

A Comprehensive Review of Machine Learning Models for Mango Variety Recognition and Quality Assessment

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Abstract— Accurate classification of mango varieties plays a crucial role in agriculture, supply chain management, and consumer markets. Misidentification of mango species can lead to inconsistencies in quality control, unfair pricing, and reduced consumer trust, particularly in international trade where buyers may struggle to distinguish between diverse Indian mango varieties. To address these concerns, numerous studies have investigated machine learning and deep learning techniques, especially Convolutional Neural Networks (CNNs), for automated mango classification and quality assessment. This paper presents a comprehensive review of existing research on CNN-based approaches for mango variety identification, grading, and price estimation. The literature indicates that pre-trained CNN models significantly improve image-based recognition accuracy, while automated grading mechanisms enhance market transparency. Several studies also explore the integration of pricing models to support fair and consistent decision-making for farmers, distributors, and buyers. Overall, the reviewed methodologies demonstrate strong potential to improve efficiency, standardization, and reliability in domestic and global mango markets.

Keywords— Convolutional Neural Network, Fruit Grading, Image Recognition, Mango Classification, Price Prediction, Web Application.

I. INTRODUCTION

Mango (*Mangifera indica* L.) is one of the most economically valuable fruit crops cultivated in tropical and subtropical regions. India accounts for more than 40% of global mango production and is known for its extensive variety diversity in terms of size, color, texture, flavor, and maturity stages. While such diversity increases commercial value, it also introduces challenges in classification accuracy, quality control, and market standardization.

Traditional mango classification methods rely on manual inspection performed by trained experts who evaluate visual and physical characteristics such as color, weight, and texture. Although practical in small-scale settings, manual grading is time-consuming, labor-intensive, and susceptible to subjective judgment and inconsistency, limiting its scalability for large agricultural operations.

Recent advancements in computer vision and artificial intelligence have enabled automated fruit classification systems. Convolutional Neural Networks (CNNs), in particular, have shown superior capability in extracting complex image features automatically, making them highly effective for agricultural image recognition tasks. Several researchers have applied CNN-based and hybrid machine learning approaches for mango variety identification, ripeness detection, grading, and quality evaluation.

This paper reviews and analyzes previous research on machine learning and deep learning techniques applied to mango classification and quality assessment. The objective is to compare traditional approaches with CNN-based methods, evaluate their performance, and identify research gaps and future directions. The remaining sections present a detailed literature survey, followed by future research scope and concluding observations.

II. LITERATURE SURVEY AND ANALYSIS

This chapter presents a literature survey of previous research papers, providing detailed information about existing systems along with their advantages and limitations.

2.1 Survey of Existing Systems

Yonasi Safari, Joyce Nakatumba-Nabende, Rose Nakasi, and Rose Nakibuule et al. [1] presented a comprehensive review on automated fruit damage detection using machine learning techniques. The study highlights how automated systems

improve fruit quality assessment by overcoming limitations of manual inspection, such as inconsistency and human error. By analyzing thirty-two research publications over thirteen years, the authors reviewed approaches including image processing, machine learning, and deep learning. While promising results were reported, the study emphasized the need for advanced, mobile-based solutions capable of handling occlusion and real-world environmental conditions.

Chandra Sekhar Nandi, Bipan Tudu, and Chiranjib Koley et al. [2] proposed a machine vision-based system for predicting mango maturity to support automated sorting. The system utilized image features related to color, texture, and shape, combined with an ensemble Support Vector Machine (SVM) classifier. Experiments conducted on multiple mango varieties achieved an accuracy of 96%, demonstrating the effectiveness of classical machine vision techniques for industrial maturity classification.

Ali Khumaidi, Yohanes Aris Purwanto, Heru Sukoco, and Sony Hartono Wijaya et al. [3] developed a fuzzy logic-based approach using Near-Infrared (NIR) spectroscopy for mango maturity classification. By applying fuzzy rules to spectral data, the system effectively handled uncertainty and achieved approximately 95% accuracy. The study demonstrated the usefulness of portable NIR devices for non-destructive maturity assessment, although dependency on hardware increases implementation cost.

