Journal of Information Systems and Telecommunication
Vol.12, No.2, April-June 2024, 162-169
http://jist.acecr.org
ISSN 2322-1437 / EISSN:2345-2773

Ensemble learning of Ada-boosting Based on Deep Weighting for Classification of Hand-written Numbers in Persian (With the doctors' prescription approach)

Amir Asil[1], Hamed Alipour[2*], Shahram Mojtahedzadeh[1], Hasan Asil[4]

[1].Department of Electrical Engineering, Faculty of Electrical and Computer Engineering, Azarshahr Branch, Islamic Azad University, Iran
[2] .Department of Electrical Engineering, Faculty of Engineering, Tabriz Branch, Islamic Azad University, Iran
[4] .Department of Computer Engineering, Faculty of Electrical and Computer Engineering, Azarshahr Branch, Islamic Azad University, Iran

Received: 03 Feb 2023/ Revised: 02 Feb 2024/ Accepted: 06 Jun 2024

Abstract

Converting handwritten data to electronic data is one of the challenges that have been raised over the past years. Considering that these data are used in various sciences, solving this challenge is of great importance. One of these sciences is medical science that doctors use in prescriptions. This project tries to classify handwritten numbers with the approach of solving the challenges of handwritten data. Over the past years, a variety of solutions have been developed to transform handwritten data based on machine learning. Each method categorizes or clusters the data based on the type of data and its use. In this paper, a new approach based on hybrid methods and deep learning is presented for the classification of Persian handwritten data. By combining Ada and convolution, a deeper examination of the data is performed in basic learning. The purpose of this research is to provide a new technique for classifying images of Persian handwritten numbers. The structure of this technique is based on Ada Boosting, which in turn is based on weak learning. This technique improves learning by repeating weak learning processes and updating weights. Meanwhile, the proposed method tried to employ stronger language learners and provide a stronger algorithm by combining these strong learners. This method was evaluated on the Hoda standard dataset containing 60,000 training data. The results show that the proposed method has more than 1% less error than the previous methods. In the future, as the base learner develops, new mechanisms can be introduced to improve results with new types of learning.

Keywords: Deep learning; Adaboosting; handwritten data; convolution; classification.

1- Introduction

In the modern information age, the volume of electronic documents and files are is huge [1]. Processing of these files requires lot of time and cost. For example, there are great volumes of handwritten data that cannot be converted to electronic text manually [2]. In recent years, the importance of using high speed computer systems has been taken into account. Different approaches are used to infer knowledge from such documents. Classification is one of these methods. Classification and clustering are the most important tools in artificial intelligence [3].

In artificial intelligence, deep learning is a machine learning technique that teaches computers to learn what human beings do naturally.

In deep learning, a computer model learns how to classify images, text or sound directly. Deep learning models are highly accurate and sometimes their performance exceeds that of the human beings. Deep learning methods have become very popular in recent years and were used in various projects [4]. In deep learning, the nonlinear properties of several layers are extracted and transferred to a classifier and a combining layer to combine features and make predictions [5]. The deeper the hierarchy of the layers, the more nonlinear properties are obtained and the better the results. Convolution, DBNs, etc. are examples of

✉ **Hamed Alipour**
Hamed.Alipour@iaut.ac.ir

these networks that have many applications such as image processing [6].

In addition to various deep learning techniques, combinatorial approaches to machine learning have also been considered. Combined methods are general techniques of machine learning. By combining different predictions, these methods try to provide more accurate results in solving problems. These include boosting, bagging, and stacking [7].

The present aims at combining deep learning methods with combining methods. This method aims to reduce the error rate in the classification of Persian letters with by using the proposed technique. For this combination in this study, adaboosting is combined with convolution.

