Classification of Raisin Grains Using Machine Vision and Artificial Intelligence Methods

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Classification of Raisin Grains Using Machine Vision and Artificial Intelligence Methods

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ABSTRACT

In this study, machine vision system was developed in order to distinguish between two different variety of raisins (Kecimen and Besni) grown in Turkey. Firstly, a total of 900 pieces raisin grains were obtained, from an equal number of both varieties. These images were subjected to various preprocessing steps and 7 morphological feature extraction operations were performed using image processing techniques. In addition, minimum, mean, maximum and standard deviation statistical information was calculated for each feature. The distributions of both raisin varieties on the features were examined and these distributions were shown on the graphs. Later, models were created using LR, MLP, and SVM machine learning techniques and performance measurements were performed. The classification achieved 85.22% with LR, 86.33% with MLP and 86.44% with the highest classification accuracy obtained in the study with SVM. Considering the number of data available, it is possible to say that the study was successful.

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Kuru Üzüm Tanelerinin Makine Görüşü ve Yapay Zeka Yöntemleri Kullanılarak Sınıflandırılması

MAKALE BİLGİSİ

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ÖZ

In this study, machine vision system was developed in order to distinguish between two different variety of raisins (Kecimen and Besni) grown in Turkey. Firstly, a total of 900 pieces raisin grains were obtained, from an equal number of both varieties. These images were subjected to various preprocessing steps and 7 morphological feature extraction operations were performed using image processing techniques. In addition, minimum, mean, maximum and standard deviation statistical information was calculated for each feature. The distributions of both raisin varieties on the features were examined and these distributions were shown on the graphs. Later, models were created using LR, MLP, and SVM machine learning techniques and performance measurements were performed. The classification achieved 85.22% with LR, 86.33% with MLP and 86.44% with the highest classification accuracy obtained in the study with SVM. Considering the number of data available, it is possible to say that the study was successful.

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1. INTRODUCTION *(GİRİŞ)*

Raisins are a concentrated source of carbohydrates and a nutritious snack, containing antioxidants, potassium, fiber and iron [1]. Turkey is one of the countries that ranks top in the world's grape production. Approximately 30% of the grapes produced in Turkey are considered as table, 37% as dried, 3% as wine and 30% as other products [2].

There are many applications of traditional methods for assessing and determining the quality of foods.

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However, these can be time consuming and expensive. In addition, human-made procedures from traditional methods can be inconsistent and more inefficient, as well as physical conditions such as fatigue and even people's psychological mood can affect the outcome of the work. These negative situations and problems are the main reasons for developing alternative methods to quickly and precisely evaluate the basic features of products such as raisins. Machine vision system is one of these alternative methods. Using machine vision, it is possible to extract features from images and use them to measure and evaluate the quality of various products [3, 4].

For this reason, when looking at the studies carried out in recent years using machine vision systems and image processing techniques on raisins from food products, it is seen that the products are examined in terms of many physical features such as color, texture, quality and size.

Okamura et al. (1993) extracted wrinkle and shape features from raisin images. They used the Bayesian classifier for classification. According to the results, they stated that the classification was more sensitive than the results of human hand operations [5].

Omid et al. (2010), developed a system for taking images and classifying processes to obtain the size and color features of raisins by using image processing technique. The resulting images were processed and property inferences were made and then classified into two classes in color and size. When the results obtained from the algorithm are analyzed, they obtained approximately 96% classification accuracy [6].

Yu et al. (2011), divided it into four classes according to color, shape, and degree of wrinkle using the support vector machine (SVM) for raisin classification. By using color and texture features on raisin images, they have achieved approximately 95% classification accuracy, which is the highest classification rate by the SVM algorithm. [7].

Mollazade et al. (2012), obtained 36 colors and 8 shape features over color images for four different raisin varieties. They reduced the number of features to 7 by using a correlation-based feature selection process to select the most effective out of a total of 44 features. They have worked with four different algorithms: artificial neural networks (ANN), SVM, decision trees (DT) and Bayes networks (BN) to classify raisins. They obtained 96.33% with ANN algorithm as the highest classification accuracy [4].

Angadi and Hiregoudar (2016) have used the application of MATLAB for the classification of raisins using image processing techniques. They achieved an average of 95% accuracy in their study using color and size features [8].

