. The recommended indoor temperature range is 18°C - 30°C [19]. If the temperature exceeds 30°C, it is recommended to lower it by increasing air circulation with additional ventilation. If the temperature is below 18°C, a room heater is needed using environmentally friendly and healthy energy sources. 3. Counting Visitors and Counting Transactions. According to [20], there is a circulation space of 20% or 259.2 cm² in the dine-in area. The space required for one person to eat is 1.2 m², so if the café can accommodate 40 visitors, it requires 48 m² of dining space. 4. Security door lock and touchless employee attendance. Maintaining social distancing to reduce interactions between employees and visitors is necessary. This touchless system is also built for security door locks, where only employee access cards are allowed to enter the café's service area. When tapping an e-card, data will be transmitted via the Internet to connect to the Telegram application on the manager's phone as a notification. If the e-card is not recognized, continuous notifications will be sent to the manager's Telegram, and the security post alarm will sound. With this feature, café security and employee attendance can be monitored remotely in real-time. 5. Body temperature measurement with infrared and disinfectant provision. Before entering the café, visitors and employees must measure their body temperature to ensure it is within the normal or healthy range. According to [21, 22], the normal human body temperature range for adults is 36.5°C - 37.2°C. To prevent the spread of the Covid-19 virus, an infrared thermometer is needed for touchless body temperature measurement. The smart café system uses a maximum body temperature value of 36.95°C for body temperature measurement.

III. Results and Discussion

When analyzing the system design, it is necessary to test the performance of the Smart Café System using IoT for Real-Time Remote Monitoring and Updates. This is done to achieve good results and ensure that the device meets expectations. The first step is to test the device to ensure it functions properly.

i. System Performance Testing

Figure 7 shows the results of testing the RFID Tag & Reader used for monitoring employee attendance with a touchless system via Telegram. When an employee or someone taps a card, the manager, operator, or owner's mobile phone screen will display whether the card is recognized.

Power Supply testing was conducted to determine the output voltage obtained after implementation on the PCB. The Power Supply used has two outputs, 5 VDC and 12 VDC. The voltage on the Transformer supplied to the Power Supply is 15 VDC with a current of 3A. Testing was performed using a Multimeter to determine the output voltage and the resulting waveform.

In Figure 8, the regulator IC for 5 VDC is IC7805, and for 12 VDC, it is IC7812. The transformer is connected to an On-Off switch and a fuse before connecting to the 220 VAC (Alternating Current) cable. The transformer is used to convert 220 VAC to 15 VRMS to enter the Power Supply, which uses 12 VDC and 5 VDC. The RMS voltage used in the Power Supply is 15 VRMS, while the alarm, exhaust fan, and mist maker have a value of 12 VRMS. The generated peak voltage is:

$$V_{P(PS)} = V_{RMS} + \frac{V_{RMS}}{\pi}$$

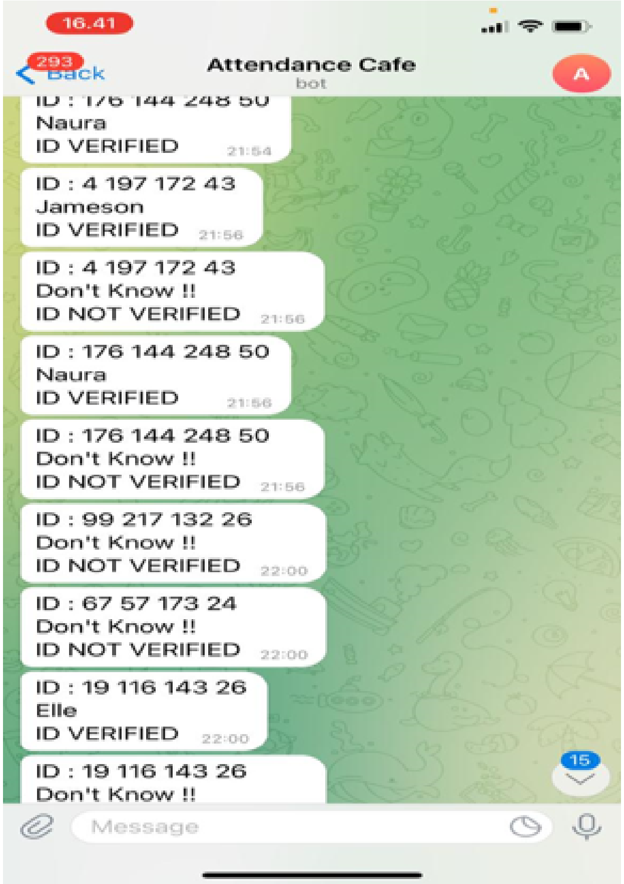

Figure 7: Display on Mobile Phone during RFID Testing

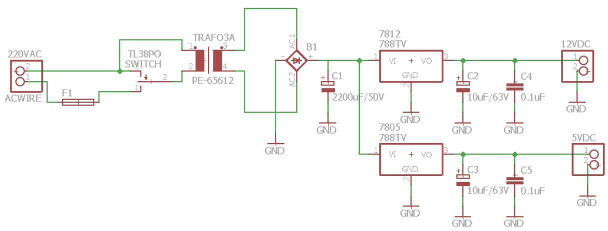

Figure 8: Power Supply Schematic Diagram

$$= 15 + \frac{15}{3.14} = 19.777\,V_P$$

$$V_{PP(PS)} = 2 \times V_P = 39.554\,V_{PP}$$

This test ensures that the source voltage connected to the device meets the required specifications. If the voltage is not correct, it can cause a short circuit in the current flowing through the circuit and damage the component ICs.

