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Optimization of raisin sorting machine using genetic algorithm

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Abstract

Sorting agricultural products refers to grading food and other crops based on size, color, appearance, and other factors such as separating impurities, fruits, and damaged and rotten products. Today, sorting technology and related equipment for grading agricultural crops are progressing in developed countries, which can be found in most large agricultural units. Therefore, initial packaging and transportation of the product are facilitated, and more added value can be provided for farmers. This study aimed to optimize the raisin sorting machine based on a genetic algorithm to increase the quality of raisin grading. Therefore, a seedless white variety of grape samples were randomly selected and prepared from an orchard in Makan, East Azerbaijan, Iran. Digital image processing techniques such as the image processing toolbox in MATLAB were used to extract features from an image for sorting. Other meta-heuristic algorithms such as PSO, differential evolution, and artificial bee colony algorithm were used to evaluate the accuracy of the results. According to the results, the artificial bee colony algorithm had better accuracy than other algorithms, but the convergence speed was lower, and the computational volume was higher. However, the genetic and PSO algorithms had an accuracy almost equal to the artificial bee colony algorithm despite having a higher speed of convergence and lower computational operations, which can be used as the best algorithm in this application. Differential evolutionary algorithms and harmony search require processing in many iterations, and the computation time is not economical. Therefore, the clustering of raisins in industrial units requires high clustering speed and minimum error to avoid discarding or outliers, and genetics and PSO algorithms were acceptable.

Keywords: Agricultural crops, Sorting, Raisins, Genetic algorithm, Image processing
2020 MSC: 68U10, 68W50

1 Introduction

Iran is one of the essential countries regarding raisin as a dried grape product, prepared using different cultivars with different methods. Another good feature of raisin cultivars is early ripening and quick drying. Sultana seedless grape is one of the cultivars used in large quantities to prepare raisins with a pleasant and sweet aroma. The origin of this grape is Asia Minor, but today it is cultivated in countries such as America, Australia, Turkey, and Greece. This variety also has more cultivated in Iran than other grape varieties. The product of this cultivar is primarily used for preparing raisins, while it is also used for preparing grape juice, grape juice, and fresh consumption [5]. Grapes are one of the leading agricultural products, which have been cultivated since prehistoric times. According to the International Food and Agriculture Organization, the world production of grapes is currently more than 75.8 million tons [7]. The product of this variety is considered the dominant variety among other grape varieties due to its export

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importance in the form of raisins, juice, and even fresh consumption. Iran was the largest and most crucial producer of raisins and grape juice in the world until the Second World War and often held first or second place [13]. Raisins were used in Rome as prizes for people who decorated places of worship and for winners in sports competitions. Farmers of Iran produce many types of raisins from different types of grapes using different methods, used in cooking, nuts, and other applications [20]. Iran is the eighth country in terms of cultivated area and the seventh country in the world in production. The implementation of the plan increases Iran's raisin export to 150,000 tons, resulting in 180 million dollars in foreign currency income [12].

Storing grapes as raisins has some benefits, including weight and bulk reduction, which helps reduce packaging, and storage and transportation costs [17]. The aroma components of raisins are free volatile compounds, which are limited in glycosides [3]. The quality parameters of raisins, like other dried fruits and vegetables, can be significantly affected during the dehydration process, depending on the operating conditions and pretreatments as well as the drying technology [14]. On the other hand, sorting is a term meaning grading and categorizing crops, which is utilized as an introduction to packaging these products. Approximately all fruits and vegetables are offered in sorted and labeled form in the fruit and vegetable markets of modern societies, making it more accessible for the customer to recognize the quality of the product with a more regular distribution and supply. Today, sorting technology and related equipment for grading crops are progressing in developed countries, which can be found in most large agricultural units or their vicinity. Therefore, the initial packaging and transportation of the product are facilitated, leading to more added value for the farmers of these countries. Using sorted and packaged agricultural products has led to establishing modern stores and removing traditional ones from the service cycle. Evaluating energy and environmental indicators is a common method for estimating sustainable production in different agricultural sectors [13]. Bulk raisin classification is one of the main challenges for raisin producers and buyers worldwide [7]. Kong et al. [8] designed an apple weighing machine for separating and measuring apple fruit based on two weighing and material transfer units. The fruit is directed into the transmission channel after weighing and processing the data and then transferred and graded to one of the six outlets embedded in the channel. The critical height test of the fruit fall was conducted to prevent fruit bruising on the steel surface, and the critical height of the apple was determined as much as 6 cm. The inclination angle of the fruit transfer channel was 22 degrees to prevent mechanical damage to the apple fruit, in which the speed of fruit movement inside the channel reaches 1 m/s. The theoretical investigation of the impact force on the fruit in the channel determined that the machine did not cause any damage to the fruit during the grading process. The purpose of sizing is to present fruits and vegetables to the market based on the taste of the consumer. Another purpose of sizing is to offer small and large fruits and vegetables to the market at different prices, according to the different abilities of consumers. Fruits and vegetables of the same size can be packed with a specific pattern with a balanced shape, leading to better protection of the fruits and maximum use of the space inside the package.

