

Crop Defect Detection Robot with Automatic Pesticide Spraying System

Prof. Karuna Mahajan¹, Mr. Tejas Bijewar², Miss. Rutuja Dhope³, Mr. Aditya Gaikwad⁴,

Mr. Harshad Hebule⁵

¹Prof. Karuna Mahajan, Zeal College of Engineering and Research, Pune

²Tejas Bijewar, Zeal College of Engineering and Research, Pune

³Rutuja Dhope, Zeal College of Engineering and Research, Pune

⁴Aditya Gaikwad, Zeal College of Engineering and Research, Pune

⁵Harshad Hebule, Zeal College of Engineering and Research, Pune

Abstract

The goal of the research paper "Crop Defect Detection Robot with Automatic Pesticide Spraying System" is to create an intelligent agricultural robot for smart farming applications by combining image processing, artificial intelligence, and the Internet of Things. Manual labor, excessive chemical use, and direct human exposure to hazardous materials are all part of traditional pesticide spraying techniques. These traditional methods are labor-intensive, ineffective, and frequently cause environmental harm because of their uncontrolled spraying. An ESP32-CAM module serves as the central vision unit in the suggested system, which takes real-time pictures of crop leaves. It detects crop diseases such as fungal infections, brown spotting, or yellow leaves through the use of image processing techniques based on artificial intelligence. Upon detecting any defect in the crops, the robot automatically triggers its pesticide spraying technique, which is applied selectively to the infected part. Farmers can check on the health of their crops and the work being done by the robot via a mobile or web application that connects with the system using its Wi-Fi capabilities, due to the incorporation of the IoT platform. With this innovative approach, costs are reduced, less manual labor is required, less pesticide is used, and sustainable practices are encouraged. The paper demonstrates how modern automation is revolutionizing traditional agriculture through smart precision agriculture utilizing low-cost embedded devices, artificial intelligence, and IoT technologies.

Keywords: Internet of Things (IoT), ESP32-CAM, Smart Agriculture, Image Processing, Artificial Intelligence, Crop Disease Detection, Automatic Pesticide Spraying, Sustainable Farming.

1. INTRODUCTION

The agriculture sector plays an important role in the economy; however, traditional farming practices still use manpower for checking crop status and spraying pesticides. Despite being healthy or diseased, farmers regularly spray pesticides across all the fields.

This leads to overuse of chemicals, increased costs, environmental contamination, and risks to people's health due to exposure to such substances.

With advancements in IoT and embedded systems, there is a chance to replace the above practice using smart farming technology. The objective of precision farming is to detect any issue within crops and spray pesticides based on the need. A number of farmers, however, lack an automatic and affordable system for detecting diseases among crops. This paper suggests a smart crop defect detection robot that is integrated with an automatic pesticide spraying system in order to address these issues. The system employs AI-based image processing techniques to identify diseases like leaf discoloration and spots after using an ESP32-CAM module to take real-time plant photos. The robot triggers a controlled spraying mechanism that targets the impacted plant specifically when it detects a defect. A Wi-Fi-based dashboard for remote monitoring and control is another benefit of IoT integration. This study shows how integrating robotics, AI, and IoT can improve agricultural output, cut down on chemical waste, and guarantee sustainable crop management.

2. Body of Paper

2.1 Literature Review / Related Work

Screenshot of article Smart agriculture and precision agriculture systems have witnessed tremendous progress with work that has already taken place on AI and IoT in the field of research. Based on image processing and deep learning techniques like CNN many researches is done for plant disease detection. These systems have been reported to perform accurately on such models in a controlled environmental setup.

There are also some IoT based agricultural monitoring systems available for monitoring soil moisture, temperature and humidity. Moreover, autonomous robots and drones have been made for spraying pesticides to lessen manual work and improve working efficiency.

Most existing systems are either purely focused on disease detection with no means of automated spraying or blanket pesticide spraying without defect localization.

So far, there is a gap in the development of an integrated system that should be low cost and should contain all real time image based crop defect detection with automatic targeted pesticides spraying and IoT based monitoring on a single platform for making it compact. In this paper, it is presented a solution to bridge these gaps integrating ESP32-CAM, AI-powered image processing, robotic mobility and cloud monitoring which could help in sustainable and accurate farming.

