

Identification of soluble solid content and total acid content using real-time visual inspection system

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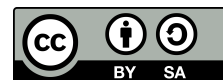
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ABSTRACT

This paper presents the framework for identifying materials using a fused descriptor-based approach, leverage computer vision techniques. The system is structured into three phases: derivation, extraction, and portrayal. Initially, the system employs K-means clustering techniques for establishing derivation. Following derivation, the system utilizes variety, texture, and shape-based feature extraction methods to extract relevant features from the soluble solid content and total acid content using real-time visual inspection system. A "consolidating" fusion feature is explored in the final phase using classification algorithms like C4.5, support vector machines (SVM), and k-nearest neighbors (KNN). The performance evaluation of the recognition system demonstrates promising results, with accuracy rates of 97.89%, 94.60%, and 90.25% achieved by using C4.5, SVM, and KNN separately. This indicates that the proposed fusion strategy effectively supports accurately recognizing materials using a fused descriptor-based approach.

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1. INTRODUCTION

Agriculture plays a significant role in India's economy, mainly focusing on horticulture and producing fruits and vegetables. Machine vision approaches hold promise in agriculture, especially in tasks like quality assessment and sorting fruits and vegetables based on appearance. By automating these processes, efficiency can be improved, and the quality of agricultural products maintained consistently [1]-[4]. The adoption of computer-based intelligent systems for automated quality assurance in agriculture can bring several benefits to producers and consumers. Computerized systems can process large quantities of produce much faster than manual inspection, allowing producers to handle higher volumes and meet market demands more effectively. By using standardized algorithms, automated systems can assess the quality of agricultural products consistently, reducing variations, and ensuring that consumers receive consistently high-quality produce.

Automation can lead to cost savings by reducing the need for manual labor and minimizing waste through more accurate sorting and grading of produce. High-quality produce can command better prices in the market, benefiting producers financially and enhancing their competitiveness. Consumers are more likely to trust and continue purchasing agricultural products that consistently meet their quality expectations, leading to increased satisfaction and loyalty. Embracing technology-driven solutions like machine vision represents a step towards modernizing India's agricultural sector, making it more resilient and competitive globally [5], [6]. Overall, implementing computer-based intelligent systems for automated quality assurance has the potential to revolutionize the agricultural industry in India, leading to increased productivity, profitability, and consumer satisfaction.

The study analyses a substantial number of papers on this topic and highlights the potential of AI and computer vision technologies in addressing challenges within the farming industry. Role of AI and PC vision highlight how these technologies are utilized in rural areas, particularly in agriculture. This method evaluates or assesses the effectiveness or impact of the articles reviewed in the study. The study delves into various aspects related to farming, including explicit models (presumably models developed using AI), information preprocessing (preparing data for analysis), information inspection strategies (methods for analysing data), and the importance of accuracy in execution [7]-[9]. Indeed, the advancement of agribusiness is crucial not only for economic growth but also for ensuring food security and meeting the demands of the population. India's prominence as a significant exporter of agricultural products underscores the importance of maintaining high quality throughout the supply chain until these products reach consumers. The statistics you've provided about the literacy rates in India highlight an existing gender disparity in education. While the overall literacy rate is 72%, the proficiency rate is notably higher among males (80.6%) compared to females (62.8%) [3], [10].

Your statement highlights a significant challenge facing agriculture in rural India: the need for more education among many farmers hampers their ability to access and effectively utilize modern agricultural technologies. Despite the efforts of the Indian government to implement various schemes aimed at improving the economic conditions of farmers, the lack of education among a large portion of the rural population limits the adoption and utilization of these programs for smart farming practices [11]. Furthermore, you mentioned previous research that has explored the use of computer vision techniques, particularly in the context of recognizing and classifying fruits and vegetables. This research has employed various descriptors to differentiate images and utilized support vector machine (SVM) classifiers to assess different datasets. However, evaluating these systems, particularly with natural product datasets, has shown a low precision rate [12], [13]. This indicates that while computer vision technology holds promise for improving agricultural practices, there are still challenges to overcome, such as improving the accuracy and reliability of image recognition and classification algorithms.

