

AI and IoT Based Smart Detection System for Saffron Plant Diseases Using Image Analysis

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1. Introduction

Saffron is one of the most valuable and delicate crops cultivated in many re-gions of the world. However, saffron plants are highly susceptible to several diseases that affect both the leaves and underground corm structures. Some of the most common diseases affecting saffron cultivation include Saffron Wilt Disease, Leaf Spot Disease, and Corm Rot Disease. These diseases are mainly caused by fungal pathogens that infect plant tissues and disrupt the normal transport of water and nutrients, eventually leading to reduced plant growth and crop yield. Early detection of plant diseases is very important to minimize crop losses and maintain sustainable agricultural production. Traditional disease detection methods rely mainly on manual observation by farmers, which may not always be accurate and often detects the disease at later stages. With the advancement of Artificial Intelligence (AI) and the Internet of Things (IoT), smart agricultural monitoring systems can be developed to detect plant diseases automatically. The proposed system uses environmental sensors and deep learning-based image analysis to monitor plant health and identify diseases. The system analyzes four types of im-ages, including healthy leaf images, wilt infected leaf images, spot disease leaf images, and infected corm images, to improve the accuracy of disease detection and classification.

2. Problem Statement

Saffron crops often suffer from diseases such as wilt disease, leaf spot disease, and corm rot disease, which significantly affect crop productivity and quality. These diseases can spread rapidly under favorable environmental conditions such as high humidity, high soil moisture, and unsuitable soil pH levels. One of the main challenges faced by farmers is the late detection of plant diseases. Most farmers identify diseases only after visible symptoms appear on leaves or corms. By that time, the disease may already have spread widely across the field, causing major crop losses. 1 Another issue is the lack of continuous monitoring of environmental conditions that contribute to disease develop-ment. Parameters such as soil moisture, temperature, humidity, and soil pH play a major role in fungal disease growth. In addition, traditional detection methods do not effectively analyze different types of plant images. A system that can analyze multiple image types (healthy leaves, diseased leaves, and infected corms) along with environmental data is required to improve disease detection accuracy and provide early warning alerts to farmers.

3. Proposed Solution

To solve this problem, an AI and IoT based plant disease detection system is proposed. The system integrates environmental monitoring with image-based deep learning techniques to detect plant diseases at an early stage. IoT sensors are installed in the saffron field to continuously monitor environmen-tal parameters such as soil moisture, temperature, humidity, and soil pH. These sensors collect real-time data and transmit it to a processing system. At the same time, cameras capture plant images from the field. The system processes four types of images: Healthy leaf images Wilt infected leaf images Leaf spot disease images Corm rot infected images A Convolutional Neural Network (CNN) model analyzes the captured images to detect visual symp-toms such as leaf discoloration, wilting patterns, spot formations, and corm rot damage. The environmental sensor data and image features are combined to train a machine learning model that predicts disease occurrence. Based on the analysis, the system classifies plant conditions into the following cate-gories: Healthy plant Wilt disease infection Leaf spot disease infection Corm rot infection If the system detects a high probability of disease occurrence, it automatically sends alert notifications to farmers through SMS or a mobile application, allowing them to take preventive measures quickly.

4 .Technologies Used

- Soil Moisture Sensor
- Temperature Sensor
- Humidity Sensor
- Soil pH Sensor

- Arduino Uno / ESP32 Microcontroller
- Raspberry Pi
- Camera module
- WiFi / LoRa communication module
- Software Technologies
- Artificial Intelligence (AI)
- Machine Learning (ML)
- Deep Learning
- Convolutional Neural Network (CNN)
- Image Processing
- Programming Development Tools
- Python Programming
- OpenCV for image processing
- TensorFlow / Keras for CNN model development
- IoT cloud platform or local server
- Mobile application or SMS alert system

4.1 Expected Impact

The proposed AI–IoT based disease detection system will significantly improve saffron crop monitoring and disease management. By analyzing both environmental conditions and multiple types of plant images, the system can detect diseases at an early stage. The use of four image categories (healthy leaf, wilt leaf, spot disease leaf, and infected corm) helps improve the accuracy of the deep learning model and enables more reliable disease classification. Farmers will receive real-time alerts when environmental conditions favor disease development or when symptoms are detected in plant images. This allows them to take immediate preventive measures such as adjusting irrigation, applying fungicides, or removing infected plants. Overall, the system will help reduce crop losses, improve agricultural productivity, lower manual labor requirements, and support smart farming and sustainable agriculture practices.

