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AI-Based Rapid Plant Disease Detection

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A B S T R A C T :

In recent decades the entire global agriculture is severely impacted by the plant diseases, which cause lower crop harvest and have an great impact on food security. In the traditional disease detection techniques farmers have to manual do the disease inspection, which is labour-intensive and more time-consuming, and cause human error. In this study the authors team proposed a AI-based Rapid Plant Disease Detection System which utilize the Convolutional nural network(CNN) and AI techniques to increase the performance of the plant disease identification . The proposed model utilizes deep learning-based image processing to accurately identifying the signs of the disease, by analysing the images of the plant leafs. The proposed model uses CNN architectures to train the dataset of the plant images and several disease classes by extracting the features and classify the diseases. The proposed model uses advanced preprocessing methods like noise reduction, image augmentation, and colour normalisation process to increase the resilience of the model and also the accuracy, precision, recall, and F1-score metrics are used to estimate the model's effectiveness, which ensures accurate and effective detection of diseases. Through this method of disease identification farmers can precisely identifies the disease and take the preventive actions as early as possible which helps to lowers the crop losses and increase agricultural productivity. This study also highlights how the AI-driven plant disease detection can significantly enhance the precision agriculture, and leads to more technologically advanced and sustainable farming.

Keywords: Deep Learning, Plant Disease detection, Agriculture, Convolutional Neural Networks (CNN).

1. Introduction

In an emerging economies like India, agriculture is crucial but food security is still a major concern. But the leading problem in agricultural sector is the Plant diseases, which affect crop yield and financial gain . Preventing losses to the agricultural sector requires early detection of plant leaf diseases (4).This leades to an urgent need of an automated system which can recognise those diseases and assist farmers in taking the necessary actions to eliminate crop loss . Traditionally Farmers have been using their own eyes to identify plant diseases, and not all them were able to do so in the same way. As artificial intelligence advances,the computer vision capabilities must be integrated into the agricultural sector (5).In this paper we have employed an deep learning techniques. In order to obtain improvised results, deep learning offers numerous advantages when working with images, especially in image classification. The process starts with labelling the images of the leaves from diseased crops based on the disease pattern, enhancing the information in images of the diseased leaves using pixel-based operations, and finally the convolutional neural networks is used to identifies the diseases (6).Our research goes beyond disease detection to include treatment methods. We examine the complicated nature of disease management, applying our shared knowledge to provide useful recommendations for the maintenance and restoration of contaminated vegetation (10).

Related work

Accroding to Luo, Yuexuan, et al. Using a convolutional neural network (CNN) for plant diseases identification is a hot research topic in smart agriculture. But due to the memory-intensive and compute-intensive characteristics of CNN algorithm, they faced an difficulty to implement CNN on edge terminals with limited memory and computational resources. In this study they used the Field Programmable Gate Array (FPGA) to accelerate the CNN model to identify the plant diseases. At First they designed a 7-layer simple-structured network called "LiteCNN" with only 176 K parameters and 78.47 M floating point operations (FLOPs).Then they train the LiteCNN using knowledge distillation method to reach the accuracy of 95.24%. Secondly, they designed the acceleration circuit of LiteCNN and implemented it into "ZYNQ Z7-Lite 7020″ FPGA board. Further to speed up the plant disease identification, they used the following methods such as they used the Separable convolution instead of regular convolution, and to load the data they used a low-redundancy block convolution approach .Then they fused the fully-connected layer with the Batch Normalization (BN) layer; They used the half float data to express the Feature data and model parameters. They achieved the basic function of the circuit using these methods,and also they used methods like unrolling the for-loop, pipelining the for-loop, loop flattening and array partitioning to optimize the parallelism of the circuit. Finally, the LiteCNN on the FPGA board was verified and the plant disease identification reaches the accuracy of 95.71 %, and the inference speed of 0.071 s per frame, and the power consumption was 2.41 W [1].

Verma, Sahil, Prabhat Kumar, and Jyoti Prakash Singh suggests a single lightweight CNN model for diseases identification. They suggested a model , which employs several convolution layers of varying sizes at the same level to precisely identify the diseases in the affected area of varying sizes . According to the results of their experiments, they suggested that their model achieved an accuracy of 84.4% with only 387,340 parameters, which outperforms a number of benchmark CNN models, including VGG16, VGG19, ResNet50, ResNet152,ResNet50V2, ResNet152V2, MobileNetV2, DenseNet121, DenseNet201, InceptionV3, and Xception. Additionally, their suggested model demonstrates its effectiveness as a multipurpose tool by distinguishing between healthy and infected categories of each crop separately and achieved accuracies of 99.74%, 82.67%, and 97.5% for maize, rice, and wheat . Due to its lightweight nature and better performance, their proposed model becomes better and more viable for real-time crop disease detection even in the limited resource environments [8].