Karimi et al. (2017) has designed an expert system for measuring the quality and purity of raisins in his work. Textural features were extracted from 1400 pieces raisin images. Principal component analysis (PCA) was used to find the optimum features of these features. Accordingly, ANN and SVM were used to classify grapes. Compared to ANN, using the top 50 features, they achieved more efficient and accurate classification results with the SVM algorithm [3].

In this study, a machine vision system was developed in order to classify the Besni and Kecimen raisin varieties produced in Turkey. In the second section of the study, information about obtaining the image, the operations performed on the images, feature extraction stage, performance evaluation and cross validation is given. The third section provides information about the classification models used in the study. In the fourth section, the results obtained in the study are explained in detail. In the final section, discussion topics are given.

2. MATERIAL AND METHOD *(MATERYAL VE METHOD)*

In this study, firstly, raisin sample images were obtained and images were processed by using various image processing techniques. The images obtained were first converted to grayscale images and then converted to binary images. Using the imcomplement function on binary images, black areas are converted to white and white areas to black. Later, the images were cleared of noise. In the next phase, various morphological feature inference operations were applied on the obtained images. During the classification phase, the classification of raisins was performed using LR (Logistic Regression), MLP (Multi-Layer Perceptron) and SVM machine learning techniques. In the final phase, the performances of the techniques used were evaluated. The necessary process steps for the classification of raisins are given in Figure 1.

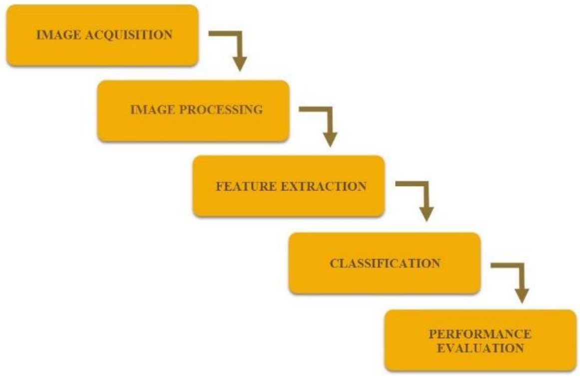


Figure 1. The necessary process steps for classification of raisins *(Kuru üzümlerin sınıflandırılması için gerekli işlem adımları)*

2.1. Image Acquisition *(Görüntünün Elde Edilmesi)*

The images of the raisins used in the study were taken using a four side closed box with a camera on it and a lighting mechanism inside. The reason why the box is enclosed is to prevent it from receiving reverse light from the outside and to prevent shadow formation on the samples. The box floor is set to white so that raisins can be easily distinguished during image processing. Figure 2 shows the system design used to obtain sample images of raisins.

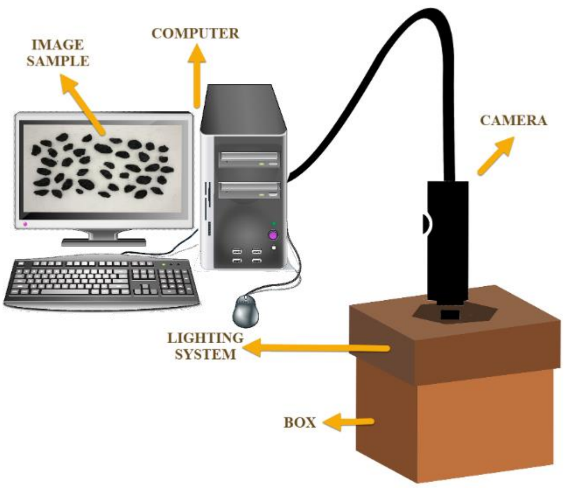
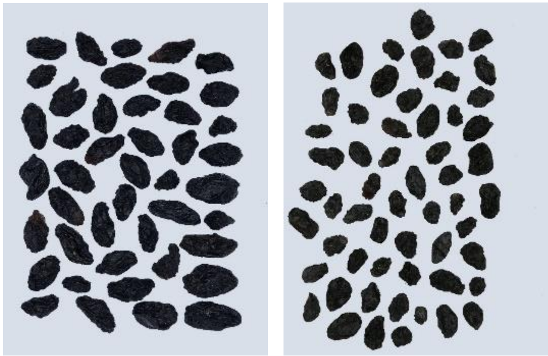


Figure 2. The computer vision system used to acquisition images *(Görüntü elde etmek için kullanılan sistem)*

A total of 900 images of raisins were obtained from both types of raisins used in the study, including 450 pieces. Sample images of the raisin varieties obtained are given in Figure 3.