4.2 AI and IoT Based Detection System for Corm Rot Disease

Introduction:

Corm rot disease is a major plant disease that affects the underground storage organ known as the corm. This disease is commonly caused by fungal pathogens and leads to severe crop losses if not detected at an early stage. Early detection and monitoring are essential for preventing the spread of the disease and maintaining crop productivity. Modern technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) provide advanced solutions for real-time monitoring and disease prediction in smart agriculture systems.

Visual Symptoms (Field and Corm Level):

Corm rot disease can be identified through several visible symptoms observed in the field and within the corm structure.

5. The major observed features include:

- Brown or black internal
- vascular discoloration
- Soft and shriveled bulb texture
- Basal plate infection
- Poor or no sprouting of the corm

6. Corm Rot Disease

These symptoms indicate the progression of fungal infection inside the plant tissue.



Figure 1: Corm Rot Disease Symptoms

7. AI and IoT for Corm Rot Disease Detection

Artificial Intelligence combined with the Internet of Things can be used to develop an intelligent agricultural monitoring system. This system enables early detection and monitoring of corm rot disease by continuously collecting environmental and soil data from the field. The integration of AI and IoT allows farmers to monitor crop conditions in real time and receive alerts when environmental conditions favor disease development.

8. Concept of AI and IoT in Plant Disease Detection

In a smart agriculture system, IoT sensors are deployed in the field to collect environmental and soil parameters. These sensors continuously gather data related to crop conditions. The collected data is transmitted to a cloud server or local processing unit where AI algorithms analyze the information. Based on the patterns detected in the data, the AI system predicts the probability of disease occurrence. When a high risk of disease is identified, farmers receive alerts or recommendations through a mobile application. This approach provides an early warning system before visible disease symptoms appear.

9. IoT Components Used

Sensors:

Different sensors are used to monitor environmental and soil conditions that influence disease development.

Soil Moisture Sensor:

This sensor detects soil moisture levels. High soil moisture creates favorable conditions for fungal growth.

Temperature Sensor:

This sensor measures environmental temperature, which affects pathogen growth and disease progression.

Humidity Sensor:

High humidity levels significantly increase the risk of fungal infection.

Soil pH Sensor:

This sensor helps analyze soil chemical conditions that may influence plant health and pathogen activity.

Hardware Components:

The hardware required for the IoT monitoring system includes:

- Arduino Uno or ESP32 microcontroller.
- Raspberry Pi for processing and data management.
- WiFi or LoRa communication module for wireless data transmission.
- These components enable real-time data collection and communication between sensors and the AI system.

10. AI Model for Disease Prediction

The AI model analyzes multiple types of data to predict the occurrence of corm rot disease. These include environmental sensor data, image data of corms, and historical disease records. Several machine learning algorithms can be used for disease prediction, including:

- Random Forest.
- Support Vector Machine (SVM).
- Artificial Neural Network (ANN).
- Convolutional Neural Network (CNN) for image-based detection.

10.1 The output of the AI model classifies the plant condition into three possible categories

:

- Healthy condition
- Early disease risk
- Severe infection stage

11. Proposed Methodology

- Step 1: Data Collection: The first step involves collecting relevant data from the field.
- This includes: Sensor data such as temperature, soil moisture, and humidity. Images of both healthy and infected corms.
- Step 2: Data Preprocessing The collected data must be processed before training the AI model. The preprocessing stage includes: Removing noise from sensor readings. Normalizing environmental data values. Resizing and standardizing image inputs.
- Step 3: Model Training Machine learning models are trained using the collected environmental data and disease labels. The model learns patterns associated with disease occurrence.
- Step 4: Prediction System After training, the AI model predicts disease probability based on environmental conditions and image analysis.
- Step 5: Alert System When the predicted disease risk becomes high, the system automatically sends alerts to farmers through SMS or a mobile application.

