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Application of Genetic Algorithm in Sorting Dry Fruits and Agricultural Products: Optimization of Sorting Devices

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Abstract

Sorting is a term that means grading and categorizing agricultural products and is an introduction to agricultural product packaging. In addition, in the fruit and vegetable markets of modern societies, almost all fruits and vegetables are offered in sorted and labeled form, and this will make it easier for the customer to recognize the quality of the product and will lead to a more regular distribution and supply. Sorting and grading of products is a continuous system that includes preservation, transportation, distribution, sale, and final consumption. However, all sorting and grading devices should be optimized and evaluated so that in case of any technical violation or update, they do not encounter problems in providing services and their work is not disrupted. Therefore, in this study, evaluation, and optimization of bulk raisin sorting machine, which is one of the main challenges of raisin producers and buyers in the world, was done. In this research, grape samples were randomly selected and prepared from the seedless white variety. For classification, digital image processing techniques were used to extract features from an image from the image processing toolbox in MATLAB. Other algorithms were used to evaluate and validate the accuracy of the results. These algorithms included honey bee inter colony harmony, differential evolution, and PSO. According to the results of the bee colony algorithm, it had higher accuracy, but the speed of convergence was lower and therefore needed to spend more time on calculations. But the genetic algorithm had almost the same accuracy as the honey bee algorithm, and on the other hand, the convergence speed was higher. Differential evolution and harmony search algorithms required many iterations of image processing and were not cost-effective in

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terms of computation time. On the other hand, raisin clustering requires high speed and accuracy in an industrial unit to avoid product wastage. Therefore, according to the results, genetic algorithms and PSO have the best performance in terms of speed, accuracy, and the need for fewer calculations than other algorithms, and these algorithms can be used for other sorting devices as well.

Keywords: Dried fruit, raisins, sorting, image processing, PSO algorithm, genetic algorithm.

1. Introduction

Agricultural products, from which food is derived, perish much earlier when they are in unfavorable conditions. Spoilage is caused by microbial degradation or chemical reactions that cause changes in the product and may reduce its quality and have a potential health risk and finally lead to a significant economic loss (1-3). Sorting and packing is the most important factor in preserving agricultural products and one of the important solutions to minimize this problem. Sorting and packaging is a continuous system of product preparation for transportation, distribution, storage, sale, and final consumption, and if the methods are weak or non-existent, large amounts of product will be lost. If the qualitative and quantitative level of sorting and packaging operations increases, the product loss will be less (4, 5). In addition, any principled, attractive, and competitive packaging in the market will result in significant added value (6). Product sizing means separating the product into different categories in terms of size, in other words, sorting is defined in terms of size. The purpose of sizing is to present fruits and vegetables to the market based on the taste of the consumer. Another purpose of sizing, according to the different abilities of consumers, is to provide micro and large fruits and vegetables to the market in different sizes. Fruits and vegetables of the same size can be packed with a specific pattern, as a result, the package will have a balanced shape, and more importantly, it will provide better protection for the fruits and maximum use of the space inside the package. On the other hand, grapes have been cultivated since prehistoric times, and according to the International Food and Agriculture Organization, the global production of grapes is currently more than 8.75 million tons. (7). In a study, apricot, cherry, and tomato fruits were examined to design a fruit sorting machine using machine vision. The division of fruits was done based on handling using the biological substances in them. Based on the obtained information, the algorithm was designed and the fruit sorting machine was designed and built in the Abaqus software environment and evaluated (8). Abbasgholipour et al. (2012) performed image processing with a genetic algorithm in a raisin classification system based on a V-Gen machine. The GA-based segmentation scheme, described in this paper, is a novel and simple approach for robust segmentation of a raisin image into desired,

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unwanted, and background regions. GAHSI performance analysis showed that, for machine vision-based desirable and undesirable raisin, GA-based color image segmentation in HSI color space is an effective method (9). GAHSI achieved a similar segmentation performance to that obtained by applying cluster analysis to the resulting images (10). To improve the segmentation scheme, different imaging devices, and color transformations as well as GA encoding and operators should be further investigated in future research (11). Laribi et al. (2004) used the gray level co-occurrence matrix to classify bulk raisins. In this research, using the visual method, the quality measurement of the mass production of raisins was done in two different cases. In the first case, 6 layers of a combination of good and bad raisins, and in the second case 15 layers of a combination of good and bad raisins and wood, thorn and thorn were investigated (12). The classification results with LDA and SVM methods showed that the best classification accuracy of 6 classes was achieved with the linear SVM method, which had 85.55% accuracy. The results for the classification of 15 classes including good, bad, and thorn and Shashank raisins showed that the best open result was obtained with the linear SVM method but with lower accuracy of about 63.55%. The results showed that the GLCM method was able to reliably detect the mass product class of raisins and can replace the expert in raisin processing factories (13). Yun et al. (2019) used Least Squares Support Vector Machine (LSSVM) based on color combination and texture features for sorting, and in this paper, an approach based on color and texture combination features for classification Raisins were offered (14). Least squares support vector machine (LSSVM), linear discriminant analysis, and soft independent modeling of class analogy were used to construct classification models. A total of 480 images from four classes of raisin samples were captured by a Basler 601 Fc IEEE1394 digital camera, 200 images were randomly selected to create the calibration model (training set) and the remaining images were used to validate the model (prediction set) (15). Zhao (2018) studied a RAISIN separation algorithm based on deep learning and moral analysis. They proposed a segmentation algorithm for raisin extraction, and deep learning was used to predict the number of raisins in each connected region, and shape features such as roundness, area, X-axis value for centroid, and Y-axis value for centroid, axis length, and circumference of each The area was investigated. Morphological analysis, based on edge parameters including polar axis, polar angle, and angular velocity, was used to search for appropriate breakpoints that were used to identify the dividing lines between two adjacent raisins (16). To make the segmentation more accurate, some machine learning algorithms such as random forest (RF), support vector machine (SVM), and deep learning (deep neural network, DNN) are used to predict the number of raisins and decide whether the raisins need further splitting (17). Therefore, most of the research conducted in the field of fruit varieties by researchers is limited to sizing or grading. The integration of two sorting modes (grading and sizing) using a genetic

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algorithm has not been investigated by researchers, or in other words, few researchers have investigated it (18). As well, offering products in the form of sorting causes the growth of e-commerce and this makes the supply and demand market controlled, and monitoring the quality of the products offered increases and becomes more intense. Some food products cannot be dried in the traditional way and under natural light because they lose some of their pleasant properties, and in some cases, improper drying is the most important reason for spoiling the product. Therefore, it is necessary to dry grapes in a modern way and under controlled conditions so that the quality of the final product is improved and the producer gets more profit as a result of sales. Therefore, our research was focused on developing a software and hardware package based on identifying the characteristics of raisins and using genetic algorithms, and comparing their results in sorting one of the agricultural products and dry fruits, namely raisins.

2. Materials and methods

Due to the application of its results to organizations related to sorting machines, the current research was of applied research type and rational reasoning and analysis methods were used.