2.2 Problem Statement

Agriculture is a vital sector directly affecting food production and farmers' livelihoods. Crops disease is just another of the major problems facing farmers in terms of both the quantity and quality of the agricultural output. In most cases, farmers have to identify the disease through physical inspection, and this is neither an easy nor a timely affair. Detection of the pathogen in such a case becomes rather difficult as the signs of diseases are very subtle and at the end, many crops suffer before they are identified. Besides, monitoring a large portion of the agricultural land by farmers becomes rather time-consuming. Also, there may be lack of expert advice on disease diagnosis and treatments.

2.3 Objectives

For designing and developing an intelligent crop disease detecting system based on artificial intelligence technology.

- To capture the pictures of crops and analyse them for any diseases.
- To classify the various kinds of crop diseases.
- To monitor the environment conditions such as temperature, humidity, and moisture content in the soil through sensors.
- To raise relevant alarms or provide necessary recommendations to the farmers regarding crop diseases.
- To reduce the manual efforts needed for monitoring the crops.
- To help the farmers improve crop productivity.

2.4 Methodology

To guarantee effective crop monitoring and automated spraying, the suggested system uses an organized AI and IoT-based methodology.

First, as the robot traverses the field, the ESP32-CAM module takes live pictures of the plant leaves. In order to identify symptoms like yellowing, black spots, or odd texture patterns, the captured images are processed using

either embedded AI algorithms or a connected cloud-based model.

During the processing phase, there are:

1. Obtaining images
2. Preprocessing images (colour enhancement and noise reduction)
3. Feature extraction (analysis of colour and texture)
4. AI-model-based classification

The microcontroller unit receives a signal if the system detects an infected plant. The motor driver circuit, which regulates the pesticide pump and spraying nozzle, is then triggered by the microcontroller.

To ensure that the least amount of chemicals are used, the robot only sprays pesticide on the identified infected area. The cloud-based database is continually updated by the IoT system with information about the location of the field, the spraying process, and the health condition of the plants. This information can be accessed through a web portal or a mobile application. An accurate, automatic, and intelligent crop disease management process will surely result from this approach.

2.5 Implementation

The suggested Smart IoT-based Parking System is a combination of a number of hardware components collaborating to provide an efficient parking management system.

1. Camera Module Camera modules are used to capture live pictures of crop leaves and plants. This information is then processed with the help of image processing techniques and deep learning models to determine any diseases or deformities in the crops. The camera plays an essential role in detecting early signs which cannot be easily identified by the farmers themselves.
2. Microcontroller (Arduino / Raspberry Pi / ESP32) A microcontroller functions as the brain of the system. It performs tasks like collecting information from sensors, controlling various hardware components, and communicating with the disease identification model.
3. Temperature and Humidity Sensor The temperature and humidity sensors keep track of the environment in which the crops are planted. Both humidity and temperature play a crucial role in crop cultivation because almost all plant diseases require a particular range of humidity and temperature to thrive.
4. Soil Moisture Sensor Soil moisture sensors are used to determine the moisture content in the soil. This is useful in determining whether the crops are receiving sufficient water. Incorrect moisture content in the soil might lead to stress in plants, which would favor disease development.
5. IoT Communication Module (Wi-Fi/GSM Module) IoT communication modules facilitate the transmission

of real-time information on crops. This helps in remote monitoring of crops and disease alert systems under environmental threats.

2.6 Results and Discussion

PCB designing:

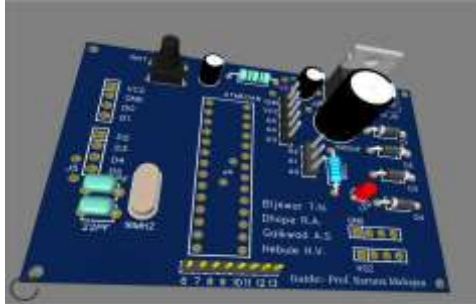


Fig 1: PCB

A Printed Circuit Board (PCB) serves as the foundation of an electronic system, mechanically supporting and electrically connecting various components using conductive copper tracks, pads, and other features etched from copper sheets laminated onto a non-conductive substrate. In this project, a custom PCB design was done where the ESP32-CAM module, motor driver, and power supply were combined into one board. The design ensures efficient signals distribution, noise elimination, and effective power distribution. SMD component use played a big role in ensuring a compact circuitry design and efficient circuit operation.

