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Leaf Disease Detection Using Convolutional Neural Networks

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ABSTRACT

Agriculture has a significant role in India's socio-economic growth. Leaf infections are one of the most serious issues in agriculture. Leaf diseases lead to low productivity in Agriculture. Early detection of disease leads to better productivity. The identification of tomato leaf diseases using deep learning techniques is explored in this work. To detect the disease, a dataset containing Bacterial spot, Late blight, Yellow leaf curl virus, and healthy leaves was collected. To detect these diseases different CNN (Convolutional Neural Networks) architectures were used. The performance of CNN when applied on this dataset is 94.20%.To further improve the classification accuracy data augmentation is used. 4,000 input images are increased to 30,000 by using data augmentation. Grid search is applied to CNN model to find best hyper parameters. After application of grid search, a CNN model with best hyper parameters identified using grid search is trained and the accuracy of that model is 98.20%.

KEYWORDS: Leaf diseases, CNN, Tensor flow, Data augmentation, Grid search, GUI.

1. INTRODUCTION

India is the world's second-largest agricultural products producer. Agriculture is directly or indirectly responsible for two-thirds of the population's livelihood. Main problem in agriculture is low productivity. One of the reasons for low productivity is plant leaf diseases. Leaf diseases occur due to bacteria, virus, fungus and pets. Identifying disease and using proper pesticides can improve the growth in plants.

Tomato is major crop in India. Tomato plant leaves are affected by different diseases. Leaf diseases will spoil the whole plant and also tomatoes. Due to this, production of tomato will reduce. Early detection of disease can improve production of tomatoes. Here, 4 different diseased leaves were taken.

1.1. Healthy leaf

Figure1. Tomato Healthy Leaf

1.2. Bacterial spot

Figure2. Tomato Bacterial Spot Disease

Bacterial spot occurs on both leaves and tomatoes. This disease occurs due to xanthomonas bacteria. This disease can occur at different temperatures ranging from75 to 86 F and high precipitation. Symptoms of bacterial spots are dark brown to black circles on leaves. Spots develop to more than 3mm in diameter. Using a pesticide with chlorothalonil, mancozeb or copper, can control the disease.

1.3. Yellow leaf curl virus

Figure3. Yellow Leaf Curl Virus

Yellow curl leaf virus is from Begomovirus family and it is a DNA virus. It is most destructive disease found in tropical and subtropical regions. This virus is transmitted by insect called silverleaf whitefly or sweet potato whitefly. Symptoms of this disease is yellow leaf edges, leaf mottling and reduced the leaf size.The garden can be protected from whitefly infestations by adding floating row covers.

1.4. Late blight

Figure4. Tomato Late Blight Disease

The fungus phytophthora infestans causes late blight. This disease is also transmitted through wind. Symptoms of late blight disease is gray-green spots on leaves. Symptoms will not appear until blossom. Treatment for this disease is watering the plant in early morning and dry out during day. Destroying all tomato debris after harvest. Use copper based fungicide and organocide.

Manual detection of diseases is time consuming process. Manual detection of diseases can be done only by experts and they will suggest the proper pesticide to farmers. The expert suggestion may not be available to all farmers at all times. So, tomato leaf disease detection system which can automatically detect the tomato leaf diseases using deep learning techniques is developed. This system also suggest necessary action to be taken to prevent further loss.

Machine learning approaches are outperformed by deep learning technologies. Deep learning methods will directly extract features of images. Mostly CNN is used for feature extraction. In this proposed method, CNN (Convolutional Neural Networks) is used to detect the tomato leaf diseases. Data augmentation is applied to increase the dataset for better performance.

2. LITERATURE SURVEY

Sardogan, et al., have used Learning Vector Quantization (LVQ) neural network and Convolutional Neural Network (CNN) for detecting leaf diseases in tomato plants [19]. Tomato plants are affected by bacteria, virus and fungal diseases. CNN and LVQ are applied to a dataset consisting of 500 leaf images. Automatic feature extraction is done using CNN. The

extracted features are given as input to LVQ neural network which generate leaf diseases as output. Dataset consisting of 20 images of each leaf disease is used as test set to assess performance of model. Accuracies for different leaf disease detection techniques are in the range of 80% to 90%. By using CNN with different type and number of filters we can further improve the accuracy.

