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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 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. 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. In addition, any principled,

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attractive, and competitive packaging in the market will result in significant added value (1). 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. (2). 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 (3). 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, 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 (4). GAHSI achieved a similar segmentation performance to that obtained by applying cluster analysis to the resulting images (5). 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 (6). 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 (7). 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 (8). 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 (9). 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) (10). 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

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dividing lines between two adjacent raisins (11). 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 (12). 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 algorithm has not been investigated by researchers, or in other words, few researchers have investigated it (13). 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. 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 (14-16). 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 1).

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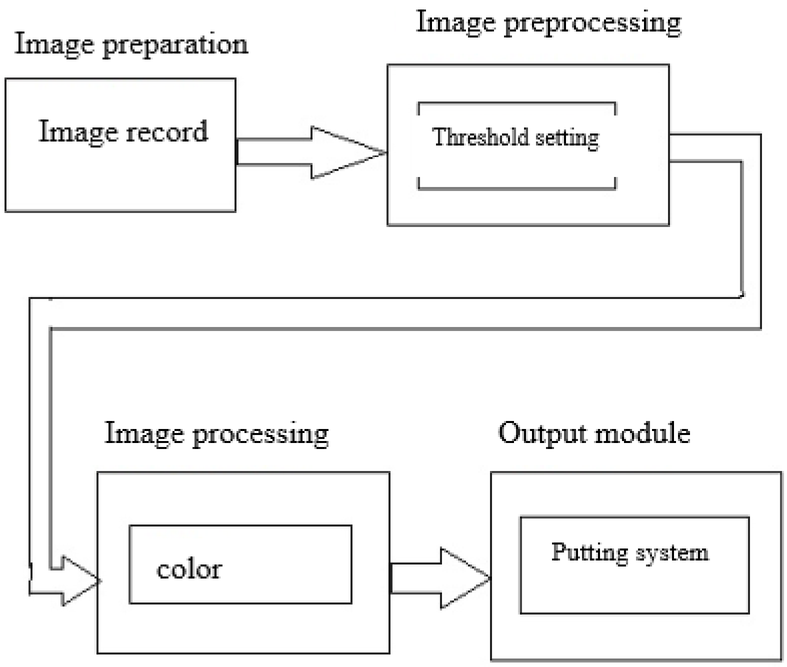

Figure 1: Research workflow and system architecture

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. Pre-processing

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 (17).

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 2).

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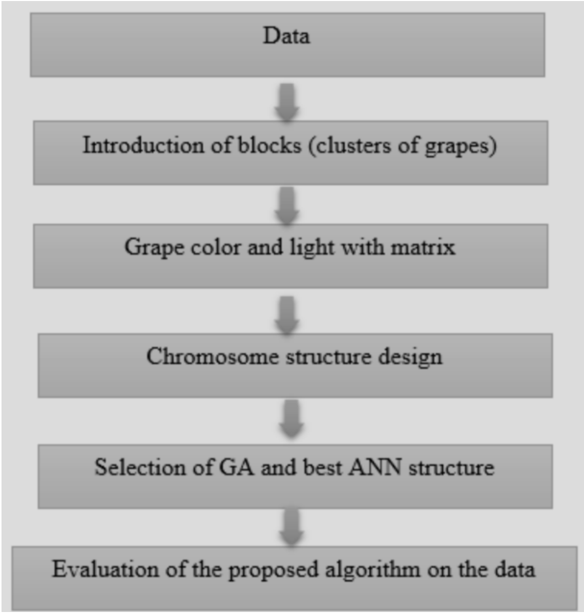

Figure 2: Diagram of the proposed algorithm

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).

$$CM = \begin{bmatrix} TP & FP \\ FN & TN \end{bmatrix} \quad (1)$$

$$SE = \frac{TP}{TP+FN} \times 100 \quad (2)$$

$$SP = \frac{TN}{TN+FP} \times 100 \quad (3)$$

$$AC = \frac{TP}{TP+FP} \times 100 \quad (4)$$

$$CCR = \frac{TP+TN}{TP+FP+TN+FN} \times 100 \quad (5)$$

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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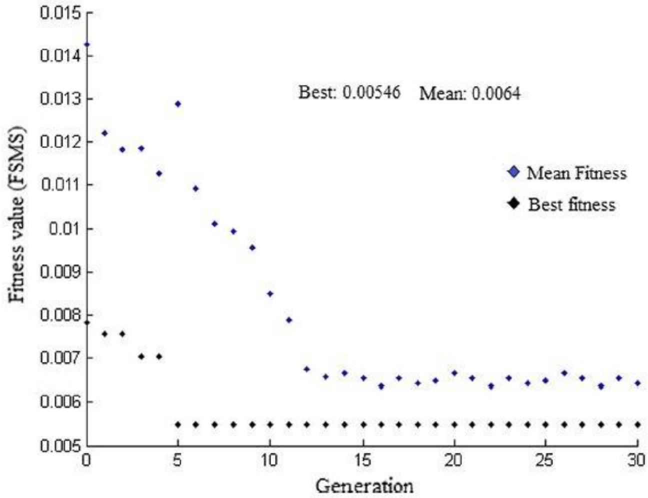