System Implementation Output:

The recommended Crop-I model was used for testing and training for crop condition detection through the Edge Impulse platform. The trained model was based on an image-based object detection pipeline that had four output classes which include coriander bacteria, curry tree caterpillar, good coriander, and good curry tree. The trained model achieved a validation F1-score of 100%, indicating perfect precision and recall in classification. According to the confusion matrix, the trained model did not mis-classify any images of all the four classes, thus showing that the model could easily differentiate the good and bad crop samples.

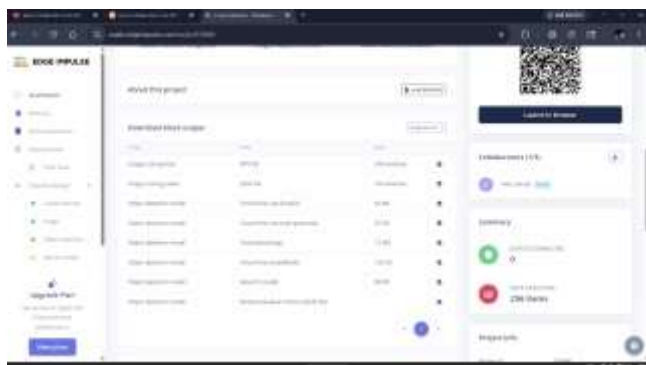


Fig.2 Impulse Design

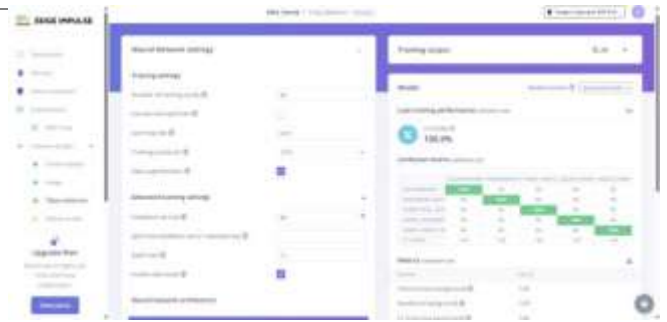


Fig.3 Model Training Results

Also, measures of performance like precision and recall were both equal to 1.00, which validates the strength of the model. It was effectively optimized with int8 quantization, which also makes it smaller without sacrificing accuracy, enabling it to be deployed to edge devices such as the ESP32-based camera module.

