

# Cotton Leaf Disease Recognition System for Agricultural Crop Health Monitoring Using Deep Learning

**Dr. M. Purnachandra Rao<sup>1</sup>, K. Rajya Lakshmi<sup>2</sup>, K. Mounika<sup>3</sup>, P. Venkata Pratyusha<sup>4</sup>,  
P. Kusuma<sup>5</sup>**

Associate Professor, Department of Information Technology,

KKR & KSR Institute of Technology and Sciences, Guntur, AP, India<sup>1</sup>

Student, Department of Information Technology,

KKR & KSR Institute of Technology and Sciences, Guntur, AP, India<sup>2-5</sup>

**Abstract:** Agricultural production greatly depends on crop yield, production and quality of the crops. For increasing the overall Agricultural Production we have to detect and identify the crop diseases early and manage the diseases using specific types of techniques which are effective and efficient for the development of crop health. If we can't identify the crop diseases at the early stage it effect the income of the crop production. By using the traditional methods we can detect the plant and leaf diseases but it is a time consuming process and not that much efficient. And the traditional methods are suitable for only the small areas of crops, but not suitable for larger area of crops. Traditional methods provide very low accuracy. In this project, we can easily detect the disease at earlier by using Artificial Intelligence especially Deep Learning. The system uses artificial intelligence model to grasp the leaf patterns and checks whether the plant is healthy or not. It classifies the image and detects the disease at the earlier and provides the solution for the disease. The developed model distinguishes the plant leaves that are healthy or not. Comparing to the traditional methods this modern methods like deep learning will provide faster and accurate results. And the modern methods are cost effective and reduce the dependent on experts, integration with mobile or web applications. Overall by utilizing these deep learning techniques it helps the farmers to take action immediately, and increases the crop yield and quality and reduces the crop loss and provides sustainable agriculture.

## I. INTRODUCTION

Agricultural Productivity plays an important role in Indian economy and it provides food for the economy which helps in growing of the population. Crop health is the major concern which helps in the rapid development of the crops. By attacking these diseases like blight, mildew and rust are the common plant leaf diseases which help in damaging of crops. We have to detect these diseases in the early stage which helps in the increasing of the crop production.

Early detection is very important because it affects the factors like crop yield, and quantity and quality of the crops. In olden days, we had used the traditional methods like visual inspection with the help of the persons who are having a lot of experience in the stream of agriculture. But this is very time taking process and it requires a lot of experience and it not efficient. By using these traditional methods it is very difficult to monitor large area of crops where it requires extra time and high level of experience. And the other drawback of using of traditional methods is many of the plants show similar indications which effect the delay of the treatment. These similar indications lead to incorrection of diagnosis.

So, by using Modern methods like Artificial Intelligence especially Deep Learning helps in the early detection of the crops using the images. The Deep learning techniques such as Convolutional Neural Networks (CNN) which have a strong foundations on the classifying the images helps in the identification of the leaf diseases such as blight, mildew and rust. These images scan the crop and if there any diseases it detect at the early stage using deep learning techniques. By using these CNN methods it classifies the images and detects the diseases and provides the results with high accuracy. The deep learning models helps in identification of the diseases without human intervention.

Overall, The modern techniques helps in increasing the crop yield, detecting the leaf and cotton diseases, which is very effective and efficient and without requiring the human effort, fast working, reduces overall crop loss and in the increment of the agricultural productivity and sustainable agricultural production.

**II. LITERATURE REVIEW**

The applications of machine learning and deep learning play an important role in smart agriculture and helps in improving the yield of crop. This automation and smart agriculture is required for early detection of cotton leaf disease to increase yield quality of the crop. Particularly for the economically important crops like cotton has a serious impact on crop quality and food security. Joshi et al. (2025) [1] presented a YOLOv8 based deep learning system for cotton leaf disease classification using 10fold cross validation, obtaining exceptionally high performance with Top\_1 accuracy of 99.60% and strong memory and F1 score results. The use of k fold authentication improved robustness across various field images, minimizing overfitting and improving generalization to real world scenarios Kolachi et al. (2023)[2] developed a YOLOv5 framework for classification of cotton disease, comparing different YOLO versions (v5, v6, v7) on an domain specific dataset. The system achieved around 92% accuracy, achieving real-time detection with less time (~25 ms), although performance varied according to disease types. Singh et al. (2025)[3] proposed a hybrid BERT ResNet PSO deep learning model for detection of cotton disease. Their model used BERT like method to segment disease parts, ResNet is used for deep feature extraction, and Particle Swarm Optimization (PSO) to increase classification accuracy, achieving 98.5% accuracy on PlantVillage dataset images compared with standard CNN baselines. Patra and Gajurel (2024)[4] suggested a low parameter model deep learning framework integrating MobileNet with transfer learning, data enhancement, and optimization techniques. This model gives 98.42% of accuracy across seven cotton disease types and minimized computational complexity, making it more responsive for deployment in low resource environments. Ahmad et al. (2024) [5] examined Vision Transformers (ViTs) for detection of cotton leaf disease, reviewing five CNN and two transformer architectures. The ViT method achieved 96.72% binary accuracy and 93.39% multi model accuracy, suggesting the transformer system can record long-range and conditional features effectively. Lakshmi et al. (2025)[6] introduced a multi modal deep learning system that gives spectral, thermal, and hyper spectral imaging to increase accuracy in disease detection, dealing with limitations of traditional single-modality imaging models