2- Literature Review

Only few studies have been performed on the classification of Persian handwritten letters based on machine learning. One of these studies has been on recognition of handwritten numbers based on pre-classification [8]. In another study, Mahabadi et al. used a fuzzy method for the classification of images [9]. Soltanzadeh et al. used the gradient and support vector to classify Persian images [10]. In another study, an intelligent method was presented for feature selection based on binary gravitational search algorithm in Persian handwritten number recognition system. In this method, the fitness function associated with Persian handwritten recognition system error is minimized by using binary gravitational search algorithm and by selecting appropriate features. Implementation results show that the intelligent feature selection technique is able to select the most effective features for the recognition system [9]. In another study, rotation-invariant classification was introduced [10]. In another research, a new method called NeuroWrite has been presented. In this unique method, deep neural networks have been used to predict the classification of handwritten digits [11]. This model is extremely accurate in identifying and classifying handwritten figures using the power of Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN). As you know, recognition of handwritten digits is a topic of interest for computer vision scientists [12,13]. In the research based on this method, a satisfactory and appropriate algorithm for this multi-class classification problem (0-9) has been presented. The purpose of this research is to compare seven machine learning algorithms in terms of their performance criteria in recognizing handwritten digits using two datasets [14,15]. In this research, models of nearest neighbors (kNN), support vector machine (SVM), logistic regression, neural network, random forest (RF), simple Bayes and decision tree based on this in relation to the area under the curve (AUC), accuracy (ACC)) are evaluated [16]. The National Institute of Standards and Database Technology (MNIST) modified common dataset and the Hand Digit Classification (HDC) dataset were the image providers on which this research was conducted [17]. The results confirm that the neural network model is an excellent classifier for this problem. However, it provides similar results to other machine learning classifiers in several cases. In another research, to capture segment-level sentiment fluctuations in an utterance, sentiment profiles (SPs) have been proposed to express segment-level soft labels [18].

There are two main approaches to combinatorial approaches: including Bagging and Boosting. Extensive research has been done on these two techniques. G-Boosting, AdaBoost, LogitBoost, and GentleBoost ... are some of the subset algorithms of boosting [19, 20].

AdaBoost is one of the first boosting algorithms introduced by Freund and Schapire [21]. The main idea of Boosting Algorithm is to give more weight to samples that have been incorrectly classified by current hypotheses [22, 23]. Various solutions such as classifying into two other classes, etc., have been proposed for the multi-class classification [24, 25]. These methods have been increasingly developed. Another method for multi-class classification is the N-ary technique, which can solve multi-class classification problems by splitting them into binary sets [26]. There is another method based on annotation and tagging of untagged data [27]. Another study was performed on combining methods and deep learning in object recognition [28].

In research conducted by Farkhi and etc, the recognition of Persian handwritten digits was used to read check amounts and postal code digits, etc. The purpose of presenting this research was to identify Persian handwritten digits that are written by different people's handwriting so that they can be used in automation software such as postal code reading in the post office department. To perform and test, a database of handwritten figures is needed, which is available in the mnist database for the English language and the Hoda database for the Farsi language, which had about two thousand samples for each digit. In this research, deep learning has been used to identify Persian handwritten digits, which is implemented in such a way that it is done with a deep Boltzmann machine and a two-layer automatic encoder, in which 200 neurons are used in each layer. The method proposed by this team showed a number recognition percentage of up to ninety-two percent [29].

In machine learning, learning transfer and generalization are important and fundamental capabilities. In the research conducted by Nowrozi, self-supervised learning was used to classify images. In this research, as a monitoring method, by using jigsaw puzzle and guessing the angle of rotation, it has been tried to classify handwritten images by

generalizing the domain. This method has reduced errors and improved [30].

The goal of transfer learning (TL) with convolutional neural networks is to improve performance on a new task using knowledge of similar tasks previously learned. This has greatly helped image analysis as it overcomes the problem of data scarcity and also saves time and hardware resources. However, transfer learning is arbitrarily configured in most studies. In this research, an attempt has been made to provide a solution for choosing the model and TL approaches for image classification work [31].

