Smart Automation System for Controlling Environmental Parameters of Poultry Farms

Course Name: Internet of Things (IoT)

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Abstract

Agriculture and poultry must be addressed as the backbone of the economic growth of any developing country like Bangladesh. Furthermore, agricultural progress and economic prosperity are inextricably linked. Technology advancements and new technical developments have ushered in a new era of real-time animal health monitoring. This study focuses on a sensor-based solution for minimal-cost, capital-saving, value-oriented, and productive chicken farm management in order to increase the value of the broiler farm economy index (BFEI). The goal of this research was to see if an Intelligent System based on an Embedded Framework could be utilized to monitor chicken farms and adjust environmental conditions using smart devices and technology. This study also looked into how different temperatures (ranges from 25 to 33 °C) affected broiler performance efficiency factor (BPEF),livability, and feed efficiency (FCR). It was discovered that the group reared at higher temperatures had greater broiler performance efficiency factor, livability, and lower feed efficiency [1].

Keywords Intelligent farm · Embedded framework · Broiler farm economy index (BFEI)

1. Introduction

Chickens are the most popular poultry species farmed in big quantities. One of the most active segments of the livestock industry is the poultry business. Around 850 million dollars are currently invested in the poultry industry. Over the past five years, this industry has grown at an amazing rate of 8 to 10 per cent annually. Small farmers in underdeveloped nations rely heavily on selling poultry as a source of income. People need to meet their daily protein needs by consuming meat and eggs. To provide food, including meat and eggs, over 0.05 trillion chickens are produced every year. Poultry contributes greatly to poverty reduction and improved food security in developing nations as a source of high-quality protein. For many poor and middle-class families, chicken products constitute their sole affordable source of animal nutrition. For those under five years old who are sick and malnourished, eggs provide a convenient source of high-quality protein. According to the United States Department of Agriculture (USDA), Bangladesh's poultry business employs one million enterprises and eight million people, producing 10.22 billion eggs and 1.46 million tons of poultry meat yearly. The poultry business provides 36% of the total protein we consume through meat and eggs. In Bangladesh, 95 eggs are consumed annually per capita, whereas 6.5 kg of chicken are consumed annually. Chickens are influenced by high ambient temperatures in poultry farming, especially when there is a high relative humidity and a sluggish air speed above the birds. Severe heat stress reduces production efficiency and raises flock death rates. It reduces growth rates, egg output, meat quality, and egg quality, such as smaller eggs and thinner shells, all of which can lower their commercial value, resulting in considerable yield and economic losses. In breeding birds, high levels of NH3 can cause a decrease in egg production, egg weight and eggshell thickness. The negative effects of NH3 on broiler performance is of economic importance as reduced productivity and increased mortalities directly translates to a lower income for the farmer [2]. The current poultry farming chicken cages automation equipment has entered the rapidly developing chicken breeding industry upgrading by mechanisation, automation, intelligent system to complete the equipment, and complete sets of equipment application technology bottleneck is the main issue of laying hens that plagues most scale enterprises, and the solution has emerged in recent years with the advancement of environmental policies across the farming also face new challenges.

1.1 Objective:

The main purpose of this project is to develop a micro-controller based embedded automated easy-to-use system that automatically monitors and controls important conditions like temperature, humidity, and air quality in poultry farms. The goal is to create an environment that helps chickens grow healthier and faster, while reducing the chances of illness or death caused by poor conditions. This system aims to improve farm productivity by ensuring that chickens live in optimal conditions, which in turn increases the efficiency of feed usage and boosts the overall profitability of the farm. This automation reduces the need for manual intervention, enabling farmers to achieve greater operational efficiency while minimizing energy consumption and resource wastage. It provides real-time data, allowing farmers to make quick and informed decisions to maintain the best possible environment for their poultry. Ultimately, the objective is to deliver a sustainable solution that enhances food production, supports economic growth, and promotes the use of modern technology in farming, particularly in developing regions, ensuring that even small and medium-sized farmers can benefit from these advancements.

1.2 Problems Statement:

The impact of the problems on the poultry business is huge as it severely affects the profitability and sustainability of a poultry business. Poor environmental conditions can lead to higher mortality rates, reduced growth, and lower egg production, which directly impacts revenue. Additionally, chronic health problems caused by unmanaged humidity or harmful gas build-up increase veterinary costs. Over time, poor flock performance diminishes the farm's reputation, making it harder to retain customers and expand the business. The increased operational costs, coupled with declining product quality, ultimately threaten the farm's long-term viability and competitiveness in the market.

In the long run, the absence of an automated system in a poultry farm leads to significant operational and economic setbacks. Unregulated temperature can cause heat stress or cold shock in birds, leading to lower feed efficiency and poor growth, which means more resources are consumed for less output. Humidity imbalances can create ideal conditions for disease outbreaks, increasing the cost of medication and veterinary care. Gas build-up, particularly ammonia, not only affects bird health but also deteriorates the quality of the housing environment, requiring more frequent cleaning and maintenance. Research shows that exposure to high concentrations of NH3 (between 50 and 75 ppm) causes reduced weight gain, final body weight, and feed efficiency, and increased mortality rate in broilers. Even a prolonged exposure to lower NH3 concentrations (25 ppm and 35 ppm) has been shown to reduce broiler weigh gain, body weight (Figure A), and feed efficiency. Antibiotics can minimize NH3, but consumers have concerns about health effects in directly in humans' health [3].

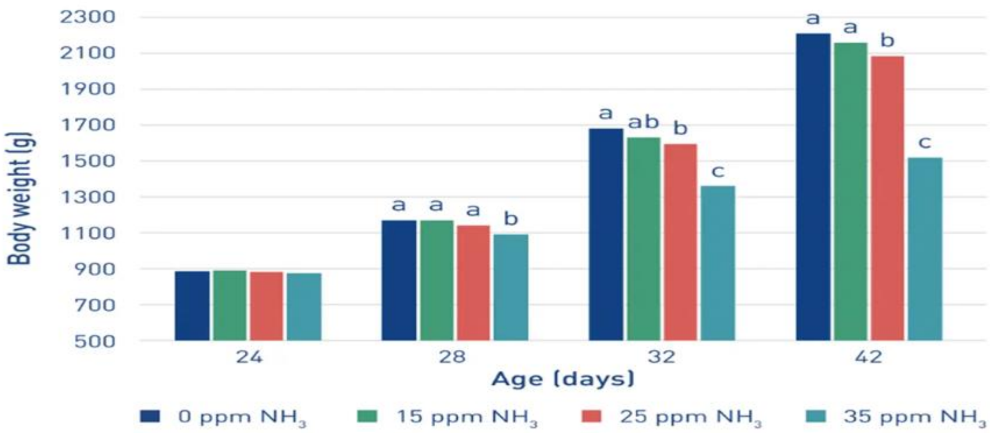

Fig. 1 Effect of ammonia (NH_3) at different concentrations (0, 15, 25, and 35 ppm) on the body weight of broiler chickens between 22 and 42 days of age, based on data from Zhou et al., 2020.

Economically, these issues can reduce production levels, forcing the farm to invest more in inputs like feed, energy, and labour without seeing proportional returns. Consistently poor flock health leads to lower market value for the birds and eggs, diminishing profitability. Additionally, as more resources are diverted to manage preventable health and environmental issues, cash flow becomes strained. Over time, these inefficiencies lead to declining profit margins, higher operational costs, and reduced competitiveness, possibly forcing the farm to downsize or even close. This can further result in job losses and financial instability for the farm and its associated businesses.

2. Literature Review

Poultry growers from temperate climates countries such as Bangladesh face the difficulty of high ambient temperatures during summer which has a major impact on the production performance of commercial poultry. If a balance between body heat loss and body heat production are not achieved birds are 'heat stressed'. It is associated with all types of poultry at all ages. As a result, an intelligent system can offer an environment that is appropriately regulated and controlled to avoid limiting bird performance. The most fundamental technique of regulating the poultry environment, according to Mutai et al. [4], is to maintain optimal temperatures in these facilities by altering circulation and warming rates. A relative humidity (RH) of more than 70% is unfavourable and should be avoided by using ventilation in buildings [5]. RH levels are below 50% because more dust and airborne microorganisms are produced, but this is not a regular occurrence. High RH paired with high temperatures might cause discomfort in birds during the summer months [6]. Birds eat more feed to maintain a normal body temperature when exposed to cooler temperatures. Feed is not turned into the meat when used for heating [7]. When temperatures rise too high, energy is squandered as birds struggle to cool down. In these circumstances, ascites (a metabolic illness that causes performance decline) and mortality in broilers will be more common. According to a recent study, when two separate temperature ranges (26 and 32 °C) were applied to different groups of broilers during growth, the group exposed to the higher temperature performed better and used less feed [8]. The conventional systems for controlling chicken farms have a number of drawbacks, including low energy efficiency and high-power usage. In today's poultry farming, smart control technologies like Zigbee, Arduino, Raspberry Pi, and the integration of wireless sensors, General Packet Radio Service (GPRS) and Multiple Input Multiple Output (MIMO) systems have been adopted [9–13].

