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trn:oid:::27005:74233176

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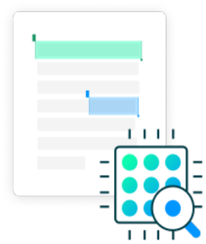

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1

An automated system for IoT-based sustainable crop protection from rain, hail, and fog

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Abstract— ***Agriculture is the most important sector for development in Bangladesh. Because of climate change, rainfall has been erratic over recent years. Vegetables and crops, especially winter vegetables, are damaged in our country because of the untimely rain, hailstorm, and heavy fog. Now our main challenge is to protect the crops from rain, hailstorm, and fog. IoT is a revolutionary technology and is used in a wide range, including smart cities, smart homes, smart traffic management, etc. The IoT implementation area is so broad and can be utilized in every sector. This research work is about crop protection systems in agriculture.***

Keywords: *Bangladesh, IoT, Agriculture, Sensor, Protect crop, Poly, Plastic nets*

I. INTRODUCTION

Agriculture is essential to Bangladesh's economy, being the backbone of the country's GDP and serving as a key source of income for the majority of its people. Agriculture contributed 20% of GDP in 2009-10, with the crop sub-sector contributing 12% at constant prices (Government of Bangladesh, 2010).This contribution underscores the significance of agriculture not only in economic terms but also as a cornerstone of national food security and rural employment. Agriculture employs over 85% of the rural population, either directly or indirectly, highlighting the sector's vital role in defining the country's socioeconomic environment [1].

Considering its significance, agriculture in Bangladesh has various challenges, with climate change becoming one of the most significant concerns in recent years. Climate change influences agricultural productivity by increasing the frequency and degree of natural disasters including floods, cyclones, and droughts. According to a World Bank research, Bangladesh is one of the most climate-vulnerable countries in the world, with sea-level rise predicted to result in a 17% loss of agricultural land by 2050. Climate change has consequences that go beyond physical devastation, endangering food security, disrupting distribution networks, and destabilizing rural lives. For a country where agriculture employs a considerable portion of the employees, such disruptions constitute an important threat to the entire economy.

The implementation of IoT in agriculture has allowed farmers to more effectively track and oversee their activities. Sensors, drones, and automated systems have been employed to collect real-time data on soil moisture, temperature, humidity, and insect activity, allowing for better decision-making.In Bangladesh, where conventional farming practices remain prevailing, the acceptance of IoT-based solutions symbolizes a paradigm change. Farmers could use IoT to enhance utilization of resources, save expenditures, and limit risks associated with unexpected weather patterns and natural calamities.

One significant application of IoT in agriculture is the creation of crop protection systems to protect crops from adverse weather. In Bangladesh, winter vegetables are particularly vulnerable to rain, hail, and fog, which can significantly interfere with output and quality. To address this issue, an IoT-based crop protection system has been constructed, using sensors that monitor environmental variables such as rainfall and fog intensity. This technology automatically establishes preventative safeguards, such as crop covering during heavy rains or foggy circumstances, to minimize damage and ensure uninterrupted growth.

The implementation of IoT in crop protection not only increases output but also improves the agricultural sector's general durability. For example, studies have shown that IoT-enabled systems may increase production of crops by up to 25% while reducing losses caused by environmental variables

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[3]. These systems encourage sustainable farming practices by minimizing the use of water, fertilizers, and pesticides. In a country like Bangladesh, where resources for agriculture are frequently low and the effects of climate change are severe enough such technologies have enormous promise for maintaining food security and economic stability.

Technology of information and communication is utilized to adjust all agricultural operations and activities in an IoT-based agriculture system. Numerous aspects of human existence, including advanced industries, smart cities, and cutting-edge technologies in linked automobiles, could be impacted by the Internet of Things [2]. However, the Internet of Things may have an even significantly larger effect on agriculture. The formed solution discussed in this paper depicts an IoT-based crop protection system designed to protect crops from rain, hail, and fog, particularly winter vegetables, based on various sensors (to detect rain and fog). The system's main impact is to improve and increase the quantity and reduce damage to crops from natural disasters.