Extracting information from text images identified from the Internet channel is one of the most important problems of information collection systems in the field of information technology. This problem becomes more acute when we know that among the multitude of text images, only a small percentage of identified text images have informational value. In another research, a classification method based on image zoning was used to analyze text images and access their content. In this algorithm, with the help of a two-step zoning method, the image areas are identified, then with the help of a hierarchical classification structure, the type of the area is determined in terms of text or photo (non-text). In the following, by defining the value of the text of a text image, we try to categorize the text image into one of two semantic groups, valuable and worthless. The proposed algorithm is evaluated on a database of textual and non-textual images provided from images available on the Internet. The results of the tests show the effectiveness of the proposed method in the semantic classification of images based on the user's definition of valuable and worthless textual images. The presented algorithm has provided 98.8% classification accuracy for classifying valuable text images from worthless ones [32].

Local binary pattern is a widely used descriptor in feature extraction from texture images. Convolutional deep neural networks are also considered to be the best classification tools with very high accuracy. In another research, a structure for combining the features of local binary pattern and deep convolutional neural network for the classification of noisy texture images has been presented, which provides very high accuracy for the classification of noisy texture images. This method consists of two feature extraction tools. In one tool, local features of texture images are extracted in the form of a 3D histogram using the complete local binary pattern. In the second tool, texture features are reduced using DenseNet-121 deep convolutional neural network. This part, which is used in the feature combination process, significantly reduces the dimensions of the 3D histogram by using a shallow convolutional neural network to combine with deep features. The accuracy of the proposed model has been evaluated on Outex, CUReT and UIUC noise datasets with Gaussian noise, point noise and salt pepper noise with different intensities, and the classification accuracy of the proposed method for different amounts of noise is improved between 3 has had 15 percent [33].

In another research that has been done on the classification of images using deep neural networks, which has led to the emergence of attention-based classification systems. Unlike the methods that use only one classifier to categorize images, in this research, a method for simultaneously using attention-based classifiers with different attentions and calculating the result of their results has been presented. In this research, two general methods are proposed to calculate the result of the classification results: simple voting and calculation of the result based on Bayes logic. Examining the results of this method on the CIFAR10 data set shows the positive effect of the proposed methods on improving the classification accuracy [34].

Since the classification process is completely dependent on the extracted features, it is necessary to act very intelligently in the extraction and selection of images to achieve the ideal accuracy. In the research conducted by Babaian and etc, the evaluation of deep learning in image classification has been considered. In this research, the Python programming language was implemented using the pytorch library. In the classification of images, 38 categories of objects in two groups of test and training and a total of 2,746 photos were examined. In order to evaluate two methods, deep neural network and support vector machine were compared [35].

Deep learning networks have been used to solve various problems such as image classification, object identification, image extraction, etc [36, 37]. These networks try to optimize these techniques by applying different methods.

The deep models of image classification include two deep models of PixelRNN and DCGAN. A new combined model was also provided by Daniel Fritis based on the combination of PixelRNN and DCGAN to detect images [38]. The Gan is another project for image classification, which is related to K-class classification [39, 40].

By creating different layers, deep networks model data features in more details. They have a have great power [33, 41]. One of these deep networks is the Eight Network, which is based on convolution and has eight layers. [42, 43] This model has been used in a variety of problems including video classification, face recognition and action recognition [44]. Other projects in this area have been the use of convolution as a weak learner in the combined Boosting algorithm [45]. The present study is to present a multi-class model based on the ada boosting and convolution combined method for the classification of Persian images (handwritten numbers).

3- Proposed Algorithm

The present study aims at providing a new technique for classification of the images of handwritten Persian numbers. The structure of this technique is founded on Ada Boosting, which in turn, is based on weak learning. This technique improves learning by iteration of the weak learning processes and updating weights. In the meantime, the proposed method tried to employ stronger learners and present a stronger algorithm by combining these strong learners.

The proposed method is to improve image classification and to reduce errors by combining Ada Boosting and basic learning. Figure 1 shows the general structure of the Ada Boosting method.

