Journal of Computing & Biomedical Informatics
ISSN: 2710 - 1606
Volume 08 Issue 01
2024

Research Article
https://doi.org/10.56979/801/2024

Automated Indoor Plant Health and Pest Control System Leveraging Frontier Technologies for Enhanced Agriculture

Ashar Ahmed[1*], Muhammad Anus[1], Ali Saqlain[1], Waqas Jan[1], and Syed Muhammad Atif[1]

[1]College of Computing & Software Engineering, ZUFESTM, Karachi, Pakistan.
Corresponding Author: Ashar Ahmed. Email: asharahmedkhan49@gmail.com

Received: April 29, 2024 **Accepted:** September 29, 2024

Abstract: The rapid advancement in artificial intelligence and robotics has revolutionized the field of agriculture, particularly indoor farming. This paper presents an innovative solution for enhancing plant health and pest control in indoor farming environments using AI. The system employs a combination of cameras, robotics, and AI algorithms to monitor, analyse, and manage plant health, disease detection, and pest control. This paper introduces an automated system that leverages artificial intelligence and robotics to address these challenges. The purpose is to enhance plant health, identify diseases, and provide automated pest control, thus improving indoor farming outcomes. The system employs a network of cameras moved by a robotic mechanism to capture plant images. AI algorithms analyse these images to determine plant health and identify specific diseases. Automated watering is triggered when soil moisture falls below 45%. Thermal cameras detect pests, prompting automated spray treatments. A web application records and displays plant health, watering schedules, temperature data, pest control percentages, and offers recommendations for timely interventions. It indicates that the system effectively maintains and enhances plant health, detects diseases, and controls pests, thereby increasing the yield and quality of indoor farming produce. The significance of this system lies in its potential to optimize indoor farming, reduce the need for human intervention, and lower the environmental impact of pest control methods. It offers a cost-effective, efficient, sustainable solution for the emerging field of indoor farming.

Keywords: Robotics Mechanism; Esp32cam; Indoor Farming and Planting; Pest Control; AI algorithm.

1. Introduction

An Automated Plant Health Pest Control System is a cutting-edge agricultural technology that integrates sensors, actuators, and data analysis to optimize the well-being of crops and protect them from pests and diseases. By leveraging real-time data, this system enables farmers to monitor environmental conditions and plant health remotely through a user-friendly web application. It offers automated responses to factors like soil moisture, temperature, and pest outbreaks, ensuring timely interventions to maximize crop yields while minimizing the need for chemical pesticides. This innovative solution represents a sustainable and efficient approach to modern agriculture, contributing to improved crop management and overall food security.

2. Purpose

The purpose of an automated plant health and pest control system for indoor planting is to create a controlled and optimal environment for indoor plants, enhancing their growth, health, and overall well-being.
2.1. Optimized Growth Conditions

The system provides an environment where various factors like light, temperature, humidity, and nutrient levels are precisely controlled to meet the specific needs of different plant species. This optimization can lead to faster growth and healthier plants.

2.2. Consistent Watering:

Automated watering ensures that plants receive the right amount of water at the right time, preventing both over-watering and under-watering, which can stress or damage plants.

2.3. Monitoring and Feedback:

The system continually monitors environmental parameters and plant health, providing real-time data and feedback. This information is invaluable for plant caregivers, enabling them to make informed decisions and promptly address any issues.

Pest and Disease Prevention: The system can incorporate sensors and mechanisms for early detection and prevention of pests and diseases. It can, for example, trigger the release of beneficial insects or apply organic pest control measures when issues are detected.

2.4. Energy Efficiency:

Indoor plant health systems are often designed to be energy-efficient by using efficient LED grow lights and heating/cooling systems, saving on energy costs.

2.5. Labor and Time Savings:

Automated systems reduce the need for manual care and intervention. This is particularly beneficial for those who may not have the time or expertise for intensive plant care.

2.6. Year-Round Gardening:

Indoor systems enable year-round gardening, regardless of external weather conditions. This is advantageous for growing plants that wouldn't survive outdoors in certain climates.

2.7. Data-Driven Decisions:

The system collects data over time, allowing plant caregivers to make data-driven decisions, such as adjusting light cycles, nutrient levels, or humidity to optimize plant growth.

2.8. Remote Monitoring and Control:

Many systems can be controlled remotely through smartphones or computers. This means you can check on your plants and make adjustments even when you're away from home.

