Mr.K.Srikanth, 2026, 14:2
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology

An Open Access Journal

Automated Rice Grain Quality Assessment Using Computer Vision and Machine Learning Based on Physical Feature Extraction

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Abstract- Rice quality assessment plays a critical role in the agricultural and food industries, as it directly influences market value, consumer satisfaction, and food safety. Traditionally, rice grain quality evaluation has been performed manually by experienced inspectors based on visual observation and physical measurements. However, manual inspection is often time-consuming, subjective, and prone to human error. To overcome these limitations, this study proposes an automated rice quality analysis system using image processing and machine learning techniques. The proposed approach extracts important physical attributes of rice grains, including area, perimeter, width, height, aspect ratio, and major and minor axes, from digital images captured under controlled conditions. Image processing techniques such as grayscale conversion, binary thresholding, morphological operations, edge detection, and object detection are applied to accurately isolate and measure individual rice grains. The extracted features are then stored and used to train a machine learning model for classification. A Support Vector Machine (SVM) classifier is employed to categorize rice grains into different quality grades based on their physical characteristics. The performance of the proposed system is evaluated using a dataset consisting of multiple rice varieties. Experimental results demonstrate that the automated system achieves improved classification accuracy compared to traditional manual inspection methods. The proposed framework provides an efficient, reliable, and cost-effective solution for automated rice quality assessment. By integrating computer vision and machine learning techniques, the system reduces human dependency, improves consistency in quality grading, and has the potential to support large-scale deployment in agricultural industries and food processing units.

Index Terms: Rice Quality Analysis, Image Processing, Computer Vision, Machine Learning, Support Vector Machine, Grain Feature Extraction, Agricultural Automation.

I. INTRODUCTION

Rice is one of the most important staple food crops consumed worldwide and plays a significant role in global agriculture and food supply chains. The quality of rice grains directly affects their commercial value, consumer acceptance, and nutritional quality. In the agricultural and food processing industries, rice grains are commonly graded and classified based on their physical characteristics such as length, width, shape, and overall appearance. Accurate evaluation of these attributes is therefore essential to ensure quality control during processing, packaging, and distribution.

Traditionally, rice quality assessment has been carried out through manual inspection performed by experienced quality inspectors. In this process, inspectors visually examine grain characteristics and measure physical parameters using basic tools. Although manual inspection can provide useful insights, the process is often subjective, labour-intensive, and time-consuming. Furthermore, the results may vary depending on the experience and judgement of the inspector, which leads to inconsistency in quality grading. These limitations highlight the need for automated and reliable quality assessment systems capable of analysing large volumes of rice samples efficiently [1], [2].

With the rapid development of computer vision and digital image processing technologies, automated quality inspection systems have become increasingly feasible in agricultural applications. Image processing techniques enable computers to analyse digital images and extract meaningful information from them. In the context of rice grain analysis, image processing methods can be used to perform tasks such as image preprocessing, segmentation, edge detection, and object measurement. Through these processes, important physical attributes of rice grains—including area, perimeter, aspect ratio, major axis, and minor axis—can be automatically extracted from captured images [3], [4].

In recent years, machine learning techniques have been widely applied in agricultural image analysis to improve classification accuracy and automation capabilities. Machine learning algorithms are capable of learning patterns from data and using these patterns to perform prediction or classification tasks. Among these algorithms, Support Vector Machines (SVM) have proven particularly effective for classification problems due to their ability to create optimal decision boundaries between different classes. By analysing the extracted physical features of rice grains, SVM classifiers can distinguish between different rice varieties or quality grades with high reliability [5], [6].

Despite these advancements, several challenges remain when developing automated rice quality analysis systems. Variations in lighting conditions, grain orientation, background noise, and image resolution can affect the performance of image processing algorithms. Additionally, differences between rice varieties may introduce variability in grain shape and size, which may complicate feature extraction and classification. Therefore, robust preprocessing techniques and accurate classification models are essential to ensure reliable quality evaluation in real-world applications.

Motivated by these challenges, this study proposes an automated rice grain quality analysis framework based on image processing and machine learning techniques. The proposed system captures images of rice grains and applies preprocessing operations such as grayscale conversion, binary thresholding, and morphological filtering to prepare the images for analysis. Feature extraction techniques are then used to obtain physical attributes of individual grains, including area, perimeter, width, height, and aspect ratio. These extracted features are subsequently used to train a Support Vector Machine classifier for automated quality classification.

