

Rice Diseases Pests and Nutritional Deficiency Classification using Convolutional Neural Network

Yusha Bhabay¹ and Anand Mane²

¹⁻²Sardar Patel Institute of Technology, Mumbai-400058, India
Email: yusha.bhabay@spit.ac.in, anand_mane@spit.ac.in

Abstract— The major cereals crops cultivated in India is wheat, pearl millet, rice, sorghum and maize they accounts for around 52% of the total crop cultivation. India being the second largest producer of rice after China exports rice to over 150 countries in the world. In order to increase the productivity to the fullest the crop field must be free from the diseases (fungal and bacterial), viruses, pests and nutritional deficiencies. As the rice crop gets affected due to the diseases like brown spot, sheath blight, blast, sheath rot and etc. if not detected can kill the rice leaf. There are some major pests of the rice crop attacks every portion of plant stem bores, leaf hoppers, grain sucking insects, root feeders, defoliators and etc. These pests usually disturb the plant growth cycle by sucking the plant sap, reducing root system, damaging shoots and reduces photosynthetic capacity thereby reducing yields. Also some symptoms on leaf appears when the plant suffers from nutritional deficiencies: micro nutrients required in greater quantity whereas macro-nutrients required in small quantities. In order to increase the crop exports and to feed the growing population the crop field must be free from all the pests, diseases and deficiencies. In this paper we proposed a model which detects the rice crop pests, diseases and primary nutritional deficiencies with good accuracy in the real time. In our experiments we have trained multiple transfer learning algorithms InceptionV3, VGG19, Xception, InceptionResNetV2 and also a CNN model without transfer learning. The models are trained on the datasets from the kaggle database and the accuracy of different models are compared and finally with InceptionV3 and InceptionResNetV2 model we achieved a best validation accuracy of 95.56%.

Index Terms— Deep Learning, convolutional Neural Network, Transfer Learning, InceptionV3, VGG19, Xception and InceptionResNetV2.

I. INTRODUCTION

In India rice is cultivated in approximately half the total states with a major production in West Bengal, Tamil Nadu, Uttar Pradesh, Chhattisgarh, Punjab, Andhra Pradesh, Assam, Bihar Haryana and Odisha. According to the Directorate General of Commercial Intelligence and Statistics data, India had exported non-basmati rice USD 2 billion in 2019-20 compared to USD 4.8 billion in 2020-21 and USD 6.11 billion in 2021-22 [21]. The need for the rice crop from various countries are increasing every year also the population of India and other countries are also increasing to feed these growing population and to export the rice crop the crop field must be free from the fungal, bacterial diseases also from the pests and nutritional deficiencies.

The rice plant diseases includes nursery diseases and main field diseases. Blast, Bacterial Blight and Rice Tungro are the nursery diseases whereas Brown Spot, Sheath Rot, Sheath Blight, False Smut, Leaf Streak and

etc. are the main field diseases.

Blast: It is the very important fungal disease worldwide because of the destruction it may cause to the entire field. The leaf shows elliptical spots with red-brown margins and greyish white centre. In case of high infection it can kill plant at a growing stages causing yield loss.

Bacterial Blight: It is a bacterial disease found on the edges and the tip of the leaf with the water-soaked lesion initially and later gray-white lesion and finally dries out results in poor grain quality.

Rice Tungro: It is a viral disease the plants shows yellow-orange discoloration which starts from the tip and gradually covers the whole blade. It is transmitted to other plant by hopers causing the entire field infection leads to partially filling grains.

Sheath Rot: It is also a fungus disease which covers the major leaf part. On the Sheath some irregular spots appears with a gray centre and brown margin or sometimes may be gray-brown throughout causing grain discolouration.

Sheath Blight: It is also a fungal disease which is found on the sheet having gray-white centre with dark brown irregular outlines. It has the ability to reduce the crop yield by 50%.

False Smut: It is also a fungal disease. It occurs during the grain ripening stages initially the smut balls are in orange colour later they turn green-black. It does not contribute in major crop loss but it threatens food safety.

Leaf Streak: It is also a fungal disease. Initially it appears as a small dark green streak on a leaf later it turns yellow or brown in colour. It reduces the leaf area causing reduction in photosynthesis hence reduces crop yield. Infection from the pest on the rice crop can be found on all parts of plants including leaf, neck and node. They also attacks the rice grains during the storage. Some major pests includes stem bores, leaf hoppers, grain sucking insects, root feeders, defoliators and etc.