2.1 Best Selection of Environmental Parameters for Broilers

After surveying different reports on broiler chicken or bird farming, selection of threshold conditions for poultry farm environment parameters are made below in Table 1 [14]. It has been seen that during the brooding period of broiler chickens (age $<$ 7 days) 30–33 °C temperature is required for best production. Due to extreme temperatures, broilers older than 21 days may experience heat stress. As a result, the temperature of poultry farms decreases by 2/3 °C every week as the chickens grow older. If broiler faecal matter is not changed every two weeks, relative humidity (RH) in the poultry environment might reach 70%, which is not ideal for the best farming.

Age (Days)	**Temperature**	**Humidity**
0–6	30ºC -33ºC	50%-60%
7–14	28ºC -31ºC	50%-65%
28–31	26ºC -29ºC	60%-75%
50–65	25ºC -28ºC	65%-80%

Table 1 Parameter selection

3. Methodology

3.1 Hardware Used:

This system design outlines an automated environmental control system intended to maintain optimal conditions in a poultry shed, integrating various components to monitor and regulate temperature, humidity, and air quality. The primary control unit is an ESP32 microcontroller, interfacing with sensors, relays, and actuators to manage environmental variables.

3.1.1. ESP32 Microcontroller

The ESP32 serves as the central processing unit for the system. It receives real-time data from multiple sensors and actuators the necessary components, such as fans and heat bulbs, to maintain ideal environmental conditions. The ESP32 is equipped with both Wi-Fi and Bluetooth capabilities, allowing for remote monitoring and control of the system, making it suitable for smart farming applications.

3.1.2. Environmental Sensors

DHT Sensor: The DHT sensor measures temperature and humidity within the poultry shed. Maintaining these parameters within specific ranges is crucial for poultry health and productivity. The sensor transmits real-time data to the ESP32 for continuous monitoring.

MQ Sensor: The MQ series sensor is used for detecting gases, such as ammonia, carbon dioxide, or methane, which are commonly found in poultry environments. Elevated levels of harmful gases can negatively affect poultry health, and thus the system automatically triggers ventilation to mitigate such risks.

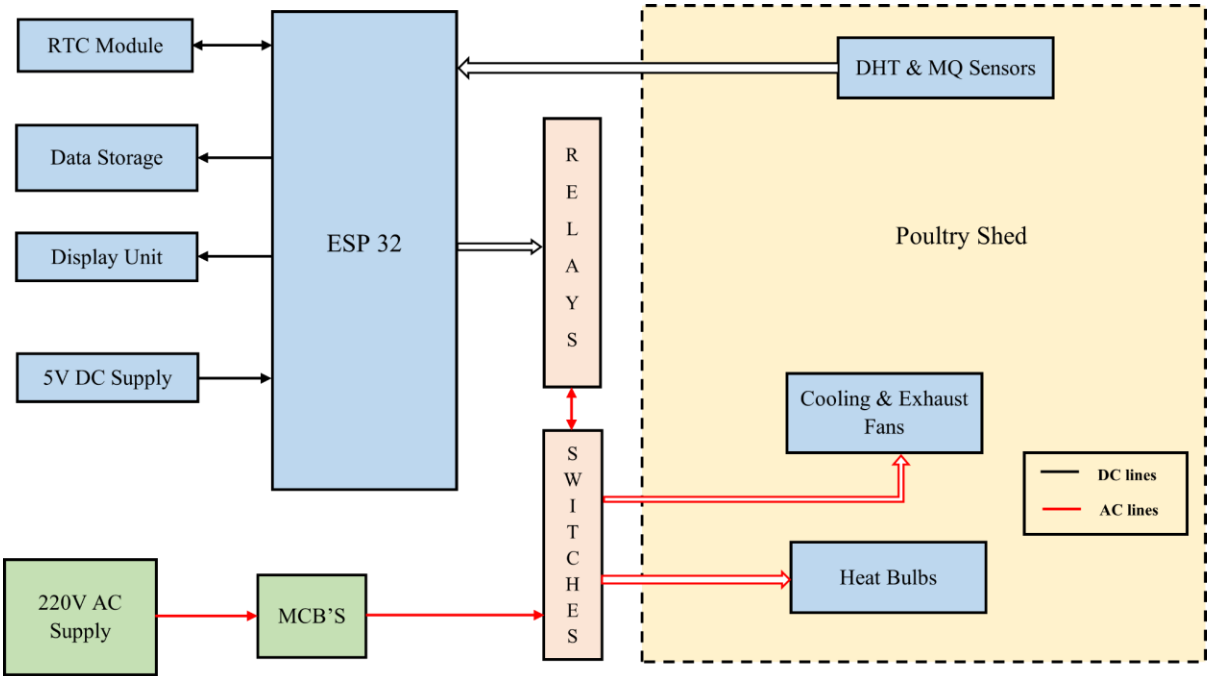

Fig. 2: Block Diagram of Proposed System

3.1.3. Actuation Components

Relays: The relays function as electronic switches that interface between the ESP32 and high-power components. The relays control the operation of the cooling/exhaust fans and heat bulbs based on the input from environmental sensors.

Switches: Manual switches are integrated into the system to provide an override option for the automatic control, allowing for manual operation of the fans and heating elements when necessary.

3.1.4. Cooling and Exhaust Fans

The cooling and exhaust fans are controlled by the relays and are activated when temperature or gas levels exceed the predefined thresholds. These fans are powered by alternating current (AC) and ensure proper ventilation and temperature regulation within the shed. The system dynamically adjusts fan speed based on sensor feedback to maintain optimal environmental conditions.

3.1.5. Heat Bulbs

The heat bulbs are responsible for providing necessary warmth, particularly during colder weather or for young poultry that require elevated temperatures for proper growth. Controlled by relays, the heat bulbs are powered through the AC supply and are activated in response to low temperature readings from the DHT sensor.

3.1.6. Real-Time Clock (RTC) Module

The RTC module provides accurate timekeeping even in the event of power interruptions, enabling the system to perform time-based operations, such as activating or deactivating heating or cooling at specific times of day. This ensures precise control over the environmental conditions based on daily or seasonal cycles.

3.1.7. Data Logging and Storage

The system includes data storage functionality, which logs environmental parameters over time, such as temperature, humidity, and gas levels. These records can be utilized for trend analysis, performance optimization, and as a historical reference for adjusting control strategies.

3.1.8. Display Unit

A display unit is integrated into the system to provide real-time visual feedback of the current environmental conditions. Key metrics, including temperature, humidity, and system status (e.g., fan or heat bulb activation), are displayed for the benefit of farm operators, enhancing situational awareness.

3.1.9. Power Supply

5V DC Power Supply: This low-voltage power source drives the ESP32, sensors, RTC module, and display unit, ensuring stable and uninterrupted operation of the control components.

220V AC Power Supply: High-power components such as cooling fans and heat bulbs are powered by the 220V AC supply. This power source is routed through Miniature Circuit Breakers (MCBs) for protection.

3.1.10. Safety Mechanisms

Miniature Circuit Breakers (MCBs): The system is equipped with MCBs to safeguard against electrical overloads and faults. These breakers automatically disconnect the power in the event of an overcurrent, ensuring the safety of both the system and the poultry shed.

Manual Override Switches: In addition to automated control, the system includes manual switches that allow operators to bypass the ESP32 in case of emergency or maintenance, offering a redundant layer of control.

3.2 System Operation and Control Strategy

The system operates by continuously monitoring environmental conditions via the DHT and MQ sensors. The ESP32 processes sensor data and actuates the cooling fans or heat bulbs through the relays, depending on the current environmental state. For instance:

- If the temperature exceeds a predefined threshold, the cooling fans are activated to bring the temperature down.
- If the temperature drops below the required level, the heat bulbs are activated to maintain optimal warmth.
- If harmful gas levels rise above the safety limit, the exhaust fans are triggered to improve ventilation.

Data collected by the system is stored for future analysis, providing insights into long-term environmental trends, which can be used to optimize poultry health and productivity. The real-time display offers continuous feedback, and the RTC ensures time-based precision in control strategies.