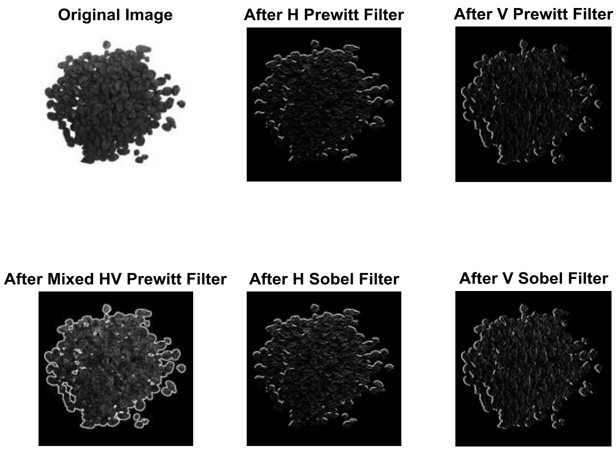
Figure 3: Mean and best-fit values for test data in each generation

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

$$FSMS = \frac{TP + FP}{TP + TN + FN + FP} \qquad (6)$$

2.9. 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 (18). 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.



Black Raisins

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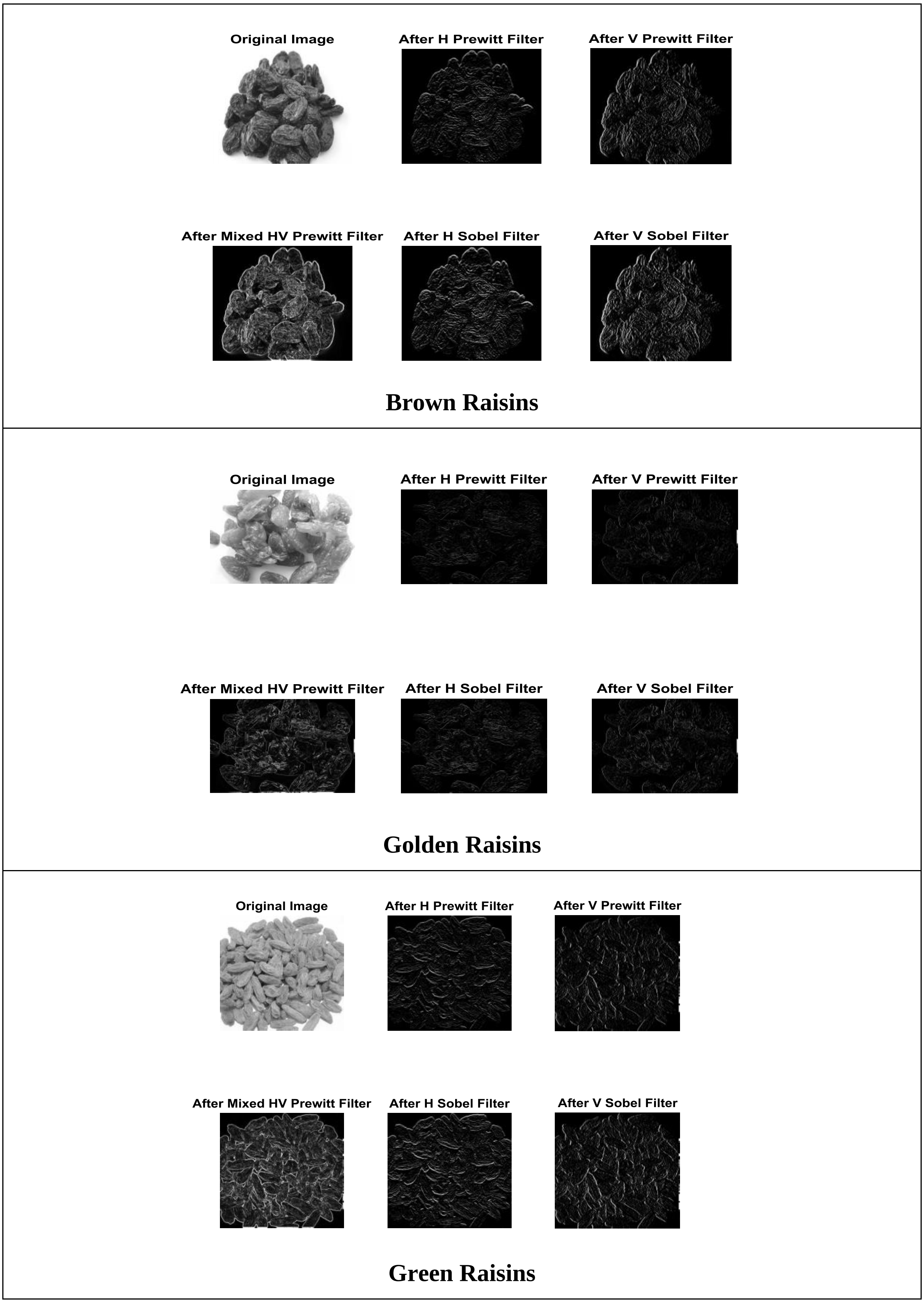

