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Cotton Leaf Diseases Detection and Classification using Deep Learning

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ABSTRACT:

Agriculture Productivity is the key component of Indian economy. Therefore the contribution of cash crops and food crops is highly important for both the environment and human beings. In India, cotton is one of the most important commercial crops cultivated. Cotton is said to be the most important cash crop in India it is also known as “White Gold” or “The King of fibers” among all cash crops in the country. The Indian textile industry uses a wide variety of fibers and yarns, with the approximately cotton to non-cotton fibers consumption ratio is 60:40. Due to crops diseases, many crops succumb to those diseases every year. It is very difficult for the human eye to identify the exact type of disease on the leaves of the crop.

Many crops succumb due to insufficient diagnosis and lack of information. For agricultural improvement and growing economy of India, detection of leaf diseases of cotton is essential. Early detection of cotton leaf hoppers can increase crop yields, reduce losses and make agriculture more sustainable. Cotton disease sampling plays an important role in research to detect and classify cotton leaf diseases. It extracts various features of images. Like the color of the actual infected image, there are many diseases on the cotton leaf so the color of the leaves also varies for different diseases. Thus, in order to detect the cotton leaf diseases accurately, the use of image processes, machine learning and deep learning techniques can be helpful. The main goal of this paper is to detection and classification of cotton leaf diseases. The cotton crops leaves images are collected from cotton fields using a digital camera/smart phone. Various pre-processing techniques as filtering, background removal, segmentation and enhancement are done. Classification based on selecting appropriate features such as color, shape and texture of images done by using CNN classifier techniques.

Keywords- Cotton, Leaf diseases, Image pre-processing, filter, Image segmentation, Machine learning, deep learning, detection, classification etc.

INTRODUCTION:

In India, near about 40 -50 million people are employed in cotton processing and trade, and also, cotton plays a very important role in the agricultural and industrial economy. The basic raw material of the textile industry is cotton fiber. Near about 20 percentage of the world's cotton is consumed in India. Overall, India is the second-largest consumer of cotton in the world. Cotton-Production Gujarat state is the largest State in India, and Maharashtra state is the second largest state Cotton-Producing. With an estimated production, the vidarbha region is the largest producer of cotton in the state of Maharashtra. Akola, Yavatmal, Amravati, Buldhana, and Washim are the primary cotton-growing districts in Western Vidarbha. According to a report of AICRP (All India Coordinated Research Project on Cotton), the area under cotton in the current year in the country decreased by 3.67%, and cotton production decreased by 4.18% compared to last year. Several diseases in cotton crops leaf are a major warning sign that has an impact on both financial and commercial influence. However, its production is often threatened by various leaf diseases that can drastically reduce both yield and quality. It is important to identify cotton diseases at an early stage. If we need to save cotton, then it is necessarily accurate identification of cotton disease and discovered early.

An Indian farmer, it is done to identifying cotton leaf diseases or pests are traditionally. Sometimes, experts also diagnose these issues with an open eye, but this method is labor-intensive, time-consuming, and challenging in developing countries Due to a shortage of experts in rural areas. After diagnosis, experts may recommend pesticides to control cotton leaf disease. However, this traditional approach can lead to problems, as diseases with similar symptoms may be misdiagnosed. Additionally, misdiagnosis can result in the use of inappropriate or overly toxic pesticides, which can harm crop production and the environment [2]. Early detection and accurate classification of these diseases are critical for effective crop management, enabling timely interventions and minimizing the use of pesticides. Traditional methods of disease diagnosis rely heavily on visual inspection by experts, which are time-consuming, labor-intensive, and prone to human error. With the advent of machine learning (ML) technologies, there is significant potential to enhance the accuracy and efficiency of disease detection in cotton crops. To overcome the above stated problems, an automatic and Artificial Intelligence based crop disease detection system has drawn a huge research interest in the agriculture section. For the automatic cotton leaf disease identification system, it needs to collect images from cotton leaves, an extensive feature, and image processing. The open research opportunities for feature extraction with high computational capacity are that Computer vision, Machine Learning (ML) and Deep Learning (DL). For the diagnosis of cotton leaf diseases, automating image processing and machine learning techniques must be used. A machine learning (ML) is a new branch of data mining which is enables a programmer to predict outcomes more accurately without having to be explicitly programmed[3]. There are various methods for identifying and classifying various diseases of cotton such as Bacterial, fungal and viral, in the soil for the purpose of detecting and controlling their spread on cotton leaves. Using a variety of machine learning algorithms the farmers are then presented with information on the disease and potential treatments [1]. Machine Learning algorithms are frequently divided into two categories supervised and unsupervised. Many researchers have recently focused on the agricultural sector to identify and classify crop diseases through automatic methods. The Deep learning and Computer vision those two are examples of modern technologies that enable the automatic identification of agricultural illnesses without human intervention. For the purpose of identification of crops disease, a computerized method would be less expensive quick, and more accurate.

