(REVIEW ARTICLE)

IOT-Driven Smart farming: Enhancing mushroom cultivation with environmental control and image-based disease detection

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Abstract

Mushroom farming is a rapidly growing segment of sustainable agriculture, offering high nutritional value and commercial viability. However, maintaining optimal environmental conditions and preventing disease outbreaks are major challenges. This paper proposes a comprehensive Internet of Things (IoT) based smart system that automates the monitoring and control of the growing environment while integrating image- based disease detection through deep learning. The solution reduces labor intensity, improves yield quality, and enables remote farm management.

Keywords: IoT; Mushroom Cultivation; Disease Detection; Raspberry Pi; Sensors; Python; Open CV; ESP32

1. Introduction

The IoT-based smart mushroom cultivation system with integrated disease detection marks a significant advancement in smart agriculture techniques. This system is designed to address key challenges faced in traditional mushroom farming, such as inconsistent environmental conditions, disease outbreaks, and high labor dependency. Using Internet of Things (IoT) sensors, the system continuously vital environmental parameters such as temperature, humidity, carbon dioxide (CO_2) levels, light intensity, and soil moisture. Maintaining these parameters within optimal ranges ensures healthy mushroom growth and improves both yield and quality.

Sensors data is transmitted in real time to the raspberry pi or cloud platform, where it can be analyzed to automate environmental control.Additionally, automation enhances precision and reduces the need for constant supervision.The integration of machine learning (ML) techniques,enable intelligent decision-making and early disease detection based on environmental and visual data. Through image processing and pattern recognition algorithms, the system can identify early symptoms of fungal or bacterial infections in the mushroom beds. This allows for immediate intervention, thereby minimizing crop loss and preventing the spread of disease.

Furthermore, the adoption of such a system significantly lowers operational costs over time. It reduces labor requirements, optimizes resource use (like water and electricity), and improves consistency in output. With the help of predictive analytics, the system can also provide insights for future crop cycles, contributing to better planning and farm management.

2. Overview of query by image content

The block diagram in Figure 1 illustrates an IoT-based smart mushroom cultivation system integrated with a disease detection mechanism. This system consists of multiple sensors, a raspberry pi, and actuators that work together to control optimal growing conditions and detect early signs of disease. The sensor module includes temperature,

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humidity, soil moisture, light, and CO_2 sensors, which continuously monitor the environmental parameters inside the mushroom cultivation chamber. These sensors provide real-time data to the Raspberry Pi, which serves as the central processing unit. A camera module is also connected to capture images of the mushrooms for disease detection using image processing and machine learning techniques.

The ESP32 processes the collected sensor data and Raspberry pi captured images, sending relevant information to a Cloud base IoT platform for remote monitoring and analysis. Based on the processed data, the system automatically controls the actuators such as the water pump, cooler, and fan to adjust temperature, humidity, and other conditions, ensuring an ideal environment for mushroom growth.

This integration of IoT with automation and disease detection reduces manual intervention, minimizes the risk of crop loss, and enhances the overall yield and quality of mushroom production.
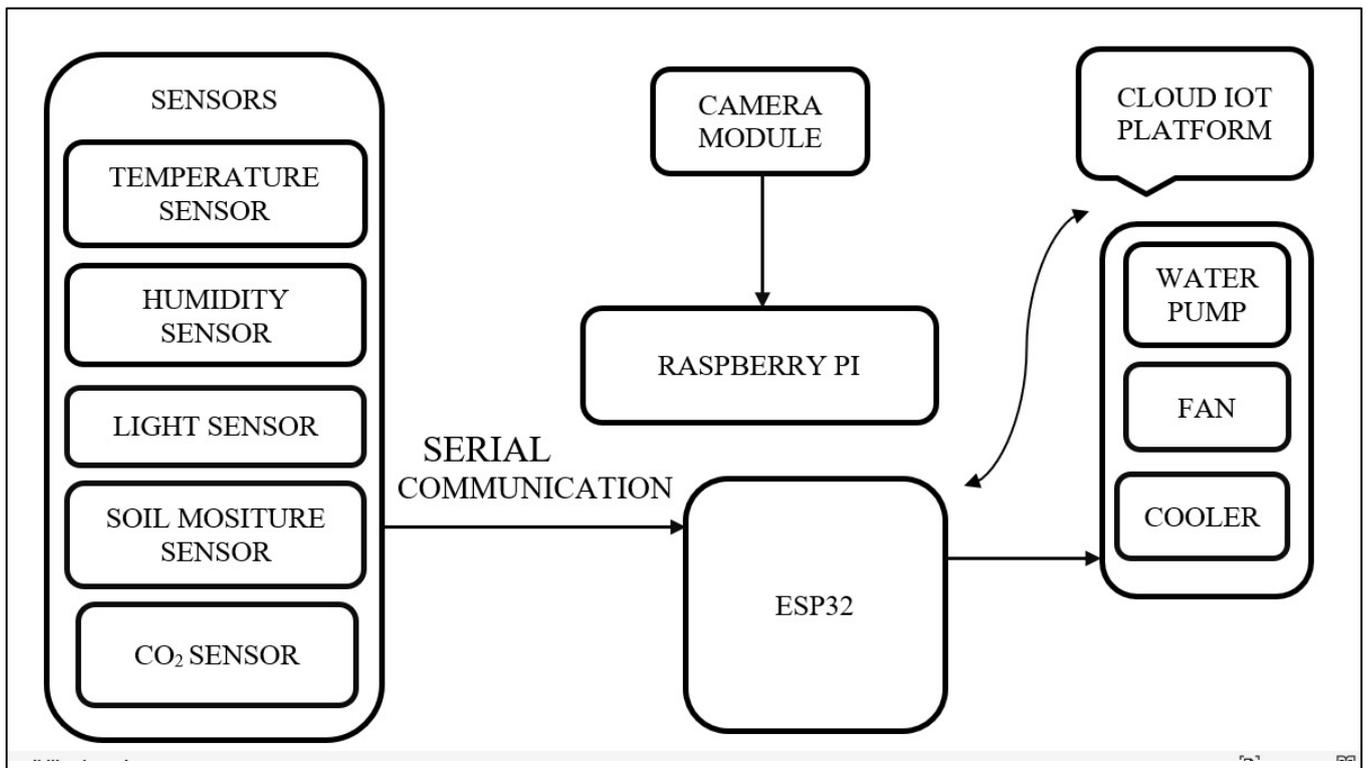

