

Pest and Disease Video Classification with Convolutional Neural Network and Transfer Learning

ABSTRACT

The important field crops of agriculture are affected due to attack of various pests and diseases which leads to reduction in crop production. Early classification and identification of pests and diseases in plant helps farmers to take mitigation steps. To address this issue with computer vision based techniques, convolutional neural network (CNN) based deep learning models were studied for classification of pests and diseases videos. Six different CNN models were developed. Two approaches namely from scratch learning and transfer learning were used, with data augmentation techniques such as reflection, scaling, rotation, and translation are also applied to prevent the network from overfitting. The classification accuracy of 99.19%, 99.08% and 98.80% was attained in VGG19, DENSENET201 and CNN 5 Layer model. The results demonstrated that CNN models with good architecture can classify pests and diseases with good performance.

Keywords: Convolutional Neural Network, Pest and Disease Classification, Video Classification, Transfer Learning

1. INTRODUCTION

Plant pests and diseases are responsible for major economic losses in the agricultural production. Timely detecting and identifying them is essential to cure and control them. Traditional manual identification of insects is typically labour-intensive, time-consuming and inefficient. The computer vision based techniques of image processing using machine learning was developed for accurate classification and identification of pests and diseases to overcome these problems in agriculture research field. (Thenmozhi & Srinivasulu Reddy, 2019) have developed crop pest classification model based on deep convolutional neural network and transfer learning and the results demonstrated that the proposed CNN model is effective in classifying various types of insects in field crops. (Zhang et al., 2019) have proposed cucumber leaf disease identification with global pooling dilated convolutional neural network and suggested three improvements over the classical neural network (CNN) and AlexNet models. Experimental results on the datasets of six common cucumber leaf diseases demonstrate that the proposed model can effectively recognize cucumber diseases. (Ferentinos, 2018) has describes convolutional neural network models to perform plant disease detection and diagnosis using simple leaves images of healthy and disease plants through deep learning methodologies. Several model architectures were trained, with the best success rate of 99.53%. (Kamilaris & Prenafeta-Boldú, 2018) have presented a survey on the use of deep learning in agriculture. In his paper, a survey of 40 research efforts that employ deep learning techniques were studied and findings indicate that deep learning provides high accuracy, outperforming existing commonly used image processing techniques. (Saleem et al., 2019) have studied different handcrafted visual leaf features, their extraction techniques, and classification methods and concluded that AlexNet, a Convolution Neural Network(CNN) based approach is outperformer and robust when the training dataset is small. (Da Silva et al., 2019) have evaluated three CNN architectures (AlexNet, VGGNet and ResNet) with synthetic images for estimating soybean leaf defoliation and found that root mean square error of only 4.57%, which is an expressive result for leaves with severe

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defoliation. (Picon et al., 2019) have presented that over the last years, a number of image analysis based methodologies have been proposed for automatic image disease identification. Among these methods, the use of Deep Convolutional Neural Networks (CNNs) has proven tremendously successful for different visual classification tasks. (Uzal et al., 2018) have presented a study to estimate seed-per-pod for plant breeding using deep learning and highlighted the particularly high increase in generalization capabilities of a deep learning(CNN) approach over a classic machine vision approach. (Barbedo, 2018) presented an investigation on the application of the concepts of deep learning and transfer learning to the problem of plant disease classification and concluded that CNNs are indeed powerful tools that can suitably deal with plant pathology problems. (O'Shea & Nash, 2015) outlined the basic concepts of Convolutional Neural Networks explaining the layers required to build one and detailing how best the structure the network in most image analysis tasks. (Padmanabhan, n.d.) explored the use of convolution neural networks(CNNs) for the image classification and image captioning problems. He concluded that deep learning is an extremely powerful tool. Tuning hyper parameters also proved to boost the performance of CNN models by a good amount. (Mohammed Inayathulla et al., 2020) proposed a methodology to calculate the screen time of characters appearing in the video by using classification-count method. Supervised learning methodology with Convolutional Neural Network as the classifier is used in this paper. (Islam et al., 2021) reviewed on different approaches and methods in video classification with their advantages, findings, limitations, challenges, data summary, research gaps and performance. It is concluded that video based approach for video classification works better over text and audio. (Butt et al., 2020) presented a study to detect video surveillance using VGG19 and the proposed system outperformed with 81% accuracy as compared to state of the art systems. (Ramesh et al., 2020) studied a simple convolutional neural network on Video Classification. This network gave less computational cost and good accuracy rate. (Ren et al., 2019) surveyed on video classification methods based on deep learning and analyzed the differences in performance of typical algorithms, summarized the commonly used video classification datasets. (Deshpande et al., 2020) studies video classification using machine learning and concluded that convolutional neural networks are accustomed detect features within the video images. (Karpathy et al., n.d.) studied large scale video classification with convolutional neural network and concluded that the convolutional neural networks are capable of learning powerful features from weakly labeled data that far surpass feature based methods in performance. (Rachmadi et al., 2016) presented a video classification system by combining the keyframe extractor system and convolutional neural network (CNN) classifier. As a result, the system is effective and the average accuracy is increased compared with the system without using the key frame extractor system.