Figure 4: Response of different filters in image edge detection

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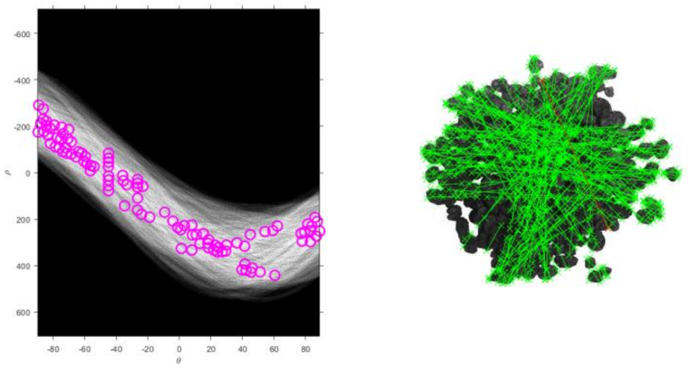
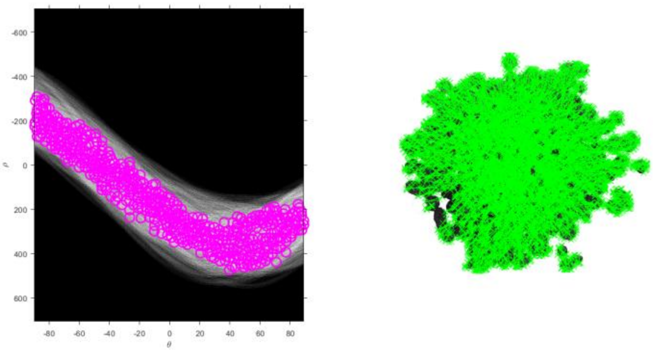
2.10. Non-linear spatial filter

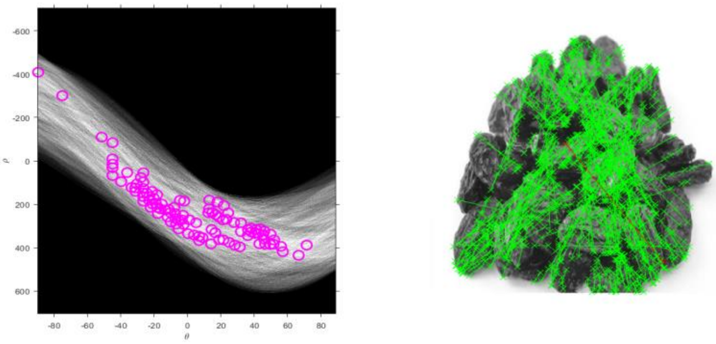
Hough transform (19) is a feature extraction method in image analysis, computer vision, and digital image processing. This method looks for examples of a pattern in an image. These samples may not be complete and may be distorted to some extent. Hough transform is a simple method to find a certain shape 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