Crossover RGBD highlight, proposed by [14], aims to identify fruit images. It utilizes a correlation table to assess precision across different variations and combinations of descriptors, including merged variety with shape descriptors. Another effective method involves using deep learning techniques for fruit recognition, as described by [15]. This approach has achieved an 85.11% accuracy rate, indicating its effectiveness in accurately identifying fruit images. Research conducted by [16] focuses on using variety and texture descriptors to assess the quality of fruits. They have achieved a high precision rate of 91.67%, specifically for the Apple dataset. Given the advancements in these methodologies, there's a need to conduct a comprehensive literature review to analyze the various approaches used in image recognition and pattern analysis within the domain of fruit identification. Such a review would help to synthesize existing knowledge, identify research gaps, and guide future developments in this field. Several studies focused on image analysis and pattern recognition in various fields, including agriculture and healthcare [17]. This study utilizes a comparative instructive assortment for analysis, employing a partitioned image approach. They remove the part vector of the image using a collection descriptor. These researchers also employ a similar preliminary educational assortment, analyzing the mean and derivation of fruits and vegetables. They achieve a high accuracy rate of 90.6% using the CCV+LTP combined descriptor [18]. This researcher proposes a framework for image verification, known as a "bag of parts" approach [19]. AI-based techniques are gaining popularity and attention across various domains, including agriculture, healthcare, and data processing. These researchers explore the impact of different performance metrics on the same dataset and briefly discuss factors influencing data preparation sizes [20], [21].

Many researchers have experimented with various descriptors, but selecting the most suitable one for extracting features from images remains a significant challenge [22], [23]. Developing a descriptor that

effectively captures the unique visual characteristics of fruits and vegetables adds complexity to the task. Furthermore, the challenge is accurately categorizing fruits and vegetables based on different performance metrics. This involves identifying the type of produce and assessing its quality, ripeness, and other attributes, which can vary significantly. Collaborative efforts among researchers, industry experts, and data scientists are essential to address these challenges. Establishing standardized datasets for benchmarking and sharing research findings can facilitate progress in developing robust recognition systems. Moreover, exploring innovative approaches in machine learning, image processing, and computer vision can help overcome the complexities associated with fruit and vegetable classification and quality assessment.

2. PROPOSED WORK

2.1. Dataset

The brightness contrast in the classification of apples, kiwis, cabbages, and melons can be seen in Figure 1. This suggests that each fruit type exhibits distinct brightness characteristics that can aid in their classification depicted in Figure 1(a). In Figure 1(b), the strawberry class is depicted with various postures. This indicates the variability in the appearance of strawberries, which can pose challenges for classification algorithms. Figure 1(c) demonstrates fluctuations in the number of images of red tomatoes. This variation could be due to factors such as lighting conditions, camera angles, or different sources of image collection. Lastly, Figure 1(d) addresses the pattern of trimming and partial obstruction. This likely refers to situations where parts of fruits or vegetables are obscured or partially visible in the images, which can affect the accuracy of classification algorithms. Under uproarious and obscuring items are displayed in Figure 1.