Raisins should be graded and measured like other dried fruits and products due to their small size and being one of the export products of the country. Therefore, precisely sorting of this product is one of the most critical parts of the export and supply of raisins. Electronic sorting machines cannot be widely used for grading products at a reasonable cost in the current conditions of Iran due to the system complexity, relatively low capacity, high cost of production, and lack of sufficient information on the biomechanical properties of the product [16]. For this purpose, optimization of a genetic algorithm was used for raisin sorting. A genetic algorithm is a computational optimization algorithm that effectively searches different regions of the solution space in each iteration by considering a set of solution space points. Although the objective function is not calculated for all solution space points in the search mechanism, the process of the algorithm proceeds in such a way that the probability of the convergence of the solution to the absolute optimal point is higher than its convergence to the local optimal point.

This research focused on developing a software and hardware package based on identifying the characteristics of crops. The applied machines called sorting machines were very expensive and as big as a room. Manual sorting is laborious, tedious, time-consuming, and inaccurate. Poor classification and sorting lead to reduced quality assurance. Hence, an automatic sorting system should be created for traders and small farmers. Raisins are graded to obtain the best quality according to the industry standard. The automatic sorting system increases production and reduces the dependence on human resources, which uses different algorithms to extract fruit features and classification technologies and overcome the problems of manual sorting.

2 Material and methods

This study was conducted by digital image processing techniques to extract features from an image. Therefore, a computer vision system was used instead of human vision. The machines are expensive, and the algorithm used is very complex. Therefore, this study aimed to evaluate the sorting machine or the packaging machine for raisins using a genetic algorithm method with low cost. The developed system mainly consists of three main parts of conveyor, imaging, and sorting system.

2.1 Initial preparation of samples

The grape sample was a seedless white variety, which was randomly selected and prepared from an orchard in Makan, East Azerbaijan, Iran. Two shrubs next to each other, which had almost the same conditions in terms of water supply, fertilization, and other pre-harvest factors, were selected to prepare samples due to a large number of test samples and the limitation of the clusters of each shrub (Figure 1).

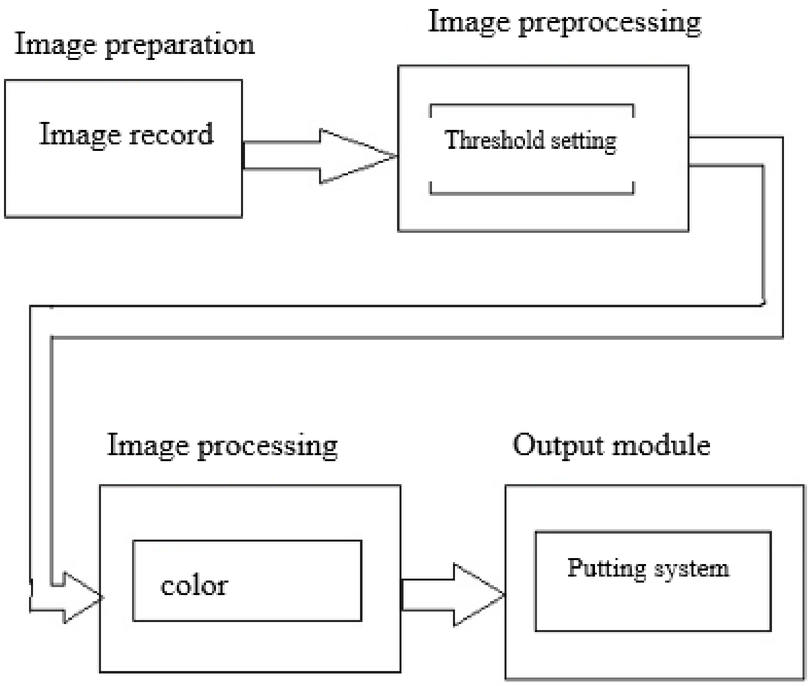


Figure 1: System architecture; Resource: (author)

2.2 Image acquisition

In the first step, RGB color images were recorded using a digital camera with the required resolution for good quality. In this research, a raspberry pi camera and some other cameras such as mobile and USB cameras have been used. Approximately the same results were achieved using any of the mentioned cameras [2].

2.3 Image preprocessing

In preprocessing, the image was thresholded to detect the raisin by removing the background.

2.4 Output module

The classified data were output to hardware after image processing, which further processed these to enable linear actuators to sort the raisins.

2.5 Mechanical assembly and operation

This study aimed to evaluate low-cost raisin sorting using the genetic algorithm method. Thus, a high-resolution camera was required to achieve the speed of the existing sorting machine. However, these cameras were expensive, and the mechanism used for such a sorting device was complex due to requiring an air compressor. Therefore, a new mechanism was designed to move the raisin in front of the camera. The complete mechanical assembly is shown in Figure 2.