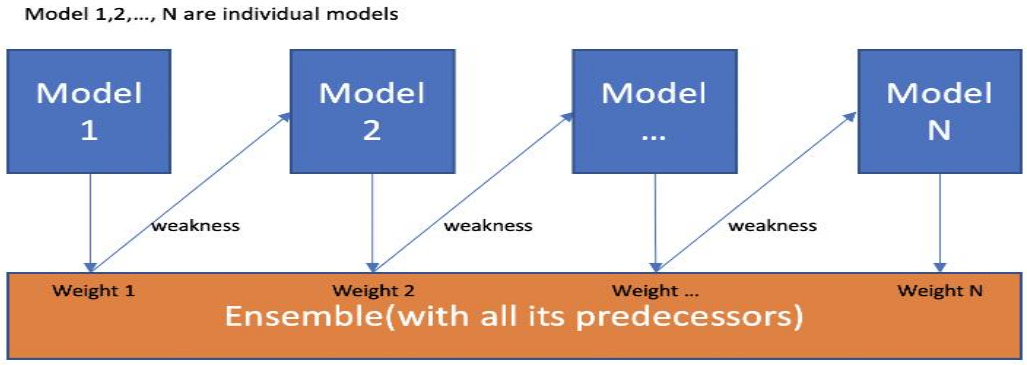


Fig. 1. The structure of the Ada Boosting method [13]

Ada Boosting involves weak learning, and tried to enhance learning by weighting. Proper selection of basic algorithms can help improve learning. Different basic learning methods were used in different problems. This study is to use deep learning to improve this algorithm.

Each hybrid method includes four components of the training set, basic learner, generator, and compiler. The components of the proposed method are:

Training set: A training set includes labeled examples used for training. The training set of this project consists of handwritten data. Some of the data will be used for training and some for testing

Basic Learner: A basic learner is a learning algorithm used to learn a training set. In this algorithm we will use deep learners for the classification. The learning algorithm used in research is convolution, which has two convolution functions for each class. This is in line with greater convergence. On the other hand, the strategy of convolution is reducing the error rate in learning.

Generator: Generator is used to create different classifiers. Different classifiers are created at each step of the Ada boosting method.

Compiler: the compiler is used to combine classification methods. Various methods have been proposed to combine the classifiers. Majority voting is one of the most widely used methods, which functions similar to the non-weighted averaging.

However, rather than averaging out the output probability, the … (?) array counts the predicted labels of the basic learners and makes a final prediction using the highest-rated label. The majority voting can take a non-weighted average using the basic learner label and choose the label with the most value. One of the disadvantages of majority voting is the loss of data because it only uses the predicted labels. Figure 2 shows the general structure of the proposed algorithm.

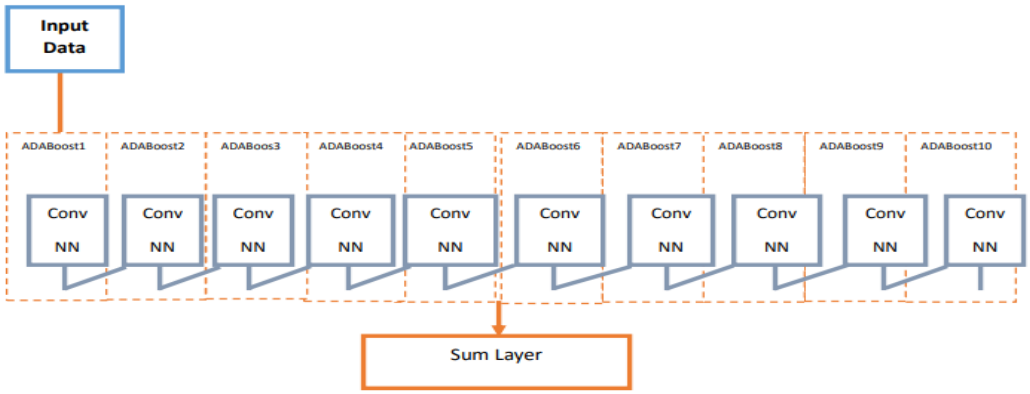


Fig. 2. The structure of the deep Ada boosting method

Let the training sets of (x1, c1), (x2, c2), (x3, c3), and so on; where the input Xi ∈ Rp is the qualitative or quantitative output ci, but it is assumed to be in the set {1,2,3, ⋯ k}. K is the number of classification classes. Training datasets are independent from one another.

