CNN Model for Identifying Banana Leaf Disease Using image processing

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Abstract

Bananas are commonly distributed and massively popular fruit in the world mostly in the regions of warm climatic conditions and sub-tropical regions. Nonetheless, banana has numerous diseases that attack crops including moko, black sigatoka, yellow sigatoka, panama disease and various insects among others. Such pathogens can drastically lower the production and other quality parameters. Therefore, diagnosis of infections early and properly to prevent the loss of economic resources would be key. This paper presents an automated instrument that can utilized to diagnose banana leaf diseases based on CNN, a renowned machine learning tactic that proved to be adaptable towards image categorization matters. The suggested system will have to capture the images of the banana leaf and other observable symptoms, pre-process the same and then train a CNN model in order to classify and identify the disease/condition. Banana is a very common and vastly cultivated Fruit in many parts of the globe, mostly in warm geographical and sub-tropical regions. However, banana crops suffer a good number of diseases such as Moko, black sigatoka, yellow sigatoka, Panama disease and various pests. Such diseases may seriously compromise yield and other quality parameters of production. Hence, early and proper diagnosis of infections to curtail economic loss would be essential. In the proposed work, we present an automated tool to detect banana leaf diseases via a powerful artificial intelligence method called CNN, which proved to be relevant to image classification problems. The suggested system will acquire the images of the banana leaf and its observable symptoms, perform a few pre-processing steps, and train a CNN model, subsequently, to categorize and determine the disease/condition. In this paper, the accuracy rate was 94.89%.

Keywords: *Banana disease, deep learning, pre-processing, CNN*

1. Introduction

Bananas are a significant fruit crop cultivated on a massive scale in tropical and subtropical areas but are vulnerable to other predictable diseases of the leaves which can drastically reduce the consequent outputs as well as fruit quality. A few of them are Moko, Black Sigatoka, Yellow Sigatoka, Panama disease and insect pest infestation. They have enormous economic consequences on the farmers since they not only decrease the output but also alter the adherence of the market quality specifications.

Traditional means of plant disease diagnosis compel one to physically examine the plant process cumbersome, time consuming and prone human error. As artificial intelligence- especially imagery processing and deep learning- develop, practical automated solutions are becoming real. CNNs have proven to provide a high performance in processing the image-based data to detect diseases. The choice to use CNNS can be explained by fact that this method offered ability to correctly and within a short time Determine the various types leaf infection with image data.

Order to come up a functioning CNN-based type of classification to banana leaf diseases, images will have to be gathered, images will undergo preprocessing before the model trained on features of material impact. This enhances speed in process of detection and reduces use of expert analysis. The final user aspect is to have an automated and reliable early warning tool of crop management to the farmer to enable timely interventions. CNN-based systems are an efficient and state art solution to the problem of detecting banana leaf diseases.

2. Literature Survey

Akshara Gupta et al. [1] Deep learning-based approach employing CNN has utilized detection of banana leaf diseases. The model trained on dataset of pre-processed images that represent both healthy, diseased leaf conditions. By learning distinguishing visual patterns, the CNN effectively classifies the leaf images with high accuracy. This automated method enhances both the speed and reliability of disease diagnosis, reducing dependence on manual inspection. The system achieved an accuracy of 96.4%, enabling farmers to take timely preventive measures and limit the spread of infections in banana crops.

Arjun Jadhaw et al. [2] Research has explored both classical modern machine learning methods and deep learning techniques diagnosing banana leaf diseases. Annotated image datasets were employed to study common infections such as Panama disease, Black Sigatoka, and Yellow Sigatoka. Among the models evaluated—SVM, K-means clustering, CNN—the CNN model produced the highest accuracy of 95.8%. The results demonstrate that deep learning, and CNNs in particular, provide superior precision and scalability compared to traditional approaches. The study also underlines the potential application of these methods for real-time disease monitoring in agricultural fields.

Edwin Kambo et al. [3] deep learning model stayed to classify points of Black Sigatoka disease in banana leaves. The proposed CNN-based system is capable of identifying early, moderate, and severe phases of infection. Using a carefully prepared dataset of annotated images, model achieved an accurateness of 93.6%. The study highlights importance of stage-wise classification for effective disease management. The main goal is to enable timely and stage-specific interventions in banana farming, thereby improving crop health and productivity.

