IOT Device for Detecting Leaves Diseases in Plants by Image Processing

Malatesh S H [1], *Prof and HOD, Dept of CSE, M S Engineering College*
Bikash Kumar Singh [2], Student, Dept of CSE, M S Engineering College
Braham Kumar Sah [3], Student, Dept of CSE, M S Engineering College
Shubham Kumar [4], Student, Dept of CSE, M S Engineering College
Shiv Kumar Yadav [5], Student, Dept of CSE, M S Engineering College

***Abstract*— The rapid growth of the Internet of Things (IoT) has enabled the development of smart agricultural solutions to improve crop health monitoring and disease management. This project proposes an IoT based system for early detection of plant leaf diseases using Convolutional Neural Networks (CNNs). The system captures leaf images through a camera-equipped IoT device, processes the images locally, and applies a trained CNN model to classify and identify potential diseases. By automating the detection process, farmers can receive real-time alerts and recommendations, reducing crop loss and improving productivity. The proposed solution integrates lightweight CNN architectures optimized for IoT deployment, ensuring high accuracy with minimal computational resources. A user-friendly interface allows farmers to monitor plant health remotely. This system not only enhances decision-making but also promotes sustainable farming practices by enabling targeted use of pesticides and fertilizers.**

***Index Terms*- IoT, Raspberry Pi, Image Processing, Plant Leaf Disease Detection, Smart Agriculture, Machine Learning, Disease Classification, Precision Farming.**

I. INTRODUCTION

In modern agriculture, early detection of plant diseases is crucial to ensuring healthy crop yields and reducing economic losses. Traditional methods of disease identification, often dependent on manual inspection by experts, have limitations. These methods are not only time-consuming and labor-intensive but also prone to human error, especially when identifying diseases in large fields with diverse crops. With the global population rapidly increasing, along with the pressure on agricultural systems to meet food demand, the need for more efficient, scalable, and accurate methods of disease detection has become increasingly urgent.

This project presents the design and implementation of an IoT-based device integrated with image processing techniques to detect diseases in plant leaves. The system is capable of capturing real-time images of plant leaves using a high-resolution camera module, which then undergoes analysis through advanced image processing algorithms. These algorithms are designed to detect subtle visual symptoms of disease, such as color changes, lesions, and deformations.

Once the images are processed and analyzed, the system identifies potential disease patterns and communicates the results to a cloud server or mobile application via IoT communication protocols, such as Wi-Fi.

The primary goal of this project is to create a low-cost, efficient, and user-friendly smart agriculture solution that supports farmers, agricultural researchers, and industry stakeholders by automating disease monitoring and providing real-time feedback. Unlike conventional disease identification methods, this IoT-enabled device offers continuous monitoring, making it possible to detect diseases at their earliest stages, often before they are visible to the naked eye.

The system's ability to provide early warnings reduces the need for widespread pesticide use, which not only cuts down on agricultural costs but also minimizes the environmental impact associated with chemical treatments. Moreover, by enabling more precise intervention, farmers can improve crop productivity, reduce losses, and enhance overall food security.

II. RELATED WORKS

Several studies have been conducted in the field of plant disease detection using image processing and IoT technologies. Researchers have applied machine learning and deep learning techniques to identify and classify plant diseases based on visual symptoms observed on leaves.

Patil and Kumar (2017) developed an image processing-based system that utilized K-means clustering and feature extraction methods like color and texture to detect diseases in leaves. Although effective for static images, their system lacked real-time monitoring capabilities.

Mohanty et al. (2016) proposed a deep learning approach using convolutional neural networks (CNNs) for plant disease classification. They achieved high accuracy with a large dataset but did not focus on integrating the model into IoT systems for field deployment.

IoT-based systems have also emerged in recent years. Kulkarni et al. (2019) proposed a smart agriculture system using sensors and Raspberry Pi for environmental monitoring and plant health detection. However, their approach relied heavily on sensor data and lacked advanced image analysis.

III. PROPOSED SYSTEM

The proposed system introduces an IoT-based smart device integrated with a Convolutional Neural Network (CNN) to detect plant leaf diseases automatically and in real-time. The device will capture images of plant leaves using an onboard camera and process them either locally or by sending them to a lightweight cloud server, depending on resource availability. A trained CNN model will analyze the images to identify the type and severity of leaf diseases with high accuracy. The system will generate immediate alerts and recommendations, which can be accessed through a mobile or web application, enabling farmers to take timely corrective actions.