The classification aims at finding C(x) based on the training data. With the new input x, we can obtain a class label of {1,. . . , K}.

Ada Boost adopts an iterative procedure. This method predicts the classifier based on the combination of weak learners. At first there are equal weights among the sample. The weights are then updated with each iteration and change in the subsequent classes. The number of iterations in learning is usually between 500 and 1000. The score of each step is taken as a coefficient and multiplied by the classifier. Finally, these classifiers are combined linearly. ALG. 1 shows the Ada Boosting algorithm [26]:

It should be noted that theoretically, the error rate err(m) is less than ½ in each weak classifier [8]. When the number of classes is k, the error probability is (K−1)/K. In Ada-Boosting method, when the error rate is greater than ½, weak learners do not have a high efficiency [26].

Algorithm 1. AdaBoost

1. Initialize the observation weights $w_i = 1/n$ $i = 1, 2,\ldots,n$.

2. For m = 1 to M:

(a) Fit a classifier $T^{(m)}(x)$ *to the training data using weights* w_i.

(b) Compute

$$err^{(m)} = \sum_{n}^{i=1} w_i \prod(c_i \neq t^{(m)}(x_i)) / \sum_{n}^{1=1} w_i$$

(c) Compute

$$\alpha^{(m)} = log \frac{1 - err^{(m)}}{err^{(m)}}$$

(d) Set

$$w_i \leftarrow w_i \,.\exp(\alpha^m .\ \prod\left(c_i \neq t^{(m)}(x_i)\right))$$

for i = 1, 2,…,n.

(e) *Re-normalize* w_i.

3. Output C(x)

$$C(x) = \arg\max_k \sum_{m=1}^{M} \alpha^{(m)} \prod_i \left(T^{(m)}(x) = k\right))$$

ALG2. Ada boosting algorithm

This study is to propose a new algorithm based on Ada Boosting to classify multi-classes. We use weak deep learning methods to solve this problem. As mentioned, the two classes of the convolution network are used in the weak learner for classification. Generally, a convolutional neural network is a hierarchical neural network with its convolutional layers adopted alternately with the pooling layers and thereafter, there are a number of interconnected layers. It has high capabilities in partial learning due to the deepness of these networks. This method is to increase the network's capabilities to the optimized level for the Ada boosting. The Ada Boosting method based on weight updating tries to increase the weight of false guesses in successive iterations, so that a better training takes place in the subsequent learning. If we let the weight of weak learning (convolution) to be W' I, Alg. 2 will be the proposed algorithm for this method:

Algorithm 2. Deep AdaBoosting

1. Initialize the observation weights $w_i = 1/n$ $i = 1, 2,\ldots, n$.

2. For m = 1 to M:

(a) Fit a classifier $T^{(m)}(x)$ *to the training data using weights* w_i.

(b) Compute

$$err^{(m)} = \sum_{n}^{i=1} w_i \prod(c_i \neq t^{(m)}(x_i)) / \sum_{n}^{1=1} w_i$$

(c) Compute

$$\alpha^{(m)} = log \frac{1 - err^{(m)}}{err^{(m)}}$$

(d) Set

$$w_i \leftarrow w_i' + (w_i \,.\exp\left(\alpha^m .\ \prod\left(c_i \neq t^{(m)}(x_i)\right)\right) + \log(k - 1))/2 \qquad w_i' \text{ is weight CNN in week leaner.}$$

for i = 1, 2,…,n.

(e) *Re-normalize* w_i.

3. Output C(x)

$$C(x) = \arg\max_k \sum_{m=1}^{M} \alpha^{(m)} \prod_i \left(T^{(m)}(x) = k\right))$$

ALG. 2. Proposed algorithm based on combining weights

4- Evaluation of the Proposed Algorithm

In order to evaluate this method, the above algorithm was implemented in MATLAB and evaluated on the Hoda database. Hoda handwritten numbers set is the first large set of Persian handwritten numbers, consisting of 102353 black-and-white handwritten samples. The set was developed in a master's project on handwritten form

recognition. The data of this set were collected from about 12000 completed forms.