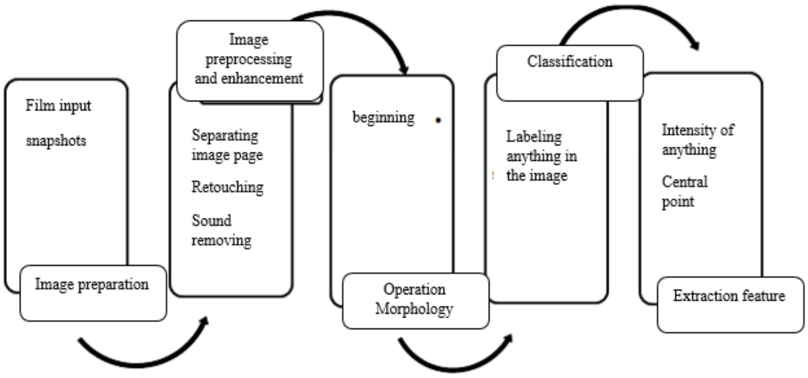


Figure 2: Image processing flow

2.6 Genetic algorithm

The development of the proposed algorithm consisted of three stages. The first step was developing the image processing algorithm to extract the color features and prepare the data set matrix.

This study was conducted on four types of raisins based on color, including black, brown, golden, and green raisins. Other meta-heuristic algorithms such as PSO, differential evolution, and artificial bee colony algorithm were also used to evaluate the accuracy of the results [18]. First, conventional methods were used for image clustering, and its problems were analyzed. Then, the cluster centers were determined automatically using the color features in the second stage, which included two parts. In the second part, the cluster centers were determined using the images taken by the camera (Figure 3).

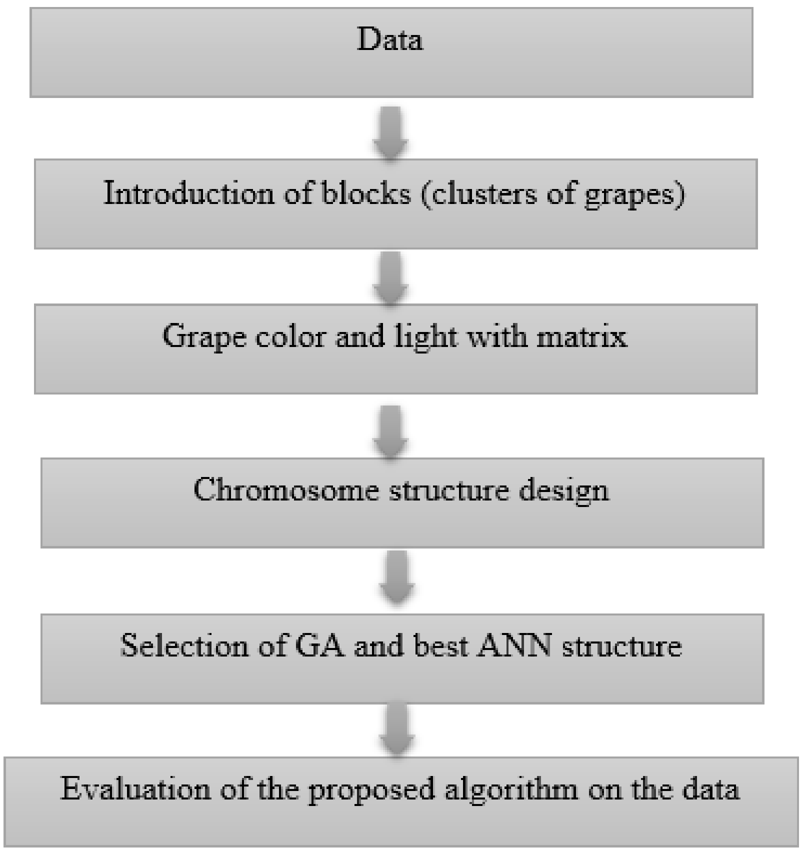


Figure 3: Diagram of the proposed algorithm

2.7 Evaluation of the classification algorithm

The performance of the proposed classification algorithm was evaluated by forming a classification matrix (CM), and several statistical indices were calculated, including classification sensitivity (SE), specificity (SP), accuracy (AC), and correct classification rate (CCR). The mentioned indicators were determined using the equations introduced by Kunal et al. [4]:

$$CM = \begin{bmatrix} TP & FP \\ FN & TN \end{bmatrix} \tag{1}$$

$$SE = \frac{TP}{TP + FN} \times 100 \tag{2}$$

$$SP = \frac{TN}{TN + FP} \times 100 \tag{3}$$

$$AC = \frac{TP}{TP + FP} \times 100 \tag{4}$$

$$CCR = \frac{TP + TN}{TP + FP + TN + FN} \times 100 \tag{5}$$

3 Results

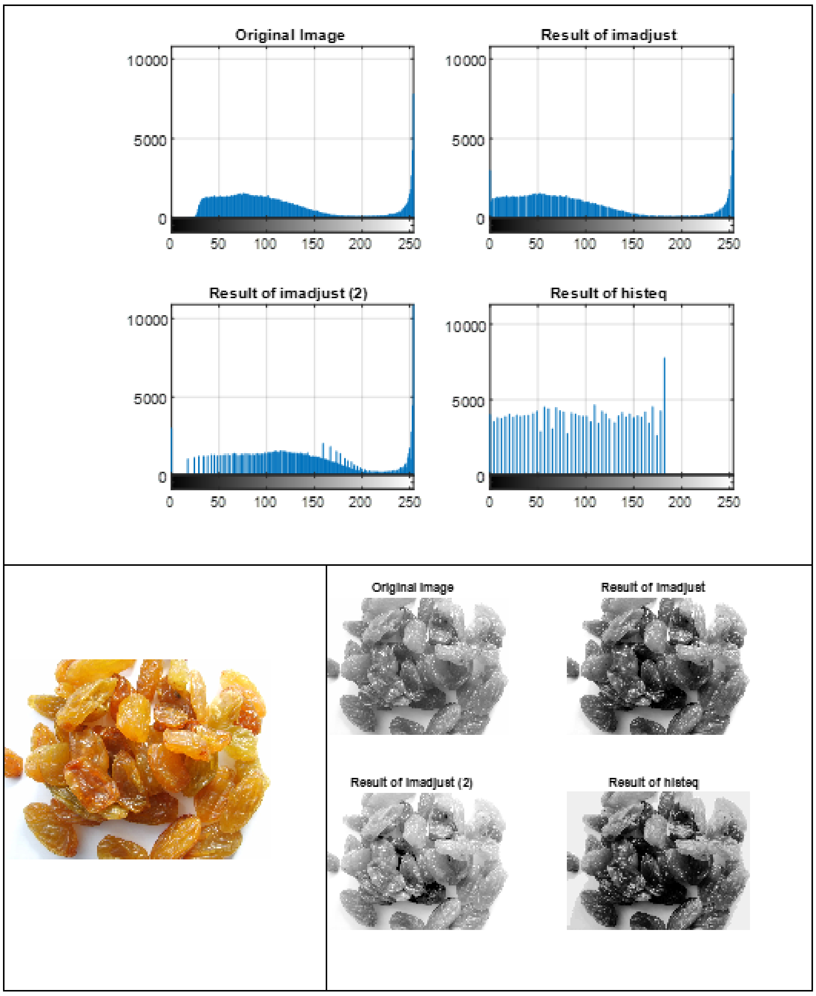
In this research, raisins were considered a random quantity, and the examples of these random quantities were the captured images. Image resolution for object detection is increased by applying statistical distribution to the data, which is possible by widening image histograms. The statistical law of large numbers was used to have a more accurate estimate of the image samples to reduce the estimation error.

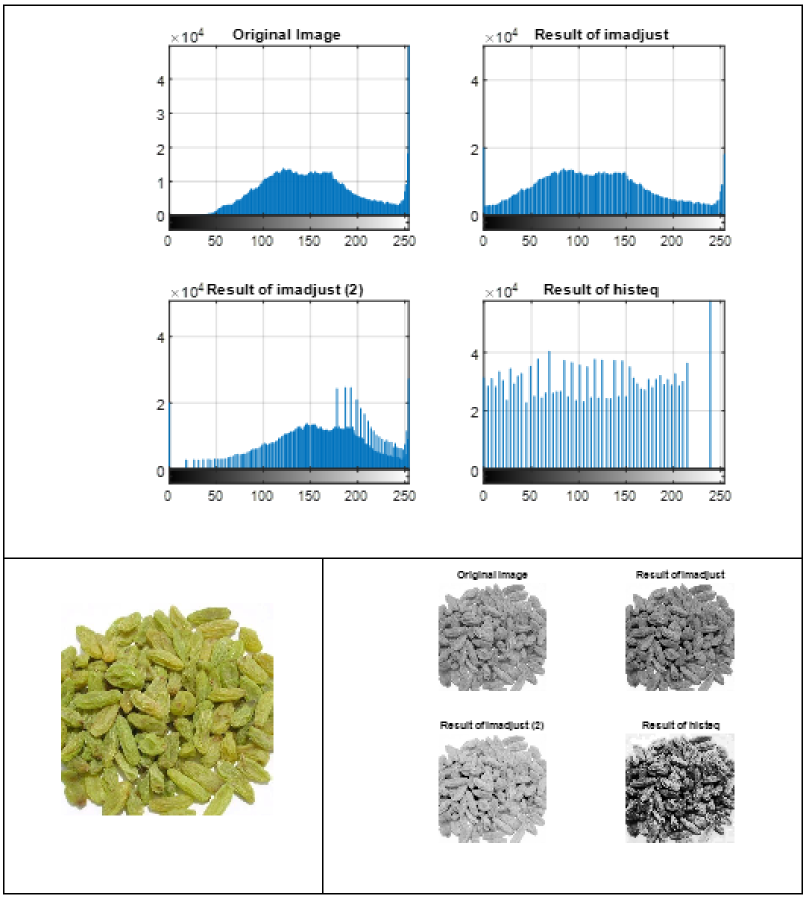
Figure 4 shows the histogram of the images obtained from raisins for the original and the processed images in both color and grayscale modes. In this figure, the contrast was increased by smoothing the histogram.