2.1. Gathering information

The method of collecting information was library, field, and consulting studies and research. In this way, firstly, the theoretical foundations of the sorting machine were collected using a library method. And if needed, library studies and articles were used to collect samples.

2.2. Preliminary preparation of samples

In this research, four types of raisins based on color, title, black raisins, brown raisins, golden raisins, and green raisins, which are also shown in Figures (1) was used. After that processing, these four types of raisins were mixed and separated by a genetic algorithm. Other meta-heuristic algorithms such as PSO, differential evolution, and honey bee colony vant harmony have been used to evaluate the accuracy of the results. The processes include two stages (19-21). First, conventional methods were used for image clustering and its problems were analyzed. After that, in the second stage, which includes two parts, the cluster centers were determined automatically using the defined color features, and in the second part, the cluster centers were determined using the images taken by the camera, which increased the accuracy of the processes (Figure 2).

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Brown Raisins

Black Raisins

Green Raisins

Golden Raisins

Figure 1: Type of raisins used in this study

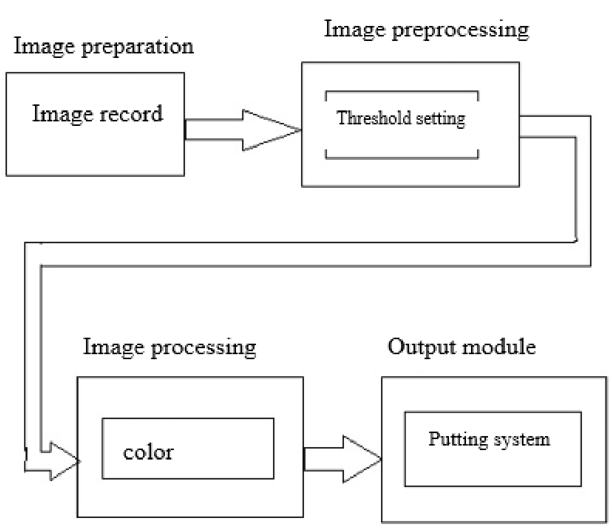

Figure 2: Research workflow and system architecture.

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2.3. Imaging

The image or sequence of images was taken with a camera, which usually requires the imaging system to be set up before use.

2.4. Preprocessing

In the pre-processing step, the image was subjected to low-level operations. The purpose of this step is to reduce the noise and separate the signal from the noise from the data. This work is usually done by using various image processing methods such as: applying digital filters, convolutions, correlations, sobel operator, pixel thresholding, Fourier transform, and performing motion estimation for local areas of the image, which is also known as optical flux estimation (22).

2.5. Mechanical assembly and operation

Our main goal was to investigate and evaluate the classification of raisins at a low cost using the genetic algorithm method and to achieve the speed of the existing sorting machine at a lower cost, a new mechanism was designed to transfer the raisins in front of the camera.

2.6. **Genetic algorithm**

The development of the proposed algorithm consisted of three stages. The first step was related to the development of the image processing algorithm to extract the color features and prepare the dataset matrix (Figure 3).

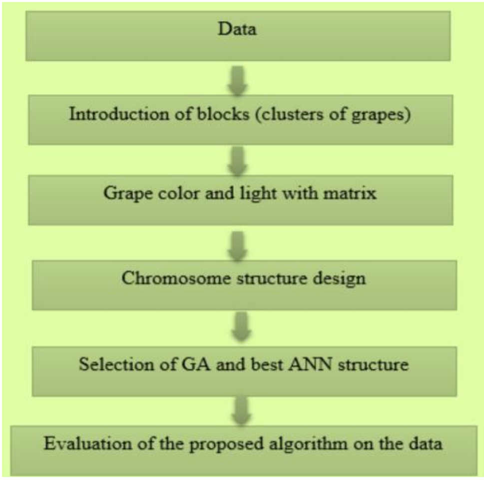

Figure 3. Diagram of the proposed algorithm.

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2.7. Performance evaluation of the classification algorithm

The classification performance of the proposed classification algorithm was evaluated by forming a classification matrix (CM). Calculation of several statistical indices including correct classification rate (CCR), accuracy (AC), specificity (SP), and classification sensitivity (SE) was performed, these indices were calculated using the following equations (Table 1).

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

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

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

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

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

Table 1
Statistical indicators of the evaluated classifier.

	Classifier indicators	SE	SP	AC
ANN-GA algorithm presented in this study	Grape	99.22	99.13	99.07
	Leaf	99.83	99.76	99.50
	Others	99.15	99.80	99.61
	CCR	99.40		
GDA1 algorithm	Grape	21.77	88.14	75.78
	Foliage	88.14	21.77	40.10
	CCR	57%		

2.8. Fitness performance

The goal function clearly defines the desired goals and can be freely chosen for the desired behavior. The main purpose of the objective function was to minimize the fraction of misclassified samples (FSMS) (Figure 4).

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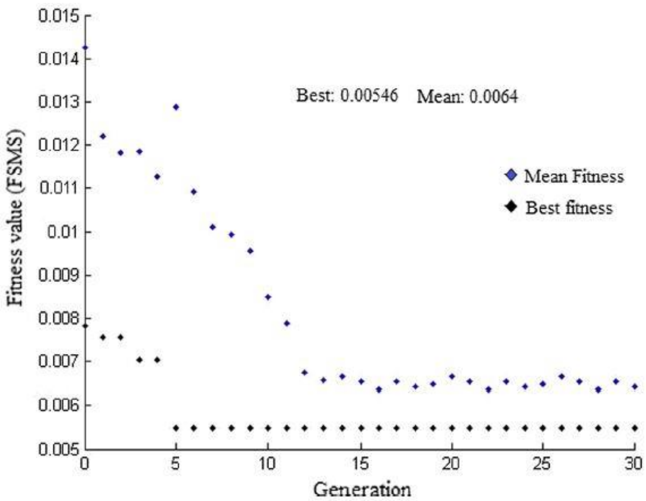

Figure 4. Mean and best-fit values for test data in each generation.

Therefore, the objective function was constructed by minimization and the operating cost was obtained using the following equation:

$$FSMS = \frac{TP + FP}{TP + TN + FN + FP} \tag{6}$$

3. Results

In this research, we considered raisins as a random quantity, and the examples of these random quantities are the pictures that were taken. By applying statistical distribution to the data, the resolution of the image is increased to detect objects, and this is possible by widening the histograms of the image. To have a more accurate estimate of the image samples, we used the statistical law of large numbers, that is, we reduced the estimation error. Histogram uniformity contrasts with the image higher compared to its initial state, which means improving the quality of the image and increasing the accuracy of subsequent processing. Although this method can increase the contrast of the image, the resulting image usually has unnatural enhancement and intensity saturation, it is also powerful in defining the boundaries and edges between different objects, but it may reduce local details. To make the histogram uniform, a transformation like T must have two properties:

• This transformation function should be monotonically ascending

• For r in the interval [0,1], the values of T(r) should also be in the interval [0,1].

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These conditions ensure that the scope of the output is the same as the input, and also that the mapping is one-to-one, preventing ambiguity.

