Plant Leaf Disease Detection and Classification using Optimized CNN Model

Prabavathi S, Kanmani P

Abstract: Our economy depends on productivity in agriculture. The quantity and quality of the yield is greatly affected by various hazardous diseases. Early-stage detection of plant disease will be very helpful to prevent severe damage. Automatic systems to detect the changes in the plants by monitoring the abnormal symptoms in its growth will be more beneficial for the farmers. This paper presents a system for automatic prediction and classification of plant leaf diseases. The survey on various diseases classification techniques that can be used for plant leaf disease detection are also discussed. The proposed system will define the cropped image of a plant through image processing and feature extraction algorithms. Enhanced CNN model is designed and applied for about 20,600 images are collected as a dataset. Optimization is done to enhance the accuracy in the system prediction and to show the improvement in the true positive samples classification. The proposed system shows the improvement in the accuracy of prediction as 93.18% for three different species with twelve different diseases.

Keywords: Agriculture, Classification, CNN, Image processing, Optimization.

I. INTRODUCTION

Agriculture is a very ancient methodology of food source. It is a very important source of economy all over the world [4]. Without food no one can survive in this world. Plants are important not only humans, even animals rely on plants for their food, oxygen etc., To increase the production of crops, the government and researchers are taking immense steps which are successfully running in the real world. Once a plant gets infected with any kind of disease, then the entire living things will get affected in one or other form [9]. This plant disease may occur in any part of the plant like stem, leaf, branch and so on. And even the type of diseases affecting the plants may also vary like fungal, bacterial diseases etc., [3] The disease that affects the crops will depend on factors like climatic conditions.

There are a huge number of people who are starving for food. This happens because of insufficient production in food crops. Even drastic climatic changes will affect the growth of plants [2]. This kind of natural disaster cannot be helped.

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Identifying the plant disease in early stages helps in preventing huge loss of crops. Farmers are supposed to use proper pesticides for their crops [9]. Too much chemicals (pesticides) are dangerous for the crops as well as the farming land. Getting experts' advice will help from exceeding use of chemicals on plants. Huge research has been done on the plants to help farmers and also people interested in the agricultural field [10]. Disease detection is easy when it is visible to a human's naked eye [3]. Once the farmer has enough knowledge and continuous monitoring of the crops, then the disease may be detected and treated earlier. But this stage exists only when the disease is severe or the production of crops is less [6]. When the number of crops increased or the production is high then this type of detecting disease won't work. Then arises the new techniques. Automated techniques for diseases detection are introduced which makes the farmer's life easier [1]. The results produced in this kind of technique are efficient for both small and large production of crops. Importantly the results are accurate and take very less time to detect the diseases. Machine learning and neural networks play a vital role for these technologies [5]. In this paper, Deep Convolutional Neural Network (CNN) is used to classify the diseased and healthy leaves and to detect the disease in the affected leaves. The CNN model is built to fit both healthy and diseased leaves, the images are trained in the model and the output will be produced according to the input leaf. Following this section 2 will explain the dataset collection, and section 3 explains the image pre-processing, section 4 will explain about training and testing data and finally section 5 explains the Deep learning model which is used to detect the diseases in the plant leaf. The methodology and the results obtained are shown in the experimental results.

II. LITERATURE REVIEW

In agriculture, due to climatic conditions, there are drastic changes and different types of diseases are affecting the crops. There are a lot more ways to detect the disease in the plant. To detect the plant leaf diseases, the considered dataset taken is the combination of both healthy and diseased leaves of different crops. The methods such as deep learning techniques and computer vision are used for the implementation in this paper. The neural network that is used to detect the disease and train the model is chosen as Convolution neural network (CNN). MobileNet and InceptionV3 are models used and the accuracy obtained is 99.62%. (Omkar Kulkarni, 2018). [2]The training model VGG and AlexNetOWtBn of CNN is used to detect the disease of the plant leaves.

