Review of the Application of CNNs to Detect Newly Emerging Plant Diseases

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Abstract

Early detection of diseases is a crucial factor in agriculture for ensuring the efficient growth of plants and maximizing yield. Various newly emerging diseases make the detection of diseases and hence the prevention of the crops a very difficult and complicated task. Even expert farmers can not recognize these types of diseases with direct observation of leaves with the naked eye. The only solution to detect these diseases is to use machine learning concepts. Deep learning with convolutional neural networks (CNNs) is a recent trend in the recognition and categorization of newly emerging plant diseases. In this paper, a review of the application of convolutional neural network (CNN) algorithms in detecting and classifying newly emerging plant diseases is presented.

Keywords: *Deep learning, Plant diseases, Image processing, Convolutional neural network, Data set.*

I. INTRODUCTION

Agricultural production is an antiquated means of obtaining food. Without food, no one can survive [1]-[5]. Advanced detection of plant diseases supports the prevention of huge crop losses. Farmers must apply the appropriate insecticides for their crops based on the disease. Too many pesticides are hazardous to crops [6]. If the disease is not correctly identified, the wrong use of pesticides damaged crops. When a disease is visible to the naked eye, it is easy to detect, but difficult to identify and classify the exact disease. Hence, the spotting of plant disease by human visualization is a more complicated task and less potent. As it is done with a limited set of leaf images, in many cases, it may end up in wrong conclusions about the disease. Hence, automatic identification techniques are the best solutions for the early detection of diseases, as they take less effort, and time, and provide more accuracy [7].

Farmers will be benefited much from the introduction of automated disease detection tools [8]. In the literature, the application of image processing and convolutional neural networks are widely used to detect diseases [9]-[12]. This technique uses the image of the leaf and a computer performs numerous aspects for the identification and detection of the related diseases to which that image belongs. The CNN models are widely used to train the system on both healthy and sick leaves based on the data set [10]. The trained system predicts output in response to the image of the input leaf [13]. The common plant diseases in the present day scenario are Apple black rot [1], Potato early blight [2], Tomato mosaic virus [8], Northern corn leaf blight [11], etc., which are difficult to be identified by farmers with the naked eye. Hence, this method is a more accurate method to resolve this problem [14]-[16]. The characteristics of present day diseases are:

1. Apple Black rot:

This disease is caused by the fungus Botryosphaeria obtusa. Diseased limbs show symptoms that resemble fire blight [15]. They seem as reddish-brown sunken areas with large stony cracked bark. The main characteristic for identification is leaf lesions start as very small purple spots [18]-[21]. As they grow up, there is a brown-tan center with darker margins and a purple outline that resemble a frog's eye, this stage is called frog-eye disease.

Fig (1). Apple Black rot

2. Potato Early blight:

Early blight is originated by the fungus Alternaria solani. This disease in essence affects stems and leaves [2]. The main characteristic to identify this disease is circular dark brown spots on the lower leaves.

Fig (2). Potato early blight

3. Tomato mosaic virus

Tomato mosaic virus is a vital and extremely contagious disease and is also rigid to find [8]. It can be found in any growth stage of a plant. The main characteristic to identify this disease is leaves may glance akin to ferns with elevated dark green regions and also become stunted.

Fig (3). Tomato mosaic virus

4. Northern corn leaf blight

It is caused by the fungus Setosphaeria turcica. Traits rise mainly on underneath leaves, leaf lesions are long (one to six inches) & ovoid, grey-green at the first time but then turn into pale grey or tan. Under moisture conditions, dark grey spores are generated [9].

Fig (4). Northern corn leaf blight

5. Rice Leaf smut

It is caused by the fungus Entyloma oryzae. This fungus produces raised pointed black spots on both sides of the leaves. Infection is heavy enough to kill the tips of leaves [6].

Fig (5). Rice Leaf smut

The diseases and characteristics of detection are tabulated in TABLE I.

TABLE I: Diseases and Recognition Method

Disease	Characteristics
Apple Black rot [1]	Leaf lesions start as very little purple spots and frog-eye structures.
Potato early blight [2]	Circular dark brown spots on the lower leaves.
Tomato mosaic virus [8]	Leaves may glance akin to ferns with raised dark green regions and also become stunted.
Northern corn leaf blight [9]	On underneath leaves, leaf lesions are long & ovoid, gray-green at the first time but then turn into pale gray or tan.
Rice leaf smut [6]	Pointed black spots on both sides of the leaves.