The main motive of this article is to present a model for the identification of cotton crop leaf diseases and classify them that helps farmers identify cotton leaf diseases timely and also helps to improve production. The proposed method in this article employs pre-trained models with knowledge stored in the weights (Image-Net) that are converted into an experiment for the feature extraction process using a transfer learning technique. For classification, machine learning and data analysis are used, and the outcomes are compared using different performance metrics. The major contributions of this research are: Implementation of the pre-trained deep learning-based feature selection techniques on segmented images and Implementation analysis of machine learning classification techniques using pre-trained deep learning models based on selected features. The experimental results are in comparison to existing techniques with high parameters for the classification of cotton leaf diseases. The goal of this study is to provide a comprehensive approach to the detection and classification of cotton leaf diseases using deep learning, contributing to the advancement of precision agriculture and the sustainability of cotton farming. Through this research, we aim to demonstrate the potential of ML-driven disease management systems to not only improve crop health but also optimize resource usage and reduce environmental impact.

COTTON LEAF DISEASES AND THEIR CHARACTERISTICS:

Every crop in agriculture field is primarily affected by three types of diseases such that viral, bacterial, and fungal. These diseases can effect by any stage of the cotton such as seedling, cotyledons, cotton bolls, mature cotton leaves etc. Viral diseases occur in cotton leaf when a virus enters the plant through lesions, mechanical injuries, infected leaves, or other pathways. These diseases disrupt the natural growth of the plant and reduce crop yields. An example of a viral disease is Cotton Leaf Curl Virus, Cotton Yellow Leaf Curl Virus (CYLCV) etc. Bacterial diseases are caused by bacteria that can infect various parts of the cotton, including stems, leaves, and roots. Bacterial diseases can significantly impact on plant health, yield, and fiber quality. A common example of a bacterial disease is Bacterial Blight. Fungal diseases are caused by various fungi that attack different parts of the cotton. These are typically controlled with fungicides. An example of a fungal disease is Fusarium Wilt. A few diseases occur on cotton are as follows:

A. Cotton Leaf Curl Virus:

Cotton Leaf Curl is one of the most significant viral diseases affected by cotton crop. Cotton Leaf Curl Virus is a major challenge to cotton cultivation, particularly in regions with high whitefly populations and favorable environmental conditions. Leaf Curl Virus disease is caused by a group of viruses known as Begomovirus, which are transmitted primarily by whiteflies. Symptoms of Cotton Leaf Curl Virus are: Leaf Curling, Yellowing, stunted Growth, Mosaic Patterns etc.

B. Bacterial Blight of Cotton:

Bacterial Blight diseases is a significant disease in cotton crop that are caused by the bacterium Xanthomonas citri pv. malvacearum. It is primarily affected by the leaves, stems, and bolls of cotton crop, leading to severe yield losses if not managed properly. Since bacterial blight is often difficult to treat once it has infected a plant, prevention is the most effective strategy. Symptoms of Bacterial Blight of Cotton are Water-soaked lesions, Yellowing, Necrosis, canker formation, rotting of Bolls, Premature shedding etc.