25 different plant datasets in the combination of plant and disease, containing healthy and infected plants. The obtained success rate is 99.53%. (Konstantinos P. Ferentinos, 2018) [1]. Deep Learning is used to detect the disease in the plants. The neural network used in the prediction is the CNN model. The specific disease is not detected, whereas the plant leaves will be differentiated into healthy and diseased based on the image of the plant leaf. The dataset is small which is of only 1400 images. The accuracy obtained is 99.6%. (Parismita Bharali et al. 2019).[3]

In this paper, only rice leaf diseases were considered for examination. The affected portion of the rice leaves are separated and trained in CNN model. The important advantage is automatic feature generation without any human interference. The classifier used is the softmax classifier. The dataset taken are only grey scale images. K-nearest neighbour and SVM are also used and compared with the CNN model. This is a survey paper which is a comparison of two to three classifiers. (Ankur Das et al 2020).[4]

Maize leaves are focused for disease detection. VGG16 and VGG19 are the models of CNN which are used to classify the leaf images into healthy and unhealthy plant leaves. Since CNN suffers from identifying optimal hyperparameters, Orthogonal learning Particle Swarm optimization (OLPSO) is used for finding the optimal values. Oversampling and under sampling methods are used to fix the problem of imbalanced dataset. The result is compared with InceptionV3 and Xception which are the pre-trained models of CNN. This model gives accuracy of about 99.8% whereas the InceptionV3 and Xception gives only 96% of accuracy. (Ashraf Darwish et al. 2019).[5]

The method proposed is to identify the Strawberry disease automatically. The main motive of this paper is to detect the disease and get immediate feedback from the framer so that the disease can be treated as soon as possible. Data aggregation and disease identification are the two steps performed with the help of CNN model. The accuracy gained is 89.7% and it can be extended to different crops and even in different geographical areas. (Hyeon Park et al. 2017).[6]

To extract the features from the raw image automatically, a CNN model is used. Only tomato leaves are considered and diseases are detected. Nearly 15,000 infected images are taken for training and testing. AlexNet and GoogleNet are the CNN models used to detect the disease and SVM and Random forest are also performed and they are compared. To obtain 99.18% of accuracy, both deep models and shallow models are performed in this paper. (Mohammed Brahimi et al. 2017).[7]

Image processing is used to capture high resolution images of both healthy and unhealthy leaves. For segmentation and clustering of images, K-means Clustering is used. For training and classification of leaf images Random Forest Classifier and K-means clustering are used. Only four diseases namely Alternaria Alternata, Bacterial Blight, Anthracnose and Cercospora Leaf Spot are classified and studied. The study could have extended in studying a lot more diseases. (Abirami Devaraj et al. 2019). [8]

Plant diseases either on the stem or leaf are captured in image processing. Cash crops are given importance in detecting the disease since it is in need by humans. Artificial neural network (ANN) and K-means Clustering is used in

disease detection. The control of pesticides is done by Agrobot (Agricultural Robot). A DC motor with wheels is connected to the Agrobot to spray the pesticides in specific disease detected areas. Since different crops use different methods for calculating accuracy, the accuracy changes for each crop. (Shivani K. Tichkule et al. 2016).[9]

Tea leaf diseases are detected to prevent the fast spread of disease. Image processing is used to identify and classify the tea leaf into a healthy and a diseased leaf. Support vector Machine (SVM) is the classifier used to extract the features of the leaf. The advantage is the time consumption for processing the given samples. In comparison with other classifiers and neural networks, the accuracy obtained here is high which is 93%. (Md. Selim Hossain et al. 2018).[10]

For detecting diseases an expert system, that is automatically the system will detect the disease or the symptoms of the disease, is built. Support Vector Machine (SVM) is used to predict the disease once the image processing is done to the leaf images. Mobile applications are developed with scripting languages which are user friendly and useful for the farmers to protect their crops. The accuracy obtained using SVM is 95% which is high when compared to random forest and linear regression. (D. O. Shamkuwar et al. 2018).[11]

A dataset of apple leaf image which contains six classes of diseases including healthy leaves are taken for research. Deep learning and neural networks are used for disease recognition. DenseNet-121 is the deep convolution network used which is better than the other than traditional methods. Three types of regression are used for multi-label classification. It importantly uses the functions like focus loss and cross entropy loss functions to identify the diseases in the apple plant. The accuracy obtained was around 93%. (Yong Zhong et al. 2019).[12]

