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Human Face Recognition Using Deep Neural Networks

Derin Sinir Ağlarını Kullanarak İnsan Yüzü Tanıma

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ABSTRACT

In recent years, many researchers have been using computer-based systems containing artificial intelligence applications for different applications. Human recognition application is one of the studies carried out in this field. Face and object recognition applications, which were originally designed for security measures, are also used in the entertainment and shopping sectors recently. These applications are gaining even more popularity with the mobile application development of various companies. In face recognition applications, deep learning methods can be preferred if the data is large and complex. In this study, a 3-layer Convolutional Neural Network (CNN) has been developed for a face recognition application. The developed model was applied to the Libor Spacek's Facial Images Databases dataset. As a result of the application of the proposed method on the data set, it was determined that the accuracy rate was 99.29%. This means that the application can be adapted for real recognition systems.

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ÖZET

Son yıllarda birçok araştırmacı farklı uygulamalar için yapay zeka uygulamalarını içeren bilgisayar tabanlı sistemler kullanmaktadır. Kişi tanıma uygulaması da bu alanda yapılan çalışmalardandır. İlk zamanlarda güvenlik önlemleri için tasarlanan yüz ve nesne tanıma uygulamaları, son zamanlarda eğlence ve alışveriş sektörü alanlarında da kullanılmaktadır. Bu uygulamalar, çeşitli firmaların mobil uygulama geliştirmeleriyle daha da popülerlik kazanmaktadır. Yüz tanıma uygulamalarında, verilerin büyük ve karmaşık olması durumunda derin öğrenme yöntemleri tercih edilebilmektedir. Bu çalışmada da bir yüz tanıma uygulaması için 3 katmanlı bir Evrişimli Sinir Ağı (ESA) geliştirilmiştir. Geliştirilen model Libor Spacek's Facial Images Databases veri setine uygulanmıştır. Önerilen yöntemin veri seti üzerine uygulanması sonucunda %99.29 doğruluk oranı olduğu belirlenmiştir. Bu da uygulamanın gerçek bir tanıma sistemine uyarlanabileceği anlamına gelmektedir.

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1. INTRODUCTION

In recent years, thanks to the development of technological innovations, many researchers have started to take an intense interest in human-computer interactive systems. The basic usage approach of human-computer interactive systems is to obtain personal data, process this data and then automatically use them according to the relevant fields. In recent years, as an example of human-computer interaction studies, person recognition-identification studies have become a leading research area. Identification studies are one of the important issues in terms of people's security. In many cases, identification is made using various methods to identify the individual who is authorized to do a job or the individual who is effective in the realization of a negative situation that has occurred. While these methods used in identification are carried out in the form of password verification, in criminal cases, mostly physical structures or behaviors are examined and estimation processes are carried out for identification. In this context, fingerprints, signatures, the structure of the DNA molecule used to distinguish living things have been widely used for many years in identification and matching processes. [1-2].

With the rapid development of technology, new tools are included in our life's day by day. In the last period of the 20th century, mobile phones began to be included in human life to be always accessible. These devices, which were used for communication in the early periods, gained additional functional features with the desire of their manufacturers to stand out from the competition. Especially in the early 2000s, every mobile device has turned into an interactive and multi-functional device with one or more cameras. Today, cameras are easily accessible in all areas of life, and they are widely used with the tendency of individuals to keep memories of their lives alive. Images of many visual elements are photographed every day, and these photos contain a lot of data.

Similar to the development processes of mobile phones, camera security systems have been increasingly used since the last period of the 20th century. These systems instantly record the images obtained from many cameras, and at the same time, they are instantly examined by individuals and interventions are carried out when necessary. Although common methods used in identification have various advantages and disadvantages, one of the limitations can be considered as the access of additional hardware devices. Today, the widespread use of cameras in all areas of life and the non-contact way of obtaining data increase the importance of identification from images. In this study, face recognition was performed with a 3-layer Convolutional Neural Network (CNN) developed with deep learning techniques, which have become widespread recently, instead of traditional face recognition methods. The proposed model was developed for the reference dataset Libor Spacek's Face Images dataset and the codes were developed in MATLAB environment. Then, the results of the developed model were evaluated with performance criteria. Firstly, the network was trained with some of the original data from the face dataset, and then testing of model was performed with the rest of data that had not been introduced to the network before. As a result of the studies carried out, an accuracy rate of 99.29% was determined. It is predicted that the method proposed in the scope of the study can be used successfully in different fields or in real recognition studies.