According to the above uniformizer function and considering the normalized histogram of the image in discrete mode, the transformation function that uniformizes the histogram was expressed as:

$$s = T(r) = (L-1)\sum_{j=0}^{k} p_r(r_j) = \frac{(L-1)}{MN}\sum_{j=0}^{k} n_j, k = 1,2,3,\ldots,L-1 \qquad (7)$$

where MN was the total number of pixels in the image, the number of pixels that have brightness, and L was the number of possible levels of brightness in the image. Actually, first, the normalized histogram should be calculated and then the cumulative histogram of the input image should be calculated and finally, the numbers should be transferred back by mapping each pixel in the input image with brightness to a pixel corresponding to the brightness of the output image which has a more balanced histogram. Figure 5 shows the histogram of the images obtained from raisins for the original image and the processed image in both color and grayscale modes. In this figure, the contrast has been increased by smoothing the histogram.

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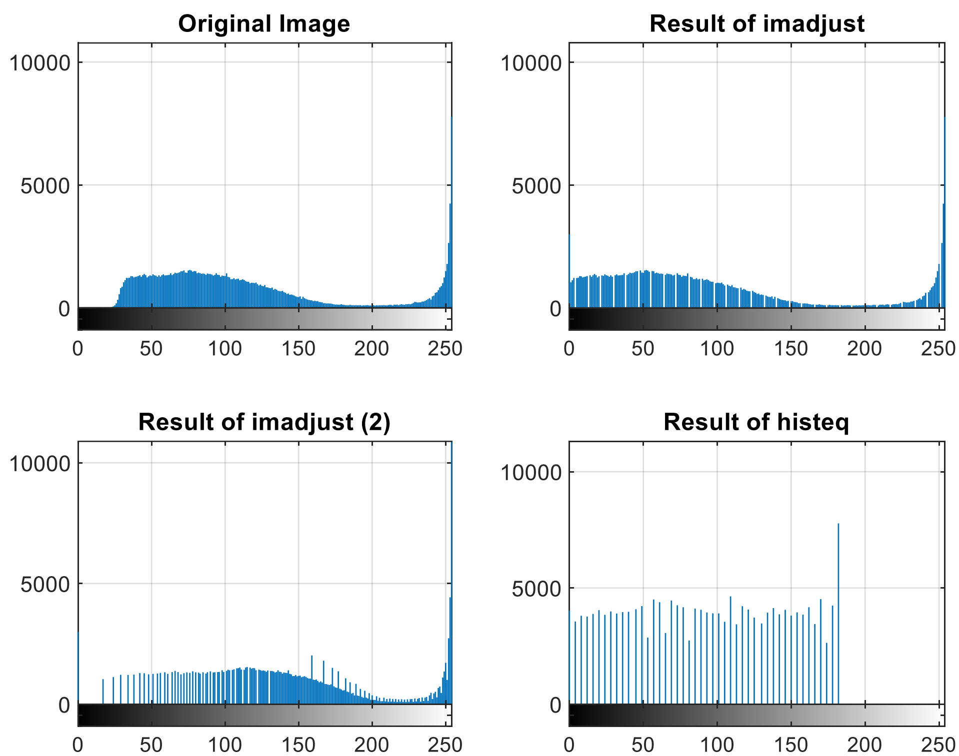

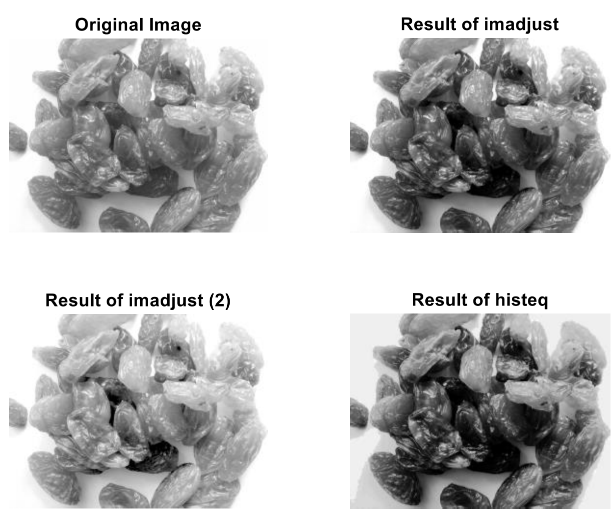

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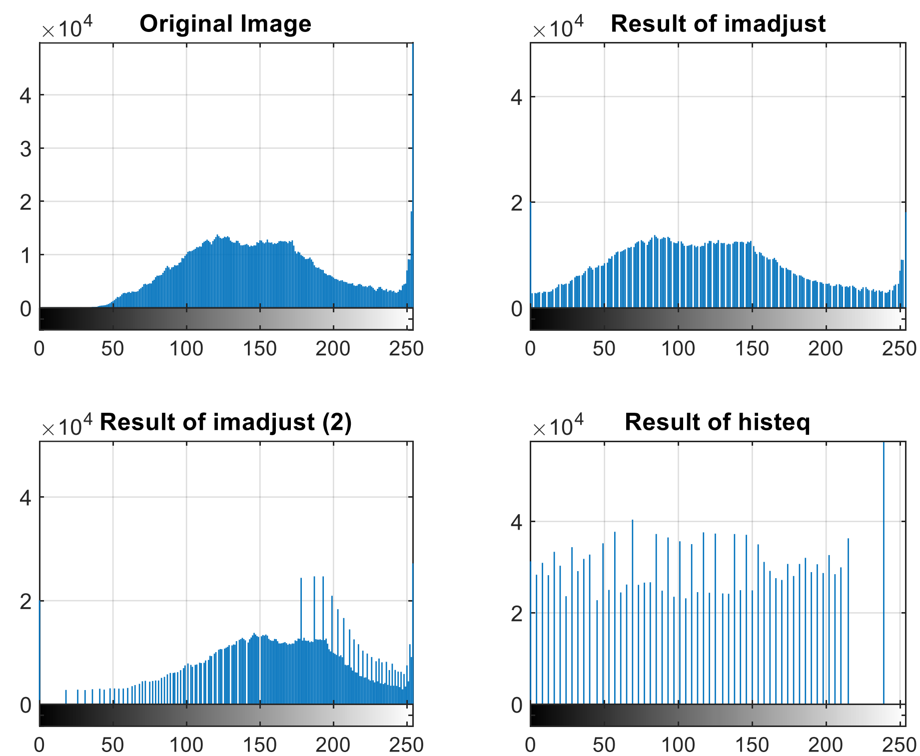