C. Fusarium Wilt:

Fusarium Wilt is a fungal diseases and it is a serious threat to cotton crops, especially in regions with hot, warm and dry climates. It is a soil-borne fungal disease caused by *Fusarium oxysporum* f. sp. *vasinfectum*, which primarily affects cotton crop. Fusarium Wilt disease causes significant yields losses by reducing plant vigor, affecting the vascular system of the cotton.

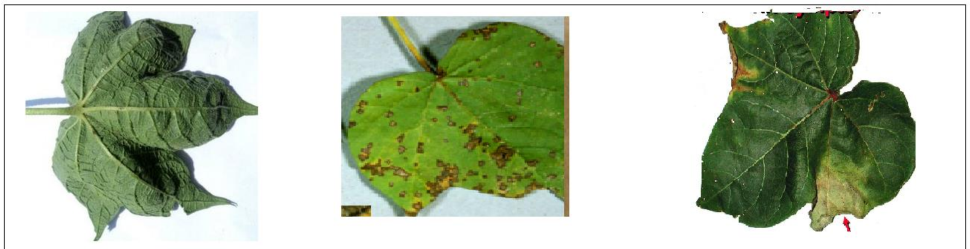


Fig (1): A.Cotton Leaf Curl Virus B.Bacterial Blight of Cotton C.Fusarium Wilt

LITERATURE REVIEW:

Md. Manowarul Islam et al., authors study presents a "deep learning (DL)-based approach for cotton disease detection, leveraging transfer learning (TL) algorithms". The dataset underwent preprocessing steps including resizing, sharpening, rescaling, shearing, zooming, and horizontal flipping before being split for training and testing. Prominent TL models 가 VGG-16, VGG-19, Inception-V3, were evaluated for their performance on the cotton disease dataset using metrics like precision, recall, and F1-score. There proposed model demonstrated the highest accuracy at 98.70%. They subsequently had chosen to power a web-based application for real-world agricultural use and this tool support farmer to agricultural sector with disease self-validation, consultation, and management.

D. Gosai et al., researchers in their research work have trained a model to recognize some unique harvests and 26 diseases from the public dataset which contains 54,306 images of the diseases and healthy plant leaves that are collected under controlled conditions. This paper worked on the ResNets and achieved high accuracy results. For the image classification, ResNets achieve a much better result. The ResNets techniques applied some of the parameters like scheduling learning rate, gradient clipping, and weight decay. This ResNets model is able to predict every image in the test set perfectly without any errors. In the future, more work on larger datasets of images and try to achieve high accuracy results.

The authors Saleem et al. used the Internet of Things (IoT) and the Radial Basis Function Network (RBFN) algorithmt for to develop an insect pest prediction system (IPPS). The system factors in environmental conditions such as temperature, humidity, rainfall, and wind speed to forecast pest activity. Specifically, it predicts whitefly attacks based on these parameters and a predefined economic threshold level. There was tested RBFN algorithm for the performance; and it achieving an accuracy rate of 82.88%.

Author Md. Rayhan Ahmed , introduced in thier proposed a novel approach for detecting defects in cotton leaves and plant tissues using a Deep CNN-based model, DCPLD-CNN, alongside eight specialized pre-trained Deep CNN. To enhance training, the Iterated Distillation and Amplification (IDA) method was employed to increase the dataset size. Customized pre-trained models were also trained and evaluated. The DCPLD-CNN model demonstrated the best performance as training iterations increased, it achieving a high accuracy of 98.77%.

R.Meena Prakash et al., their proposed work entitled "Crop Disease Detection and Classification", used Convolutional Neural Network (CNN) in their propsed method. Transfer learning and hyper-parameters optimized Convolutional neural network algorithm used in their work. For the classification of plant diseases and performance analysis Transfer learning with popular models – AlexNet, VGG16, ResNet50 and DenseNet121 are used. Also, optimized Convolutional Neural Network with tuned hyper-parameters is proposed to improve the performance of CNN. The method is tested for classification of maize leaves belonging to four classes – healthy, common rust, Northern leaf blight and Gray spot. Their proposed system give the Classification Accuracy 0.9721 is achieved for DenseNet121 and the results are superior to the state of the art methods over 2.95%.

