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IoT-Based Smart Mushroom Polyhouse

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Abstract: The process of growing mushrooms requires a lot of attention because it depends on the precise temperature, humidity, and moisture conditions in the growing medium. Unfortunately, with the application of conventional methods, the majority of these parameters are adjusted by hand, leading to many inconsistencies, increased labor costs, and decreased efficiency. This paper describes an innovative mushroom polyhouse design that incorporates the IoT technology, artificial intelligence, and ESP32-based microcontroller as well as a number of sensors. The system constantly monitors several main variables such as temperature, humidity, and the moisture of substrates and adjusts them by turning on the required devices, e.g. exhaust fans, humidifier, and pumps, in a closed-loop mode.

Furthermore, the system is integrated with the cloud service where one can monitor all these variables and even adjust some of them. Such an approach increases automation and allows avoiding numerous mistakes. Consequently, it enhances the effectiveness of growing mushrooms, reduces expenses, and eliminates the likelihood of any losses due to improper adjustment of growing conditions.

Keywords: IoT, Smart Agriculture, ESP32, Mushroom Cultivation, Automation

I. INTRODUCTION

The cultivation of mushrooms like the Pleurotus ostreatus needs precise maintenance of environmental conditions in order to produce high-quality and high yield output. Different from other plants, mushrooms are more susceptible to fluctuations in the levels of temperature, moisture, and humidity of the growth substrate. Small fluctuations in these environmental factors may affect the rate of growth of the mushrooms, their form, and the yield output produced. During conventional mushroom farming, the farmer must consistently and frequently maintain the aforementioned factors manually.

As a result of the development of smart technology, the application of the Internet of Things (IoT) in farming is considered an ideal approach to solving these problems. IoT-enabled devices provide constant monitoring of environmental factors through sensors, whereas microcontrollers help analyze collected information and manage control processes automatically [2], [3]. These systems decrease human involvement in the operation of equipment and increase the precision of environmental regulation. Moreover, implementing machine learning and intelligence in IoT-enabled devices helps detect unfavorable environmental conditions and predict them before they can harm crops [4], [5].

In recent years, it has been proven that IoT-based monitoring systems can help achieve the necessary microclimate conditions to grow mushrooms. Automated monitoring systems, which use sensors, and cloud technology platforms, for example, are more efficient, respond instantly, and provide higher levels of uniformity [6], [7]. Moreover, wireless sensor networks are vital in ensuring effective communication among all system components [8]. It should be noted that keeping relative humidity at a high level is crucial to achieving fungal growth and producing mushrooms [9].

Further improvements to the smart farming process are achieved through cloud computing technology platforms that facilitate remote surveillance, storage, and analysis of information. Cloud computing technology platforms give users access to environmental information in real time, allowing them to monitor and control the system using their mobile phones, thus improving efficiency and convenience [10]. It should also be noted that low-cost microcontroller solutions have been found to be successful in smaller rural farms [11].

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With this in view, the use of AI-enabled Internet of Things in the development of smart polyhouses can be viewed as an effort to introduce a fully automated system for mushroom farming. Through the use of sensors, actuators, and remote monitoring, the microclimate in the controlled environment will be maintained efficiently.

This strategy is expected to overcome the disadvantages associated with current techniques while developing a highly scalable and effective system that can help enhance precision agriculture.

II.LITERATURE REVIEW

Latest developments in smart farming have focused on utilizing IoT and smart systems in order to enhance the agricultural produce and the environmental conditions. The right temperature, humidity, and moisture levels of the substrates are important during mushroom farming to ensure high-quality and uniform yield. If these are not maintained, then the quality and consistency of the produce will be adversely affected.

Recent developments have revealed that deep learning models are helpful in classifying mushrooms automatically. Consequently, it reduces the effort involved manually and saves a lot of time [12]. In addition to that, the use of IoT-based platforms is promising because it helps stabilize the environment through automatic monitoring and control operations [13].

IoT sensors used in farming are relatively cheaper and have become prevalent in smart farming practices, especially for small-scale farming. Although they are less precise in terms of their readings, they have been found to be reliable enough for a controlled environment [14]. Besides, precision farming emphasizes the importance of establishing microenvironmental conditions for farm produce to minimize the impact of outside environmental conditions on crop growth [15]. Finally, there have been major advancements in the development of efficient greenhouses and poly-houses using IoT [16].