Peyal, Hasibul Islam, et al. propose that using deep learning-based lightweight 2D CNN architecture is an effective way to classify 14 classes of both tomato and cotton crops, with 12 diseased classes and two healthy classes . They proposed an smartphone-assisted plant disease diagnosis system model in which they implemented an Android application called "Plant Disease Classifier" .Their experiments reveal that, despite having a fewer parameters, the proposed model performs better than the pre-trained models like VGG16, VGG19, and InceptionV3 .Their proposed model achieves higher accuracy than the MobileNet and MobileNetV2 while using a slightly larger parameters. These models classification accuracy ranges from 57% to 92%, while the proposed model's average accuracy is 97.36%. In addition, the F1-score, recall, and precision of the proposed model is 97% and Area Under Curve (AUC) score is 99.9% . which reveals that the performance of the proposed model is very good .Also they used a class activation Maps using the Gradient Weighted Class Activation Mapping (Grad-CAM) techniques for visual explaination of the disease detection and heatmaps to indicate the responsible region for classification.

3. Problem statement

In India, plant diseases cause more than 15 % of the crops get into waste, making it a major issue that needs to be resolved. This leades to an urgent need of an automated system which can recognise those diseases and assist farmers in taking the necessary actions to eliminate crop loss . Traditionally Farmers have been using their own eyes to identify plant diseases, and not all them were able to do so in the same way. As artificial intelligence advances,the computer vision capabilities must be integrated into the agricultural sector (2). Another important factor in agricultural production is the severity of the disease which has a direct impact on the yield and quality of the plants and crops. In order to effectively monitor and control the disease not only the type , but also the severity of the disease must be clarified (6).

Utilising the deep learning techniques , the proposed system aims to provide an solutions to farmers, researchers, and other agriculture-related individuals by detecting the plant diseases and provide a proper guidance on the effective treatment strategies.

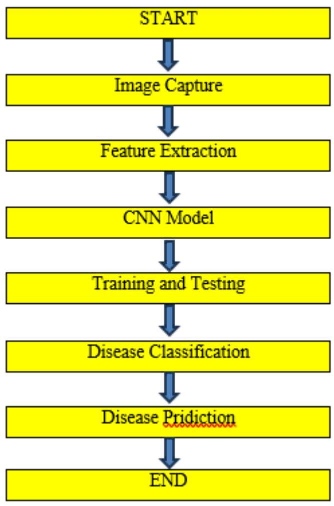
4. Metodology

The proposed system aims to address the problems associated with traditional plant disease identification, which is more time-consuming and prone to human error, and requires specialised knowledge. The proposed system utilize the deep learning models to give the real time insights to the farmers,researchers,and agricultural professionals by analysing the plant leaf images for disease detection. The proposed system functions by collecting a large dataset images of plants which includes healthy and diseased samples and also to increase the accuracy of the detection these images undergoes to the preprocessing techniques which includes the methods like segmentation, contrast enhancement, and noise reduction . Then a CNN model is used to train the dataset, by collecting important features like texture, colour, and shape patterns to differentiate between various plant diseases. At last the model is adjusted to improve prediction accuracy and decrease false detections.

4.1 Flow chart

Fig.1. (a) Flowchart shows the activities performed while developing the model.

a



4.2 Steps and Approches:

- **Image Capture:** It is the first process by which the users can take pictures of plant leaves to begin the system's image acquisition process and also to increase the detection accuracy, the system demands high-quality image input. A web application or mobile app can also be used to upload images for analysis.
- **Image Preprocessing:** It is the process by which the preprocessing techniques are used to improve the clarity and eliminate noise of the images before the images were feed into the CNN model.The majority of the preprocessing actions are Resizing: Creating uniform image dimensions for consistent analysis.
- **Feature Extraction:** It is the process were the CNN plays as the main role.In this process Convolutional Neural Network (CNN) takes image of the leaf and extracts key characteristics like texture, colour, and shape . Convolutional, pooling, and activation functions are examples of CNN layers that aid in identifying pertinent disease features.
- **CNN Model Processing:** A trained CNN model examines the extracted features and contrasts them with established disease patterns after processing the preprocessed image. In order to ensure high accuracy, a sizable dataset images of healthy and diseased plants is used to train the CNN model.
- **Disease Classification:** Using the patterns it has identified, the model divides the leaf into two groups: healthy and diseased..
- **Evaluation and Suggestions:** When a disease is identified by the CNN model, the system produces a thorough report that includes the following informationsuch as the name and symptoms of the disease ,Potential causes Suggestions for treatment (pesticides, organic solutions, preventive measures).