R. M. Prakash et al., The authors employ transfer learning with popular pre-trained models such as AlexNet, VGG16, ResNet50, and DenseNet121 to classify plant diseases. These models are fine-tuned and evaluated for their performance on a dataset of maize leaves, categorized into four classes: healthy, common rust, Northern leaf blight, and Gray spot. Additionally, an optimized CNN with tuned hyper-parameters is proposed to address performance limitations commonly associated with arbitrary hyper-parameter selection.

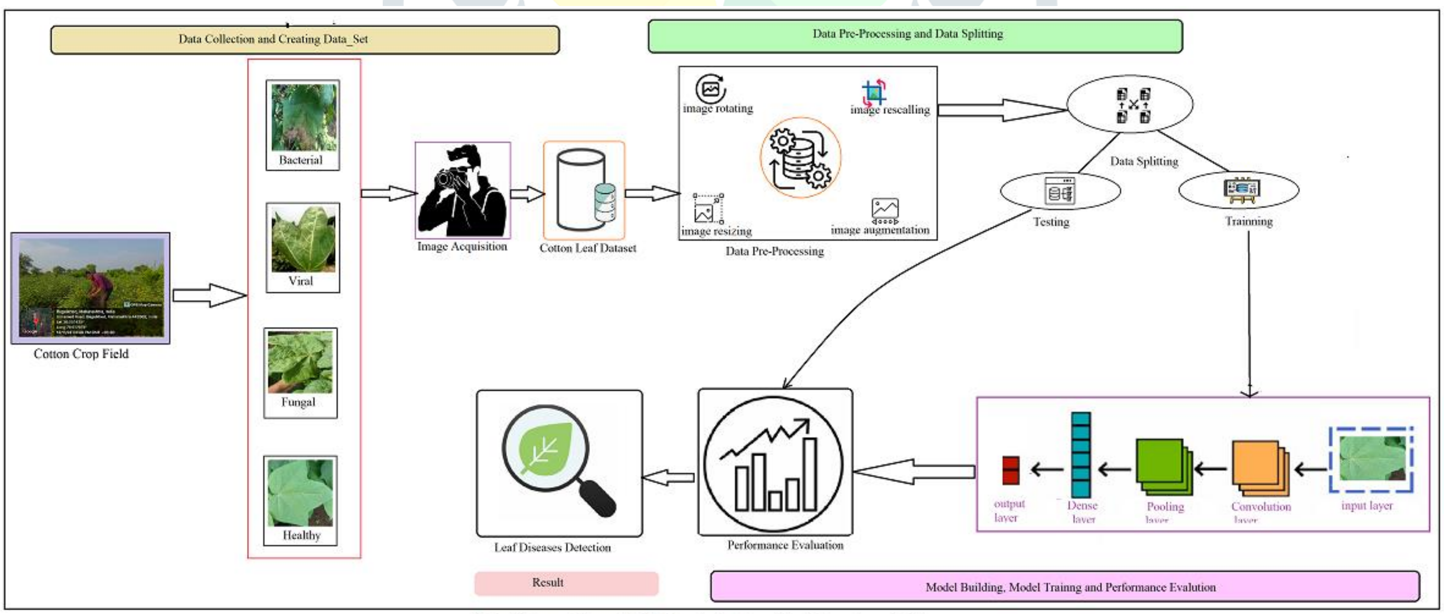
Bhumika S.Prajapati et al, in this paper present the survey on detection and classification of cotton leaf disease using image processing and machine learning techniques was carried out. Also researchers discussed on background removal and segmentation techniques. Through this survey, they concluded that which method is useful for background removal color space conversion from RGB to HSV. They also found that thresholding technique gives good result compared to other background removal techniques and also found performed color segmentation by masking green pixels in the background removed image and then applying otsu thresholding on the obtained masked image to get binary image. Researchers also found that SVM gives good results, in terms of accuracy, for classification of diseases. There are five major steps in here proposed work, out of which three steps have been implemented in his work this are Image Acquisition, Image pre-processing, and Image segmentation and remaining two steps are feature extraction and classification which we will implement in our future work.