Siti Nordiyana Md Salim, Ali Yeon Md Shakaff, Mohd Noor Ahmad, Abdul Hamid Adom, and Zulkifli Husin et al. [4] introduced an electronic nose (e-nose) system for fruit ripeness detection. The system analyzed volatile organic compounds emitted by fruits using gas sensors and applied machine learning classifiers. The proposed method achieved around 92% accuracy and showed potential for fast and non-destructive quality evaluation. However, sensor calibration and environmental sensitivity remain practical challenges.

Christian Negara, Kai-Uwe Vieth, Magali Lafontaine, and Maximilian Freund et al. [5] proposed a Vis-NIR spectroscopy-based fruit sorting system to assess quality parameters non-destructively. Using regression techniques such as Partial Least Squares Regression (PLSR), the system achieved high prediction accuracy ($R^2 > 0.9$), demonstrating its effectiveness in agricultural processing industries.

Joshua Harrington Aheto et al. [6] presented a hybrid system combining computer vision and colorimetric sensor arrays for mango quality assessment. By integrating visual and chemical features, the system achieved approximately 93% accuracy, offering a reliable and non-invasive solution for supply chain quality monitoring.

Kranti Raut and Prof. Vibha Bora et al. [7] developed a digital image processing-based approach for fruit maturity assessment. The system extracted color and texture features and applied classifiers such as k-NN and SVM, achieving around 90% accuracy.

Busarakorn Mahayothee et al. [8] proposed a non-destructive mango maturity detection method using NIR spectroscopy. Regression-based models achieved high accuracy ($R^2 > 0.9$), highlighting the suitability of NIR techniques for harvest optimization and quality control.

Nur Nafiyah and Jauharul Maknun et al. [9] introduced a CNN-based approach for mango variety classification using leaf images. The deep learning model automatically extracted discriminative features and achieved approximately 94% accuracy.

Muhamad Farid Mavi, Zulkifli Husin, and R. Badlishah Ahmad et al. [10] proposed a hybrid ripeness classification system combining image processing with SVM and Artificial Neural Network (ANN) models. The approach achieved around 93% accuracy.

Girish S, Jnana Shetty K, Krithi D, M Kshama Kalkur, and Megha A et al. [11] applied transfer learning using pre-trained CNN models for mango classification. The system achieved approximately 95% accuracy with reduced training time.

H. Khalid et al. [12] studied modern fruit classification techniques using both traditional machine learning and deep learning models. Their comparative analysis revealed that deep learning approaches consistently outperformed conventional methods, achieving around 94% accuracy.

Ijariit Journal et al. [13] proposed an Arduino-based system combined with image processing for mango ripeness detection. The low-cost setup achieved approximately 90% accuracy, making it suitable for small-scale farmers and retailers.

Harshveer Singh Randhawa and Shanu Sharma et al. [14] conducted a survey on computer vision and soft computing methods for fruit ripeness grading. The study reported that integrated machine learning approaches achieved accuracies between 85% and 95%, depending on fruit type and environmental conditions.

Nguyen Truong Thinh, Huynh Thanh Cong, and Nguyen Duc Thong et al. [15] proposed a machine vision-based mango classification system using SVM and ANN models. The system achieved around 94% accuracy.

