MULTIDISCIPLINARY APPLIED RESEARCH AND INNOVATION
e-ISSN: 2773-4773

MARI

Vol. 6 No. 4 (2025) 337-344
https://publisher.uthm.edu.my/periodicals/index.php/mari

An Intelligent Weather System for Outdoor Clothes Drying

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DOI: https://doi.org/10.30880/mari.2025.06.04.048

Article Info

Received: 1 September 2025
Accepted: 15 October 2025
Available online: 1 December 2025

Keywords

ESP32, IoT, Rain Sensor, Smart Home, Automation

Abstract

This project introduces an Intelligent Weather System designed to automate the outdoor clothes drying process, especially in tropical climates like Malaysia, where rain is frequent and unpredictable. The system utilizes an ESP32 microcontroller, rain sensor, and servo motor to detect rain and respond automatically by covering the clothes rack. Integrated with the Blynk IoT platform, users receive real-time updates and control options via a smartphone. Testing showed the system worked well in simulation and individual component tests, although the physical prototype faced power issues. This project demonstrates the potential of automation and IoT in household applications, offering convenience and protection against unexpected weather.

1. Introduction

Because of Malaysia's unpredictable weather and heavy rainfall, working adults struggle to complete home tasks like laundry. Many people cannot monitor the weather changes during the day, so they hang their damp garments outside while at work. Frequent rain in humid climates significantly impacts household chores, leading to inconvenience [1-2]. Given Malaysia's hot and humid environment, rain is frequent, leaving clothes damp and unusable, which wastes time and effort as clothes must be dried again [3]. Studies have shown that the unpredictability of weather patterns in tropical regions can lead to increased stress and frustration among homeowners, affecting their daily routines [4].

An Intelligent Weather System for Outdoor Clothes Drying has been devised to address this issue. Using Internet of Things technology, this system automatically detects when it is raining and covers the laundry to keep it dry. Because it removes the need for physical intervention, users can go about their day without worrying about how the weather may affect their laundry. Innovations such as this can significantly enhance the convenience of daily chores and contribute to overall household efficiency by reducing manual labor [5].

IoT, the most significant emerging trend in technology, has launched an unprecedented information revolution [6]. The Intelligent Weather Alert System allows users to remotely control their laundry drying and receive real-time updates via an Internet of Things platform. For people with hectic schedules, this means less time spent checking on laundry and greater convenience. Recent research indicates that smart home devices save time and lead to more sustainable living practices by optimizing household resource use [7].

Using IoT makes it easier to manage drying clothes and gives users peace of mind, especially for those with tight schedules and unpredictable weather. It is a practical, time-saving solution that helps people dry their laundry without manual effort. Moreover, integrating automated systems for household chores has improved user satisfaction, allowing users to focus more on their professional and personal lives rather than daily tasks [8].

2. Methodology

This project aims to create an Intelligent Weather System that is practical, effective, and weather-adaptable. In order to identify environmental changes, such as rain or temperature swings, the system combines sophisticated sensors, actuators, and a microcontroller-based platform. In response, the drying rack cover is either opened or closed. This creative method maximizes drying conditions in favorable weather while guaranteeing clothing protection in unfavorable weather.

This project's methodology takes a methodical and planned approach to guarantee the system's usability, dependability, and functionality. Choosing the required hardware and software components and establishing the project's needs are the first steps in the design and planning phase. This entails selecting sensors integrated into the physical system, such as a servo motor, a rain detection sensor, and an LCD for the user interface.

Implementing the control logic to read sensor data, drive the servo motor, and handle user notifications is the primary goal of the software development phase. In order to provide seamless and automated functioning, the system is configured to react dynamically to current weather conditions. Following the original development, a thorough testing and validation process is carried out to assess the system's performance in various weather conditions. This stage is crucial for locating and fixing any problems or irregularities in the system's operation.

The optimization and integration phase enhances the system's scalability and energy efficiency, ensuring that the software and hardware components cooperate effectively. The technique ensures that the Intelligent Weather System achieves its objectives by emphasizing affordability, simplicity of deployment, and the possibility of integration with smart home ecosystems, providing dependable and user-friendly outdoor clothes drying solutions.

