

An Intelligent Greenhouse Monitoring Framework for Automated Mushroom Cultivation

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Abstract—Mushroom cultivation requires careful monitoring of environmental conditions and growth stages to maintain crop quality and productivity. Traditional cultivation practices often depend on manual observation, which can delay the identification of abnormal conditions and make cultivation management difficult. This paper presents an intelligent greenhouse monitoring framework for mushroom cultivation that combines artificial intelligence (AI), image-based analysis, environmental condition assessment, and cultivation guidance. The proposed framework includes mushroom image uploading and analysis, growth-stage identification, crop health assessment, a climate simulation module, a mushroom species library, cultivation history, and an AI-based assistance interface. The system provides stage-dependent cultivation recommendations and supports the monitoring of parameters such as temperature, relative humidity, light intensity, and carbon dioxide concentration. The software framework is designed to support future integration with Internet of Things (IoT) sensors and automated environmental control devices. The proposed approach aims to improve the accessibility of cultivation information and support informed decisions during mushroom production. Its practical effectiveness must be established through systematic testing using representative mushroom images, environmental measurements, and cultivation trials.

Index Terms—Artificial intelligence, automated cultivation, greenhouse monitoring, Internet of Things, mushroom cultivation, growth-stage identification, environmental monitoring.

I. INTRODUCTION

Mushroom cultivation is an important agricultural activity that provides nutritious food and supports

income generation. However, successful mushroom production depends on maintaining suitable environmental conditions throughout the cultivation process. Parameters such as temperature, relative humidity, light intensity, and carbon dioxide concentration influence mushroom growth and development. These requirements vary according to the mushroom species and its growth stage. Therefore, continuous monitoring and timely management are essential for maintaining crop quality and achieving consistent production. Traditional mushroom cultivation methods often rely on manual observation and periodic environmental measurements. These methods can be time-consuming and may delay the identification of abnormal conditions, such as unsuitable temperature, excessive moisture, or possible contamination. In addition, identifying the mushroom species and determining its current growth stage can be challenging for inexperienced growers. These limitations create a need for an intelligent monitoring framework that combines environmental assessment, image-based analysis, and cultivation guidance. Recent developments in the Internet of Things (IoT) and Artificial Intelligence (AI) provide opportunities to improve greenhouse monitoring. IoT sensors can collect environmental data, while AI-based image analysis can assist in identifying mushroom species, estimating growth stages, and observing visible crop abnormalities. Integrating these technologies can help growers access relevant information and make informed cultivation decisions. The proposed framework aims to address these challenges by integrating mushroom image analysis, growth-stage assessment, environmental condition

simulation, a species library, cultivation history, and an AI-based assistance interface. Users can upload mushroom images, review the analysis, and receive recommendations related to the estimated growth stage. The framework also provides a foundation for future integration with IoT sensors to collect real-time environmental measurements and support automated control.

II. RELATED WORK

Research on intelligent mushroom cultivation has explored environmental sensing, IoT-based monitoring, automatic control, and AI-assisted crop analysis.

Rukhiran et al. [1] presented an IoT-based mushroom cultivation system integrated with solar renewable energy. Their work investigated environmental monitoring and control using sensors, data collection, and dashboard visualization. This research demonstrates the relevance of combining environmental monitoring with resource management. Recent work on IoT-enabled mushroom growth management has combined environmental sensors with deep-learning-based growth monitoring for controlled cultivation environments [2]. Such approaches illustrate the potential of combining sensor measurements and visual crop information.

AI-based mushroom monitoring has also been investigated using object-detection models. Nopiandi et al. [3] studied the use of YOLOv8 Nano for monitoring oyster mushroom growth stages, together with environmental sensors and a dashboard. Their work demonstrates the potential of computer vision for supporting growth-stage monitoring.

Although these approaches provide useful foundations, a cultivation framework must also consider usability, species-dependent recommendations, historical tracking, and the integration of multiple monitoring functions. The proposed framework brings these functions together through a common software interface. Its advantages over existing systems should be established through comparative testing rather than assumed.