II. METHODOLOGY

The automated intelligent polyhouse system will help to control and monitor the environment required for mushroom growth. This is achieved using the feedback concept, which will help in controlling parameters such as temperature, humidity, and moisture content of the substrate, as illustrated in Fig. 1.

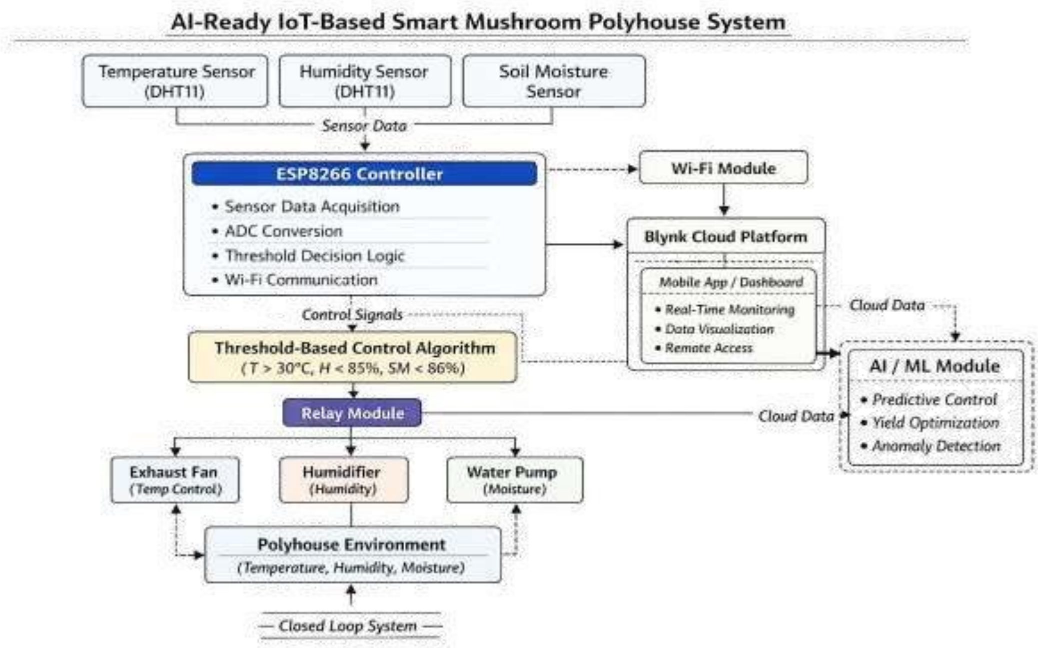

Figure 1: Block Diagram of AI-Driven IoT Smart Mushroom Polyhouse System

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The system contains three main components including sensory units, controller units, and actuator units. The sensory units are comprised of sensors such as humidity, temperature, and soil moisture (DHT11). These sensors keep a record of the environmental conditions within the polyhouse.

ESP32, which is used as the central controller, forms the crux of the system. It gathers information through input from sensors, compares this input data with threshold values, and based on it, activates and deactivates particular devices.

Actuators are basically devices that get the work done. This system comprises actuators like exhaust fans, humidifiers, and water pumps which are controlled using relay modules. For example, once the temperature becomes higher than the required limit, exhaust fans are activated. In case of low humidity, humidifiers turn on. Moreover, the water pump helps keep the substrate moist. Another aspect of this automated system is its integration with the Internet of Things (IoT). This enables users to monitor and control the system remotely using mobile applications.

It can thus be concluded that this automated system will help control the environment, reduce manual effort, and improve efficiency.

III. SYSTEM DESIGN & IMPLEMENTATION

The intelligent polyhouse technology is aimed at developing a conducive artificial environment for mushroom production. This is achieved through the coordination between the sensor, controller, and actuator units, which help control environmental conditions within the polyhouse. The first step is done by the sensors that detect information from the surroundings and relay it back to the controller, which in turn controls the actuators.