2.1 System Block Diagram

The block diagram system shows how data and control work together in this smart weather system. At the heart of it all is the ESP32 microcontroller, which gathers information from the rain sensor that measures moisture and humidity. When rain is detected, the ESP32 activates a 90° servo motor to rotate a protective roof over the clothes rack. At the same time, notifications are sent to the Blynk mobile app, so users can stay updated and respond promptly, even from afar. Fig. 1 shows the block diagram representing the overall structure of the Intelligent Weather System.

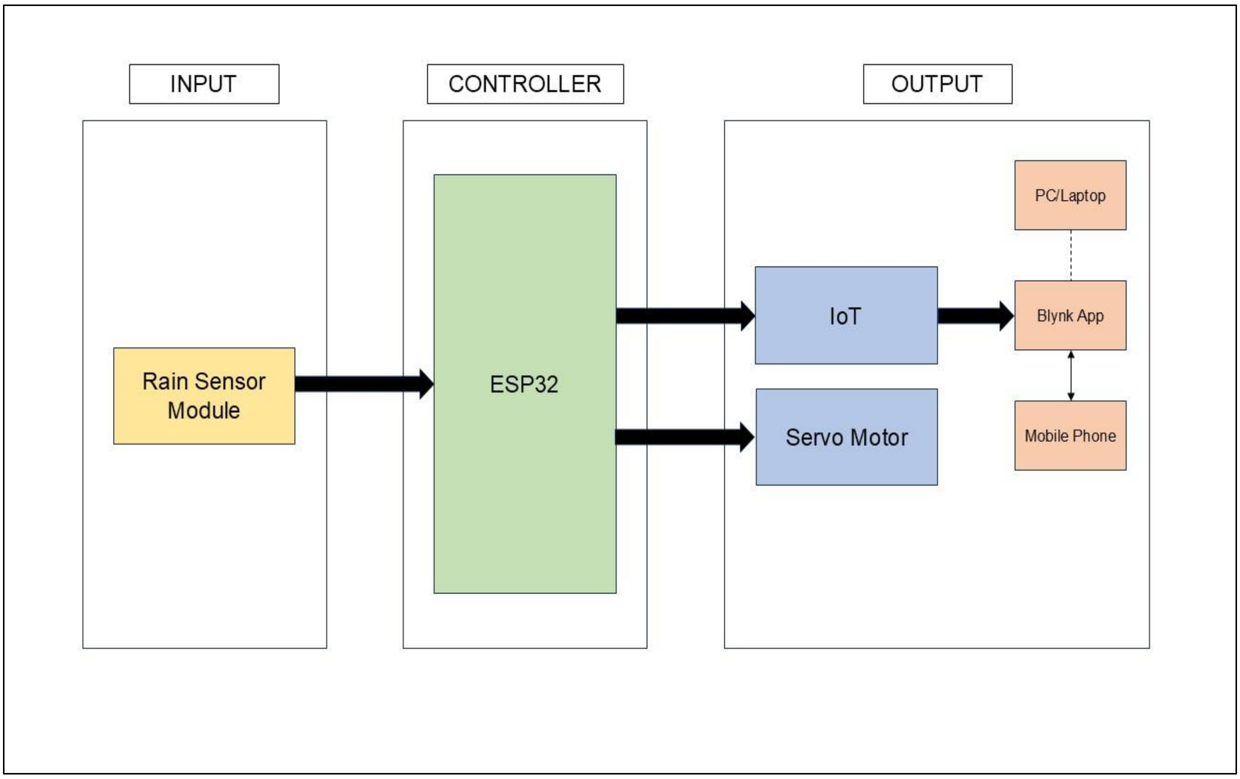


Fig. 1 *System block diagram of An Intelligent Weather System*

The flow chart defines the operational logic of the system. The process begins by checking whether clothes are present on the rack. If they are, the rain sensor is continuously monitored. Upon detecting rain, the system commands the motors to close the roof and pull the clothes rack under cover. If no rain is detected, the system maintains or restores the drying position. Notifications are sent at each stage to keep the user updated, enabling remote awareness and decision-making. Fig. 2 is the flowchart that outlines the logical workflow of the Intelligent Weather System for Outdoor Clothes Drying, detailing how decisions are made based on weather conditions and laundry presence.