Stem Borers: The stem borer insects feed in the stem during the growth stage the eggs are layed by moth on the rice leaf, from the egg larva bore into the stem of rice plant causing the death of shoot resulting in no panicles which means no grain.

Leaf Hopper: Leaf hoppers are the sucking insects feeds onto the stem and absorbs the plant juice causing the plant to completely dry out, it also works in transmitting the disease known as tungro in the crop field.

Grain sucking insects: These bugs penetrates the growing grain and sucks the white fluid from the grains causing no filling of grains.

Root Feeders: Rice water weevil and Termites are the examples of root feeder these pests feed onto the roots and drastically reduce root system causing the reduction in growth and low yield.

Defoliators: Number of larvae and beetles comes under this category which feeds onto the rice leaf reducing the overall rice area resulting in the reduction of photosynthetic process of plant and low yield.

There are some essential nutrients which is required for humans, animals as well as plants. Rice crops suffers from the different nutritional deficiencies which include primary nutrients, secondary nutrient (micro-nutrients and macronutrients). The primary nutrients includes Nitrogen, Phosphorus and Potassium. These are required for carbohydrate production, protein synthesis, root development, plant cell division (growth), seed production, disease resistance, plant maturation and fruit development etc. when rice plant is nutrition deficit it shows symptom visible on the leaf depending upon the nutritional deficiency which it is suffering from.

Nitrogen: It is the most common deficiency which rice plant suffers most the leaves shows light green colour or lemon-yellow colour the field appear as a yellowish in colour. In severe nitrogen deficiency leaf may die.

Phosphorus: It is required during the entire plant growth till the cutting phase. Leaves shows dirty dark green colour, erected older leaves become brown and dies also red and purple spot may develops on the leaf. Phosphorus helps in root development, flowering and ripening.

Potassium: After nitrogen rice plant lacks potassium, when plants lacks potassium the leaf shows yellowish brown margin and rolling of leaf may be observed. It helps in lodging prevention, root growth, resistance to diseases and pests.

II. LITERATURE REVIEW

Plants when infected by diseases, pests, virus shows symptoms on the leaf, neck, nodes, roots and panicles also the various symptoms are visible when they are suffering from nutritional deficiencies. Among the different parts of plant leaf is considered to be an important part as plant carries photosynthesis process from leaf and produces food (grain in case of rice) but due to the infection pests, diseases and nutritional deficiencies the overall areas of the leaf blade gets reduced hence reduction in the overall yield. The leaf shows some visible symptoms like spots, change in colour and etc. depending upon the infection and deficiencies. These visible

changes on the leaf can be identified and classified using machine learning algorithms by passing digital photos of different class of diseases and pests.

Payal and P. Kukana in [1] proposed a method to classify Blast, Bacteria Blight, Brown Spots and Sheath Rot. The infected images of paddy leaves are captured manually from the camera with 768*1024 dimension resized to 109* 310 pixels and saved in BMP format. For improving the image processing the images are converted in gray scale and noise, unrequired spot are removed using median filtering operation, the PCA algorithm helps in extracting features of the images and the classification is done using MSVM which gives an accuracy of 98.8%.

S. Ghosal and K. Sarka in [2] proposed a two model to classify Rice Leaf Blight, Rice Leaf Blast and Brown Spot diseases with CNN transfer learning model and CNN without transfer learning model. The diseased leaf are collected from camera, internet, resized to 224*224 pixel and augmented to increase the dataset, the accuracy of 74% is achieved with CNN without transfer learning and it gets improved to 92.46% with VGG16 transfer learning model.

C. Rahman et al. in [3] proposed a method to classify rice diseases as well as pests using transfer learning model. The diseased and pest infected images are collected and resized depending upon the architecture requirement, to increase the image count the images are augmented and then trained using different transfer learning algorithm (VGG16, InceptionV3, MobileNetv2, NasNet Mobile, SqueezeNet v1.1 and also a simple CNN) but with the fine-tuned VGG16 the accuracy of 97.125 is achieved.

S. Ramesh and D. Vydek in [4] proposed a model using CNN to classify Bacterial blight, Blast, Brown Spot and Sheath Rot using deep neural network. The images for the classification is captured from the field and resized to 300*450 pixel and the leaf part is focused by eliminating the background. The JOA method is used for precisely detecting the diseases, but for a comparison ANN, DAE and DNN is also trained and finally the test accuracy of 97% is achieved with DNN JOA algorithm.