(a) (b)

Figure 3. Sample image of raisin varieties used in the study ((a) Besni, (b) Kecimen) *(Çalışmada kullanılan kuru üzüm çeşitlerine ait örnek görüntü ((a) Besni, (b) Keçimen))*

2.2. Image Processing *(Görüntü İşleme)*

In the process of image processing, the pre-processes required for the most accurate way to perform feature extraction and classification are explained. The image processing phase has a critical importance as it directly affects feature inference and thus the classification outcome. All these were taken into account during the processing of the image.

Image processing was performed using the MATLAB application. The images obtained from the camera were converted primarily to grayscale image and then to binary image in preparation for the feature extraction phase. Since raisins are closer to black color, background color tone is chosen white. Therefore, using the imcomplement function on binary images, white areas are converted to black and black areas to white. Finally, the images are free of the noise on them. The preprocessing steps performed on raisin images are given in Figure 4.

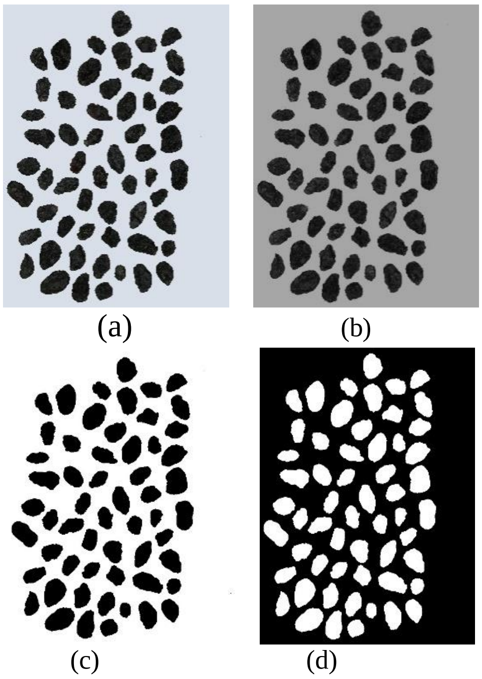


Figure 4. The preprocessing steps performed on images ((a) Real image, (b) Grayscale image, (c) Binary image, (d) Imcomplement image) *(Görüntüler üzerinde gerçekleştirilen ön işlem aşamaları ((a) Gerçek görüntü, (b) Gri tonlamalı görüntü, (c) İkili görüntü, (d) Terslenmiş görüntü))*

2.3. Feature Extraction *(Özellik Çıkarımı)*

During the feature extraction phase, a number of feature inferences were performed for each of the raisins found on the images. Feature extraction process was carried out in terms of morphological features. A total of 7 morphological features were inferred for each one raisin grain.

Morphological feature inference is a wide variety of image processing processes that process images based on the shapes found on the images. In this process, each pixel in the image is adjusted according to the value of the other pixels around it [9]. The morphological features and descriptions used in feature inference are given below.

Area: Gives the number of pixels within the boundaries of the raisin grain.

Perimeter: It measures the environment by calculating the distance between the boundaries of the raisin grain and the pixels around it.

MajorAxisLength: Gives the length of the main axis, which is the longest line that can be drawn on the raisin grain.

MinorAxisLength: Gives the length of the small axis, which is the shortest line that can be drawn on the raisin grain.

Eccentricity: It gives a measure of the eccentricity of the ellipse, which has the same moments as raisins.

ConvexArea: Gives the number of pixels of the smallest convex shell of the region formed by the raisin grain.

Extent: Gives the ratio of the region formed by the raisin grain to the total pixels in the bounding box.

2.4. Performance Evaluation *(Performans Değerlendirmesi)*

As a result of creating a new model required for classification problems or using existing models, achieving success on that model is calculated by the number of correct estimates. This situation has an impact on the accuracy of the classification rather than predicting whether the model is good. Therefore, the confusion matrix is used to explain the estimated assessments of the classification. The matrix, which gives information about the estimated classes and real classes performed via a classification model on test data, is the confusion matrix [10]. In Table 1, the confusion matrix used in the classification of raisins is given.

There are four parameters in the confusion matrix. These are named as tp: true positives, fp: false positives, fn: false negatives, tn: true negatives. Examples correctly classified into the positive class are called true positives. Examples correctly classified into the negative class are called true negatives. Examples of positive classes that are falsely classified as negative are called false negatives, and examples of negative classes that are falsely classified as positive are called false positives [11].