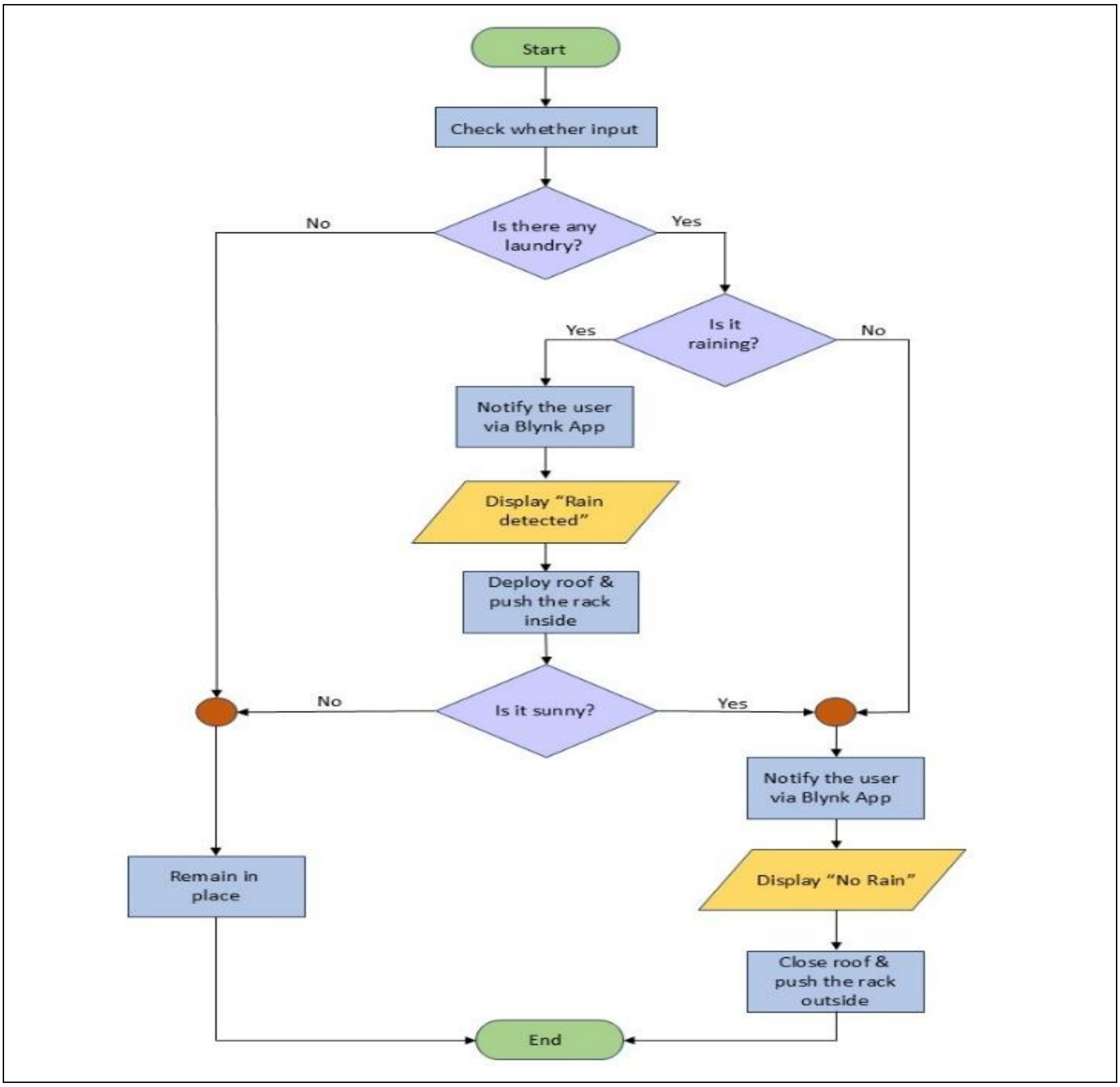


Fig. 2 *Flow Chart of An Intelligent Weather System*

2.2 Schematic Circuit

The system was tested on Wokwi to verify its functions. Fig. 3 shows that in the "Rain Detected" situation, the rain sensor identifies precipitation and sends a signal to ESP32, which processes the input and deploys the cover to protect the clothes. The servo motor is then activated to deploy the cover. Simultaneously, the system sends an alert to the user through the IoT platform (Blynk), ensuring they are informed about the weather change and the system's action to safeguard the clothes.