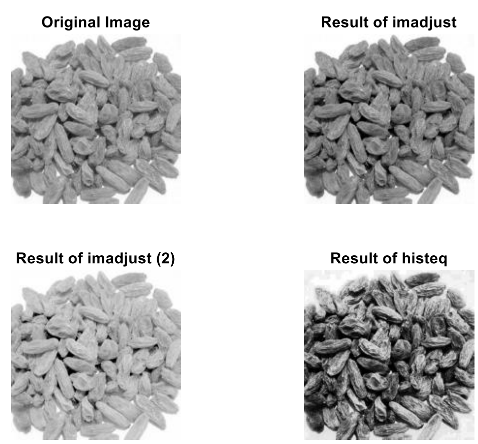

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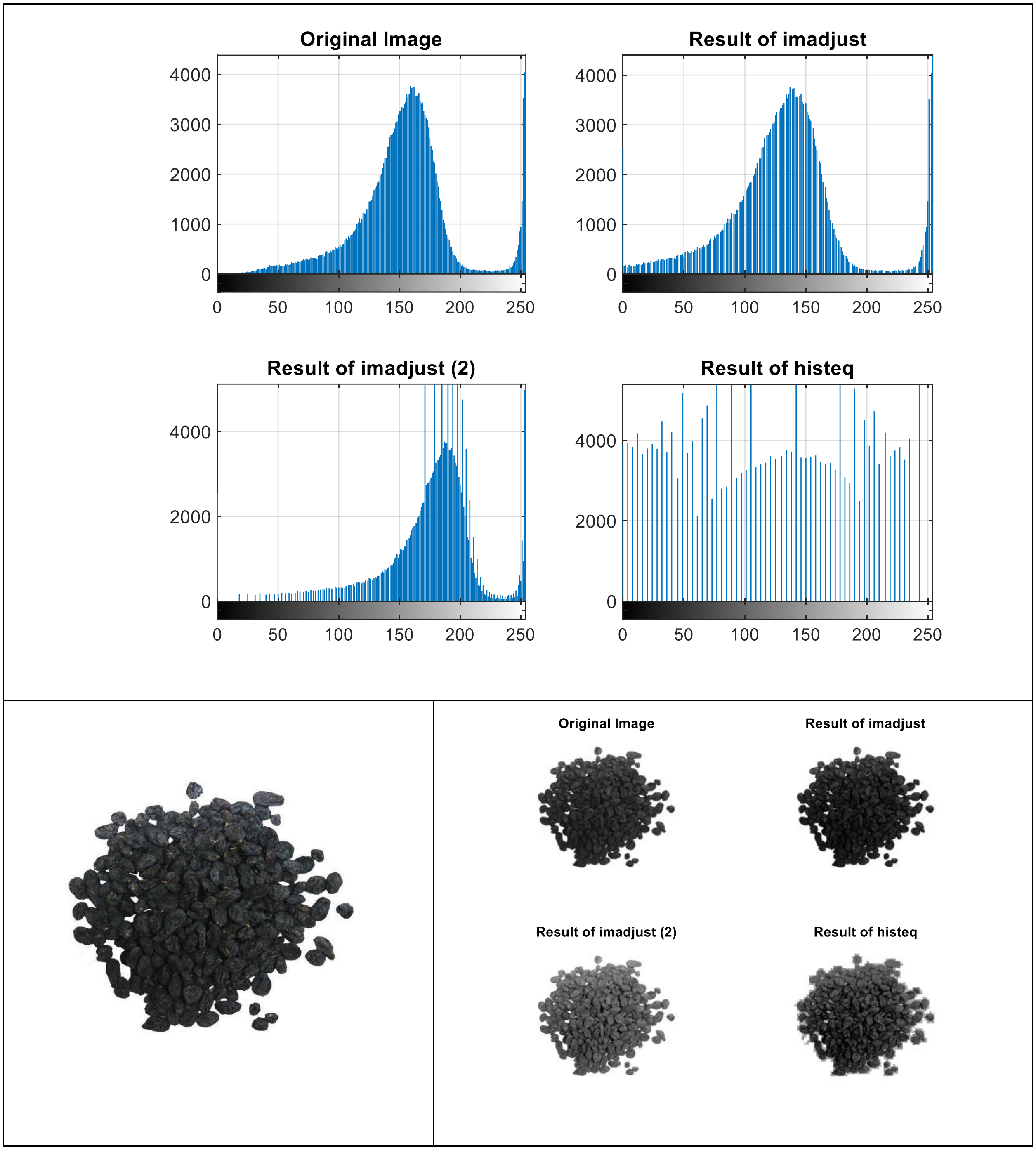

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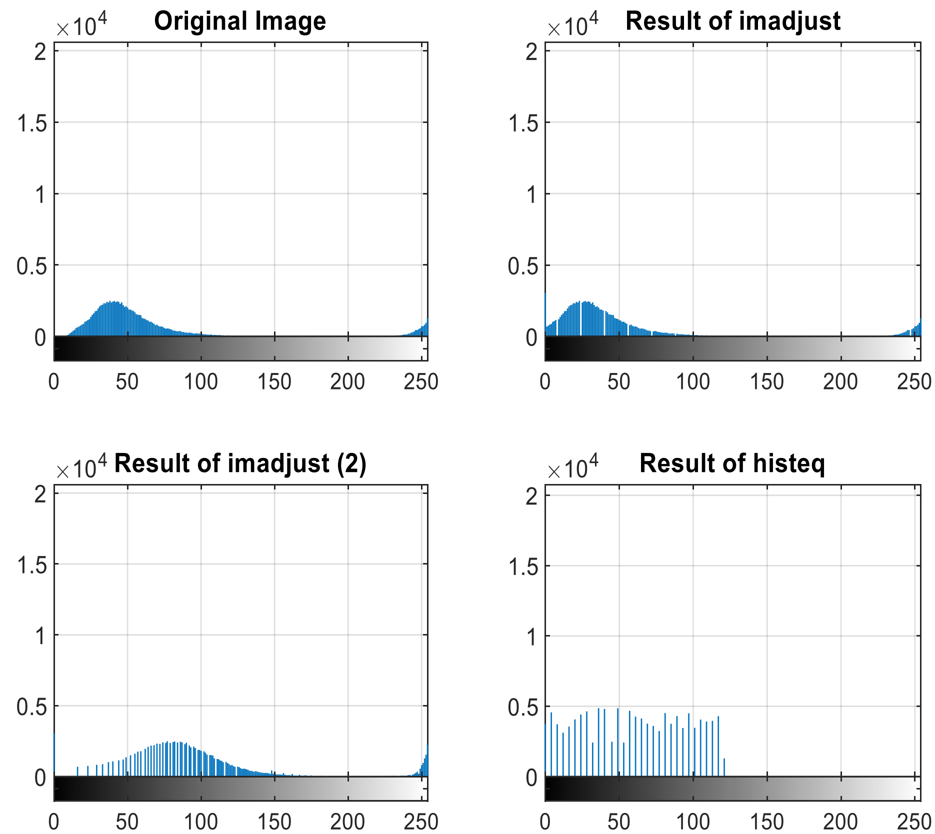

Figure 5. Histogram of images obtained from raisins and histogram uniformity for better identification of elements.

3.1. Filters and edge detection

In the image, the boundary between two areas that have a significant difference in brightness, color, or texture is usually called an edge (23). One of the advantages of edge extraction in an image is the ability to separate and distinguish objects from the background. In this research, various filters and methods were evaluated to detect the edges of objects in the image taken from raisins. Figure 6 shows the response of different filters in image edge detection.

