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An Integrated System for Leaf Disease Prediction and Crop Management

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Abstract.

Plant diseases are an issue for people who grow plants everywhere. People who grow plants for a living have to deal with these plant diseases. It affects their lives. Plant diseases can be really bad, for people who need plants to survive. The ways we use now to find plant diseases are not very good because they need someone who knows a lot about plants to look at them. This makes it hard for farmers in away places to know if their plants are sick. This paper is about making a system that can look at a picture of a leaf and tell us what is wrong with the plant. We use something called Convolutional Neural Networks to do this. We do not need any equipment to help us we just need a picture of the leaf. This system can look at the picture. Tell us what disease the plant has. This is a good solution for farmers because it can help them know what is wrong with their plants and they can make their plants healthy again. Plant Disease Recognition is a deal and this system can help with that. The Plant Disease Recognition System is very good, at analyzing a leaf image and recognizing a disease.

Keywords. plant disease classification, convolutional neural network, deep learning, PlantVillage, precision agriculture, leaf image analysis

1. INTRODUCTION

Agriculture plays a critical role in economics worldwide. Among the challenges the sector faces plant diseases remain one of the most challenging threats to crop productivity and food security. Plant diseases significantly reduce crop yield and quality, directly impacting the livelihoods of farmers globally.

Traditionally, farmers inspect plant leaves visually to assess their health. However, this approach often fails to detect diseases at early stages, as leaves may appear healthy externally while already being infected. Today, advances in artificial intelligence provide powerful tools for automated image-based analysis. Deep learning convolutional neural networks (CNNs), a type of model, examine leaf images to detect and recognize them abnormal patterns with high accuracy [1].

2. LITERATURE REVIEW

2.1 Machine Learning based Agriculture Systems

With machine learning being one of the best ways of analyzing patterns and predicting results, it has been widely adopted in the agriculture sector. Machine learning has been shown to be an excellent resource when it comes to such aspects as yield forecasting, weather prediction, and nutrient testing. Nonetheless, machine learning has had the greatest success so far in diagnosing plant disease using image recognition. The convolutional neural network is primarily designed for working with visual information, whereby it recognizes patterns from the information provided. CNN models have been widely used for detecting plant diseases from leaf images with high accuracy.

2.2 Existing Approaches in Disease Prediction

The early approaches that made use of ML for diagnosing plant disease focused on classical machine learning techniques, including Support Vector Machines (SVM), Decision Tree, and Random Forest. Classical approaches needed manual extraction of features from the images to be used by the algorithm; in essence, human experts were responsible for defining such features as texture, colors, and shapes. However, this approach performed poorly when working with large datasets and was incapable of detecting small differences between diseases with visual similarities. The CNN algorithms have become preferable to classical ML algorithms due to their ability to automatically extract features. Traditional approaches also include image segmentation and soft computing techniques for disease detection. CNN-based models have also been successfully applied to classify potato leaf diseases.

2.3 Research Gap

Most of the existing methods include the use of IoT sensors, soil analysis, weather conditions, and crop suggestions, along with disease prediction. However, despite their usefulness, such methods can be costly, complicated, and difficult for farmers to adopt. There is a need for simpler methods that only use machine learning for predicting diseases based only on leaf images. The performance of deep learning models depends on dataset quality and environmental factors [2].

3. METHODOLOGY

In the proposed model, an image-based machine learning technique is adopted to identify diseases in plants. Only leaf images are considered, and there is no requirement to employ any IoT sensor devices. This makes the approach simpler, scalable, and easily accessible to farmers.

3.1 System Overview

This is accomplished by the use of a well-designed pipeline that resembles a natural leaf inspection process but with much more accuracy through the deployment of machine learning approaches. This is achieved by having the user upload an image taken on their mobile device or camera of a particular plant leaf. Upon upload into the system, a number

of pre-processing stages are performed to transform the image into a machine learning compatible format.

3.2 Dataset Description

The model is developed using the PlantVillage dataset, which contains over 54,000 images depicting both healthy and diseased plants from various crops. This dataset's diversity allows the model to identify unique features of different disease categories.

3.3 Data Preprocessing

Pre-processing of data is significant phase ensuring that the image is processed in order for the model to use them effectively. In order to maintain uniformity among all images, the dimensions of each image is standardized to 224×224 pixels. Normalization of pixel values further helps in enhancing the learning process of the model. Apart from this, there are other data augmentation techniques which involve operations like rotating, flipping, zooming, and adjusting brightness of images in order to improve the performance of the model.