V. Shrivastava, M. Pradhan and M. Thakur in [5] proposed a model to classify Bacterial Leaf Blight, Rice Blast, Sheath Blight, Brown Spot, False Smut and Sheath Rot using different transfer learning model by first capturing the diseased images from the field and training the models such as VGG16, AlexNet, ResNet152V2, InceptionResNetV2, InceptionV3, MobileNet, Xception, NasNetMobile, DenseNet169 and NasNetLarge the highest classification accuracy of 93.11% is achieved with VGG16 model.

A. K and A. Singh in [6] proposed a model to detect Sheath Blight, Leaf Streak, Blast and brown Spot using regional convolutional network. The infected leaf images are collected and median filtering operation is performed to remove outliers and noise, they proposed two model Faster R-CNN and Mask R-CNN which classifies the disease with testing accuracy 85.4% and 87.45% respectively.

S. Nalini et al. in [7] proposed a method to classify Brown Spot, Leaf Smut and Bacterial Leaf Blight using deep neural network. The diseased leaf of rice plant is collected using camera and resized to 300*450 pixel then HSV operation is performed to remove the background. Different state of art methods such as DNN-CS, Training Phase SVM, Testing Phase SVM, 5-Fold SVM and 10-Fold SVM is compared. With DNN-CSA the error in classification gets reduced and achieves highest accuracy of 96.96%.

G. Sagarika, S. Krishna Prasad and S. Mohana Kumar in [8] proposed a model to detect the Brown spot, Leaf Blast, Bacterial Blight and Leaf streak using convolutional neural network. A dataset with 60 images of rice leaf is gathered from internet. Accuracy of 94.12% is achieved with 10 layers of convolution by running the model for maximum 20 epochs.

P. Mekha and N. Teeyasuksae in [9] proposed a model to classify Brown Spot Rice disease, Bacterial Leaf Blight disease and Brown Spot Rice disease using various machine learning algorithm such as Decision tree classification algorithm, Random forest classification algorithm, Nai'Ve-Bayes classification algorithm and Gradient Boosting classification algorithm, with Random forest classification algorithm accuracy of 69.44% is achieved.

K. Teja, B. Reddy, L. Kesara, K. Kowshik and L. Panchaparvala in [10] proposed a transfer learning model to classify three diseases such as brown spot, bacterial leaf blight and leaf smut. The infected 40 images of rice leaves per class are captured in sunlight with white background. InceptionV3 model is tested on the testing images which provides 99.33% accurate classification.

S. Zainorzuli, S. Afzal Che Abdullah, H. Abidin and F. Ahmat Ruslan in [11] proposed a model to classify pest such as hispa and diseases such as brown spot and leaf blast using transfer learning model. The images are collected from kaggle database. The highest accuracy of 89.83% is achieved with GoogleNet as compared to AlexNet and ResNet-50 with learning rate 0.001 and number of epoch 30.

H. Andrianto, Suhardi, A. Faizal and F. Armandika in [12] proposed a model which classify the diseases and pests and diseases such as Hispa, Leaf Blast and Brown Spot by providing an application on the smart phones using VGG16 transfer learning model which achieves validation accuracy of 60%.

S. Zakzouk, M. Ehab, S. Atef, R. Yousri, R. Tawfik and M. Darwees [13] proposed a model to classify leaf blight, brown spot and leaf smut using AlexNet deep learning architecture. The diseased images are resized to 227*227 pixel to improve feature selection and reduce training time. With learning rate 0.001 and number of epoch 50 the AlexNet achieves the accuracy of 99.71%.

K. Jena, S. Kumar Bhoi, D. Mohapatra, C. Mallick and P. Swain in [14] proposed model to detect Hispa, BrownSpot and LeafBlast using supervised machine learning algorithm such as k-NN, SVM, NN, DT, LR, RF, NB and AB. The accuracy of NN model is highest when compared to other supervised learning algorithm for NF value 2, 3, 5, 10 and 20.

H. Haiyan and S. Chang in [15] proposed a model based on artificial intelligence to classify diseases and pests in the rice field. The diseased images are smoothened, the colour and morphological differences are used as a features for classification then several CNN model are trained and the best model is selected.

M. Latte and S. Shidnal in [16] proposed a model which identifies Nitrogen, Phosphorus and potassium deficiencies using colour features. Total 500 images are captured and resized to 225*225 pixel later noise reduction is done using median filtering operation. Colour pattern and colour properties of healthy and deficit leaves are stored in database which is used to classify nutrition deficiencies.

M. Sharma, K. Nath, R. Sharma, C. Kumar and A. Chaudha in [17] using CNN based deep learning models. The images are gathered from kaggle database and also from mendely dataset. The images are converted into 300*300 pixel and augmentation is performed on the dataset to increase the total count later various model combination from InceptionV3, ResNet152V2, Xception, DenseNet201, InceptionResNetV2, and VGG19 are trained and achieves 92% accuracy for kaggle dataset and 100% accuracy for mendely dataset.