Figure 1 General Block Diagram of Smart Mushroom Cultivation and Disease Detection System

3. Survey

The paper titled "A Low-Cost Centralized IoT Ecosystem for Enhancing Oyster Mushroom Cultivation", authored by Deepesh Prakash Guragain, Bijaya Shrestha, and Iswor Bajracharya, was published in 2024 in the Journal of Agriculture and Food Research. This study presents a comprehensive and scalable IoT-based solution aimed at improving oyster mushroom farming, especially in developing countries where traditional cultivation methods are still prevalent. The system integrates real-time environmental monitoring, disease detection using deep learning (achieving 98.33% accuracy), agronomist advisory support, and an agro-eCommerce platform. A controlled experimental setup showed a 49% increase in mushroom yield compared to traditional methods, highlighting the system's effectiveness in maintaining optimal climatic conditions and improving productivity. The ecosystem also helps bridge the gap between farmers and agronomists, streamlines trade by bypassing intermediaries, and supports sustainable agricultural practices.

The paper titled "IoT Based Smart Mushroom Growing Kit", authored by Ammar A.M. Al-Talib, Cynthia Kuan Jing Ting, Noor Idayu Mohd Tahir, Ain Atiqa Binti Mustafa, and Tan Yong Hui, was published in 2024 at the International Conference on Artificial Life and Robotics (ICAROB2024) in Oita, Japan. This study presents the design and development of an Internet of Things (IoT)-based smart mushroom growing kit aimed at addressing the increasing global demand for

fresh and high-quality mushrooms. The system utilizes an ESP32 microcontroller to monitor and control environmental conditions such as temperature, humidity, CO_2 levels, and water level through various sensors and actuators. These parameters are regulated using a user-friendly interface on the Blynk IoT platform, allowing real-time remote monitoring and adjustment via smartphone. The prototype demonstrated improved cultivation outcomes, including faster growth (reducing the development period from eight to five days) and higher yield (60 grams vs. 49 grams using traditional methods). Sensor accuracy was validated with minimal error (below 6%), confirming the system's reliability. Overall, the proposed kit offers an efficient, cost-effective, and sustainable solution for mushroom cultivation, particularly suited for small-scale urban farmers and hobbyists.

The paper "Smart Mushroom Cultivation using IoT" by Sampada Singh, Simran, Sneha Anand, and Sushma S J (2020), reported in the International Journal of Engineering Research & Technology (IJERT), proposes an IoT-based solution to automate and optimize mushroom cultivation. The system utilizes a Raspberry Pi 3B+ as the main controller, connected to multiple ESP8266 nodes that gather real-time data from various sensors such as DHT11 for temperature and humidity, MG811 for CO_2 concentration, and soil moisture sensors. Data is updated to the cloud every 15 seconds, enabling continuous monitoring and automatic actuation of irrigation and environmental control systems. A drip irrigation system managed by solenoid valves ensures precise moisture control, while a dynamic website developed using Django provides an interface for users, including customer, employee, and administrator access levels. Additionally, a conveyor belt system is employed to reduce human intervention and maintain hygiene by automating the transfer of mushroom beds. This integrated approach effectively addresses challenges in traditional mushroom farming by improving efficiency, maintaining optimal growing conditions, and reducing manual labor.