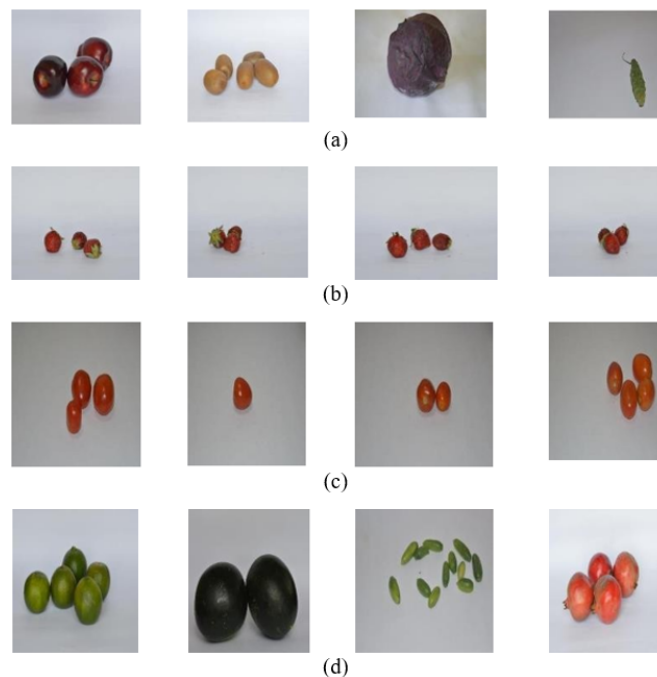


Figure 1. Sample of data-set: (a) illumination differences, apple, kiwi, cabbage, and bitter melon; (b) pose differences, strawberry; (c) variance on the number of images, tomato red; and (d) sample of cropping and partial occlusion

2.2. Segmentation process

A methodology for background subtraction in fruit and vegetable images is essential for accurate object recognition. The approach utilizes a K-means clustering technique to perform background subtraction, as detailed in references [24], [25]. The study uses a dataset containing images of twenty different fruits and vegetables to evaluate the efficiency of the recognition system. The K-means clustering method is employed among other available segmentation techniques. Figure 2 likely illustrates a flowchart depicting the background

subtraction process using the K-means clustering technique. The RGB image is converted into the Lab* color space, known for its perceptual uniformity. K-means clustering in 'ab' space: the K-means algorithm is applied in the 'ab' color space to segment the image into different regions based on color similarity. Additionally, tiny openings in the segmented image are eliminated. By following this methodology, the background of the fruit and vegetable images can be effectively subtracted, leading to improved object recognition accuracy. Figure 3 illustrates the flow diagram of background reduction based on K-means clustering, detailed details in Figure 3(a) segmentation process image, Figure 3(b) segmentation image, Figure 3(c) segmentation process image under noisy, and Figure 3(d) segmentation process results under noisy. This process is crucial for various applications, including automated fruit sorting, and quality inspection in agriculture.