3. Methodology

3.1. Plant Detection

we source a dataset from Kaggle and annotate it on rob flow and used augmentation and prepossessing techniques to make the datasets more effective. we used three disease Bacterial Spot, Black Rot and Scab. Datasets splits 80% of training 10% of valid and testing. Model is trained it on yolov8 custom model. we use 100 epochs to train model with picture size of 640 and batch size 16. It set up robotic mechanism which will move in front of every plant will click pictures from esp32 camera board. image separation is also implemented through OpenCV in esp32 cam board. Web application use model to detect and identify diseases in every plant. The esp32 cam board is programmed to control the robot mechanism in a strategic manner. The robot follows a predefined movement trajectory and stops at each plant for 5 seconds to capture a clear and Semantic segmented image using the embedded ESP32-CAM board. This process enables the collection of plant images for subsequent analysis and monitoring purposes. This integration of the ESP32-CAM board with the robotic mechanism allows for efficient and systematic data acquisition, which is crucial for comprehensive plant analysis and monitoring.

3.2. Pest Detection

The AMG8833 captures thermal data as a grid of temperature values. You will need to collect this data continuously. You can interface with the sensor using an Arduino and collect temperature readings from the grid.it need to establish a baseline temperature for the healthy plant.

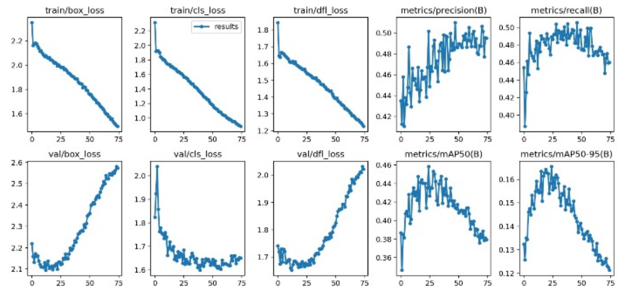

Figure 1. Epochs Training and validation

This can serve as a reference point. When an insect comes into the field of view, it will generate a heat signature different from that of the plant. You can set temperature thresholds to trigger an alert to Arduino and start spraying pesticide spray when a temperature anomaly is detected.

Pesticides can have different effects on plants. Some may cause localized heating, while others may lead to cooling in specific areas. Monitor the temperature changes in the plant canopy and look for anomalies that might indicate pesticide damage.

3.3. Watering System

Automated watering system that adjusts watering based on temperature involves incorporating a temperature sensor into your setup. This sensor measures the ambient temperature, which can be crucial for plant care, as plants' water requirements often vary with temperature. In your Arduino code, you can read temperature data from this sensor and make watering decisions based on both soil moisture and temperature. Arduino continuously monitors the soil moisture level using a soil moisture sensor and the ambient temperature using

A temperature sensor as Shown in fig 2. You set specific thresholds for both moisture and temperature based on the needs of your plants. If the soil moisture drops below a certain threshold and the temperature is within the desired range, the system activates the water pump to deliver water to the plants. This ensures that the plants receive water when both moisture and temperature conditions are appropriate for their growth. By integrating temperature data into the decision-making process, your automated watering system becomes more sophisticated, allowing it to adapt to changing environmental conditions. This can help ensure that your plants receive the right amount of water at the right time, which is essential for their health and growth. You can fine-tune the moisture and temperature thresholds based on your plant's specific requirements and observe how they respond to the automated system to achieve the best results.