2. LITERATURE STUDIES

The early stage of face recognition studies and the current stage of studies show differences. While early studies were described as traditional methods, today's studies are generally characterized as modern methods that make use of deep learning methods. Facial recognition studies are still one of the trending topics.

Bledsoe developed the first semi-automatic facial recognition system in 1966. In 1971, another study on face recognition was conducted by Goldstein et al. Bloedsoe (1966) and Goldstein et al. (1971) used the size and position of parts of the face such as ears or eyes to extract features in their studies. Goldstein et al. (1971) predicted that an individual should be distinguished from a population of 255 individuals with 6 characteristics in their study. In the mentioned studies, feature extractions and calculations are performed semi-autonomously [3-4]. Although the first studies on identification with face recognition started in the 1960s, a system that could perform automatic diagnosis was proposed in Kanade's doctoral thesis in 1973. This system, created with similar feature extraction methods, is the first automatic face recognition system. The system included techniques for matching various parts of the percentage and did the calculations automatically [5-6]. Turk and Pentland (1991) shared a study that can detect a human face almost simultaneously from an image in which people are constantly in motion, and also identify who it belongs to. The work includes the concept of eigenface calculation. They state that they have achieved 96% success in different light environments in their studies. At the same time, they reported that they achieved 85% success according to the direction variation and 64% according to the size variation. Gross et al. (1992) stated in their study that both the examination of face-selective neurons in the monkey temporal lobe and facial recognition disorders after brain injury in humans became very active research areas. They stated that it reflects the more general role of the temporal cortex in pattern recognition. They pointed out that there are various facial processing disorders in humans resulting from damage to different areas, reflecting interference in the processing of the face image at different levels. This study is an important study as one of the face recognitions based on pattern recognition [7]. Zhao et al. (2003) stated in their study that one of the most used applications of image processing is face recognition that have gained tremendous interest in recent years. The authors thought that one of these reasons was due to legal and commercial processes. Another reason was that they thought the idea had a long-term construction phase. The authors stated that machine learning systems, which already have a

developed structure, do not carry the success criterion to the desired level due to the disrupting factors in real systems. Exposure changes and lighting levels are examples of these disruptive factors. Briefly, the authors stated that the existing studies cannot be considered sufficient in terms of human perception. The authors presented a critique of their article, which included two different face recognition working groups, a group of still images and a group of videos. The authors stated that they carried out a study, firstly, to perform a comprehensive literature review, and secondly, to gather information on facial recognition systems developed with machine learning algorithms [8]. Tolba et al. (2006) mentioned in their study that the face recognition task has been recently researched. In their article, the authors stated that they present a current review of face recognition research. Firstly, they introduced the concept of facial recognition and its usage field. Then, they gave a literature study of the latest face recognition methods. The authors have clarified some definitions and limitations of databases used to measure the performance of face recognition techniques. They explained a summary of the Face Recognition Vendor Test (FRVT), a detailed evaluation of automatic face recognition challenge and its outcomes [9].

Abdur Rahim et al. suggested that various inferences can be made about the current mood and physical conditions based on the human face and presented a study in which they performed the face recognition process by using the Local Binary Patterns (LBP) method. Within the scope of the study, the authors also mentioned the difficulties of the face recognition process and the diversity of its usage areas and stated that this diversity also affects many applications used in daily life. In addition, the authors stated that face recognition methods consist of feature extraction and classification processes. Face detection, which is the first of these, has the task of determining the sequential detection and recognition algorithms that aim to model the face. They stated that the most characteristic and unique features of the face images were extracted during this stage. They stated that during the classification phase, the facial images were compared with the images in the database. They evaluated face recognition empirically in their study by considering both shape and texture features representing face images based on Local Binary Models for person-independent face recognition. They firstly divided the face area into small regions and they extracted Local Binary Patterns (LBP) and histograms and then they combined them into a single feature vector. They emphasized the extracted feature vector forms an efficient representation of the face and this vector can show similarities between images. The authors stated in their study that their study is a successful application for person recognition from facial images [10].