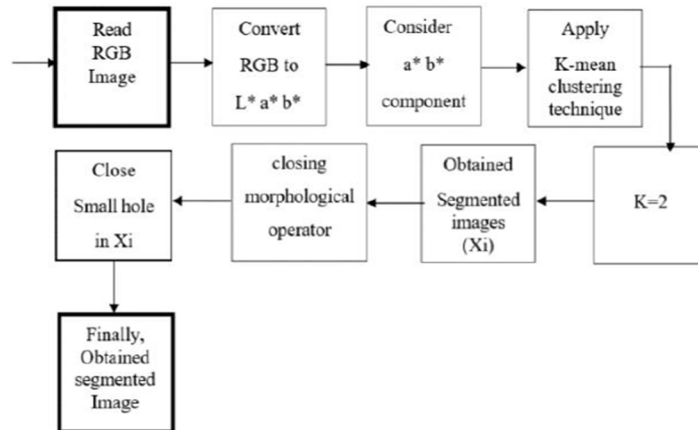


Figure 2. Flow chart for background subtraction based on K-means clustering

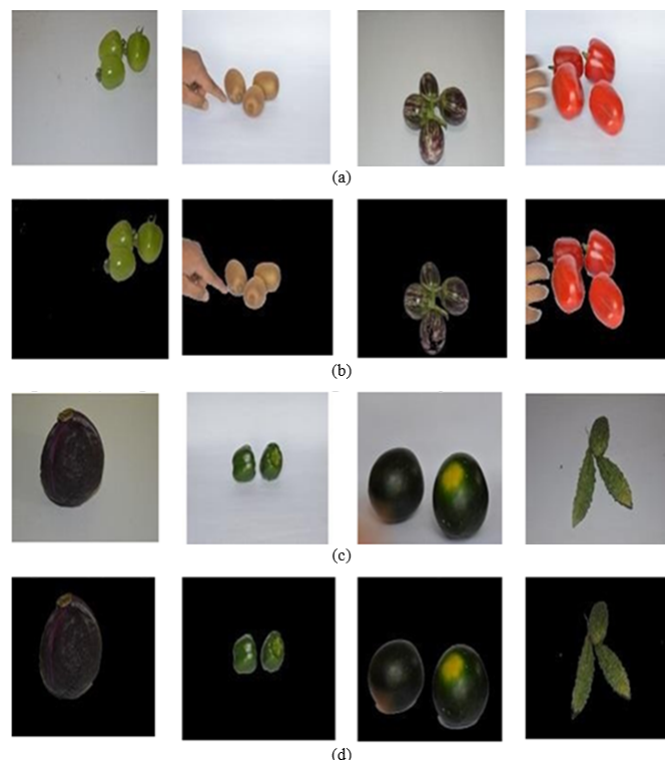


Figure 3. Flow chart for background subtraction based on K-means clustering: (a) segmentation process image, (b) segmentation image, (c) segmentation process image under noisy, and (d) segmentation process results under noisy

2.3. Feature extraction

The paper highlights the importance of specific properties such as area, posture difference, peculiarity, and repeatability in developing an effective fruit and vegetable recognition descriptor. The overview suggests that individual descriptor-based features may not adequately capture the quality of the image. Hence, the proposed approach integrates descriptors related to variety, surface, and shape to enhance the effectiveness of the recognition system. By combining these different aspects, the system aims to provide a more comprehensive and accurate analysis of the images, ultimately improving the recognition performance. Several color and texture functions have been employed to validate the accuracy and performance of the proposed approach. By leveraging these diverse features, the system aims to capture color and texture variations inherent in fruits and vegetables, contributing to more accurate and robust categorization results. However, further research is needed to refine and optimize these feature extraction methods for enhanced performance across different applications and scenarios.

3. RESULTS AND TEST CASE ANALYSIS

The framework involves utilizing machine learning algorithms such as C4.5 [26], [27], KNN [28], [29], and SVM [30], [31] for classification. To assess the framework's performance, you've listed several evaluation metrics, including classification accuracy, sensitivity, specificity, false positive rate, and false negative rate. These metrics are commonly used to evaluate the effectiveness of classification algorithms. The results and comparisons of recognition accuracy are based on different features using the C4.5 and SVM classifiers. According to Figure 4, the comparison graphs show that color + texture features yield the highest recognition accuracy, followed by a combination of color + texture + shape features. This indicates that incorporating color and texture information enhances recognition accuracy. Additionally, the graph suggests that shape-based features alone yield the lowest accuracy, likely due to the variability in the shape of fruits in the images.

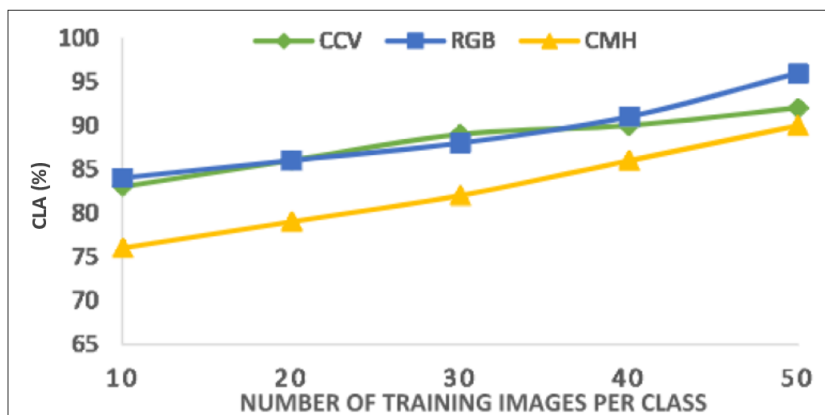


Figure 4. Comparison graph for higher accuracy per class with CMH+ LBP+ ZM feature using a SVM classifier

Figure 5 illustrates the comparison graph of recognition accuracy for various fruits and vegetables based on the combination of state-of-the-art features. The comparison graphs consistently demonstrate that color and texture-based features can achieve a reasonable accuracy rate across different situations. Additionally, in some cases, the fusion of these features indicates even better performance and higher accuracy. However, the graph also highlights that the shape-based element extraction strategy fails to deliver satisfactory results in all cases. This could be attributed to challenges such as cropping, partial occlusion, and variability in the shape of fruits and vegetables. Figure 5 is divided based on accuracy, showcasing the fruits and vegetables with the highest and lowest recognition accuracy. This division helps visualize which items are easier or more difficult to recognize based on the extracted features. Overall, the results suggest that while color and texture-based features perform well across various scenarios, there are still challenges associated with accurately recognizing

objects based solely on shape features. Further refinement of shape-based extraction methods may be necessary to improve accuracy in challenging situations.

