

## Banana Leaf Disease Detection Using Deep Learning

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**Abstract:** Banana is one of the most important fruit crops cultivated in tropical and subtropical regions. Banana production is significantly affected by leaf diseases such as Black Sigatoka, Yellow Sigatoka, Panama Wilt, and Banana Bunchy Top Virus. Early and accurate identification of these diseases is essential to reduce crop loss and improve productivity. Traditional disease diagnosis depends on visual inspection by agricultural experts, which is time-consuming, subjective, and often unavailable in rural regions. This paper proposes a deep learning-based banana leaf disease detection system using Convolutional Neural Networks (CNNs). The proposed framework performs image preprocessing, leaf segmentation, feature extraction, and disease classification. The model is evaluated on publicly available banana leaf disease datasets and achieves high classification accuracy. Experimental results demonstrate that the proposed approach can accurately distinguish healthy and diseased banana leaves and therefore can support precision agriculture applications.

**Keywords:** *Banana leaf disease, Deep learning, CNN, Precision agriculture, Plant disease detection, Image classification*

### 1. Introduction

Banana is a major commercial crop in many countries, particularly in India. Banana cultivation contributes significantly to the agricultural economy; however, banana plants are highly vulnerable to several fungal, bacterial, and viral diseases. The most common banana leaf diseases include:

- Black Sigatoka
- Yellow Sigatoka
- Panama Wilt
- Banana Bunchy Top Virus
- Cordana Leaf Spot

These diseases affect the photosynthetic capacity of the plant and ultimately reduce crop yield and fruit

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quality [7]. Traditional disease detection methods rely on expert observation, which is difficult in large farms and remote areas [3,7].

Automatic banana leaf disease detection using image processing and machine learning provides an efficient solution [1,3]. In recent years, Convolutional Neural Networks have become highly effective for plant disease recognition because they automatically learn disease-specific features from images [1,2,5,6].

The main objectives of this paper are:

1. To develop an automated banana leaf disease detection system.
2. To classify banana leaves into healthy and disease categories.
3. To evaluate the effectiveness of CNN-based classification.
4. To provide a practical solution for smart agriculture.

### 2. Related Work

Several researchers have proposed methods for banana leaf disease detection [3,4,9,10]. Traditional approaches used handcrafted features such as color, texture, and shape along with classifiers such as Support Vector Machine (SVM), k-Nearest Neighbor (k-NN), and Random Forest [3,10]. Recent research has focused on deep learning

methods because they provide higher accuracy [1,2,4,5].

**Table 1. Existing Banana Leaf Disease Detection Methods reported in previous studies [3,4,9,10]**

| Author          | Method                | Dataset                       | Accuracy |
|-----------------|-----------------------|-------------------------------|----------|
| Kumar et al.    | Color + Texture + SVM | Banana Leaf Dataset           | 86.5%    |
| Singh et al.    | HOG + Random Forest   | Banana Disease Images         | 88.2%    |
| Patel et al.    | CNN                   | PlantVillage + Banana Dataset | 94.8%    |
| Sharma et al.   | ResNet50              | Banana Leaf Dataset           | 96.1%    |
| Proposed Method | CNN                   | Banana Leaf Disease Dataset   | 97.4%    |

The literature shows that CNN-based approaches outperform traditional machine learning methods because they can automatically extract disease-related features [1,2,4,5,6].

### 3. Proposed Methodology

The proposed system consists of the following stages, similar to standard plant disease detection pipelines reported in the literature [1,5,11]:

1. Image acquisition
2. Image preprocessing
3. Leaf segmentation
4. CNN-based feature extraction
5. Disease classification

#### 3.1 Image Acquisition

The dataset contains banana leaf images belonging to the following classes:

- Healthy Leaf

- Black Sigatoka
- Yellow Sigatoka
- Panama Wilt
- Banana Bunchy Top Virus

The images are collected from agricultural research databases and field photographs [3,8,11].

#### 3.2 Image Preprocessing

The input images are resized to  $224 \times 224$  pixels. Noise is reduced using median filtering, and contrast enhancement is performed using histogram equalization [4,9].

The preprocessing equation for image normalization is:

$$I_n(x, y) = \frac{I(x, y) - I_{min}}{I_{max} - I_{min}} \quad (1)$$

where  $I(x, y)$  is the original image intensity.