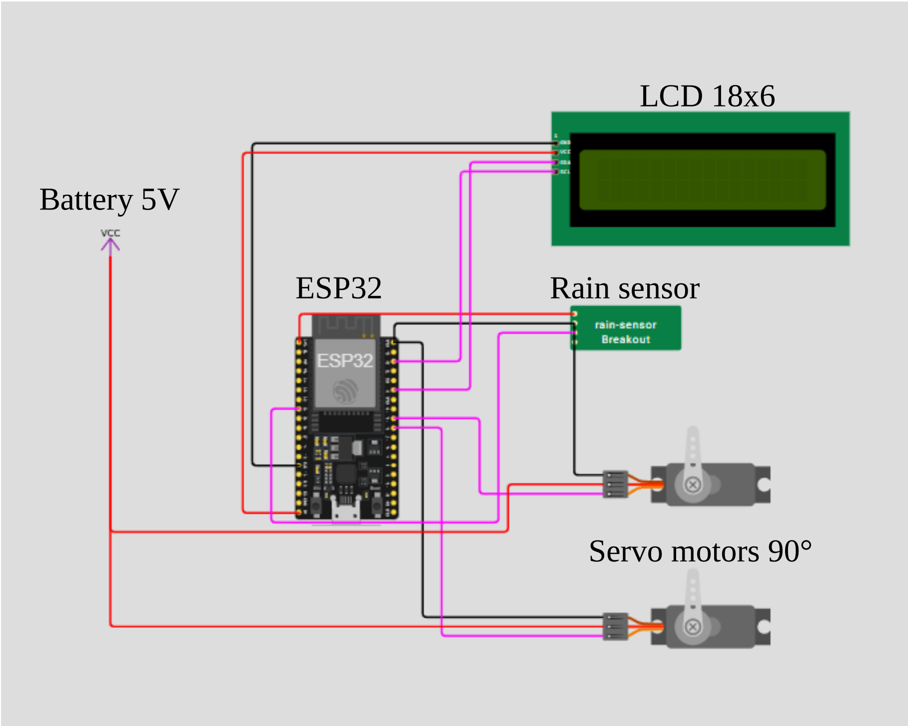


Fig. 3 *Systematic Circuit of An Intelligent Weather System*

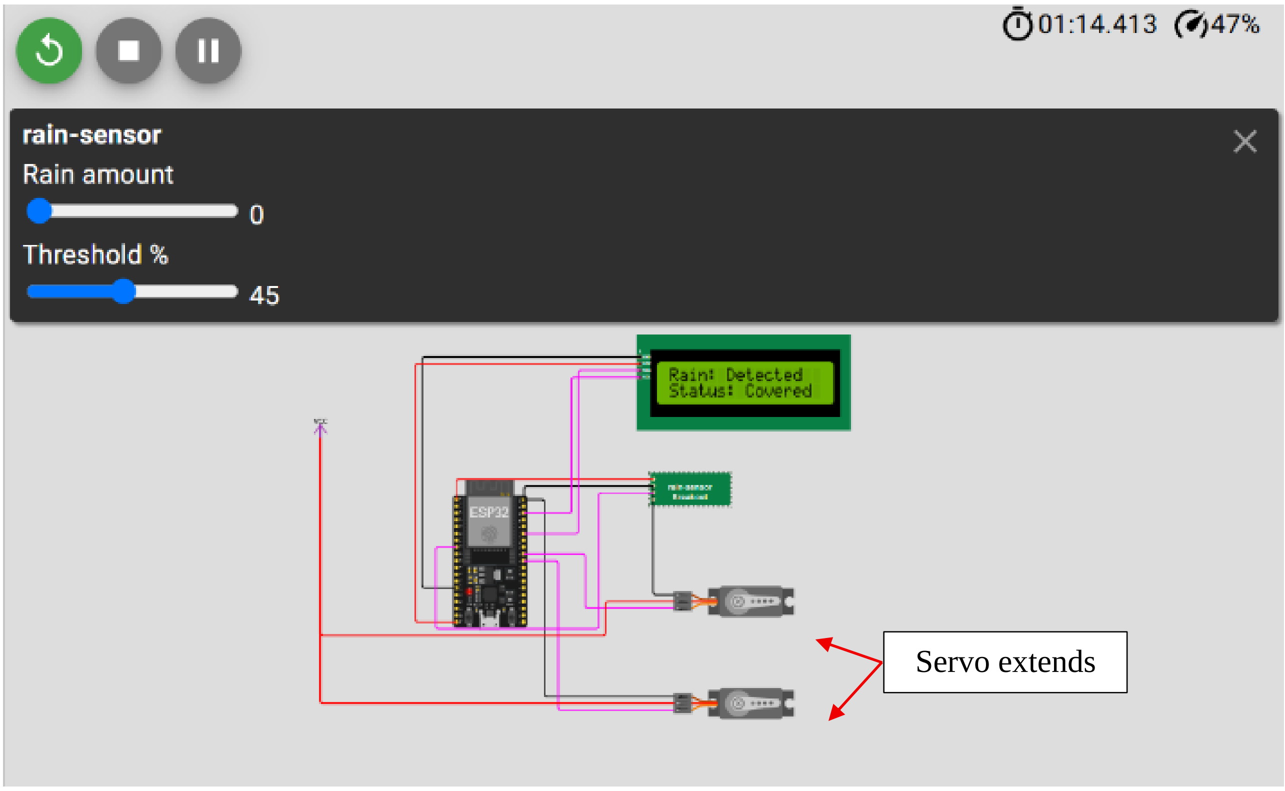
2.3 Simulation

The testing phase of the Intelligent Weather System for Outdoor Clothes Drying was aimed at verifying the integration of hardware components and evaluating whether the system responded as expected under real conditions. The system was designed to function autonomously, using environmental sensor input to control mechanical movement and notify the user via IoT. Specifically, the rain sensor was expected to detect precipitation and trigger the ESP32 microcontroller to activate a servo motor, which would either deploy or retract a roof cover over a clothes