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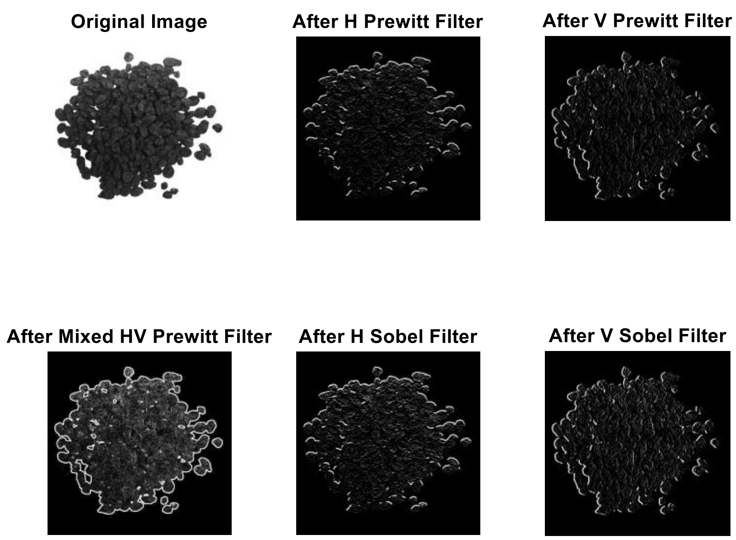
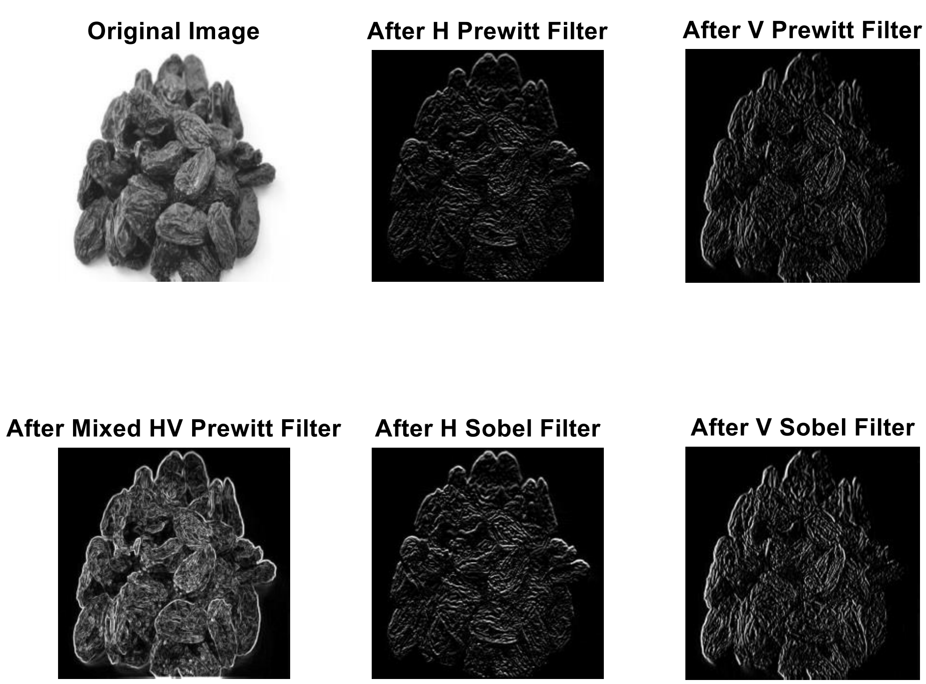


Black Raisins



Brown Raisins

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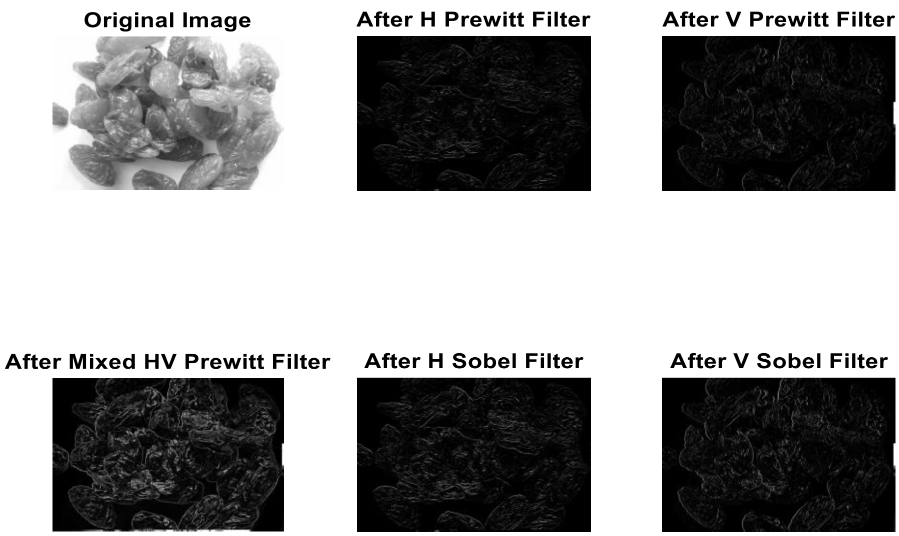
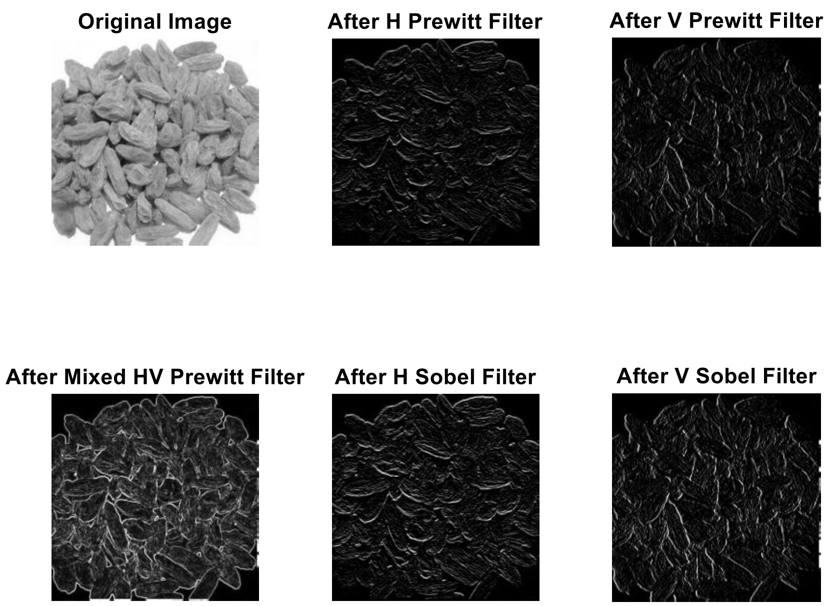


Golden Raisins



Green Raisins

Figure 6. Response of different filters in image edge detection.

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3.2. Genetic algorithm results

Figure 7 shows the result of genetic algorithm in data clustering.