Figure 9 shows the results of testing the Push Button as a Transaction Counter to determine the number of dine-in and take-away transactions per day conducted by the cashier. The results show 8 dine-ins and 9 take-aways.

Figure 10 shows the results of testing the DHT11 sensor as a monitor of temperature and humidity inside the Café, indicating whether the conditions are normal. This system is also connected to a Humidifier and Cool-

Figure 9: Transaction Counter Test Results

ing Fan, which will activate if the café's temperature and humidity are abnormal. Similarly, the LM35 temperature sensor monitors the kitchen's temperature. If the kitchen's temperature is abnormal, the alarm will sound to avoid fire risks.

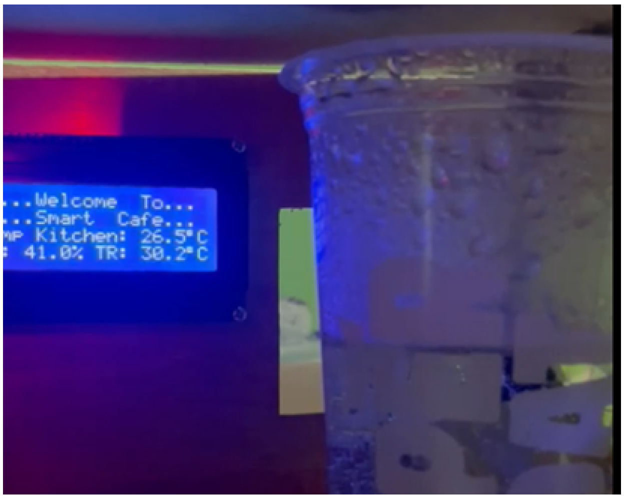

Figure 10: DHT11 Sensor Test Results for Temperature and Humidity Monitoring in the Café

Figure 11 shows the results of testing the MLX 90614 sensor, which measures body temperature without contact. This sensor works by capturing a person's body temperature data using an infrared system.

Figure 12 shows the results of testing the IR Sensor, which operates after someone passes the MLX 90614 sensor. If a person's body temperature is normal, they will proceed to the café entrance. Before entering the café, the person will receive disinfectant, activated when they enter the booth. The booth contains an IR

Figure 11: Body Temperature Measurement Using MLX 90614 Sensor

Sensor that detects the person's presence. Additionally, Ultrasonic Sensors at the café entrance and exit doors count the number of visitors entering and leaving the café to determine the café's capacity.

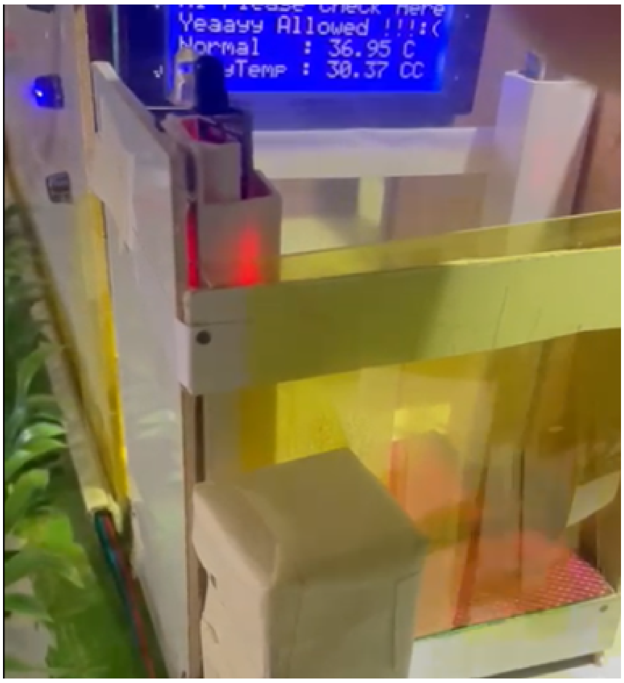

Figure 12: IR Sensor Test Results After Passing the MLX 90614 Sensor

The DHT11 Sensor, LM35 Sensor, Ultrasonic Sensor, and Push Button will be connected to the IoT platform. The IoT platform will read the temperature and humidity inside the café, the kitchen's temperature, the number of dine-in visitors, and the total daily transactions input by the cashier.

ii. Smart Café System Analysis

The LM35 Sensor circuit with LPF as a temperature detector in the café kitchen has a maximum temperature limit of 38°C. The detected temperature affects the voltage supplied to the connected circuit. The higher the temperature in the café, the higher the circuit's voltage. The Temperature Detector Circuit represents temperatures from 0°C to 100°C with a supplied voltage of 0 VDC to 12 VDC. When the temperature exceeds 38°C, the 0 VDC alarm will activate with a delay of 1000 ms.