**III. METHODOLOGY****a. Proposed System**

The proposed system represents an leaf automation and cotton leaf disease recognition system framework using different types of deep learning techniques to improve crop yield, quality and crop health monitoring. The system uses Convolutional Neural Networks (CNN) with transfer learning to accurately identify diseases from different types of leaf images. Initially the first step is taking the input from the leaf images undergo the preprocessing step to enhance the quality. this helps in maintaining the equal proportion. The preprocessed images are then transfer to a deep learning trained model that automatically extracts the some separate features and classify which are healthy or diseased categories. The use of transfer learning will helpful in reducing the cost, and the complexity and the usage of expertized scientists. This transfer learning improves the accuracy. The system is used to design to be cost efficient, scalable, reliable, and easily available to the real world applications.

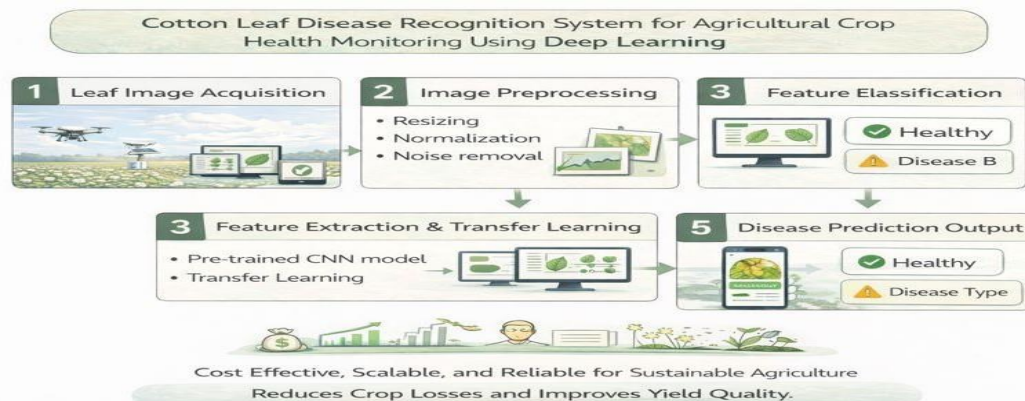


Fig-1: Proposed Architecture of Cotton Leaf Disease Recognition System Using Deep Learning

**b. Data Collection**

In the context of agriculture leaf images regarding cotton plants includes both healthy and damaged leaves. The datasets regarding these leaves will be available from large and applicable data sets which are publicly available to everyone and also from the reliable sources of agriculture. These datasets consists of multiple diseases categories and data is collected from different types of data sets in terms of classification and accuracy. These datasets

are easily available to everyone. The diseases which occur to the cotton leaves are categorized as fungal, bacterial and viral infections. We have to capture the leaf images in different types of scenarios like light conditions, origin of the leaves and the images backgrounds are also considered. These scenarios will be helpful to scan the images with high amount of quality. These separate scenarios will be helpful in representing the impact of real fields and also improvement of model learning. This variability helps us to learn the features which have strong generalization capability.

### **c. Image Preprocessing**

After the collection of the data from the datasets we have to collect the images of healthy and damaged leaves. These collected images are preprocessed to attain and improve the certain quality and maintain equal proportion. There are several steps include in this preprocessing of data. The steps are:

1. We have to resize the image by using suitable Convolutional Neural Networks (CNN) to obtain a fixed solution.
2. The Preprocessing also helps in removal of the noise because these noises create a lot of unwanted deviations.
3. The preprocessing provides in the image enhancement techniques for the improvement of the image quality.
4. Pixel Normalization is also one of the step in preprocessing of image.
5. The Preprocessing of image also facilitates the Data augmentation techniques such as rotation, flipping, scaling which improves diversity of data.

These steps enhance the quality of the image, improves model performance, increase the dataset size, reduce the overfitting of the image and overall increasing of the performance.