Geetabai S Hukkeri et al. [4] To classify plant leaf diseases, the study used pretrained Convolutional Neural Network (CNN) models VGG16 and ResNet50, which are pretrained on the ImageNet dataset, to detect diseases for various plants. The methodology made use of transfer learning, which expertly reduced training time and even achieved accuracy from 94% to 96.2%. It demonstrates the transfer learning may be one best options for the identification of agricultural diseases. In conclusion, the study illustrates that pretrained architectures are a sound and scalable approach to monitoring plant health in applied everyday situations.

Ilham Rahmana Syihad et al. [5] The study looked into application of deep learning methods for banana leaf disease detection. The study used the VGG-19 and ResNet50 models classify illnesses. With accurateness rates 92.8% and 94.3%, these designs produced remarkable results, proving the usefulness of deep convolutional networks for the identification in plant diseases. The findings demonstrate that sophisticated neural models speed up the diagnosis procedure addition to improving classification accuracy. This work's main goal is assisting farmers in identifying issues early on and enhancing crop management in general.

3. Proposed methodology

Because of varying climatic factors like nutritional deficiencies temperature, humidity and other obstacles, banana plants are exposed to change of diseases. The goal of research is to create an image classification tool that can precisely classify type of disease and determine banana leaf illnesses early on. The CNN technique is utilized in system to accurately identify diseases. Figure 1 shows workflow of proposed system.

Proposed system provides an automated and reliable method for identifying banana leaf using image processing, Convolutional Neural Networks (CNN). The process designed reduce manual intervention, improve accuracy, and enable early diagnosis. The major steps are as follows:

Key Steps in the Methodology:

1. **Image Acquisition:**
    - Capture banana leaf images directly from fields using cameras, smartphones, or drones.
    - Collect images under varying lighting and environmental conditions to improve model robustness.
2. **Image Preprocessing:**
    - To ensure consistent dimensions, resize and normalize photos.
    - Enhance quality by applying noise removal and contrast adjustment.
    - Perform segmentation to focus on the diseased region of the leaf.
3. **Data Augmentation:**
    - Utilize transformations including cropping, flipping, rotation, and brightness changes.
    - Increases dataset diversity and prevents model overfitting.
4. **Feature Extraction Using CNN:**
    - Automatically learn discriminative features instead of relying on manual feature selection.
    - To get leaf characteristics like texture, color and form use a number of convolution and pooling layers.
5. **Disease Classification:**
    - Fully connected layers of CNN classify leaves into categories like healthy, Sigatoka, Black Sigatoka, etc.
    - Output provides the specific type of disease detected.
6. **Result Output & Decision Support:**
    - Display results in addition to confidence ratings of each prediction.
    - Suggest suitable fertilizers, pesticides, or treatment methods for early intervention.