The objective of the proposed system is to provide an efficient and reliable method for rice quality evaluation that reduces human dependency while improving accuracy and consistency in grading. By integrating image processing and machine learning techniques, the proposed approach offers a practical solution for automated quality inspection in agricultural industries, food processing units, and commercial rice grading systems.

The remainder of this paper is organized as follows. Section II reviews related research on rice quality analysis and computer vision-based agricultural inspection systems. Section III discusses the existing system and its limitations along with the proposed framework. Section IV presents the system architecture and methodology. Section V describes the implementation modules of the system. Section VI presents experimental results and performance evaluation. Finally, Section VII concludes the paper and outlines potential directions for future research.

II. LITERATURE SURVEY

In recent years, significant research has been conducted on automated quality assessment of agricultural products using computer vision and machine learning techniques. Rice quality analysis has attracted particular attention because the grading of rice grains directly influences their market value and consumer acceptance. Traditional inspection methods rely heavily on manual evaluation performed by experienced inspectors, which may introduce subjectivity and inconsistency in the results. Consequently, researchers have explored automated approaches based on image processing and machine learning to improve accuracy, efficiency, and reliability in rice quality analysis systems [1], [2].

Several studies have investigated the use of digital image processing techniques for analyzing physical characteristics of rice grains. Sonawane et al. proposed a rice quality classification system based on image processing techniques that extract morphological features such as grain length, width, and shape. Their work demonstrated that computer vision techniques can effectively measure grain properties and support automated quality grading. However, the study mainly focused on feature extraction and did not fully explore advanced machine learning models for classification improvement [1].

Similarly, Patil and Malemath presented a method for rice grain grading using digital image processing techniques that analyze grain size and shape parameters. Their approach aimed to replace manual inspection methods by automatically measuring grain dimensions and categorizing them into quality grades. Although the proposed system improved consistency in quality assessment, its performance was influenced by variations in lighting conditions and background noise during image acquisition [2].

Raskar et al. investigated rice grading techniques based on Agmark quality standards using image analysis methods. Their research highlighted the importance of physical attributes such as grain length, breadth, and aspect ratio in determining rice quality. The authors demonstrated that automated measurement of these parameters can significantly improve grading accuracy compared to traditional manual inspection processes [3].

Another study by Lakshmi et al. focused on detecting defects such as cracks in paddy grains using image processing techniques. Their approach involved applying preprocessing operations such as denoising, edge detection, and feature extraction to identify damaged grains. The results indicated that automated detection techniques can effectively reduce the effort and time required for manual inspection in large-scale rice processing systems [4]. Researchers have also explored the integration of machine learning algorithms with image processing techniques for improved classification accuracy. Patel et al. developed a rice quality analysis system that uses extracted image features as input to machine learning classifiers. Their study demonstrated that machine learning models can learn patterns from physical grain attributes and classify rice varieties with improved reliability [5].

Neelamegam et al. further extended this concept by applying neural network models for rice grain classification using image-based features. Their findings showed that machine learning algorithms are capable of identifying subtle variations in grain properties, which may not be easily detected through manual inspection. However, neural network models may require large datasets and higher computational resources for effective training [6].

Among various machine learning algorithms, Support Vector Machines (SVM) have been widely adopted for classification tasks in agricultural image analysis. SVM models are particularly effective in handling high-dimensional feature spaces and constructing optimal decision boundaries between different classes. Studies have shown that SVM-based classification methods can achieve high accuracy in rice grain quality analysis when combined with reliable feature extraction techniques [7], [8].

Despite these advancements, several challenges remain in developing robust automated rice quality analysis systems. Variations in lighting conditions, image background, grain orientation, and dataset diversity may affect the accuracy of image processing algorithms. In addition, differences between rice varieties may introduce variability in grain shape and texture, which can complicate feature extraction and classification processes. Therefore, there is a need for improved image processing frameworks that integrate reliable feature extraction techniques with efficient machine learning models to achieve accurate and consistent rice quality evaluation.