3.1 Filters and edge detection

The border between two areas in the image with a significant difference in brightness, color, or texture is called an edge. One of the advantages of edge extraction in an image is the ability to separate and distinguish objects from the background, leading the edge detection process to be used in various applications such as zoning, extraction of boundary features, and shape description. Dividing an image into objects and background by following the dividing line between them is an essential step the analyzing and interpreting images.

This study used different filters and methods to detect the edges of objects in the image taken from raisins. Figure 5 presents the response of different filters in image edge detection.


Original Image
Result of imadjust
Result of imadjust (2)
Result of histeq
10000
5000
0
0 50 100 150 200 250


Original Image
Result of imadjust
Result of imadjust (2)
Result of histeq
×10^4
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0 50 100 150 200 250

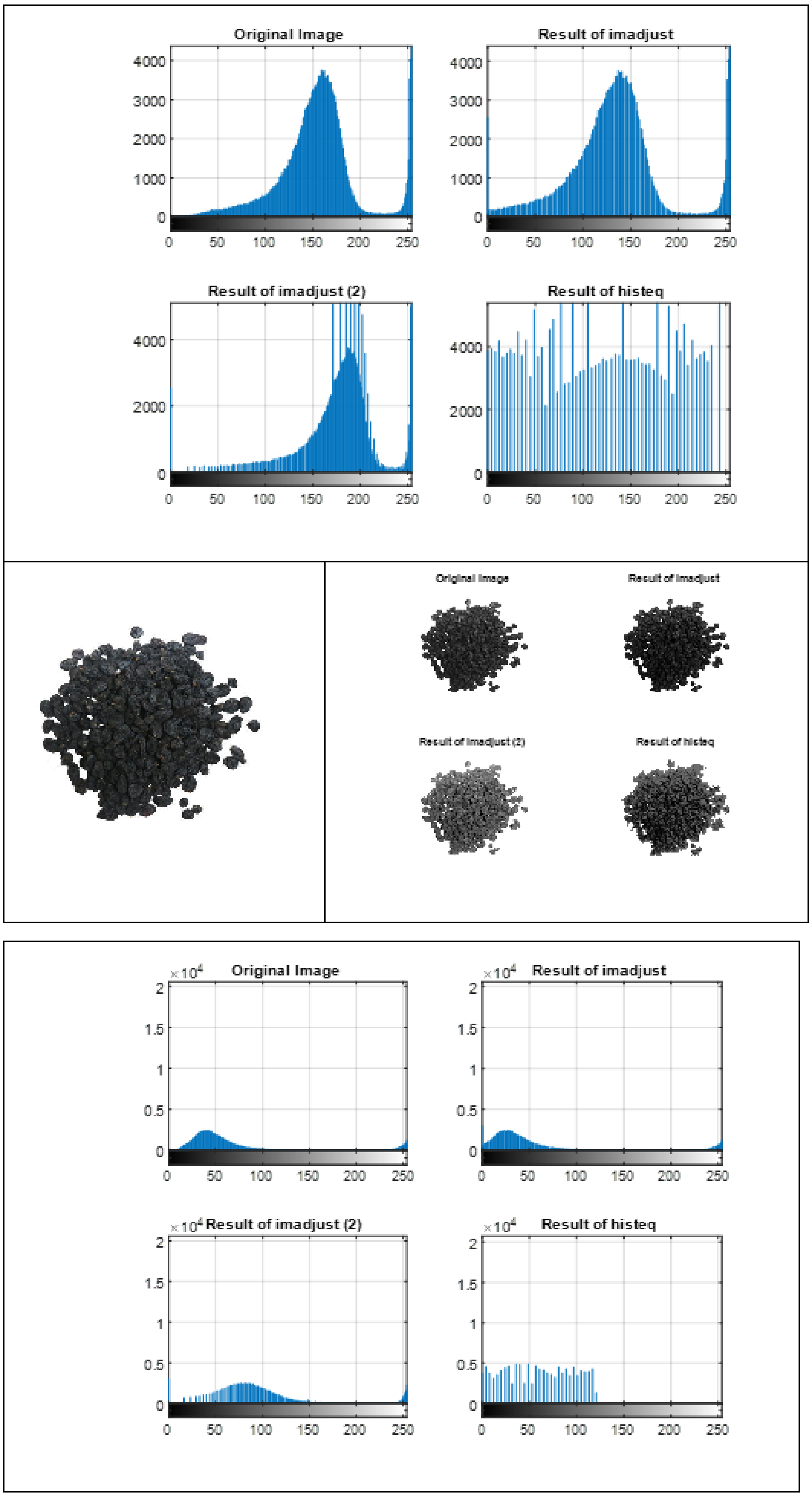
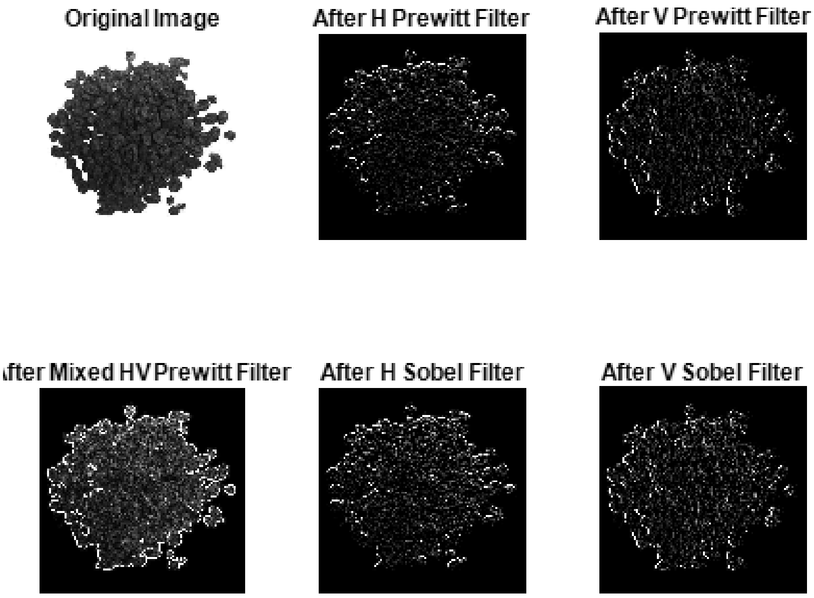
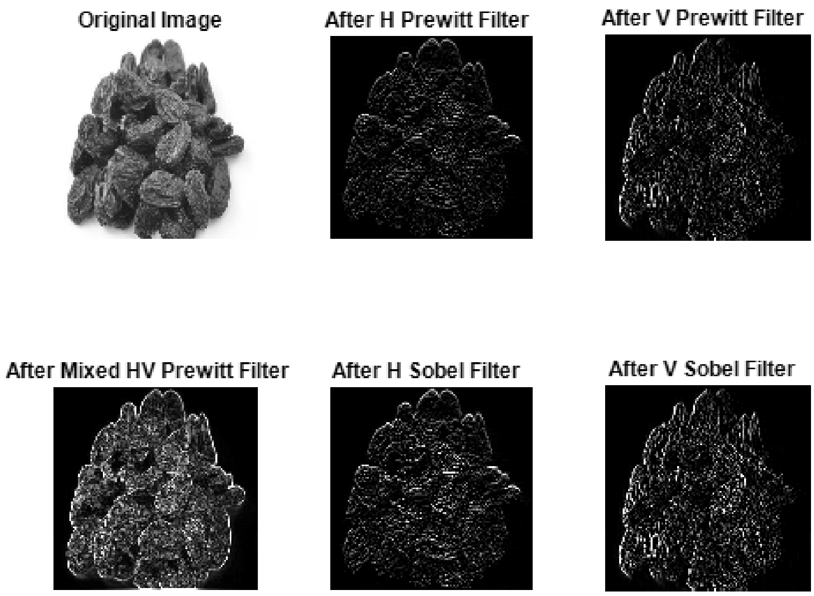