The paper titled "Mushroom Disease Detection and Classification Using Machine Learning Techniques", authored by Rakesh Kumar Y, Dr. V. Chandrashekar, and Navya Vemula, was published in 2024 as part of the proceedings of the 4th IEEE International Conference on Data Engineering and Communication Systems (ICDECS). This research proposes a machine learning-based approach to automatically detect and classify common mushroom diseases—such as dry bubble, cobweb, wet bubble, mites, and bacterial blotch—using image processing and classification algorithms. The proposed methodology compresses image pre-processing, feature extraction through the Gray-Level Co-occurrence Matrix (GLCM), followed by classification utilization Random Forest (RF) and Multi- class Support Vector Machine (MSVM) algorithms. The experimental results, conducted on a dataset of 2,420 images, indicate that the Random Forest classifier outperforms MSVM, achieving an accuracy of 82% compared to 76%. The study concludes that Random Forest is more effective for this task and suggests future enhancements through additional feature extraction methods to further improve classification performance.

The research paper titled "Harnessing AI for Agriculture:Oyster Mushroom Disease Detection with IoT and Web Application on Growing Bags Using Deep Learning", authored by Wongpanya S.Nuankaew, Phacharapol Sombutthai, Watchrapong Monkhuan, Thapanapong Sararat, Pratya Nuankaew, was published in the 10th International Conference on Digital Arts, Media and Technology (DMAT) and 8th ECTI Northen Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (NCON) presents an integrated system that combines deep learning, IoT, and web technologies to detect green mold disease in oyster mushrooms. The methodology involves collecting a dataset of 2,400 images (1,200 infected and 1,200 uninfected mushroom bags), followed by preprocessing using data augmentation techniques such as shear, zoom, rotation, and horizontal flips to enhance model generalization and mitigate overfitting. Three CNN architectures— DenseNet201, ResNet50, and InceptionV3—were trained and evaluated using Keras with TensorFlow

2.17.1 in Google Colaboratory. The best-performing model, DenseNet201, achieved the highest accuracy of 92.50%, precision of 98.73%, and F1-score of 91.99%, significantly outperforming ResNet50 and InceptionV3, which had accuracies around 52.33% and 50.50% respectively.

The paper titled "Automated Disease Detection in Oyster Mushroom Cultivation Using Deep Learning Technique" Shilpashree P S E&CE Siddaganga Institute of Technology Tumkur, India, Chandru V E&CE Siddaganga Institute of Technology Tumkur, Shrishail Lagali E&CE Siddaganga Institute of Technology Tumkur,Ramesh G N E&CE Siddaganga Institute of TechnologyTumkur, Chetan D E&CE Siddaganga Institute of Technology Tumkur, India the study proposes an automated, real-time image-based disease detection system for oyster mushroom cultivation using the YOLOv5 object detection model. The methodology includes collecting a dataset of 1,100 labelled images (450 healthy and 650 diseased) from online sources and local mushroom farms. Images were pre-processed through augmentation techniques such as vertical flipping, rotation, brightness adjustment, and noise addition to improve model generalization. The YOLOv5 model was trained using this enhanced dataset to classify mushrooms as either healthy or diseased in real-time.The results demonstrated high performance: for diseased mushrooms, the model achieved **94% precision**, **93% recall**, and an **F1-score of 84%**; for healthy mushrooms, it achieved **88% precision**, **85% recall**,

and an **F1-score of 86%**. The overall classification accuracy was around **90%**. The model's high Area Under the Curve (AUC) and effective separation of classes in PCA visualization confirmed its strong discriminative capability. This deep learning approach, using YOLOv5, proves to be an efficient and scalable solution for early fungal disease detection, reducing dependency on manual inspections and supporting sustainable and productive mushroom farming.

4. Key discoveries of the review

The surveyed studies highlight the effectiveness of combining IoT and AI in smart mushroom cultivation. Guragain et al. achieved a 49% yield increase and 98.33% disease detection accuracy using a deep learning–driven IoT system. Al-Talib et al.'s low-cost ESP32-based kit reduced growth time and boosted yield, while Singh et al. showcased an automated Raspberry Pi system that minimized manual labor. For disease detection, Random Forest achieved 82% accuracy (Rakesh Kumar et al.), DenseNet201 reached 92.5% accuracy and 98.73% precision (Nuankaew et al.), and YOLOv5 offered ~90% accuracy in real-time classification (Shilpashree et al.). Image augmentation and real-time monitoring proved vital for accuracy and responsiveness. Despite challenges like internet dependency and limited datasets, these technologies show strong potential for scalable, sustainable, and efficient mushroom farming.