III. PROPOSED METHOD

The proposed system presents an intelligent greenhouse monitoring framework for automated

mushroom cultivation by integrating Artificial Intelligence (AI), environmental assessment, and cultivation guidance. The main objective is to support growers in monitoring mushroom development, identifying environmental problems, and making suitable cultivation decisions. The framework consists of several interconnected modules. First, the image upload and mushroom identification module accepts images of mushroom crops and analyzes their visual characteristics to estimate the mushroom species. The growth-stage detection module estimates the current cultivation stage, such as inoculation, colonization, pinning, fruiting, or harvest readiness. Based on the analysis, the system provides stage-specific cultivation recommendations. The environmental monitoring module focuses on temperature, relative humidity, light intensity, and carbon dioxide concentration. The climate simulator allows users to examine environmental conditions and compare them with suitable reference ranges for the selected mushroom species. In the proposed IoT extension, sensors connected to a microcontroller such as the ESP32 can collect environmental measurements and transmit them to the monitoring dashboard. Similar sensor-based approaches have been investigated in existing mushroom cultivation research. The AI-based guidance module analyzes available crop information and environmental conditions to suggest appropriate cultivation practices. It can highlight abnormal conditions and provide recommendations for further inspection. The species library provides reference information, while the history module stores previous analyses for future review. An AI chat interface allows users to ask cultivation-related questions and obtain relevant guidance. The overall workflow is Image Upload and Sensor Data Collection → AI Analysis → Growth-Stage Identification → Environmental Assessment → Risk Identification → Cultivation Recommendations → Dashboard and History Storage.

The proposed framework aims to combine crop analysis and environmental monitoring within a single interface, reducing dependence on manual observation. Physical sensor integration and automatic actuator control can be implemented as future extensions if they are not yet available. The system's effectiveness should be evaluated using diverse mushroom images, validated sensor readings, and practical cultivation experiments.

IV ARCHITECTURE

The Intelligent Greenhouse Monitoring Framework for Automated Mushroom Cultivation works on the principle of Artificial Intelligence (AI)-based image analysis and environmental monitoring. It helps users monitor mushroom growth and understand the environmental conditions required for healthy cultivation. The user uploads a mushroom image

through the web application. The AI system analyzes the image to identify the mushroom species, determine its growth stage, and assess visible health conditions. Based on the analysis, the system provides suitable cultivation guidance and recommendations to support effective crop management. The system includes a climate simulation module to understand the effects of temperature, humidity, light intensity, and carbon dioxide (CO₂) levels on mushroom growth.

