Lightweight Object Detection Model for False Smut Detection in Rice Leaf with Eigen-Cam Interpretability

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Abstract - Agriculture plays a vital role in many economies, with rice being a key staple crop; however, diseases such as false smut significantly affect yield and quality. This paper proposes a cost-effective and real-time disease detection system using a lightweight YOLOv8 model deployed on a Raspberry Pi. The system captures rice leaf images through a camera module and accurately identifies infected regions. Additionally, IoT-based sensors are used to monitor soil moisture and pH levels, and the collected data is transmitted to a cloud platform for analysis. Based on detection results and environmental conditions, automated actions such as activating a water pump or sprayer are performed using a relay module. The proposed system reduces manual effort, enables early disease detection, and improves overall crop productivity.

Key Words: Rice Disease Detection, False Smut Disease, YOLOv8, Raspberry Pi, Smart Agriculture, Crop Health Monitoring.

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1. INTRODUCTION

Rice is a vital staple crop, particularly in countries like India, but its productivity is significantly affected by diseases such as false smut, which reduces yield and grain quality. [1]Traditional disease detection methods are manual, time-consuming, and often inaccurate, while laboratory approaches are costly and unsuitable for real-time use. [2]To address these challenges, this paper proposes an intelligent system that combines a lightweight YOLO-based deep learning model for real-time disease detection with Eigen-CAM for visual interpretability. [3]The system is implemented on a Raspberry Pi, which integrates a camera module for image capture and sensors to monitor environmental factors such as temperature, soil moisture, and pH. [4]The collected data is analyzed to support timely decision-making, while relay-based automation enables control of irrigation and related processes. This approach provides a cost-effective, scalable, and efficient solution for smart agriculture, improving crop health monitoring, reducing manual effort, and enhancing overall productivity.

2. LITERATURE SURVEY

S. Tan et al. [5] proposed a deep learning-based system for rice disease detection using advanced convolutional neural networks, achieving high accuracy under field conditions. H. Lu et al. [6] developed an image-based rice disease classification method that improves early detection and reduces dependency on manual inspection. J. Yu et al. [7] introduced a crop monitoring system integrating image processing techniques, enabling efficient identification of disease-affected regions in plants.Redmon et al. [8] presented the YOLO (You Only Look Once) algorithm for real-time object detection, providing high speed and accuracy suitable for agricultural applications. Jocher et al. [9] further improved YOLOv8, making it more efficient and lightweight for deployment on embedded systems like Raspberry Pi.

Various researchers have explored IoT-based smart agriculture systems due to their ability to monitor environmental conditions in real time. Several studies [10] demonstrated the integration of soil moisture, temperature, and pH sensors for continuous crop monitoring.

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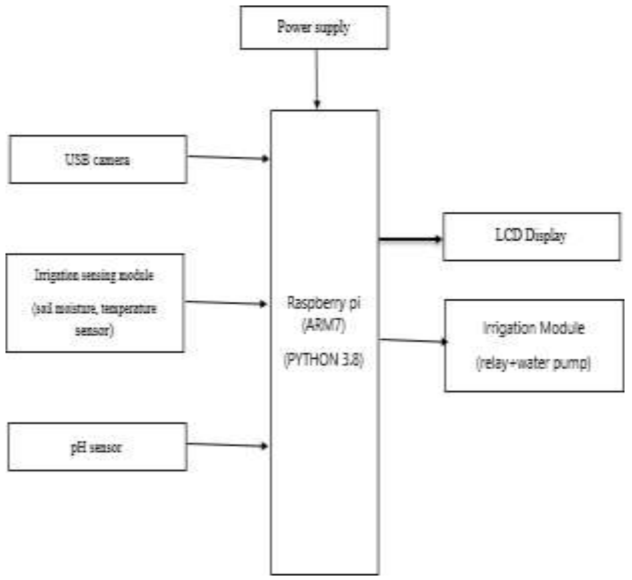
Other works [11] focused on combining deep learning models with IoT platforms to provide intelligent decision-making for disease control and irrigation management.Recent advancements [12,13]have emphasized integrating disease detection, environmental monitoring, and automation into a single system. These approaches improve crop productivity and reduce manual effort; however, challenges such as computational



complexity and real-time performance on low-power devices still remain.