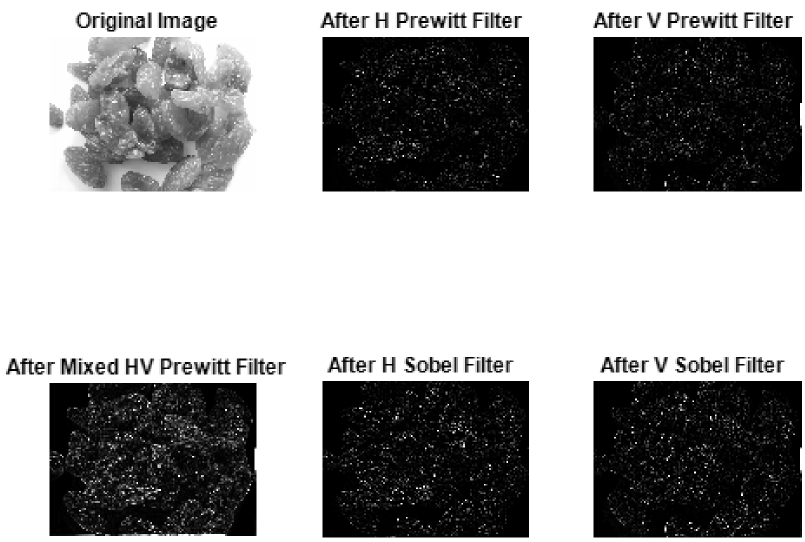
Figure 4: Histogram of images taken from raisins and histogram smoothing for better identification of elements