Figure 2. Watering System

3.4. System Architecture

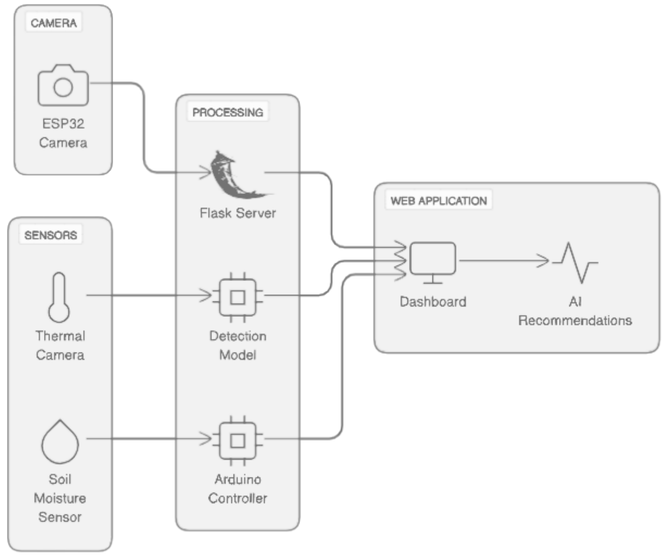

Figure 3. Architecture system

4. Results

4.1. Disease Detection

Post-segmentation, the segmented images are fed into separate modules responsible for disease and pest detection. The Disease Detection Model and Pest Detection Model individually analyse these segmented images, employing machine learning or AI algorithms to identify diseases and pests within the plant images, respectively. Both models provide detection results based on their analysis of the segmented regions.

This workflow ensures a systematic process of capturing plant images, transferring them for analysis, segmenting the images, and subsequently employing specialized models to detect diseases culminating in actionable results for plant health assessment as shown in Fig 4

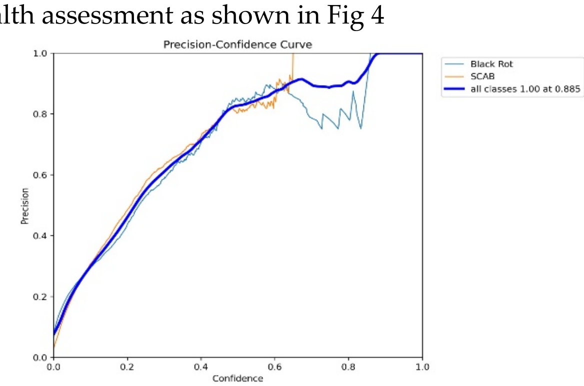

Figure 4. Precision and Confidence Curve

Figure 5. Semantic segmented image and Detections

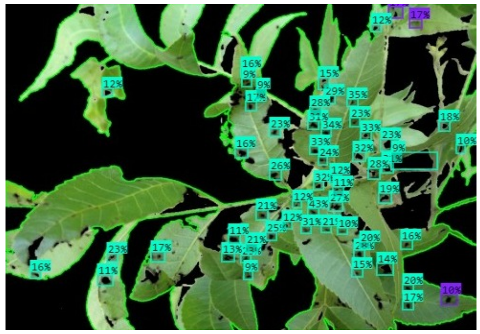

Figure 6. Disease detection

4.2. Pest Detection

Pests can cause localized changes in temperature due to their metabolic activity, which can be detected by thermal cameras. For instance, clusters of pests might generate slightly higher temperatures compared to the surrounding healthy areas. Thermal cameras create a visual representation of temperature variations in the observed area. Pests can sometimes create hotspots or cooler spots on plants, which might be distinguishable in the thermal images as shown Fig 7.

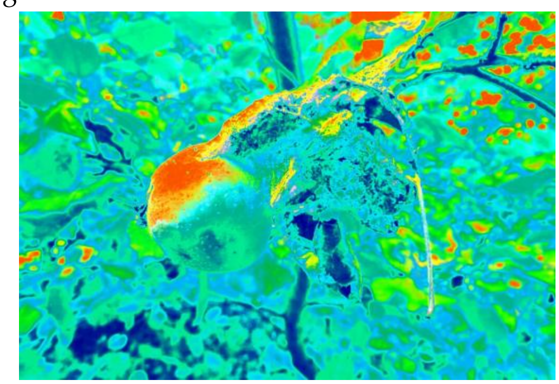

Figure 7. Pest Detection

4.3. Automated Watering

The automated watering system integrates a Soil Moisture Sensor, Arduino board, and a Water Pump to ensure precise and timely watering based on soil moisture levels. Functioning autonomously, the Soil Moisture Sensor continually measures soil moisture content. This data is relayed to the Arduino board, which compares the current moisture level against a predefined threshold, typically set at 45%. When the measured moisture falls below this threshold, signalling dryness, the Arduino triggers the Water Pump. Activating the pump, it dispenses water to the plants until the soil moisture rises above the threshold, ensuring that watering occurs only when necessary.