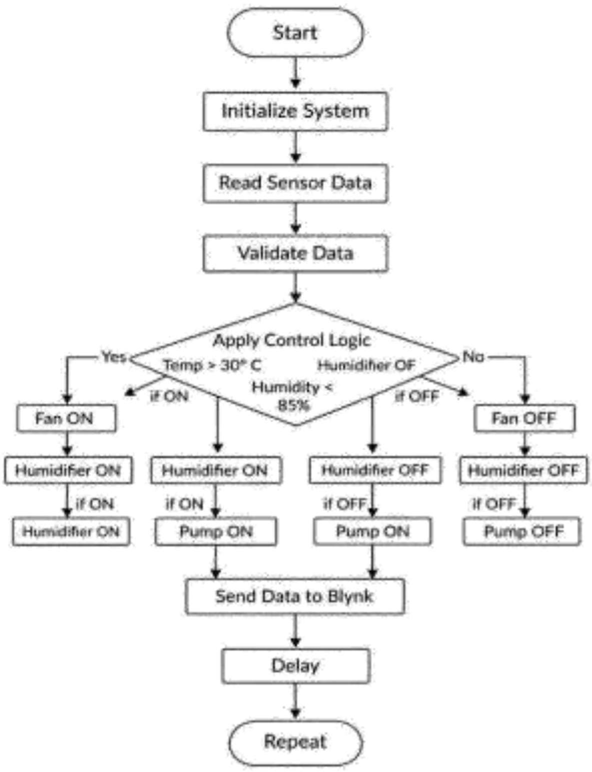

Figure 2: Flowchart of AI-Driven IoT Smart Mushroom Polyhouse System

It starts with gathering information from the environment through the use of sensors. A DHT11 sensor senses temperature and humidity levels within the polyhouse. Soil moisture sensors detect the amount of moisture within the substrate. These data are then sent to the ESP32 microcontroller, as shown in Fig. 2.

Afterward, the ESP32 analyzes the collected data against pre-set threshold levels. It determines the next step that should be undertaken to create favorable conditions. The ESP32 is an excellent choice for agricultural IoT systems since it performs reliably and is equipped with wireless connectivity [21]. If the temperature exceeds the set limit, the exhaust fan operates

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to lower the temperature level. In case the humidity level decreases, the humidifier turns on to increase the level. Whenever the moisture within the substrate drops below the required value, the water pump turns on to provide moisture. Proper maintenance of microclimatic conditions ensures the achievement of high yield and quality [24]

A flow chart of the operation is presented below, indicating how each activity is performed, starting from sensing to the decision-making process.

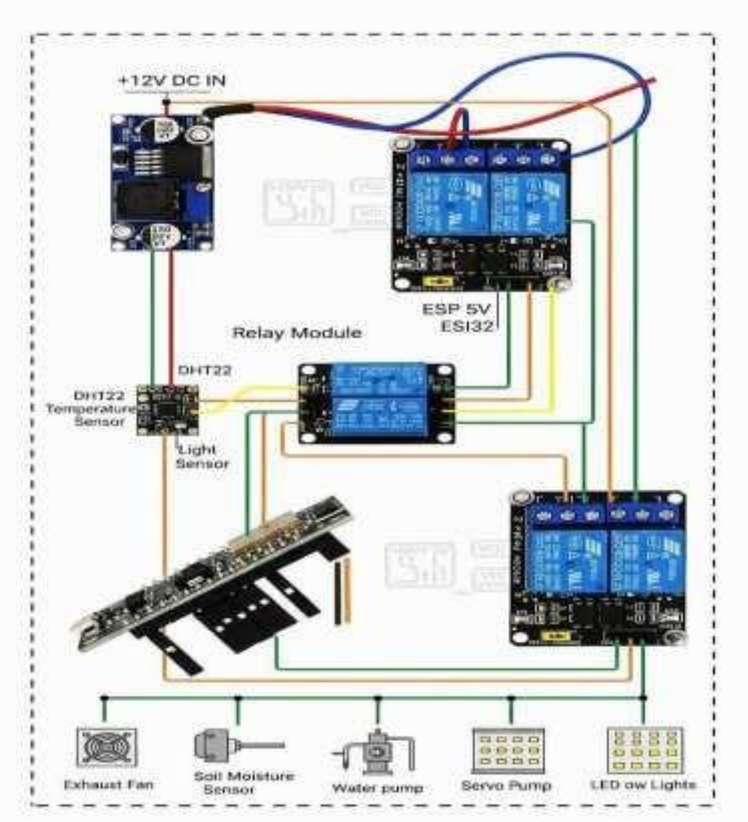

Figure 3: Circuit Diagram of the Smart Polyhouse System

In this case, the ESP32 is responsible for controlling and monitoring the system as a bridge between the sensors and actuators. In this regard, the DHT11 sensor is interfaced with a particular digital input of the microcontroller whereas the soil moisture sensor is interfaced with one of the analog inputs. The general connection circuit of the system is illustrated by Fig. 3 below.