3.4 CNN Architecture

The CNN model used in this paper employs several layers that learn increasingly complex features from the images. The initial convolution layers receive images as inputs and detect local features such as color gradients and edge patterns. These layers produce feature maps that represent various visual characteristics extracted from the input image.

3.5 Model Training

The model is trained using the Adam Optimizer, with a learning rate set at 0.001 and a batch size of 32, over the course of 40 epochs. The dataset is divided into training, validation, and testing sets in proportions of 70%, 15%, and 15%, respectively.

The backpropagation process minimizes cross-entropy loss function for multi-class classification.

3.6 Model Validation and Performance Metrics

After the model has been successfully trained, the next step will be evaluating its effectiveness. It will be performed using the metric of accuracy, which provides an overview of results obtained but in case some difficulties arise during the classification of specific classes, we will need metrics of precision, recall, and f1 score[3].

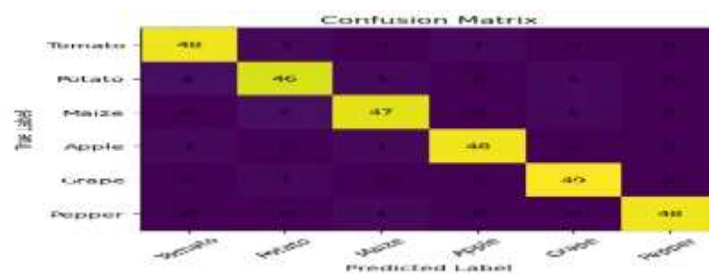
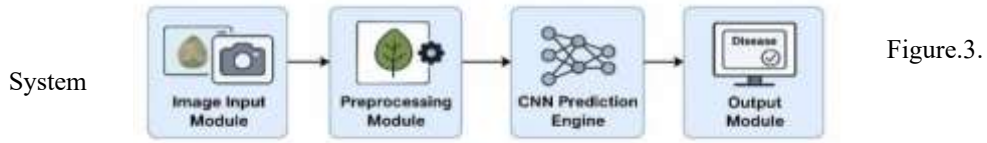


Figure. 2. Confusion Matrix of CNN Model

4. SYSTEM DESIGN

The proposed system's design is composed of four distinct modules that contribute to the processing of input data to generate the final diagnosis. The first module includes the process of inputting image data from users and the second one involves pre-processing the image before analyzing it. The essential component of the implemented system comprises the CNN prediction engine which performs the analysis of the image and generates predictions, and the third module involves converting these predictions into useful outputs [4].



Architecture of Proposed Model

5. RESULT AND ANALYSIS

As per the detailed study of the CNN, the following results are obtained; that is, it shows a level of accuracy of about 94.32%. This means that the network has a very high level of accuracy in the classification of various diseases. From the validation graph, it is clear that there is no case of overfitting, as there is a correlation between the accuracy levels [5].

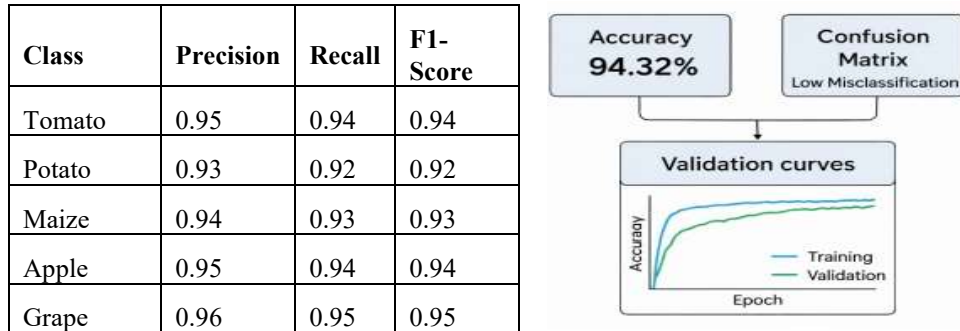


Table 1. Performance Metrics of CNN Model Figure. 4. Performance Evaluation Results

6. LIMITATIONS

Even though the proposed algorithm gives highly accurate results, it was mainly developed using the PlantVillage dataset consists of images captured in controlled environments. Real-life situations can be affected by many environmental conditions, like lighting changes, background noises, and leaf obstruction, among others. The next step for future works would be to train the model using real field images [6]

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Biographies



Subodhini Gurav received the bachelor's degree in computer engineering from Shivaji University in 2022, the master's degree in computer engineering from Savitribai Phule Pune University in 2026, respectively.