Surampalli Ashok et al., proposed a method in their research article that achieved an accuracy of 98%. The approach utilized a Convolutional Neural Network (CNN) algorithm for hierarchical feature extraction, mapping the input image pixel intensities and comparing them with a trained dataset. Adjustable parameters of the leaf portions were optimized by minimizing errors over the training set. The method classified the images into disease-affected and normal leaves. For implementation, artificial neural networks, fuzzy logic, and hybrid algorithms were employed. The proposed work offers potential for extension with new algorithms to enhance performance in comparison to existing techniques. A key focus for future developments could be real-time plant disease categorization, which would play a significant role in selecting the most suitable technique.

Akhtar et al., their proposed work entitled "Automated plant disease analysis (APDA): performance comparison of machine learning techniques", which is contains a four-phase framework for plant disease detection. In the first step, they are collect the rose image dataset from the tea research institute, Mansehra and the second step, they perform a segmentation process that can be used to convert original images to binary images where white color is represented with the diseased region and black color is represented with the non-diseased region. In the third step, perform feature extraction. For feature extraction there are used three methods such as statistical features, discrete cosine transforms (DCT) and discrete wavelet transforms (DWT). In the fourth step, perform different machine learning classification methods like KNN, decision tree, NB, RNN, SVM, etc. By combining SVM with DCT and DW achieved high accuracy results i.e. 94.45%.

PROPOSED METHODOLOGY:

In this section we present the proposed work to detection and classification of cotton leaf diseases. General approach for detecting the cotton leaf disease is composed of two main steps first is image pre-processing and another is classification of disease using deep learning techniques. The architecture of proposed methodology for detection and classification of cotton leaf diseases can be divided into several stages as shown in figure (2). In this section we will discuss about the Acquisition of RGB Image, Preprocessing of acquired Image, Image segmentation and Feature extraction steps of image processing and classification.



Fig(2): Architecture of Proposed Methodology for detection and classification of cotton leaf diseases

A. Acquisition of RGB Image:

We have captured images from western vidarbha region. The dataset of images required for work was taken by smart phone camera (16 megapixel camera) as shown in figure (3). Images were stored in .jpg format. Resolution of the image is 4000×3000. This dataset contains high-quality RGB (red, green, blue) format cotton leaf images which include healthy leaf images and disease leaf images. There are total 430 images of cotton leaf curl Virus, Bacterial blight, and Fusarium Wilt. We have set the white and yellow background while capturing leaf images.

Fig(3):Original RGB Image

B. Pre-Processing of acquired Image:

While during creating the dataset various types of noise such as image shadow, light reflection on the image, and some parts of water soaked region might be present in the images. That time for getting better result we need to reduce noise, Adjust brightness and improve clarity; The Purpose Pre-Processing is to prepare the images for analysis by removing noise and enhancing features. Various pre-processing techniques such as image cropping, image resizing, color transformation, enhancement, segmentation, augmentation, and filtering is done for removing noise and enhancing images in dataset. This process is necessary of acquired images to train any deep learning model for classification tasks. Image is resized to 200 × 200; contrast stretching is done for improving quality of image as shown in figure (4).

