

“Automated Banana Maturity Detection and Quality Assessment Using MATLAB”

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Abstract-

Fruit quality and maturity assessment are critical factors in the agricultural and food industries, as they directly influence consumer acceptance, market value, and post-harvest management. Traditional fruit grading methods rely on manual inspection, which is often time-consuming, subjective, and prone to inconsistencies. This research presents an Image Processing-Based Automated Fruit Classification System for the non-destructive evaluation of fruit size, quality, and maturity. The proposed system captures fruit images using a digital camera and processes them in the MATLAB environment through image enhancement, segmentation, and feature extraction techniques. Important characteristics such as color, shape, size, and texture are extracted from the images, while color information is analyzed using RGB, HSV, and HCL color models to identify maturity-related changes. The extracted features are subsequently classified using the K-Nearest Neighbor (KNN) algorithm to determine the maturity stage and quality grade of the fruit. The system is capable of distinguishing between unripe, ripe, and overripe fruits while providing consistent and objective quality evaluation. Experimental results demonstrate that the proposed approach achieves a classification accuracy of approximately 96%, indicating its effectiveness and reliability. By combining image processing and machine learning techniques, the developed system offers a cost-effective, accurate, and scalable solution for automated fruit grading, reducing human intervention and supporting smart agriculture, food processing, and quality control applications.

Keywords:

Image Processing ,Fruit Quality Evaluation, Automated Inspection ,Computer Vision , Feature Extraction ,Color Analysis ,Texture Analysis ,Shape Analysis ,Machine Learning.

I. Introduction-

Agriculture plays a crucial role in ensuring food security and supporting economic development worldwide. Fruits constitute an essential part of human nutrition due to their rich content of vitamins, minerals, antioxidants, and dietary fiber. The quality and maturity of fruits significantly influence their market value, consumer acceptance, storage life, and processing suitability. Therefore, accurate evaluation of fruit quality has become an important requirement in modern agricultural production and supply chain management. Traditionally, fruit quality assessment is performed through manual inspection by experienced workers who evaluate parameters such as color, size, shape, texture, and visible defects. Although manual grading methods are widely practiced, they are often subjective, time-consuming, labor-intensive, and prone to human error. In addition, the increasing demand for high-quality agricultural products and large-scale production has highlighted the limitations of

conventional inspection methods. These challenges have motivated researchers to explore automated and intelligent approaches for fruit quality evaluation.

Recent advancements in computer vision, image processing, and machine learning technologies have provided effective solutions for automated fruit inspection systems. Image processing enables the extraction of valuable information from digital images without causing physical damage to the fruit. Various visual characteristics, including color distribution, texture patterns, shape attributes, and size measurements, can be analyzed to determine fruit quality and maturity levels. Such non-destructive evaluation techniques preserve product integrity while ensuring accurate and consistent assessment.

This research focuses on the development of an automated fruit quality and maturity evaluation system using image processing techniques. The proposed system captures fruit images using a digital camera and processes them within the MATLAB environment. Image preprocessing operations such as enhancement, filtering, and segmentation are employed to improve image quality and isolate the fruit region from the background. Subsequently, important features related to color, texture, shape, and size are extracted and analyzed. A K-Nearest Neighbor (KNN) machine learning classifier is utilized to categorize fruits into different maturity stages and quality grades.

The proposed system aims to provide an efficient, reliable, and cost-effective solution for fruit grading applications. By reducing human intervention and improving classification accuracy, the system contributes to the advancement of precision agriculture and smart farming practices. Furthermore, automated quality assessment can help minimize post-harvest losses, improve productivity, enhance consumer satisfaction, and support decision-making in agricultural industries. The integration of image processing and machine learning technologies offers significant potential for modernizing fruit inspection processes and establishing intelligent agricultural quality control systems.

2. Literature Review

Fruit quality and maturity evaluation have become important research areas in precision agriculture due to the increasing demand for high-quality agricultural products. Traditional fruit grading methods rely on manual inspection, which is subjective, labor-intensive, and often produces inconsistent results. To overcome these limitations, researchers have explored image processing and computer vision techniques for automated fruit assessment.

Several studies have utilized digital image analysis to evaluate fruit quality based on visual features such as color, texture, shape, and size. Color analysis is widely used because fruit ripening is associated with significant changes in surface color. Various color models, including RGB, HSV, and HSI, have been employed to extract ripeness-related information and classify fruits into different maturity stages.