3.1 Block diagram

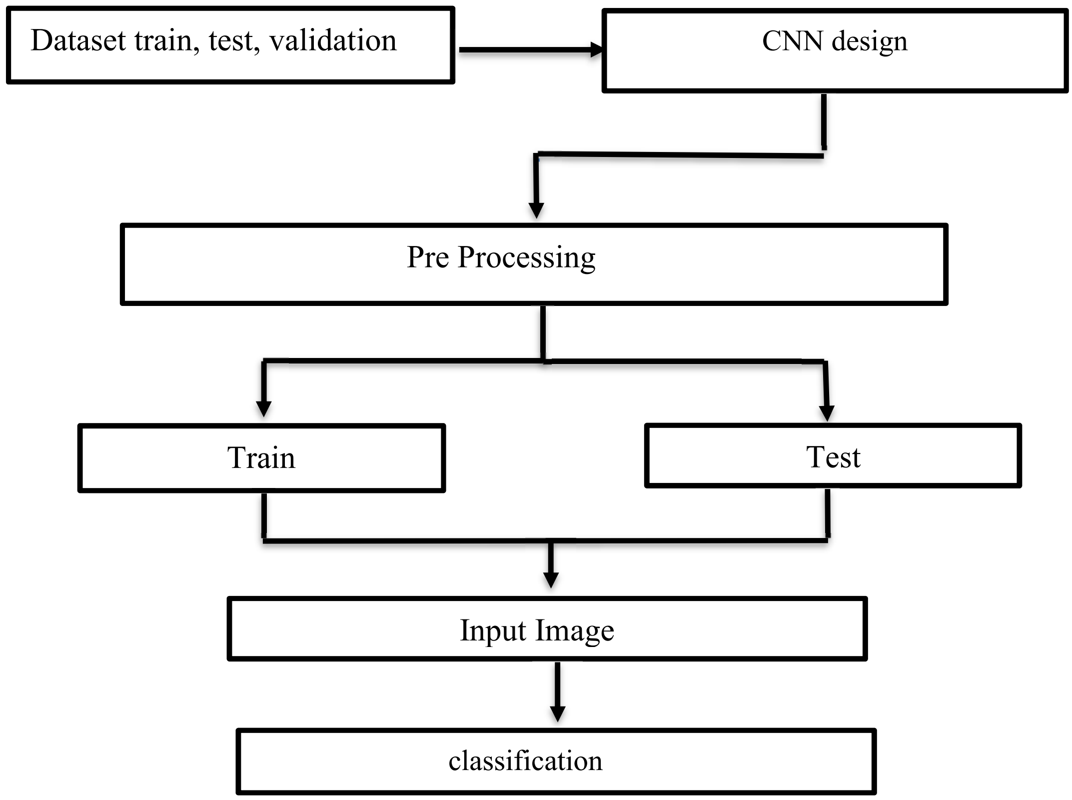

Figure 3.1.1 Proposed model diagram

3.2. Dataset

The Kaggle website provided the data needed to identify banana leaf disease for purpose of study. Both of the 1,554 photos in dataset are in good condition and diseased. The dataset is separated into three sections: test, train, and Val. The train dataset consists of 1104 images from 6 classes, whereas the Val dataset consists of 450 images from 6 classes. A sample of the example photo is highlighted in figure 2 below.

Category	***Images***
Banana Black Sigatoka Disease	184
Banana Healthy Leaf	184
Banana Insect Pest Disease	184
Banana Moko Disease	184
Banana Panama Disease	184
Banana Yellow Sigatoka Disease	184

Table 3.2.1 Dataset table

Healthy Leaf — Black Sigatoka Disease — Insect Pest Disease

Banana Moko Disease — Panama Disease — Yellow Sigatoka Disease

Figure 3.2.2 Sample images

3.2. Preprocessing

The pictures included in the dataset can serve a purpose for data preparation. Images can be resized, reshaped, and converted to arrays as preprocessing steps. For preprocessing we are using numerical Python, because machine was unable to classify the photos. Photos can be converted to an array using (numpy). Images with pixel values will range 0 to 256. Preprocessing can be completed before training neural network model.

3.3. CNN Based Classification

CNN is deep neural network models and multilayered architecture. CNN consists clearly-defined input, output and hidden layers which can used to classify the images. It is one of the good solutions for computer vision applications. Compared with other algorithms, the CNNs require less pre-processing.

3.4 Training the Model

Images from real-world properties showing healthy and diseased banana leaves used train Convolutional Neural Network (CNN) model. The dataset split into training, testing data, as is customary when employing an 80:20 ratio, order to improve generalization. Several techniques for picture augmentation and preprocessing used to improve feature extraction, reduce overfitting. Categorical cross-entropy was used loss function and Adam optimizer to assemble the CNN model for quick and efficient convergence. For purpose of identifying, classifying various banana leaf illnesses, convolutional neural network trained for tried-and-true epochs, and performed well terms of accuracy.

4. mathematical model

Here are some key mathematical formulas commonly used when training a CNN for image grouping (like identifying banana leaf diseases):

1. **Categorical Cross-Entropy Loss (used as the loss function):**

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

Where:

- C = number of classes (disease categories),
- y_i= true label (1 if the class is correct, 0 otherwise),
- $\hat{y}_i$ = predicted probability for class iii.

2. **Softmax Activation (used in the output layer):**

$$\hat{y}_i = \frac{e^{Z_i}}{\sum_{j=1}^{C} e^{Z_i}}$$

Where:

- Z_i= output (logit) for class iii,
- C= total number of classes.

3. **Accuracy Metric:**

$$\text{Accuracy}=\frac{Number\ of\ correct\ prdiction}{Total\ pridiction} \times 100$$

4. **Precision, Recall, and F1-Score (for evaluating performance):**

$$\text{Precision}=\frac{TP}{TP+FP}\ ,\ \text{Recall}=\frac{TP}{TP+FN}\ ,F1 = 2\times\frac{Precision\times\text{Recall}}{\text{Precision}+\text{Recall}}$$

Where:

- TP = True Positives,
- FP = False Positives,
- FN = False Negatives.