### **d. Feature Extraction Using CNN**

Feature Extraction using Convolutional Neural Networks (CNN) is an important step in image based disease detection systems. Generally in traditional methods will particularly rely on human intervention and that will be very time consuming and includes very high level of complexity. Unlike those traditional methods, CNN automatically learn important and reliable features directly from input images. The CNN consists of different types of convolutional layers which are applied to the input images to capture the important patterns regarding the presented leaf images. In the base layers, The CNN learns low-level features such as edges, corners, colors varieties. As this CNN goes deeper, it extracts high-level features like textures, shapes and specific patterns regarding diseases such as spots, discolorations and leaf deformations. The CNN also includes different types of pooling layers such that they are helpful to reduce the dimensions while acquiring the important information. This feature is also helpful in extracting of robust features and this will help in the improvement of accuracy. These extracted features are then passed to fully connected layers for the classification of diseases, and making CNN highly effective for the agricultural image analysis.

### **e. Transfer Learning**

In the project of cotton leaf disease recognition system, transfer learning plays an important role in the development of our project. Because it inculcates the concept of CNN and improves image classification accuracy and reduce training time and provides high quality. Deep learning will have to develop from the scratch. Instead of training this deep learning model from the starting a pre-trained convolutional neural network is utilized. Because these pre-trained will have strong inbuilt and meaningful features from different types of large datasets. The learned weights which are occurred from the pre-trained models are reused, and the last final layers are fine-tuned using the datasets that is relatable to cotton leaf image datasets. This allows the model to adapt previously learned different types of features such as edges, textures, colors, shapes to the specific disease patterns like spots, discolorations. Transfer learning enables effective quality and enhances the robustness and generalization capability of the system which we have been proposed.

### **f. Disease Classification**

In the proposed system, disease classification is done by using the features which are extracted from the deep learning model which is trained. By classifying these images will help the farmers in the earlier without any involvement of humans. These images which are extracted are passed through layers which are fully connected. By passing through these layers these helpful in the classification of healthy and diseased images with high accuracy and quality. This classification will also be helpful in the disease categorization. Here one of the classifier is used that is softmax classifier is used in the final layer to assign probability scores of each class. Note all the probability values. From all the probability values select the highest probability value, the system classifies the given input images and classifies either its healthy or diseased image or it will be affected by any other cotton disease. By classifying these images it will enable fast and accurate identification of leaf diseases, and reduce the human intervention. This classification helps the farmers in the development of crops and early detection of diseases and the disease description, classification of diseases, disease percentage and provides prevention tips and promotes sustainable agriculture.

**g. Model Evaluation and Performance Analysis**

In the proposed cotton leaf disease detection system, model evaluation is performed to measure the effectiveness and reliability of the deep learning model which is trained. After training the model is sent for the testing purpose using different types of unseen leaf images to assess its quality, and generalization capability. Standard evaluation metrics such as accuracy, precision and recall, F1 score is used. These are helpful in the analyzing of classification performance. Here a type of matrix is used that is confused matrix is employed to visualize correct and incorrect predictions across different types of disease classes. The results which are obtained from these are usually compared with conventional disease direction methods to improve the accuracy and reduce the detection time. This performance analysis confirms that the system which we have been proposed based upon deep learning system provides reliable and efficient disease classification.

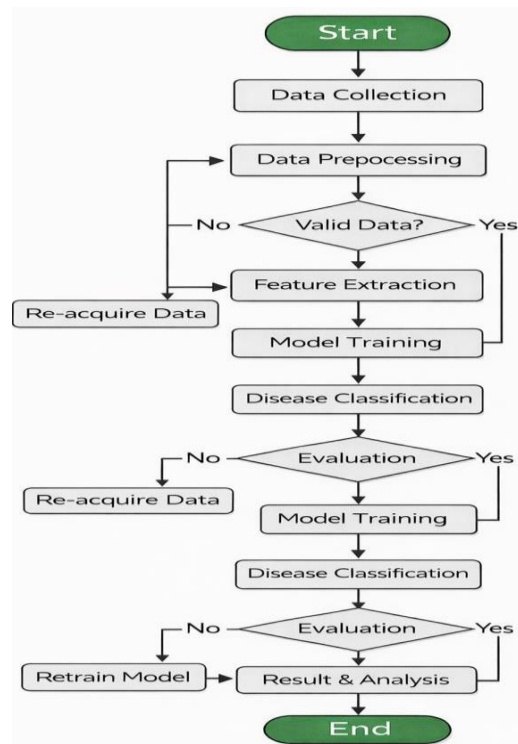


Fig-2: ML - Based Cotton Leaf Disease Detection Workflow

**IV. RESULTS**

The results represent the practical analysis of the Cotton Leaf Diseases Recognition system which is based on Convolutional Neural Networks (CNN) with transfer learning. The performance of this model is evaluated using classification methods and compared them with traditional machine learning and deep learning approaches. This system accurately identifies the healthy and diseased cotton leaves are analyzed, demonstrates its potential contribution for early detection of disease and effective agricultural decision making.