Table 1 Comparsion of IoT and machine learning approaches for mushroom cultivation and disease detection

Author, Title	Methodology+	Results	Limitations and Recommendations
A low cost Centralized IoT Ecosystem for Enhancing Oyster Mushroom Cultivation, Deepesh Prakash Guragain, Bijaya Shrestha, Iswor Bajracharya. 2024	Random Forest and Multiclass SVM using GLCM-based feature extraction Feature Extraction Accuracy: Random Forest 82%, MSVM 76%	A feature extraction accuracy of about 99.8%.	-The system depends on stable internet and electricity, which may be lacking in rural areas. -It was only tested on oyster mushrooms. -Enable offline features for low-connectivity areas. -Use predictive tools to estimate future yields.
IoT Based Smart Mushroom Growing Kit", Ammar A.M. Al-Talib, Cynthia Kuan Jing Ting, Noor Idayu Mohd Tahir, Ain Atiqa Binti Mustafa, and Tan Yong Hui. 2024	ESP32-based IoT system with sensors for temp, humidity, CO_2, water level; real-time monitoring via Blynk app	Reduced growth cycle from 8 to 5 days; yield improved from 49g to 60g; sensor error < 6%	Designed for small-scale use; future improvements can include AI integration for predictive insights
Smart Mushroom Cultivation using IoT" Sampada Singh, Simran, Sneha Anand, and Sushma S J .2020	Raspberry Pi + ESP8266 network; sensor- based automation; Django web dashboard; conveyor belt for hygiene	Real-time data every 15 sec; automated irrigation; efficient cultivation	More testing needed in large-scale farms; AI integration could improve disease prediction
Mushroom Disease Detection and Classification Using Machine Learning Techniques", Rakesh Kumar Y, Dr. V. Chandrashekar, and Navya Vemula. 2024	Image preprocessing + GLCM for feature extraction; Random Forest and MSVM classifiers	RF: 82% accuracy; MSVM: 76% accuracy	Limited to five diseases; further feature extraction methods recommended for improvement
Harnessing AI for Agriculture:Oyster Mushroom Disease Detection with IoT and Web	Deep learning (DenseNet201, ResNet50, InceptionV3) + IoT + Flask- based web system	DenseNet201: 92.5% accuracy, 98.73%	Small dataset; system depends on fixed camera angle; computational complexity may hinder deployment

Application on Growing Bags Using Deep Learning", Wongpanya S.Nuankaew, Phacharapol Sombutthai, Watchrapong Monkhuan, Thapanapong Sararat, Pratya Nuankaew		precision, 91.99% F1-score	
Automated Disease Detection in Oyster Mushroom Cultivation Using Deep Learning Technique	YOLOv5 model with image augmentation; 1,100 labeled images; PCA and ROC analysis for evaluation	Precision: 94% (diseased), 88% (healthy); Accuracy ~90%; High AUC and class separation	Some false positives/negatives; further dataset expansion and model optimization needed for real-world use

Table 2 Comparison Table with Different Methods and Accuracy.

SL NO	Methods	Accuracy(%)
1.	Deep Learning + IoT Ecosystem	98.33% accuracy
2.	Blynk IoT platform	60g vs 49g yield
3.	Django dashboard	Real-time updates every 15 sec
4.	RF & MSVM with GLCM features	RF: 82%, MSVM: 76%
5.	DenseNet201, ResNet50, InceptionV3 (CNN)	DenseNet201: 92.5%, 98.73% precision
6.	YOLOv5 object detection	~90% overall accuracy, F1-score: 84–86%

5. Conclusion

The survey shows that integrating IoT and AI in mushroom cultivation significantly improves yield, disease detection, and automation. Deep learning models like DenseNet201 and YOLOv5 achieved high accuracy (up to 98.33%) in identifying infections. IoT setups using Raspberry Pi, ESP32, and sensors helped regulate growth parameters through real-time sensing and automation. Platforms like Blynk and Django enabled remote access and control, benefiting small-scale and urban farmers.While Random Forest and MSVM models were simpler, they had lower accuracy (82% and 76%). Limitations include small datasets, camera dependency, and reliance on stable internet. Future work should focus on scalability, offline access, and predictive analytics. Overall, smart mushroom systems offer a cost- effective, efficient, and scalable solution for modern agriculture. The integration of IoT and AI not only reduces manual labor but also ensures timely interventions, enhancing both crop quality and consistency. These systems allow for precise control over environmental parameters, which is crucial for sensitive crops like mushrooms. Additionally, the incorporation of image-based disease detection minimizes crop loss by enabling early identification and response. With further improvements in data collection and connectivity, these technologies hold strong potential for transforming traditional farming into a more intelligent and sustainable practice.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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