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Mango Classification and Disease Prediction Using VGG16 and Transfer Learning

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Abstract- Agriculture has driven India's economic development significantly.Automation in agriculture enhances quality, productivity, and national economic growth. The manual grading of fruits is inefficient, inconsistent, and prone to bias. Mangoes are cherished not just for their taste but also for their nutritional value. Often called the "King of fruits", the mango's appealing aroma, flavorful pulp, and high nutritional content make it popular worldwide. In 2021, mangoes were the third most exported tropical fruit by volume after pineapples and avocados. Asia was the world's largest mango producer in 2021, exporting 912,510 tons. Mango crops are susceptible to various diseases throughout their lifespan, which significantly affects the quality and quantity of fruit production. These diseases are caused by a range of pathogens, including bacteria, fungi, viruses, algae, and insects. These pathogens can attack all parts of the mango plant, from the trunk and branches to the leaves, twigs, petioles, flowers, and fruits. Pests and diseases are major challenges in mango cultivation, often resulting in degraded yields. Artificial intelligence (AI) is a promising solution for improving pest and disease management in mango orchards. Relying solely on manual observation is often insufficient and typically requires expert guidance. To address this issue, image-processing techniques can be implemented to create automated systems. Specifically, deep learning algorithms can be employed to train these systems to distinguish between images of healthy and diseased mangoes. This allows researchers and farmers to accurately identify diseases at an early stage of development.Through the analysis of mango fruit images, it is possible to classify and identify both healthy and diseased specimens. In the proposed system, the following four feature vectors were utilized: color, morphology, texture, and hole structure on the fruit. The following is a summary of the techniques and challenges associated with fruit disease detection, as discussed in the abstract. In recent years, deep learning (DL), particularly convolutional neural networks (CNNs), has emerged as the most popular method among researchers owing to its impressive results. This research compares the performance of VGG16, ResNet50, Inception-V3, AlexNet, and MobileNet architectures in identifying pests and diseases, with a focus on using VGG16. It is crucial to approach this task with care, respect, and truth, ensuring secure and positive responses that promote fairness and avoid any harmful, unethical, prejudiced, or negative content. A Convolutional Neural Network (CNN) utilizing the VGG16 architecture achieved a high accuracy of 92.50% when trained over 50 epochs, surpassing the performance of AlexNet. Mangoes are nutritional powerhouses that boast vitamins A and C, which are crucial for healthy skin and a robust immune system. Imagine mangoes as concentrated sunshine from Miami—they're bright, energizing, and essential for overall wellness.These fruits are also an excellent source of dietary fiber, promoting a healthy digestive system.Mangoes are abundant in antioxidants, remarkable compounds that combat free radicals and contribute to overall vitality.Think of these fruits as your personal tropical protectors, diligently working to keep your body in optimal condition.This paper aims to classify mangoes based on three categories: whether it's a mango or not mango, whether it's healthy or unhealthy and whether it's ripe and unripe. For classification, we have used three different deep learning models.

1. Diseased detection model:predicts if the mango has any disease.
2. Health detection model:classifies the mango as healthy or unhealthy.
3. Ripeness detection model:determines whether the mango is ripe or unripe.

Method of Classification:
A. Convolutional Neural Network(CNNs) have been used to process the image data of mangoes.CNNs are a class of deep neural networks that excel at image classification tasks.These models are trained on a large dataset of mango images to predict the various categories mentioned above.
B. Transfer Learning with VGG16 :We used a well-known pretrained model, which has been fine-tuned for mango classification tasks to improve accuracy and reduce training time.