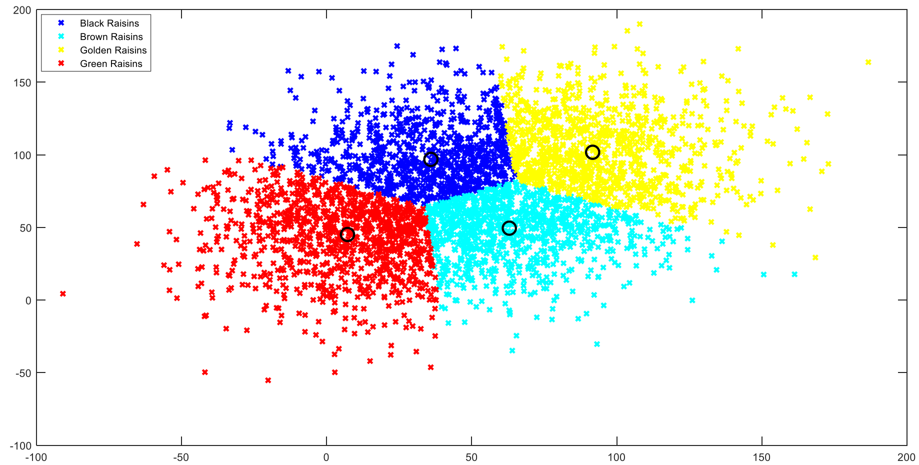

Figure 7. Display of genetic algorithm response in data clustering

To evaluate the data, one image of all four types of data was considered as input, where the user specifies the types of raisins in the image. Figure 8 shows the image used in this research and how raisins are defined.

Figure 8. Showing the selection of complications on the photo.

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The clustering results of image 7 using genetic algorithm are shown in Figure 9.

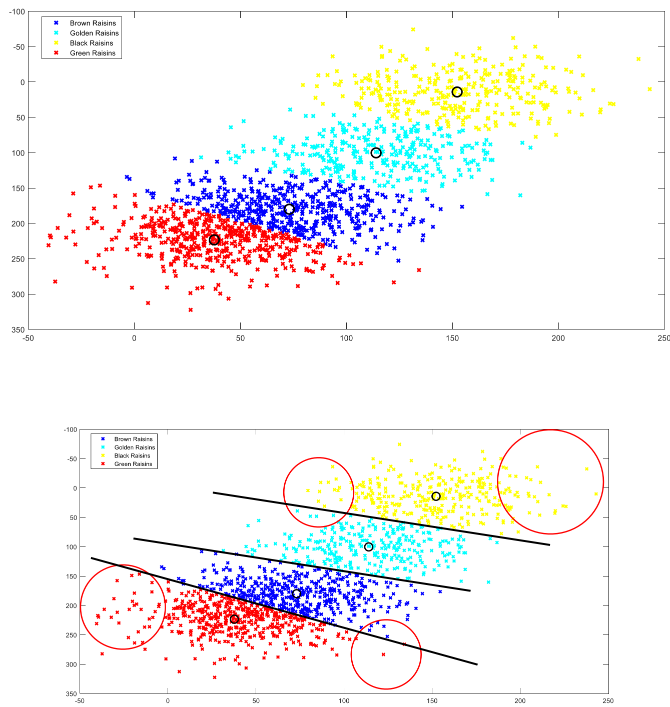

Figure 9. Genetic algorithm results.

In Figure 9, the parts shown with red circles are the detection error of the algorithm, which can be caused by the noise of the images or the failure of the problem itself.

According to the processed results, the bee inter 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. Table 2 shows the number of iterations, convergence speed, and final accuracy for 1000 samples.

Table 2. 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

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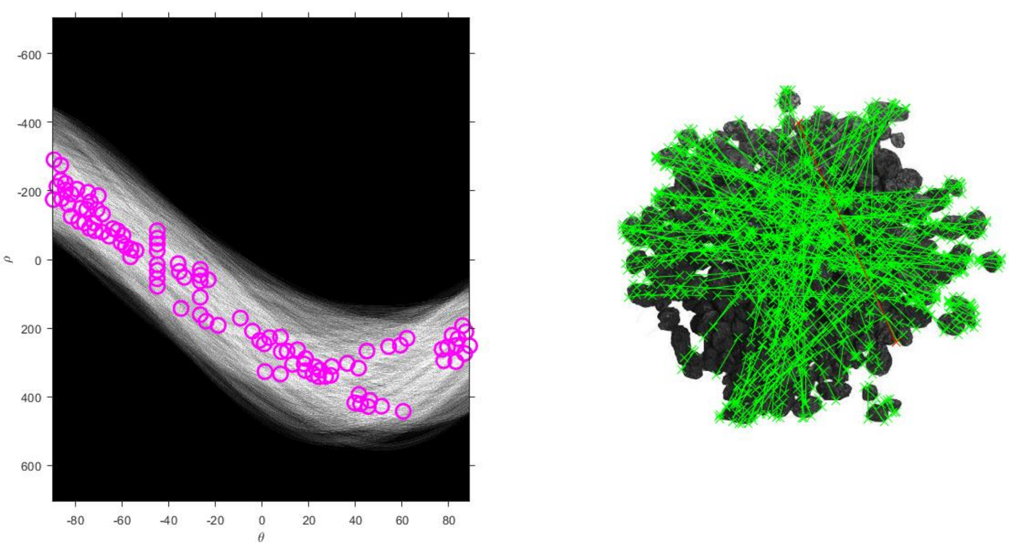
Differential Evolution	500	91.56%	8
Harmony Search	300	89.21%	7

3.3. Non-linear spatial filter

Hough transform (24) is a feature extraction method in image analysis, computer vision, and digital image processing. This method looks for examples of a pattern in an image. These samples may not be complete and may be distorted to some extent. Hough transform is a simple method to find a certain shape in the image. This method is used for curves that can be expressed in parameter space. This transformation was used to detect the distance between the raisins in the photo, that is, the position of the image points and the distance between the raisins were obtained, that is, the position, distance, and gray level of the raisins can reduce the clustering error of the genetic algorithm, and the algorithm in cases where a complication other than raisins be among the samples, easily recognize it and consider it as a separate cluster. Figure 10 shows the results of the implementation of Hough transformation for the images of raisins used in this thesis.