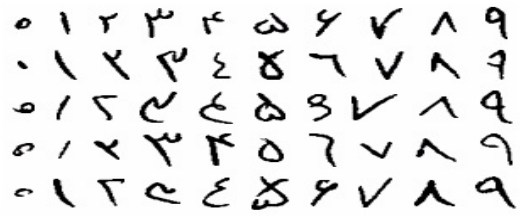
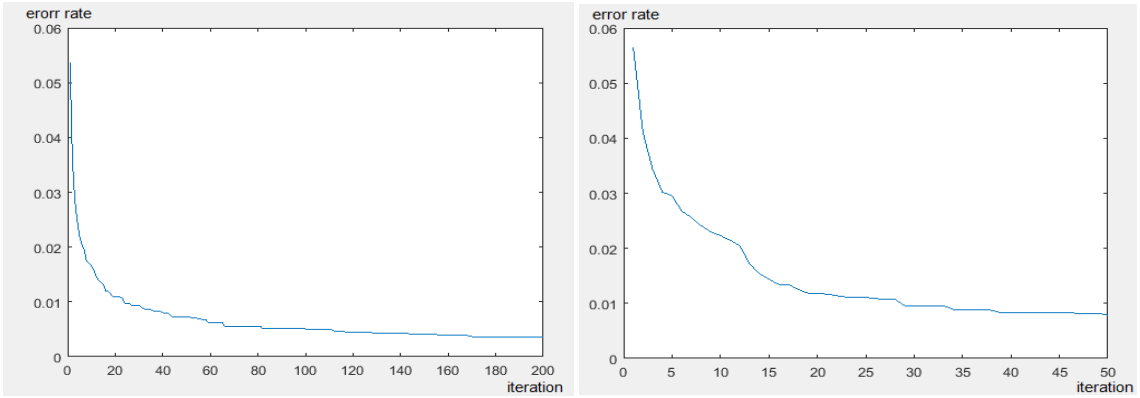


Fig. 3. An example of handwritten data

The number of training samples is 60000 and test samples 20000. Figure 3 shows examples of these numbers.
Previously proposed techniques [30, 31] are used to compare the results of this study. On the other hand, for a more accurately evaluation the results of each test were assessed with a number of iterations. The results of these evaluations are presented in the following section.
Comparison of the results
To evaluate the results of this study, as presented in Section 4, iterative training was performed and tests were made thereafter. Figure 4 shows the evaluation results with a number of iterations.



50 iterations 200 iterations

Fig. 4. Error rate with various numbers of iterations

As shown in Figure 4, the error rate decreases with increasing number of iterations.
error rate: This is a measure of how wrong the classifier would be if it predicted just the majority class. The formula is (Actual: No/Total Sample).
The results are then compared with the literature [30]. Compared with other proposed methods, the error rate is reduced in this method. Table 1 shows the rate of correct classifications.

Table 1: Comparison of error rates by types of algorithms

Deep AdaBoost	*conscious methods*	*different methods*
99.9	94.91	98.16

Figure 5 shows the comparison diagram for the proposed algorithm and different methods. The aim of this project is to reduce the error rate in the classification of handwritten data. After the implementation and training and homogenization of the error rate in the number of repetitions, a comparison has been made.

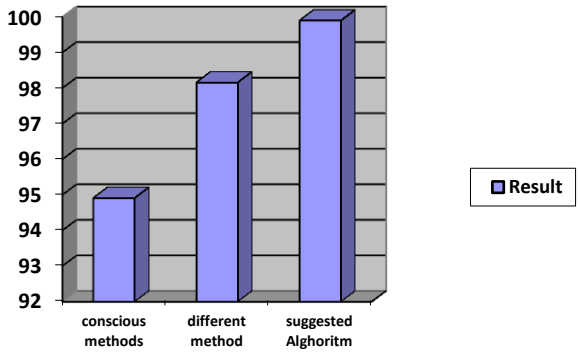


Fig. 5. Results of the correct classification of different algorithms

According to the above, the error rate has reduced more than 1% in the proposed method.