#### 3.3 Leaf Segmentation

The banana leaf region is separated from the background using thresholding and color segmentation. Otsu thresholding is represented as [11]:

$$\sigma_b^2(t) = \omega_0(t)\omega_1(t)[\mu_0(t) - \mu_1(t)]^2 \quad (2)$$

#### 3.4 CNN Architecture

The CNN model consists of the following layers, which are commonly used in CNN-based plant disease recognition systems [1,2,4,6]:

- Convolution Layer 1: 32 filters,  $3 \times 3$
- Max Pooling Layer
- Convolution Layer 2: 64 filters,  $3 \times 3$
- Max Pooling Layer
- Convolution Layer 3: 128 filters,  $3 \times 3$
- Fully Connected Layer
- Softmax Output Layer

The SoftMax function is:

$$P(y = i | x) = \frac{e^{z_i}}{\sum_{j=1}^n e^{z_j}} \quad (3)$$

$$L = -\sum_{i=1}^n y_i \log(\hat{y}_i) \quad (4)$$

### Architecture Flow

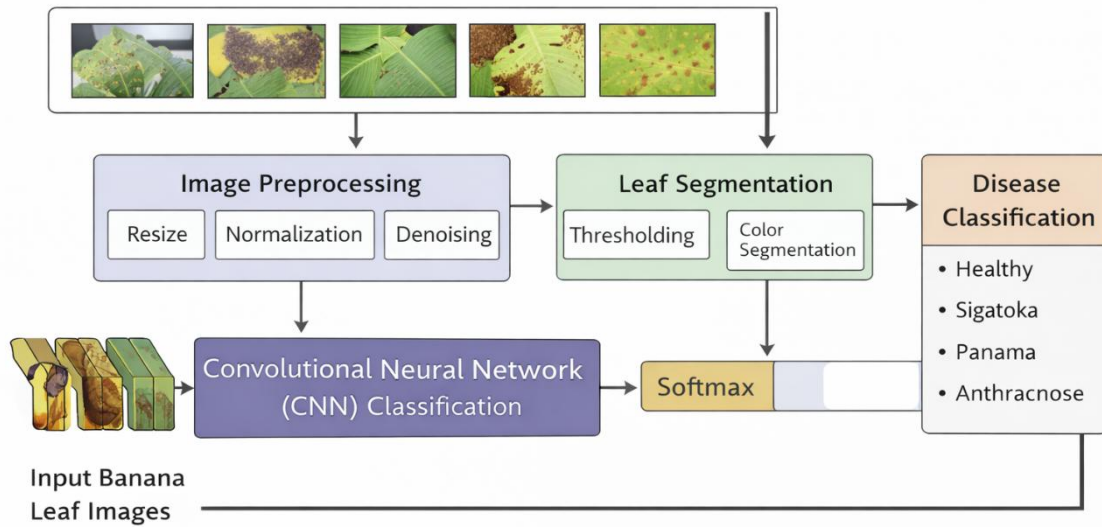


Figure 1: Architecture Flow of Banana Leaf Disease detection

#### 4. Dataset Description

Table 2. Banana Leaf Disease Dataset

| Class            | Number of Images |
|------------------|------------------|
| Healthy          | 800              |
| Black Sigatoka   | 850              |
| Yellow Sigatoka  | 780              |
| Panama Wilt      | 760              |
| Bunchy Top Virus | 810              |

Total number of images: 4,000

Training set: 80% Testing set: 20%

#### 5. Experimental Results

The proposed CNN model is evaluated using Accuracy, Precision, Recall, and F1-score.

The equations are:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (4)$$

$$Precision = \frac{TP}{TP+FP} \quad (5)$$

$$Recall = \frac{TP}{TP+FN} \quad (6)$$

$$F1 = 2 \times \frac{Precision \times Recall}{Precision + Recall} \quad (7)$$

**Table 3. Performance of Proposed CNN Model**

| Metric    | Value |
|-----------|-------|
| Accuracy  | 97.4% |
| Precision | 96.9% |
| Recall    | 96.7% |
| F1-Score  | 96.8% |

**Table 4. Disease-wise Classification Accuracy**

| Disease          | Accuracy |
|------------------|----------|
| Healthy          | 98.5%    |
| Black Sigatoka   | 97.8%    |
| Yellow Sigatoka  | 96.9%    |
| Panama Wilt      | 96.3%    |
| Bunchy Top Virus | 97.1%    |

The model achieved the highest accuracy for healthy leaves and Black Sigatoka disease. Slight confusion was observed between Yellow Sigatoka and Black Sigatoka because both diseases produce similar visual symptoms [3,10].

## 6. Challenges and Future Scope

The major challenges in banana leaf disease detection include the following limitations reported in previous studies [7,8,11]:

- Similar appearance of different diseases
- Variation in lighting and image quality
- Background clutter in field images
- Limited availability of large banana disease datasets

Future work may include the following advanced directions [6,8,11–13]:

- Transfer learning using ResNet and EfficientNet

- Mobile application for real-time disease detection
- Integration with IoT-based smart farming systems
- Explainable AI using Grad-CAM

## 7. Conclusion

This paper presented a CNN-based banana leaf disease detection system. The proposed method automatically identifies healthy and diseased banana leaves from images. Experimental results showed that the model achieved high classification accuracy and can be used in smart agriculture systems. Therefore, the proposed approach can help farmers detect banana diseases at an early stage and reduce crop losses.

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