Black Raisins with 100 Numpeaks

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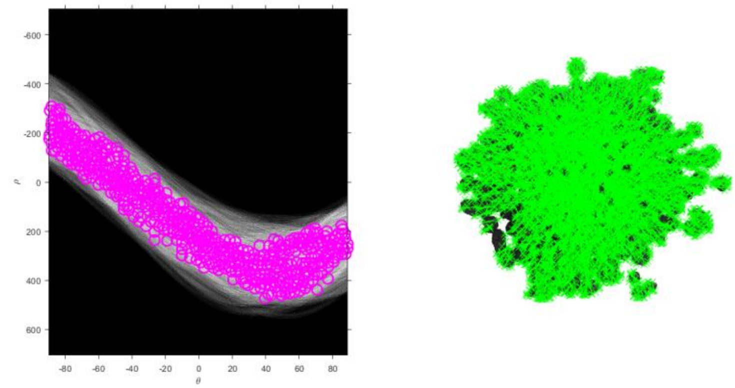
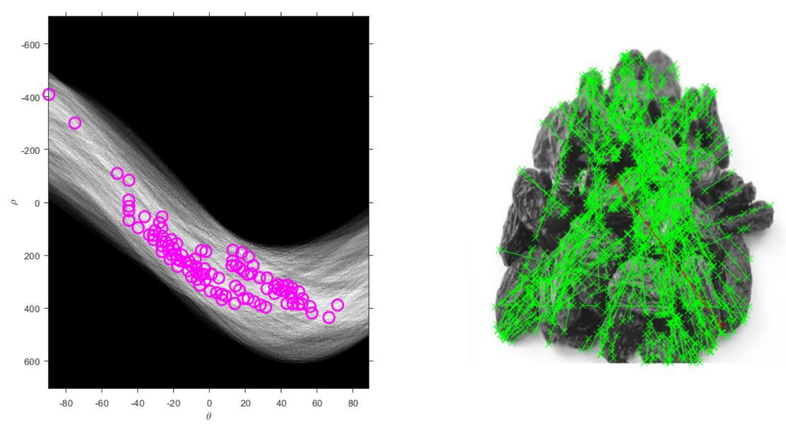
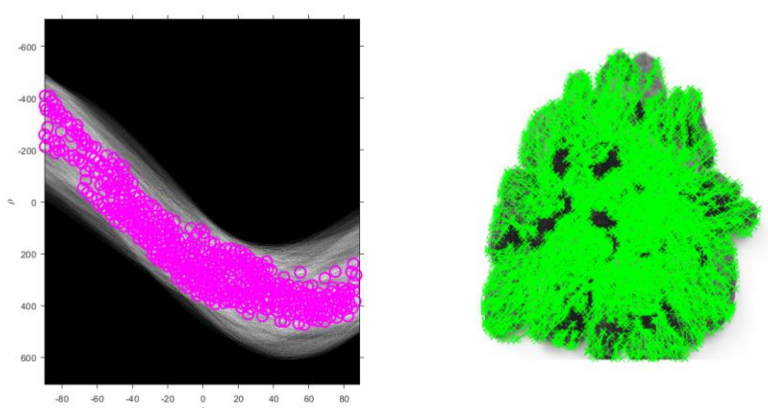


Black Raisins with 500 Numpeaks



Brown Raisins with 100 Numpeaks



Brown Raisins with 500 Numpeaks

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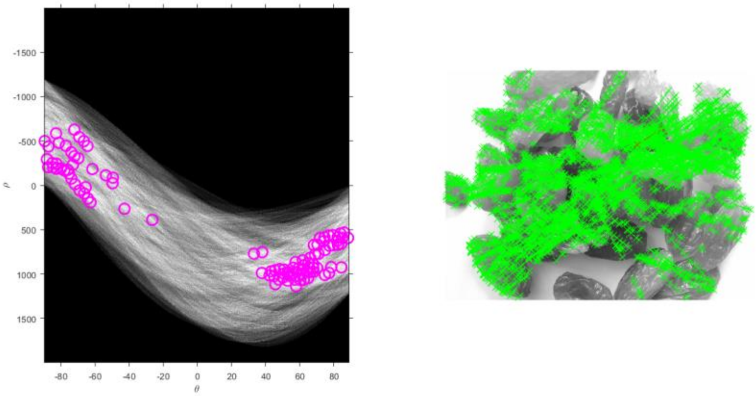
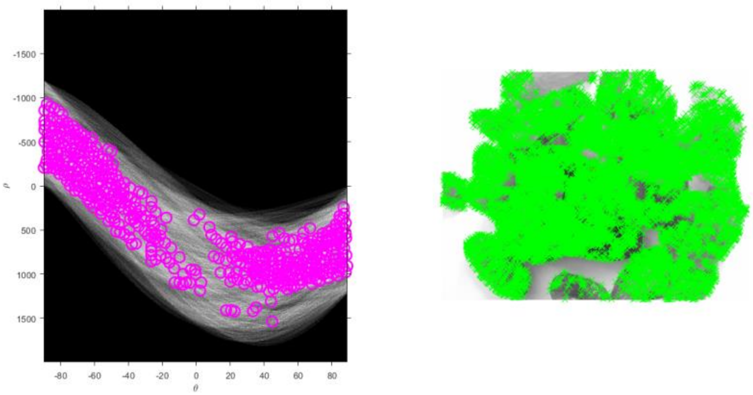
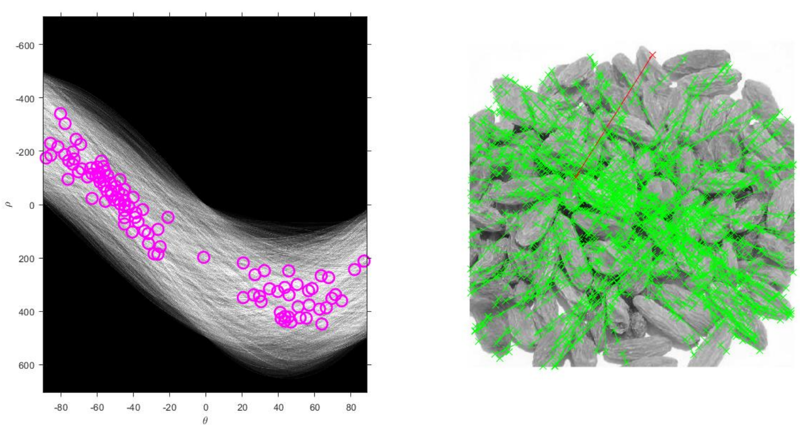


Golden Raisins with 100 Numpeaks



Golden Raisins with 500 Numpeaks



Green Raisins with 100 Numpeaks

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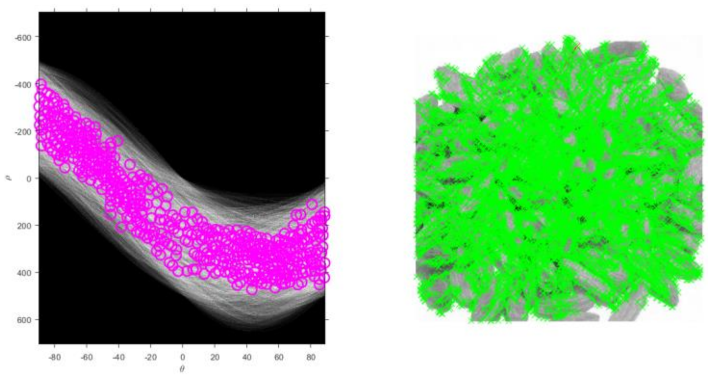

Green Raisins with 500 Numpeaks

Figure 10. The results of Hough transform to extract image features.