C. Lisu, S. Yuanyuan and W. K in [18] proposed a model to detect nitrogen deficiencies in rice plant using Support vector Machine. The images of rice leaf and sheath are collected for all growth stages, colour characteristics are used as features for identification and the optimal characteristics is selected using SVFS to reduce the redundant information finally the validation accuracy of 88% for stage 1, 98% for stage 2, 90% for stage 3 and 100% for growth stage 4 is achieved.

C. Wang, Y. Ye, Y. Tian and Z. Yuin [19] proposed a model to classify Nitrogen, Phosphorus and potassium deficiencies using reinforcement learning. The images are resized to 500*500 and 224*224 pixel in order to train transfer learning model. The study focuses on GoogleNet, DenseNet121 and ResNet152 transfer learning model also the CNN selfdesigned model is also trained. The comparison result shows that the highest accuracy 97% is achieved with denseNet-121 model.

Z. Xu et al. in [20] proposed a deep convolutional network to classify macro nutrients and micro nutrients such as N, P, K, Ca, Mg, S, Mn, Fe, Zn and Si. The images are captured during entire growth stage by changing the nutrition's every third day. Fine-tuning is done on models such as ResNet with 50 layers, Inception-v3, DenseNet with 121 layers and NasNet-Large. The accuracy of DenseNet with 12 layers outperforms other state of art model with validation accuracy of 98.62%.

III. METHODOLOGY

A. Dataset Collection

The images of the rice plant for the healthy, diseased, pest infected and primary nutrition's deficit are collected from the kaggle database as well from the internet sources. The diseases and pests focused in this study includes Blast, Blight, Tungro, Hispa and Brown Plant hopper. This study also focuses on primary nutritional deficiency such as Phosphorus, Nitrogen and Potassium. There are total nine classes including healthy class with 75 images in each classes. The dataset are then splitted into training, validation and testing set with 60 images in training set, 10 images in validation set and 5 images in test set per classes.

B. Preprocessing

The images downloaded from the kaggle database are not having different resolution and having redundant information. The original images downloaded were in the different pixel range for example 310*3834, 1862*1862 and etc. The images are first padded with the black background to make it square.

The application called photoshop is then used to remove the redundant information from the images by focusing only on the rice leaf and plants. The redundant information is cropped and filled with black colour in the images. Finally the images are resized to 224*224 pixel for the transfer learning models such as InceptionV3, ResNet152V2, Xception and InceptionResNetV2, also resizing operation is performed on the whole dataset to 500*500 pixel to train a CNN model without transfer learning.

C. Augmentation

The images from the training dataset are having 60 images per classes are augmented separately by flipping top to bottom, flipping left to right and rotating the images with a 90 degree shift and an original images. After the augmentation operation each class image count get increased to 240 images from 60 images.

D. Model Training

The Convolutional neural network with transfer learning models such as InceptionV3, VGG19, Xception, InceptionResNetV2 are trained using the image dataset with a 224*224 pixel for the 12 epochs, optimizer used is adam and for 16 batch size.

Also the Convolutional Neural network model without transfer learning is trained to classify the nine classes with an image size of 500*500*3 passed through convolution, batch normalization, max pooling with a rectified linear unit (relu) as activation function and finally dense layer with 9 neuron with a sigmoid activation function. The model is trained for 100 epochs with a batch size of 16. The dataset is splitted into 80% training set and 20% for testing set.

The best model from the various transfer learning model is selected and saved which is used further to create web application on the local host to classify different rice pests, diseases and nutritional deficiency classes in real time.

