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# Deep Learning in Marble Slabs Classification

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**ABSTRACT**

*The process of classification of marble slabs has an important place in terms of construction sector and demands. Despite the advanced mines and construction equipment in Turkey and the world, the separation of cut marble process is a problem that has not been solved yet. The lack of a standard for the classification of marbles and the use of human factors for this process lead to erroneous and inefficient determinations. In this study, for the first time the Deep Learning method has been tried on marbles, and the components obtained from Deep Learning layers have been examined and the success of classification has measured. Thanks to the successful results, the basics of the Deep Learning network have been laid for future marble databases.*

## 1. INTRODUCTION

Artificial intelligence has become popular in industry, medicine, defence, agriculture, and informatics nowadays and the developed countries have been trying to improve their producing systems expeditiously by using artificial intelligence technologies. These systems which have an important place in terms of improving the product quality, productivity and added-value are supported by the governmental incentives and universities and they are the most important issues that have to be put emphasis on within the scope of Industry 4.0. Many systems or problems can be modelled and then solved with machine learning algorithms after determining their appropriate features. For instance, person's gender can be learnt from the wave length of the sound data and according to the blood values, it can be designated whether the person is ill or not. However, today to determine the features of the related problem is a challenging process that takes too much time and requires a specialist in the related field. Furthermore even if the systems are modelled theoretically, they reveal different impacts under the real life conditions and due to the factors such that sun light and temperature may change the colour values of the item, the systems are improved with difficulty. Alternatively, determination and variability of the complex features obtained to develop a model can be solved by using more basic presentations. Deep Learning, a popular method today, enables computers to create more complex concepts from simple concepts. Basic concepts such as edge, contour, and corner can be formed with the help of a Deep Learning system and then human figures can be obtained by combining these concepts. Basic presentations provide information to Deep Learning Program that tries to make sense out of the data and is one of the artificial intelligence approaches; each concept is defined with the relations to the concepts more simple than itself [1].

Due to the improvements in building industry and increasing demands in terms of aesthetics throughout the world, interest and demand in marble varieties such as travertine, onyx, and granite increase simultaneously. Turkey holds various and plenty of marble reserves and is one of the leader stone manufacturer countries in the world. Besides utilisation demands, technological improvements and industry have also effect on. Turkey has important business organizations and construction equipment in terms of extracting the natural stones from mines and first processing. However, there is a deficiency in fine cut and classification of stones obtained. Especially in terms of classification, nearly all marble businesses carry out man-made identification and human eye and skill are not competent enough to specify which classes marble stones belong to since there are various types and homogeneity of marble stones. When a human eye looks at objects that have the same colour and type, it gets tired and its selectivity decreases biologically. Therefore, classification failure due to the man skills is usually faced at the businesses and thereby production and productivity

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decline. The most important criterion for the marbles to be selected in accordance with the requirements is colour harmony. Besides, there are some areas on the surface having different textures and colour with different dimensions. A human eye expects fluidity when looking at the natural stones and these areas spoil aesthetics of the stones. Even though the classifications are tried to be formed according to the stone's variety and demand for the marbles used for surface coating at the businesses, classification standards are not stated. Besides, when the differences in marble vein and user defects are added, stones are not able to be classified properly [2].

Image processing and artificial intelligence based autonomous systems are generally presented as solution method in order to designate the classes of marble slabs. When the studies carried out are analysed, it is seen that although there is a great demand for the marble throughout the world, there are few studies in this field. It is observed that mostly classifications and texture analysis of the stones such as marble, granite have been executed in the studies carried out. Martinez-Alajarin et al. [3] studied on various statistical features of marble surfaces and used the features on different colour spaces for classification. Selver and Akay [4] utilized histogram features of the marbles for classification. In their studies Benavente and Pina [5] carried out classification and segmentation processes of the marbles by using morphological operations. In their studies López et al. [6] used spectral features to classify granite stones in marble type. In their studies Şişeci and Cetişli [2] suggested a new class description for clustering algorithm that is one of the unsupervised learning methods as well as travertine plates. They used both colour and homogeneity analysis as features for algorithms. In their studies Şişeci et al. [7] developed a new rapid clustering method and used this method for separation of marbles. In their studies Turhal et al. [8] detected fringe areas and cavities on marble images by using digital image processing. They calculated marble surface unevenness by utilizing these features. Moghaddam et al. [9] tried to classify the marble slabs using image processing methods. In their studies Kemaloglu et al. [10] developed an automatic system that can classify marbles by utilizing controlled and uncontrolled learning algorithms.