According to Ghazi et al. (2016) stated in their study that face recognition methods performed with deep learning have high success in cases where there are operations to be performed on a complex data set. However, the authors stated that no evaluation was made on the behavior of the system against changes caused by ambient lighting or exposure angles, which may affect the recognition accuracy. In their study, the authors conducted a detailed study to evaluate the performance of deep learning-based face recognition under a variety of conditions, including varying head exposure angles, upper and lower face occlusion, varying illumination, and misalignment due to faulty facial feature localization. They used VGG-Face and Lightened CNN deep learning models to extract facial representations. The results indicated that although deep learning algorithms provide a powerful model for face recognition applications, they still need to take advantage of preprocessing to gain better performance under specific conditions such as exposure and illumination normalization. Especially if these parameters are not included in the learning algorithm, the importance of preprocessing that needs to be applied to the image increases. In addition, deep learning methods have the potential to tolerate errors that may arise from misalignment and location errors based on facial features to a certain extent, thanks to their structure [11].

Haq et al. (2017) conducted a study on face recognition with Support Vector Machine using LBP Methods. The authors stated that face detection is very important for situations requiring high security. The authors said that by classifying the patterns based on prior knowledge or statistical information of the patterns, they not only offer various solutions to pattern recognition problems, but also help in detecting, recognizing, and authenticating what is desired. The authors stated that a better face recognition can be achieved by factors such as good training of the classifier, making the input images desirable. The authors noted that the illumination of the image effects the face recognition accuracy and does not produce the best-matched results with Single Sample Per Person where only one training sample is available. In their study, the authors stated that they present a working model by generating normalized histograms to train the SVM classifier by taking different sample images and extracting Local Binary patterns, and then classifying the input research images using Binary and Multiclass Support Vector Machines. Although the authors clearly demonstrated in the final part of their study the simplicity and robustness of LBP-based facial representation extraction in terms of facial expression, aging, illumination, and alignment, they noted that some improvements are still need [12].

Qu et al. (2018), in their study, stated that the success of deep learning methods on complex and high-dimensional data is improving day by day and their application areas are increasing. When the results of other common face recognition algorithms are examined, it has been stated by the authors that the success of face recognition processes performed with the help of deep learning has superiority in terms of accuracy. By combining FPGA and CNN [3] methods, the authors proposed a method that significantly affects the recognition accuracy. The authors presented the proposed method in two steps. The first of these consists of obtaining the parameters. With the help of these parameters, the training of the model is carried out. In the second step, the obtained face recognition approach is combined with FPGA. The FPGA accelerates the computing speed of the network thanks to parallel processing to achieve real-time processing of face recognition. The authors claimed that they obtained 400FPS as the recognition

speed of the system, far beyond the current results. Finally, the authors stated that the recommended recognition rate is 99.25% higher than the human eye. They also said that the proposed method give good results under complex light environment [13].

Öziş et al. (2020) developed a face recognition system with Raspberry Pi in their study. The authors stated that image processing applications have been widely used in recent years, especially in terms of safety and health. They stated that some of these studies showed that applications such as license plate recognition, person recognition, face recognition in terms of security gave many useful results from the statistical information. In addition, in terms of health, they mentioned that there are applications in image processing to obtain preliminary diagnosis and preliminary information in terms of health. In their study, the authors proposed a study focusing on the field of face recognition among image processing applications. They said that the usage areas of face recognition systems are increasing in parallel with the development of image processing technologies and machine learning. The authors stated that in their study, it was carried out by making use of the Haar-cascade classification feature applied to find objects on the image. In addition, it was stated that the OpenCV (Open Source Computer Vision Library) library was preferred as an image processing library in the study. In their study, the authors stated that this system, which detects the faces in the image taken with the Raspberry Pi camera module and frames the detected faces, records the images of the faces it finally detected. In the last part of the studies, the authors stated that there may be a potential study that can help many sectors, especially security systems [14].

Başaran E. (2020) has done a thesis on face recognition and person re-recognition for person recognition. The author stated that face recognition and person re-recognition applications are needed in many different areas, especially in individual and social security, forensic cases, and entertainment. The author said that facial images contain rich and highly distinctive features for person identification. He also mentioned that the fact that face images can be obtained without contact and cooperation causes face recognition applications to have a wider application area than applications using other biometric identifiers such as iris and fingerprint. The author emphasized that the scientific part and the original aspect of the thesis were calculated by calculating the distance between the images using the reordering algorithm for his thesis work. Finally, the author stated that as a result of the experiments on the SYSU-MM01 and RegDB datasets he used, the proposed method proved successful [15].

Table 1. Comparison of the proposed approach with the studies in the literature.