Table 1. Confusion matrix used in raisin classification *(Kuru üzüm sınıflandırmasında kullanılan karmaşıklık matrisi)*

		Predicted	
		Kecimen	Besni
Actual	Kecimen	tp	fp
	Besni	fn	tn

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The performance metrics for two-class classification are calculated benefiting from Table 1. Calculation formulas for success criteria are given in Table 2 [12].

Table 2. Calculation formulas for performance success criteria *(Performans başarı ölçütleri için hesaplama formülleri)*

No	Performance Measure	Formula
1	*Accuracy*	$\frac{tp+tn}{tp+fp+tn+fn}x100$
2	*Sensitivity*	$\frac{tp}{tp+fn}x100$
3	*Specificity*	$\frac{tn}{tn+fp}x100$
4	*Precision*	$\frac{tp}{tp+fp}x100$
5	*F1-Score*	$\frac{2tp}{2tp+fp+fn}x100$
6	*Negative Predictive Value*	$\frac{tn}{tn+fn}x100$
7	*False Positive Rate*	$\frac{fp}{tn+fp}x100$
8	*False Discovery Rate*	$\frac{fp}{tp+fp}x100$
9	*False Negative Rate*	$\frac{fn}{tp+fn}x100$

2.5. Cross Validation *(Çapraz Doğrulama)*

Cross-validation is a method of error prediction developed with the aim of improving the security of classification. Cross-validation divides the dataset such that it is random to a determined number of subsets for training and testing. It accepts one of the subsets as a test set, and the system is trained with the remaining sets. This process is repeated up to the number of data sets and the system is tested [13]. Figure 5 shows the cross-validation method.

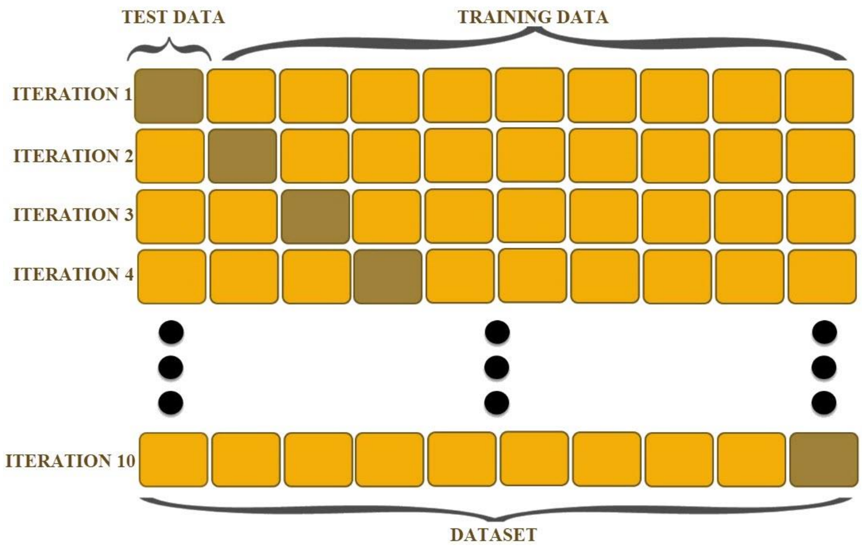

Figure 5. Cross-validation *(Çapraz Doğrulama)*

In the study, the number of cross-validation repeats was selected as k=10. 1/10 of the data set is divided for testing and 9/10 for training. For the entire dataset, these operations are repeated and the system test is completed.

3. CLASSIFICATION MODELS *(SINIFLANDIRMA MODELLERİ)*

Classification models are a method of high importance used in various fields. In class determination, classification algorithms are used to determine which class the data belongs to. The classification model is a model based on prediction. The purpose of the classification is to enable the data to be separated using the common features of the data [14]. In this study, models were created using LR, MLP and SVM techniques in order to classify raisin grains according to their features.

3.1. Logistic Regression (LR) *(Lojistik Regresyon)*

LR is one of the widely used statistical models. In LR, the dependent variable is estimated from one or more variables. LR clarifies the relationship between dependent variables and independent variables. In LR, variables do not need to require a normal distribution [15, 16]. Because the predicted values in LR are probabilities, they were bounded by 0 and 1. The reason for this is that LR predicts its probability and not itself in the results [17].