2. MATERIAL AND METHODS

2.1 Data Collection

In the experiment, video clips for four different pests and diseases are collected from BTRS (Bidi Tobacco Research Farm) and MVRS (Main Vegetable Research Farm) of Anand Agricultural University. The video clips are prepared in day light field condition using Redmi Note Pro 10 mobile camera with 30 fps. The video clip length is 5-15 seconds and recording format is .mp4. The details are presented in Table 1 and Figure 1.

Table 1. Pests and Diseases

#	Crop/Plant	Pest and Disease Name	Video Image	Center
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1.	Tobacco	<i>Helicoverpa armigera</i> (Hub) (Common Name: Catterpillar)		BTRS
2.	Brinjal	Fruit Shoot Borer		MVRS
3.	Chilli	Leaf Curl		MVRS
4.	Tobacco	White Spot		BTRS

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Figure 1. Pests and Diseases Dataset (PDD)

2.2 Data Preprocessing

The video classification task of convolutional neural network requires video frames as images. Hence, video clips need to be transformed into image frames as presented in Table 2. Considering spatiotemporal nature of video, every third frame is extracted and stored as image from each video clip. As a result, we get image data set from more number of video clips. It will reduce the dataset size which ultimately leads to less training time for model, less computing power and memory requirements.

Table 2. Extracted images from video clips

Pest and Disease Name	PDD Dataset (Extract every 3rd image)
HelicoverpaArmigera(Catterpillar)	2152
Fruit Shoot Borer	2301
Leaf Curl	2043
White Spot	2188
Total Images	8684

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2.3 Data Augmentation

Data augmentation is a technique of artificially increasing the training set by creating modified copies of a dataset using existing data. It includes making minor changes to the dataset or using deep learning to generate new data points. Augmented data is driven from original data with some minor changes. We make geometric and color space transformation such as flipping, resizing, cropping, brightness and contrast to increase the size and diversity of the training set. Augmentation prevents models from over fitting and improves model accuracy. (A Complete Guide to Data Augmentation | DataCamp, n.d.)

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2.4 Transfer Learning

In this study, transfer learning approach was applied to retrain CNN models. The CNN learning models contain layered architecture with different layers to learn complex features of the images and finally, all these layers are connected to a fully connected layer to get the final results. In transfer learning, this layered architecture is allowed to use the pre-trained models without its final classification layer as fixed feature extractor to achieve better classification performance with less training time. We mainly explored three deep learning models based on CNN such as such as ResNet101V2, VGG19, DENSENET201 for classification.

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2.5 CNN Architecture

We explored different model architectures with the main structure as depicted in Figure (2) and (3). The CNN Architecture with training from scratch is explored with three, four and five CNN layers and four dense layers. The CNN Architecture with transfer learning was explored with ResNet101V2, VGG19, DENSENET201 with four dense layers.