Index Terms - CNN, VGG16, Transfer learning

INTRODUCTION

Agriculture is a major pillar of India's economy, contributing to approximately 70% of its overall economic activity. India possesses extensive agricultural land and is a significant agricultural producer.The country produces a substantial 44.04 million tons of fruit annually, making it the second-largest fruit producer globally.India's fruit production accounts for 10% of the world's total fruit output. In the agricultural sector, automation plays a crucial role in enhancing quality, boosting productivity, and driving economic growth.Mangoes, scientifically known as Mangifera indica, are often regarded as the "king of fruits owing to their rich taste, distinctive flavor, and numerous health benefits. Mangoes are not only delicious but also packed with essential nutrients, such as vitamins A and C, as well as fiber and minerals, such as potassium, iron, copper, calcium, phosphorus, zinc, manganese, and selenium. Leaves, the most sensitive part of a plant, are typically the first to exhibit signs of disease. Continuous disease monitoring is crucial throughout a crop's life cycle, from planting to preharvest. Uncontrolled diseases can lead to significant productivity losses and negative economic impacts. Fruit diseases, poor environmental conditions, and pathogens such as bacteria and viruses diminish both the quality and quantity of fruit produced. Deep learning algorithms trained on images of healthy and diseased mangoes offer a solution for early and accurate disease identification by researchers and farmers. The strength of deep learning lies in its ability to quickly and accurately analyze images for disease detection in mangoes. In agriculture, automation enhances the quality, productivity, and economic growth. Convolutional Neural Networks (CNNs), a deep learning technique, are particularly valuable for automated defect detection in mangoes, a major and nutritionally rich crop in India.[1]. Global mango production is estimated at 50.6 million tons, with India accounting for 39% of this total. Following India, the largest mango producers are in Thailand and China. Within India, the primary mango-producing states include Uttar Pradesh, Tamil Nadu, Telangana, Andhra Pradesh, Kerala, Bihar, and Karnataka. [2]. Although mango production in India grows annually, the country's mango exports are limited. This limitation stems from the absence of nondestructive, reliable, and automated technologies for quality assessment. Therefore, prioritizing effective pest and disease control is vital for guaranteeing fruit quality and enhancing its appeal in global markets [12].Researchers have developed numerous prominent deep learning architectures, including AlexNet, GoogleNet, VGGNet, ResNet, InceptionResNet-v2, v3, Inception-v4, and DenseNet.

Basic step of Fruit Disease Detection

Step 1: Image Acquisition: This is the first step of image processing, in which the camera is used to capture fruit images in digital form and stored in digital media.

Step 2: Image Pre-processing: This section removes noise, smoothens the image, and resizes the images. RGB images were converted into gray images. In addition, the contrast of the image increased at a certain level.

Step 3. Image Segmentation: Segmentation is used to partition an image into multiple parts.

Step 4: Feature Extraction: This section is used to obtain features, such as color, texture, and shape, which reduce resources to describe a large set of data before the classification of the image.

Step 5: Classification: This section analyzes the numerical properties of the image features and organizes their data into categories. A neural network is used to train and classify fruit diseases.

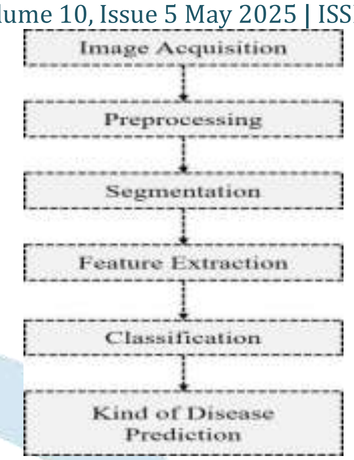

Fig 1 - General Method of Fruit Disease Detection

Features used to detect fruit disease include:

Color: One of the most important indicators of crop quality

Texture: Information patterns or structural arrangements observed in an image

Shape: A feature used to extract feature vectors

Size: A feature used to extract feature vectors

Distance to stem end: distance of defects to the nearest stem end. Other features used to detect fruit disease include the Global Color Histogram (GCH), Color Coherence Vector (CCV), Local Binary Pattern (LBP), and Completed Local Binary Pattern (CLBP). The Development of the CNN model that includes Stuff, such as RGB Color, Histogram, and centroid features obtained via K-means clustering, is expected to boost the classification accuracy. These varying methods contribute greatly to the enhancement of the effectiveness of fruit sorting and disease detection by methods based on images.