Black Raisins with 500 Numpeaks



Brown Raisins with 100 Numpeaks

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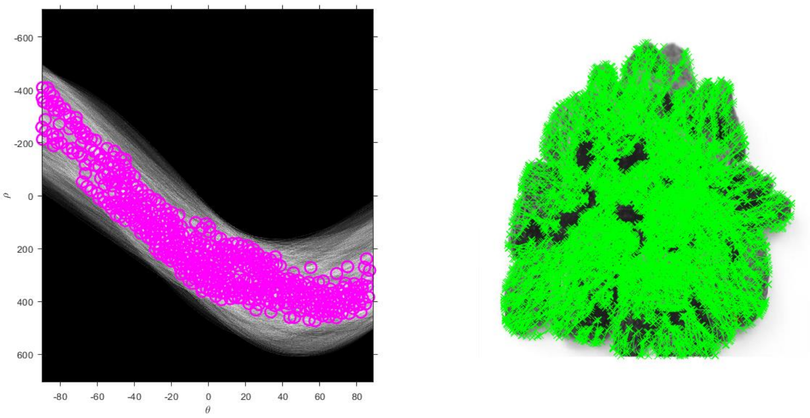
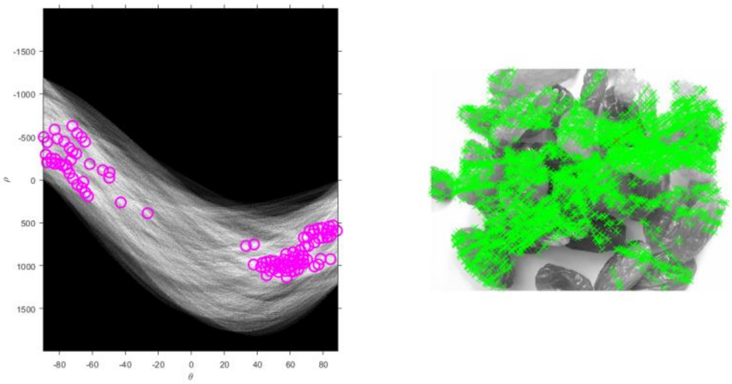
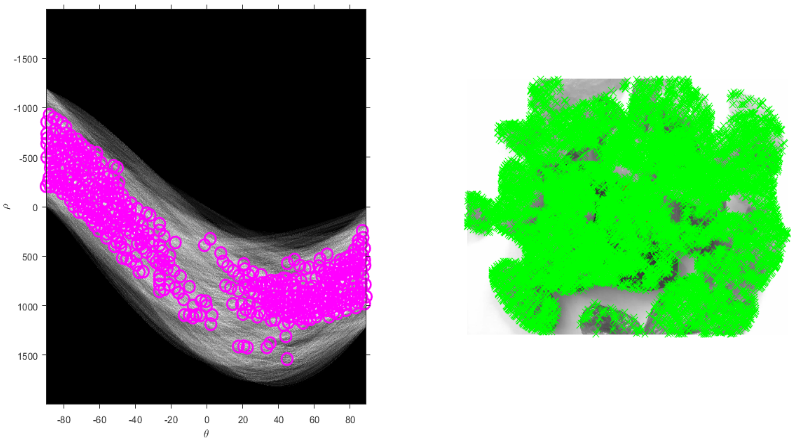


Brown Raisins with 500 Numpeaks



Golden Raisins with 100 Numpeaks



Golden Raisins with 500 Numpeaks

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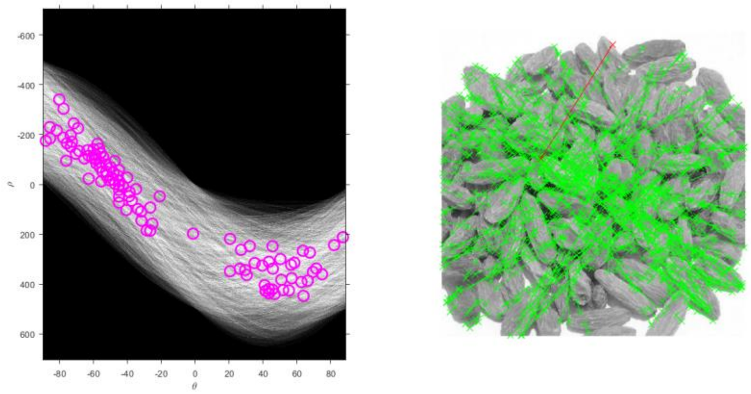
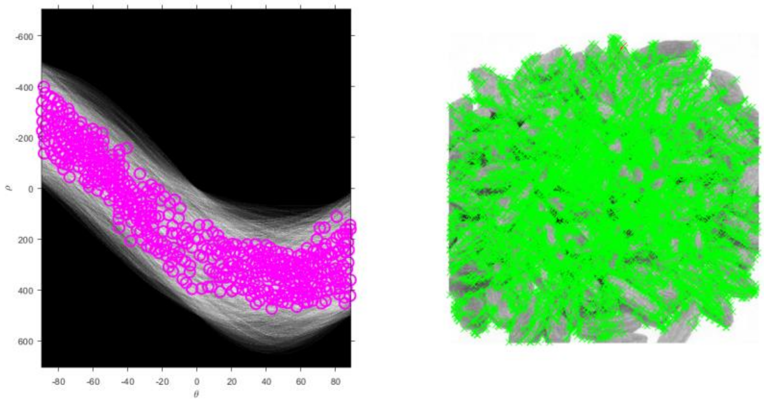


Green Raisins with 100 Numpeaks



Green Raisins with 500 Numpeaks

Figure 5: 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.