Example alert message: “High risk of Corm Rot detected due to high soil moisture and temperature.”

12. Advantages of the AI and IoT Detection System

The proposed system offers several advantages for modern agriculture:

- Early disease prediction.
- Reduction of crop losses.
- Real-time monitoring of environmental conditions.
- Automated disease diagnosis.
- Support for smart farming practices.

13. CNN Model Architecture for Disease Detection

- **Input Layer:** The input to the Convolutional Neural Network (CNN) model is an RGB image of the corm. The image is resized to 224×224 pixels before being fed into the network.
- **Convolution Layers:** Convolution layers extract important disease-related features from the image, such as rot spots, color variations, and texture changes.
- **ReLU Activation Function:** The Rectified Linear Unit (ReLU) activation function introduces non-linearity into the model, enabling it to learn complex disease patterns.
- **Max Pooling Layer:** The pooling layer reduces the spatial dimensions of feature maps while preserving important features. This process reduces computational cost and improves model efficiency.
- **Flatten Layer:** The flatten layer converts the two-dimensional feature maps into a one-dimensional vector that can be used for classification.
- **Fully Connected Layer:** This layer learns high-level relationships between extracted image features and disease categories.
- **Output Layer:** Softmax classifier produces final results: Healthy Corm, Corm Rot Diseased.

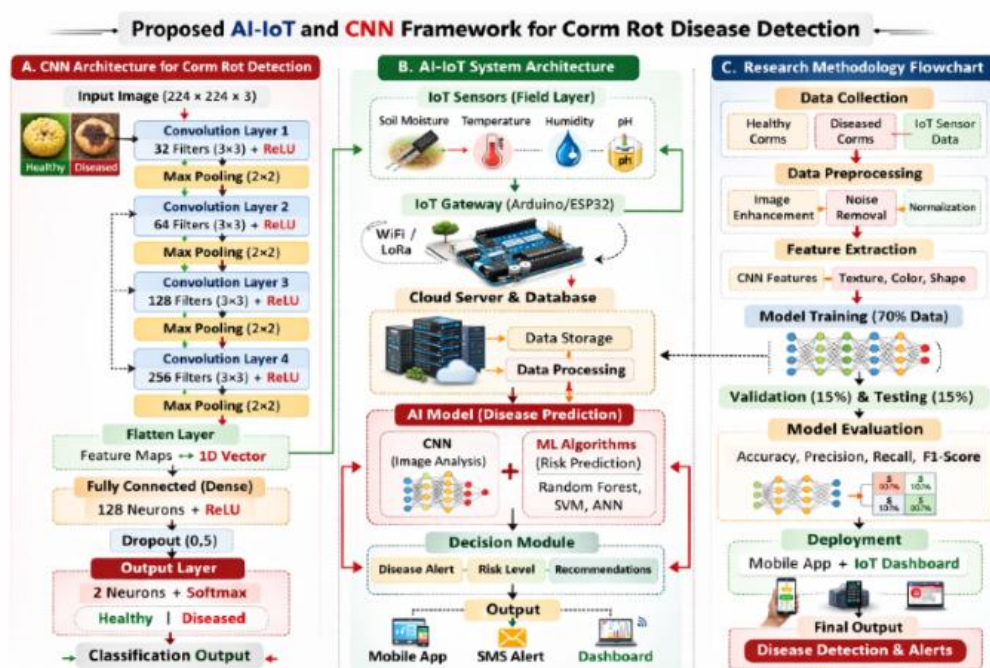


Figure 2: Proposed AI-IoT Framework for Corm Rot Disease Detection

14. Saffron Wilt Disease

Saffron wilt disease is one of the most serious diseases affecting saffron cultivation. The disease is primarily caused by the soil-borne fungal pathogen *Fusarium oxysporum*, which infects the plant through the corm and root tissues. The pathogen blocks the vascular system of the plant, preventing the proper transport of water and nutrients. As a result, infected plants gradually lose vigor and eventually collapse. Early detection of saffron wilt disease is essential to minimize crop losses and maintain sustainable saffron production.