Authors (year)	Method	Accuracy (%)
Guo et al. (2000) [16]	ORL Support vector machines (SVM) and nearest center classification (NCC)	94-98
Agarwal et al. (2010) [17]	Artificial Neural Network (ANN)	97
Ramaiah et al. (2015) [18]	Convolutional Neural Network (CNN)	94.1
Khiyari and Wechsler (2016) [19]	Convolutional Neural Network (CNN)	80-90
Kamencay et al. (2017) [20]	Convolutional Neural Network (CNN) Principal Component Analysis (PCA), Local Binary Patterns Histograms (LBPH) and K–Nearest Neighbour (KNN)	98.3
Coşkun et al. (2017) [21]	Convolutional Neural Network (CNN)	98
Hansen et al. (2018) [22]	Convolutional Neural Network (CNN)	96.7
Khan et al. (2019) [23	Convolutional Neural Network (CNN)	98
Zulfiqar et al. (2019) [24]	Convolutional Neural Network (CNN)	98.76
Abinaya et al. (2020) [25]	Local Binary Pattern (LBP) and Gray Level Co-Occurrence Matrix (GLCM)	96.4
Sharma et al. (2020) [26]	PCA+LDA, PCA+MLP, PCA+NB, PCA+SVM	97-100
This study	CNN, CNN+Adaboost Classifier	99.29 – 97.33

As can be seen from Table 1, the calculated performance values of the proposed models are well-marked compared to the literature. When the literature is examined, it is seen that CNN-based models exhibit high success. The proposed model has proven to be feasible by achieving a high success rate in the literature.

3. DATASET

The dataset used in this study was taken from Libor Spacek's Facial Images Databases, which is an open-source dataset. The data used is kept here in four compressed archives. These four data sets are faces94, faces95, faces96, grimace. These datasets are also sorted according to increasing difficulty. Faces 96 and grimace datasets are the most challenge between these datasets because of different reasons. These difficulties are defined as the background and scale diversity on faces for the faces96 dataset and the extreme diversity of expressions in the

grimace dataset. All images are stored in 24-bit RGB, JPEG format. These datasets were obtained from 395 people. The number of images per person is 20 and the total number of images is 7900. Most individuals are between the ages of 18-20, as the age range in the dataset is mostly first-year undergraduate students, but there are some older individuals as well. The data set consists of images obtained differently to allow different (male, female, people of different races, glasses, beards, S-VHS video camera, 24-bit color JPEG, artificial lighting, fluorescent overhead mixture, and tungsten) scenarios and to increase the degree of difficulty [27].
Within the scope of this study, the images of 125 individuals were used from the faces96 dataset. Images contain both male and female images in 196×196 size. Some images are illustrated as in the Figure 1.

Figure 1. Some sample images of people used in this study.

4. THEORETICAL BACKGROUND

4.1. Convolutional Neural Networks

In recent years, Convolutional Neural Networks (CNN) models have been used especially in image recognition and processing problems. In fact, CNN models were developed from multilayer artificial neural networks (ANN) models. CNN models consist of two steps, as in Figure 2, feature extraction with convolution layers and classification with multilayer ANN layers added afterward.

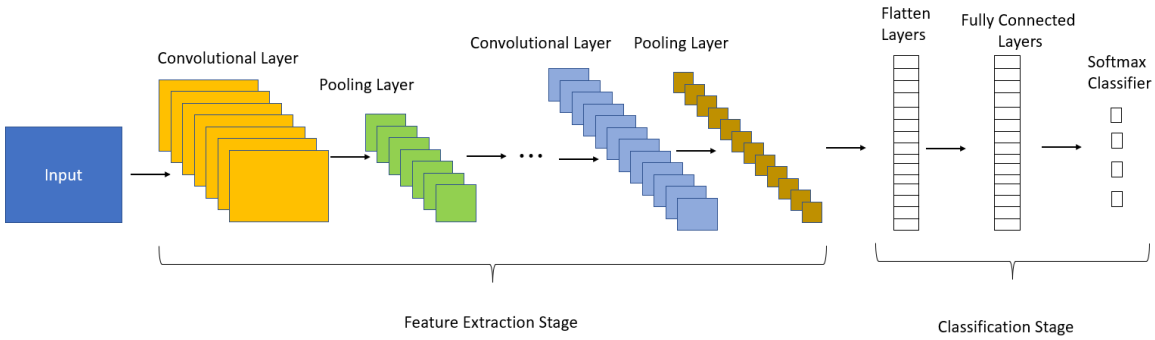


Figure 2. A sample CNN architecture.