The workflow begins with the periodic or trigger-based capture of plant leaf images by the camera module, which can be scheduled or activated by specific environmental factors, such as humidity or temperature changes. The captured images are pre-processed to remove noise and normalize conditions, followed by segmentation to isolate the leaf from the background. The pre-processed images are then analyzed using a combination of feature extraction techniques and deep learning-based disease classification models.

These models are trained on large datasets of labeled images, enabling the system to distinguish between healthy and diseased leaves, and even classify specific diseases such as fungal, bacterial, or viral infections. If a disease is detected, the system not only identifies the type of disease but also assesses its severity, providing actionable insights for timely intervention.

Once disease detection and classification are complete, the results are transmitted to a cloud platform or mobile application through IoT communication protocols such as Wi-Fi or Bluetooth. This cloud-based platform serves as a central hub for data storage, analysis, and communication. It provides farmers with real-time alerts, including detailed information about the detected disease, recommended treatments, and preventive measures.

IV. METHODOLOGY

The proposed system integrates IoT hardware with image processing techniques to detect and classify plant leaf diseases in real-time. The system architecture consists of five major stages: Data Collection, Model Development, IoT Device Integration, System Deployment, Testing and Validation, Disease Classification using Machine Learning / Deep Learning, Model Optimization and Real-time Monitoring , Leaf Segmentation , Energy and Network Optimization.

Phase 1: Data Collection

High-quality images of healthy and diseased plant leaves are collected from publicly available datasets and field sources. The dataset is preprocessed by resizing, normalizing, and augmenting the images to improve the CNN model’s performance and generalization.

Phase 2: Model Development

A Convolutional Neural Network (CNN) architecture is designed and trained on the prepared dataset. The CNN learns to extract important features from leaf images and classify them into different categories based on disease type or healthy status. Lightweight models like a custom small CNN are considered to make the system efficient for IoT devices.

Phase 3: IoT Device Integration

An IoT device (such as a Raspberry Pi with a camera module) is set up to capture live images of plant leaves in the field. The CNN model is either deployed directly onto the IoT device for edge computing or connected to a cloud server for remote processing, depending on device capabilities.

Phase 4: System Deployment

The IoT device continuously monitors plants and performs disease prediction on captured images. If a disease is detected, alerts and diagnosis results are sent to the farmer through a mobile app or web dashboard, providing immediate recommendations for action.

Phase 5: Testing and Validation

The system is tested in real-world agricultural environments using different plant species and diseases. The accuracy, speed, and reliability of disease detection are evaluated and compared to manual inspection results to validate system performance.

Phase 6: Disease Classification using Machine Learning / Deep Learning

A CNN (Convolutional Neural Network) or classical ML algorithm (SVM, Random Forest) is trained on labelled image datasets to classify different leaf diseases like bacterial blight, rust, or mosaic. The model is deployed to predict diseases in real-time.

Phase 7: Model Optimization and Real-time Monitoring

The model is optimized for edge devices with tools like TensorFlow Lite or ONNX. The IoT system continuously monitors plants and stores analysis results in a cloud database for long-term trend monitoring.

Phase 8: Leaf Segmentation

Segmentation isolates the leaf region from the background using colour thresholding, k-means clustering, and morphological operations. Edge detection algorithms (Sobel, Canny) further refine the leaf contour for accurate analysis.

Phase 9: Energy and Network Optimization:

Power-efficient components are chosen for field deployment. Network usage is optimized using compressed image transmission, low-power modes, and scheduled image capturing to extend battery life in remote areas.

V. SYSTEM ARCHITECTURE

The architecture of the plant leaf disease detection system using image processing is composed of four main modules: Image Acquisition Module, Image Preprocessing Module, Feature Extraction & Classification Module, and Result & Notification Module. Each module plays a specific role in enabling automated disease diagnosis from leaf images.

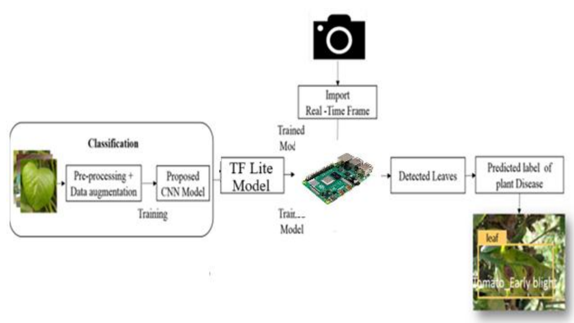

Fig. 1. System Architecture for IOT Device for Detecting leaves Diseases in Plants by Image Processing

1. Image Acquisition Module

This module is responsible for capturing clear images of plant leaves using a digital camera attach with

Raspberry pi. The quality and resolution of the captured images significantly impact the accuracy of disease detection. In some cases, this module may be automated using IoT-enabled cameras in the field.