CNNs is a breed of deep neural network and it has become a more significant part of computer vision [23]-[27].This computer vision responsibility is to enable the system and computer to take relevant information from digital images, visual inputs and videos. CNNs works by using series of convolutional layers, which apply filter to the input image that helps to extract important features and patterns from data [28].

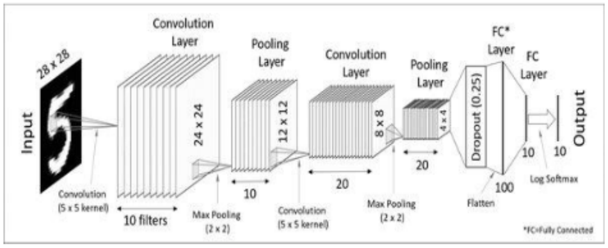
CNN layers -: Typically it consists of 3 layers.

Convolutional layer:

This layer is the elementary unit of CNNs. The component in this layer is filter/Kernel which performs convolution operations [26]. Nonlinear-activation function is also be the part of this layer. The major function of this layer is applies set of filters to the input image to bring out relevant information from it [29]-

[32].Every filter is a small matrix that glides over the image and perform mathematical operations.

Fig (a). A typical CNN



Pooling layer:

The main task of this layer is to reduce the dimension of images while take care of their important attributes [33].Window size and stride are the hyper parameter of the pooling layer [34].There are 2 classes of pooling, one is Max pooling which takes maximal element from each of the window . Another one is average pooling that enumerates the moderate of elements present in the field of feature map which is surrounded by the filter [35].

Fully connected layer:

The final classification decision is done by this layer and it also connect the neurons between two different layers [36]-[38].It applies set of weights to the input data and produces the output that corresponds to the class probabilities [39].

II. LITERATURE SURVEY

This part consists of research on CNN with different technologies.

Sheikh MH, Mim TT, Reza MS, Hena MH, proposed "Leaf Diseases Detection for Commercial Cultivation of Obsolete Fruit in Bangladesh using Image Processing System" [1]. They worked on obsolete fruits of Bangladesh and collected about 5000 images for a dataset. There are 8 different fruit images and about ten variety of diseases detected.

For images, an RGB color model has been used. It has a ReLU activation function and multiple layers. For decreasing the learning rate Adam algorithm is implemented. The accuracy obtained from this system is 92.56%.

Alok Kumar and Ankit Kumar, proposed plant disease detection using VGG 16 [2]. In this paper, they did a plant disease detection system using convolutional neural network architecture. For the classification and extraction of images, they referred VGG 16 algorithm. They worked on potato and tomato diseases which results in an accuracy of 94.6% and 88.6% respectively.

Nishant Shelar, Suraj Shinde, Shubham Sawant, Shreyash Dhumal, and Kausar Fakir, proposed plant disease detection using CNN [3]. In this paper, a CNN model is used for the automatic noticing and classification of plant leaf disease. They tested their proposed model on 13 different species with 38 classes. They work with image generator API by Keras, from this, they can do image processing. Also, they created VGG 19 model for prediction which is an advanced convolution model. Finally, they deployed it to the Android app. The accuracy obtained from this model is 95.6%.

Omkar Mindhe, Omkar Kurkute, Shrutika Naxikar, and Prof. Nikhil Raje, proposed "Plant Disease Detection using Deep Learning" [4]. This paper is capable of detecting fourteen crop species and twenty six common diseases. They use ResNet 34 as a neural network. They also developed a web application to make the project accessible worldwide. The accuracy obtained is 96.21%.

Manvi, G. G., N, G. K., Sree, G. R., Divyanjali, K., & Patil, K.,proposed "Plant Disease

Detection using Deep learning" [5]. This project is based on deep learning and fostering a web application. This web application distinguishes plant infections. The dataset consists of 61,486 images and 35 classes. They developed the web application using Flask. In that web application, they upload the image and detect what kind of disease it has and also provide the solution. The accuracy obtained from this paper is 96.7%.