Fig(4): Resized Image

C. Image segmentation:

Image Segmentation is the process of categorize the cotton leaf image into smaller portions of texture, containing similar characteristics. The proposed methodology is used to image segmentation process to determine the boundary of the cotton leaf and label it into pieces. Similarity and Dissimilarity are two properties used to stop the process of segmentation. In image segmentation process, green pixels are masked and removed from the image. Green pixels are removed by extracting HSV components of the background removed image. Then we applied threshold value to the H component of the background removed image. We set HSV components to zero whenever if the threshold value of H component is greater than the specified threshold as shown in fig. The following equation defined the process of segmentation with color-based thresholding.

$$|g(x,y)| = \begin{cases} 0, f(x,y) < T \\ 1, f(x,y) \geq T \end{cases}$$

D. Feature Extraction of Segmented Image:

The next stage proposed model after segmentation of cotton leaf image of the disease detection and classification approach is feature extraction. Feature extraction plays a significant role in image classification. This approach has tracked down that morphological outcomes give preferable outcomes over different features. It tends to be identifying the infected cotton leaf of the classification cotton image. The purpose feature extraction is to extract key features from leaf images for disease recognition. From the green pixels removed image mean and standard deviation will be extracted for the color features. Each disease can be differentiated by two diseased parts such as shape and size. In shape features like that area; perimeter, aspect ratio, and diameter are used to find size of the disease part. Texture features such as energy, entropy, homogeneity, cluster shade, cluster prominence are extracted from the green pixels removed image. Shape features are extracted from the Otsu segmented (binary) image. Using Grey Level Co-occurrence Matrix (GLCM) texture features can be extracted.

E. Classification:

In this classification stage performs any of the machine learning or deep learning techniques for classifying the various diseases in cotton leaf. In our proposed methodology will be used Convolution Neural Network (CNN) technique for detection and classification. The compared image is classified into four categories bacterial blight, curl virus, fussarium wilt (disease affected) leaf and healthy (normal) leaf as the image classifier technique that has been deployed. The results of the same are stored into the database for further detection and analysis.

F. Detection and Classification of Plant Disease:

This is the final outcome stage of our proposed system. In this stage, users can identify and characterize the plant infection.

EXPERIMENT SETUP:

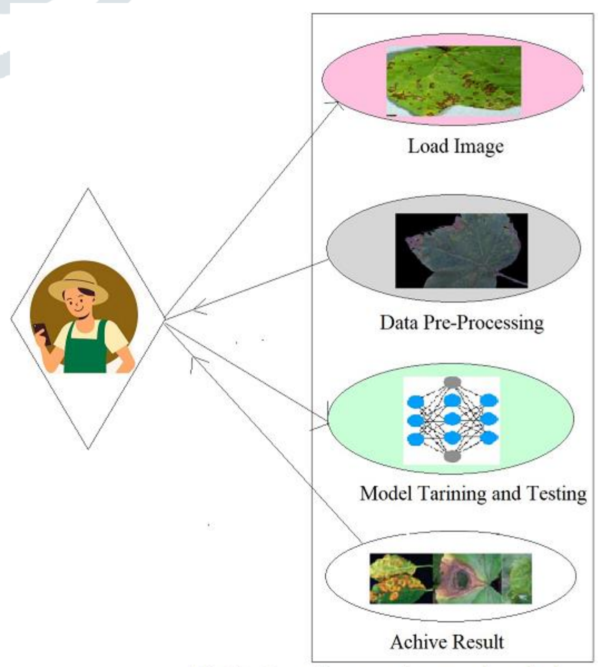
a. Experiment setup:

For the experimental setup, PC used for all investigations has an 8 GB graphics card, 8 GB RAM, a Core i5 processor, 64-bit Windows 10 running at 1.80 GHz, and the Open source Python programming language with Sklearn, Tensorflow, Keras, pandas, NumPy, etc. packages are used.

b. Case diagram of proposed method:

The preprocessing phase involves resizing the input images to a standardized format, followed by converting them into NumPy arrays for computational efficiency. Subsequently, the dataset is organized by segregating the images and their corresponding labels. The model is trained on a specific dataset comprising images of diseased plant leaves, which serve as the primary focus of this study. The labeled data is stored in pickle files for efficient retrieval during the model's training phase.