3.2. Multilayer Perceptron (MLP) *(Çok Katmanlı Algılayıcı)*

Today, many artificial neural network models have been developed to be used for specific purposes, and MLP is one of the most widely used in these models. The sequence of neurons in MLP is in layers. Along with two main layers, there is also a hidden layer between these layers. MLP can have multiple hidden layers within it. The input layer, the first of the main layers, contains information about the problem that needs to be solved. The second main layer, the output layer, is the layer from which the output for the information processed in the network is received [18, 19]. Additionally, it is also possible to monitor and modify the network structure during the training period at MLP [20]. MLP parameters are given in Table 3.

Table 3. The parameters of MLP *(MLP parametreleri)*

Parameters	
Activation function	Sigmoid
Learning rate	0.3
Hidden layer number	4
Maximum number of epochs to train	500

3.3. Support Vector Machine (SVM) *(Destek Vektör Makinesi)*

SVM is a core-based method of forming a hyperplane for classification and regressions. SVM has the ability to classify data as linear in two-dimensional space, planar in three-dimensional space and hyperplane in multi-dimensional space with separation mechanisms [21, 22]. SVM finds the best hyper plane separating the data of the classes and performs the classification process. The best hyperplane for an SVM is the one with the largest margine between the two classes [23].

Different types of kernel functions are used in SVM models. In this study, classification was performed using the polynomial kernel function.

4. RESULTS *(SONUÇLAR)*

In order to classify the rice varieties used in our study, preprocessing was applied to the images we obtained and a total of 900 pieces raisin grain were obtained and 7 morphological features were inferred for each of these. The minimum, mean, maximum and standard deviation data of morphological features for both types of raisins are given in Table 4. Figure 6 shows the distribution of raisin varieties on the features.