Table 1 shows the temperature values in the kitchen measured by the LM35 sensor and the humidity and temperature in the café measured by the DHT11. The average temperature measured by the LM35 is 30.67°C, and by the DHT11, it is 32°C. The kitchen temperature is lower than the café temperature. Generally, the average temperature difference is 1.33°C. However, the DHT11 occasionally resets during data collection at 19:20, as shown in Table 2.

Table 1: LM35 Temperature Data from Thinger.io

Time	RH (%)	Temp. LM35 (°C)	Temp. DHT11 (°C)	Diff Temp (°C)
23:29	43	28.622	32.200	3.578
23:28	43	28.198	32.200	4.002
23:27	43	32.602	32.200	-0.402
23:26	43	32.135	32.099	-0.036
23:25	44	28.327	32.099	3.772
23:24	44	28.584	32.000	3.416
23:23	44	28.708	31.899	3.191
23:22	43	30.545	31.899	1.354
23:21	45	29.395	31.799	2.404
23:20	44	39.616	31.700	-7.916
Average	43.6	30.6732	32.0095	1.3363

Table 2: Temperature and Humidity LM35 vs. DHT11

Time	RH (%)	Temp. LM35 (°C)	Temp. DHT11 (°C)	Diff Temp (°C)
19:36	35	29.020	33.799	4.779
19:31	35	30.507	33.700	3.193
19:26	35	28.633	33.700	5.067
19:20	0	26.388	0	-26.388
19:19	0	27.940	0	-27.940
19:18	0	28.380	0	-28.380
19:17	0	32.070	0	-32.070
19:16	0	28.370	0	-28.370
19:15	0	27.526	0	-27.526
19:14	0	29.809	0	-29.809
Average	10.5	28.864	10.1199	-18.744

The MLX 90614 sensor is used to detect a person's body temperature using infrared. This sensor is located at the entrance process before entering the café area, as only those with normal body temperature or a maximum of 36.95°C are allowed. The MLX 90614 sensor measurement results can be seen in Table 3.

The Ultrasonic Sensor is used as a Visitor Counter for dine-in customers. This sensor simplifies controlling the café's capacity. In this study, the Ultrasonic Sensor reads the distance of a person entering the café

Table 3: MLX 90614 Temperature Data from Thinger.io

Time	MLX 90614 (°C)	Result
18:37	31.709	Health
19:31	31.529	Health
19:26	31.390	Health
19:20	31.409	Health
19:19	31.610	Health
19:18	31.330	Health
19:17	31.629	Health
19:16	31.469	Health
19:15	31.629	Health
19:14	31.390	Health
Average	31.509	

as 1 cm. Based on the data in Table 4, the placement distance of the Ultrasonic Sensor affects the detection of the total number of visitors in the café. Specific placement is needed to ensure accurate detection.

Table 4: Ultrasonic Sensor Experiment

Experiment	Visitors	Distance (cm)			Ultrasonic Detection
		1	2	3	
1	2	O			2
2	1		O		0
3	3	O			3
4	2			O	0
5	4	O			4
6	1	O			0
Total	13				9

The Push Button as a Counter Transaction for café customers ordering dine-in and take-away is used to determine the total daily transactions. Each cashier has three push buttons: one for adding, one for subtracting in case of input errors, and one for resetting the counter. When the reset button is pressed, the LED will activate, indicating that the Counter Transaction is being reset. The type of Push Button affects the readable data.

IV. Conclusion

Based on the results of the discussion on the Design and Development of a Smart Café System Using IoT for Real-Time Remote Monitoring and Updates, it was found that monitoring temperature, humidity, visitor count, and transaction count using the Thinger.io IoT platform with a registered account has been successfully tested. The Power Supply used has voltages of 5 VDC and 12 VDC with a current of 3A, which is suitable for the components used. The comfort conditions of the café are maintained by monitoring the number and condition of visitors and employees using the MLX 90614 sensor, which utilizes infrared to measure body temperature. Additionally, visitors are automatically sprayed with disinfectant. The air quality can also be automatically controlled if the café's temperature or humidity is abnormal, activating the Cooling Fan and Humidifier. Therefore, this IoT-based smart café system design is highly beneficial for café managers/owners, visitors, and employees in providing comfort and protecting against diseases caused by air quality and humidity. The café's condition can also be monitored in real-time, anytime and anywhere.

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