When the studies carried out on marbles are examined, it is seen that to determine the colour and texture features of marbles and to use these features for classification generally come into prominence. Although there are also autonomous systems formed by using these methods, since the related systems are mostly affected by the real life conditions, they do not work at the desired productivity and accuracy depending on the sun light, temperature and working hours. Furthermore, the developed systems use features that are very selective and last too long to detect and these parameters differ in real life practice. Therefore to benefit from the interaction of more basic information enables the marbles to be classified better and to be affected by the external effects less. Deriving from these basic features, Deep Learning is suggested as the best method required to be used for the classification of marbles that are more complex.

When the studies carried out on deep learning are examined, even though the first algorithms emerged in 1980s, the most significant step for training the deep networks was taken in 2006. In their studies, Hinton et al. [11] suggested deep belief networks. These networks are composed of various hidden variables and all units on each layer are linked to all units of the neighbour layers. Layer training is conducted by using an uncontrolled avid pre-cultivation method. After that Bengio et al. [12] and Ranzato et al. [13] used the uncontrolled avid pre-cultivation method to train the other deep networks. In their studies Bengio and LeCun [14] showed that many nonparametric learning-directed popular approaches are limited in learning skills of large-scale complex functions. Delalleau and Bengio [15] compared deep and shallow architecture of neural networks and emphasized the importance of Deep Learning. Pascanu et al. [16] tried to expand recurrent neural networks to the deep recurrent neural networks. Montufar et al. [17] examined the complexity of functions calculated by deep feed-forward neural networks.

Unlike the former studies, Deep Learning was used on marbles in this study for the first time and results of the layers were examined and then achievement of classification was tried to be tested. Thereby, it is leaded up to develop a Deep Learning Network that is able to learn a database formed for marbles throughout the world and then estimate the marble classes such as AlexNet [18] and GoogleNet [19] which can generally estimate ImageNet [20] properly consisting of 1.2 million images in total at 1000 different classes and ones of the convolutional neural networks.

This study is organized such that: This section gives information about marble and Deep Learning, and literature research. In Section 2, Deep Learning and its layers are explained; furthermore, data set is also examined. Experimental studies about convolutional neural network and their results are given in Section 3. The conclusion is given in Section 4.

## 2. MATERIALS AND METHODS

In this study 80 marble samples that Ref. [2] used to suggest a new class definition for travertine slabs taken from Başarırlar Marble Company in 45x45 cm dimensions were used. These marbles belong to travertine slabs class and they are suggested as 9 classes such as first qualities (D1A, D1D, D, M, S), second qualities (D1A_2K, D1D_2K, D_2K) and non-homogenous ones. Although non-homogenous samples cover few samples that do not fit in both classes well, when it is required to classify as first and second quality, it will be better to include them to the second quality. Therefore, 80 marble

samples are tried to be classified as first quality and second quality class in this study. For classification achievement, an accuracy criterion is used.