Agriculture remains an essential component of the economy of Bangladesh, supporting an important portion of the population in the countryside while contributing considerably to the national GDP. However, the sector is dealing with growing difficulties, especially due to the effects of climate change, which promises to weaken production and efficiency. Implementation of IoT-based solutions is a possible path for solving these difficulties, as they offer tools for upgrading farming processes and protecting crops from climate-related risks. Bangladesh can improve its agricultural resilience, protect livelihoods, and assure a steady food supply for its rising population by using the power of the Internet of Things.

II. Literature Review

Agriculture research is being expanded in a variety of ways in order to improve agricultural productivity in terms of both quality and quantity. The researchers have worked on a variety of projects involving soil attributes, various weather conditions, and crop scouting. The model for intelligent agriculture based on IoT is explained in [3] which uses farm, server, and client-side are the three modules. This agriculture model provides automatic irrigation and lives data to application modules. In [4] authors have proposed automatic irrigation systems and crop protection systems with IoT. The sound recognition array in this system describes four sound sensing modules. A microcontroller that has been programmed controls the modules. The ultrasonic sensors were strategically placed to detect small animals. And the light is detected by the Light Dependent Resistor Module and tells whether it is day or night to the microcontroller. The installation of soil moisture sensors allows for automatic irrigation. Some projects' authors, such as [5,] designed and implemented an automation system. This system moisture sensor detects soil moisture and evaluates the potential difference between soil moisture levels. If the potential difference is less than the value, a relay connects the microcontroller to the pump, which is used to irrigate the soil. Later on, a smart agriculture system has been suggested in [6-8]. The Internet of Things provides the platform for researchers to maintain data in real time and instantly send an alert to farmers based on sensor node data. Farmers could use the collected data to identify fertilizer needs for the current crop fields. It will be beneficial with the development of intelligent climate solutions and disaster monitoring.

Despite significant development in smart farming practices, certain issues remain unanswered. For instance, while technology exists that automates watering and protects crops from tiny animals, there are few full solutions to protect crops toward severe weather like rain and fog. In addition, most present solutions require significant human contact or are prohibitively costly for small-scale farms. The present study addresses that gap by suggesting a reliable, cost-effective crop protection system that works effectively with minimal human interaction. The proposed approach focuses on crop protection against rain and fog, utilizing proficient IoT technologies to ensure timely and precision intervention. By combining weather tracking sensors, automated processes, and real-time data analytics, this system intends to address a critical gap in the present landscape of smart agriculture systems by offering a comprehensive solution for farmers worldwide.

III. PROPOSED METHODOLOGY

The primary goal of this study is to develop an Internet of Things-based crop protection system which utilizes servo motors to automatically cover and uncover crop fields while requiring little human interaction. The appliance responds to environmental circumstances such as rain, hail, and fog. This system has been designed to provide cost-effective, dependable, reliable and effective crop protection from severe weather.

The main component used in the system:

3.1 *Servo Motor*

Servo motors, shown in Fig. 3.1, are often employed in automation technology considering their excellent accuracy, acceleration, and ability to control angular or linear motion. These motors have a self-contained mechanism which includes a motor, a control circuit, and a feedback mechanism, allowing them to execute exact movements. Their small dimensions and adaptability make them appropriate for a wide range of applications across industries.

Fig 3.1: Servo Motor

In our study, servo motors are specifically used for automatic crop covering and uncovering. This application ensures that crops are effectively protected from environmental elements such as extreme sunlight, rain, and cold. The method of operation uses servo motors that provide rapid and precise movements, allowing the covering mechanism to respond dynamically to changing weather conditions. This not only improves crop safety but also reduces the need for manual intervention, hence increasing agricultural productivity.

Fig 3.2: *Arduino UNO R3*

3.2 *Arduino UNO R3*

The Arduino Board, depicted in Figure 3.2, is an open-source microcontroller designed by Arduino.cc and based on the ATmega328P microcontroller manufactured by Microchip. It provides a versatile and user-friendly environment for experimentation and integrated system development.