14.1 Field Symptoms

The symptoms of saffron wilt disease appear gradually in the field and become more severe as the infection progresses. Farmers can identify the disease through several visible indicators observed in leaves and corm tissues.

The major symptoms include:

- Gradual yellowing of saffron leaves.
- One-sided drying of leaf tissues.
- Brown vascular ring inside the corm when cut open.
- Complete collapse of the plant in advanced stages.

These symptoms occur due to fungal colonization within the vascular tissues, which obstructs water and nutrient transport throughout the plant.

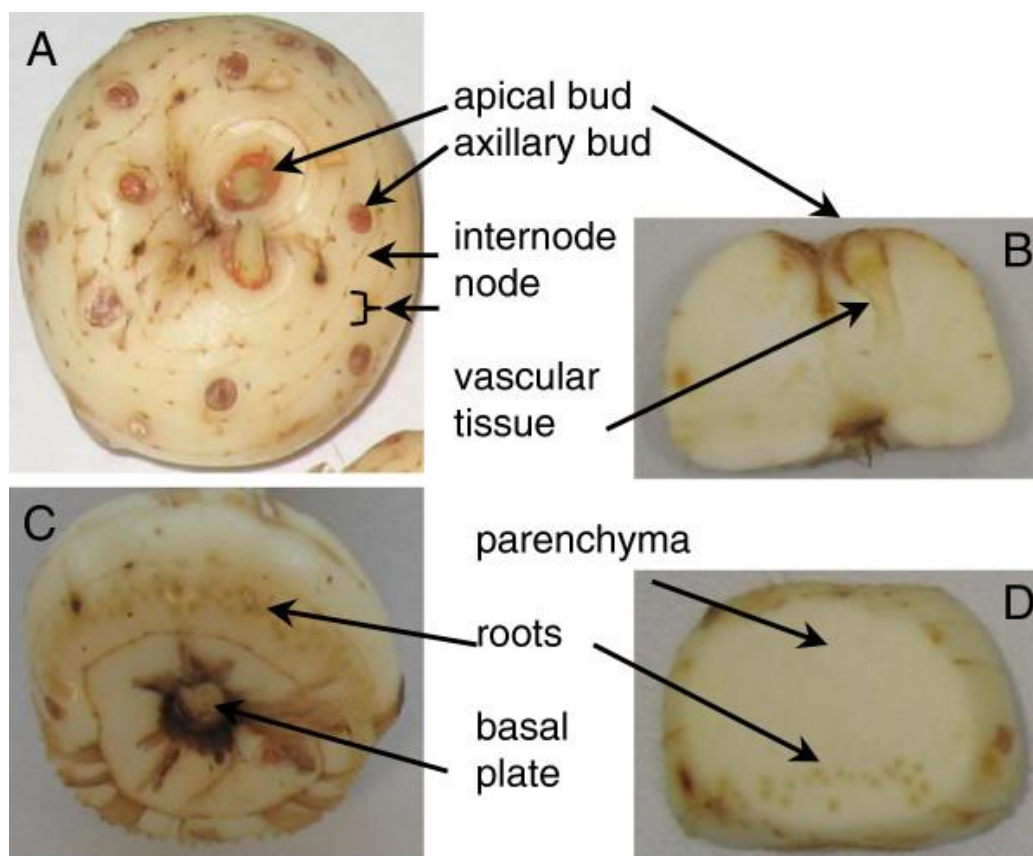


Figure 3: Saffron Wilt Disease Symptoms

15. Proposed Algorithm for AI-Based Saffron Wilt Disease Detection

This research proposes an Artificial Intelligence and Internet of Things (AI-IoT) based detection system for identifying saffron wilt disease at an early stage. The proposed system integrates environmental sensor monitoring with image-based deep learning analysis. Environmental parameters such as soil moisture, temperature, humidity, and soil pH are continuously collected using IoT sensors deployed in the saffron field. At the same time, images of saffron plants and corms are captured using field cameras.