Ahmed, Kawcher & Shahidi, Tasmia & Irfanul Alam, Syed & Momen, Sifat, proposed "Rice Leaf Disease Detection Using Machine Learning Techniques" [6]. This paper uses machine learning to detect 3 different rice leaf diseases (bacterial leaf blight, brown spot, and leaf smut). They work on four different algorithms, they are KNN, decision tree, Logistic regression, and Naive Bayes. Different accuracy levels are obtained from these four algorithms. Finally, they found the best accuracy of about 97.9167% with the help of a decision tree algorithm.

Bhairu Jangid and As, Prof.R.S. Sharma, proposed rice disease detection using Deep learning VGG-16 model and Flask [7]. In this paper, the disease of rice plants was exhibited using the VGG 16 model. For the identification of diseases, they collected 4500 rice plants pictures. They got 90% accuracy from this model.

Sunil S.Harakannanavar, Jayashri M.Rudagi, Veena Puranikmath, Ayesha Siddiqua, and R Pramodhini, proposed plant leaf disease detection using computer vision and machine learning algorithms [8]. They used computer vision procedures with RGB turning to gray, K-means clustering, HE, & contour aligning in pre-processing steps. The principal component analysis, multiple descriptors discrete wavelet transform, and GLCM are used to take out instructive characteristics of leaves samples. Machine learning paths such as SVM, K-NN, and CNN are used to differentiate infected or no-diseased leaves. In the future, they are looking for a fusion technique for the extraction of significant attributes. The proposed method DWT+PCA+GLCM+CNN gave 99.09 % accuracy.

Hassan, Sk & Maji, Arnab & Jasiński, Michał &Leonowicz, Zbigniew & Jasińska, Elżbieta,proposed . "Identification of Plant-Leaf Diseases Using CNN and Transfer-Learning Approach" [9]. In this paper, they implemented the identification of diseases in the early stage and improved the production of cultivated crops. Mainly in this paper, they put back convolution with depth-distinguishable convolution which bring down the number of parameters of computational cost. They included 14 types of plant species with 38 types of diseases in the dataset. Similar functions like the human brain DL can solve complex problems with high validity with a low flaws.They'used`AlexNet,VGGNet16,InceptionV1,InceptionV3,ResNet152,ResNet101,InceptionResNetV2,MobileNetV1,MobileNetV2,EfficeientNet B0 models. In this model leaves are classified into two sets one is the train set and another one is the testing set. Evaluation process they split the image into 3 types of sets namely 80-20%(80% of training set and 20% of testing test),70%-30%, and 60%-40%. The complete process of performance of the models testing accuracy is AlexNet 98.64%, VGG 98.87%, ResNet 92.56%, CNN 97.11%, Inception-V3 98.42%, InceptionResNet-V2 99.11%. The highest victories classification accuracy aquired in EfficientNet B0 was 99.56%.

M. E. H. Chowdhury et al., proposed "Automatic and Reliable Leaf Disease Detection Using Deep Learning Techniques"

[10]. In this paper, they developed a deep convolutional neural network based on a latterly developed Efficient CNN model. This EfficientNet B7 was superior at an intolerance features from images compared to other architecture. This paper inspect how model scaling CNN –based architecture performed opposed to each other in 2 tasks i.e., fractionalization and categorization of tomato images. This study was splitted into 3 sub-tasks (2 classes, 6 classes, and 10 classes). In the twin grouping of healthy and infected tomato leaves, the EfficientNet-B7 model be revealed an all-inclusive accuracy of 99.95%.

Syarief, Mohammad & Setiawan, Wahyudi proposed a "Convolutional neural network for maize leaf disease image classification" [11]. This paper classified images using 7 architectures and three classification methods (SVM, KNN, and Decision Tree). Generated best categorization by AlexNet with SVM gives 95% efficiency.

Rani, Pushpa Athisaya Sakila, and N. Suresh Singh, proposed "Paddy leaf symptom-based disease classification using deep CNN with ResNet-50" [12]. In this paper, they compared their proposed model with some algorithms- Genetic algorithm (96%), Adaboost algorithm (88%) and Bagging algorithm (86%). From the comparison, it was proved the proposed model Deep CNN with ResNet 50 gave better accuracy of 97.3%.

The accuracy for different algorithm models available in the literature is tabulated in TABLE II.

TABLE II. Accuracy Table.