The Arduino UNO R3 has 14 digital input/output pins (6 of which can be utilized as PWM outputs) and 6 analog input pins, which makes it ideal for connecting with an extensive selection of actuators, sensors, and other electrical components. These pins enable seamless integration with development boards, sensors, motor drivers, and external circuits, making it a popular choice for both beginners and professionals. The board additionally features a USB port, a power jack, an ICSP header, and a button to reset it. The above components make it simpler to configure and power the board while also being interoperable with a variety of peripheral equipment. In addition, it supports a variety of different communication protocols, including I2C, SPI, and UART, which extends its ability to communicate.

In our application, the Arduino UNO R3 functions as a centralized control unit, controlling data flow and communication among servo motors and sensors. It connects to the servo motors to regulate their movements while covering and uncovering the crops, providing excellent operation based on environmental information. The Arduino UNO R3's flexibility and reliability make it an excellent choice for adding technology in agricultural systems.

3.3 *Node MCU*

Node MCU shows Figure 3.3 shows a LUA code written in ASCII for the ESP8266 LAN chip. The code comes with the ESP8266 development kit. It connects the farmer's smartphone or tablet to the system via Wi-Fi protocol. The NodeMCU is part of the ESP8266 development kit, and it offers GPIO ports for attaching sensors, actuators, and other electronic components. This development board becomes especially famous because of its affordability, low consumption of electricity, and built-in Wi-Fi module, making it a great option for real-time IoT systems.

Fig 3.3 Node MCU

In our application, the NodeMCU links the farmer's smartphone or tablet to the automated crop management system via the Wi-Fi protocol. Farmers are able to utilize this hyperlink to remotely supervise and manage the system, such as controlling the servo motor operations used to cover and uncover crops. This wireless connectivity provides ease of access, enabling farmers to quickly adjust swiftly to changing conditions, improving the system's efficiency and responsiveness.

3.4 *Rain Sensor*

A rain sensor functions as a switching device. The rain sensor operates on the principle that if it is raining, the sensor will send a signal to cover the fields.

In our application, the rain sensor serves as vital for crop protection. When the sensor senses rainfall, it sends a signal to the system, which activates the servo motors to cover the fields. This receptive response defends the crops from excessive water exposure, reducing damage like waterlogging or growth of fungi.

3.5 *Fog Sensor*

Fog sensor or visibility sensor are Weather-detecting gadgets that warn or trigger when visibility drops. Fog sensors are light transmitters and receivers. Fog sensors rely on the concept of light being transmitted and received. They usually consist of a light transmitter and a light receiver. A transmitter sends out a beam of light, and the receiver detects how much light hits its. When visibility decreases due to fog, the dispersion or absorption of light affects the amount of light received by the sensor. This shift in light levels leads the sensor to send out a signal.

In our application, the fog sensor is employed to detect low visibility situations. When visibility drops below a specified threshold, the sensor may begin actions such as informing farmers or performing crop protection measures. This preserves crops from the adverse effects of fog, such as decreased sunlight exposure and potential frost hazards, improving overall cultivation effectiveness.

Algorithm for Crop Protection System:

Input: Sensor data (S_r, S_f, S_l) Threshold values (T_r, T_f, T_l)

Output: Servo motor angle (θ) to control crop covers

Step 1 Initialization:

- Set initial servo motor angle 0^0(Uncovered).
- Define threshold values: (T_r, T_f, T_l)
- Establish communication with the smartphone app.

Step 2 Sensor Reading:

- Continuously monitor (S_r, S_f), and (S_l) .

Step 3 Decision Making:

Rain Protection:

- If $S_r \geq T_r$, set $\theta = 180^0$.
- Else, set $\theta = 0^0$.

Fog Protection:

- If $S_f \geq T_f$,set $\theta = 180^0$.
- Else, set $\theta = 0^0$

Sunlight Protection:

- If $S_f \geq T_l$, set $\theta = 180^0$
- Else, set $\theta = 0^0$

Step 4 Manual Overrides:

- Listen for commands from the smartphone app.
- If a manual command is received, execute the requested action (cover/uncover).

Step 5 Actuation:

- Send control signals to the servo motor to adjust angle (θ).

Step 6 Repeat:

- Continue monitoring and decision-making in real time.