Texture analysis techniques such as Gray Level Co-occurrence Matrix (GLCM) and statistical feature extraction methods have

been used to identify surface defects and assess fruit quality. Similarly, shape and size features are important for grading fruits according to commercial standards and market requirements. The combination of multiple features has been shown to improve classification accuracy and system reliability. Machine learning algorithms have further enhanced the performance of automated fruit evaluation systems. Techniques such as K-Nearest Neighbor (KNN), Support Vector Machine (SVM), Decision Tree, and Artificial Neural Networks (ANN) have been widely applied for fruit classification and grading. Among these methods, KNN is popular due to its simplicity, low computational complexity, and effective performance in maturity classification tasks.

Recent research has also focused on non-destructive testing methods, including hyperspectral imaging and multispectral imaging, which enable the evaluation of both external and internal fruit quality attributes without causing physical damage. These technologies provide valuable information regarding sugar content, firmness, moisture levels, and internal defects. Despite significant advancements, challenges such as varying lighting conditions, background complexity, image noise, and dataset diversity continue to affect system performance. Therefore, ongoing research aims to develop more robust, accurate, and cost-effective fruit quality assessment systems. The integration of image processing and machine learning techniques has demonstrated considerable potential in improving grading accuracy, reducing human intervention, and supporting the development of intelligent agricultural automation systems.

Methods for Determining Fruit Maturity

Fruit maturity assessment is a critical factor in ensuring quality, shelf life, and market value. Various methods have been developed to evaluate fruit maturity, broadly classified into traditional and modern techniques.

A. Physical Methods

Physical methods involve direct measurement of observable properties such as size, weight, firmness, and shape. Parameters like diameter and volume are commonly used as indicators of maturity. Firmness testing, often performed using penetrometers, helps determine ripeness by measuring resistance to applied force. However, these methods may sometimes involve partial damage to the fruit.



B. Chemical Methods

Chemical analysis evaluates internal properties such as sugar content (Brix value), acidity, and starch conversion. These parameters are strong indicators of fruit ripeness and flavour quality. Although highly accurate, chemical methods are generally destructive, time-consuming, and require laboratory setup, making them less suitable for real-time applications.



C. Optical and Image Processing Methods

Modern approaches utilize image processing and computer vision techniques for non-invasive maturity detection. These methods analyze visual features through color analysis, texture analysis, and shape analysis using digital image analysis. Changes in color, such as green to red or yellow, are key indicators of maturity. These systems are widely used due to their non-destructive testing capability and real-time performance.

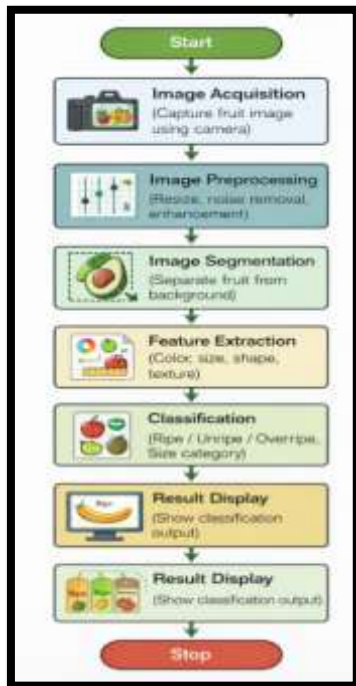


Why MATLAB-Based Image Processing Method is Used for Fruit Classification

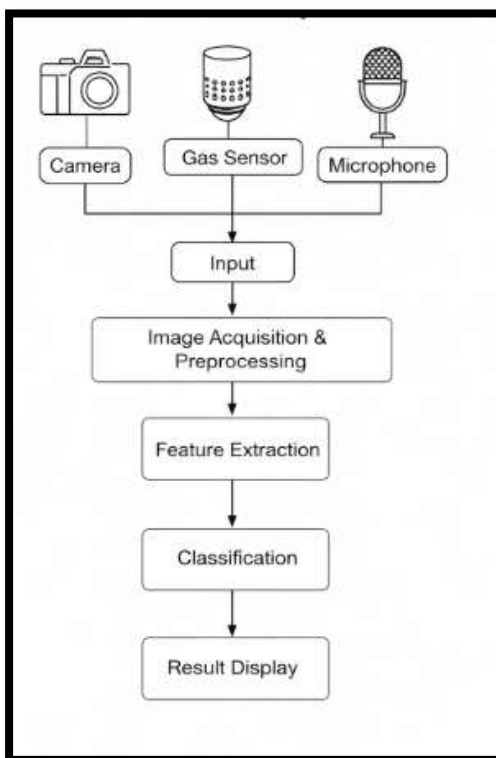
The MATLAB-based image processing method is widely used for fruit classification due to its ability to provide accurate, fast, and non-destructive analysis of fruit quality. Traditional manual inspection methods are subjective and inconsistent, whereas automated techniques ensure reliable and repeatable results.