Black Raisins



Brown Raisins



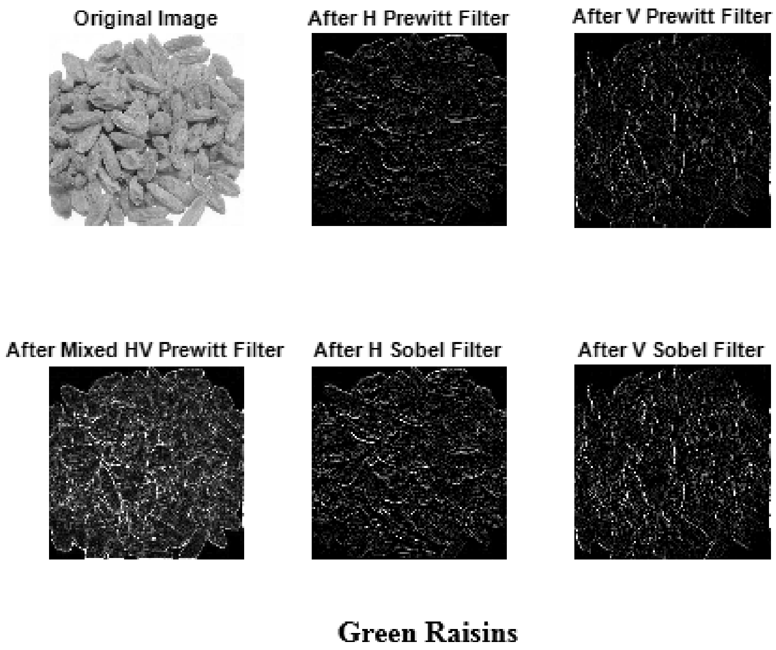


Figure 5: Response of different filters in image edge detection

3.2 Genetic algorithm results

Figure 6 represents the result of the genetic algorithm in data clustering. The colors are chosen randomly in each run, and the clustering criterion is not the displayed colors but the clustering criterion is their labels.

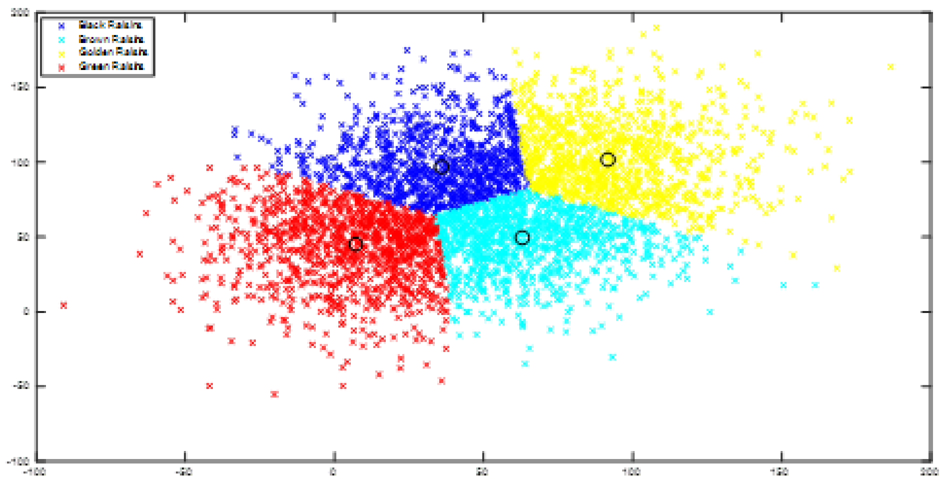


Figure 6: Genetic algorithm response in data clustering

One image of each of four types of data was considered as input to evaluate the data that the user specifies the types of raisins in the image. Figure 7 presents the image used in this research and the definition of raisins.

The clustering results of image 7 are shown in Figure 8 using the genetic algorithm.

The parts shown with red circles in Figure 8 are the detection errors of the algorithm, which can be caused by the image noise or self-malfunction. According to the processed results, the artificial bee colony algorithm was the most accurate, and then the genetic algorithm, PSO, differential evolution, and harmony search had the highest and lowest possible accuracy, respectively. The volume of calculations of the artificial bee colony algorithm is more than other methods. When the number of images and samples are large, the convergence time increases and may not be economical in terms of time. Genetic algorithm and PSO are the best algorithms for the application of this research,