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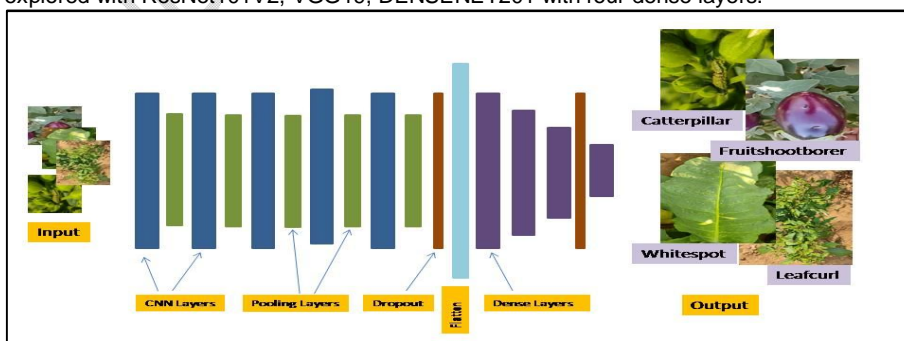


Figure 2. CNN Architecture – Training from scratch

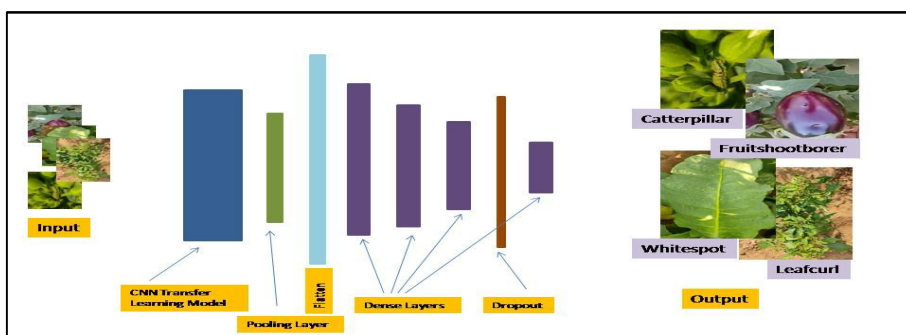


Figure 3. CNN Architecture – Transfer Learning

2.6 Parameters

All CNN models were trained using the following training parameters.

- No. Of Hidden Layers: Four
- Dropout: 0.20
- Activation Function: ReLU, Softmax
- No. Of Epoch: 25
- Learning Rate: 0.001
- Batch size: 32
- Optimizer: Adam
- [Learning Rate: 0.001, decay rate(beta1):0.9 decay rate(beta 2):0.999, epsilon: 10e-8]
- Data Augmentation:[RandomFlip: Horizontal and Vertical
RandomRotation: 0.1, RandomZoom: 0.1, RandomContrast: 0.1]
- Rescaling: 1.0/255
- Loss Function: SparseCategoricalCrossEntropy
- Training Validation Split : 80% : 20%[Training images: 6948 Validation Images: 1736]

2.7 Deployment

All CNN Models were deployed on Google Colab platform. Dataset was stored on Google Drive for training, validation and testing. All models were trained, validated and tested using GPU hardware support, Python environment with Tensorflow and Keras library.

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3. RESULTS AND DISCUSSION

3.1 Evaluation Metrics

The accuracy of the proposed classifier has been computed using the following expression which uses numerical details of correctly classified images from total sample space of pest and disease images in the dataset.

$$\% \text{ Accuracy} = \left(\frac{\text{no. of correctly recognized samples}}{\text{total no. of samples}} \right) \times 100$$

The precision, recall and F1 score are also the important measures to consider for system evaluation and are calculated as below respectively.