Proposed Flowchart:

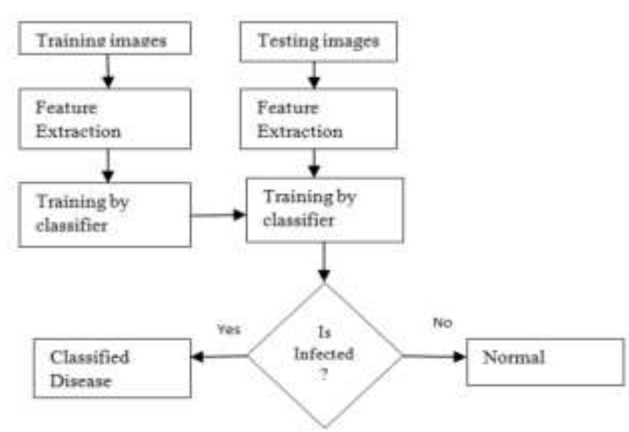

Fig: System Design for Detection of Disease

Image processing techniques and machine learning algorithms are used to detect and classify fruit diseases. Some of the methodologies used in fruit disease detection include: computer vision, machine learning, and sensor-based approaches.

In below table we can see the disease observed during the year 2017 - 2022.

Year	Treated diseases
2017	Anthracnose
2017	Powdery Mildew and Anthracnose
2018	Scab (fungus), Anthracnose (fungus), Red Rust (*Cephaleuros virescens*, an algal plant pathogen) and Sooty Mold (caused by mealy bug, scale insect and hopper)
2018	Anthracnose, Alternaria leaf spots, Leaf Gall, Leaf webber, Leaf burn of mango plant
2018	Anthracnose, Red rust, Sooty mold and scab
2019	Anthracnose
2019	Mango anthracnose disease, mango powdery mildew disease, red rust and mango Golmich.
2020	Anthracnose, Gall Midge, and Powdery Mildew
2020	Dag disease, Golmachi disease, Shutimold disease and Red Moricha disease
2021	Anthracnose
2021	Anthracnose, Apical Necrosis
2021	Sooty mold and Powdery Mildew
2021	Bacterial Canker, Powdery Mildew and Scab
2022	Mango Anthracnose, Bacterial black spot, and Sooty mold

Table 1. A list of fourteen treated mango diseases by researchers between 2017 and 2022.

2. Literature Review

Agriculture is a critical area for people to live in. Work has been toward accomplishing optimality in terms of production and quality. Image processing is a technique used to detect diseases present within an image. Previous studies have compared machine learning and deep learning techniques for detecting and classifying fruit diseases. These approaches are used to detect fruit diseases and determine their effectiveness.In this paper, A Comparative Analysis of Fruit Disease Detection and Classification [1] auther used the different approaches Support Vector Machine with K-Means (SVM), Artificial Neural Network (ANN), Convolutional Neural Network (CNN), Multi-Class Support Vector Machine (MSVM), K-means clustering, and Learning Vector Quantization Neural Network.But lastly prefers the SVM classifier with K-means clustering alternative to classification algorithm.

In this paper, A Survey on Apple Fruit Diseases Detection and Classification,[2] the author of bhavini and sheshang describes different segmentation techniques such as Histogram Matching, region-based approaches,edge detection approaches, clustering-based approaches, and color feature extraction methods: HSV Histogram, L*a*b, RGB, YUV,Global Color Histogram,Color coherence vector, mean of three-color array, and some texture feature methods are described as follows: Local Binary Pattern,Structure Element Histogram,Gray Level Co-occurrence Matrices,Gabor filter, wavelet transform, and independent component analysis. In Comparative Analysis of Fruit Disease Identification Methods: A Comprehensive Study [3] the auther Vigneswara Reddy K et al, said that the study compares older methods like visual observation, manual symptom correlation, spectroscopy, and chemical procedures with more contemporary methods like computer vision, autonomous learning algorithms, and sensor-based technologies. Precision, efficiency, cost, scalability, and ease of use are used to describe the effectiveness of each method, emphasizing the significance of utilizing technological advances to enhance the accuracy, effectiveness, and long-term sustainability of agricultural disease management. Some approaches are discussed in this paper, including visual examination, field investigation and sampling,Microscopic Analysis, Molecular Methods, Immunological Procedures, Imaging and remote sensing, computer vision, machine learning, Spectroscopy, Expert systems, and decision-making instruments.In [4] Detection and Classification of Fruit Disease: A Review,author Mrunali Desai et al., the quality and defects of fruits are checked using technologies such as MRI and X-ray imaging, which are costly for farmers to afford, occupy a large space, users need to have scientific knowledge to use and analyze the results, and have harmful effects on the specimens used for research.Naziy et al. [5] extracted trained datasets with features such as color, shape, and size extracted from the image, and the image cluster was identified using the k-means clustering algorithm. Next, a Convolutional neural network(CNN) is used to determine whether the fruit is infected. The experimental evaluation of the proposed approach is effective and 95% accurate in identifying banana, apple, and orange fruit diseases.A CNN has three main layers. They are