G.de luna, et al., have used faster RCNN Neural Network to Automatic image capturing of leaf disease detection found in tomato plants [2]. Diseases such asphoma rot, leaf miner and target spot harm tomato plants. AlexNet is used for anomaly detection and disease recognition. These methods are applied on a datasets consisting of 4,923 images. These diseases are identified by using Deep convolutional neural network. A test set consisting of 36 samples gave an accuracy of 91.6%. Retraining the CNN by giving more samples can improve the accuracy.

Durmus, et al., have applied deep learning methods for detecting leaf diseases in tomato plants [5]. Images from Plant village dataset are taken and leaves belonging to 10 classes which are both healthy and diseased are used. AlexNet and SqueezeNet are the two deep learning network architectures used for testing. Alexnet is the beginning of new CNN trend. SqueezeNet model is smaller than AlexNet model. SqueezeNet has less RAM size. SqueezeNet decreases the size of the filter, input channels, and network sampling latency. So, result not obtained at training phase, This lowers the accuracy. For mobile deep learning classification SqueezeNet is best. Advantage of using small network is cost is low and speed is high.

Goswami, et al., have used Sobel and Canny edge detectors, color conversion for techniques like k-means and otsu [6]. In this paper, they explained about different types of diseases which are caused by fungus, bacteria and virus. To increase the processing time and accuracy change the segmentation and feature extraction techniques. K-means segmentation is used for better accuracy. To detect the closer portion of the disease edge detector is used. SVM given better accuracy than other techniques in extracting the features.

Hidayatuloh, et al., have used SqueezeNet Architecture to identify the tomato leaf diseases [8]. SqueezeNet is one of the architectures of CNN. 7 types of tomato diseases are taken including healthy leaf. Total images are 1400 and these are taken from vegetable crop research institute Lembang. Accuracy obtained between 50% to 90% at each step. Increasing the data can improve the system for better result. Advantage of using SqueezeNet model, it is a good choice for implementing mobile device.

Jiang, et al., have applied Convolutional neural networks for detection of diseases in Apple leaves [9]. Datasets consists of 26,377 images of apple diseased leaves consists of 5 different types of diseases. They are Mosaic, Alternaria leaf spot, Brown spot, Grey spot and Rust. INAR-SSD model provides best result than other existing models. The overall accuracy obtained is 97.14%. Drawback is identification of Alternia and Gray spot are difficult due to similar characteristics. These leads to low accuracy. Advantage of this system is avoids the confusion among classes.

Kurale, et al., have used KNN, Support vector machine(SVM), and Neural Network in detecting leaf diseases like Early blight, Late blight, Black rot and Healthy [15]. Accuracies are ranging from 80% to 96%. K-means is used for segmentation, GLCM is used for feature extraction. For single database K-means is used and for multiple databases Neural network is used. KNN classifier gives better result and also reduces time when compared to other methods. Disadvantage in using k-means clustering algorithm is, it use only for single databases at a time.

Shetty, et al., have used convolution systems and semi supervised techniques to detect the leaf diseases of 4 classes containing of 5000 images [23]. The images are taken from plant village datasets. Result obtained from different methods are range between 70 to 90%. The algorithm is developed in python tool. Disadvantage of this model is overfitting.

Khitthuk, et al., have used Statistic-based gray level co-occurrence matrix to extract the disease features in plant leaf disease diagnosis on grape leaves [12]. Grape leaves are affected by diseases like rust, scab, downy, mildew. To classify the diseases, simplified fuzzy ARTMAP neural network is used. Here, to diagnose leaf disease 4 steps are used. They are leaf extraction, feature extraction, feature analysis and classification. The overall accuracy is between 92% to 96%. The result is desirable and suitable for real-world classification.

Kumar.S, et al., have discussed how different image processing techniques can be used to detect various plant leaf diseases [17].Various diseases of plants are described

and factors that led to the occurrence of disease are explained.

Arya M S, et al., applied image processing techniques to detect leaf diseases by using toolbox of matlab [1]. To classify the diseases Genetic algorithm is used and Arduino conveyor belt used to separate them. Tomato leaves, potato leaves and pepper leaves are taken as input images with diseases like late blight and leaf spot. Advantage of using this process is identification of disease in early stages. The best outcomes were obtained with less computing effort. Use Artificial neural network, Bayes classifier, Fuzzy logic and Hybrid algorithm to increase classification recognition rate.