rack. Simultaneously, the system would send a notification to the user via the Blynk mobile application, while the LCD would display real-time weather status updates such as “Rain Detected” or “No Rain.”

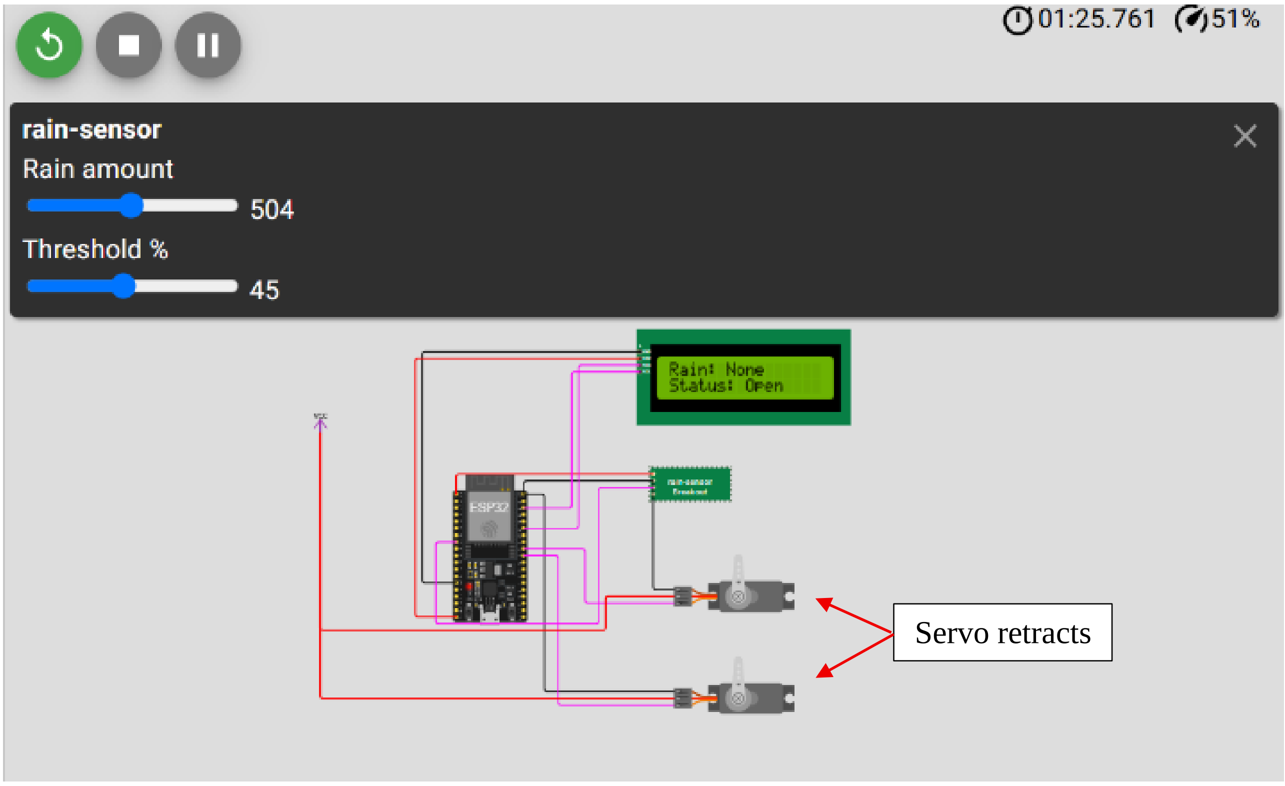
Initially, individual components such as the rain sensor, LCD, and servo motor were tested independently on a breadboard, and all showed positive results. When connected to a power supply, the sensors responded appropriately, and the servo motor performed the intended rotational movements in simulation. The ESP32 was programmed using Arduino IDE and uploaded with logic to handle environmental inputs, control outputs, and communicate via Wi-Fi with the Blynk platform.