Reference	Disease	Algorithm model	Overall Accuracy (%)
[1]	Apple Black rot	CNN+RGB color model	92.56
[2]	Tomato mosaic virus	VGG 16	88.6
	Potato Early blight		94.6
[3]	Potato Early blight	VGG 19	95.6
[4]	Apple Black rot	ResNet 34	96.21
[5]	Potato Early blight Apple Black rot	CNN +Flask web application	96.7
[6]	Rice leaf smut	KNN	72.9167
		Logistic regression	70.8333
		Decision tree	97.9167
		Naïve Bayes	50
[7]	Rice leaf smut	VGG 16	90
[8]	Tomato mosaic virus	K means clustering+ GLCM+SVM	89
		LBP+PCA+KNN+K means clustering	97.3

		DWT+PCA+GLCM+CNN	99.09
[9]	Tomato mosaic virus, Northern corn leaf blight, Potato Early blight, Apple Black rot	Inception V3	98.42
		InceptionResNetV2	99.11
		MobilenetV2	97.02
		EfficientNet B0	99.56
[10]	Tomato mosaic virus	EfficientNet B7	99.95
[11]	Northern corn leaf blight	AlexNet + SVM	95
[12]	Rice leaf smut	Deep CNN with ResNet 50	97.3

Pros and Cons for different algorithms are tabulated in TABLE III.

TABLE III. Algorithms Pros and Cons

Algorithms	**Pros**	**Cons**
VGG 16 [2] [7] [31] [35] [15] [17]	The simplest algorithm and results were amazing with an average score of 92.7% on ImageNet.	A large number of weight parameters, which is 550 Mb in size, leads to the model being large in size.
VGG 19 [3] [37] [35] [17]	It extracts rich features from the image and has a large number of pre-trained models.	Large model size and limited flexibility (may not be suitable for all CV).
ResNet 34 [4][14] [15]	Lower error percentage compare to plain-34.	Complexity is more and requires a large memory size.
K-NN [6][8] [20] [36]	Simplest and can be used for both classification and regression.	Slow algorithm and efficiency decrease when the size of the data set grows.
K means clustering [8] [18] [21] [38]	Scales to a large dataset.	Choosing k manually and clustering data of varying sizes.
Decision Tree [6][14]	Less effort for data preparation during pre-processing.	Relatively expensive as the complexity and it is unstable.
Logistic regression [6][14] [19]	This allows models to be updated easily unlike decision tree.	Requires large data set.
Naïve Bayes [6] [25]	Easy to implement and does not require as much training data.	Its estimation can be wrong in some cases. So we couldn't take the result very

		seriously.
AlexNet [11] [16] [24] [35]	It uses the ReLu activation function, and because of this function, there are not too many loss features.	It takes more time to achieve high accuracy.
SVM [8] [11] [18] [22] [23] [28]	More effective in high-dimensional places.	Not perform very well when the dataset has additional noise.
EfficientNet B0 [9] [40]	Higher accuracy and reduce computation list, and battery usage.	Works poorly on hardware accelerators.
InceptionResNetV2 [9][29]	Tutor on likewise a million images from ImageNet database.	Due to the complex structure, it takes more time.
InceptionV3 [9][27] [34][33] [39]	Greater than 78% accuracy on the ImageNet database.	Time-consuming and requires high computational power.
EfficientNet B7 [10] [32] [40]	Obtained by scaling the baseline network (EfficientNet B0) having a high accuracy rate.	Works poorly on hardware accelerators.

III. CONCLUSION

The primary objective of agriculture is to increase production yield. However, many emerging diseases are the daunting challenge of the present-day scenario. If the diseases are detected at the early stage and remedial measures are taken, good yield can be ensured. By visualization methods, experts may be able to find diseases, but accuracy cannot be maintained. The latest trend is to use modern technology in the early recognition and categorization of diseases. Recent developments in image processing and machine learning have proven the way for combining them to collect sample images of the leaves and apply machine algorithms to train the system so that it will be able to identify the diseases and classify them according to symptoms of the diseases later. As CNN system provides high processing speed and accuracy, researchers have extensively used it in the early detection of plant diseases. In this paper, we have presented a survey of CNN-based systems proposed by the researchers. It is found that CNN based method provides the highest accuracy among all the methods available as of now.

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