Singh, et al., used Image segmentation technique to detect the diseases in leafs [21]. For image segmentation, genetic algorithm is applied. Genetic algorithm is employed for Automatic Detection. Five leaf disease samples are taken. Different types of plant leaves are taken as inputs. K-means classification accuracy improved from 86.54% to 93.63%. SVM classifier accuracy improved from 95.71% to 95.71%. To improve accuracy Bayes classifier, Artificial neural network, Hybrid algorithms and Fuzzy logic are used.

Vaishnnave, et al., To detect the leaf illnesses in groundnut leaves, Image is pre processed, segmented, features are extracted and classification algorithms are applied [24]. These are affected by diseases like fungi, soil borne and viruses. To classify the diseases K nearest neighbour (KNN) is used. Images are captured from mobile or camera. The training data consists of 45 images and testing data consists of 105 images.. Use of extra classifiers in feature extraction can decrease the false classification of diseases. Disadvantage is the output is dependent on whether or not K-NN is used for ordering or regression.

Shanmugam, et al., applied canny edge detection method and histogram analysis for detecting leaf diseases [20]. The images taken are remote sensing images. 7 different types of plants are taken for detection of disease. Matlab is used in training phase. To precisely detect the edges, a canny edge detection method was applied. Histogram analysis is used to get the identification of disease correctly. Here, airborne images are used, further satellite images can also be used for this approach. Advantage is detecting disease in early stages.

Dhaware, et al., have used stages such as image acquisition, pre processing the image, segmenting it, feature extraction and classification to detect the plant leaf diseases [4]. Data contain 120 images which are healthy and diseased. In image processing for background subtraction two techniques color based and cluster based are used. Cluster based subtraction will give better result than color based subtraction. To classify the disease Support vector machine (SVM) is used. Advantage is helpful to farmers.

Yadav, et al., have pre processed the images, extracted and selected important features which are then used for classification [25].Deep convolutional neural network is applied for extracting the features from image. To select the features Particle Swarm Optimization (PSO) is used. There are 23 different classes of leaf diseases. The Total number of images is 8750 and classified into 23 classes. These images are taken from Plant village datasets. AlexNet is used for feature extraction and to classify the disease Support vector machine (SVM) is used. To improve accuracy, the number of images in the input are taken should be increased. Disadvantage is the model useful for only single leaf images.

Devaraj, et al., have used pre processing, segmentation, extraction and classification to detect the leaf disease [3]. To classify the disease Random forest is used. Diseases such as leaf spots, rots and blight are caused due to fungus. Advantage is using automatic detection system using advance technology may helpful for farmers to identify disease easily.

Kaur, et al., have done a survey on plant disease identification through images [10]. Discussed about causes of diseases like bacteria, fungus, virus. Various Disease detection techniques are discussed. Crop diseases of many forms are mentioned. Overfitting problem is observed in NN, SVM and GA.

Kumari, et al., have applied leaf disease detection techniques on two varieties of plant leaves [14]. They are Target spot and bacterial leaf spot in cotton leafs and septoria leaves spot and leaf mold in tomato leaves. For Image segmentation K-means clustering is used. For classification Neural network is used. Bacterial leaf spot, Target spot and Leaf mold accuracy rates are 90%, 80% and 100% respectively. The average accuracy of classification is 92.5%. Disadvantage is some diseases are misclassified due to same similarities.

Prakash, et al., have applied various techniques to detect leaf diseases in citrus plants [16]. For segmentation K-means is used, To extract the features Statistical gray

level co-occurrence matrix (GLCM) is used and for classification Support vector machine (SVM) is used. Dataset consists of 60 leaf images of citrus plant are taken, 35 are diseased leaves and 25 are healthy leaves. Accuracy for classification is 0.90%. Advantage is diseases are classified correctly and Disadvantage is disease classification is done to single specie only.

Reddy, et al., have used K-means clustering algorithm to detect leaf diseases [18]. Matlab is used for developing models for leaf disease detection. For classification, Support vector machine is used. By using this method disease is identified at early stages itself. To extract the features, GLCM is used. Feature extraction has a drawback, i.e., noise disturbance is more at background. The rate of recognition can be improved by using stronger feature extraction and classification methods.