Figure 7: Selection of effects on the photo

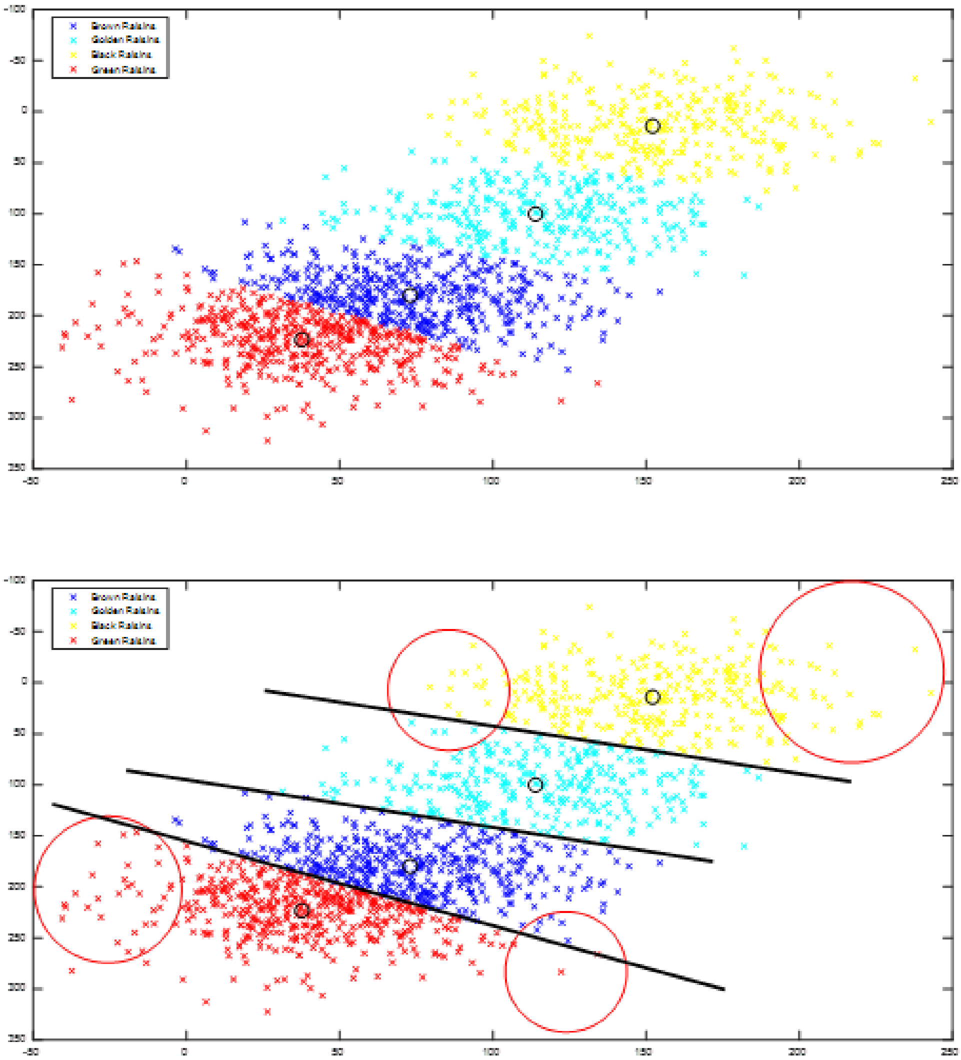


Figure 8: Genetic algorithm results

which can be easily developed for other images later. Table 1 shows the number of iterations, convergence speed, and final accuracy for 1000 samples.

Table 1: Results of meta-heuristic algorithms for 1000 samples

Algorithm	Iteration	Accuracy	Time(min)
Ant Bee Colony	200	94.31%	10
Genetic	200	93.25%	5
PSO	200	93.16%	5.5
Differential Evolution	500	91.56%	8
Harmony Search	300	89.21%	7

4 Discussion

Abbasqalipour et al. [1] proposed image processing with the genetic algorithm in a raisin classification system based on a V-gene machine. The described GA-based segmentation scheme was a novel and simple approach for robust segmentation of a raisin image into desired, unwanted, and background regions. Similar segmentation performance was obtained by applying cluster analysis to the obtained images. Different device imaging and color transformations, as well as GA encoding and operators, should be further investigated in future research to improve the segmentation scheme. Laribi et al. [9] proposed a gray level co-occurrence matrix to classify bulk raisins and measure the quality of bulk raisin products using the visual method in two cases. Xialving and Hemkleleren [11] presented an approach based on color and texture combination characteristics for the classification of raisins. Wang et al. [17] investigated the development of automatic machinery for grading raisins based on color and size. This article presented the design and testing of a raisin cutting machine based on machine vision. Li et al. [10] introduced the sorting of raisins using computer vision and designed a device for sorting raisins based on the computer vision approach consisting a conveyor belt, lighting box, control unit, and processing system. Aswati et al. [15] investigated the cost-effective grading process for grape raisins based on HSI and fuzzy logic algorithms. In this study, a database was built using images captured by a simple webcam from a local raisin market. According to raisin experts, these images are classified into four classes. Shangjing Wang et al. [6] presented the use of composite image features for rapid and non-invasive classification of raisins based on composite image features, i.e., morphological, color, and texture features. A total of 74 features (8 morphology, 30 color, and 36 texture) were extracted from RBG images. In this study, five types of classifiers, namely partial least squares (PLS), linear discriminant analysis (LDA), soft independent modeling of class comparison (SIMCA), and least squares support vector machine (LS-SVM) with linear and radial basis functions (RBF) kernels were used to establish the model based on different feature sets. Yun Zhao [19] introduced a RAISIN separation algorithm based on deep learning and moral analysis. In this research, deep learning was used to predict the number of raisins in each connected area, and the shape features were roundness, area, X-axis value for centroid, Y-axis value for centroid, axis length, and perimeter of each area. Morphological analysis was performed based on the edge parameters, including polar axis, polar angle, and angular velocity, to search for appropriate breakpoints, which are useful to identify dividing lines between two adjacent raisins. Some machine learning algorithms such as Random Forest (RF), Support Vector Machine (SVM), and Deep Learning (Deep Neural Network, DNN) were used to predict the number of raisins and decide whether to classify the raisins further.

5 Conclusion

Previous studies were limited to measurement or grading in fruit sorting. Combining two sorting modes (grading and sizing) using a genetic algorithm was not investigated by researchers so far. In this research, the results of the genetic algorithm were compared with some other meta-heuristic algorithms. According to the processed results, the artificial bee colony algorithm was the most accurate, and then the genetic algorithm, PSO, differential evolution, and harmony search had the highest and lowest possible accuracy, respectively.

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