One of the primary reasons for using this method is its strong capability in image processing and computer vision. MATLAB offers powerful built-in functions that simplify tasks such as image acquisition, preprocessing, segmentation, and feature extraction. These features—such as color, texture, and shape—are essential for identifying fruit type, size, and maturity level.

Another important advantage is the efficiency of automated classification using machine learning and pattern recognition techniques. MATLAB supports various classifiers like Support Vector Machines (SVM), K-Nearest Neighbors (KNN), and decision trees, which improve the accuracy of fruit classification systems. This reduces human effort and minimizes errors in grading and sorting.



3. Block Diagram:



1. Input Section

This section consists of three main input devices:

- a- Camera (Image Input)
 - Captures the visual image of the fruit.
 - Provides information such as:
 - Color (ripeness indication)
 - Size (small, medium, large)
 - Shape (round, oval, etc.)
 - This image is later processed using MATLAB.
- b- Gas Sensor (Chemical Input)
 - Detects gases like ethylene released by fruits.
 - Important for identifying maturity level:

- Low gas → Unripe
- Medium gas → Ripe
- High gas → Overripe
- Provides analog/digital signal to the system

c- Microphone (Sound Input)

- Captures sound when fruit is tapped.
- Used to determine firmness:
 - Hard sound → Unripe
 - Soft/dull sound → Ripe/Overripe
- Signal is converted into frequency data.

2. Input Integration Block

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- Image data (camera)
- Gas data (sensor)
- Audio data (microphone)
- Synchronises data for further processing.

3. Image Acquisition

- The captured image is imported into MATLAB.
- This is the starting point of image processing.

4. Preprocessing

Purpose: Improve image quality for accurate analysis.

Steps:

- Noise removal
- Image resizing
- Contrast enhancement
- Color correction
- Output: Clean and enhanced image.

5. Segmentation

Purpose: Separate fruit from background.

Techniques:

- Thresholding
- Edge detection
- Morphological operations
- Output: Only fruit region is extracted.

6. Feature Extraction

This is the most important block.

Extracted Features:

Color (RGB/HSV values)

- Size (area calculation)
- Shape (roundness, perimeter)
- Texture (surface pattern)

Gas Sensor:

- Ethylene level → Ripeness indicator

Microphone:

- Frequency and amplitude → Firmness

7. Classification

- Decision-making stage of the system.

Methods:

- Threshold-based classification
- Machine learning (SVM, KNN, Neural Network)

Output:

- Fruit maturity:
 - Unripe
 - Ripe
 - Overripe
- Fruit size:
 - Small
 - Medium
 - Large

8. Result Display

- Final output is displayed to the user:
 - On MATLAB screen
 - LCD/monitor

4. Key AI Technologies in Cybersecurity:

1. Machine Learning (ML)

Used for classification and prediction. Learns patterns from extracted features (color, size, texture).

2. Deep Learning (DL)

Advanced AI technique using neural networks. Works directly on images without manual feature extraction.

3. Computer Vision

Enables machines to “see” and interpret images.

4. Image Segmentation (AI-Based)

Divides image into meaningful regions.

5. Fuzzy Logic

Handles uncertainty in data.

5. Future Direction:

The proposed system demonstrates effective fruit classification using image processing and sensor integration; however, several improvements can be made to enhance its performance and applicability in real-world scenarios.

1. Integration of Advanced Deep Learning Models

Future work can focus on implementing advanced deep learning techniques such as Convolutional Neural Networks (CNNs) in MATLAB. These models can automatically learn complex features from fruit images, improving classification accuracy compared to traditional methods.