Convolutional neural network, one of the Deep Learning Algorithms, is used as a method. With Deep Learning it is tried to calculate simple main components such as line, contour, corner, colour, and texture that enable an object to be distinguished from another and also to calculate the connection of these components to the more complex components of the next layers. An image can be reconstituted by using the components the best values of which are found through training; it can be determined to which class the image belongs; the locations and type of the objects in the image can be found and an object or film stars played on a video or a TV channel momently can be detected with their locations. In Deep Learning, stochastic gradient descent with momentum (Sgdm), Rmsprop and Adam methods whose name is taken from an adaptive moment estimation are often used as the best optimization algorithms [1]. Sgdm method enables gradient to be estimated unprejudicedly by using mini piles of a certain amount of samples obtained from data distribution. Learning rate can be accelerated by increasing momentum. Momentum method has been developed to speed up learning process that is small but consistent in a high gradient problem. Rmsprop algorithm eliminates distant past points by using average approach decreasing exponentially. After the convex structure is detected with this method, AdaGrad algorithm that is another method is initiated. Adam algorithm is formed by increasing momentum of Rmsprop method [1]

When the layers of Deep Learning are examined, some important image processing techniques and convolution features are raised. The most important layers are convolution layer, non-linear operator (ReLU), pooling, fully connected layer, and softmax layer.

When convolution layer is applied to an image, specific features from the image can be obtained. This operation is carried out by treating mathematical operation on the image with a filter [21]. A mathematical operation of convolution layer is given in Figure 1.

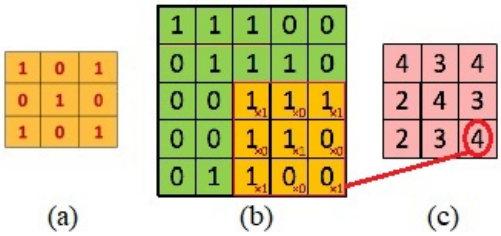


***Fig. 1.*** *Convolution operation (a) filter, (b) matrix of the image, (c) convolution result [22]*

ReLU layer applies a transfer function to the data as seen in Equation (1) and produces the positive values as same while making the negative values 0

$$f(x) = \max(0, x) \tag{1}$$

The features the number of which has been increased greatly with pooling layers can be decreased using a simple operation. Max pooling operation selects the biggest element with a specific dimension in the filter and does not select the others. Thereby, only the elements with the highest values are selected by the specific window size with specific steps and the others are elected.

Fully connected layer covers the structure of classic artificial neural networks, collects and transfers the data incoming. Generally the next layer is softmax layer and classification layer which designates class label according to the highest-value outcome is added. A classical Deep Learning network is given in Figure 2.

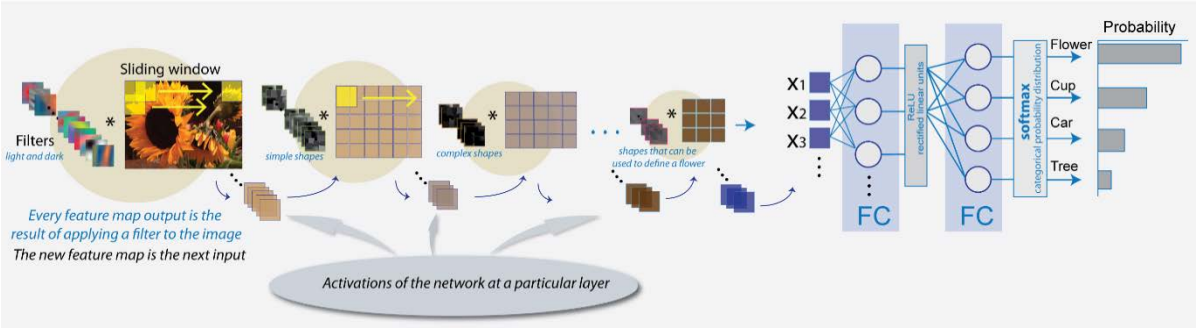


***Fig. 2.*** *Deep Learning Network [23]*

In this study, on the input layer of the Deep Learning network suggested for marbles 'imageinput' that accepts the coloured image as an input is seen and in order to simplify the calculation, it takes the pixel values of marble images sized as [100,100,3] before. Then, 'convolution2dLayer' is seen which conducts two-dimensional convolution process; the output values are inserted into 'ReLU' layer. Then, 'max pooling' layer is used to decrease the number of feature and its output leads to new layers consisting of convolution-ReLU-max pooling layers. After that, the output features are inserted into full-connected layer. Then, softmax and classification layers are used for determine the class labels. The proposed Deep Learning network is constructed as in Figure 3.