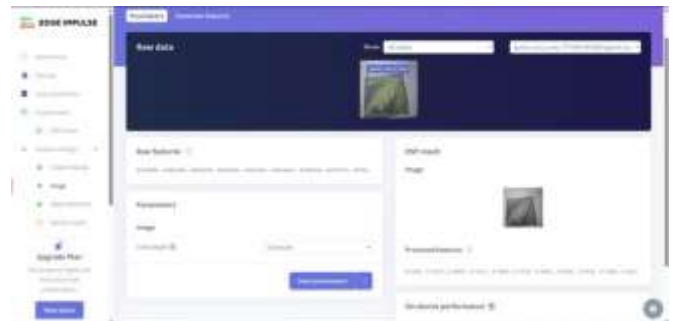


Fig.4 Raw data + DSP / Feature extraction

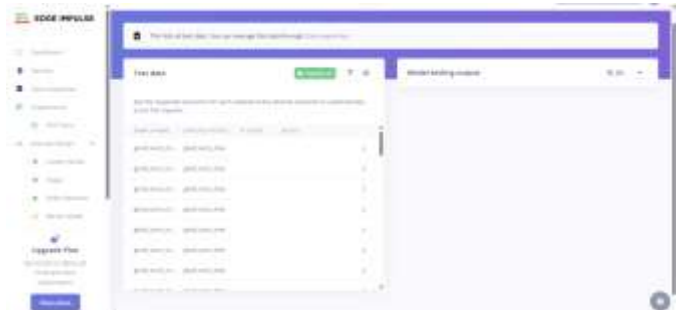


Fig.5 Classification / Testing screen

Fig -1

2.7 System Architecture

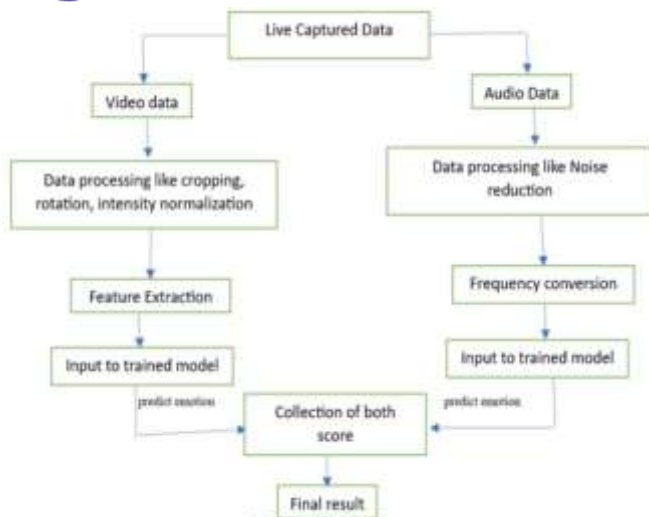


Fig -2: Architecture

2.8 Limitations

- Analysis performance may vary under poor lighting conditions.
- Continuous internet connectivity and high processing power are required for optimal functioning.

2.9 Future Scope

A solid basis for cutting-edge smart farming solutions is provided by the suggested Crop Defect Detection Robot. Potential improvements in the future could include:

- 1.Using CNN and other deep learning models to increase the accuracy of disease detection
- 2.Using GPS to map contaminated areas
- 3.An energy-efficient solar-powered system
- 4.The ability to classify multiple diseases
- 5.Predictive spraying integration with weather forecasting APIs
- 6.Implementing edge computing to speed up on-device processing

7.Expansion using drones for large-scale agriculture
 Agricultural fields can become intelligent farming ecosystems through large-scale deployment with centralized data analytics, enhancing yield quality and guaranteeing sustainable farming methods.



Fig.7 Future Scope

3. CONCLUSIONS

However, the Crop Defect Detection Robot with Automated Pesticide Spraying System differs from conventional agriculture through its application of intelligent technologies, including artificial intelligence (AI), to monitor crops and spray chemicals where necessary.

The technology is based on the ESP32-CAM, advanced image processing, and internet of things (IoT) capabilities that make it possible to detect plant disease rapidly and spray chemicals accurately.

Such an approach enables reduced pesticide usage, enhances safety for farm workers, results in cost savings, and promotes sustainable farming practices.

Moreover, it contributes to increased efficiency, improved management of plants' wellbeing, and is a vital component of precision agriculture.

Further development includes improved deep learning, GPS mapping, solar energy, and compatibility with various crop species and large farms.

4.ACKNOWLEDGEMENT

We would like to sincerely thank Prof. Karuna Mahajan for her valuable guidance, continuous support, and encouragement throughout the entire project. We also extend our gratitude to the Department of Electronics and Telecommunication Engineering at Zeal College of Engineering and Research, Pune, for providing the necessary resources and facilities that helped us complete this work successfully. We are deeply grateful to our teachers for their constant motivation, cooperation, and unwavering support during the development of this project.

5.REFERENCES

- [1] S. Sharma, R. Patel, and M. Verma, "Automatic Classification of Coffee Bean Defects in Real-Time Using Deep Learning Approach," IEEE Access / International Journal of Advanced Computer Science, 2024.
- [2] J. Müller, P. Schmidt, and L. Wagner, "Determination of Mechanical Damage by Image Processing," Computers and Electronics in Agriculture, 2022.
- [3] Y. Wang, H. Liu, and K. Zhang, "A Machine Vision System for Detection of Diseases in Crops with YOLO Models," International Journal of Agricultural and Biological Engineering, 2019.
- [4] R. Kumar, S. Singh, and A. Sharma, "An Autonomous Sprayer Robot for Field Crop Spraying Using BP Neural Network," International Journal of Intelligent Agricultural Systems, 2021.
- [5] T. Chen, L. Zhao, and M. Huang, "Fruit Trees Pest Detection from Embedded Drones Using Deep Learning," IEEE Access / International Journal of Smart Agriculture, 2021.