System Workflow:

Rain Protection: When rainfall begins, the rain sensor detects precipitation levels and sends an analog signal (S_r) to the microcontroller. The microcontroller processes this signal and determines whether the rain intensity exceeds the threshold value (T_r). If $S_r \geq T_r$, the controller activates the actuator motor to cover the crops. Once the rain stops $(S_r < T_r)$ the system uncovers the fields.

Fog Protection: During the winter season, the fog sensor continuously measures fog density and sends an analog signal $\left(S_f\right)$ to the microcontroller. If the fog density exceeds the threshold value $(S_f \geq T_f)$, the system activates the crop cover mechanism. The fields remain covered until $\left(S_f < T_f\right)$, after which the crop covers are retracted.

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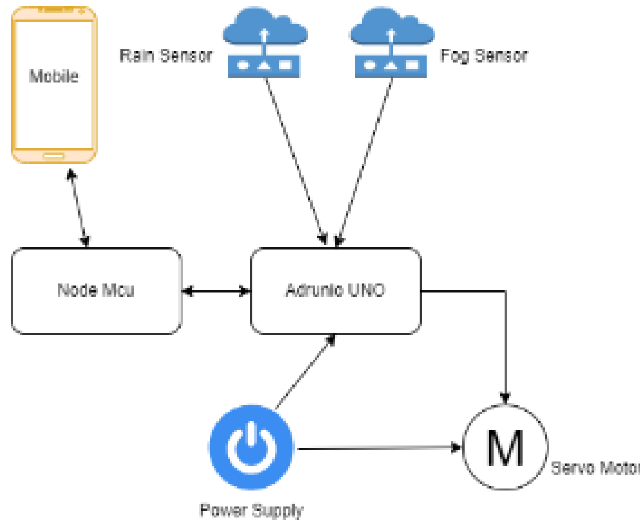

Fig-1: System Architecture

Sunlight Protection: The light sensor (LDR module) monitors light intensity and sends a signal (S_l) to the microcontroller. If light intensity exceeds a predefined threshold $S_f \geq T_l$, the system activates shading to protect crops from heavy sunlight. Once the light intensity reduces below $S_f > T_l$, the shading mechanism is retracted.

Manual Operation: The system includes a smartphone or tablet application that allows farmers to override the automatic controls. Through the app, farmers can manually cover or uncover fields, adjust thresholds (T_r, T_f, T_l), and monitor real-time sensor data.

Equation

1. **Rain Intensity Condition**

$$Cover\ Status = \begin{Bmatrix} Covered\ if\ S_r \geq\ T_r \\ Uncovered\ if\ S_r < T_r \end{Bmatrix}$$

2. **Fog Density Condition**

$$Cover\ Status = \begin{Bmatrix} Covered\ if\ S_f \geq\ T_f \\ Uncovered\ if\ S_f < T_f \end{Bmatrix}$$

3. Light Intensity Condition

$$Cover\ Status = \begin{Bmatrix} Covered\ if\ S_l \geq T_l \\ Uncovered\ if\ S_l < T_l \end{Bmatrix}$$

4. Servo Motor Position

$$\theta = \begin{Bmatrix} 180^0\ for\ covered\ status \\ 0^0\ for\ uncovered\ status \end{Bmatrix}$$

2. System Architecture

The overall architecture of the system is illustrated in Fig-1. The setup involves sensors placed strategically within the crop field to detect weather conditions. These sensors are connected to the MCU, which processes sensor data and triggers the servo motors and actuators accordingly.

Figure 4.1 below illustrates the system's working procedure:

Sensor Data Flow: The sensors continuously monitor the weather conditions and feed information to the Arduino.

Control Flow: The Arduino interprets this information, regulates the servo motors, and decides whether to cover or reveal the crops.

Manual Control Flow: The farmer can use the smartphone app to override the automatic system and manually control the mechanism.

Working Procedure:

The working procedure of the system involves several stages, from sensor data collection to activating the servo motors for crop protection. Below is a detailed breakdown of the process. Fig-4.1 shows the working procedure of the system.