The plant interaction between the microRNA(miRNA) and long non-coding RNA (lncRNA) is predicted with the help of some traditional neural networks. They play an important role in the genes of plants. The neural networks used are CNN and Independent recurrent neural networks (IndRNN). Since these neural networks are used to predict the interaction between miRNA and lncRNA it is called CIRNN. This is used to extract the representation of sequence features. The inaccuracy caused by human factors can be overcome by this experiment. It will be useful in dealing with large-scale data. Accuracy varies on the length of the data. (Peng Zhang et al. 2020). [13]

The occurrence of pests and diseases in cotton is predicted. The prediction is done in a time series manner. The neural network used is Long Short-Term Memory (LSTM). LSTM is more likely to RNN (recurrent neural network). Climatic conditions are an important factor for the prediction. LSTM decides the weather factors for cotton crops. Different accuracy is obtained for the predictions of different pests and diseases. (Qingxin Xiao et al. 2018).[14]

The disease is detected by Multi-model LSTM-based Pre-trained CNN (MLP-CNN) classifier. This MLP-CNN is a hybrid mode which is a combination of CNN and LSTM networks.

The feature extraction is done by CNN models and they are fed into LSTM layers to detect the pest and disease. The accuracy obtained is 99.2%. (Muammer Turkoglu et al. 2019).[15]

III. PROPOSED METHODOLOGY

A. Dataset collection

Dataset used here is the PlantVillage dataset [16]. It is an open-source dataset which consists of about 20,600 images of plant leaf. Three different species of plant leaves are used for this research process such as Tomato, Potato and Pepper. This disease identification is done by using both healthy and infected leaves. Nearly 12 diseases for 3 species of plant leaves are included in this dataset along with their respective healthy leaves. The original size of the leaf images in the dataset are 256x256. It will be segmented and resized further for processing of data. The sample dataset is shown in Fig 1.

Figure 1. Sample Dataset.

B. Image pre-processing

Pre-processing of images is important because we need a uniformity in images and to have a common background. It will help in increasing the accuracy of the neural network model. But here we are not using any image pre-processing technique before training the model. The dataset collected is directly trained by the CNN model which is built already. To reduce overfitting of the model we are rotating all the leaf images in the collected dataset from 0-360º i.e., in all different angles. It helps in enlarging the dataset. The architecture diagram of this model is shown in Fig 2.

C. Deep learning model

Convolution Neural Network (CNN) is the deep learning model used here for identifying the diseases in the plant leaves. Since there is no image pre-processing done, the images in the dataset will be converted into an array and be trained. The CNN model will run on Windows (any version above 7) or Ubuntu (64-bit) Operating Systems. On top of the TensorFlow GPU backend, a deep learning package called Keras is used to build the CNN model. TensorFlow is the framework used as a backend which provides both high and low-level APIs to support the deep learning model. Keras is an open-source neural network library which provides only high-level APIs (Application Programming Interface). Both

Keras and TensorFlow are used to build and train deep learning models easily. So, here Keras is built on top of TensorFlow for ease in training the model and making it little user-friendly.
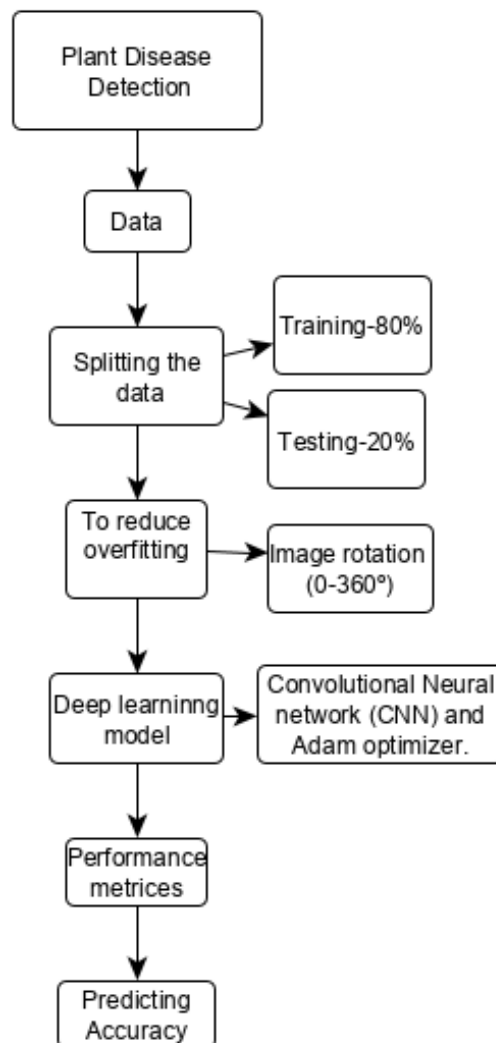

Figure 2. Architecture Diagram.