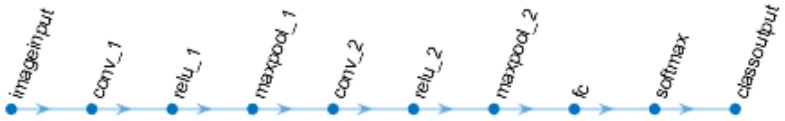


***Fig. 3.*** *Deep Learning network formed for marble*

As seen in Figure 3, the recommended deep learning network consists of 10 layers.

## 3. EXPERIMENTAL STUDIES

In this study, 80 marble images which were used by Şişeci and Cetişli [2] for their studies are utilized to show the applicability of Deep Learning method to the marbles. Among these samples which are classified as first and second quality, non-homogenous marbles are accepted as second quality. It is tried to find out the classification achievement tested by 5-fold cross validation. Furthermore, while components at the fully connected layer outputs of the related deep network are determined, fully connected layer (fc) and softmax outputs of any marbles are also obtained. Classification achievement is tested with Sgdm, Rmsprop and Adam training algorithms. In the study where different iteration numbers are used, filter dimension is specified as 2x2 for the first of the convolution layers as a result of various tests and then units are stride by twos and 50 different filters are formed; dimension of the filter of the second convolution layer is specified again as 2x2 and then units are stride by twos and this time 10 different filters are formed. Filter at both max pooling layer is designated as 3x3 and then units are stride by threes. The beginning learning rate is determined as 0.0001.

According to different iteration and training algorithms, classification accuracy values of the test set are given in Table 1.

According to the Table 1 for the developed deep network, while the components on the fully connected 'fc' layer outputs of the network holding the best parameter results are seen in Figure 4, 'fc' and 'softmax' layer outputs for any marble from the first class are seen in Figure 5.

***Table 1.*** *Classification accuracy values of the marble slabs with Deep Learning*

| Iteration | Sgdm (%) | Rmsprop (%) | Adam (%) |
|---|---|---|---|
| **100** | 62.50 | 62.50 | 62.50 |
| **300** | 62.50 | 68.75 | 75.00 |
| **500** | 66.25 | 62.50 | 75.00 |

When Table 1 is analysed, it is seen that achievement values obtained by Adam algorithm gives good results in marble classification and Deep Learning method can be used for marbles. Thus, instead of classical systems that last too long and tens of features are tired to be designated one by one, Deep Learning method enables the appropriate decomposition process to be completed in a very short span of time by training the filters.