5- Conclusion

Various methods have been proposed for handwritten number classification. But most of these methods were related to English datasets and little was done on Persian datasets. Deep learning methods, especially the convolution technique, have also been used extensively in solving complicated problem and in image processing.

Convolution is one of the learning methods offered for images classification. In fact, combinatorial classifications are presented to enhance the network capabilities. In this research, a combination of Ada Boosting and convolution methods was adopted to present a new model for the classification of Persian handwritten data. Due to the advantages of the convolution method and the Ada Boosting, the combinational updating of weights was performed in the proposed algorithm. The results show that the proposed method has a lower error rate than the previous methods by more than 1%. In the future, by developing basic learner, new mechanisms can be provided to improve the results by new types of learning.

References

[1] Maziyar Kazemi, Muhammad Yousefnezhad, Saber Nourian, "Persian Handwritten Letter Recognition Using Ensemble SVM Classifiers Based on Feature Extraction", National Conference on Intelligent Systems and Information and Communications Technology, At Tabriz, Iran, Volume: 12

[2] Addakiri K., Bahaj M. (2012) "On-line Handwritten Arabic Character Recognition using Artificial Neural Network", International Journal of Computer Applications (IJCA), Volume 55.

[3] Alizadeh H., Yous efnezhad M., Minaei-Bidgoli B. (2015)"Wisdom of Crowds Cluster Ensemble", Intelligent Data Analysis, IOS Press, Vol. 19(3).

[4] sadafsafavi, mehrdad jalali, Recommendation model of places of interest according to people's behavior pattern based on friends list based on deep learning, Journal of Information Systems and Telecommunication (JIST),2021-11-17,http://ijece.org/en/Article/29095

[5] Jamshid bagherzadeh, hasan asil, proposing a New Method of Image Classification Based on the AdaBoost Deep Belief Network Hybrid Method, TELKOMNIKA, Vol 17, No 5, 2019

[6] Mohammad Ebrahim Khademi, Mohammad Fakhredanesh, Farsi Conceptual Text Summarizer: A New Model in Continuous Vector Space, Journal of Information Systems and Telecommunication (JIST),2019-11-04,http://jist.ir/en/Articl /15222

[7] Cheng Ju and Aur´elien Bibaut and Mark J. van der Laan, The Relative Performance of Ensemble Methods with Deep Convolutional Neural Networks for Image Classification, cornell University,2017: arXiv:1704.01664v1 [stat.ML] 5 Apr 2017

[8] amin Ollah Mah Abadi, Abdolmajid Jazemian," Fuzzy diagnosis of Persian handwritten numbers" ،THE CSI JOURNAL ON COMPUTER SCIENCE AND ENGINEERING, no 4, 2006

[9] Najmeh Ghanbari, mohamad Razavi, hasan Nabavi," A Smart Properties Selection Method Based on Binary Gravitational Search Algorithm in Persian Handwriting Number Recognition System", Electrical and Computer Engineering of Iran, 2011

[10] Kottakota Asish, P. Sarath Teja, R. Kishan Chander, Dr. D. Deva Hema, NeuroWrite: Predictive Handwritten Digit Classification using Deep Neural Networks, Artificial Intelligence,2023,https://doi.org/10.48550/arXiv.2311.01022

[11] Diaa s AbdElminaam email orcid 1; Farah Essam2; Hanein Samy2; Judy Wagdy2; steven Albert2, MLHandwritten Recognition: Handwritten Digit Recognition using Machine Learning Algorithms, Journal of Computing and Communication, Volume 2, Issue 1, January 2023, Page 9-19

[12] Danveer Rajpal & Akhil Ranjan Garg, Ensemble of deep learning and machine learning approach for classification of handwritten Hindi numerals, Journal of Engineering and Applied Science volume 70, 2023