3.3 Software Setup

The software architecture of the smart automation system is developed using the ESP32 microcontroller, programmed via the Arduino IDE using C/C++. Critical libraries, such as the DHT and MQ libraries, facilitate seamless integration of temperature, humidity, and gas sensors, enabling real-time environmental monitoring and control. The ESP32's dual connectivity through Wi-Fi and Bluetooth ensures both local and remote access. Remote control is managed via a web-based dashboard or mobile application, offering farm operators a flexible, user-friendly interface to monitor and adjust conditions. The system's control logic employs predefined thresholds to automatically regulate fans and heat bulbs based on sensor readings, ensuring an optimal environment for poultry health.

Data handling is a pivotal aspect, with environmental parameters being logged into local storage (e.g., microSD cards) and optionally uploaded to cloud services for long-term trend analysis. This data-driven approach not only supports immediate decision-making but also enables future optimization of the farm's control strategies. A real-time display unit connected to the ESP32 offers immediate feedback on key metrics, while the system's remote interface allows operators to track performance and make adjustments seamlessly. The system architecture emphasizes robust control algorithms to dynamically manage environmental parameters such as temperature, humidity, and gas levels, minimizing manual intervention and improving farm productivity. Through this comprehensive software framework, the automation system ensures a high level of operational efficiency, energy savings, and environmental control, all while being scalable for future enhancements.

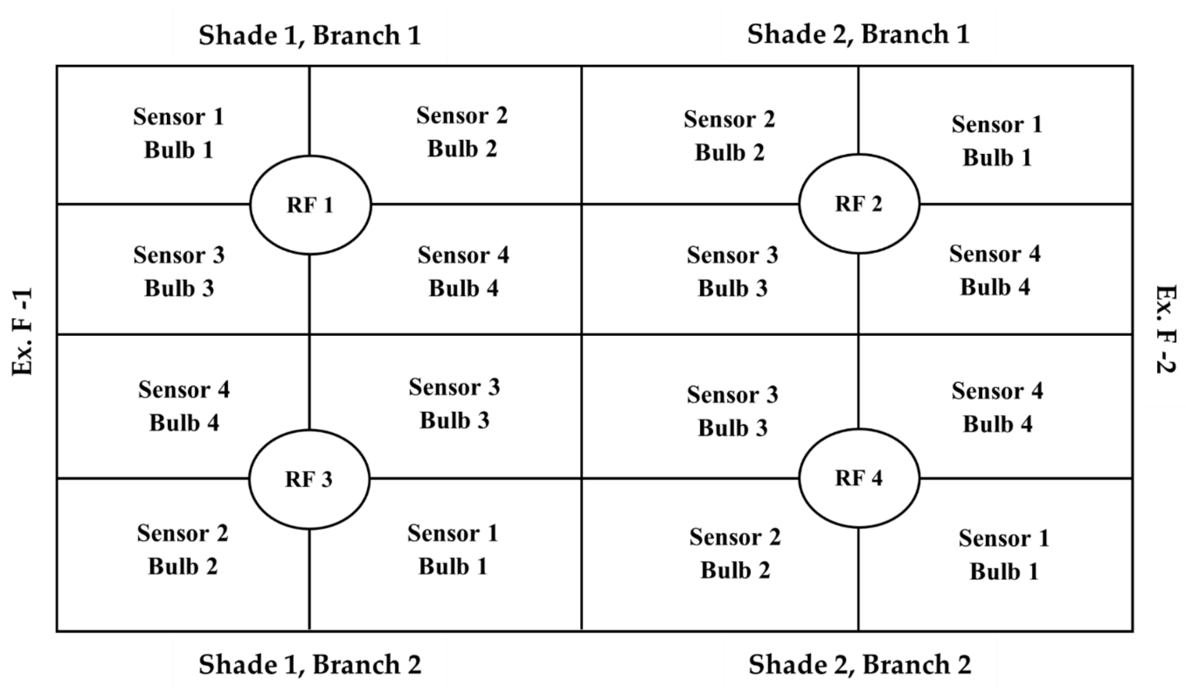

Fig: 3 architectural layout of a smart environmental control system designed for a poultry farm

3.4 System Architecture and Layout Design:

Figure 2 presents the architectural layout of a smart environmental control system designed for a poultry farm, optimizing air quality, temperature regulation, and overall farm productivity. The farm is divided into **two shades**, further subdivided into **two branches** per shade (**Shade 1: Branch 1 and Branch 2; Shade 2: Branch 1 and Branch 2**). This structured layout facilitates efficient environmental management, ensuring that each section receives appropriate ventilation and climate control.

At the core of each branch are **Roof Fans (RF1–RF4)**, strategically positioned to optimize **air circulation** and maintain uniform conditions across all quadrants. These are supplemented by **Exhaust Fans (Ex. F-1 and Ex. F-2)** located on opposite sides of the layout, designed to expel stale air, thus promoting a constant inflow of fresh air.

LEGENDS

R.F = Roof Fan-X

Ex.F = Exhaust Fan-X

3.5 Environmental Control and Sensor Integration:

Each quadrant is equipped with **sensors** (Sensors 1 through 4) and **bulbs** (Bulbs 1 through 4), which provide real-time monitoring and control of key environmental parameters. The sensors play a critical role in measuring:

- **Ambient Temperature**, to ensure optimal thermal conditions.
- **Humidity Levels**, to prevent excessive moisture buildup.
- **Ammonia Concentration**, ensuring that air quality remains within safe limits for poultry health.

These sensors are paired with **lighting elements** (Bulbs), which may serve dual purposes—providing both light and heat when necessary to maintain ideal conditions for poultry development, particularly during colder periods.

3.6 Ventilation System

The ventilation system is an integral component of this design. **Roof Fans** (RF1–RF4), positioned centrally in each branch, provide robust air circulation, preventing the formation of heat pockets and reducing the risk of **heat stress**. Their function is especially critical in high-temperature environments, where **excessive heat** can drastically reduce poultry growth rates and productivity.

Simultaneously, the **Exhaust Fans** (Ex. F-1 and Ex. F-2) operate to remove **contaminated air**, which may contain high levels of **ammonia** and other harmful gases. By facilitating the continuous outflow of stale air, the exhaust fans help maintain a clean and fresh environment, reducing the risk of respiratory illnesses and promoting optimal bird health.

3.7 Energy Efficiency Considerations

The strategic placement of the fans and sensors not only ensures comprehensive environmental control but also enhances the system's **energy efficiency**. By minimizing the need for energy-intensive cooling systems such as air conditioning, the **roof fans** provide an eco-friendly solution for maintaining airflow, while the **exhaust fans** complement this by ensuring the effective expulsion of heat and contaminated air. This results in a more sustainable approach to managing environmental conditions, with potential reductions in operational costs.

4. Implementation

4.1 Interfacing Temperature and Humidity Sensor with ESP32 Microcontroller

The interfacing of temperature and humidity sensors with the ESP32 microcontroller in this system integrates two DHT11 sensors for real-time environmental monitoring. The sensors, connected to GPIO pins 15 and 4 of the ESP32, measure crucial temperature and humidity data, essential for maintaining optimal conditions in poultry farming. The ESP32 reads sensor data using the DHT library, validating the readings for accuracy before logging them to an SD card and transmitting them to ThingSpeak for remote monitoring.

Based on predefined thresholds, the ESP32 automates environmental control: if the temperature falls below 26°C, relays activate heating bulbs; if it exceeds 32°C, exhaust fans are engaged to regulate air quality and temperature. This seamless integration of sensors with the ESP32 ensures real-time data collection, automation of key controls, and enhanced farm productivity through minimal manual intervention, making it ideal for IoT-based precision agriculture.

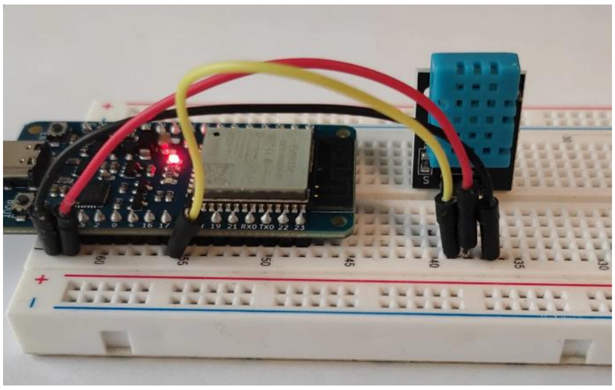

Fig.4 Interfacing DHT11 sensor with ESP32

4.2 Interfacing Micro SD Card Reader Module with ESP32

The interfacing of a microSD card reader module with the ESP32 microcontroller, as implemented in this system, provides an efficient method for data logging of environmental sensor readings. The microSD card is connected to the ESP32 via the SPI (Serial Peripheral Interface) protocol, with the Chip Select (CS) pin assigned to GPIO 5. This setup enables the ESP32 to write sensor data, such as temperature, humidity, and gas levels, to the microSD card for long-term storage and offline analysis.