A conventional convolutional neural network model consists of six steps: convolutional layers, rectified linear unit (ReLU), pooling layers, a flattening layer, Fully Connected (FC) layers and softmax classification layer. In the first step, a set of convolution filters is applied to the input image to enable certain features from the images. Convolution layers are used to obtain feature information from input images. Following the convolution layer, negative values are usually set to zero and positive values remain unchanged with the ReLU activation function to increase the training speed [28].
One way to reduce the size of the output image is pooling operation. The aim of the pooling layers is to make the output simpler with nonlinear down sampling and thus, the model learns by reducing the number of parameters.

The pooling operation can be performed with the average, maximum calculations. These steps are repeated for many layers, and each layer gains unique properties. In convolutional neural networks, the pooling process is generally used after the convolution layer.
In order to reduce the processing cost by reducing the size of the output image, stride operation can also be performed. While the process can be performed by shifting the filter one pixel in convolution or pooling operations, it can also be done by shifting more than one pixel by increasing the number of steps. Thus, larger and more complex patterns of input can be detected with stride operation.
Feature matrix sizes obtained at layer outputs can be reduced. In addition, taking into account the edge pixels features can make the model more effective. For this reason, it can solve the edges of the input slice by padding the rows and columns with zeros or pixel values on the edge before the convolution operation. The most common use of pixel padding is to produce output with the same dimensions as the input.
In the flattening layer, obtained two-dimensional feature arrays are converted to a flattened linear vector to use for as input to the fully connected layers. FC layers can combine all the local features of each previous layers and are learned by updating the weight and bias values by the feedback method, as in Artificial Neural Networks (ANNs). All these processes are completed by adding the softmax function to the last layer of the model to get the final classification result [29].

4.2. AdaBoost Classifier

In fact, AdaBoost is an ensemble classifier, and it can combine weak classifiers to form a strong classifier. At each iteration, it creates the classifier using a simple learning algorithm called the base learner. Then, the model determines the weight coefficient to this classifier. The final classification decision is made because of the weighted voting of the weak classifiers based on their weight coefficients. The lower the weak classifier error, the higher its weight in the final vote. There is great flexibility in the design of the weak classifier set, as weak classifiers predict slightly better than random guessing.
AdaBoost algorithm uses some parameters for definitions:
D_n={(x_1, y_1),…,(x_n, y_n)}} and T parameters represent the training set and the algorithm's iteration time, respectively. T parameter can be determined manually and predefined. In each iteration of t=1,⋯,T,, the coefficient of a weak $h^{(t)}$ classifier $a^{(t)}$ is adjusted from the set H resulting from the classifier.
Algorithm in its simplest form, H represent a finite set of binary classifiers with the form h: Rd→ {-1,+1}, and the base learner performs a detailed search on H set at each iteration. The final output of the AdaBoost model is a discriminant function created by weighted voting of weak classifiers [30].

5. EXPERIMENTAL RESULTS

During the model training phase, 70% of the data was used in the training and the rest 30% of the data is used in the testing phase. In other words, 1750 sample images of a total of 2500 images were used in the training phase of the model, and 750 images were used in the testing phase of the model. In the model performance evaluation, the confusion matrix, and the f-score, recall, precision, accuracy values obtained from this matrix were obtained.
All applications were implemented using MATLAB Deep Learning and Statistical machine learning tools [31]. Before the implementation phase, all the images were converted to 224×224 size. Figure 3 shows developed two model for face recognition application. As can be seen, the three layers consist of convolution and pooling layers.