4.4. Project Prototype

Figure 8. Prototype

4.5. Web Application

In web Application you can get every detail information about your plant. As shown in figure 9

Figure 9. Web application Dashboard

5. Conclusion

In conclusion, the development and implementation of the plant monitoring, disease detection, and automated watering system have resulted in a comprehensive solution aimed at enhancing agricultural management practices. Through the integration of hardware components, including the ESP32 module for image acquisition and an Arduino Uno for automated watering control, coupled with sophisticated software modules for image processing, disease detection, and a user-friendly web interface, the project achieved several significant milestones. The system exhibited commendable accuracy in disease and pest detection, leveraging machine learning algorithms and semantic segmentation techniques. This precision, coupled with the ability to trigger automated watering based on soil moisture readings, presents a proactive approach to plant care, ensuring timely intervention when anomalies are detected. Additionally, the web application interface facilitated easy visualization and interpretation of the detection results, enhancing user accessibility and decision-making. However, while the project showcases promising outcomes, several areas merit further exploration and refinement. Addressing limitations such as hardware constraints, improving model accuracy, scalability, and ensuring robustness under varying environmental conditions stand as crucial considerations for future iterations. The project underscores the significance of technology in agriculture, offering a glimpse into the potential advancements that integrated systems bring to efficient plant care. Moving forward, continual iterations and enhancements will refine this system, contributing to more sustainable and effective agricultural practices, thereby fortifying our efforts towards ensuring global food security. This project serves as a foundation for further innovation, highlighting the intersection of technology and agriculture, and sets the stage for ongoing advancements in automated plant monitoring and care.

References

1. A. Hassan, Siah. b Sheng, W. Shah, N. Bahaman, "An Automated Irrigation System Using Arduino Microcontroller" Malaysia: Research Gate, December (2018)
2. Safwan Assaf Hamoodi, Ali Nathim, Ghanim M Haydar, Ghanim Kaplan "Automated Irrigation System Based On Soil Moisture Using Arduino Board" Iraq: Bulletin of Electrical Engineering and Informatics, February (2020)
3. Anneketh Vij et al. "IoT and Machine Learning Approaches for Automation of Farm Irrigation System" India: Science Direct Conference Paper, November (2020)
4. Gomathy Nayagam, B. Vijayalakshmi and K. Somasundaram "Control of pests and diseases in plants using IOT Technology" India: Science Direct Journal, February (2023)
5. Abdul Razak, Muhammad Hafiz Isyraf "Remote Irrigation Monitoring for Smart Greenhouse" Turkey: UTPEDIA, September (2021)
6. Mr. M. Gopi Krishna and Ms. K. Swetha "An IoT Instrumented Smart Irrigation System Using Raspberry Pi" Turkey: Turkish Online Journal of Qualitative Inquiry, July (2021)
7. Imrus Salehin, M. Noman, Baki Ul-Islam, Israt Jahan and Prodipto Bishnu. "Intelligence agriculture crop-pest detection system using IoT automation system" Bangladesh: Indonesian Journal of Electrical Engineering and Computer Science, November (2021)
8. Arathi Reghukumar and Vaidehi Vijayakumar "Smart Plant Watering System with Cloud Analysis and Plant Health Prediction" India: International Confrence On Recent Trends In Advanced Computing, October (2019)
9. Thinura Nethpiya Ariyaratne, Diyon Yasaswin Vitharana, Don Ranul Deelaka and Maduranga Herath "IoT Smart Plant Monitoring, Watering and Security System" Sri Lanka: Journal of Electrical Engineering and Computer Science, March (2022)
10. Murk Chohan, Adil Khan, Rozina Chohan, Saif Hassan Katpar and Muhammad Saleem Mahar "Plant Disease Detection using Deep Learning" Pakistan:International Journal of Recent Technology and Engineering, May (2020)
11. Jayme Garcia Arnal Barbedo "Plant disease identification from individual lesions and spots using deep learning" Brazil: Science Direct, April (2019)
12. Samir Bhattarai, "New Plant Diseases Dataset." India: Kaggle, New Plant Diseases Dataset (kaggle.com), December (2018)
13. Ali, S., Rehman, S. U., Imran, A., Adeem, G., Iqbal, Z., & Kim, K.-I. (2022). Comparative evaluation of AI-based techniques for zero-day attacks detection. Electronics, 11(23), 3934. MDPI.
14. Bhatti, D. S., Saleem, S., Imran, A., Lim, B. H., & Kim, K.-I. (2022). Detection and isolation of wormhole nodes in wireless ad hoc networks.