Kannan, et al., employed a convolution neural network with data augmentation to detect tomato leaf diseases [11]. Six different types of tomato disease leaves are taken. Data augmentation increased 4 times of the actual data. To classify, ResNet-50 is imported. The model is developed using pyTorch. Accuracy is 97%. The major drawback in this model is Training with new datasets will take more time. Advantage is this model can also detect the diseases of plants like Apple, Potato, Cucumber, Brinjal

Hari, et al., have applied convolution neural network for detection of plant leaf diseases [7]. Datasets consists of different plant varieties with both diseased and healthy leaves. Datasets are taken from freely available sources and manually. When tested in the field, the accuracy was good. Modify the architecture to improve better accuracy.

Kosamkar, et al., have utilized convolution neural network to find leaf diseases [13]. The system focuses on feature extraction and preprocessing. Datasets are taken from plantvillage. Tensor flow technology used to recommend the pesticides. Accuracy is 95.05%.

Singh. Et al., have utilized convolution neural network to find out about leaf diseases [22]. Datasets taken are healthy and diseased leaves. Accuracy is more with CNN compared to random forest classification models. Random forest model is ineffective and time consuming compared to convolution neural network. Increase the input data to give better accuracy.

3. ARCHITECTURE

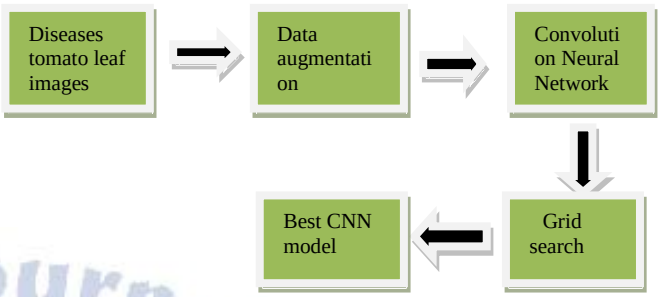


Figure5. Building the Neural Network Model

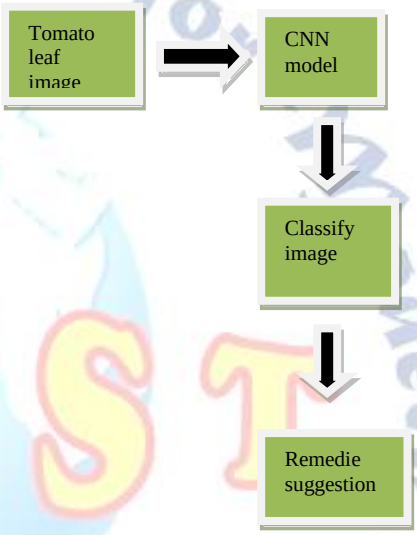
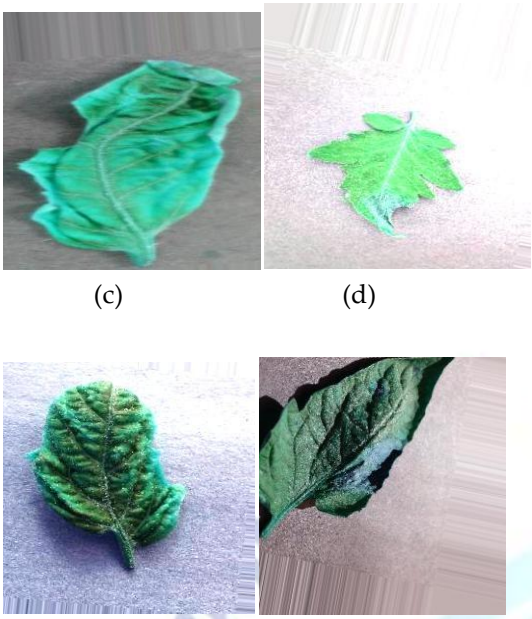


Figure6. Classification of Tomato Leaf Images

4. DATA AUGMENTATION

To expand the size of data, data augmentation is used. It will reduce the overfitting. Data augmentation gives better performance. The Techniques of data augmentation used are rotation range=15, width shift range=0.2, height shift range = 0.2, rescale = 1./255, shear range = 0.2, zoom range = 0.2, horizontal flip = True, fill mode = 'nearest', data format = 'channels last', brightness range =[0.5, 1.5].

