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External Features Based Grading of Mangoes Using Deep Learning

Sai Sathwik Reddy Mulukalla[1], Praneeth Rao Kadari[2], Karan Singh Rathod[3]

CSE (Data Science), Institute of Aeronautical Engineering, Hyderabad, India[1]

CSE (Data Science), Institute of Aeronautical Engineering, Hyderabad, India[2]

CSE (Data Science), Institute of Aeronautical Engineering, Hyderabad, India[3]

Abstract: The accurate grading of mangoes based on external features is a critical task in the agricultural industry, impacting both market value and consumer satisfaction. Traditional methods of grading are labor-intensive and often subjective, leading to inconsistencies and inefficiencies. This study proposes an automated mango grading system utilizing deep learning techniques, specifically leveraging the MobileNet architecture, to address these challenges. MobileNet, known for its efficiency in mobile and embedded vision applications, is employed to classify mangoes based on visual attributes such as size, color, and surface defects. The proposed model is trained on a comprehensive dataset of mango images, annotated with corresponding grades. Performance metrics, including accuracy, precision, recall, and F1-score, are used to evaluate the system. Experimental results demonstrate that the MobileNet based grading system achieves high accuracy and robustness, significantly outperforming traditional methods. This approach promisesto enhance the efficiency and consistency of mango grading, providing a scalable solution for real-time applications in the agricultural sector.

Index Terms: Deep Learning, MobileNet, Transfer Learning, Feature Extraction, Image Classification

I. INTRODUCTION

The agricultural industry continually seeks innovative solutions to enhance productivity, efficiency,and quality control. Mango grading, a crucial process in the post-harvest handling of this popular fruit,significantly influences market value and consumer satisfaction. Traditionally, mango grading has relied on manual inspection methods that are labor-intensive, timeconsuming, and subject to human error and variability. These conventional approaches often result in inconsistencies and inefficiencies,impacting both producers and consumers. Recent advancements in technology, particularly in the field of deep learning, have paved the way for automated solutions that promise to revolutionize agricultural practices. Deep learning models, with their ability to learn and interpret complex patterns from data, offer a powerful alternative to traditional grading methods. Among these models, MobileNet stands out for its efficiency and suitability for mobile and embedded applications, making it an ideal choice for real-time agricultural tasks. This study proposes a novel mango grading system based on the MobileNet architecture, focusing on external features such as size, color, and surface defects. By leveraging a deep learning approach, the system aims to provide accurate, consistent, and scalable grading of mangoes. The research involve straining the MobileNet model on a comprehensive dataset of mango images, annotated with corresponding grades, and evaluating its performance using standard metrics such as accuracy,precision, recall, and F1-score. The primary objective of this research is to demonstrate the efficacy of a MobileNet-based grading system in improving the accuracy and reliability of mango grading. The proposed system has the potential to enhance operational efficiency, reduce labor costs, and ensure uniform quality standards,thereby benefiting the entire supply chain from producers to consumers. Through this study, we aim to contribute to the growing body of knowledge in precision agriculture and highlight the practical applications of deep learning in the agricultural sector. CNNs are used to extract features at a high level from pictures. They use several layers of processing to capture different features of the picture, such as textures, edges, and more intricate structures.Examples of architectures are ResNet, Inception, and VGG19. Transform learning is an advanced approach in machine learning that focuses on improving model performance by transforming data representations. This involves enhancing features through techniques such as image filtering, edge detection, and color space adjustments, which highlight relevant aspects of the data. Unlike traditional methods, transform learning allows models,particularly deep learning models like convolutional neural networks (CNNs), to learn these complex transformations during the training process. By optimizing and finetuning models with transformed data, transform learning aims to create more informative and robust feature sets. MobileNet is a family of efficient and lightweight deep learning models designed for mobile and embedded vision applications. Developed by Google, MobileNet utilizes depth wise separable convolutions, significantly reducing the number of parameters and computational cost compared to traditional convolutional neural networks (CNNs).

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This efficiency makes MobileNet particularly suitable for real-time applications on devices with limited computational resources, such as smartphones and IoT devices. Despite its compact size, MobileNet achieves high accuracy in various image classification tasks, making it an ideal choice for applications like automated mango grading in agriculture.