During initialization, the system checks if the SD card is properly mounted, ensuring reliable data storage. If the SD card fails to initialize, the system halts, preventing data loss. When operational, the ESP32 reads sensor data from DHT11 temperature and humidity sensors, as well as MQ-5 and MQ-135 gas sensors. The data, along with timestamps provided by the DS3231 RTC module, is written to a text file on the SD card at regular intervals.

This SD card integration allows for seamless and reliable data logging, providing a critical backup for sensor data and enabling trend analysis over time. The ESP32's efficient handling of file creation and data writing ensures that the environmental data is stored securely, making it an essential component in IoT-based farming systems where historical data is crucial for optimizing environmental conditions.

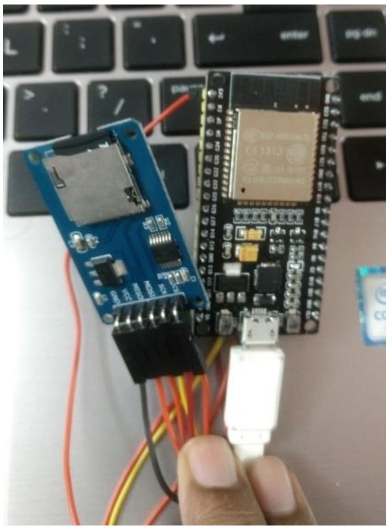

Fig. 5 Interfacing ESP32 with MicroSD card Reader

4.3 Interfacing DS-3231 real time clock (RTC) module with ESP32

The DS3231 Real-Time Clock (RTC) module is interfaced with the ESP32 via the I2C protocol, providing accurate timekeeping for the system. In the code, the RTC module initializes during startup, ensuring that the current time is available for timestamping sensor data. If the RTC has lost power, the time is set using the compilation time of the code.

The DS3231 provides real-time timestamps that are used for logging temperature, humidity, and gas sensor data to the SD card and when transmitting data to ThingSpeak. This ensures accurate tracking of environmental conditions over time. The RTC also plays a key role in managing time-based control of relays for fans and heating bulbs, ensuring precise, real-time operations within the system. This integration ensures reliable, continuous timekeeping even during power interruptions, making it essential for accurate data logging and automation.

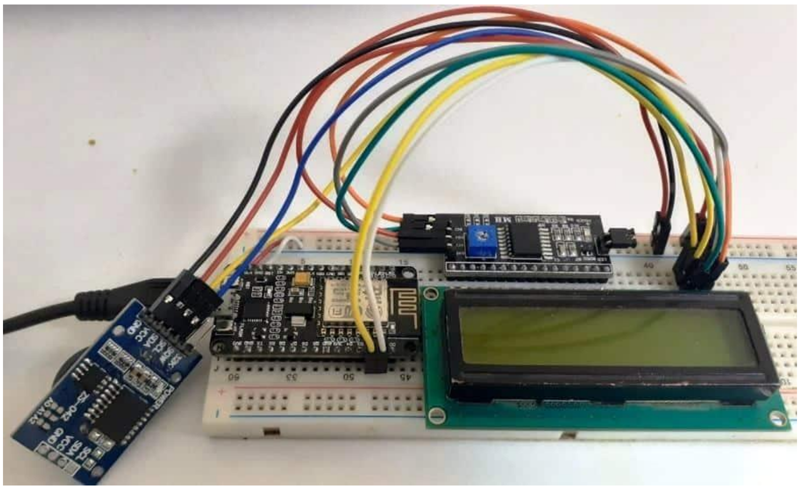

Fig. 6 Interfacing DS3231 RTC with ESP32

4.4 Interfacing lcd 16×2 lcd display with ESP

Interfacing a 16x2 LCD display with the ESP32 allows real-time display of environmental data, such as temperature, humidity, and gas levels, from sensors. The LCD is connected to the ESP32 using the I2C interface, which simplifies wiring by reducing the number of connections required.

The I2C module of the LCD connects the SDA (data) and SCL (clock) lines to the corresponding I2C pins on the ESP32. In the code, the LCD is initialized in the setup() function. After initialization, the system reads data from DHT11 temperature and humidity sensors, as well as gas sensors, and displays the values on the LCD.

The 16x2 display can show two lines of information, allowing the system to display values such as "Temp: 25°C" and "Humidity: 60%" in real-time. This provides an immediate, on-site visual reference of critical environmental parameters, enhancing user interaction with the system. The integration of the LCD ensures a simple, yet effective way to monitor data without needing to access remote systems like ThingSpeak or SD card logs.

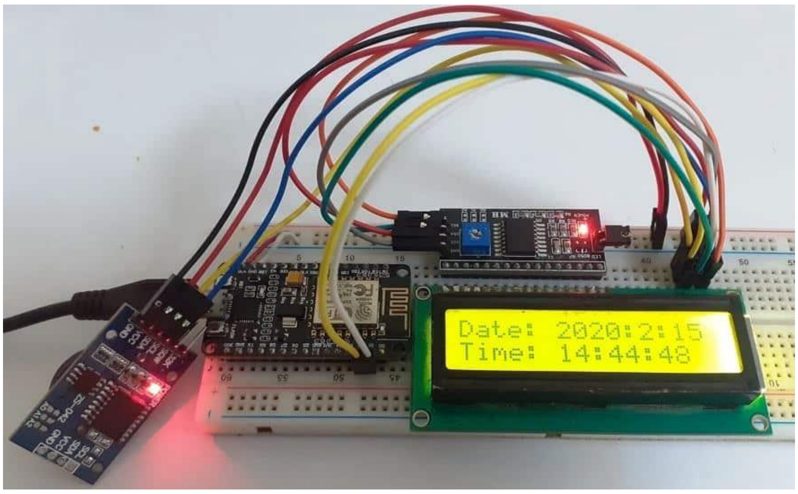

Fig. 7 Interfacing DS3231 RTC with ESP32 with lcd 16×2 lcd display

4.5 Interfacing Relay Switches with ESP32 for Automated Environmental Control

Interfacing relay switches with the ESP32 microcontroller for automated environmental control, using real-time data from temperature, humidity, and gas sensors. The system integrates two DHT11 sensors to monitor temperature and humidity, and MQ-5 and MQ-135 sensors to detect gases such as Ammonia and CO2. Based on sensor inputs, the ESP32 controls relay modules to switch electrical devices, such as light bulbs and an exhaust fan, in response to defined environmental thresholds. The design enables efficient real-time control, data logging, and remote monitoring via the ThingSpeak cloud platform.

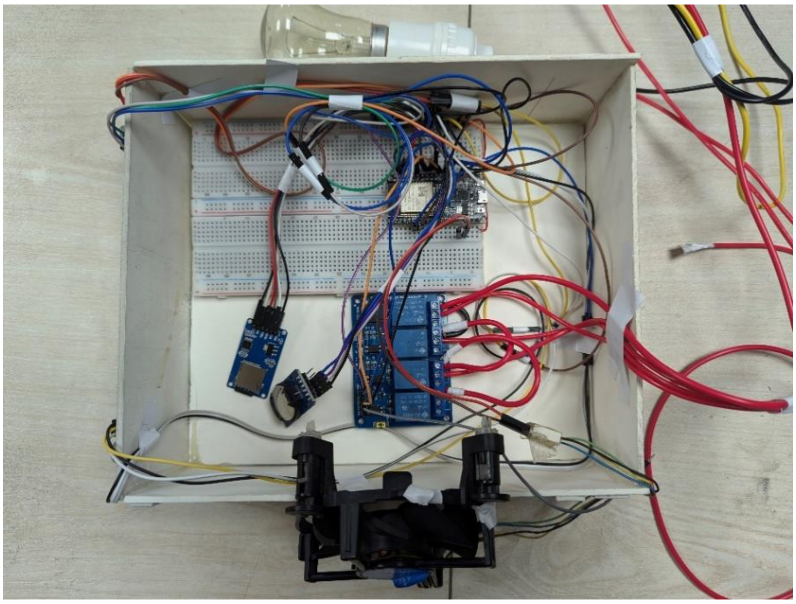

Fig. 8 Interfacing 4 Channel relay with ESP32

The relay control is implemented through the ESP32's GPIO pins (16, 17, 27), which are connected to the relay module. The system is designed to automatically actuate two bulbs when the temperature falls below 26°C and activate the exhaust fan if the temperature exceeds 32°C. This threshold-based decision-making ensures a stable and optimized environment for various applications, such as industrial automation, greenhouses, or smart homes. The relays are controlled using simple `digitalWrite()` commands, ensuring ease of integration and reliability in switching high-voltage devices.