(a) (b)



(c) (d)

(e) (f)

Figure7. Examples of Augmented Images (a) Rotation, (b) Height shift, (c) Zoom, (d) Brightness, (e) Width shift, (f) Shear

5. CONVOLUTIONAL NEURAL NETWORK

In this system, Convolutional Neural Network is used to detect the leaf diseases. It is an Artificial Neural Network and it is designed to process pixel data.5 layers of CNN are used to detect tomato leaf diseases. The important components of CNN are Convolution layers. It convolve the input data and pass the output to next layer. Pooling layers reduces the size of the data and converts outputs as cluster. Send it as single neuron to next layer. Small clusters are combined via local pooling. All neurons are affected by global pooling. The maximum value from each cluster is used in Max pooling, while the average value from each cluster is used in average pooling. Every neuron in one layer is connected to every neuron in next layer in fully connected layers. Dropout layer prevents neural network from overfitting. For Regression problems, the Half-mean-squared-error loss function is used. Categorical cross entropy is used for classification.

The Cross-entropy can be calculated using the formula:

If number of classes M equals to 2, cross entropy can be calculated as,

$$-(y\log(p) + (1-y)\log(1-p)) \qquad (1)$$

If number of classes M > 2 (i.e. multiclass classification), calculate a separate loss for each label per observation and sum the result.

$$-\sum_{c=1}^{M} y_{o,c}\log(p_{o,c}) \qquad (2)$$

Where,

M : number of classes

Log : the natural log

Y : binary indicator(0 or 1) if class label c is the correct classification for observation o

P : predicted probability observation o is of class c

6. GRID SEARCH

Grid search is a technique that finds the best hyper parameter values. This search performs on specific parameters. Grid search can save time and efforts. In this paper three hyper parameters are tuned using grid search.

- Optimizer = Adam, SGD, RMSprop
- Activation = relu, sigmoid, tanh and
- Learning rate = le-1, le-2, le-3

The results obtained from grid search are shown in table,

Table1. Grid Search Results

Optimizer	Activation	Learning Rate	Accuracy
Adam	Relu	Le-1	22.40
Adam	Relu	Le-2	27.80
Adam	Relu	Le-3	98.20
Adam	Sigmoid	Le-1	27.00
Adam	Sigmoid	Le-2	23.20
Adam	Sigmoid	Le-3	22.60
Adam	Tanh	Le-1	25.20
Adam	Tanh	Le-2	22.40
Adam	Tanh	Le-3	95.80
SGD	Relu	Le-1	94.60
SGD	Relu	Le-2	96.80
SGD	Relu	Le-3	86.00
SGD	Sigmoid	Le-1	25.00
SGD	Sigmoid	Le-2	21.00
SGD	Sigmoid	Le-3	25.80
SGD	Tanh	Le-1	92.60
SGD	Tanh	Le-2	91.60
SGD	Tanh	Le-3	40.20
RMSprop	Relu	Le-1	24.80
RMSprop	Relu	Le-2	59.20
RMSprop	Relu	Le-3	97.00
RMSprop	Sigmoid	Le-1	24.20
RMSprop	Sigmoid	Le-2	88.00
RMSprop	Sigmoid	Le-3	26.80
RMSprop	Tanh	Le-1	22.40
RMSprop	Tanh	Le-2	26.20
RMSprop	Tanh	Le-3	96.00

Best Accuracy obtained by using parameters optimizer is adam, activation is relu and learning rate is le-3 is 98.20% after data augmentation. Before data augmentation for same parameters accuracy obtained is 94.20%. so, data augmentation is a better way to obtaine good accuracy.

7. CONCLUSION AND FUTURE WORK

Tomato leaf diseases were discovered using Convolutional neural network in this study. Healthy, Yellow leaf curl virus ,Bacterial spot, and Late blight diseases leaves were among the 4 varieties of tomato leaves tested. For improved performance, the input dataset size is increased using data augmentation techniques. To find best parameters for the model, grid search is applied. The accuracy of best model when optimizer is adam, activation is relu and Learning rate is le-3 are used as parameters is 98.20%. In future, the model can be extended to detect other types of tomato leaf diseases and this model can also be used to detect leaf diseases in variety of plants. Farmers will benefit greatly from this leaf disease detection. This system helps them for early identification of the diseases. This model be used to suggest remedial measures to be taken once leaf disease is detected.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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