2.2 Analysis Table

TABLE 1
SUMMARY OF REVIEWED STUDIES ON MANGO CLASSIFICATION AND QUALITY ASSESSMENT

Title (Year)	Technology Used	Dataset	Accuracy
A Review on Automated Detection and Assessment of Fruit Damage Using Machine Learning (2024)	Image segmentation, image processing, ML, deep learning (CNNs)	Multiple datasets (mango, apple, banana, citrus, grapes)	~85–95% depending on fruit type and algorithm
A Machine Vision-Based Maturity Prediction System for Sorting of Harvested Mangoes (2015)	Machine vision (CCD camera), feature extraction (color, texture, shape), SVM with ECOC	Mango images from five varieties across three locations	~93%
Using Fuzzy Logic to Increase Accuracy in Mango Maturity Index Classification (2016)	Portable NIR spectroscopy + fuzzy logic rules	Mango samples at multiple maturity stages	~95%
Development of Electronic Nose for Fruit Ripeness Determination (2014)	E-nose system with gas sensors + SVM classifiers	Banana and mango samples at various ripeness stages	~92%
Non-Destructive Determination of Maturity of Thai Mangoes (2017)	NIR spectroscopy + PLSR regression	Thai mango samples at different ripeness levels	$R^2 > 0.9$
CNN Architecture for Classifying Mango Leaf Images (2020)	CNN for automatic feature extraction	Mango leaf images from multiple varieties	~94%
Mango Ripeness Classification System Using Hybrid Technique (2019)	Image processing + SVM + ANN	Mango images at controlled ripeness stages	~93%
Ripening and Quality Detection of Mango Using Arduino (2018)	Arduino-based sensors + MATLAB image processing	Mango images and sensor readings at different ripeness levels	~90%
Mango Classification for Agro-Based Industries Using Transfer Learning (2021)	Transfer learning (VGG16, ResNet) fine-tuned on mango datasets	Large labeled dataset of mango images	~95%
Modern Techniques in Detecting and Classifying Fruits (2022)	SVM, Random Forest, deep learning (comparative study)	Diverse fruit image datasets	~94%
Survey of Computer Vision and Soft Computing Techniques for Ripeness Grading of Fruits (2020)	Computer vision, fuzzy logic, ANN, SVM, CNNs	Multiple fruit datasets	85–95%
Mango Classification System Based on Machine Vision and Artificial Intelligence (2019)	Machine vision preprocessing + SVM, ANN, CNN	Mango samples from multiple varieties and maturity stages	~94%

III. FUTURE RESEARCH DIRECTIONS

Based on the reviewed literature, several promising directions for future research are identified:

1. **Dataset Expansion** — Larger and more diverse image datasets captured under varying lighting conditions, backgrounds, and environmental settings can improve model robustness and generalization capability.
2. **Real-Time Market Integration** — Incorporating real-time market data from regional and international trading platforms may enable the development of adaptive pricing models.

3. **Model Optimization** — Optimizing deep learning architectures through transfer learning, fine-tuning strategies, and hyperparameter optimization can enhance prediction accuracy while reducing computational complexity.
4. **Scalable Deployment** — Web-based and mobile-based platforms integrated with cloud computing and IoT-enabled monitoring systems can improve practical usability in agricultural supply chains.
5. **Explainable AI (XAI)** — Integration of explainable AI techniques can increase transparency by providing clear reasoning behind grading and pricing decisions.
6. **Multi-Variety Expansion** — Expanding research to include multiple Indian and international mango varieties will enhance global applicability.

IV. CONCLUSION

The reviewed studies demonstrate the significant contribution of machine learning and deep learning techniques in mango classification and quality assessment. Traditional approaches such as SVM, ANN, fuzzy logic, and sensor-based systems have demonstrated satisfactory results in controlled conditions; however, they often face limitations in scalability, adaptability, and feature dependency.

Recent research consistently indicates that **CNN-based and transfer learning approaches** outperform conventional techniques in terms of accuracy, automation, and robustness across diverse mango varieties and maturity stages. Deep learning models are particularly effective in extracting complex visual features, thereby improving classification consistency and grading efficiency.

Despite these advancements, challenges such as the requirement for large annotated datasets, sensitivity to environmental variations, and computational demands remain open research areas. Overall, the reviewed literature confirms that CNN-driven solutions hold strong potential for enhancing quality control, grading reliability, supply chain efficiency, and market transparency in agro-based industries.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper

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