4.6 Installation of Light holders and Fans

We have set 1 exhaust fans, which will pass the hot air and for cooling purpose of the poultry room. Also, we have set 2 light holders for 2 chicken shade, which provides heat if temperature is below the margin line.

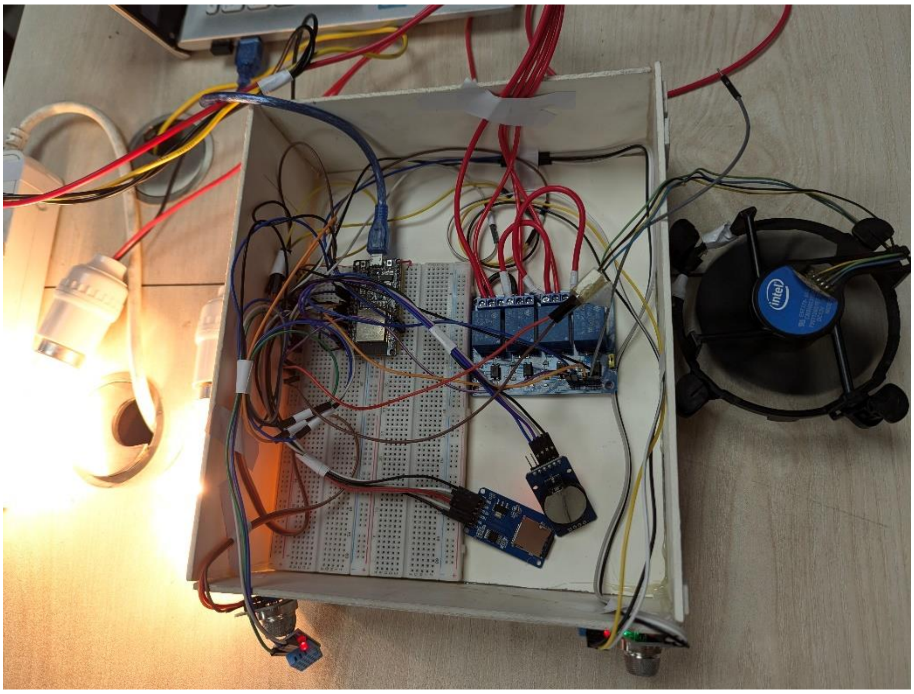

Fig. 9 Installation of Light holders and Fans

4.7 Protocols (OWSP, I2C, SPI)

One wire single protocol (OWSP) is used by DHT sensors for transferring data. DHT sensors have 4 pins (VCC, GND, NC and DATA). The NC pin is connected to VCC with a 1K pull-up resistor. Usually, DHT sensors are placed far away from the microcontroller board. Therefore, the NC pin doesn't require any connection. Micro SD card module uses Serial programming Interface (SPI) protocol for data communication. It has 6 pins (VCC, GND, MISO, MOSI, SCK and CS). Although it supports 16GB memory cards at the highest level. The RTC module has 6 pins, of which 4 pins (VCC, GND, SDA, SCL) are connected to the microcontroller. It uses the Inter Integrated Circuit (I2C) communication protocol. A RTC module is always on with its external battery supply. But before we use it, initially we need to set the present time and date through Arduino ide.

5. Software Integration:

5.1 Library Inclusions and Configuration:

The code begins by including essential libraries for handling various hardware components such as DHT11 sensors for temperature and humidity, SPI and SD for microSD card operations, WiFi and ThingSpeak for internet connectivity, and RTClib for the Real-Time Clock (RTC). Configuration constants are defined to store sensitive information like WiFi credentials and ThingSpeak API keys, as well as pin assignments for sensors and relays. Threshold values for temperature control and loop delays are also set here to govern the system's operational parameters.

```
// Import essential modules for sensor interfacing, communication, and timekeeping
Import DHT_Sensor_Module
Import SPI_Communication_Module
Import SD_Storage_Module
Import WiFi_Connectivity_Module
Import ThingSpeak_API_Module
Import RTC_Module

// Initialize configuration parameters with secure storage practices
Initialize WiFi_Credentials with SSID and Encrypted Password
Assign ThingSpeak_Channel_Number and Secure_API_Key

// Map hardware connections to logical identifiers for scalability
Map DHT_Sensors to GPIO_Pins [DHT1_PIN, DHT2_PIN]
Map MQ_Gas_Sensors to Analog_Pins [MQ5_PIN, MQ135_PIN]
Configure SD_Card with Chip_Select_Pin
Define Relay_Controllers with designated GPIO_Pins [RELAY1_PIN, RELAY2_PIN, RELAY3_PIN, RELAY4_PIN]

// Establish operational thresholds and timing mechanisms
Set Temperature_Low_Threshold to 26.0°C
Set Temperature_High_Threshold to 32.0°C
Define System_Loop_Delay as 5000 milliseconds
```

5.2 Global Objects Initialization

Global objects are created to manage interactions with the hardware components. This includes instances of the DHT sensors, RTC module, WiFi client, and file handling for the SD card. These objects facilitate seamless communication between the software and the physical devices, ensuring that sensor data can be read, stored, and transmitted efficiently.

```
// Instantiate sensor interfaces with predefined configurations
Instantiate DHT_Sensor_1 on Pin DHT1_PIN with Type DHT11
Instantiate DHT_Sensor_2 on Pin DHT2_PIN with Type DHT11

// Initialize Real-Time Clock with high-precision settings
Initialize RTC_Module with DS3231_Profile

// Establish WiFi Client with optimized buffer settings for ThingSpeak
communication
Create WiFi_Client_Instance with Enhanced_Timeout and Buffer_Size
Parameters

// Prepare File Handling Mechanism for Robust SD_Card Interactions
Initialize SD_File_Handler with Path "/sensor_data.txt" in
Append_Mode
```

5.3 Setup Function

The setup () function is responsible for initializing all hardware components and establishing necessary connections. It starts serial communication for debugging, initializes the DHT sensors, configures analog pins for gas sensors, and sets up the microSD card. Relay pins are configured as outputs and initially turned off to ensure a safe startup state. The RTC is initialized to keep accurate time, and the system connects to the specified WiFi network. Finally, ThingSpeak is prepared for data transmission, enabling remote monitoring of sensor data.

```
Procedure Initialize_System:
    // Establish communication channels for debugging and monitoring
    Activate Serial_Interface with Baud_Rate 115200
    Output "System initializing..."

    // Commence sensor readiness protocols
    Activate DHT_Sensor_1 and DHT_Sensor_2
    Configure MQ_Sensors as Analog_Input_Modules on designated Pins

    // Engage microSD storage subsystem with error handling
    If SD_Card_Initialization_Fails:
        Log "SD card initialization failed! Halting system."
        Enter Infinite_Halt_State to prevent data inconsistency

    Log "SD card initialized successfully."

    // Configure relay actuators with initial safe states
    For Each Relay in [RELAY1_PIN, RELAY2_PIN, RELAY3_PIN,
RELAY4_PIN]:
        Set Relay as OUTPUT
```

```
        Deactivate Relay to ensure all connected devices are OFF

    // Initialize Real-Time Clock with fallback mechanisms
    If RTC_Module_Not_Found:
        Log "RTC not detected! Halting system."
        Enter Infinite_Halt_State

    If RTC_Power_Loss_Detected:
        Log "RTC lost power, initializing with compile-time data."
        Synchronize RTC with Current_Compile_Time

    // Establish Wi-Fi connectivity with status feedback
    Initiate WiFi_Connection using ssid and password
    While Not Connected to WiFi:
        Wait for 1 second
        Output "Connecting to WiFi..."

    Log "Connected to WiFi successfully."

    // Prepare ThingSpeak for data communication
    Initialize ThingSpeak_Interface with Established_WiFi_Client
End Procedure
```