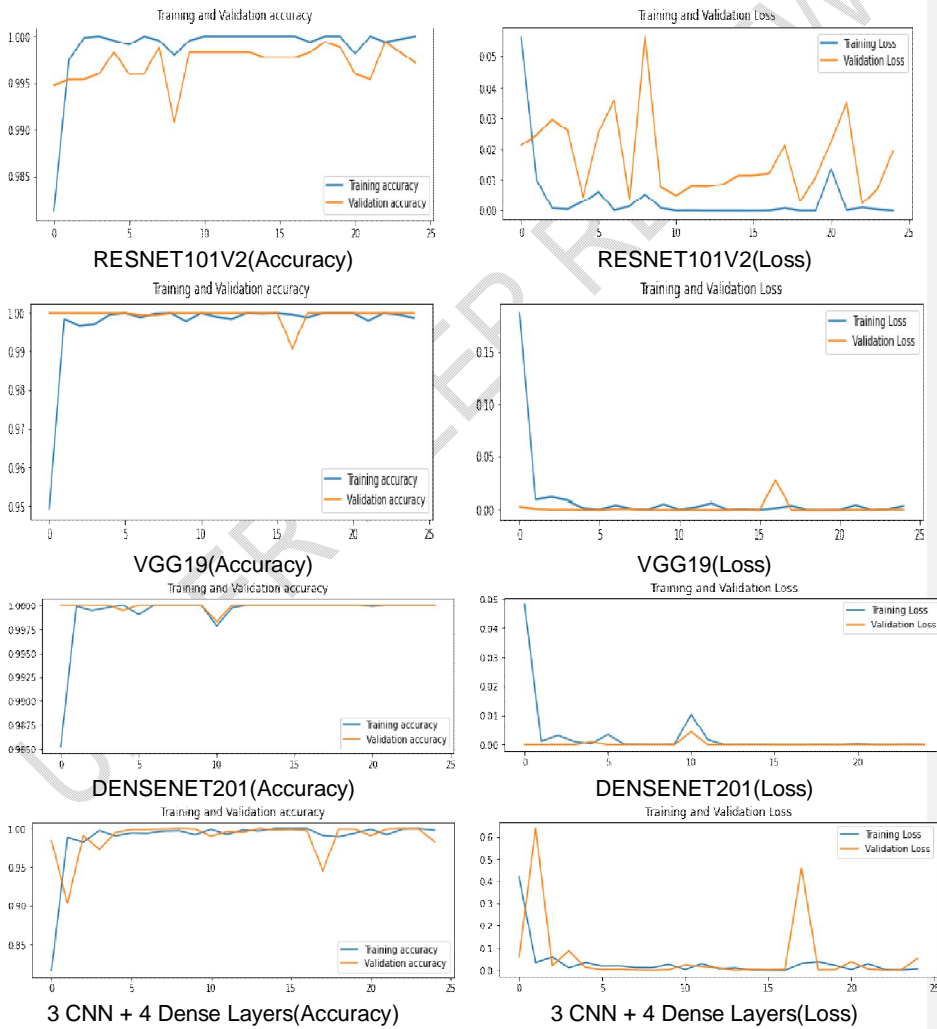
$$\text{Precision} = \frac{\sum \text{True Positive}}{\sum \text{Predicted Condition Positive}} \times 100$$

$$Recall = \frac{\sum True\ Positive}{\sum Condition\ Positive} \times 100$$

$$F1\ Score = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

3.2 Training and Validation Results

All CNN Models were trained using the training parameters. The Comparison of the models for the training and validation data set shown in Figure 4.



