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Research Article

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Classification of Pistachio Images with The ResNet Deep Learning Model

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HIGHLIGHTS

- Correct classification of Pistachio is very important in terms of trade.
- In this study, the results for each fold of the dataset are listed.

Abstract

Pistachio, which is grown in many parts of the world today, has an important place in the agricultural economy. In order to maintain this economic value, the post-harvest industrial classification process is very important to obtain efficiency from this harvest. In the process of separating pistachios, an efficient classification process is needed in order for different pistachio species to appeal to different markets. For this reason, the classification process of pistachios is very important. In this study, Kirmizi and Siirt pistachio classification with 2148 images was made using ResNet architecture. After the statistical experimental studies, the highest classification accuracy was obtained from fold-1 as 88.5781% and the Accuracy value was 0.86168 after the classification process.

Keywords: Pistachio Classification, Deep Learning, ResNet

1. Introduction

Pistachio, whose homeland is the Middle East, is produced in our country, especially in Gaziantep; It grows in Siirt, Şanlıurfa, Adıyaman, Kahramanmaraş, Diyarbakır provinces. Pistachio is grown in Turkey, India, Iran, Iraq, Mexico, America, China, Greece and Syria. In 2019, global pistachio production was approximately 0.9 million tons, with Iran and the United States as leading producers, accounting for 74% of the total. Secondary producers were China, Turkey and Syria (Anonymous, 2022). The 2020 report stated that almost half of global pistachio production in 2019 came from the United States (Anonymous 2020; Anonymous 2021). Table 1 shows the pistachio production data for 2019 (Anonymous, 2022).

World total pistachio production in 2019 decreased from 1,390,269 tons in 2018 to 911,829 tons in 2019. Pistachio cultivation studies for international markets were carried out in Georgia and neighboring Caucasus countries in 2019 (Anonymous 2020).

Pistachio is produced in more than 40 provinces in Turkey. However, the Southeastern Anatolia Region, which has a large area that meets the climatic demands of Pistachio to a large extent, provides approximately 95% of Turkey's production. It grows mostly in almost every region near Şanlıurfa, Gaziantep, Nizip, Siirt,

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Kahramanmaraş, Adıyaman, Diyarbakır, Karaman and Göksu. While Gaziantep has the largest pistachio production area in Turkey for years, Şanlıurfa had the largest production area in 2014 (Anonymous 2014). Approximately 80% of Turkey's pistachio area is in the provinces of Şanlıurfa and Gaziantep (Anonymous 2019).

Table 1. Pistachio production amount of countries

Pistachio production, 2019	
Country	Production (tons)
Iranian	337,815
ABD	335,660
Chinese	106,155
Turkey	85,000
Syria	31,813
World	911,829

Pistachio is known to affect many aspects, especially heart health (Dreher, 2012; Kay et al., 2010). Among the foods we eat, pistachios are one of the most nutritious products. It provides 560 calories per 100 g and is a rich source of protein, several dietary minerals and B vitamins (Ertürk et al., 2011). Figure 1 shows the basic parts of the pistachio (Ozkan et al., 2021).