3. EXISTING SYSTEM

Over the years, several approaches have been proposed for plant disease detection. Traditional methods primarily rely on manual inspection, which is inefficient and prone to errors. With the advancement of digital image processing, techniques such as color segmentation, edge detection, and texture analysis have been used to identify diseased regions in plant leaves.[14]Machine learning approaches, including Support Vector Machines (SVM) and Decision Trees, have been applied for classification tasks. [15]However, these methods require manual feature extraction and are limited in handling complex patterns

Limitations: Existing methods are slow, less accurate, and depend on manual inspection. They require high computation, are affected by environmental conditions, lack interpretability, and do not support real-time monitoring or automation in agriculture.

4. PROPOSED SYSTEM

The proposed system is an intelligent and automated solution for detecting False Smut disease in rice crops using deep learning and IoT technologies. It uses a lightweight YOLOv8 object detection model to identify diseased regions from images captured by a camera. The system is designed to run on a Raspberry Pi, which acts as the central processing unit, making it cost-effective and suitable for real-time field applications. To improve transparency, Eigen-CAM is integrated to generate heatmaps that highlight the infected areas, helping users understand how the model makes decisions.

In addition to image-based detection, the system incorporates sensors such as soil moisture, temperature, and pH sensors to continuously monitor environmental conditions. These parameters play an important role in disease development and crop health. The Raspberry Pi collects and processes both image and sensor data to make intelligent decisions. Based on the analysis, the system provides suitable recommendations and can automatically control devices like water pumps using relay modules.

An LCD display is used to show real-time information, including disease status and sensor readings. Overall, this system reduces manual effort, improves detection accuracy, enables early disease identification, and supports smart [3]G. Jocher et al., “YOLOv8: State-of-the-Art Object Detection Model,” *Ultralytics*, 2023.

Fig.1: Block Diagram of Lightweight Object Detection Model for False Smut Detection in Rice Leaf with Eigen-CAM Interpretability

5. IMPLEMENTATION AND RESULTS

The Fig.2 shows the hardware implementation of the proposed smart agriculture system for rice disease detection and environmental monitoring. The setup is centered around a Raspberry Pi, which acts as the main processing unit. A camera module is connected to capture real-time images of rice leaves for disease detection using

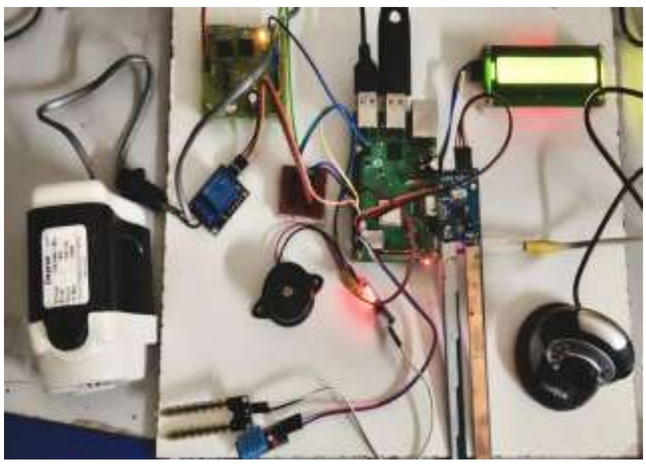


Fig 2 :Hardware set up of proposed system

a deep learning model. Various sensors, including a soil moisture sensor and a temperature sensor, are integrated

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to continuously monitor field conditions. The collected data is processed by the Raspberry Pi to make intelligent decisions.

The Fig.3 the real-time output of the system in the Python IDE, displaying sensor data such as pH, temperature, humidity, and soil moisture. The system continuously monitors these values and indicates irrigation status using "Water: YES/NO." When low moisture is detected, it generates an alert and automatically activates the water pump

through a relay. This output confirms the system's ability to monitor environmental conditions and perform automated irrigation efficiently.