II. LITERATURE SURVEY

Nguyen Duc Tai, Wei Chih Lin, Nguyen Minh Trieu and Nguyen Truong Thinh, "Development of a Mango-Grading and -Sorting System Based on External Features, Using Machine Learning Algorithms", April 2024. This paper proposes a system to grade and sort mangoes based on their external features using machine learning algorithms. The system uses image processing to take pictures of the mangoes and then analyzes the images to determine the grade of the mango.

This system can sort mangoes faster and more accurately than humans.Processing speed of the ensemble learning method is slower than some individual ML algorithms. This is because the ensemble learning method involves a larger number of calculations.[1].

Thanh-Nghi Doan and Duc-Ngoc Le-Thi, "A Novel Mango Grading System Based on Image Processing and Machine Learning Methods", 2023. The system utilizes various image processing methods like Otsu thresholding, contour analysis, Canny edge detection for blemish detection. The authors built a new dataset of high-quality images of local mangoes for training and evaluation. The paper discusses the importance of considering local grading standards for better accuracy.The computational cost of the system is not discussed (e.g., processing time per image). The paper doesnot mention how the system addresses potential issues with data augmentation, such as introducing unrealistic blemishes[2].

Hafiz Muhammad Rizwan Iqbal and Ayesha Hakim, "Classification and Grading of Harvested Mangoes Using Convolutional Neural Network". This study showcases there markable potential of CNNs in revolutionizing mango cultivar classification and grading. The high accuracy achieved, particularly with Inception v3, highlights the ability to automate the process with minimal human error. Data augmentation further strengthens the models generalizability. It's noteworthy that while Class I and II grading requires improvement, the overall accuracy remains impressive. The potential for ontree classification and further feature extraction advancements promises even greater efficiency and consistency within the Pakistani mango export industry[3].

Yonis Gulzar, "Fruit Image Classification Model Based on MobileNetV2 with DeepTransfer Learning Technique", January 2023. The model is based on MobileNetV2, a light weight CNN, making it suitable for mobile applications. The authors modified the MobileNetV2 architecture by adding five layers, which improved the accuracy compared to the original model. The model was trained on a dataset of 40 different fruit varieties.The paper provides a promising approach to fruit image classification using a modified MobileNetV2 architecture. The model's accuracy and lightweight design make it suitable for real-world applications, such as mobile apps for fruit identification[4].

Bin Zheng and Tao Huang, "Mango Grading System Based on Optimized Convolutional Neural Network" The paper "Development of a Mango-Grading and -Sorting System Based on External Features, Using Machine Learning Algorithms" provides a comprehensive overview of the volume estimation method described above is a simplified approach based on the assumption that the mango has an ellipsoid shape. This assumption might not perfectly capture the actual shape of the mango, which can vary. However, it provides a reasonable estimate of the volume and can be useful as an input feature for the classification model.[5].

III. EXISTING METHOD

A. Manual Grading

This traditional method relies on human inspectors visually evaluating mangoes based on established standards, considering factors like size, shape, color, and surface defects. While this method is widely used, it has limitations like subjectivity, inconsistency, and high labor costs.

B. Automated Grading Systems

These systems utilize advanced technologies like:

- Image Processing and Machine Learning:Cameras capture images of mangoes, and algorithms extract features like size, shape, color, and surface defects. Machine learning models are then trained on large datasets to classify mangoes based on these features, achieving high accuracy and efficiency compared to manual grading.
- Near-Infrared (NIR) Spectroscopy: This technique analyzes the internal properties of mangoes nondestructively, detecting internal defects and maturity levels. This offers valuable insights beyond visual inspection.

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IV. DEMERITS OF EXISTING SYSTEM

A. Manual Grading

- Subjectivity: Human inspectors can exhibit variations in their assessments due to individual differences in perception and interpretation of grading standards. This leads to inconsistencies in grading results.
- Labor Costs: Manual grading requires significant manpower, increasing operational costs and potentially limiting throughput.
- Limited Scalability: Expanding manual grading operations to meet large-scale demands can be challenging due to labor requirements

B. Automated Grading Systems

- Maintenance and Expertise: Maintaining and operating these systems might require specialized technical expertise, adding an additional layer of complexity.
- Potential for Errors: While automated systems offer high accuracy, they are not perfect. Factors like lighting variations, overlapping fruits, or sensor calibration issues can still lead to errors in grading.