4.3 Model Description

CNNs are made up of several layers that collaborate to identify and categorise an image's features. CNNs learn features automatically from raw pixel data without human assistance, in contrast to traditional machine learning models. CNNs' capacity to capture spatial hierarchies—from basic edges to complex textures is their main advantage.

A CNN consists of several specialized layers, each serving a distinct function in feature extraction and classification:

- **Input Layer :** The layer that receives the raw data (image) as a pixel grid for example(128x128x3 for RGB images) is known as the input layer through which the model's learning efficiency is improved by normalising the pixel values.
- **Convolutional Layer:** This layer is CNNs' main component .This layers uses the filters (kernels) to examine the picture and extract features like edges,textures,shapes.This layer also includes the operations like involving a dot product between the filter and a section of images and feature map creation.
- **Activation Function (ReLU):** The network can learn intricate relationships because of to the non-linearity introduced by the Activation Function (ReLU),and the Rectified Linear Unit (ReLU) substitutes zero for negative values in order to prevent the saturation problems
- **Pooling Layer (Downsampling) :** Another layer is Max Pooling layer which chooses the highest values to reduces the spatial dimensions within a region.The average values within a region is calculated using average pooling.Pooling layers preserve key features while lowering computation.
- **The Fully Connected (Dense) Layer :** It is the layer which transforms the features that were extracted into a final classification.The Different classes (such as "Healthy" vs. "Diseased") are given probabilities by this layer.
- **Output Layer:** It is the final layer which employs Sigmoid (binary classification) or Softmax (multi-class classification) functions and determines the final predicted category.

4.4 Utilising the Results:

This analysis's remarkable 99.68% accuracy rate in identifying healthy and unhealthy leaves has numerous real-world applications in a variety of fields.These can a;lso be used in :

Early Disease Detection: In addition to traditional techniques, this technology functions as a powerful early warning system for diseases of plants. Early disease detection can reduce crop losses [12].

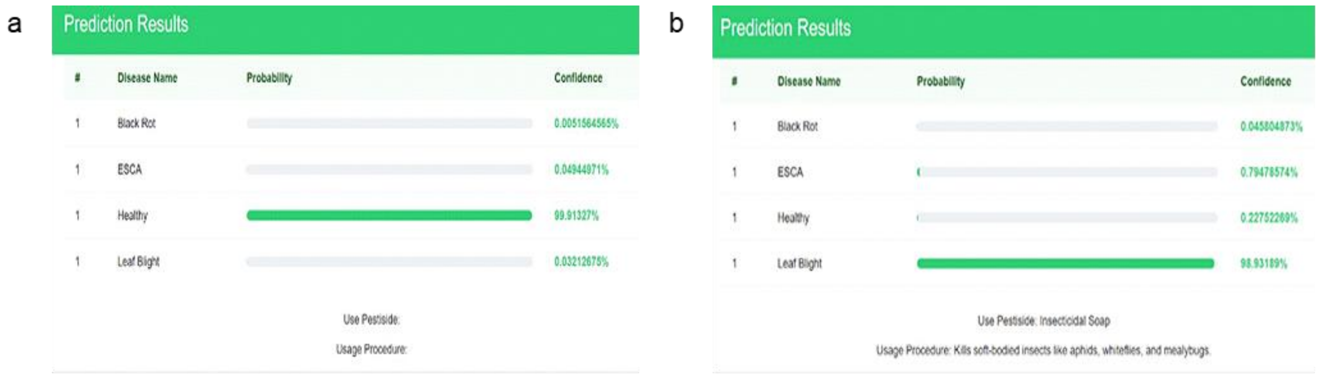
Precision in Agriculture: By combining with precision agriculture practices, these highly accurate disease detection systems can assist farmers in utilising these methods to quickly identify plant diseases and take appropriate action. They can employ strategies like the targeted use of pesticides in fields, which can help save money and preserve resources [11].

Botanical Research: Bo Researchers and botanists can use these methods to better understand plant diseases by studying them in their natural habitats [15].