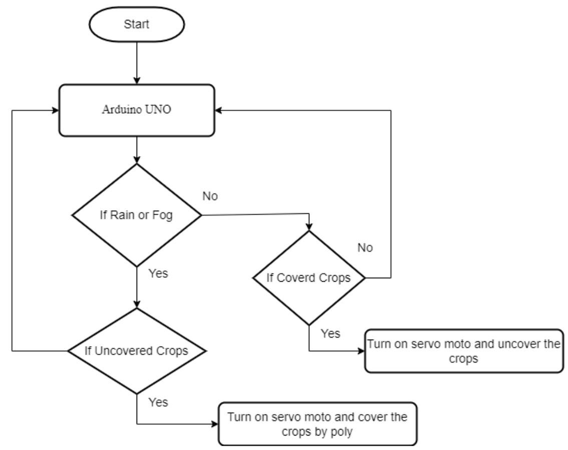

Fig 4.1: Working Flow Chart

Sensing the Weather Conditions:

Rain Detection: The **Rain Sensor** continuously monitors the rainfall levels. When rain begins, the sensor detects it and sends a signal to the Arduino UNO. The Arduino processes the input signal and determines if the rainfall exceeds a certain threshold (T_r).

- If the **rain intensity** (S_r) exceeds (T_r), the Arduino sends a signal to the **servo motor** to rotate to the "cover" position, thus deploying the crop cover to protect the crops from rain.
- When the rain stops, the **Rain Sensor** detects the absence of rain, sending a "no rain" signal to the Arduino. The Arduino then triggers the servo motor to rotate back to the "uncover" position, retracting the crop cover.

Fog Detection: Similarly, the **Fog Sensor** continuously monitors fog levels in the environment. If the fog (S_f) exceeds a certain threshold (T_f), the Arduino commands the servo motor to cover the crops.

- If the fog level is below the threshold $(S_f < T_f)$ the system uncovers the crops.

Servo Motor and Actuation Mechanism:

The servo motor is directly controlled by the Arduino board. The servo motor moves the crop cover by rotating its arm. The arm is connected to a covering mechanism, which is usually a polyethylene tarp or shade cloth that shields the crops from environmental conditions.

Covering the Crops:

- When a signal from the rain or fog sensor is received by the Arduino, it sends a command to the servo motor to rotate the arm to a 180∘ position (or other appropriate angle), effectively covering the crops.
- The covering mechanism, attached to the motor arm, moves accordingly, providing protection to the crops from rain or fog.

Uncovering the Crops:

- When the rain stops or the fog level reduces, the Arduino sends a command to the servo motor to rotate the arm back to its starting position (0° or flat).
- The crops are then uncovered, and **the covering mechanism retracts.**

Manual Operation via Smartphone App:

In addition to the automatic weather management, the system allows human operation via smartphone or tablet. The manual control capability is enabled by the Node MCU, which has Wi-Fi connectivity for remote control.

- The **Node MCU** connects to the internet through Wi-Fi and establishes a connection with the farmer's mobile application.
- The farmer can use the app to **monitor real-time sensor data** (rain levels, fog levels, etc.), **adjust thresholds** for rain and fog, and **manually control the system** by sending commands to the servo motor (e.g., to cover or uncover the crops).
- For example, if the farmer wants to manually cover the crops in advance of a predicted rainstorm, they can use the app to turn on the motor. Similarly, they can uncover the crops when they choose.

Communication Between Components:

- The **Rain** and **Fog Sensors** send analog data to the **Arduino**. The Arduino processes these inputs and sends commands to the **servo motor** and **actuators**.
- The **Node MCU** communicates with the Arduino through a serial interface or using a protocol such as SPI or I2C, and it also allows the system to be controlled via the farmer's mobile device over the **Wi-Fi** network.

IV. RESULT

In Bangladesh, untimely rains are increasing and destroying our crops. We cannot stop the rain, but we can take the necessary precautions to protect our crops. The suggested IoT-based crop protection system is intended to protect crops from weather conditions such as rain and heavy fog, thus increasing productivity and reducing crop damage. Rain and fog sensors detect weather conditions and automatically control servo motors to cover or expose crops. When rain is detected, the rain sensor transmits signals to the Arduino microcontroller, causing the servo motor to deploy a protective cover over the crops. Similarly, the fog sensor monitors fog levels and triggers the covering mechanism when visibility drops below a predetermined threshold. When conditions improve, the sensors tell the machine to uncover the crops. Farmer can operate the system using a mobile app by the help of wifi protocol. During the summer season farmers can cover the crops field by mobile app to keep soil moisture in the soil.