According to the performed processes, the bee colony algorithm has better accuracy than other algorithms, but the speed of convergence is lower and the amount of calculations it performs is more. But the genetic and PSO algorithms have accuracy almost equal to the honey bee algorithm, and on the other hand, it has a higher convergence speed and a lower amount of computational operations and can be used as the best algorithm in this application. In Figures 11 we have shown the accuracy and convergence speed graph for the algorithms used in this thesis. Differential evolutionary algorithms and harmony search require processing in much iteration, so the computation time is not economical. Therefore, raisin clustering, which is done in industrial units, requires a high speed of clustering and minimum error to avoid discarding. Therefore, it seems that the acceptable algorithm is genetics and PSO. Figure 11 is the result of calculations for 1000 data.

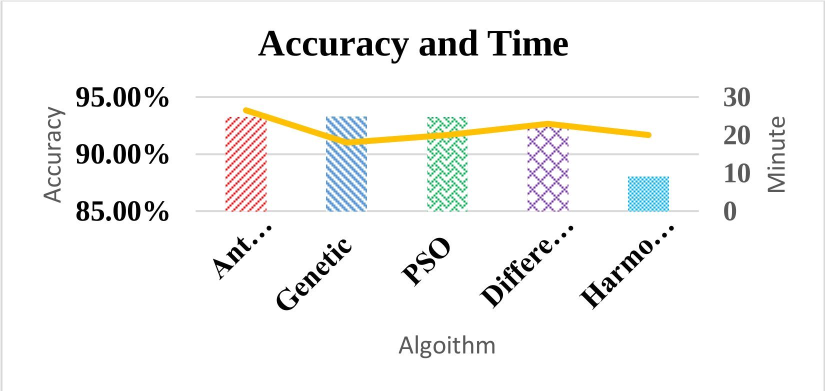

Figure 11. Accuracy and convergence speed graph for 1000 samples.

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To increase the complexity of the clustering operation and put the algorithm in stricter conditions. We increased the number and dispersion of samples to 3000 samples and increased the number of iterations of the algorithm to 500 which is shown in Figures 12 of accuracy and convergence speed for the algorithms used in this thesis.

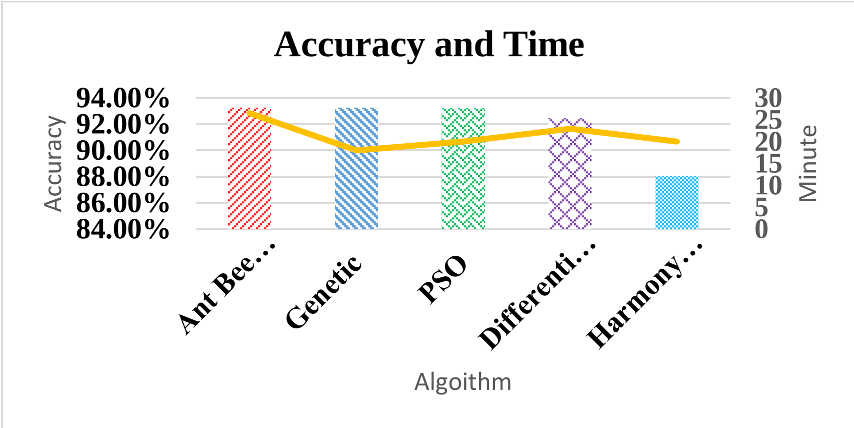

Figure 12. Accuracy and convergence speed graph for 3000 samples

4. Discussion

Li et al. (2011) introduced the classification of raisin quality using Least Squares Support Vector Machine (LSSVM) based on color combination and texture characteristics. Least squares support vector machine (LSSVM), linear discriminant analysis, and soft independent modeling of class analogy were used to construct classification models (25). A total of 480 images from four classes of raisin samples were captured by a Basler 601 Fc IEEE1394 digital camera, 200 images were randomly selected to create the calibration model (training set) and the remaining images were used to validate the model (prediction set). Omid et al. (2010) introduced a design and testing of a raisin cutting machine based on machine vision (26). The proposed MV system consists of electronic, pneumatic, and mechanical components. The hardware is made up of a conveyor belt, eight pneumatic valves, a compressor, and a control unit. The controller, which has a microcontroller as its core, is used to communicate between the PC and the pneumatic valves through the RS232 serial port. Using the recording card, the camera sends the pictures of the raisins to the computer, which is processed and sorts the raisins accordingly (27). Sathya Bama et al., (2011) introduced the sorting of raisins using computer vision and in this research, a device for sorting raisins was designed and built based on the computer vision approach. This system consisted of a conveyor belt, lighting box, control unit, and system processing (28). The feature

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color is the most important parameter in the classification and the type of raisin was developed and implemented in MATLAB to process the image and extract useful features of the recorded images. This algorithm consisted of background segmentation, raisin selection, and feature extraction. The developed algorithm first extracts the raisins by it and then removes the background from the captured images. After that, it sorts the raisins according to their RGB color. The final step in the algorithm was sorting on and off sorting. The mechanism used to automatically sort the system could be easily adapted to sorting other crops such as peanuts and almonds. Swati et al., (2013), designed a cost-effective grading process for grape raisins based on HSI and fuzzy logic algorithms. However, the existing grading systems in some countries are based on human experts and the judgment of image-based sorting and grading systems developed in developed countries are expensive and sometimes slow because they perform individual raisin analysis (29). This work proposes to develop a cost-effective grading process for grape raisins that judges bulk grading. According to the opinion of raisin experts, these pictures related to raisins are placed in four levels. Hue, Saturation, and Intensity (HSI) features of these images are obtained to develop a fuzzy logic system to classify images of different degrees (30). The gaussian membership function is used to develop these four cases. The fuzzy performance of the classification system is measured in the form of success rate. The results show that for more than four features, graded raisins can be classified with a 100% success rate (31). Wang et al. (2012) introduced a scheme for quick and non-invasive classification of raisins using composite image features; a new approach for non-invasive classification of raisins based on composite image features, i.e. morphological, color, and texture features was presented. A total of 74 features (8 morphology, 30 colors, and 36 textures) were extracted from RBG images (32). Seven types of models were created based on different feature sets. They were three types of models built based on single feature sets, three types of models built based on a combination of two feature sets, and one type of model built based on a combination of all feature sets. 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 function (RBF) kernels. It was used to establish the model based on a set of different features (33).

Li (2011), Raisin recognition levels based on neural networks and digital images are investigated. Considering the back parts of raisin grade identification in China, which still relies on photoelectric classification and manual separation, this researcher presented this method based on computer vision technology and digital image processing. The length of the short axis determined its location

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and calculated 7 parameters, chroma, length, width, etc., four of which were selected as the main features of the network BP input for network construction and identification (34-36).

5. Conclusion

Most of the research done in the field of fruit sorting by researchers is limited to sizing or grading. The combination of two sorting modes (grading and sizing) using a genetic algorithm had not been investigated by researchers. Therefore, in this research, the results of the genetic algorithm were compared with some other meta-heuristic algorithms and their results were shown. According to the processed results, the bee inter 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.

Data availability statement

The following supporting information can be downloaded at Journal Website.

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Conflicts of Interest

The authors declare no conflict of interest.

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