1.Convolutional layer
2. Pooling layer
3. Fully-connected layer

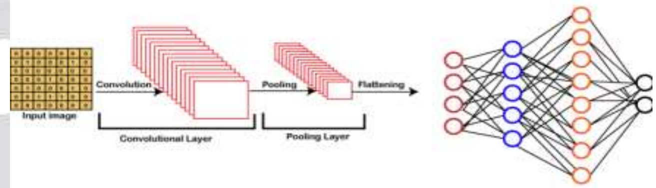

Fig.4 Architecture of CNN

In [6] FRUIT DISEASE DETECTION, Mrs.P.Laxmi et al,Overall, the code demonstrates the process of loading a pre-trained CNN model, preparing testing data, making predictions, evaluating model performance, visualizing results, and presenting the findings in a structured manner. This serves as a practical example of using deep learning for fruit classification tasks.

[7] In this study, different deep learning frameworks were used, such as RESNET50-V2, INCEPTION-V3, MOBILENET-V2, INCEPTION-RESNET-V2, XCEPTION, MOBILENET, and VGG-16 for identification fruit diseases. VGG-16 obtains a higher accuracy than the other deep learning models (96.10 %). In the entire experimental analysis, VGG-16 outperformed higher accuracy than over all deep learning algorithms.

In this paper, the author introduces an automated mango fruit disease detection method using whale optimization with a quasi-recurrent neural network (WOA-QRNN) model, which is applied to infected mango images. The WOA-QRNN method focuses on leveraging deep learning to identify mango fruit disease. To achieve this, the WOA-QRNN technique starts with image preprocessing using bilateral filtering (BF) for noise reduction. Subsequently, adaptive threshold-based segmentation is applied, followed by feature vector generations using the VGG -16 mode.This research highlights the effectiveness of combining deep learning, with optimization algorithms for automated mango fruit disease detections.[11]

3. PROPOSED METHODOLOGY

In the current research, the researchers developed a deep learning model that was trained with different datasets. This dataset includes different diseased and heathy mango fruits, namely heathy mango, and diseased mango. The CNN model was used as a classifier to validate the input image. The model classifies an input image as diseased or fresh healthy depending on the type of fruit given as input to the classifier. If the input image is a fresh fruit, the model predicts that it is a fresh fruit, and if the input image is a diseased fruit, it classifies it as a diseased fruit. Finally, the result is known to the end user. Figure 2 below shows the architecture and flow structure of the model for classifying the input image into two different classes as healthy and diseased fruit.

Pseudo code for the Convolutional Neural
Network for disease recognition of Mango fruit

Diseases Detection and Classification Procedure:
Input: fruit image
Output: Classified fruit disease
Algorithm:
1. Load a images for training
2. Read image for testing.
3. Perform feature extraction using color features i.e. Global color histogram (GCH), Color coherence vector (CCV) and texture features i.e. Local binary pattern (LBP), complete local binary pattern (CLBP), Local ternary pattern (LTP), Texture Features.
4. Perform feature level fusion using color and texture features.
GCH+TEXTURE
GCH+LTP
TEXTURE+GCH+LBP
TEXTURE+LBP
TEXTURE+CLBP
TEXTURE+LTP
TEXTURE+CLBP+LTP
5. Apply Convolution neural network classifier on the segmented image. imageInputLayer ([77 100 3]); convolution2dLayer(2,6); ReluLayer(); maxPooling2dLayer(2,'Stride',2); fullyConnectedLayer(3); softmaxLayer(); classificationLayer()]
6. If fruit is infected by any disease then go to step 7 otherwise go to step 8.
7. Apply k mean clustering for image segmentation.
8. Fruit is normal or ordinary fruit.
9. Result the classified fruit as follows by using Mango classification model.