5. Graphs

5.1 Model Accuracy Comparison:

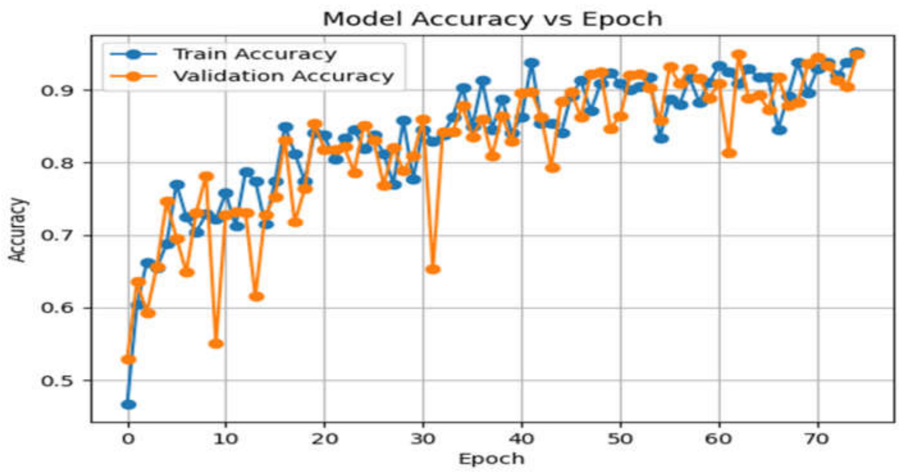

Figure 4.1.1 Accuracy v/s epochs graph

Two curves can see in the graph above. Training accuracy is shown by the blue curve, whereas testing accuracy is represented by the orange curve. This graph displays the same 94.89% accuracy as figure 4.1.1

6. Experimental results

The way in which developed CNN was assessed with a labelled dataset of images of banana leaves, which included healthy leaves and leaves with leaf spot disease. After exploring the performance of some standard pre-processing techniques, the photos were separated into training, validation and testing datasets, to ensure that the system could be evaluated on an independent set of images, to assess the model's classification performance during the experimentation process. After some experimenting the model learnt to classify the leaves into different disease categories, with a very high level of accuracy. We computed various metrics which recommended as measures for classification performance, including the precision, recall, F1-score and overall accuracy of the results. The results indicated proposed CNN based benchmarking approach represented a reasonable detection rate, with very few false predictions, suggesting the method would be appropriate for early diagnosis of banana leaf disease in a commercial setting. Furthermore, compared to existing methods, our The CNN-based approach offered more trustworthy data, with faster processing times potentially making real-time agricultural activity commercially viable.

7. Conclusion

The study demonstrates that CNN is an effective method classify and identify banana leaf diseases through image processing. CNN able to learn distinguishing features from images, such color, shape, and texture, without requiring hand-crafted features typical from the previous methods, improving the accuracy of diagnosis. Models are very efficient at early detection, supporting farmers by limiting the loss, and acting upon sites of infection quickly. CNN has a greater potential for pattern recognition compared to classical approaches, especially when the relationships of features are complicated. It acts as an efficient method to solve agricultural issues. Using CNN to detect banana diseases in photos is valuable, it benefits precision cropping, assists farmers in managing crops, and supports sustainable banana production.

8. Future Enhancement

The CNN-based disease detection system for banana leaves can be upgraded in particular instances. For example, during different angles, lighting conditions, and varying settings This system have more image data added to the datasets which support the model's adaptation to real-world situations on the farm. The synergy also allows the start-stop system to be synergised with either drones or mobile applications; effectively allowing the plantation to be observed in real time and continually. Again, possible upgrading is done through increasing the use of transfer learning, or hybrid deep learning architectures such as Efficient Net or Vision Transformers to attain significantly reduced training time and increased accuracy. The model could also be used to numerically grade the severity of the disease, which will help farmers prioritise the amount of infection for getting additional care on their crops. Moreover, can be possible to detect very early physiological changes of plants through video analysis or multispectral imaging which will enable a better diagnosis. Implementation of modifications to ensure the system can work on edge devices or offline on smart phones would also render it friendlier in the absence of internet connection in the rural setting. Lastly, the established tool can be combined with agricultural advisory portals and explainable AI capabilities, giving farmers not only the recommended treatment course but also explaining which areas of the leaf had contributed to diagnosis, which enhances trust and practicability.

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