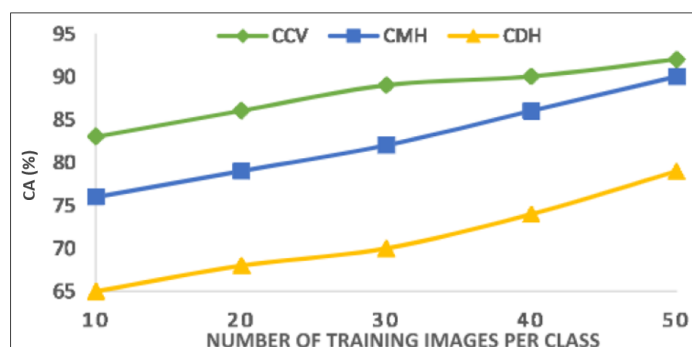


Figure 5. Comparison graph for lower accuracy per class with CMH+ LBP+ ZM feature using a SVM classifier

4. PERFORMANCE ANALYSIS

Table 1 provides insights into the performance of different classifiers, namely C4.5, SVM, and KNN, in the context of the proposed acknowledgment arrangement for fruits and vegetables. According to the table, the C4.5 classifier demonstrates superior performance, with results practically identical to those of the SVM and KNN classifiers. Specifically, the bogus positive rate for the C4.5 classifier is notably lower, standing at 1.80. This indicates a lower rate of false positives, which is desirable in classification tasks as it reflects the ability of the model to identify true negatives accurately. Comparatively, while the SVM classifier achieves a simulated favourable rate of 3.88, it also exhibits a higher misleading positive rate of 7.20. Comparisons based on performance accuracy rate are depicted in Table 2.

Table 1. The C4.5, SVM, and KNN classifiers based on various performance metrics

Classifiers	Accuracy	Sensitivity	Specificity	Precision
C4.5	95.89	81.90	99.20	93.60
SVM	96.50	84.97	94.24	85.32
KNN	91.35	87.16	90.80	99.12

Table 2. Comparison based on performance accuracy rate

Dataset	Pre-processing	Classifiers	CA in %	Reference
Fruits - vegetables	K-means	C4.5	95.79	Proposed
Fruits	Parallel processing	Linear SVM	81.68	[25]
Apple	Calyx detection	SVM	93.87.5	[23]
Fruit and vegetable	Thresholding based	Neural network	96.30	[20]
Fruits - vegetables	K-means	MSVM	94.80	[14]
Citrus	HSV	KNN	93.67	[18]
Date fruit	Binary threshold	BPNN	82.34	[22]

5. CONCLUSION

The comparison between the proposed paper C4.5, SVM, and KNN classifiers indicates that the C4.5 classifier consistently outperforms the KNN classifier across all performance metrics. This finding suggests that the C4.5 classifier is better suited for the classification problem. Moreover, the research demonstrates that a combined-based descriptor, specifically the CCV+CSLBP+ZM mix-based descriptor, delivers promising results across all classifiers (C4.5, SVM, and KNN). This indicates the effectiveness of incorporating multiple descriptors for improved classification accuracy. Overall, the recognition system achieves satisfactory performance accuracy, with rates of 97.89%, 94.60%, and 90.25% using the C4.5, SVM, and KNN classifiers,

respectively. These experimental results highlight the significance of selecting the appropriate classifier for achieving optimal performance in classification tasks involving fruits and vegetables. Additionally, the proposed fusion scheme demonstrates its potential to significantly enhance the accuracy of recognizing various fruits and vegetables. In conclusion, the proposed framework, particularly with the C4.5 classifier and the combined descriptor, holds promise for accurately identifying fruits and vegetables, showcasing the importance of thoughtful classifier selection and feature fusion in classification tasks.





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