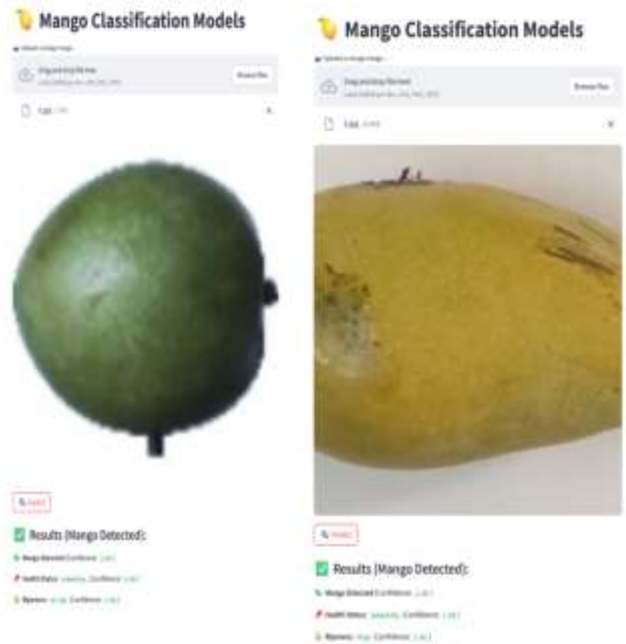

Fig: Results of CNN Model

RESEARCH METHOD

This application uses deep learning to analyze images of mangoes and classify them based on three characteristics: whether the fruit is a mango, whether it's healthy, and whether it's ripe.The models are trained using a convolutional neural network architecture(VGG16) to deliver accurate predictions from visual inputs.Simply upload a mango image and receive a detailed report on the fruit's classification.

Methodology:

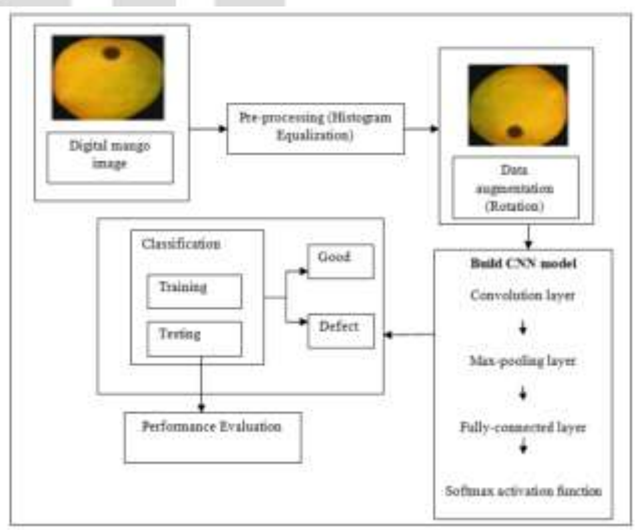

Fig: Overview of Proposed Methodology

Table: Main technical parameters of the CCD camera

Model	MER-500-14GC
Data interface	GiveVision
Sensor	1/2.5"COMS
Resolving power	2592 × 1944
Frame rate (fps)	14 fps @ 2592 × 1944
Pixel size (μm)	2.2 × 2.2
Black and white/color	Color
A/D	12 bits
Optical interface	C
Size (mm) (W × H × D)	29 × 29 × 29