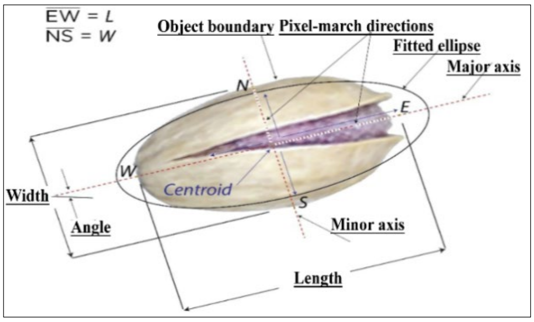


Figure 1. Basic parts of pistachio

There is more interest in red and Siirt pistachio varieties because of their higher economic value (Tunalıoğlu and Taşkaya 2003). In the literature, different studies have been carried out to provide more economic gain from peanuts and by applying different methods. Çetin et al. developed an algorithm to determine the closed and open state of the peanut shell. They made the open and closed states of pistachio shells with a success rate of 99% (Cetin et al., 2004). Casasent et al. achieved an 88% classification success of x-ray images of pistachios (Casasent, 1998). Automatic classification is required for product types from different suppliers. In this way, the value of pistachios in the market is also increased. For this reason, it is very important to develop the processes applied in the post-harvest processes of pistachio. Thus, by using new techniques and technologies, more efficiency is obtained from products with high economic value (Atay, 2007). In a different study, Abbaszadeh et al. used deep auto-encoder neural networks to divide peanuts into two different classes as problematic and unproblematic. As a result of this study, they reported that they achieved 80.3% correct classification success of problematic pistachios (Abbaszadeh et al., 2019). Rahimzadeh and Attar developed an image-processing-based system to determine whether different peanut species are open-mouthed or closed-mouthed. After extracting the features of pistachio images, CNN-based ResNet50, ResNet152 and VGG16 models were used to classify. The average classification success achieved as a result of applying these models is 85.28%, 85.19% and 83.32%, respectively (Rahimzadeh and Attar, 2021). Table 2 shows the studies on Pistachio in the literature.

Table 2. Pistachio studies in the literature.

	Data Pieces	**Class**	**Method**	**Accuracy (%)**
(Dini et al., 2020)	**958**	**2**	**ResNet**	**97.20**
[14]	305	2	Deep Auto-encoder Neural Network	80.30
			ResNet50	85.28
[15]	3927	2	ResNet152	85.19
			VGG16	83.32
This study	2148	2	ResNet	86.16

2. Materials and Methods

In this study, ResNet architecture was used to classify pistachio images belonging to 2 different species. In experimental studies, 5-fold crossvalidation was performed. Experimental studies were carried out with confisioun matrix as a statistical method. In general, the formulas related to CM are shown in Figure 2.

Sensitivity or True Positive Rate	$TPR = \frac{TP}{TP+FN}$	**False Negative Ratio**	$FNR = \frac{FN}{TP+FN}$
Specificity or True Negative Rate	$TNR = \frac{TN}{TN+FP}$	**Accuracy**	$ACC = \frac{TP+TN}{TP+TN+FP+FN}$
Precision or Positive Predictive Value	$PPV = \frac{TP}{TP+FP}$		
Negative Predictive Value	$NPV = \frac{TN}{TN+FN}$	**F-Measurements**	$FM = \frac{2}{\frac{1}{TPR}+\frac{1}{PPV}}$
False Positive Ratio	$FPR = \frac{FP}{TN+FP}$	**Matthews Correlation Coefficient** $MCC = \frac{TP \times TN - FP \times FN}{\sqrt{(TP+FP)(TP+FN)(TN+FP)(TN+FN)}}$	

Figure 2. Statistical measurements

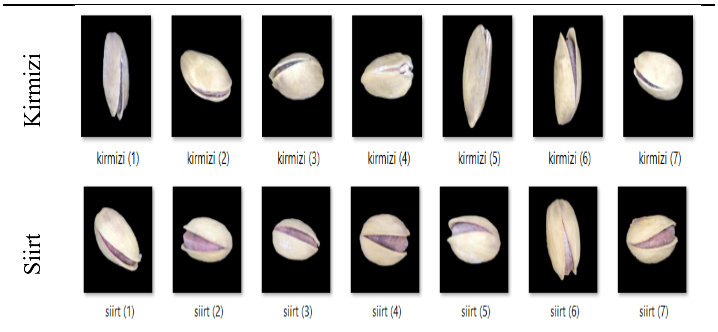
The parameters used in the ResNet architecture are shown in Table 3.

Sample images of pistachio cultivars used in the database are shown in Table 4. (Ozkan et al., 2021; Sıngh et al., 2022).

Table 3. Parameters of ResNet architecture

inputSize	32x32
MiniBatchSize	16
MaxEpochs	10
ExecutionEnvironment	Gpu
Shuffle	Every-epoch

Table 4. Pistachio Types



2.1. ResNet Architecture

It is the convolutional neural network model that won the ILSVRC competition by Kaiming He et al. in 2015 with a 3.57% error rate. ResNet is designed to train more layers than previous models and consists of a total of 152 layers. ResNet has now introduced a method called a learning block to solve the "disappearing gradient" problem. The most important feature of this architecture is that it now consists of learning blocks. An approach called jump links is used in this block. The skip link connects directly to the output, skipping the training several layers. This approach is that instead of the layers learning from the underlying mapping, the mesh now allows the mesh to conform to the mapping. This allows to train much deeper neural networks (Kaya, 2021). The residual learning block structure that makes up the network is given in Figure 3. (He et al., 2016).