**a. Experimental Setup**

The experiments are conducted using Cotton Leaf Image Dataset which consists healthy leaf images and diseased leaf images, collected form available agricultural datasets. This dataset includes the various disease categories of the leaves to ensure diversity. The data set splits into 80:20 training and testing set which ensures unbiased performance. In training, the leaf images are normalized and resized into fixed resolution. The required feature values are acquired by the Z-score normalization. The CNN based transfer learning model was implemented using Python, deep learning libraries such as TensorFlow and Keras. For comparison purpose some baseline models are included such as Decision Tree (DT), Random Forest (RF), Support Vector Machine (SVM).

**4.2 Evaluation Metrics**

The performance of all models was evaluated using standard classification evaluation metrics, defined as follows:  
Convolution Operation (CNN)

$$F(i, j) = \sum \sum I(i + m, j + n) X K(m, n)$$

Softmax Function (Disease Classification)

$$P(class_i) = \frac{e^{x_i}}{\sum_{j=1}^c e^{z_j}}$$

Accuracy (Performance Evaluation)

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

### 4. 3. Performance Analysis and Comparison

Model	Accuracy (%)	Precision	Recall	F1-Score
Decision Tree	78.4	0.76	0.74	0.75
Random Forest	84.6	0.83	0.82	0.82
SVM	86.1	0.85	0.84	0.84
Basic CNN	91.3	0.91	0.90	0.90
CNN + Transfer Learning (Proposed)	96.8	0.96	0.97	0.96

Table 1: Performance Comparison of Models

## V. DISCUSSION

The Leaf and Cotton Disease Recognition System shows the effective application of deep learning techniques for automated agricultural crop health monitoring. This system identifies various diseases of cotton and leaf using image data with high accuracy. By using this disease recognizing system reduces the manual dependency and time consuming and requires expert knowledge. Image based disease detection prevents high yield loss and allows early identification of crop infections, leaf spot diseases and powdery mildew etc. Data preprocessing techniques such as image resizing, normalization, and augmentation played a crucial role in improving model generalization and make it high robust. Deep Learning model helps to show strong performance in recognize healthy crop from diseased ones and background conditions. Anyway the systems work influenced by the quality and different datasets. Limited real-world variations like extreme weather effects, overlapping leaves, and multiple diseases in a single image can affect prediction accuracy. Moreover, the computational cost of training deep learning models can be expensive, which may pose challenges for large-scale deployment in low-resource environments. The proposed system provides a scalable and efficient solution for accurate agriculture. It has strong potential to be integrated with mobile applications or IoT-based smart farming systems, making disease detection accessible to farmers in real time.

## VI. CONCLUSION

The aim of this project is improving agriculture crop health monitoring and presents a deep learning-based Leaf and Cotton Disease Recognition System. The designed model classifies the crop diseases using leaf images and supports latest farming practices by using deep learning techniques. This system provides early crop disease detection and increases the crop productivity. This might reduce the manual efforts and improves the diagnosis accuracy. Through this automated recognition system farmer and improves measures and helpful to reduce economic loss. In the future, the system can be enhanced by expanding the dataset, supports additional crop types, and incorporating real-time image capture through smart phones or drone-based system. The complete project shows you how to identify the most prevalent diseases, diagnose the signs of crop infestation, and implement hands-on strategies to protect your crop and highlights the crucial role of artificial intelligence in transforming agriculture into a more efficient.

The project represents an effective leaf and cotton disease recognition system by using deep learning methods which

enhance agricultural crop health monitoring. By using convolution neural networks with transfer learning, the system able to automatically learning complicated features from leaf images and accurately classify the different disease conditions. The combination of image preprocessing and augmentation techniques result the robustness and generalization capability of the model, enabling reliable performance under varying environmental conditions. Compared to traditional manual inspection method and conventional image analysis method, the proposed approach provides high accuracy, reduced detection time, and better scalability, making it suitable for real world agriculture crop applications. The designed system provides a practical and cost-effective solution which supports early disease detection and informed decision making for farmers and agricultural professionals. Early identification of crop diseases helps reduce crop loss, minimize pesticides usage, improve overall crop productivity while promoting agricultural farming practices.

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