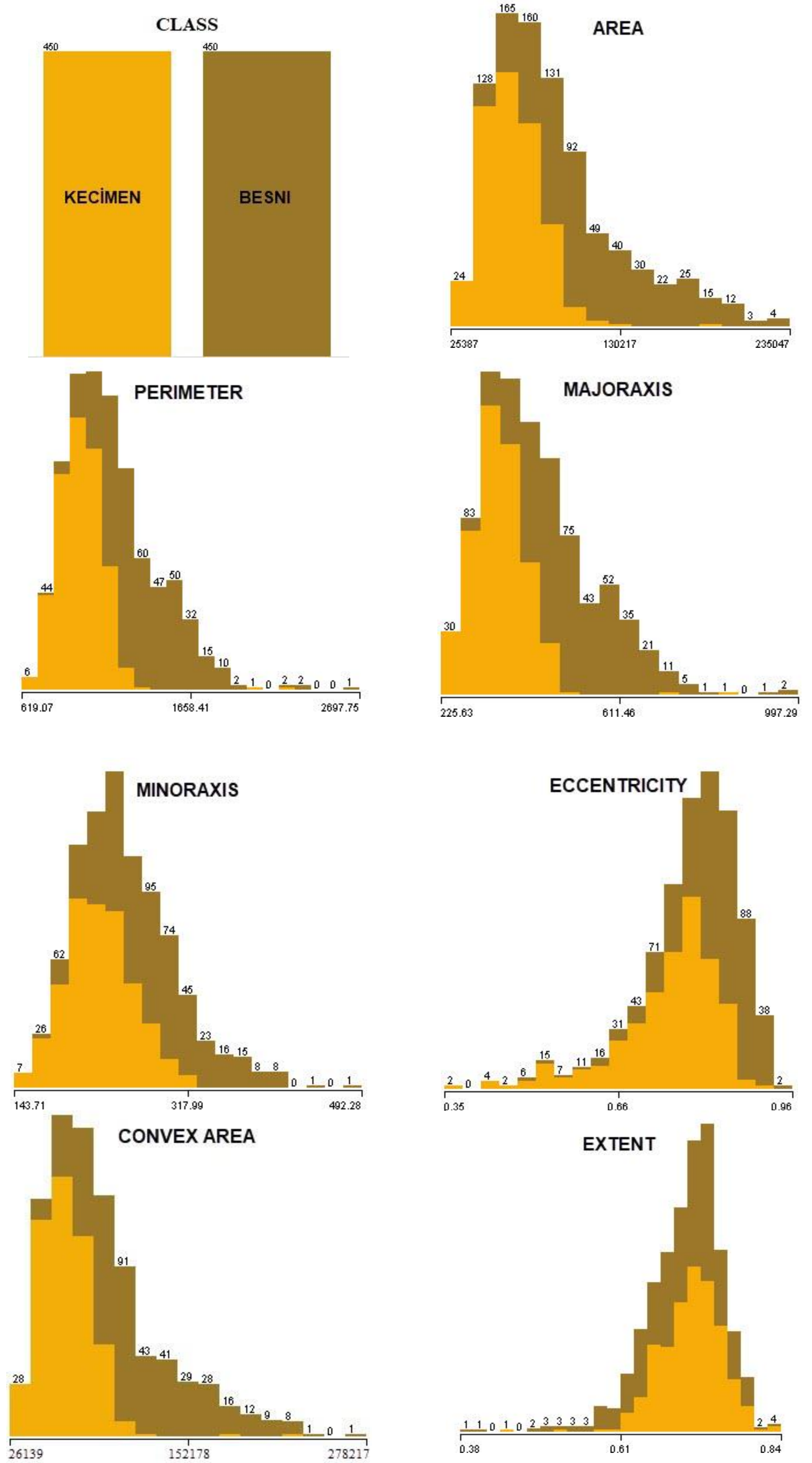

Figure 6. Distribution of raisin varieties on the features *(Kuru üzüm çeşitlerinin özellikler üzerindeki dağılımı)*

Table 4. Statistical data on the properties obtained *(Elde edilen özelliklere ait istatistiki veriler)*

No	Feature	Minimum	Mean	Maximum	Standard Deviation
1	Area	25387	87804.128	235047	39002.111
2	Perimeter	619.074	1165.907	2697.753	273.764
3	MajorAxisLength	225.63	430.93	997.292	116.035
4	MinorAxisLength	143.711	254.488	492.275	49.989
5	Eccentricity	0.349	0.782	0.962	0.09
6	ConvexArea	26139	91186.09	278217	40769.29
7	Extent	0.38	0.7	0.835	0.053

A data set was created for the features obtained in the study and models were created for classification using LR, MLP and SVM machine learning techniques and performance values were obtained. Cross validation k value was chosen as 10 in all models used. In Table 5, the confusion matrix belonging to all the algorithms used in the study is given.

Table 5. The confusion matrix data belonging to the algorithms *(Algoritmalara ait karmaşıklık matrisi verileri)*

Algorithms LR, MLP, SVM		**Predicted**	
		Kecimen	Besni
Actual	Kecimen	391 400 404	59 50 46
	Besni	74 73 76	376 377 374

Classification performance measures were calculated using the complexity matrix for each model, such as Accuracy, Sensitivity, Specificity, Precision, F1-Score, Negative Predicted Value, False Positive Rate, False Discovery Rate, and False Negative Rate. Classification performance measurement results are given in Table 6.

Table 6. Classification performance measurement results *(Sınıflandırma performans ölçüm sonuçları)*

Performance Measure	LR	MLP	SVM
Accuracy	85.22	86.33	86.44
Sensivitiy	84.09	84.57	84.17
Specificity	86.44	88.29	89.05
Precision	86.89	88.89	89.78
F1-Score	85.46	86.67	86.88
Negative Predictive Value	83.56	83.78	83.11
False Positive Rate	13.56	11.71	10.95
False Discovery Rate	13.11	11.11	10.22
False Negative Rate	15.91	15.43	15.83

As seen in Table 6, a classification success of over 85% was obtained from all the algorithms used in the study. 86.44% accuracy value achieved in the SVM model has the highest value among other models.

5. DISCUSSION *(TARTIŞMA)*

When the results obtained from the study are evaluated, higher classification successes can be achieved by increasing the number of images or features obtained from the products and adding color, shape and texture features in addition to the morphological features.

In addition to the machine learning techniques used in the current study, studies can be carried out with other techniques or hybrid models can be created.

6. CONCLUSION *(SONUÇ)*

In this study, performance measurements of 3 different machine learning algorithms were made using raisin images and morphological properties obtained from these images. Statistical datas obtained from the confusion matrix obtained from the classification result were used as performance measurement. The performance measurement given in Table 6 are obtained and compared for each method and each class. Looking at average classification accuracy, the highest value belongs to the SVM algorithm with 86.44%.

The varieties of raisins used in the study are among the products produced and exported in Turkey. Benefiting the image processing techniques used in this study, data sets can be created using the derived feature inferences and the models created, as well as for other products produced in our country. In this way, automatic systems can be designed by using the created data sets for classification, calibration of the products or to be used in different processing stages.

CONFLICT OF INTEREST STATEMENT *(ÇIKAR ÇATIŞMASI BİLDİRİMİ)*

The authors reported no potential conflict of interest.

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