A Convolutional Neural Network (CNN) model analyzes the captured images to identify disease symptoms such as leaf discoloration, wilting patterns, and tissue damage. The environmental data and extracted image features are then combined to train a machine learning model for accurate disease prediction. primary objective of the proposed system is to classify the plant condition into three categories: Healthy plant Early stage infection Severe saffron wilt infection The system continuously monitors crop conditions and provides early warning alerts to farmers when the risk of disease becomes high.

15.1 Input and Output Parameters Input Data

The system receives two types of input data:

Environmental Sensor Data

- Soil Moisture (SM)
- Temperature (T)
- Humidity (H)
- Soil pH (PH)

Image Dataset

- Leaf images of saffron plants
- Corm images of healthy and infected plants

Output Data

The output generated by the system includes:

– **Disease classification results**

- *Healthy plant
- *Early infection stage
- *Severe wilt infection

– Alert notifications sent to farmers through mobile applications or SMS.

15.2 Algorithm Explanation

The proposed algorithm begins by collecting environmental parameters from IoT sensors installed in the saffron field. These parameters are critical for disease prediction because fungal pathogens such as *Fusarium oxysporum* develop rapidly under specific temperature and moisture conditions.

Next, plant images are captured and processed using a Convolutional Neural Network (CNN). The CNN model extracts important visual features related to plant health, including leaf discoloration, wilting patterns, and structural abnormalities.

The environmental sensor data and extracted image features are combined to train a machine learning model. This hybrid approach improves the accuracy of disease detection by considering both environmental conditions and visual symptoms.

Based on the trained model, the system predicts the probability of saffron wilt disease occurrence. If the predicted probability exceeds a predefined threshold value, the system automatically generates alerts for farmers so that appropriate preventive measures can be taken.

15.3 Advantages of the Proposed Algorithm

The proposed AI-IoT based detection system offers several advantages for smart agriculture applications:

- Integration of environmental monitoring and image-based disease detection
- Early identification of saffron wilt disease
- Real-time crop monitoring using IoT technology
- Reduction of manual crop inspection and labor costs
- Improved prediction accuracy using machine learning models

This intelligent monitoring system supports sustainable saffron cultivation and helps farmers reduce crop losses caused by wilt disease.

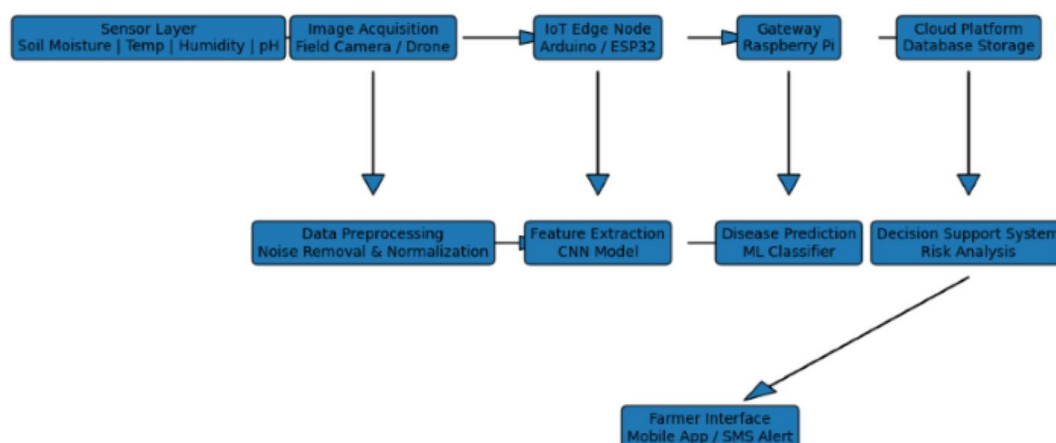


Figure 4: Block Diagram of Disease Detection System

16. Leaf Spot Disease

16.1 Visual Symptoms on Leaves

Symptoms:

- Circular yellow or brown lesions
- Yellow halo around spots
- Necrotic patches
- Premature leaf drying

17. Leaf Spot Disease

17.1 Visual Symptoms on Leaves



Figure 5: Visual Symptoms on Leaves

18. Viral Mosaic Disease

18.1 Mosaic Symptoms

Characteristics:

- Patchy light and dark green pattern
- Twisted leaves
- Stunted growth
- Reduced flowering



Figure 6: Visual Mosaic Symptoms on Leaves

19. Problem Statement

Plant diseases are a major threat to global agricultural productivity, leading to significant crop losses and economic damage. Among these diseases, Leaf Spot and Viral Mosaic diseases are commonly observed in many crops and can rapidly spread if not detected at an early stage. Traditional disease detection methods rely on manual inspection by farmers or agricultural experts, which is often time-consuming, subjective, and prone to errors. In many rural areas, farmers lack access to expert knowledge and advanced diagnostic tools, resulting in delayed disease identification and ineffective treatment. Moreover, environmental conditions such as temperature, humidity, and soil moisture influence disease development, but these parameters are rarely monitored in real time. Therefore, there is a need for an automated and intelligent plant disease detection system that can identify diseases quickly and accurately using image processing and artificial intelligence techniques. Such a system would help farmers detect diseases at an early stage and take appropriate preventive actions to reduce crop losses.

20. Proposed Solution

This research proposes an AI-based plant disease detection framework capable of identifying Leaf Spot and Viral Mosaic diseases from plant leaf images. The system integrates image processing techniques, machine learning algorithms, and optional IoT-based environmental monitoring to improve the accuracy and reliability of disease detection.

The proposed solution follows several key steps:

1. Leaf Image Acquisition

Leaf images are captured using smartphones or digital cameras in agricultural fields.

2. Image Preprocessing

Techniques such as Gaussian filtering, homomorphic filtering, and CLAHE enhancement are applied to improve image quality and remove noise and illumination variations.

3. Feature Extraction

Important disease characteristics are extracted using texture and color features, including Local Binary Pattern (LBP), Gray Level Co-occurrence Matrix (GLCM), and RGB/HSV color features.

4. Disease Classification

Machine learning algorithms such as Logistic Regression, Support Vector Machine (SVM), Random Forest, and Convolutional Neural Networks (CNN) are used to classify the leaf images into different categories.

5. Disease Prediction

The system predicts whether the leaf is healthy, affected by Leaf Spot, or affected by Viral Mosaic disease.

6. Farmer Notification

The results can be displayed through mobile applications, cloud dashboards, or alert systems to help farmers take early corrective measures.

21. Technology Used

The proposed system utilizes a combination of Artificial Intelligence, Image Processing, Internet of Things (IoT), and environmental sensors to enable accurate disease detection.

21.1 Artificial Intelligence (AI)

AI algorithms are used to analyze leaf images and identify disease patterns. In particular, machine learning and deep learning models such as Convolutional Neural Networks (CNN) are applied to automatically learn disease features from images.

21.2 Image Processing

Image preprocessing techniques such as Gaussian filtering, homomorphic filtering, and CLAHE are used to enhance image quality and highlight disease symptoms.

21.3 Internet of Things (IoT)

IoT technology can be integrated into the system to collect real-time environmental data from agricultural fields. This information helps in understanding conditions that promote disease development.

21.4 Sensors

Environmental sensors can be used to monitor parameters such as:

- Temperature
- Humidity
- Soil moisture
- Light intensity

These sensors provide valuable data that supports disease monitoring and predictive analysis.

21.5 Cloud and Mobile Applications

Cloud platforms can be used to store and process agricultural data, while mobile applications deliver disease alerts and recommendations directly to farmers.