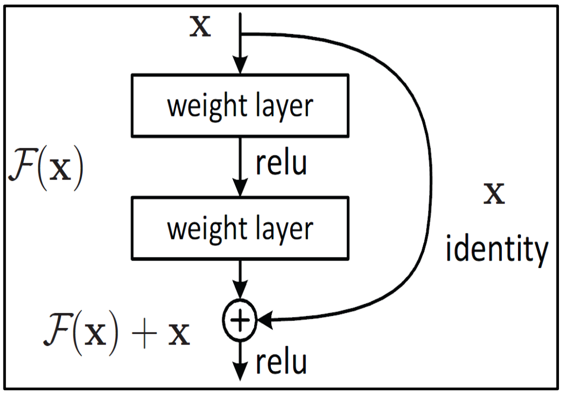


Figure 3. Residual learning block structure

The value (x) taken as input in the residual learning block is processed with two weight layers to obtain the $F(x)$ function. Then, x is added to the $F(x)$ function to obtain the $H(x)$ function. This situation is expressed as $H(x) = F(x) + x$ (He et al., 2016; Kaya et al., 2020). In the classical network model, $H(x)$ is equal to the $F(x)$ function, while the original data is added to the input in the ResNet model (Toğaçar and Ergen, 2019). Figure 4. shows an example of the classic 34-layer network structure model and the ResNet model structure (He et al., 2016).

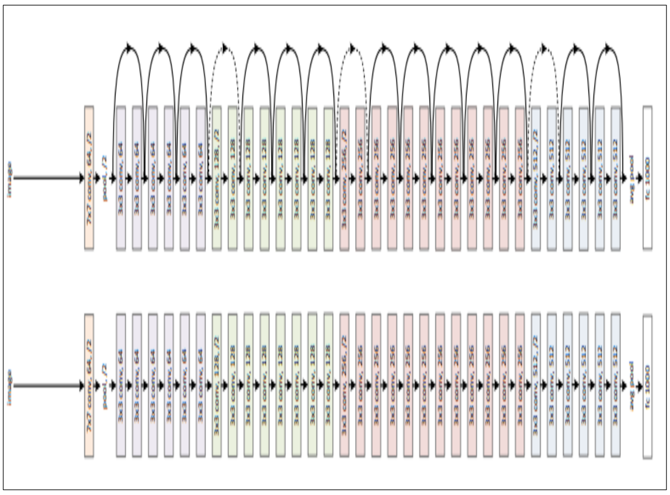


Figure 4. (Bottom) Classical network structure model (Upper) ResNet model structure

3. Results

In this study, experimental studies on the database were tested statistically. The results obtained from CM are shown in Table 5.

Table 5. Statistical results from CM

		Cl_1	Cl_2		Cl_1	Cl_2		Cl_1	Cl_2		Cl_1	Cl_2		Cl_1	Cl_2
Precision	**Fold-1**	0.8924	0.8764	**Fold-2**	0.7826	0.9007	**Fold-3**	0.9107	0.7912	**Fold-4**	0.9041	0.8473	**Fold-5**	0.9244	0.8137
Sensitivity		0.9105	0.8524		0.9473	0.6448		0.8259	0.8907		0.8821	0.875		0.8455	0.9071
Specificity		0.8524	0.9105		0.6448	0.9473		0.8907	0.8259		0.8750	0.8821		0.9071	0.8455
Accuracy		0.8857	0.8857		0.8186	0.8186		0.8534	0.8534		0.8790	0.8790		0.8717	0.8717
F-measure		0.9014	0.8642		0.8571	0.7515		0.8662	0.8380		0.8930	0.8609		0.8832	0.8578

When we examine the Table 5., it is seen that the highest Accuracy value is obtained from fold-1 with 0.8857. It is seen that the highest Sensitivity value is obtained from the 2nd fold and the Kirmizi Class with a value of 0.9473. Table 6 shows the CM results and Roc Curves for each fold