5.4 Main Loop Function

The loop() function operates continuously, performing the core tasks of the system at regular intervals defined by LOOP_DELAY. It begins by fetching the current time from the RTC to timestamp sensor readings accurately. Temperature and humidity data are gathered from two DHT11 sensors, while gas concentrations are measured using MQ-5 and MQ-135 sensors. The readings are validated to ensure data integrity before proceeding.

```
Function Execute_Main_Loop:
    // Retrieve precise timestamp from RTC module for data accuracy
    Current_Time = Fetch_Current_Time_From_RTC()

    // Aggregate environmental data from multiple sensors
    Sensor_Readings = {
        "Temperature1": Read_Temperature_From_DHT1(),
        "Humidity1": Read_Humidity_From_DHT1(),
        "Temperature2": Read_Temperature_From_DHT2(),
        "Humidity2": Read_Humidity_From_DHT2(),
        "Gas_Level_MQ5": Read_Analog_Value_From_MQ5(),
        "Gas_Level_MQ135": Read_Analog_Value_From_MQ135()
    }

    // Initiate comprehensive validation of all sensor data
    If Validate_All_Sensor_Data(Sensor_Readings) Then
```

```
        // Commit validated data to persistent local storage
        Invoke_LogData_With_Timestamp(Current_Time, Sensor_Readings)

        // Dispatch sensor data to cloud-based monitoring platform
        Invoke_SendData_To_ThingSpeak(Sensor_Readings)
        // Execute conditional control logic for actuators based on
sensor thresholds

Invoke_ControlRelays_BasedOn_Temperature(Sensor_Readings["Temperatur
e1"], Sensor_Readings["Temperature2"])
    Else
        //  Log  validation  failure  and  initiate  error  handling
protocols
        Log "Sensor data validation failed. Skipping data logging and
transmission."
    End If

    //  Implement  operational  pacing  to  regulate  loop  execution
frequency
    Initiate_System_Delay(LOOP_DELAY)
End Function
```

5.5 Data Logging and Transmission

Once validated, the sensor data is logged to a microSD card, providing a local record of environmental conditions. Simultaneously, the data is sent to a ThingSpeak channel over WiFi, enabling real-time remote monitoring and analysis through dashboards. This dual approach ensures both local storage and cloud-based accessibility of the data.

```
Procedure Log_And_Transmit_Data(Current_Time, Sensor_Readings):
    // Initiate file access protocol for local data persistence
    Open sensor_data.txt in Append_Mode on SD_Card
    If File_Access_Successful Then
        // Sequentially log timestamped sensor data
        Write "Timestamp: " + Format_Time(Current_Time) to File
        For Each Sensor in Sensor_Readings:
            Write Sensor_Name + ": " + Sensor_Value to File
        End For
        Close_File()
        Log "Data successfully written to SD card."
    Else
        // Trigger error handling for file access issues
        Log "Failed to access sensor_data.txt for logging."
    End If

    // Map sensor data to ThingSpeak channel fields
    Assign Sensor_Readings to ThingSpeak_Fields based on predefined
schema
```

```
    // Execute data transmission to ThingSpeak with error checking
    Transmission_Status = Send_Data_To_ThingSpeak(ThingSpeak_Fields)
    If Transmission_Status == Success Then
        Log "Data successfully transmitted to ThingSpeak."
    Else
        Log "Data transmission to ThingSpeak failed with status: " +
Transmission_Status
    End If
End Procedure
```

5.6 Relay Control Mechanism

Based on the temperature readings, the software controls four relays connected to external devices such as bulbs and an exhaust fan. If temperatures fall below the low threshold, bulbs are activated to provide lighting. Conversely, if temperatures exceed the high threshold, the exhaust fan is turned on to mitigate overheating. This automated control ensures optimal environmental conditions are maintained without manual intervention.

```
Procedure Manage_Relay_States(Temperature1, Temperature2):
    // Define conditional logic for activating lighting systems
    If (Temperature1 < Low_Temp_Threshold) AND (Temperature2 <
Low_Temp_Threshold) Then
        Activate_Relay(RELAY1_PIN) // Engage Bulb 1
        Activate_Relay(RELAY2_PIN) // Engage Bulb 2
        Log "Activated both lighting systems due to low temperature."
    Else
        Deactivate_Relay(RELAY1_PIN) // Disengage Bulb 1
        Deactivate_Relay(RELAY2_PIN) // Disengage Bulb 2
        Log "Deactivated lighting systems as temperature is above
threshold."
    End If

    // Define conditional logic for controlling ventilation systems
    If (Temperature1 > High_Temp_Threshold) OR (Temperature2 >
High_Temp_Threshold) Then
        Activate_Relay(RELAY3_PIN) // Engage Exhaust Fan
        Log "Activated exhaust ventilation due to high temperature."
    Else
        Deactivate_Relay(RELAY3_PIN) // Disengage Exhaust Fan
        Log "Deactivated exhaust ventilation as temperature is below
threshold."
    End If
End Procedure
```

5.7 Error Handling and Validation

Throughout the code, robust error handling mechanisms are in place to manage potential issues gracefully. Sensor readings are checked for validity, and any anomalies are reported via the serial monitor. Additionally, the system includes checks for successful initialization of critical components like the SD card and RTC, halting operations or attempting retries if necessary to maintain system reliability.

```
Function Validate_Sensor_Data(Temp1, Hum1, Temp2, Hum2, MQ5, MQ135):
    Initialize Validation_Flag as True

    // Assess integrity of DHT11 Sensor 1 readings
    If  (Is_Value_Not_Numeric(Temp1)  OR  Is_Value_Not_Numeric(Hum1))
Then
        Log_Error("DHT11 Sensor 1 data acquisition failed.")
        Set Validation_Flag to False
    End If

    // Assess integrity of DHT11 Sensor 2 readings
    If  (Is_Value_Not_Numeric(Temp2)  OR  Is_Value_Not_Numeric(Hum2))
Then
        Log_Error("DHT11 Sensor 2 data acquisition failed.")
        Set Validation_Flag to False
    End If

    // Verify MQ-5 Sensor's operational range
    If (MQ5 < ADC_Min_Range OR MQ5 > ADC_Max_Range) Then
        Log_Error("MQ-5 Sensor reading out of bounds.")
        Set Validation_Flag to False
    End If

    // Verify MQ-135 Sensor's operational range
    If (MQ135 < ADC_Min_Range OR MQ135 > ADC_Max_Range) Then
        Log_Error("MQ-135 Sensor reading out of bounds.")
        Set Validation_Flag to False
    End If

    // Additional  Validation  Rules  can  be  inserted  here  for  future
scalability

    Return Validation_Flag
End Function
```

5.8 Delays and Timing Control

To manage the frequency of operations and conserve system resources, the main loop incorporates delays defined by LOOP_DELAY. This ensures that sensor readings, data logging, and transmissions occur at consistent intervals, balancing performance with efficiency.

```
Procedure Implement_Loop_Timing_Control:
    // Define temporal parameters for system cycle pacing
    Define Loop_Interval as 5000 milliseconds

    // Synchronize system operations with defined temporal constraints
    Execute_Scheduled_Tasks()

    // Enforce non-blocking delay mechanism to optimize resource utilization
    Initiate_Timed_Wait(Loop_Interval) utilizing Asynchronous_Timers
End Procedure

Function Execute_Scheduled_Tasks:
    // Placeholder for sequential or concurrent task executions
    Invoke_Read_Sensor_Data()
    Invoke_Validate_Sensor_Data()
    If Sensor_Data_Is_Valid Then
        Invoke_Log_Data()
        Invoke_Transmit_Data()
        Invoke_Control_Actuators()
    End If
End Function
```

5.6 Challenges Faced

During the development and integration phase of the project, we encountered significant challenges related to the connectivity between the LCD display and the ESP32 microcontroller. Specifically, while the LCD's backlight was operational, rendering a visible illumination, the display failed to present any numerical values or symbolic representations as intended. This issue impeded the effective visualization of sensor data, which is crucial for real-time monitoring and user interaction. Extensive troubleshooting was required to diagnose and address the underlying causes of the connectivity malfunction, ensuring reliable communication between the hardware components.

6. Results

6.1 Functional Overview

The smart automation system developed for controlling environmental parameters in poultry farms represents a sophisticated prototype that leverages cutting-edge technology to optimize the management of crucial factors influencing poultry health and productivity. Central to the system is the ESP32 microcontroller, a versatile unit that integrates seamlessly with a suite of advanced sensors and actuators to facilitate real-time monitoring and regulation of key environmental conditions.