The proposed model architecture begins with the definition of convolution layers, followed by max-pooling layers to reduce spatial dimensions while retaining essential features. To mitigate over fitting, 25% of the total data is subjected to dropout. The output from the convolution layers is then flattened to serve as

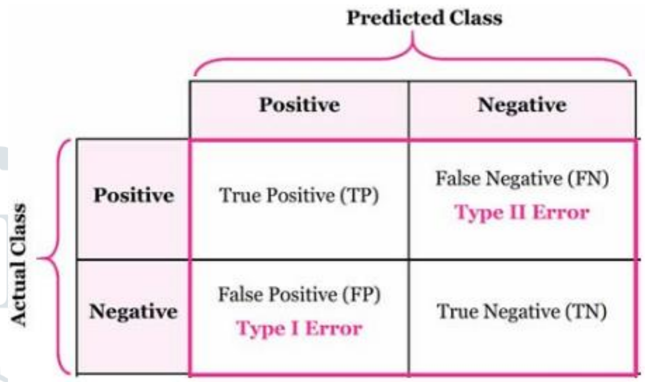


Fig(4): Case diagram of proposed method

input for the fully connected (dense) layers of the network.

c. Performance metrics:

In the base on training data we are categories or classify the data for the classification problem,; the trained model learns from the given dataset and then it classifies the new data into classes or groups based on the training. It predicts class labels as in the form of Yes/No or O/1 the output. In this research we are using confusion matrix factor to predict the number of correct and incorrect predictions made by the model by comparing them to the actual labels in the dataset. Different metrics are used to evaluate the performance of a classification model and some of them are as follows