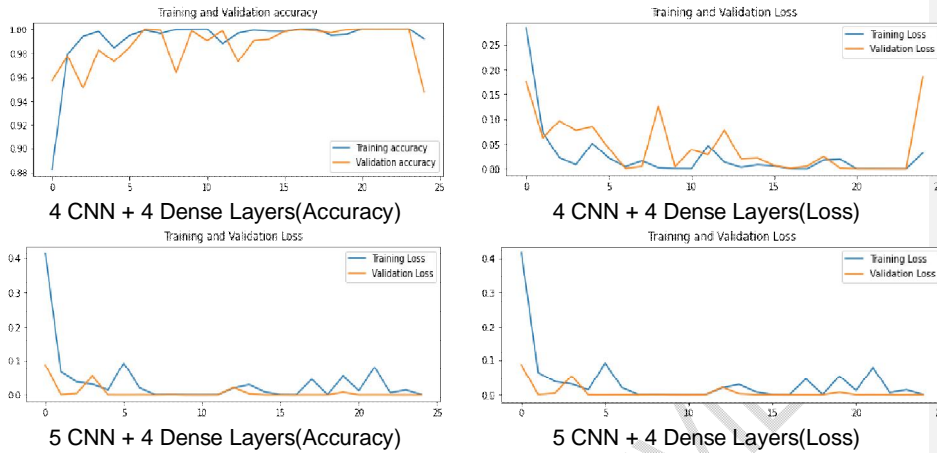


Figure 4. Accuracy – Loss Graph for Training and Validation Data Set

From Figure 4, it can be seen that all six CNN models showed very good accuracy. Each model was trained for twenty five epochs and their training and validation results are recorded for accuracy and loss parameters.

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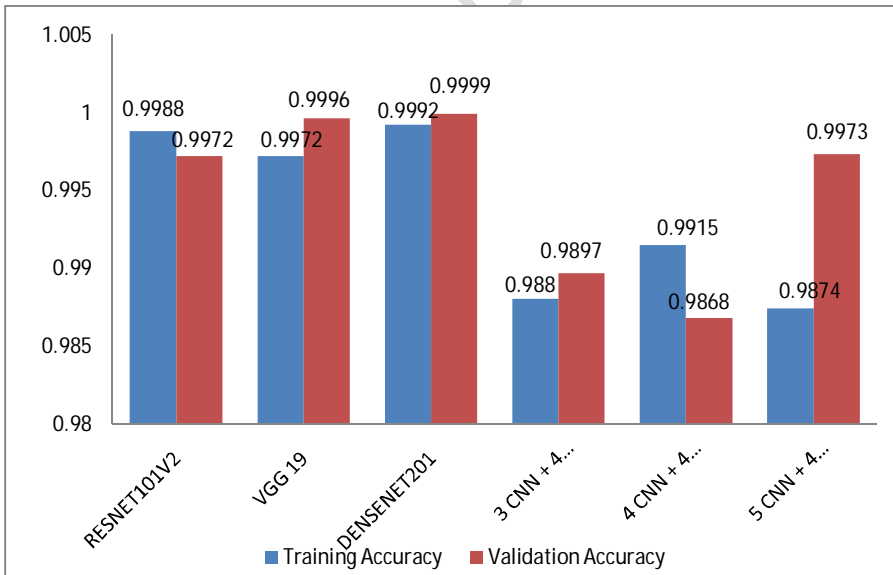


Figure 5. Training and Validation Accuracy

From Figure 5, it can be seen that among six CNN models, transfer learning models namely RESNET101V2, VGG19 and DENSENET201 are better in accuracy compare to scratch learning models with different number of CNN Layers. It also validates ((Kaya et al., 2019) that transfer learning aims to reuse the model and acquired knowledge, and likewise

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to decrease the model development time dramatically, and improves the model performance of the isolated learning model.