Fig: Basic Architecture of VGG16 Model

Fig: Proposed architecture using VGG16

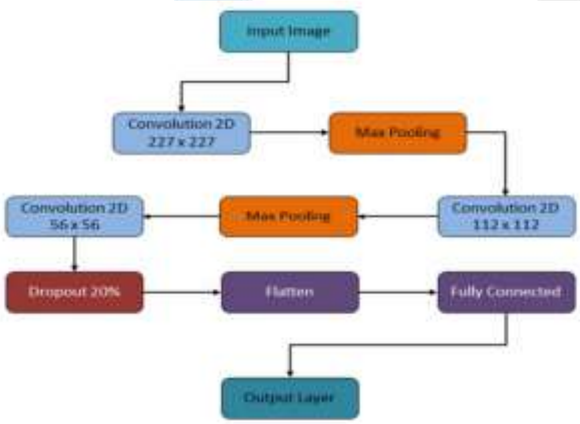

Fig: Architecture of the proposed CNN model.

About Dataset:This dataset contains images of mangoes, labeled for disease, health status, and ripeness level.The dataset was sourced from multiple farms and various regions to ensure a diverse and robust dtaset.

1. Mango Type: Identifies whether the fruit is a mango or not.
2. Health Status: Classifies the mango as healthy or unhealthy based on external characteristics like blemishes or damage.
3. Ripeness: Determines if the mango is ripe or unripe based on it's color,shape, and texture.
4. The images used for training and testing come from various sources and represent different stages of mango growth and maturity.

Note: the dataset used for training is proprietary and owned by the research team. However, a simillar dataset can be found on publicly available platforms such as Kaggle.

We also compared the performance of each model and observed that the CNN-based approach offers the most reliable and accurate results for all the classifications.

4. Experimental results and discussions

4.1. Experimental setup (Tools and Libraries used)

We used different tools such as Pycharm JETBRAINS IDE,Streamlit, Jupiter Lab, Google Colab to create the classifiers. The suggested fruit categorization architecture was created with TensorFlow and Keras, Scikit-learn, Pandas, Numpy, Mat- plotlib and Seaborn an open-source application that combines Python3 with neural networks. Jupiter Notebook is used to train and assess the model on a 64-bit Windows 11PC. The PC includes 16 GB of RAM and a 2.80GHz Intel 11th Generation Core i5 processor. The CNN model was trained and tested on a laptop with Windows operating system.

4.2. Performance metrics

To assess the efficacy of the suggested framework, we use many statistical metrics such as precision, recall, accuracy, sensitivity, and F1- score are utilized. True positive (TP), true negative (TN), false positive (FP), and false negative (FN) characteristics are determined by the confusion matrix's conclusion. The word "TP" refers to a successful detection of true instants. The abbreviation "TN" denotes a result in which the proposed system correctly recognized the kind of fruit that was misclassified. The term "FP" refers to a situation in which the suggested framework incorrectly identified a positive detection. The term "FN" refers to a case in which the suggested framework incorrectly determined the sort of negative detection. These metrics are calculated in Eqs. (1)–(4).

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

$$F1 - score = 2 \times \frac{Pr \times Re}{Pr + Re} \quad (3)$$

$$Recall = \frac{TP}{TP + FN} \quad (4)$$

4.3. Results and discussion

Using the CNN VGG16 and transfer learning model, we can classify fruit in to different categories as healthy, unhealthy, ripe, unripe and mango or not mango accurately.

5. Conclusion

In this project, we use CNN, image pre processing and TF service to display accurate results. In the future we will add more fruits and crates for users' suggestions/reviews. If implemented correctly, this future enhancement could scale to the success of this project.The trained CNN model should be capable of differentiating between healthy and diseased fruits . We have used the CNN model to identify the type of the disease the fruit is suffering and to suggest a pesticide based on image classification. For the classification and recognition of local fruits in our study, we employed some deep learning models, including Inception-v3, VGG-19, Mobile Net, and ResNet-50. Three of the models managed to attain a test accuracy rate of over 98%, which is really outstanding. Mobile Net earned the highest test accuracy rating of 99.21% when compared to those models. This kind of increased fruit classification and recognition accuracy will benefit the machine's overall performance.We have some limitations, which we will overcome in the future. Due to seasonal fruit availability, we were only able to use six different types of local fruits for our research. Nevertheless, in the future, we hope to expand our research to include additional local fruits and eventually develop a web application.

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