Table 6. CM results and Roc Curves

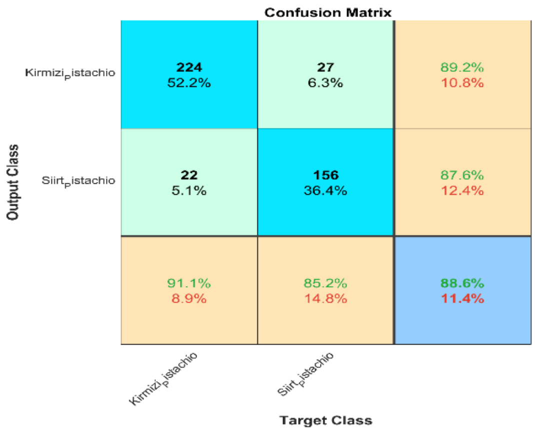
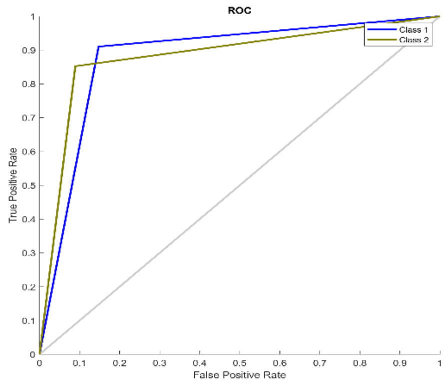
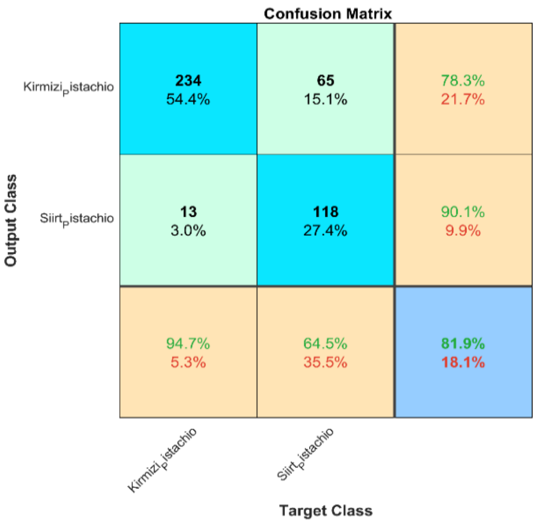
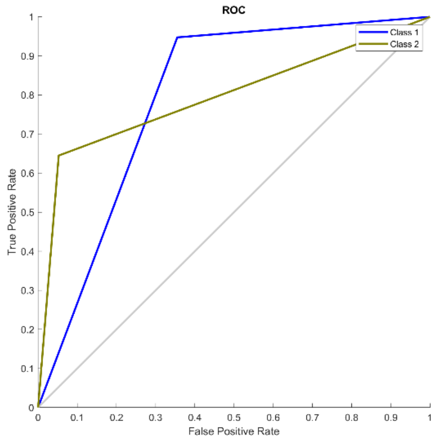
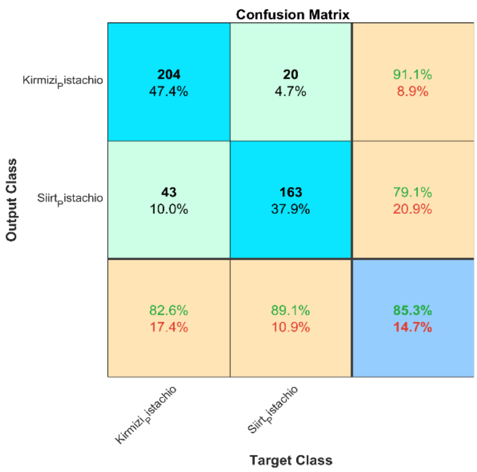
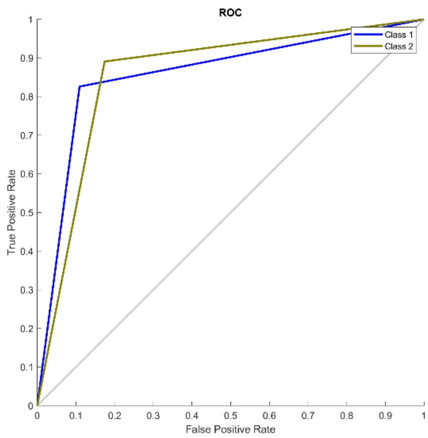
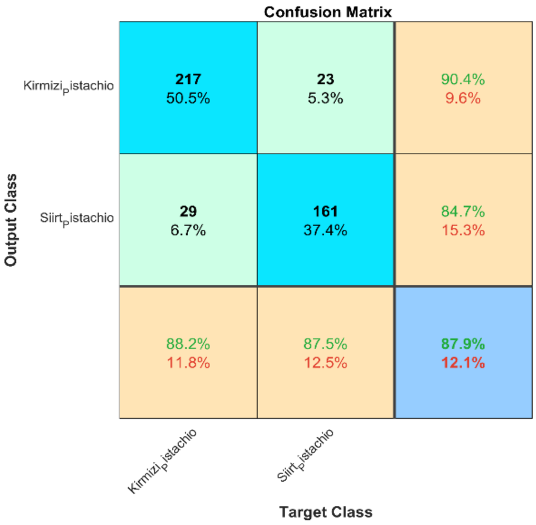
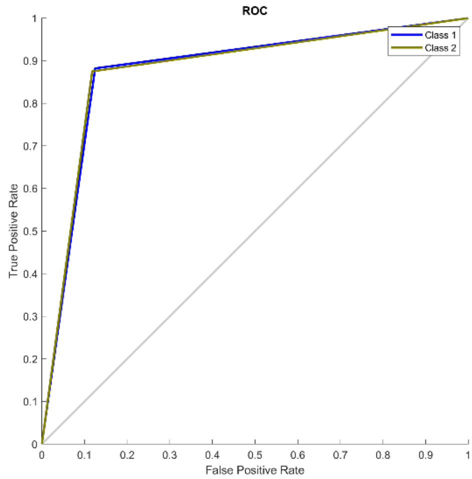
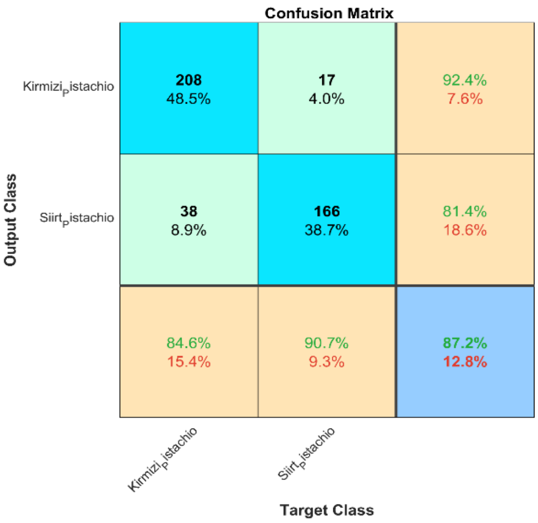
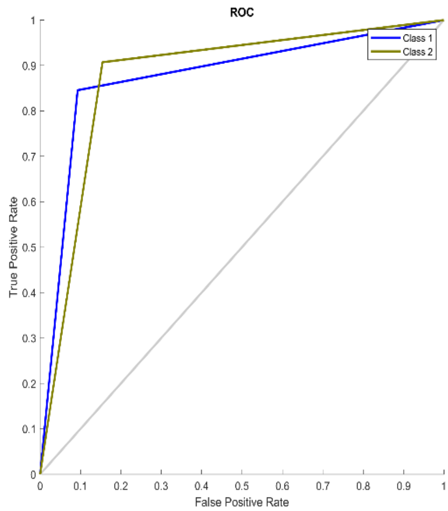
	Folds-CM Results	Folds-Roc Curve
Fold-1		
Fold-2		
Fold-3		

Table 6 (Continued). CM results and Roc Curves

Fold-4		
Fold-5		

When we examine Table 6, we see that the lowest classification success was obtained from the 2. fold with 81.9%. 88.6% classification success was obtained from fold 1. Obtained 85.3% from fold 3. The highest classification rate was obtained from fold 4 at 87.9%, which was the highest value. A value of 87.2% was obtained from fold 5.

4. Conclusions And Future Works

Together with certain countries, the pistachio market constitutes a very common trade network in Turkey. The classification process of this product, which has a widespread trade network, is also of great importance before the process of separating it into certain groups before export. In this study, two pistachio species with high commercial potential, called kirmizi and siirt, were classified using the ResNet deep learning model. In this study, two pistachio species with high commercial potential, called kirmizi and siirt, were classified using the ResNet deep learning model. After the pistachio classification process, the highest Sensitivity value from the kirmizi pistachio was obtained as 0.9473 from the 2nd fold. In future studies, classification performance can be made with different models. In addition, better classification results can be obtained by developing different hybrid models.

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