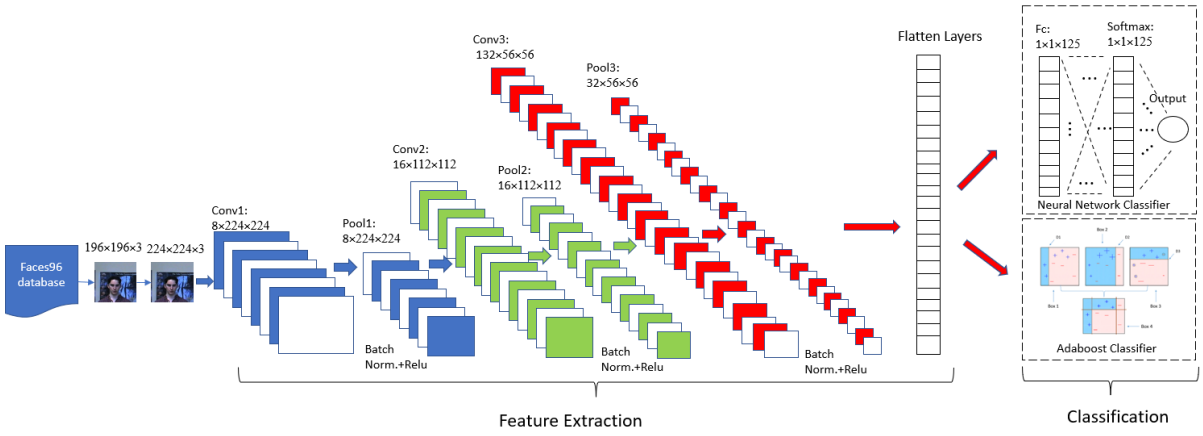


Figure 3. Proposed CNN architecture used for facial recognition.

Table 2. Model parameters.

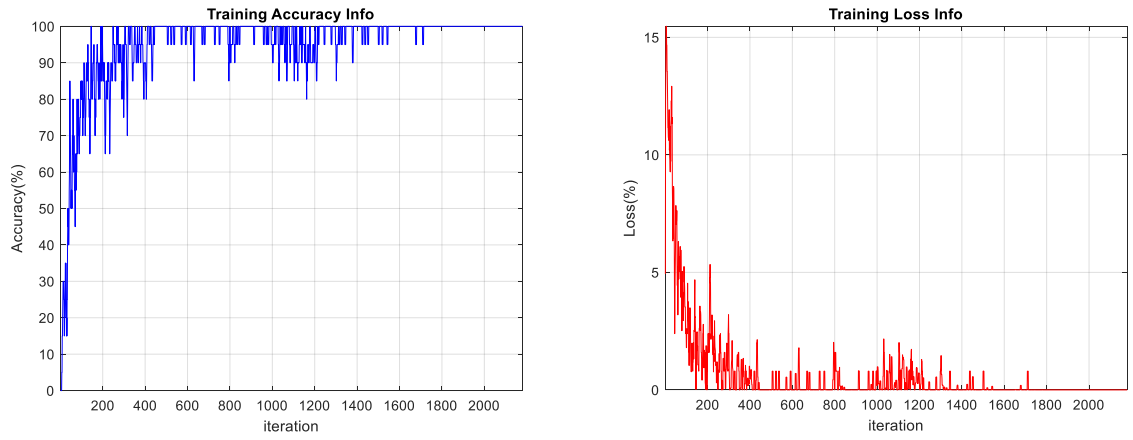
Layer Name	Function	Weight filter size	Number of filters	Output size
Input				3×196×196
Conv1	Convolution	3×3	8	8×224×224
Batchnorm1	Batch Normalization			8×224×224
ReLU1	Activation function			8×224×224
Pool1	Max. Pooling	2×2		8×112×112
Conv2	Convolution	3×3	16	16×112×112
Batchnorm2	Batch Normalization			16×112×112
ReLU2	Activation function			16×112×112
Pool2	Max. Pooling	2×2		16×56×56
Conv3	Convolution	3×3	32	32×56×56
Batchnorm3	Batch Normalization			32×56×56
ReLU3	Activation function			32×56×56
Flatten Layers	Flatten Layers			1×1×125
fc	Fully connected layer			1×1×125
Softmax	Classification layer			1×1×125

In Table 2, the feature was extracted with combination of 3 convolution and pooling layers, and then the classification process was carried out with two model that are a one-dimensional fully connected layer and a Adaboost classifier, respectively. In Table 3, the training parameters used in the single layer CNN model are given.

Table 3. Parameters used to train the model.

Parameter	Number or type
Hidden size	125
Output layer size	125
Batch size	4
Optimization function	Adam
Learning rate	0.001
Max epoch	5

The model training stage training accuracy is given in Figure 4(a) and the error function graph at the training stage is given in Figure 4(b). If the figures are examined, it can be observed that the accuracy curve stabilizes after ascension. At the same time, the error function decreased and reached its minimum value.



(a) (b)

Figure 4. (a) Accuracy rate of model training stage (b) Loss function of training stage.

After the model training was completed, the model was tested with the test data and the confusion matrix was obtained and then, the performance criterions were calculated. The performance criterions are obtained by using 10 cross-validation schemes. The calculated performance measures are given in Table 4. Model weights value of the last epoch were used for testing phase.