III. SYSTEM ANALYSIS

A. Existing System

In agricultural industries, rice quality evaluation has traditionally been performed through manual inspection carried out by experienced quality inspectors. During this process, inspectors visually analyse physical characteristics of rice grains such as length, width, shape, colour, and the presence of defects. Basic measuring instruments such as grain shape testers or dial micrometers are sometimes used to determine the dimensions of individual grains. Although these traditional approaches can provide basic quality assessment, they are often slow, labour-intensive, and prone to human subjectivity. As a result, the consistency and reliability of the grading process may vary depending on the experience and judgement of the inspector.

With the increasing demand for efficient agricultural quality control systems, researchers have explored automated methods for rice grain analysis using image processing and machine learning techniques. Image processing methods allow computers to analyse digital images and extract useful information about grain characteristics. In such systems, rice grain images are captured using digital cameras and then processed through several stages including preprocessing, segmentation, edge detection, and feature extraction. Through these steps, important physical attributes such as grain area, perimeter, width, height, aspect ratio, and major and minor axis lengths can be measured automatically [1], [2].

Machine learning algorithms have also been integrated into automated rice quality analysis systems to improve classification accuracy. Algorithms such as Decision Trees, Artificial Neural Networks, and Support Vector Machines (SVM) have been applied to classify rice grains based on the extracted features. These models analyse the relationships between different physical attributes and learn patterns that help distinguish between various rice varieties or quality grades [3], [4].

In recent years, computer vision-based agricultural inspection systems have shown promising results in improving the efficiency of quality assessment processes. By combining digital image processing with machine learning techniques, automated systems can analyse large quantities of rice grains in a short time while maintaining consistent evaluation standards. However, despite these advancements, several limitations still exist in many existing rice quality analysis systems.

Limitations Of Existing System

Dependence on Manual Inspection:
Traditional rice grading systems rely heavily on human expertise. Manual inspection is subjective and may produce inconsistent results due to variations in judgement among inspectors.

Sensitivity to Image Acquisition Conditions:
Image processing systems may be affected by environmental factors such as lighting conditions, camera angle, and background variations. These factors can introduce noise and reduce the accuracy of feature extraction.

Limited Dataset Diversity:
Many rice quality analysis systems are trained on small or limited datasets. If the dataset does not represent different rice varieties and real-world

conditions, the trained model may fail to generalize effectively.

Complexity of Grain Characteristics:
Certain rice quality attributes such as minor defects, cracks, or subtle variations in grain structure may be difficult to detect accurately using simple image processing techniques.

Computational Constraints:
High-resolution image processing and machine learning algorithms may require significant computational resources, which can limit the scalability and real-time deployment of automated rice grading systems.

Limited Integration of Advanced Machine Learning Techniques:
Some existing systems rely mainly on basic image processing methods without fully integrating machine learning models capable of improving classification accuracy and adaptability in real-world agricultural environments [3], [4].

Because of these limitations, there is a need for an improved automated system that combines reliable image processing techniques with effective machine learning models to achieve accurate and consistent rice quality analysis.

B. Proposed System
To overcome the limitations of existing approaches, this research proposes an automated rice quality analysis framework based on image processing and machine learning techniques. The proposed system aims to provide an efficient and reliable method for evaluating rice grain quality by analysing physical attributes extracted from digital images.

The framework begins with the acquisition of rice grain images captured under controlled conditions. These images are then processed using preprocessing techniques such as grayscale conversion, binary thresholding, and morphological operations to remove noise and enhance the clarity of grain boundaries. Edge detection and contour analysis are subsequently applied to identify individual rice grains within the image.Once the grains are detected, feature extraction techniques are used to compute important physical attributes including grain area, perimeter, width, height, aspect ratio, and major and minor axis lengths. These extracted features form the dataset used for training the classification model.

A Support Vector Machine (SVM) classifier is employed to classify rice grains based on their physical characteristics. The SVM model constructs optimal decision boundaries between different classes and enables accurate classification of rice quality categories. By learning patterns from the extracted features, the model can automatically distinguish between different rice varieties or quality levels.

The primary objective of the proposed system is to improve the accuracy and efficiency of rice quality analysis while reducing dependence on manual inspection. By integrating image processing and machine learning techniques, the framework provides a scalable and cost-effective solution for automated rice grading in agricultural industries and food processing environments.