$$\text{Accuracy} = \frac{TP+TN}{TP+FP+FN+TN};$$

$$\text{Precision} = \frac{TP}{TP+FP};$$

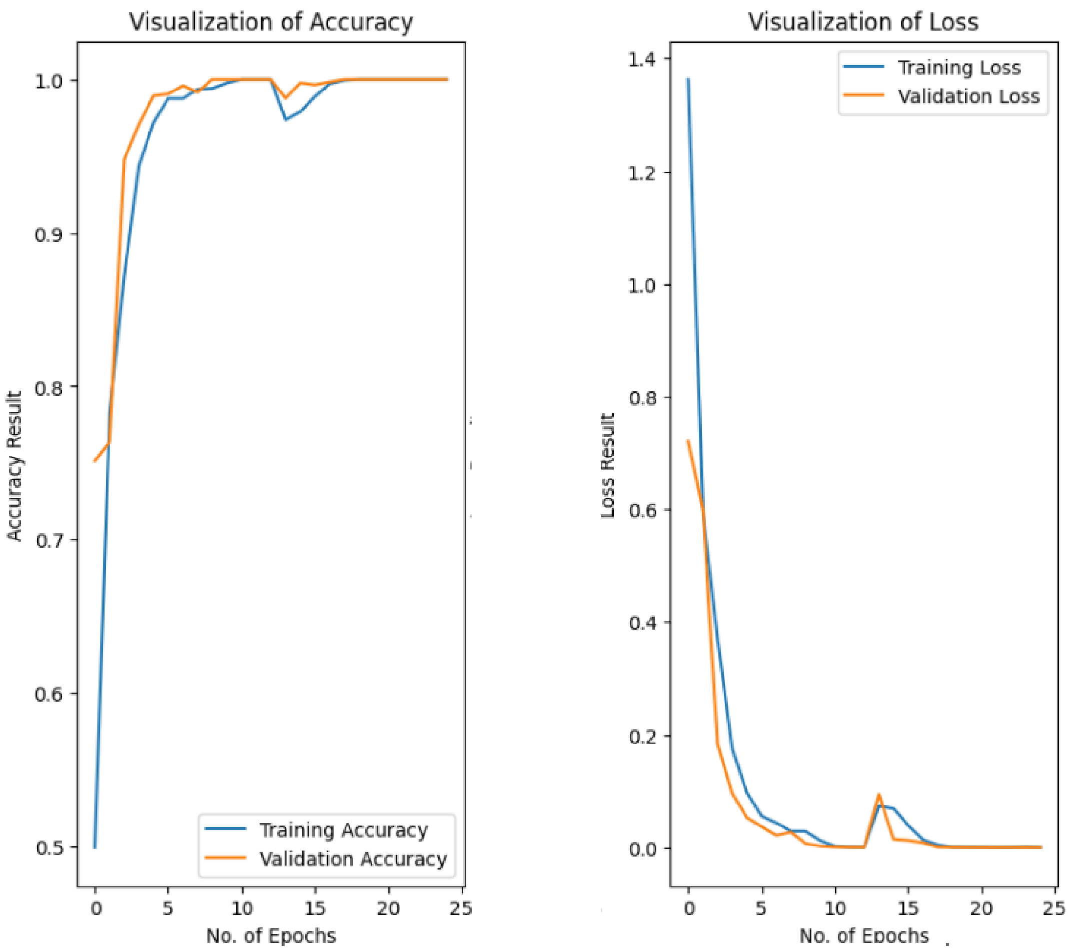
$$\text{Recall} = \frac{TP}{TP+FN}$$

$$\text{F1 Score} = \frac{\text{Precision}*\text{Recall}}{\text{Precision}+\text{Recall}}$$

RESULT AND PERFORMANCE ANALYSIS:

This research article gives the detection and classification of cotton leaf disease for the prediction of diseases and healthy leaf. For the classification required two main sections such that training and testing. Classifier is prepared for the utilizing the highlight esteems and its particular target esteems. This prepared classifier is then used to order test images. The proposed research work dataset consists of 130 images. Out of which, 30 images of Bacterial blight, 30 images of Curl virus, 30 images of Fussarium wilt and 40 images of healthy are given to train the classifier. All the cotton leaf images data are collected from different cotton filed in Buldhana and Washin district which are geographically located in western vidarbha region. The collected dataset is split into the ratio of 80:20 for training data and testing data set respectively. For the testing random image dataset is given. For the implementation purposed of this work is made by using Python 3.11 running on Windows 10 operating system. Researcher are used an x64 based processor with a speed of 3.20 GHz, RAM of size 8.00 GB and system type of 64-bit operating system. Along with Python software IDE deep learning and machine learning library and package of Pandas, sklearn, tensorflow, numpy, and matplotlib is used. In this experiment, the size of the image is reduced from the original size 4000×3000 into new size 200 ×200; due to that all the images have a unique size as the data set images were having different sizes. The labeled grayscale images are converted into a cv2 format image processing library in python.

Using the different kinds of performance metrics we are analyzed results such as training and validation accuracy and loss as shown in figure(5), we get average Training Accuracy is 96% and Validation Accuracy is 98%, precision, recall,f1-scores and confusion matrix as shown in figure(6).



Fig(5): a) Visualization of Training and Validation Accuracy b) Training and Validation Loss

	precision	recall	f1-score	support
Bacterial_blight	1.00	1.00	1.00	30
Curl_virus	1.00	1.00	1.00	30
Fussarium_wilt	1.00	1.00	1.00	30
healthy	1.00	1.00	1.00	40
accuracy			1.00	130
macro avg	1.00	1.00	1.00	130
weighted avg	1.00	1.00	1.00	130

Fig (6): precision, recall,f1-scores

CONCLUSION:

In this research work, based on convolutional neural networks architectures deep learning models were developed, for the identification of cotton leaf diseases through leaves images of diseased and healthy cotton. The training of the models was performed using a collected dataset from different crop filed cotton leaf photographs, taken in real conditions in cultivation fields. The data comprises in four distinct classes of combinations, they are bacterial blight, curl virus, Fussarium wilt, healthy. Proposed experimental results prove that the CNN results in improved in classification accuracy compared to non-optimum values. For the diseases classification, CNN achieve a much better result.

In the future, more work on larger datasets of cotton leaf and try to achieve high accuracy results and try to make integrated with smart phone applications that would provide user friendly GUI and simplicity for its usage.

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