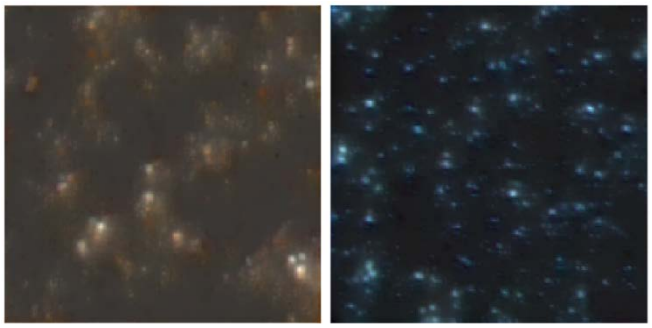

***Fig. 4.*** *Fully connected layer (fc) output on deep network*

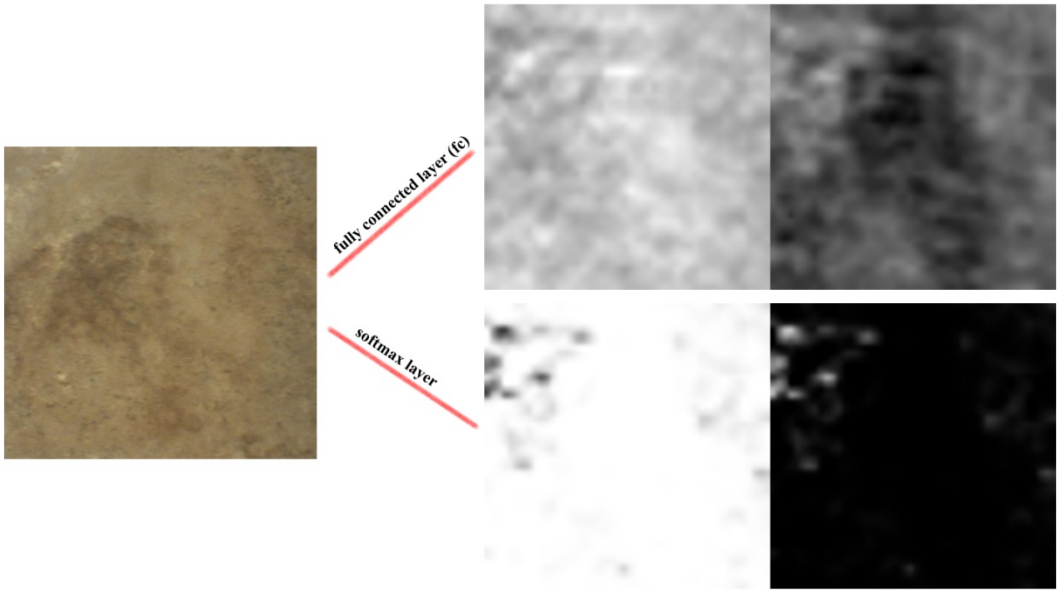


***Fig. 5.*** *Fully connected layer (fc) and softmax layer outputs for marble on deep network*

When Figure 4 and Figure 5 are analysed, it is seen that as a result of convolution the relevant filters can determine the features that can distinguish the marbles holding different classes from each other. Furthermore, as also seen in Figure 5 'softmax' layer output of marble sample selected from the first class is classified properly after being assigned to the first class with a higher value (white coloured first layer).

## 4. CONCLUSION

Natural stones that are one of the import and export products for the countries are used in many fields and preferred in terms of aesthetics and also necessity. Marble and its derivatives are used for many materials such as building sector, historical ruins and souvenir. To determine the marble veins and then to cut marble blocks is carried out in a short or long period of time. However, to make the cut marble blocks thinner as plates and then to classify them is still a complicated problem. When the classification of marble slabs is examined, it is seen that there are few studies in this field and current methods are not applied even in the literature. For this reason, information flow has not reached to the mining enterprises yet and marbles are still tried to be classified by the workers with the naked eye at the workplaces. It is regarded as necessity to make the manual selection process automatic and to carry out by using popular methods within the scope of Industry 4.0.

In this study Deep Learning method, one of the today's successful and popular artificial intelligence methods, was applied on the marbles for the first time and then component outputs of the network layers were able to be examined. Successful classification results obtained reveals the practicability of Deep Learning to the marble industry and it is shown that the method can be used for marble cutting and selection processes. Furthermore, a basis of Deep Learning network for a potential marble database that can be standardized in the future has been established.

In the future studies a detail parameter and achievement analysis of Deep Learning network to be suggested for the classification of marble slabs with more labels will be carried out. Moreover, the relevant components will be obtained before output layer of deep network and will be used as features for k-nearest neighbour algorithm and classic artificial neural networks. Thereby it is estimated to achieve to increase the success of classification. The best learning method and parameters planned to be obtained will be tested by using cross verification method and then Deep Learning network that can classify the marbles successfully will be constituted.

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