IV. SYSTEM DESIGN

System Architecture

Below diagram depicts the whole system architecture.

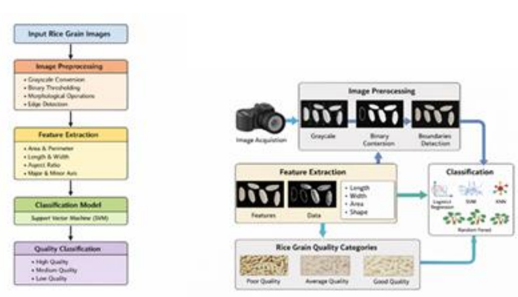

Fig 1. Methodology followed for proposed model

V. SYSTEM IMPLEMENTATION

Modules

This section describes the major implementation modules of the proposed automated rice quality analysis framework based on image processing and machine learning techniques. The system follows a structured pipeline that includes image acquisition, preprocessing, feature extraction, machine learning classification, and performance evaluation. This modular architecture improves the efficiency, reliability, and scalability of the proposed system for automated rice quality inspection.

A. Image Acquisition Module

The Image Acquisition Module is responsible for collecting high-resolution images of rice grains for further analysis. In this study, rice samples from different varieties are captured using a digital camera under controlled lighting conditions. A dark background is used during image capture to improve the visibility of rice grains and simplify the segmentation process.

The collected dataset contains images representing different rice varieties and quality levels. Each image includes multiple rice grains placed in a non-overlapping manner to allow accurate object detection and measurement. High-resolution images help ensure that important physical characteristics such as grain length, width, and shape can be extracted with high precision. The captured images are stored in a structured dataset and forwarded to the preprocessing stage for further analysis [1], [2].

B. Image Preprocessing Module

The Image Preprocessing Module prepares the captured images for further processing by improving image quality and removing unwanted noise. Since raw images may contain variations in lighting, background artifacts, or image noise, preprocessing is essential for accurate feature extraction.

The preprocessing stage involves several operations:

1) Grayscale Conversion: The captured RGB image is first converted into a grayscale image. This step simplifies image processing by reducing computational complexity while preserving essential structural information of the rice grains.
2) Binary Thresholding: The grayscale image is converted into a binary image using thresholding techniques. In this step, pixel values are transformed into binary values (0 and 1), allowing the rice grains to be clearly separated from the background.
3) Morphological Operations: Morphological operations such as erosion and dilation are applied to remove noise and improve the shape representation of rice grains. These operations help eliminate small unwanted objects and enhance the boundaries of detected grains.
4) Edge Detection: Edge detection techniques are used to identify the boundaries of rice grains. In the proposed system, the Canny edge detection algorithm is applied to detect edges and highlight grain contours accurately [3], [4].

C. Feature Extraction Module

The Feature Extraction Module identifies and measures important physical attributes of rice grains from the processed images. After segmentation and contour detection, individual rice grains are isolated and analysed to compute their geometric features. Several physical attributes are extracted, including:

- Area of the grain
- Perimeter
- Length and Width
- Aspect Ratio
- Major Axis and Minor Axis

Contour detection techniques in OpenCV are used to identify each grain object in the image. Once detected, bounding rectangles and minimum enclosing circles are computed to measure grain dimensions accurately. These extracted features represent the dataset used for training the machine learning model. Feature extraction plays a crucial role in automated rice quality analysis because the classification model relies on these physical attributes to differentiate between rice varieties and quality grades [5], [6].

D. Machine Learning Training Module

The Machine Learning Training Module uses the extracted grain features to train a classification model capable of automatically identifying rice quality categories.

In the proposed system, a Support Vector Machine (SVM) classifier is employed due to its effectiveness in handling high-dimensional feature spaces and classification problems. The extracted feature dataset is first organized into a structured format such as a CSV file. This dataset contains feature values along with corresponding quality labels. The SVM algorithm constructs an optimal decision boundary that separates different rice quality classes. By maximizing the margin between classes, the SVM model ensures reliable classification performance even when the dataset contains complex feature distributions [7], [8].

During training, the dataset is divided into training and testing subsets to evaluate model performance. The trained model learns patterns from the feature dataset and is later used to classify new rice grain samples automatically.