Research Advancements: In order to develop more novel and creative solutions, the researchers may be inspired to focus more on the relation between computer vision and agriculture by the model's accuracy. When combined, developments in distinguishing between healthy and unhealthy leaves have a significant impact on biodiversity, conservative initiatives, agricultural practices, and scientific discoveries. It demonstrates how technology can be used to address significant global issuesAn example appendix

5. Result analysis

The goal of this research was to categorise leaves into healthy and unhealthy groups. The author team included a Grape leaves data set and its diseases in this classification. We obtained an accuracy of 99.68%, and Figure 5 shows the resulted output of this analysis which was astounding and achieved an high accuracy. The author team was able to save time and money and reduce a significant amount of computational complexity with the aid of transfer learning. The losses that occur during batch processing are showed in Figure 3 and the Figure 4 shows the losses following the processing of every batch.



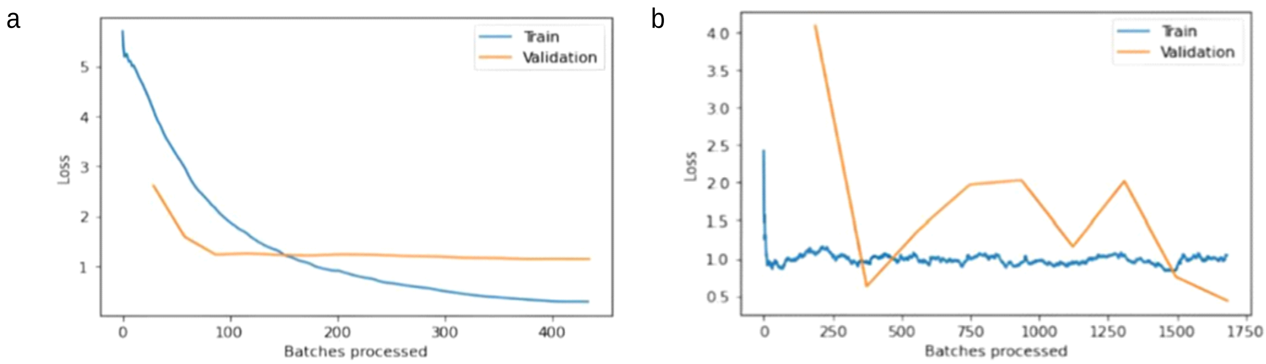


Fig. 2 - (a) depiction of losses during batch processing; (b)) depiction of losses after batch processing

Fig. 3 - (a) Prediction of Healthy Leaf; (b) Prediction of diseased Leaf

The model successfully classifies the uploaded leaf image and displays the result to the user.

6. Conlusion

A promising answer to the problems with conventional disease detection techniques is provided by the Rapid Plant Disease Detection System, which makes use of the convolutional neural networks (CNNs) and the artificial intelligence (AI). The proposed system utilizes the deep learning-based image processing to detect plant diseases accurately, and automatically, eliminating the need of manual inspection which is frequently time consuming and cause more human errors.The suggested model uses a variety of disease classes and sophisticated preprocessing methods like image augmentation, noise reduction, and color normalization to improve model robustness.

The proposed model is trained with a sizable dataset images of the plant leaf .And the performance evaluation metrics like accuracy, precision, recall, and F1-score are used to show how reliable the system is at accurately identifying plant diseases.This AI-driven method assists farmers in taking prompt action by facilitating the early detection of plant diseases.preventive measures, lowering crop losses and raising agricultural output in general. Precision farming that incorporates deep learning also enhances sustainability by improving farming's advanced technology, efficiency, and scalability.This study demonstrates how artificial intelligence (AI) can revolutionize agriculture by opening up the opportunity for data-driven, intelligent farming methods that can support sustainable crop production and global food security.

7. Future scope

Future enhancements to the Indian agricultural system could be made in a number of ways, and this research on early plant disease detection and treatment creates a way of opportunities for such advancements.

● IOT technology can help with proactive disease management by implementing real-time monitoring, and the system can be tailored to assist farmers in particular regions in meeting their unique requirements and managing the types of diseases that are prevalent in their region [13].

● Predicting diseases while taking the environment and weather into account can also improve the system's intelligence. Multilingual assistance and intuitive mobile apps can empower farmers to increase accessibility [14].

The research's future encompasses more than just diagnosing and curing illnesses. Utilising cutting-edge technologies, encouraging cooperation, and constantly improving the system will help us work towards a sustainable agriculture sector that benefits the country and its farmers.

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