V. PROPOSED SYSTEM

The proposed system aims to automate mango grading by combining deep learning(CNN)for ripeness detection with image processing techniques for other quality assessments. It involves the following stages:

- Image Acquisition: A controlled setup with uniform lighting and plain background for standardized image capture.
- Feature Extraction using Image Processing and Computer Vision
- Classification (using Machine Learning)
- Maturity Ripening Stage Detection (using Deep Learning)

VI. REQUIREMENTS

A. Hardware Requirements

The hardware specifications for using the Deep Learning project are outlined as follows:

- Processing Unit: A multicore CPU with high processing power to handle complex computations involved in training deep neural networks.
- Graphics Processing Unit (GPU): A high-performance GPU, such as NVIDIA GeForce GTX or Quadro series, to accelerate the training process of deep learning models.
- Memory (RAM): A minimum of 8GB RAM to support the loading and processing of large retinal image datasets.
- Storage: Adequate storage space, preferably SSDs, for storing datasets, model weights, and related project files.

B. Software Requirements

The software components necessary for the project implementation include:

- Operating System: Platform-independent, compatible with Windows, Linux, or macOS.
- Programming Language: Python 3.x for coding the deep learning model and associated scripts.
- Deep Learning Frameworks: TensorFlow or PyTorch for building, training, and evaluating deep neural networks.
- Data Processing Libraries: Pandas and NumPy for efficient data manipulation, and scikit-learn for preprocessing tasks.
- Image Processing Libraries: OpenCV or Pillow for handling and augmenting images.

VII. SYSTEM ARCHITECTURE

A. Dataset Collection

This stage involves assembling a diverse set of mango images. The dataset should include images representing different quality grades under consistent conditions. Images can be collected from various sources, such as online repositories, controlled setups, or through collaboration with industry partners. To ensure uniformity, photographs should ideally feature consistent lighting, plain backgrounds, and a range of perspectives.

B. Preprocessing Unit

This unit prepares the captured images for the deep learning model.

- Cleaning: Removes irrelevant or corrupted images from the dataset.
- Normalization: Standardizes the pixel values of the images for better training.
- Augmentation: Artificially increases the dataset size by generating additional images through techniques like rotation, cropping, flipping, or adding noise. This helps the model generalize better to unseen variations.

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- Feature Extraction: Applies image processing techniques to extract relevant features from the images.

C. Deep Learning Model (MobileNet)

This is the core of the system, responsible for classifying mangoes based on their quality.The proposed architecture utilizes MobileNet, a lightweight and efficient deeplearning model suitable for real-time applications with limited computational resources.The model is trained on a large and diverse dataset of preprocessed mango images labeled with their corresponding grades (e.g., excellent, good, average, poor).During training, the model learns to identify patterns and relationships between image features and quality grades.

D. Classification Unit

Once the model is trained, it receives preprocessed images of new mangoes for classification.The model analyzes the features extracted from the image and predicts the most likely grade for the mango.

E. Output Unit

The predicted grade for each mango is displayed on a user interface or sent to a control system for further processing (e.g., sorting, packaging).

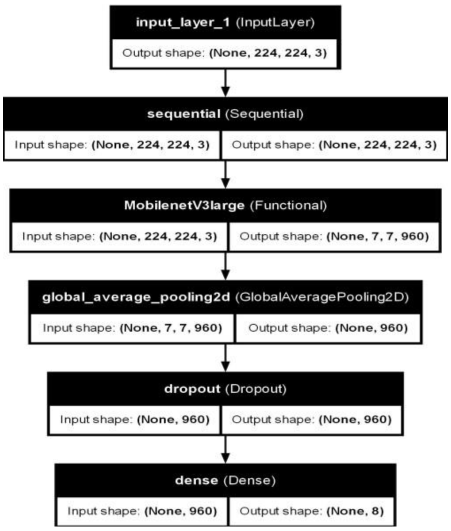

Fig. 1. MobileNet-V3 Model Architecture.

VIII. RESULTS

In this section, we present the results obtained from the experiments conducted using various deep learning architectures for the classification of mangoes. We compare the performance of each model and analyze their effectiveness in addressing the task at hand. We begin by comparing the accuracies achieved by different deep learning architectures in classifying mangoes images into eight severity categories of mango species. The following table summarizes the accuracies obtained by each model.