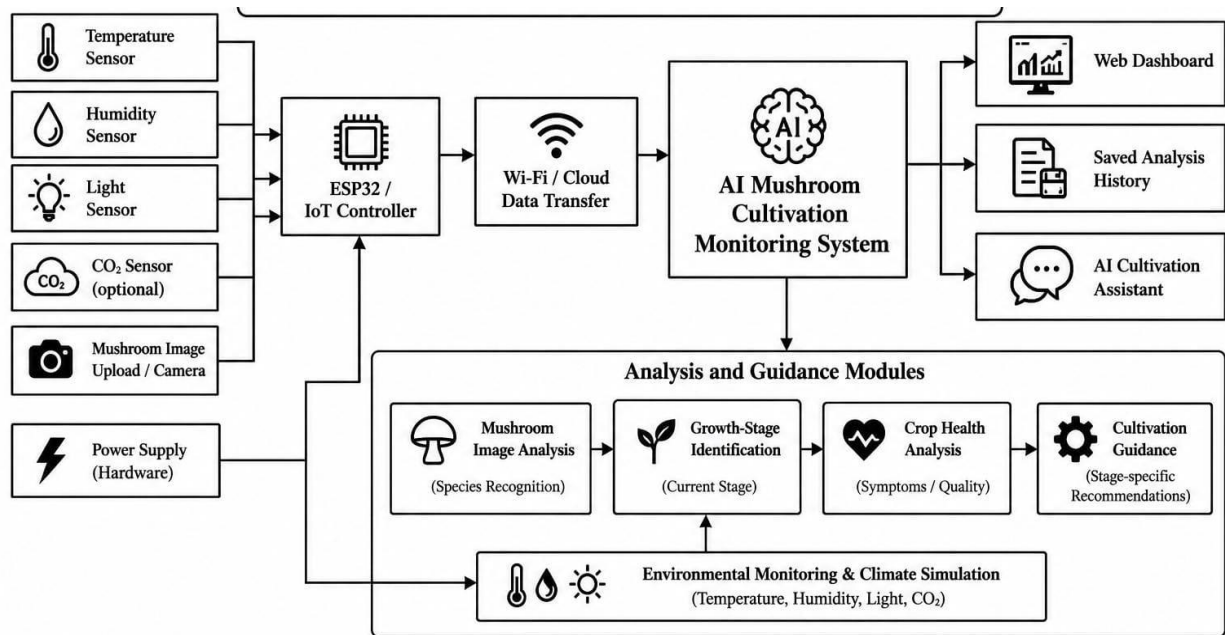


Fig: Architecture of the Mushroom Cultivation Monitoring System

The application also provides a species library containing mushroom-related information, a history section for storing previous analysis results and user notes, and an AI cultivation assistant to answer cultivation-related questions. All relevant information is presented through a user-friendly dashboard. Thus, the proposed framework combines AI technology, image analysis, and environmental monitoring to support informed cultivation decisions. It aims to simplify mushroom monitoring, reduce manual observation, and improve cultivation management. Physical sensor monitoring and automatic equipment control require additional hardware integration if they are not already implemented.

V ADVANTAGES OF THE PROPOSED SYSTEM

The proposed Intelligent Greenhouse Monitoring Framework for Automated Mushroom Cultivation

offers the following advantages:

1. Continuous Environmental Monitoring: Helps monitor important parameters such as temperature, humidity, light intensity, and CO₂ concentration.
2. AI-Based Mushroom Identification: Helps identify mushroom species from uploaded images.
3. Growth-Stage Identification: Estimates the current growth stage and provides relevant cultivation guidance.
4. Crop Health Assessment: Helps identify visible abnormalities and possible contamination for further inspection.
5. Stage-Specific Recommendations: Provides cultivation guidance based on the identified mushroom species and estimated growth stage.
6. Climate Simulation: Allows users to examine environmental conditions and understand suitable growing requirements.
7. Reduced Manual Effort: Combines crop analysis, environmental assessment, and cultivation information in one application.
8. Historical Data Storage: Saves previous analyses so

users can review crop observations and recommendations. 9. Remote Access: A web dashboard and cloud connectivity can support remote monitoring when network and IoT integration are available. 10. User-Friendly AI Assistance: Provides a chat interface to answer mushroom cultivation-related questions. 11. Expandable Architecture: Can be extended with physical sensors and automated devices such as fans or humidifiers. 12. Improved Cultivation Decisions: Combines image analysis and environmental information to help growers make informed decisions.

VI CONCLUSION

The Intelligent Greenhouse Monitoring Framework for Automated Mushroom Cultivation provides an efficient approach to mushroom monitoring using Artificial Intelligence and environmental assessment. The system analyzes uploaded mushroom images to identify species, assess growth stages, and examine visible health conditions. It also provides climate simulation, cultivation recommendations, a species library, and historical analysis records through a user-friendly dashboard. The AI cultivation assistant further helps users obtain relevant information about mushroom cultivation. The proposed integration of sensors and an ESP32 controller can support real-time environmental monitoring in the future. Overall, this framework aims to simplify cultivation management, reduce manual observation, and support better decision-making. Further development and practical testing can help evaluate its accuracy, reliability, and effectiveness under real greenhouse conditions.

VII FUTURE SCOPE

The proposed Intelligent Greenhouse Monitoring Framework for Automated Mushroom Cultivation can be enhanced in several ways in the future. Real-time environmental monitoring can be implemented by integrating sensors for temperature, humidity, light intensity, and carbon dioxide (CO₂) with an ESP32 or other IoT controller. Automatic control of fans, humidifiers, and ventilation systems can be introduced to maintain suitable growing conditions. Advanced deep learning models can be developed to improve mushroom species identification, growth-stage detection, and disease or contamination

recognition. The system can also be extended to predict mushroom yield and estimate the appropriate harvesting time using historical cultivation data.

A mobile application can be developed to provide remote access to monitoring results and cultivation recommendations. Cloud storage can be integrated to maintain long-term environmental records and analysis reports. Additionally, the AI cultivation assistant can be improved to provide more accurate, species-specific guidance in simple language.

In the future, the framework can be tested in real greenhouse environments to evaluate its accuracy, reliability, and practical usefulness. These enhancements can help develop a smarter, more efficient, and scalable mushroom cultivation system while supporting better crop management and resource utilization.

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