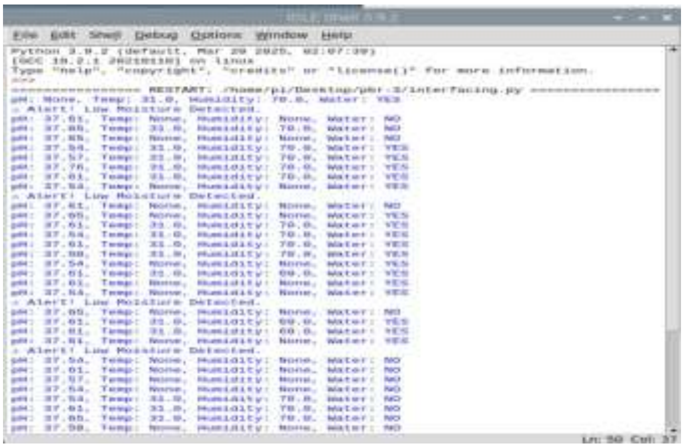

Fig.3: Sensor readings

The Fig 4 illustrates the results of the proposed rice disease detection system using the YOLOv8 model with Eigen-CAM interpretability.

The top-left image shows the original rice panicle affected by False Smut disease. The top-right image represents the detection output, where the infected regions are identified and highlighted with bounding boxes along with confidence scores. The bottom-left image shows the Eigen-CAM heatmap, which visually emphasizes the important regions contributing to the model's prediction, with red areas indicating higher relevance. The bottom-right image presents the corresponding grayscale activation map for further analysis. These results demonstrate the model's ability to accurately detect diseased regions and provide visual explanations, improving transparency and reliability of the system for real-time agricultural applications.

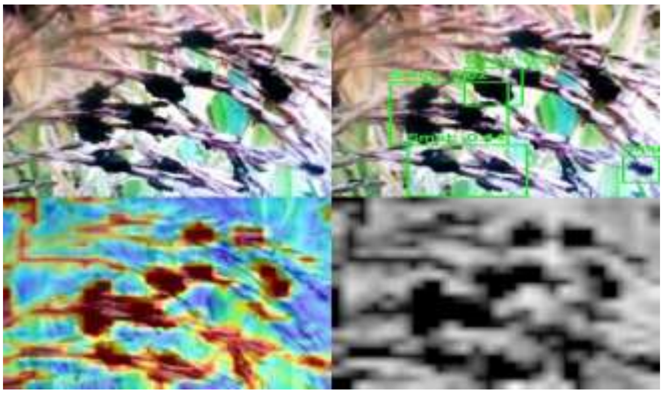

Fig.4: Emergency Alert Email Containing GPS Location

6. DISCUSSION

The proposed project demonstrates an effective approach for smart agriculture by integrating deep learning, IoT, and automation. The YOLOv8 model successfully detects False Smut disease in rice with good accuracy, while Eigen-CAM improves transparency by highlighting affected regions. The use of sensors for temperature, soil moisture, and pH enables real-time environmental monitoring. Automated irrigation through relay control reduces manual effort and ensures efficient water usage. The system is cost-effective and suitable for real-time field deployment using Raspberry Pi. However, performance may vary under different lighting and environmental conditions, indicating scope for further improvement and expansion.

7. CONCLUSION

the proposed system provides an efficient and intelligent solution for early detection of False Smut disease in rice crops. By integrating a lightweight YOLOv8 model with Eigen-CAM, the system achieves accurate detection along with clear visual interpretation. The inclusion of IoT-based sensors enables real-time monitoring of environmental conditions such as soil moisture, temperature, and pH. Automated control using relay modules improves irrigation management and reduces manual effort. The use of Raspberry Pi makes the system cost-effective and suitable for practical deployment. Overall, this project enhances crop health, increases productivity, and supports the development of smart and sustainable agriculture.

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