Model	Accuracy
Inception-V3	98.05%
MobileNet -V3	98.05%
Custom CNN	79%

Fig. 2. Accuracy Table.

The model maintains high precision and recall for different species of mangoes, demonstrating its capability in accurately identifying various species of mangoes. Achieving a validation accuracy of 98.05with MobileNet V3 underscores the model’s effectiveness in classifying eight different species of mangoes.

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The high accuracy and efficiency of MobileNet V3 make it an ideal choice for real-time mango grading systems, enhancing the accuracy and consistency of mango quality assessment. This advancement can significantly improve quality control and market value for mango producers, contributing to more efficient and reliable agricultural practices. The results indicate that the proposed system can serve as a valuable tool in the agricultural industry, ensuring better quality management and consumer satisfaction. The model exhibited high precision across all eight species, indicating that it correctly identified mango species with minimal false positives.

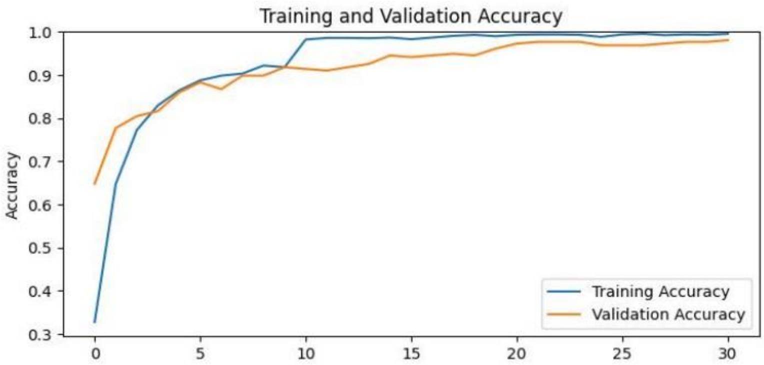

Fig. 3. Graph for Training and Validation Accuracy for MobileNet-V3.

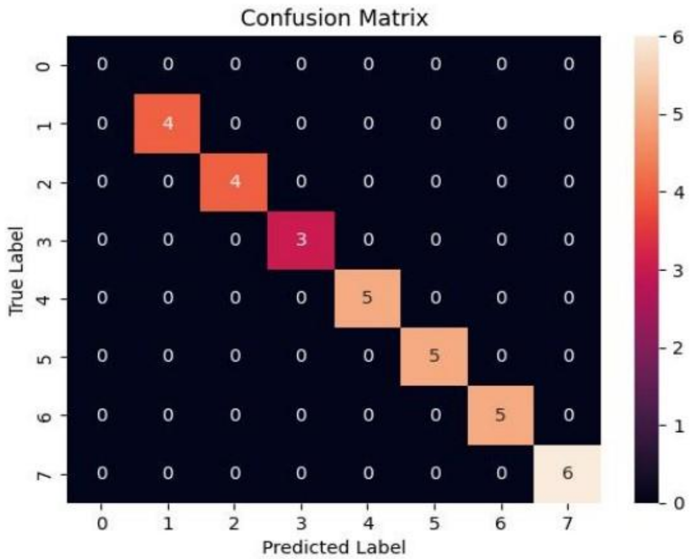

Fig. 4. Confusion Matrix.

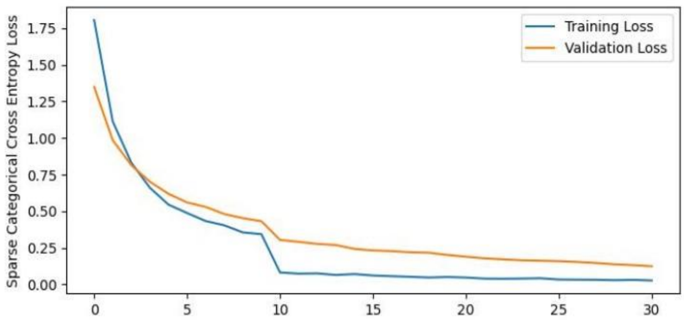

Fig. 5. Graph for Model loss for MobileNet – V3 model

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