To determine how well the IoT-based crop protection system is functioning, we can use algorithms based on machine learning to identify weather conditions and evaluate system responses. For example, we can train a model to forecast crop coverage based on weather sensor data (rain or fog levels). To assess the performance of such a model, we can use metrics like precision, recall, F1 score, and confusion matrix.

Confusion Matrix:

A **confusion matrix** is a performance measurement tool that helps evaluate the accuracy of a classification model. It provides four key results:

True Positives (TP): Correctly predicted instances when the crop should be covered.

False Positives (FP): Instances when the system incorrectly predicted that crops should be covered (e.g., no rain, but crops are covered).

True Negatives (TN): Correctly predicted instances when the crop should not be covered.

False Negatives (FN): Instances when the system failed to cover crops despite adverse conditions (e.g., rain occurred, but crops were not covered).

Given that we are trying to predict whether crops should be covered based on sensor input, the confusion matrix would look like this:

Actual \ Predicted	Cover	Don't Cover
Cover	TP	FN
Don't Cover	FP	TN

Precision, Recall, and F1 Score:

Precision measures how many of the predicted "cover" actions were correct:

$$Precision = \frac{TP}{TP + FP}$$

Recall measures how many actual "cover" actions were predicted correctly:

$$Recall = \frac{TP}{TP + FN}$$

F1 Score is the harmonic mean of precision and recall, providing a balance between the two:

$$F1 = 2 \times \frac{Precision\ \times Recall}{Recision + Recall}$$

Performance Calculation:
After testing the system, we get the following results from the confusion matrix:

- True Positive (TP) = 80
- False Positive (FP) = 10
- True Negatives (TN) = 90
- False Negatives (FN) = 20

Using these values, we can calculate precision, recall and F1 score:

Precision:

$$Precision = \frac{80}{80 + 10} = \frac{80}{90} = 0.89$$

Recall

$$Recall = \frac{80}{80 + 20} = \frac{80}{100} = 0.8$$

F1 Score:

$$F1 = 2 \times \frac{0.89 \times 0.8}{0.89 + 0.8} = 2 \times \frac{0.712}{1.69} = 0.84$$

Cost-effectiveness and dependability are important aspects of the system. It is excellent for small and medium-scale farmers since it is inexpensive and simple to execute, thanks to the use of commonly available components such as Arduino UNO, Node MCU, and servo motors. Manual control using a mobile application, enabled by the Node MCU & Wi-Fi connectivity, enables farmers to monitor and operate the system remotely, increasing its versatility.

The technology provides major benefits by minimizing reliance on manual labor and providing timely responses to severe weather conditions, both of which are crucial for protecting agricultural harvests [9]. Its ability to incorporate automation and IoT technology creates a scalable solution for modern agriculture. By reducing crop losses due to natural disasters, this technology contributes to food security and provides a viable solution to climate change-related agricultural concerns.

V. CONCLUSION

An innovative and useful way to protect crops from unfavorable weather circumstances including rain, fog, and too much sunlight is with an Internet of Things-based crop protection system. Without requiring continual human intervention, the system guarantees prompt and effective protection by utilising sensors, microcontrollers, and automation. Furthermore, the incorporation of mobile app control improves usability by enabling farmers to track and regulate the device. Small to medium-sized farmers benefit significantly from its affordability and scalability, which lower crop losses and boost agricultural output. This method promotes environmentally friendly farming practices and food security by addressing climate-related issues in farming.

The proposed IoT-based crop protection system integrates environmental sensing, microcontroller processing, and mechanical actuation to create an automated solution for safeguarding crops from rain, hail, and fog. This system promises to improve the resilience and productivity of agriculture, particularly for vulnerable winter crops in Bangladesh.

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