Figure 7: AI-IoT Disease Detection Model

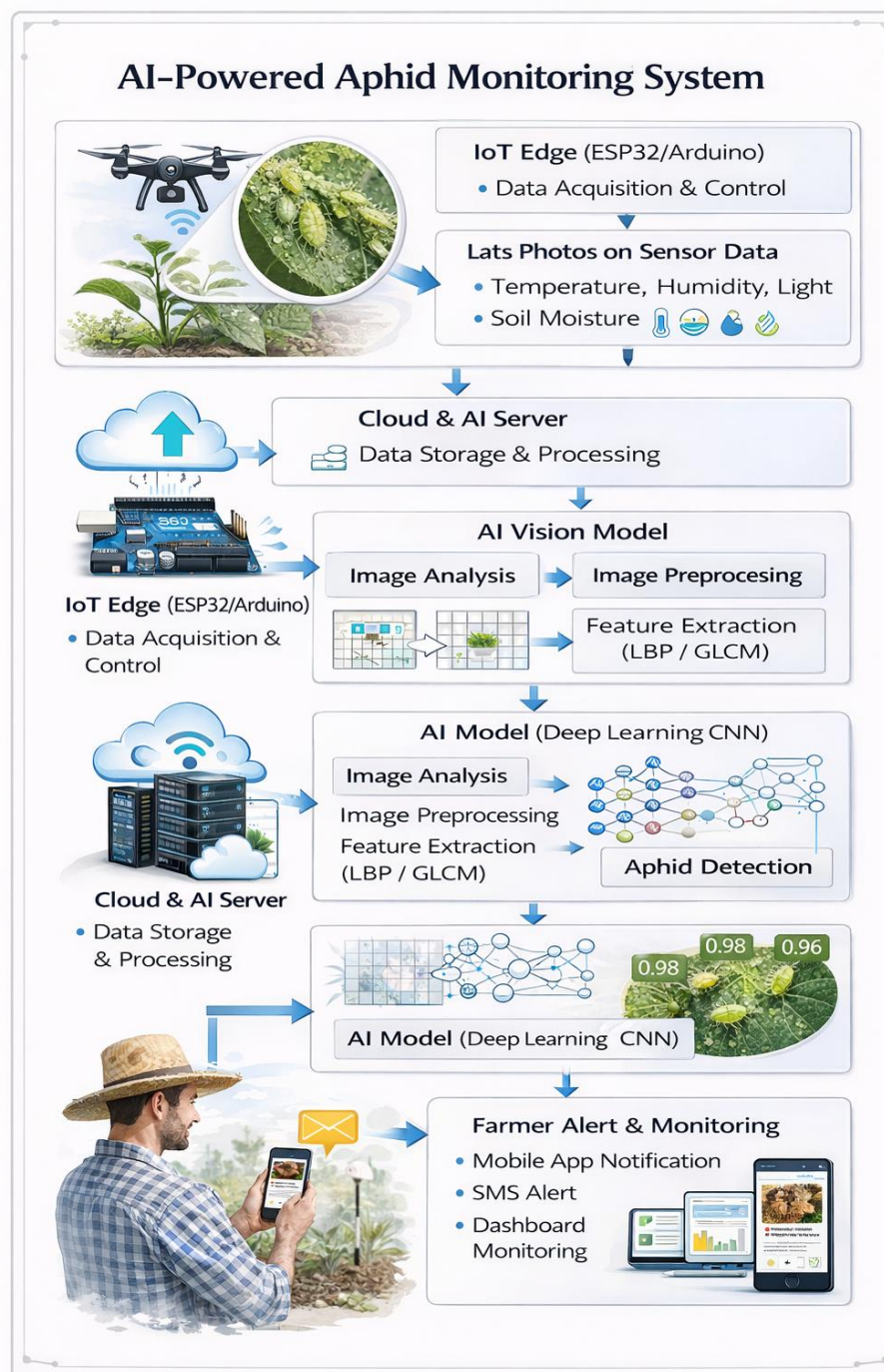


Figure 8: AI-Powered Aphid Monitoring System

22. Expected Impact

The proposed system is expected to provide several benefits for modern agriculture.

22.1 Early Disease Detection

The AI-based detection system enables early identification of plant dis-eases, allowing farmers to take preventive actions before the disease spreads.

22.2 Improved Crop Yield

By detecting diseases at an early stage, farmers can apply appropriate treatments, which helps reduce crop damage and increase agricultural productivity.

22.3 Cost-Effective Solution

The system uses low-cost technologies such as smartphone cameras and IoT sensors, making it affordable for farmers in developing regions.

22.4 Smart Agriculture Support

Integration with AI and IoT technologies supports the development of smart farming systems that monitor crop health in real time.

22.5 Decision Support for Farmers

The system can provide automated alerts, disease diagnosis, and management recommendations, helping farmers make better decisions.

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