The CNN model is built by using a sequential model. The table obtained as an output for the sequential model is illustrated in Fig 3. This model sequential stacks up sequential layers of Convolution Neural Network in the order of input to output. A function called ReLu activation function is used in all the layers. This ReLu activation is a mathematical equation that determines the output of the neural network. MaxPooling2D is used along with this Keras to reduce the computational cost. It reduces the number of parameters in the CNN layers. Dropout is used here to avoid overfitting in CNN layers. Flatten is used here to flatten the data into one dimensional. Since the data has to be converted before passing it into the next level, flatten helps to make the data one dimensional. Dense is used to collect the output from all the neurons of the previous layer and give them to the next layer.

Layer (type)	Output Shape	Param #
conv2d_1 (Conv2D)	(None, 256, 256, 32)	896
activation_1 (Activation)	(None, 256, 256, 32)	0
batch_normalization_1 (Batch	(None, 256, 256, 32)	128
max_pooling2d_1 (MaxPooling2	(None, 85, 85, 32)	0
dropout_1 (Dropout)	(None, 85, 85, 32)	0
conv2d_2 (Conv2D)	(None, 85, 85, 64)	18496
activation_2 (Activation)	(None, 85, 85, 64)	0
batch_normalization_2 (Batch	(None, 85, 85, 64)	256
conv2d_3 (Conv2D)	(None, 85, 85, 64)	36928
activation_3 (Activation)	(None, 85, 85, 64)	0
batch_normalization_3 (Batch	(None, 85, 85, 64)	256
max_pooling2d_2 (MaxPooling2	(None, 42, 42, 64)	0
dropout_2 (Dropout)	(None, 42, 42, 64)	0
conv2d_4 (Conv2D)	(None, 42, 42, 128)	73856
activation_4 (Activation)	(None, 42, 42, 128)	0
batch_normalization_4 (Batch	(None, 42, 42, 128)	512
conv2d_5 (Conv2D)	(None, 42, 42, 128)	147584
activation_5 (Activation)	(None, 42, 42, 128)	0
batch_normalization_5 (Batch	(None, 42, 42, 128)	512
max_pooling2d_3 (MaxPooling2	(None, 21, 21, 128)	0
dropout_3 (Dropout)	(None, 21, 21, 128)	0
flatten_1 (Flatten)	(None, 56448)	0
dense_1 (Dense)	(None, 1024)	57803776
activation_6 (Activation)	(None, 1024)	0
batch_normalization_6 (Batch	(None, 1024)	4096
dropout_4 (Dropout)	(None, 1024)	0
dense_2 (Dense)	(None, 15)	15375
activation_7 (Activation)	(None, 15)	0

```
Total params: 58,102,671
Trainable params: 58,099,791
Non-trainable params: 2,880
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Figure 3. Table of Sequential Model.

D. Training and Testing Data

This experimentation process has been done by splitting the entire into training and testing dataset. 80% of the data is given for training and 20% of the data is given for testing. The random state is assigned with a constant value 42. Adam optimizer is used to train the model with the batch size of 32. Trial and error method is used to determine the parameters such as epochs, batch size, image size and so on. The experiment shows the improvement in the outcome based on the number of iterations and training data size. Binary cross entropy loss function is used to compute the loss in CNN.