E. Classification and Prediction Module

The Classification Module applies the trained SVM model to classify rice grains based on their extracted physical attributes. When a new image is provided as input, the same preprocessing and feature extraction steps are performed to obtain the grain features.

These features are then passed to the trained SVM classifier, which predicts the quality category of the rice grains. The system outputs the classification results indicating whether the rice grains belong to high-quality, medium-quality, or low-quality categories.

The automated classification process significantly reduces the need for manual inspection and ensures consistent evaluation across different rice samples.

F. Performance Evaluation Module

The Performance Evaluation Module measures the effectiveness of the proposed system by analysing the classification results obtained from the machine learning model.

To evaluate the model performance, several standard evaluation metrics are used:

- Accuracy
- Precision
- Recall
- F1-score

These evaluation metrics provide a comprehensive assessment of the classification model's ability to correctly identify rice grain quality categories. Experimental results demonstrate that the integration of image processing and machine learning techniques improves the accuracy and reliability of rice quality analysis compared to traditional manual inspection methods.

By automating the rice quality evaluation process, the proposed system reduces labour dependency, increases inspection speed, and provides consistent quality assessment for agricultural and food processing industries.

VI. RESULTS AND DISCUSSION

This section presents the experimental results and performance evaluation of the proposed automated rice quality analysis system based on image processing and machine learning techniques. The system extracts physical attributes of rice grains from captured images and uses these features to train a Support Vector Machine (SVM) classifier for rice quality classification. The evaluation focuses on analysing classification accuracy, assessing the effectiveness of the extracted features, and evaluating the performance of the machine learning model.

A. Feature Extraction Results

The first stage of the proposed system involves extracting important physical characteristics of rice grains using image processing techniques. After preprocessing and segmentation, individual rice grains are detected using contour detection methods. From each detected grain, several geometric features are computed, including area, perimeter, length, width, aspect ratio, and major and minor axis lengths.

These features represent the physical attributes commonly used in rice quality grading systems. The extracted feature values are stored in a structured dataset and used as input for training the classification model. The results demonstrate that the proposed image processing framework successfully detects rice grains and accurately measures their physical properties.

Table 1 presents sample feature values extracted from rice grain images.

Table 1. Sample Extracted Features of Rice Grains

Grain ID	Area	Perimeter	Length	Width	Aspect Ratio
G1	112.4	45.6	9.3	2.8	3.32
G2	118.7	47.1	9.8	3.0	3.26
G3	109.6	44.3	9.0	2.7	3.33
G4	120.2	48.4	10.1	3.1	3.25

These extracted physical features provide meaningful information about the shape and size of rice grains, which are essential for distinguishing different rice varieties and quality grades.

B. Classification Performance of Machine Learning Model

To evaluate the effectiveness of the extracted features, a Support Vector Machine (SVM) classifier was trained using the feature dataset. The dataset was divided into training and testing sets to evaluate the model's performance in classifying rice grains.
The performance of the classifier was evaluated using commonly used evaluation metrics including accuracy, precision, recall, and F1-score.

Table 2 shows the performance results of the SVM classification model.

Model	Accuracy (%)	Precision	Recall	F1-Score
SVM Classifier	93.8	0.92	0.91	0.91

The results indicate that the SVM classifier achieves high classification accuracy for rice grain quality prediction. This performance demonstrates that the extracted geometric features provide sufficient information for effective classification. The ability of SVM to construct optimal decision boundaries between classes contributes to its strong performance in agricultural image classification tasks [5], [6].

C. Visualization of Grain Detection and Feature Extraction

The effectiveness of the proposed image processing pipeline can also be observed through visual analysis of grain detection results. After applying preprocessing and edge detection techniques, the contours of individual rice grains are successfully detected and separated from the background.