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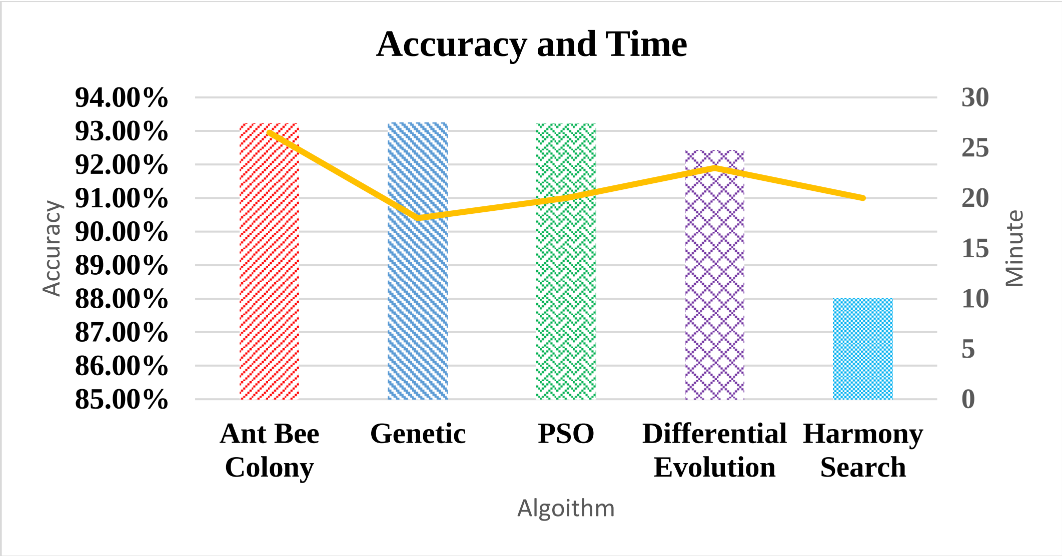

Figure 6: Accuracy and convergence speed graph for 1000 samples

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.

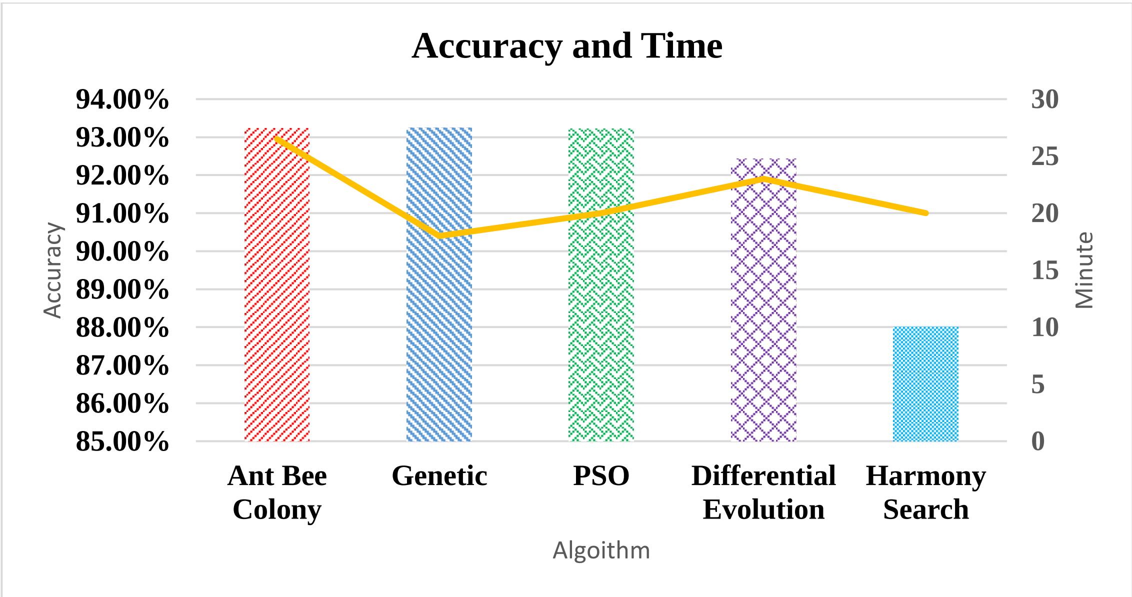

Figure 7: Accuracy and convergence speed graph for 3000 samples

3. 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

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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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