For second classification scheme, the flatten layers weight are taken as feature matrix after training of CNN is completed. And feature matrix is given as inputs to Adaboost classifier. The performance criterions of convolutional features with Adaboost classifier are given in Table 4.

Table 4. The calculated performance criterions.

Measure	Accuracy	Recall	Precision	F-Measure
CNN Model	**0.9929**	0.9950	0.9941	0.9941
Convolutional features + Adaboost Model	0.9733	0.9640	0.9780	0.9737

As can be seen in Table 4, the developed CNN model created achieved better results than Adaboost classifier. while Adaboost classifier achieves %97.33 accuracy rate, the developed CNN model obtained higher success rate than the Adaboost classifier as 99.29% for this face recognition application.

Figure 5. Accuracy rates of some images.

After the best model is determined, some random test samples and their accuracy are given In Figure 5. It is seen that all the selected samples were classified 100% correctly by the developed CNN model.

6. CONCLUSIONS

CNN models are a valuable pattern recognition method both in theory and in real-time image classification or recognition applications. In this study, a CNN model was presented for a face recognition problem. The proposed CNN model was used to classify the data set containing 20 different image samples of each individual taken from different 125 people. Model training was completed with a part of the dataset and tested with the resting part of the dataset. In addition, to see CNN model efficiency, convolutional features of CNN model are taken as feature matrix. And then, they are classified with Adaboost classifier. When the models are compared CNN model achieved more promising results than Adaboost classifier.

As a result of this study, it has been observed that the developed CNN model gives effective face recognition and high accuracy results compared to the literature studies. The proposed method provided a high accuracy for the Faces96 dataset. Also, it was observed that the variety of background and scale on the faces did not affect the accuracy of proposed model. This output is very important for real-time applications with background noise because it is not always possible to obtain images without a background in practice. At the same time, the scale diversity of the faces96 dataset did not affect the performance of the developed model. This means that the model developed for real-time applications can promise high accuracy.

In future studies, it is planned to develop a model with a faster training phase instead of the CNN model. Also, it is thought to increase dataset variety to see developed model performance. For the next studies, it is thought to use this developed CNN model for more complex face recognition problems.

Author Contributions

The authors contributed equally to the study.

Conflict of Interest

The authors of the article declare that there is no conflict of interest between them.

REFERENCES

[1] A. K. Jain, K. Nandakumar, A. Ross, "50 Years of Biometric Research: Accomplishments, Challenges, and Opportunities", Pattern Recognition Letters, vol. no. 79, pp. 80-105, 2016.

[2] A. K. Jain, A. Ross, S. Prabhakar, "An Introduction to Biometric Recognition", IEEE Transactions on Circuits and Systems for Video Technology, vol. 14, no. 1, pp. 4-20, 2004.

[3] W. W. Bledsoe, "The Model Method In Facial Recognition. Panoramic Research Inc.", Palo Alto, CA, Rep. PR1, vol. 15, no. 47, pp. 2, 1966.

[4] A. J. Goldstein, L. D. Harmon, A. B. Lesk, "Identification of Human Faces", Proceedings of the IEEE", vol. 59, no.5, pp. 748-760, 1971.

[5] M. Naeem, I. Qureshi, F. Azam, "Face Recognition Techniques And Approaches: A Survey", Science International, vol. 27, pp. 1, 2015.

[6] T. Kanade, "Picture Processing System By Computer Complex and Recognition of Human Faces", Basel: Birkhäuser, vol. 47, p. 63, 1974.

[7] C. G. Gross, J. Sergent, "Face Recognition", Current Opinion In Neurobiology, vol. 2, no. 2, pp. 156-161, 1992.

[8] W. Zhao, R. Chellappa, P. J. Phillips, A. Rosenfeld, "Face recognition: A literature survey", ACM Computing Surveys (CSUR), vol. 35, no. 4, pp. 399-458, 2003.

[9] A. S. Tolba, A. H. El-Baz, A. A. El-Harby, "Face recognition: A literature review", International Journal of Signal Processing, vol. 2, no. 2, pp. 88-103, 2006.

[10] M. A. Rahim, M. S. Azam, N. Hossain, M. R. Islam, "Face Recognition Using Local Binary Patterns (LBP)", Global Journal of Computer Science and Technology, vol. 13, no. 4, pp. 1-9, 2013.