During the final prototype assembly and just before live testing, the ESP32 microcontroller did not power on as expected. Even though several troubleshooting steps were carried out such as trying different power supply configurations and USB diagnostics, the board remained unresponsive. This situation is believed to be caused by damage during soldering or a short circuit during the connection process, possibly due to static discharge or wiring mistakes. Although the hardware could not be revived, this gave me useful experience in identifying hardware issues and showed me the importance of careful handling and assembly. It also highlighted areas that can be improved in future development of the system.

This failure occurred at a critical moment before the prototype demonstration, halting full system testing. This setback prevented validation of the complete end-to-end workflow, from sensor detection to mechanical actuation and IoT notification. Nevertheless, the simulation results and prior isolated component tests affirmed that the system logic and design were functional and well-structured. Fig. 4 (a) and Fig. 4 (b) show the testing on physical connections that occur between all the components.



(a)



(b)

Fig. 4 *(a) Simulation when the rain is detected, and (b) Second simulation when the rain stops*

3. Results and Discussions

The project was tested in two stages: simulation and hardware testing. In the simulation using Wokwi, the system worked perfectly. When rain was detected, the ESP32 triggered the 180° servo to rotate and move the roof over the clothes. The LCD displayed “Rain Detected” and the Blynk app sent a notification to the user. When the rain stopped, the roof retracted, the LCD updated to “No Rain,” and another notification was sent. This showed that the program logic and all virtual components worked well. To summarize the testing outcomes, a breakdown of each component's performance is shown in Table 1.

Table 1 *System testing results*

No.	Component	Test Purpose	Result	Status
1	Rain Sensor	Detect rain	Detected rain accurately	Working
2	180° Servo Motor	Move the roof cover	Moved as expected	Working
3	LCD Display	Show system status	Showed correct messages	Working
4	ESP32 Microcontroller	Control all operations	Failed to power up	Faulty
5	Blynk App	Send notifications via IoT	Failed to send messages in simulation	Faulty

The system proved reliable and consistent in simulation and partial hardware testing, with key components working together smoothly. The rain sensor accurately detected precipitation, the 180° servo motor operated with precise movement, and the LCD displayed clear and correct status updates. The integration with the Blynk app also allowed remote monitoring, adding value for users who are not at home. Although the ESP32 microcontroller failed during full hardware operation as intended, the system still showed strong potential in its design and functionality. Overall, as shown in Table 1, the core components met the project’s functional goals and provided a solid foundation for further development.

3.1 Results

The Intelligent Weather System was tested to evaluate the performance of key components: the rain sensor, 180° servo motor, and LCD display. These components were first tested individually in a simulation and then in physical form using a breadboard and stripboard. In all individual tests, the rain sensor responded correctly by detecting moisture, the servo motor activated accordingly, and the LCD displayed real-time status updates such as “Rain Detected” or “No Rain.”