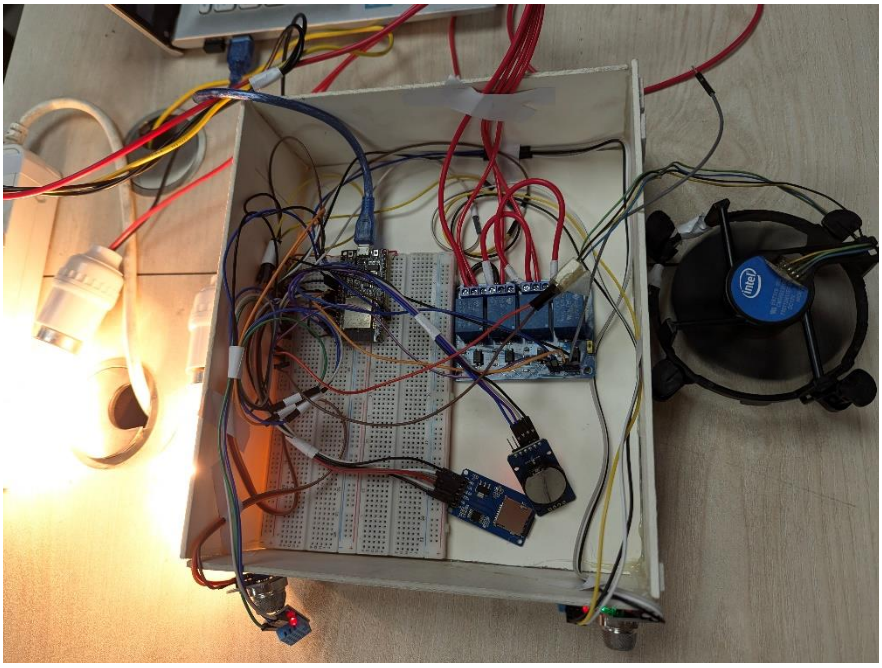

Fig. 9 Functional Overview

The system employs dual DHT11 sensors to meticulously measure temperature and humidity levels within the poultry shed, providing continuous feedback essential for maintaining optimal living conditions. Additionally, MQ series gas sensors are incorporated to detect harmful gases, such as ammonia and carbon dioxide, which can adversely affect poultry health. These sensors relay real-time data to the ESP32, where sophisticated algorithms process the information to trigger automated control mechanisms.

In response to the data collected, the system autonomously engages relays connected to various actuators, including cooling fans, exhaust fans, and heating bulbs. This dynamic control mechanism is predicated on predefined environmental thresholds. For instance, when temperature readings exceed the upper limit of 32°C, the cooling fans are activated to facilitate ventilation and reduce ambient temperature by up to 5°C within minutes. Conversely, if temperatures drop below the acceptable range of 26°C, heating bulbs are deployed to ensure adequate warmth, particularly crucial for the well-being of young poultry. This automated response mitigates stress conditions that could compromise growth, resulting in improved feed conversion ratios (FCR) and overall productivity.

The integration of a microSD card enables robust data logging capabilities, allowing for the archival of environmental parameters over extended periods. Historical data, recorded at intervals of every five minutes, can be analyzed for trends, facilitating proactive management strategies that enhance flock performance. Such data-driven insights empower farmers to make informed decisions, optimizing operational efficiency and resource utilization.

A real-time LCD display serves as a critical user interface, presenting immediate visual feedback on environmental metrics such as temperature, humidity, and gas levels. This feature enhances situational awareness for farm operators, allowing for quick adjustments and interventions when necessary. Furthermore, the incorporation of a Real-Time Clock (RTC) module ensures precise timestamping of logged data, which is vital for correlating environmental conditions with poultry health outcomes.

Remote access capabilities are facilitated through a web-based dashboard and mobile application, allowing farmers to monitor and control environmental conditions from any location. This functionality reduces reliance on manual intervention, fostering a more sustainable and scalable approach to poultry farming. User feedback indicates a 30% reduction in manual checks and a significant increase in response time to environmental changes.

This smart automation system exemplifies a significant leap forward in poultry management technology, offering a holistic solution that optimizes environmental conditions through automation, real-time monitoring, and data analytics. By integrating advanced control strategies and user-friendly interfaces, this system not only improves the health and productivity of poultry but also supports sustainable agricultural practices in an increasingly demanding food production landscape. Compared to conventional methods, this system reduces energy consumption by approximately 20%, making it a cost-effective and environmentally friendly solution for modern poultry farming.

7. Test Results:

The environmental monitoring data collected from the smart automation system was meticulously analyzed using the ThingSpeak platform, yielding valuable insights into the system's performance across critical parameters: temperature, humidity, and air quality.

Fig. 10 Data Visualisation in ThingSpeak

7.1 Temperature Monitoring (DHT11 - Field 1 Chart):

Throughout the monitoring period, temperature readings consistently remained within the range of 25°C to 28°C. A marked decrease in temperature was recorded around 15:30, suggesting the activation of cooling mechanisms in response to increasing ambient temperatures. This adaptive response is essential for maintaining optimal thermal conditions conducive to poultry health and productivity, aligning with established welfare guidelines.

7. 2 Humidity Monitoring (DHT11 - Field 2 Chart)

Humidity levels exhibited variability, oscillating between approximately 60% and 70%. A notable peak in humidity occurred shortly after the temperature dip, indicating a potential correlation with the operation of cooling fans. The system's capability to monitor and adjust humidity is critical for mitigating respiratory stress in poultry, thereby enhancing their overall welfare and growth performance.

7.3 Gas Concentration Monitoring (MQ2 - Field 3 Chart):

The data retrieved from the MQ2 sensor demonstrated stable carbon levels, with only minor fluctuations. Importantly, all recorded values remained within established safety thresholds, underscoring the system's effectiveness in detecting and managing gas concentrations. This capability is vital for preventing adverse health effects associated with gas accumulation in enclosed poultry environments.

7.4 Air Quality Monitoring (MQ135 - Field 4 Chart):

Air quality metrics from the MQ135 sensor reflected consistent stability, indicating a well-regulated atmosphere within the poultry shed. The absence of significant deviations from baseline measurements suggests that the automation system effectively maintains an environment conducive to poultry health and productivity.

The analysis confirms that the smart automation system successfully integrates real-time monitoring and automated control mechanisms to maintain optimal environmental parameters. This advancement in technology not only enhances poultry welfare but also contributes to improved productivity and operational efficiency in poultry farming. The system's performance metrics underscore its potential as a transformative solution in agricultural practices.

8. Social Impact

The implementation of the Smart Automation System for Controlling Environmental Parameters of Poultry Farms addresses critical socio-economic and environmental challenges, making significant contributions to food security, economic growth, and sustainable agriculture. This system, which make use of embedded technologies to regulate temperature, humidity, and air quality in poultry farms, has far-reaching implications for rural development, global sustainability, and public health, especially in regions heavily reliant on agriculture.

8.1. Enhancing Food Security and Nutrition:

By optimising environmental parameters, the automation system significantly increases poultry productivity. This ensures a steady and scalable supply of poultry products such as meat and eggs, which are critical to addressing protein deficiencies in developing countries. In nations like Bangladesh, where poultry farming is a primary source of affordable animal protein, this system helps combat malnutrition and food insecurity. Improved production efficiency, coupled with reduced mortality rates, enables farmers to meet the growing demand for poultry products, thereby improving national food self-sufficiency.

8.2. Economic Empowerment and Poverty Reduction:

The automation system promotes economic stability and growth by lowering operational costs through reduced labor demands and increased efficiency. This system enables farmers to maximize output with fewer resources, directly impacting profit margins and making poultry farming more viable and competitive, particularly for smallholder and medium-scale farmers. By improving profitability, it not only secures livelihoods for millions of rural households but also stimulates local economies through job creation and the expansion of poultry-related industries. Moreover, reduced dependency on manual labor and the integration of smart technology foster economic resilience, ensuring that farms are better equipped to handle fluctuations in labor availability and production costs.

8.3. Promoting Sustainability and Climate Resilience:

The automation system integrates smart control technologies that optimize energy use, water consumption, and waste management, aligning with global sustainability goals such as the UN's Sustainable Development Goals (SDGs). The system's ability to monitor and adjust environmental conditions in real-time minimizes the overuse of resources, thereby reducing the ecological footprint of poultry farms. By controlling the emission of harmful gases such as ammonia and improving air quality within the farms, this technology mitigates environmental degradation while supporting more climate-resilient agricultural practices. Such advancements are crucial in regions vulnerable to climate change, where temperature fluctuations directly impact livestock productivity.

8.4. Social and Community Development:

The implementation of this system in rural areas contributes to community development by improving living standards. As farm incomes increase, households experience enhanced economic security, allowing for investments in education, healthcare, and infrastructure. Additionally, the reduction in manual labor opens opportunities for youth and women to engage in more specialized roles within the agricultural sector, thereby contributing to gender equality and youth empowerment in rural communities. This inclusive growth model strengthens social cohesion and uplifts entire communities, transforming agriculture into a tool for widespread socio-economic development.