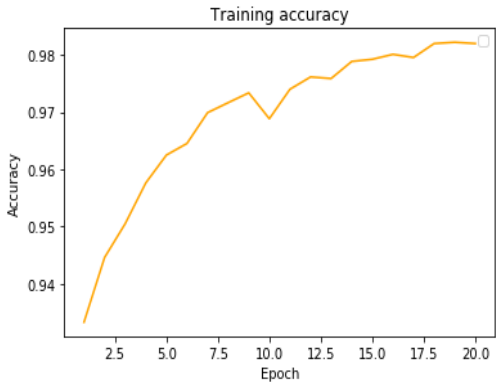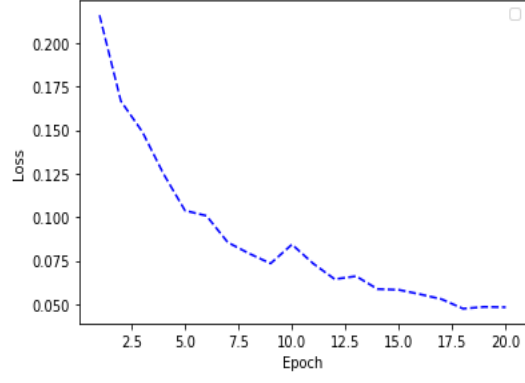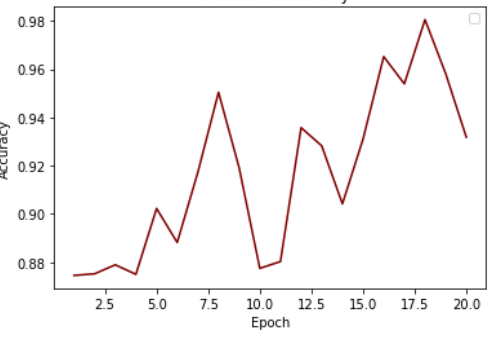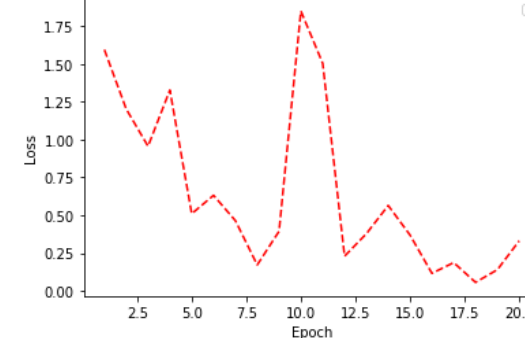
IV. RESULT AND DISCUSSION

Here by using CNN model, the leaf disease is identified. The disease is classified by the pigments in the leaf and distinguish it into healthy and diseased leaves. The probability of finding the disease will also be displayed with the use of label binarizer. Once the execution of epoch has been completed, the accuracy of the model obtained is 93.19%. To calculate the loss, binary cross entropy function is used. The obtained result is graphically represented in the figure. Since the system is compatible with only 20 epochs, only 93% of accuracy is able to be obtained. If the number of epochs has been increased, the accuracy will also be increased. But it may lead to overfitting of the model and the waiting time will be increased. Finally, when calculating the model accuracy, we obtain 93.19% within a short span of time. We are saving the file in the pickle format. Once the file is saved and loaded, the leaf image whose disease has to be detected is selected and loaded. The trained model will give the result and the probability of finding the disease. The purpose of detecting the diseases in the leaves has been fulfilled in this paper with the help of the Convolution Neural Network.

V. CONCLUSION

In this paper, the Deep Convolutional Neural Network is used to identify the disease in the leaf images has been achieved successfully. Three species of crop and 12 different diseases along with the healthy leaves on the three classes are tested in this proposed model. The number of images being used here for both training and testing includes 20,600 images. After completing the collection of datasets, the data has been sent to the built CNN model and the accuracy obtained by this methodology is 93.18%. Initially, the training and validation loss are high and becomes comparatively less when it is executed for 20 epochs (which is clearly shown in Table I. The disease identification in the leaves has been successfully done in this paper.

As an extension of this paper, a large dataset with a greater number of classes can be used. Different diseases can also be detected with this model. This disease detection mechanism can be done in different parts of the plants rather than the leaves. In this paper, accuracy is high but the resources and the execution time is high. So, refinement can be done in the future model for reducing the user waiting time. Mobile applications with user friendly GUI can be developed which will be useful for the farmers and even a person without agriculture knowledge can use it with ease.

Table 1. Experimentation Results

	Accuracy	Loss
Training		
Validation		

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