However, during full hardware integration, the system failed to operate due to hardware malfunction. The ESP32 microcontroller did not turn on after being soldered to the stripboard, most likely because of excessive heat or a short circuit during the soldering process. As a result, the board was unable to function as the main controller and the full prototype could not be tested in real-world operation. Table 2 shows the combined results of the rain sensor detection, servo motor movement, and LCD display messages during different test conditions.

Table 2 *Rain sensor test results*

No.	Test Condition	Rain Detected	Servo Motor Action	LCD Display	Result
1	No Rain	No	Roof remains open	"No Rain"	Successful
2	Rain Detected	Yes	Roof closes (rotates)	"Rain Detected"	Successful

These results confirm that the core system logic and hardware performed as intended during individual testing. Although full prototype integration was unsuccessful due to hardware failure, the results support the feasibility of the design, and the physical build demonstrates readiness for future improvements. Despite these challenges, the soldered circuit and the physical structure of the prototype were successfully assembled. Fig. 5(a) shows the soldered hardware on a stripboard, where all components were securely connected for final testing. Fig. 5(b) presents the completed prototype structure, which includes the roof mechanism designed to protect clothes from rain.

(a) (b)

Fig. 5 *(a) Soldered hardware of the project and (b) The prototype of the project*

3.2 Discussion

During the testing phase of the Intelligent Weather System for Outdoor Clothes Drying, both simulation and partial hardware integration were carried out to evaluate system behaviour. The Wokwi simulation confirmed that the programmed logic performed as expected, sensor data was processed accurately, the LCD provided appropriate real-time feedback, and the simulated servo motor responded to rain detection events. The Blynk IoT platform successfully displayed environmental readings and issued timely alerts in the virtual environment. During the physical prototype testing, the system failed to operate because of hardware problems. The ESP32 microcontroller, which acted as the main processing unit, was damaged during soldering, most likely due to overheating or a short circuit. As a result, it could not start up or communicate with the connected components. In addition, the continuous rotation servo motor did not respond even when connected directly to a power source, suggesting an internal fault. These hardware issues stopped the automated cover and clothes rack mechanism from working as intended. Despite these hardware challenges, the logic structure, simulation output, and component layout validate the functional viability of the system. The failure of the ESP32 and servo motor underscores the importance of handling sensitive electronic components with precision and the need for incorporating protective measures such as voltage regulation, heat control during soldering, and pre-testing of components before integration.

For future implementation, this system holds significant potential as a smart home solution. Enhancements can include integrating solar panels to power the system sustainably and reduce dependence on external power sources. Additionally, incorporating rain prediction models using machine learning, trained on historical weather data would allow the system not only to respond to rain but to anticipate it. Integration with voice assistants such as Google Assistant or Amazon Alexa would further increase accessibility and user interaction. The structure could also be redesigned using lightweight, weatherproof materials to make the product commercially viable for installation in various residential settings. Ultimately, with robust hardware handling and these proposed upgrades, the Intelligent Weather System can be developed into a fully functional, scalable solution to address real-world problems related to laundry management in unpredictable climates.

4. Conclusion

Through the integration of IoT technology, environmental sensors, and automated actuation, the system aimed to offer a hands-free, weather-responsive solution to protect clothes from unexpected rainfall. Although the system logic was fully developed and validated through simulation using the Wokwi platform, the physical implementation encountered hardware limitations. The ESP32 microcontroller was damaged during assembly, and the servo motor failed to operate, which impeded full prototype deployment. Despite these hardware issues, the project successfully demonstrated a feasible, scalable framework for smart household automation. With improvements in hardware resilience and system protection, the concept can evolve into a commercial-grade solution. Future enhancements could include solar energy integration, predictive weather algorithms, mobile application upgrades, and voice assistant compatibility to further increase functionality and user experience.

Acknowledgement

The authors would like to thank the Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia for its support.

Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: study conception and design: Noor Arissa Farhanah Norizan; data collection: Noor Arissa Farhanah Norizan; analysis and interpretation of results: Noor Arissa Farhanah Norizan, Nur Azliza Ahmad; draft manuscript preparation: Noor Arissa Farhanah Norizan. All authors reviewed the results and approved the final version of the manuscript.

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