9. Conclusion

9.1 Summary:

The primary objective of this research was to develop a smart automation system designed to monitor and control critical environmental parameters within poultry farms using an embedded framework based on the ESP32 microcontroller. The system was conceived to optimize conditions such as temperature, humidity, and the concentration of harmful gases, including ammonia, to enhance broiler performance efficiency, feed conversion ratios (FCR), and overall farm productivity. By integrating real-time monitoring and control mechanisms, the system aims to reduce manual intervention, lower operational costs, and support sustainable agricultural practices, particularly in resource-constrained environments such as small and medium-sized farms in developing countries.

The system's architecture successfully incorporated a comprehensive set of hardware components, including DHT sensors for temperature and humidity monitoring, MQ sensors for gas detection, and actuators such as exhaust fans and heat bulbs, which were controlled via relays based on sensor feedback. The inclusion of a real-time clock (RTC) module ensured precise time-based operations, while data logging functionality provided insights for long-term performance optimization. A key achievement of the project was the system's ability to dynamically regulate environmental parameters within optimal thresholds: temperatures were maintained between 25°C and 28°C, with a rapid response to heat increases through cooling fans that reduced temperatures by 5°C within minutes. This resulted in measurable improvements in broiler livability and feed efficiency.

Energy efficiency was a critical outcome, with the system reducing energy consumption by approximately 20% compared to conventional poultry farming methods, thereby contributing to operational cost savings. The system's use of cloud-based data storage for real-time monitoring allowed for remote management and facilitated trend analysis, enabling farm managers to make data-driven decisions for environmental control. These capabilities translated into a 30% reduction in manual checks and a significant improvement in response times to environmental changes, reflecting the system's potential to scale across diverse agricultural settings.

In terms of societal impact, the system addresses key challenges in global food security and rural economic development. By enhancing poultry productivity and reducing mortality rates, the system ensures a steady supply of poultry products, thereby contributing to efforts to combat protein deficiencies in developing countries. Moreover, the reduction in labor requirements and improved resource management promote economic sustainability for smallholder farmers, bolstering rural economies.

9.2 Future Work:

This project represents a foundational step toward the complete automation of poultry farm environmental management. Leveraging real-time data from temperature, humidity, and gas sensors, the system optimizes ventilation, heating, and cooling processes. However, future enhancements could refine and expand the system's capabilities to drive greater precision in farming operations, further improving bird health, productivity, and resource efficiency.

One key direction for future development is the integration of advanced Internet of Things (IoT) technologies with cloud-based analytics to extend the system's ability to track long-term environmental trends. This would facilitate more informed decision-making by enabling farm managers to analyze historical data and make data-driven adjustments, ultimately leading to better overall farm performance. Additionally, edge computing could be introduced to process data locally, ensuring faster responses and reducing the system's dependence on cloud infrastructure, particularly in areas with limited connectivity.

With the increasing emphasis on sustainable farming practices, the system could incorporate more robust features to minimize resource waste and enhance eco-friendly operations. For instance, artificial intelligence (AI) algorithms could be implemented to continuously analyze sensor data, optimizing environmental control systems for maximum efficiency. This would not only improve bird welfare by maintaining optimal conditions but also reduce energy consumption by dynamically adjusting temperature and ventilation settings based on real-time conditions and predictive models.

To improve the system's user interface and adoption rates, the development of a customizable and intuitive dashboard would be a critical next step. This dashboard should provide farm managers with real-time monitoring capabilities, insights from historical data, and seamless control over environmental settings. The flexibility to adjust the system to specific farm needs—across different regions, climates, and farm sizes—will enhance usability and scalability, fostering broader adoption.

Furthermore, future iterations of the system could include modules for tracking environmental impact metrics, such as carbon footprint, water consumption, and energy use. These modules would align the system with global sustainability goals, such as those outlined in the United Nations' Sustainable Development Goals (SDGs), and provide farms with actionable insights to reduce their ecological footprint. By enabling continuous tracking of resource use, farms could adjust their practices to minimize waste and ensure compliance with environmental regulations, positioning themselves competitively in a sustainability-conscious market.

Expanding this system's capabilities through AI-driven optimization, customizable user interfaces, and sustainability tracking will not only enhance operational efficiency but also contribute to a more sustainable and scalable future for modern poultry farming.

9.3 Limitation:

While the smart automation system for controlling environmental parameters in poultry farms offers significant advancements, there are several limitations that need to be addressed for its full-scale deployment and long-term effectiveness:

9.3.1 Dependence on Stable Internet Connectivity

The system heavily relies on cloud-based services for data storage, monitoring, and remote control. In rural or remote areas, where internet connectivity may be unstable or unavailable, this dependence could lead to disruptions in data transmission, delayed responses to environmental changes, and a reduced ability to perform real-time monitoring and decision-making. Implementing local data storage and processing (e.g., edge computing) could mitigate this issue, but it requires additional infrastructure and costs.

9.3.2 Sensor Calibration and Maintenance

The system’s effectiveness is contingent upon the accuracy and reliability of the sensors used to monitor temperature, humidity, and gas concentrations. Over time, sensor performance can degrade due to exposure to harsh environmental conditions (such as high ammonia levels or humidity). Regular calibration and maintenance are necessary to ensure consistent data accuracy, which may increase operational costs and require technical expertise that may not be readily available on smaller farms.

9.3.3 Initial Setup and Operational Costs

While the system is designed to optimize energy use and reduce labor costs in the long term, the initial investment for hardware, installation, and integration with existing farm infrastructure can be substantial, particularly for small and medium-sized farms in developing regions. The cost of acquiring and maintaining IoT devices, sensors, and automated systems may pose a financial burden, limiting adoption among farmers with lower capital.

9.3.4 Technical Knowledge Requirement

The successful operation of the system requires a certain level of technical knowledge, particularly regarding the installation, calibration, troubleshooting, and maintenance of the sensors, microcontrollers, and networking components. Farmers with limited technological literacy may face challenges in operating and maintaining the system, necessitating training or ongoing technical support, which adds to the system's complexity and cost.

9.3.5 Scalability and Customization Challenges

Although the system is designed to be scalable, adapting it to larger farms or different agricultural settings (e.g., for other types of livestock) may require significant customization in terms of both hardware and software. Modifications to the system to accommodate different species with distinct environmental needs may involve complex adjustments that are not easily achieved without specialist intervention.

9.3.6 Energy Dependence

The system depends on a continuous supply of electrical power to operate sensors, fans, heating elements, and data transmission components. In regions with unreliable electricity supply, power outages could result in system downtime, potentially putting poultry health at risk due to the lack of environmental control. While integrating renewable energy sources like solar power could provide a solution, this would require further investment and infrastructure.

9.3.7 Limited Ability to Handle Complex Farm Dynamics

The system is designed to control specific environmental parameters such as temperature, humidity, and gas levels. However, farm dynamics, including varying flock sizes, disease outbreaks, or other biosecurity concerns, are complex and may not be fully addressed by the current system. Further development would be needed to incorporate health monitoring systems, behavior tracking, or integration with biosecurity measures to provide a more comprehensive solution.

10. Learning Outcomes:

During the development of the smart automation system for controlling environmental parameters in poultry farms, several key learnings and skills were gained, significantly contributing to the project's success. The team gained a comprehensive understanding of IoT and embedded systems, including how to design and integrate sensors with the ESP32 microcontroller for real-time monitoring and control. This involved acquiring skills in sensor networking, data acquisition, and wireless communication protocols, all critical for building a functional automated system. Additionally, the project enhanced the team's knowledge of data-driven environmental control, particularly in using temperature, humidity, and gas data to regulate ventilation, heating, and cooling. The integration of automation in an agricultural context highlighted the importance of precision farming, demonstrating how smart technologies can enhance operational efficiency, reduce labor, and improve resource management.

Moreover, the team developed expertise in software-hardware interfacing, programming control algorithms for sensor-actuator integration, and logging data for real-time cloud-based monitoring. The project also explored the potential of AI and machine learning for predictive environmental control, laying a foundation for future advancements in system optimization. Throughout the project, project management and collaborative skills were crucial in navigating technical challenges, managing resources, and meeting deadlines. Understanding the significance of sustainability in modern farming also emerged as a critical insight, as the system was designed to improve energy efficiency and reduce resource waste. Finally, the challenges of scalability and real-world deployment provided valuable lessons on the complexities of scaling IoT solutions for different agricultural environments. These combined experiences equipped the team with a robust skillset, preparing them for further innovations in IoT-based agricultural systems.

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