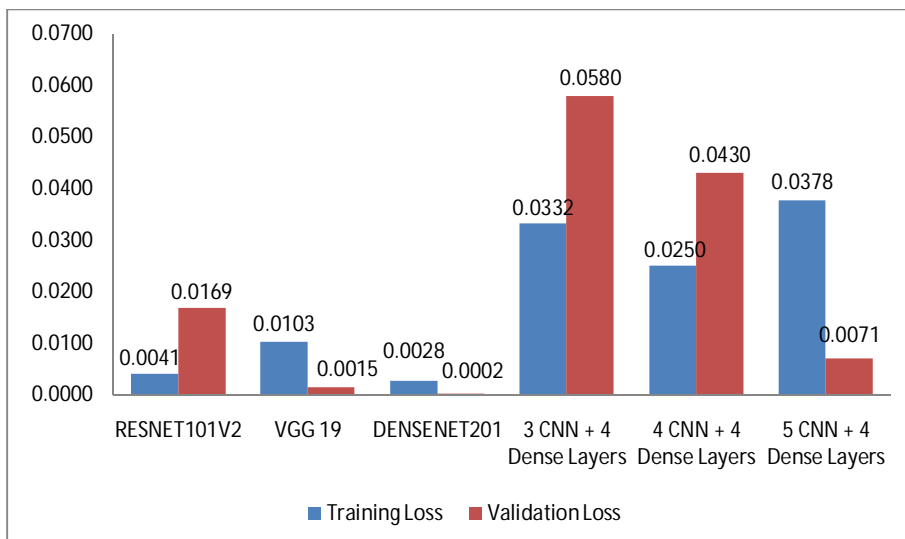


Figure 6. Training and Validation Loss

From Figure 6, it can be seen that among six CNN models, transfer learning models namely RESNET101V2, VGG19 and DENSENET201 are better in loss parameter compared to scratch learning models with different number of CNN Layers.

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3.3 Testing Results

A testing dataset having the size same as validation dataset is also prepared, tested with all six CNN models and results are presented in Table 3.

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Table 3. Performance of different CNN Models for test dataset

Performance Metrics CNN Models	Accuracy	Precision	Recall	F1 Score
RESNET101V2	0.9883	0.9758	0.9778	0.9762
VGG 19	0.9919	0.9830	0.9829	0.9830
DENSENET201	0.9908	0.9809	0.9807	0.9808
3 CNN + 4 Dense Layers	0.9695	0.9378	0.9375	0.9371
4 CNN + 4 Dense Layers	0.9738	0.9463	0.9517	0.9440

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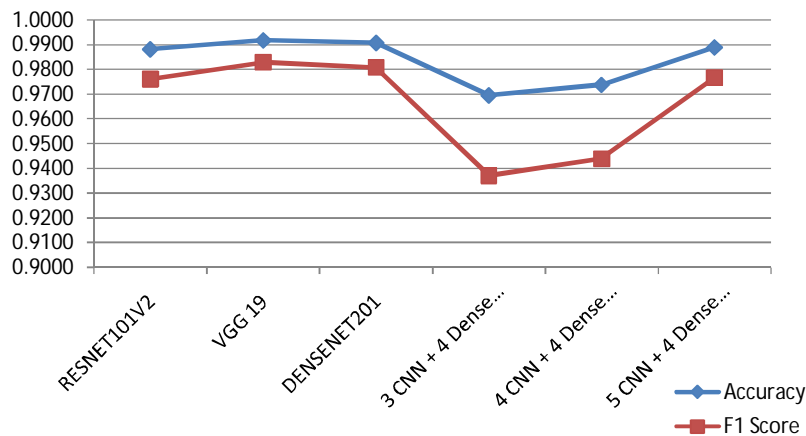


Figure 7. Performance Metrics for different CNN Models for test dataset

From Table 4 and Figure 7, it can be seen that among six CNN models, transfer learning models namely VGG19 and DENSENET201; scratch learning model with 5 CNN layers have are out perform based on accuracy and F1-score parameters.

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4. CONCLUSION

In this work, convolutional neural network architectures based deep learning models were studied. Total of six different models, three with transfer learning and three with scratch models were developed for the classification of pests and plant diseases through videos of pests and diseases of diseased plants. The training of the models was performed using dataset prepared at Anand Agricultural University Farms. The most successful model architecture, VGG19 transfer learning convolutional neural network, achieved a success rate of 99.19%. Other transfer learning convolutional neural network DENSENET201 achieved a success rate of 99.08% followed by scratch learning model CNN 5 Layers with a success rate of 98.90%. Based on this study, it becomes evident that convolutional neural networks are highly suitable for the automated classification of pests and plant diseases. As application of drone technology is increasing in agriculture, the classifier model has a place to automatically classify drone recorded videos.

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