The relay modules have been employed in order to control external devices such as exhaust fan, humidifier, and water pump among others. As mentioned earlier, these relays serve as switches that allow the use of lower power output of the ESP32 to trigger other high power electric devices. The programming is done through the Arduino integrated development environment (IDE) whereby certain thresholds are determined for temperature, humidity, and moisture.

ESP32 continually receives input from the sensors and responds promptly. When any value exceeds the threshold limits, then it switches the corresponding device to restore the ideal conditions. In case of remote monitoring and control, the system gets connected to an IoT platform like Blynk. It helps visualize the environmental parameters in real-time using a mobile interface and enables remote control of the system [28]. IoT based cloud systems enhance smart farming by improving efficiency and accessibility [10].

When implementing the system, there is wiring and calibration of the sensors that would ensure the accuracy of the data obtained. The system undergoes testing at various environmental conditions to assess its effectiveness. In general, this is a good system of automation for the purpose of maintaining the environment for mushroom farming.

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V.RESULT AND DISCUSSION

Performance analysis of the suggested intelligent IoT-based polyhouse system was carried out through observations on environmental factors and the development of oyster mushrooms in laboratory settings. The dashboard contains information about important environmental factors such as temperature, humidity, and substrate moisture. In the course of testing, the intelligent IoT-based polyhouse system was able to sustain a temperature of approximately 25°C, which is in the ideal range for growing oyster mushrooms. The observed humidity level was approximately 49%, demonstrating that the system is effective in sustaining moisture conditions close to the desired range.

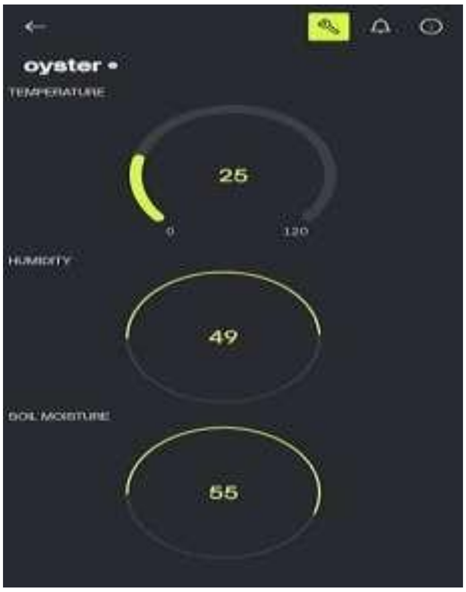

Figure 4: Real-Time IoT Monitoring Dashboard Displaying Temperature, Humidity, and Soil Moisture

Monitoring of the environment and its automatic adjustment reveal that the system is successful in ensuring a constant microclimate (Fig. 4). Monitoring through sensors also ensures accurate information on the environment, an important aspect in ensuring ideal growth conditions [14]. Furthermore, maintaining the appropriate moisture content is crucial in ensuring ideal cap formation [9].

Table 1: Mushroom Growth Progress over Three Weeks

Week	Growth Report
Week 1	Initial mycelium formation observed; white thread-like structures started spreading over the substrate.
Week 2	Rapid mycelial growth covering most of the substrate; small pinheads (primordia) started appearing.
Week 3	Fully developed oyster mushrooms with visible caps and stems; ready for harvesting.

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Figure 5: Oyster Mushroom Growth under Controlled Polyhouse Conditions

As seen in Fig. 5, the growth of the oyster mushrooms was healthy and even in the smart polyhouse. These mushrooms had an appropriate shape and density due to the fact that the environmental parameters were controlled during their growth. It should be noted that controlling humidity and temperature directly affects the growth rate of mycelia and yields [17].

Since IoT-based solutions allow monitoring the environment in real time, the use of manual work is not required. Thus, using automated systems guarantees stable functioning and resource efficiency, including the usage of water and energy. This can lead to additional economic benefits for small farmers [27].

Summing up all the findings, it should be mentioned that the proposed solution was able to guarantee favorable conditions for growing mushrooms. This helped improve production efficiency and prevent crop failure.

VI.CONCLUSION

The suggested IoT based intelligent polyhouse for mushroom cultivation is an example of a highly effective and automated method of producing mushrooms inside a controlled environment. The use of sensors to measure environment variables coupled with IoT based monitoring and control via ESP32 ensures creation of an environment conducive for mushroom cultivation with minimum human intervention. The continuous monitoring of various environmental factors, including temperature, humidity, and moisture of substrates, and even the functioning of some mechanical components like fans, humidifiers, and water pumps, aids in creating favourable conditions for growing mushrooms.

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