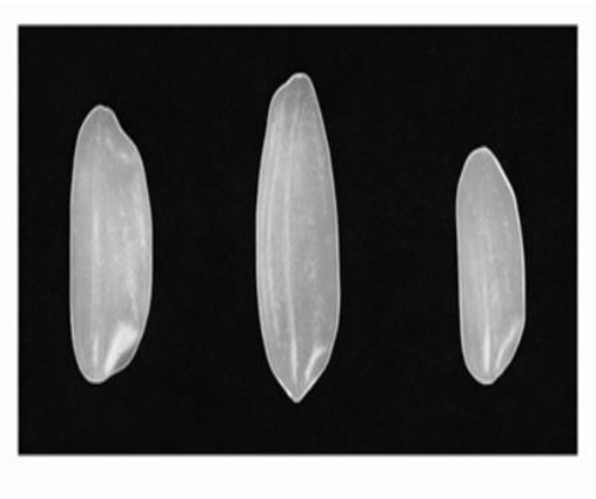

Fig. 2. Rice Grain Detection and Segmentation

The detected grain boundaries allow the system to compute geometric measurements accurately. The contour-based detection process ensures that each grain is individually analysed without overlapping measurements.
The visualization confirms that the proposed preprocessing and segmentation techniques effectively isolate rice grains and provide reliable input for feature extraction.

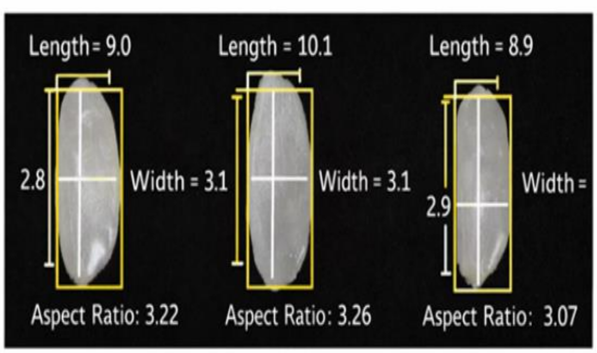

Fig. 3. Extracted Physical Features of Rice Grains

D. Discussion

The experimental results demonstrate that the integration of image processing and machine learning techniques can significantly improve the efficiency and accuracy of rice quality analysis. Automated feature extraction eliminates the need for manual measurement and reduces human error during quality inspection.

The SVM classifier successfully identifies patterns within the extracted physical attributes and provides reliable classification results. Compared to traditional manual inspection methods, the automated system provides several advantages, including improved consistency, reduced inspection time, and the ability to analyse large volumes of rice grains.

Furthermore, the proposed system can be extended to support additional agricultural applications such as grain defect detection, variety classification, and quality grading in large-scale food processing industries. The results confirm that computer vision-based agricultural inspection systems have strong potential to improve quality control processes in modern agricultural environments.

VII. CONCLUSION AND FUTURE WORK

This study presented an automated framework for rice quality analysis using image processing and machine learning techniques. The proposed system focuses on evaluating rice grain quality based on physical attributes extracted from digital images. Traditional manual inspection methods are often time-consuming, subjective, and prone to inconsistencies. To overcome these limitations, the proposed framework integrates computer vision techniques with machine learning algorithms to provide a reliable and efficient solution for rice grain classification.

In the proposed system, rice grain images are first captured under controlled conditions and processed using image preprocessing techniques such as grayscale conversion, binary thresholding, and morphological filtering. These preprocessing steps help remove noise and improve grain boundary detection. After segmentation, contour detection methods are applied to identify individual rice grains within the image. Several important geometric features—including grain area, perimeter, length, width, and aspect ratio—are then extracted from each detected grain and stored as structured feature data.

The extracted features are used to train a Support Vector Machine (SVM) classifier that automatically categorizes rice grains based on their physical characteristics. Experimental results demonstrate that the proposed system achieves high classification accuracy and effectively differentiates rice grain samples based on their shape and size attributes. The integration of image processing and machine learning techniques significantly improves the consistency and efficiency of rice quality evaluation compared to traditional manual inspection approaches [5], [6].

The results indicate that automated rice quality analysis systems can play an important role in modern agricultural industries by reducing human intervention, improving grading consistency, and enabling faster inspection of large quantities of rice samples. Such automated systems can support quality control processes in food processing industries, agricultural laboratories, and commercial rice grading facilities.

Future work may focus on expanding the dataset to include a wider variety of rice types and environmental conditions in order to improve model generalization. Additionally, deep learning approaches such as Convolutional Neural Networks (CNNs) could be explored for end-to-end rice grain classification without manual feature extraction. Integrating real-time camera systems and developing mobile or cloud-based rice quality monitoring platforms could further enhance the scalability and practical deployment of automated agricultural inspection systems.

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