[11] M. Mehdipour Ghazi, H. Kemal Ekenel, "A Comprehensive Analysis Of Deep Learning Based Representation for Face Recognition", Proceedings of the IEEE conference on computer vision and pattern recognition workshops, pp. 34-41, 2016.

[12] E. U. Haq, X. Huarong, M. I. Khattak, "Notice of Retraction: Face Recognition by SVM Using Local Binary Patterns", 14th Web Information Systems and Applications Conference (WISA), pp. 172-175, 2017.

[13] X. Qu, T. Wei, C. Peng and P. Du, "A Fast Face Recognition System Based on Deep Learning", 11th International Symposium on Computational Intelligence and Design (ISCID), pp. 289-292, 2018.

[14] H. Öziş, İ. Kandilli, M. Kuncan, M. "Face Recognition System With Raspberry Pi", 4th International Zeugma on Scientific Researches, pp. 178-185, 2020.

[15] G. Bolukbaş, E. Başaran, M. E. Kamaşak, "BMI Prediction From Face Images". 27th Signal Processing and Communications Applications Conference (SIU), pp. 1-4, 2019.

[16] G. Guo, Z. Z. Li, K. Chan, "Face recognition by support vector machines", Proceedings Fourth IEEE International Conference on Automatic Face and Gesture Recognition, pp. 196-201, 2000.

[17] M. Agarwal, H. Agrawal, N. Jain, M. Kumar, "Face recognition using principle component analysis, eigenface and neural network", 2010 International Conference on Signal Acquisition and Processing, pp. 310-314, 2010.

[18] N. P. Ramaiah, E. P. Ijjina, C. K. Mohan, "Illumination invariant face recognition using convolutional neural networks", International Conference on Signal Processing, Informatics, Communication and Energy Systems (SPICES), pp. 1-4, 2015.

[19] H. El Khiyari, H. Wechsler, H. "Face recognition across time lapse using convolutional neural networks", Journal of Information Security, vol. 7, no. 3, pp. 141-151, 2016.

[20] P. Kamencay, M. Benco, T. Mizdos, R. Radil, "A new method for face recognition using convolutional neural network", Advances in Electrical and Electronic Engineering, vol. 15, no. 4, pp. 663-672.

[21] M. Coşkun, A. Uçar, A., Ö. Yildirim, Y. Demir, "Face recognition based on convolutional neural network", In 2017 International Conference on Modern Electrical and Energy Systems (MEES), pp. 376-379, 2017.

[22] M. F. Hansen, M. L. Smith, L. N. Smith, M. G. Salter, E. M. Baxter, M. Farish, B. Grieve, "Towards on-farm pig face recognition using convolutional neural networks", Computers in Industry, vol. 98, pp. 145-152, 2018.

[23] S. Khan, M. H. Javed, E. Ahmed, S. A. Shah, S. U. Ali, "Facial recognition using convolutional neural networks and implementation on smart glasses", 2019 International Conference on Information Science and Communication Technology (ICISCT), pp. 1-6, 2019.

[24] M. Zulfiqar, F. Syed, M. J. Khan, K. Khurshid, "Deep face recognition for biometric authentication", In 2019 international conference on electrical, communication, and computer engineering (ICECCE), pp. 1-6, 2019.

[25] R. Abinaya, L. P. Maguluri, S. Narayana, M. Syamala, "A novel biometric approach for facial image recognition using deep learning techniques", International Journal of Advanced Research in Engineering and Technology, vol. 11, no. 9, 2020.

[26] S. Sharma, M. Bhatt, P. Sharma, "Face recognition system using machine learning algorithm", 5th International Conference on Communication and Electronics Systems (ICCES), pp. 1162-1168, 2020.

[27] D. Hond, L. Spacek, "Distinctive Descriptions for Face Processing", The British Machine Vision Conference (BMVC), pp. 1-4, 1997.

[28] Y. LeCun, Y. Bengio, G. Hinton, "Deep learning" Nature, vol. 521, no. 7553, pp. 436-444., 2015.

[29] I. Goodfellow, Y. Bengio, A. Courville, "Deep learning", 1st ed., London, UK, MIT press, 2016.

[30] C. Ying, M. Qi-Guang, L. Jia-Chen, and G. Lin, "Advance and Prospects of AdaBoost Algorithm". Acta Automatica Sinica, vol. 39, no. 6, pp. 745-758, 2013.

[31] M. Paluszek, S. Thomas, "Practical MATLAB Deep Learning: A Project-Based Approach", 1st ed., New Jersey, USA, Apress, 2022.