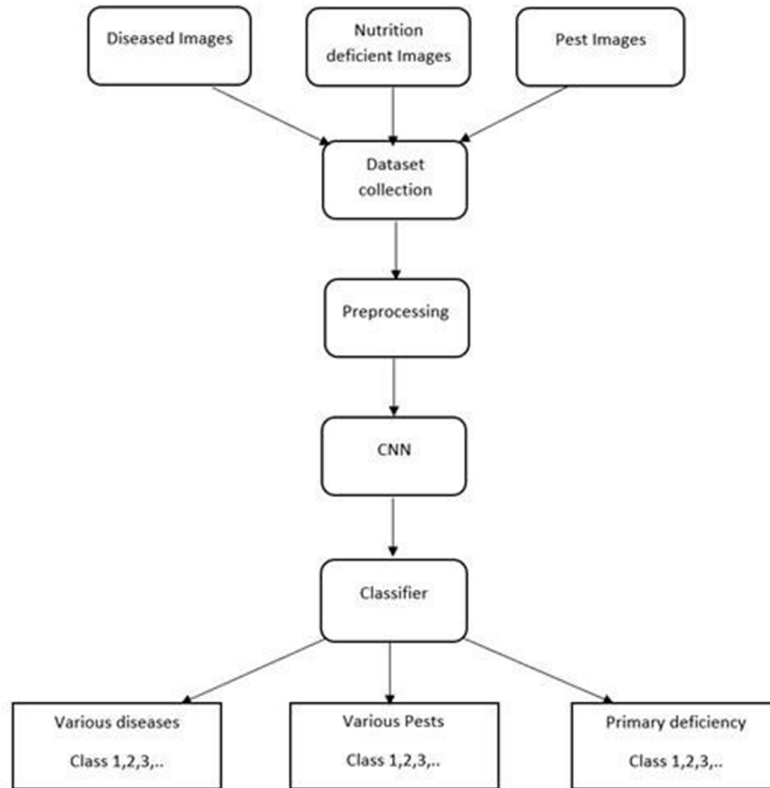


Figure 1. Overview of proposed model that classify different categories

IV. RESULTS

The different transfer learning models such as InceptionV3, VGG19, Xception, InceptionResNetV2 are trained using the google colab for the 12 epochs, 16 batch size and optimizer used is adam for all the models.

The images in the dataset are 224*224 pixel, model checkpoint and early stopping is also included while training to save the best model and to avoid resource loss. Also the CNN model without transfer learning is also trained to compare the result with the transfer learning models. The test accuracy of 89.63% is achieved which is less as compared to the InceptionResNetV2 model.

TABLE I. VALIDATION ACCURACY OF VARIOUS TRANSFER LEARNING MODELS FOR 12 EPOCHS

Epoch	VGG16	InceptionV3	InceptionResNetV2	Xception
1	64.44%	91.11%	88.89%	88.89%
2	66.67%	82.22%	93.33%	84.44%
3	68.89%	95.56%	84.44%	82.22%
4	75.56%	88.89%	80.00%	93.33%
5	75.56%	91.11%	93.33%	86.67%
6	73.33%	93.33%	91.11%	86.67%
7	73.33%	86.67%	91.11%	84.44%
8	77.78%	88.89%	95.56%	91.11%
9	80.00%	86.67%	91.11%	88.89%
10	77.78%	NA	88.89%	88.89%
11	80.00%	NA	95.56%	NA
12	80.00%	NA	93.33%	NA

Amongst the various model trained the model with best validation accuracy is selected and further used to deploy model on the local host using the flask frame work. The easy interface is provided to upload the images for the detection shown in Fig. 3.

$$\begin{bmatrix}
 12 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 3 \\
 0 & 13 & 1 & 0 & 0 & 1 & 0 & 0 & 0 \\
 0 & 0 & 10 & 0 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 9 & 0 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 3 & 9 & 0 & 0 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 14 & 1 & 2 & 0 \\
 0 & 0 & 0 & 0 & 0 & 1 & 18 & 1 & 0 \\
 0 & 0 & 0 & 0 & 0 & 1 & 0 & 19 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 17
 \end{bmatrix}$$

Figure 2. Confusion matrix of CNN model without Transfer learning

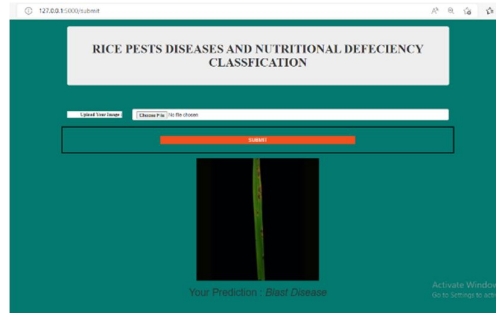


Figure 3. Interface created on the Local Host

V. CONCLUSION

In this research we have focused on detecting pests, diseases and primary nutrition deficiencies using the convolution neural network. We have developed models with and without transfer learning. The results shows that the CNN model without transfer learning provides less accuracy as compared to transfer learning model such as InceptionV3 and InceptionResNetV2. The validation accuracy of InceptionV3 and InceptionResNetV2 is 95.56% which is used in the model deployment on the local host for the classification which detects the different classes accurately. In future we would like to extend our research to increase the number of diseases, pests and micro nutrients classes.

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