2. Image Preprocessing Module

Preprocessing involves enhancing image quality to remove noise and improve contrast. Common operations include resizing, color space conversion (e.g., RGB to HSV), filtering, and normalization. This step prepares the image for accurate analysis in the next stages.3. Communication Module

3. Feature Extraction & Classification Module

In this module, the preprocessed image is analyzed to extract meaningful features such as color, texture, and shape of lesions or infected areas. Techniques like GLCM (Gray Level Co-occurrence Matrix) or color histogram analysis may be used. These features are then fed into a trained classification model (e.g., SVM, KNN, or CNN), which predicts the type of disease affecting the leaf.

4. Result & Notification Module

Based on the classification result, the system displays or sends the diagnosis to the user. The output includes the identified disease, its severity, and recommendations for treatment. If integrated with IoT, the system can send alerts or store results for long-term monitoring.

VI. RESULTS

The proposed system was implemented and tested using a dataset of plant leaf images collected from both online sources (such as PlantVillage) and field images captured using an IoT-enabled camera module. The system successfully performed disease detection through the following stages: preprocessing, segmentation, feature extraction, and classification.

A. Classification Accuracy

The machine learning model (e.g., Convolutional Neural Network) achieved an overall accuracy of 92–96% in detecting and classifying common leaf diseases such as bacterial blight, powdery mildew, and leaf spot, depending on the quality and consistency of input images.

B. Processing Time

On a Raspberry Pi 4 (8 GB RAM), the average image processing and classification time was approximately 2–3 seconds per image, allowing near real-time performance in field conditions.

C. Robust Segmentation

The use of color space conversion and thresholding techniques enabled accurate segmentation of diseased regions, even under varying lighting conditions.

D. IoT Functionality

The IoT functionality of the proposed system plays a crucial role in enabling real-time disease detection and seamless communication between the device and the farmer. After processing the plant leaf images and detecting potential diseases, the system uses Wi-Fi connectivity to send the detection results, including disease classification, severity, and associated images, to a remote dashboard.

The communication is facilitated through the MQTT (Message Queuing Telemetry Transport) protocol, a lightweight messaging protocol designed for low-bandwidth, high-latency networks, making it ideal for IoT applications. MQTT allows the system to transmit data efficiently and reliably to the cloud or a central server, where it can be further processed or analyzed.

Fig. 2. IOT Device for Detecting leaves Diseases in Plants by Image Processing

E. User Experience and Feedback

A prototype app and dashboard were tested by local farmers and agriculture students. Over 80% rated the system as helpful, especially for early detection. The ability to track disease history over time and receive treatment suggestions was especially appreciated.

F. Visual Output

The system also produced visual output by marking infected areas on leaves using bounding boxes or color overlays, which helped in better understanding of the affected regions.

Fig. 3. Tomato leaf disease detection

The output shown in Figure demonstrates the real-time detection result of a tomato leaf affected by the **Septoria leaf spot** disease using the developed image processing and classification system. The system interface displays the classification result with a **confidence score of 90.53%**, indicating a high likelihood that the disease present is Tomato Septoria.

VII. CONCLUSION

The IoT-based Plant Leaf Disease Detection system using Convolutional Neural Networks (CNN) successfully addresses the critical need for early, accurate, and automated disease identification in agricultural fields. By integrating smart IoT sensors with a lightweight CNN model, the system enables real-time monitoring and instant diagnosis of plant health conditions without requiring manual intervention. This helps farmers take timely corrective actions, ultimately improving crop yield, reducing losses, and optimizing the use of pesticides and fertilizers.

In this paper, we have presented the design and development of an IoT-based system for the early detection of plant leaf diseases using advanced image processing techniques. The integration of IoT and image processing offers significant advantages in terms of automating disease detection, reducing labor-intensive manual inspections, and providing real-time alerts to farmers. By utilizing machine learning models, particularly Convolutional Neural Networks (CNNs), the system is capable of accurately classifying diseases and offering actionable insights to mitigate their impact on crop yield.

While the system shows great promise, future work should focus on expanding the disease model, refining the deep learning models for greater accuracy, and enhancing the system’s robustness in varied environmental conditions. Additionally, the integration of more environmental sensors (e.g., temperature, soil moisture) could improve the system’s predictive capabilities. Ultimately, this research sets the foundation for a scalable, real-time plant disease detection system that could revolutionize the way plant health is monitored and managed globally, contributing to food security and sustainable agriculture.

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