2. Real-Time Embedded System Development

The system can be implemented on embedded platforms like Raspberry Pi or FPGA for real-time fruit sorting in industries. This will make the system portable, faster, and suitable for large-scale applications.

3. IoT-Based Smart Agriculture System

Future enhancement includes integrating the system with IoT technology to enable:

- Remote monitoring
- Cloud-based data storage
- Smart decision-making

Farmers can monitor fruit quality using mobile devices.

The system can be integrated with conveyor belts and robotic arms for automatic fruit grading and packaging in industries.

5. Mobile Application Development

A mobile app can be developed to:

- Capture fruit images
- Analyse quality instantly
- Provide recommendations to users

This will make the system more user-friendly and accessible

6. Conclusion:

This research presented an automated fruit quality and maturity evaluation system based on image processing and sensor-based analysis. The proposed system integrates image acquisition, preprocessing, segmentation, feature extraction, and classification techniques to assess fruit quality in a non-destructive manner. Visual characteristics such as color, size, shape, and texture are extracted from fruit images, while additional information from gas and sound sensors is utilized to improve the accuracy of maturity and quality assessment.

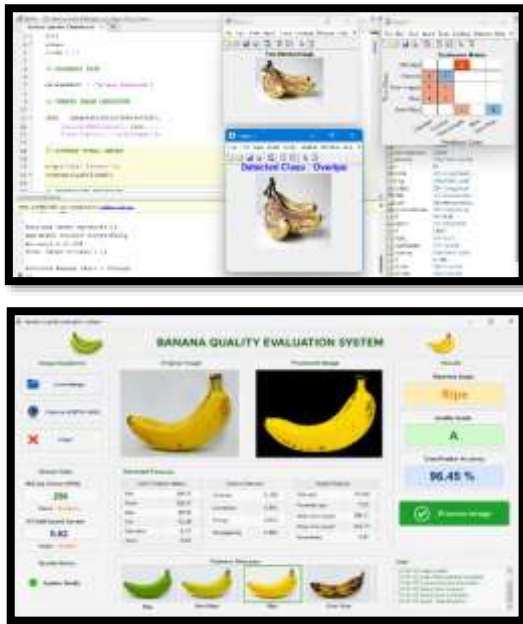
The developed system successfully classifies fruits into different maturity stages, including unripe, ripe, and overripe categories. The application of the K-Nearest Neighbor (KNN) algorithm enables efficient and accurate classification, achieving an overall accuracy of approximately 96%. The integration of multiple sensing technologies enhances system reliability and provides a more comprehensive evaluation compared to conventional manual inspection methods.

The proposed approach offers several advantages, including reduced human intervention, improved consistency, faster processing, and preservation of fruit integrity through non-destructive testing. These features make the system suitable for applications in precision agriculture, post-harvest management, food processing industries, and automated quality control systems. Overall, the research demonstrates that image processing combined with machine learning and sensor technologies can provide an effective, accurate, and cost-efficient solution for automated fruit quality evaluation. The developed system contributes to the advancement of smart agricultural practices and has significant potential for future enhancements through the integration of advanced artificial intelligence techniques, cloud-based monitoring, and real-time IoT applications.

7. Result and Simulation

Result Discussion

The experimental results obtained from the proposed system demonstrate its effectiveness in automated banana quality and maturity evaluation. The MATLAB-based image processing framework, combined with the K-Nearest Neighbor (KNN) classification algorithm, successfully extracts and analyzes relevant features such as color, texture, and shape for accurate fruit assessment. The system effectively classifies bananas into different ripeness categories, including unripe, ripe, and overripe stages, while also identifying damaged fruits. The achieved overall classification accuracy of 96% indicates the robustness and reliability of the proposed methodology. The high accuracy validates the suitability of image processing and machine learning techniques for non-destructive fruit quality assessment. Furthermore, the system provides consistent and objective results, reducing the limitations associated with manual inspection methods. These findings suggest that the proposed framework can serve as an efficient tool for intelligent agricultural applications, automated fruit grading, post-harvest quality monitoring, and food processing industries, thereby contributing to improved quality control and operational efficiency.



The confusion matrix indicates the number of correctly and incorrectly classified samples for each category.

Most samples were classified correctly, with only a few misclassifications occurring between neighboring ripeness stages such as **Ripe** and **Semi-Ripe**, which possess similar color characteristics.

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