[13] Nidhal Azawi, Handwritten digits recognition using transfer learning, Handwritten digits recognition using transfer learning, Volume 106,2023

[14] CvejicE, Prosody off the top of the head: Prosodic contrasts can be discriminated by head motion, Computers & Electrical Engineering,2024

[15] ZhangS, Combining cross-modal knowledge transfer and semi-supervised learning for speech emotion recognition Knowl-Based Syst, Computers & Electrical Engineering,2022

[16] LeeC.jun cowich, Emotion recognition using a hierarchical binary decision tree approach, Speech Commun ,2023

[17] X. Lei, H. Pan and X. Huang, "A Dilated CNN Model for Image Classification", IEEE Access, vol. 7, pp. 124087-124095, July 2022

[18] X. Jiang, Y. Wang, W. Liu, S. Li and J. Liu, "CapsNet CNN FCN: Comparative Performance Evaluation for Image Classification", International Journal of Machine Learning and Computing, vol. 9, no. 6, December 20121

[19] esmaiel miri, mohamad razavi, javad razavi, "The effect of clustering on the recognition of Persian manuscript cultivars with fuzzy classifier" ,2016

[20] ehsan jabir, reza jabir, reza ebrahimpour," A combination of two-class clauses for recognizing Persian manuscript cultivars", 16th Iranian Electrical Engineering Conference, 2007

[21] Corinna Cortes, Mehryar Mohri, Umar Syed, Deep Boosting, e 31 st International Conference on Machine Learning, Beijing, China, 2014

[22] Jafar tanha, Ensemble approaches to semi-supervised learning, UvA-DARE (Digital Academic Repository),2013, http://hdl.handle.net/11245/1.393046

[23] Ji Zhu, Hui Zou, Saharon Rosset and Trevor Hastie, Multi-class AdaBoost, Statistics and Its Interface Volume 2, 2009 349–360

[24] Freund, Y. and Schapire, R. A decision theoretic generalization of on-line learning and an application to boosting. Journal of Computer and System Sciences, 1997 119–139 MR1473055

[25] Friedman, J. Greedy function approximation: a gradient boosting machine. Annals of Statistics, 2001 1189–1232. MR1873328

[26] Friedman, J., Hastie, T., and Tibshirani, R. Additive logistic regression: a statistical view of boosting. Annals of Statistics 2000, 337–407. MR1790002

[27] Jamshid bagherzadeh, hasan asil, proposing a New Method of Image Classification Based on the AdaBoost Deep Belief Network Hybrid Method, TELKOMNIKA, Vol 17, No 5, 2019

[28] N-ary Decomposition for Multi-class Classification. Machine Learning Journal (MLJ), 2019
[29] Learning with Annotation of Various Degrees, IEEE Transactions on Neural Network and Learning Systems (TNNLS), 2019.
[30] Farrokhi, Alireza and Razavi, Seyed Nasser, Recognition of handwritten digits using deep learning, International Conference on Nonlinear Systems and Optimization of Electrical and Computer Engineering, 2014, https://civilica.com/doc/383305
[31] Mehdi Noroozi and Paolo Favaro. "Unsupervised learning of visual representations by solving jigsaw puzzles". In European Conference on Computer vision. Pages 69–84. Springer. 2016
[32] Karen Simonyi and Andrew Zisserman. Very deep convolutional networks for large scale image recognition. ArXiv preprint arXiv: 1409.1556, 2014.
[33] Pourqasem, Hossein and Hel Forosh, Mohammad Sadegh and Daneshvar, Sablan, Semantic classification of text images based on text value model, 2017, https://civilica.com/doc/1372237
[34] Aslimi Zamanjani, Javad and Shakur, Mohammad Hossein and Rahmani, Mohsen, Classification of noisy texture images using deep neural network and complete local binary pattern, 2021, https://civilica.com/doc/1362855
[35] Shahabinejad, Athara and Iftikhari, Mehdi, Image classification using deep convolutional neural networks based on distributed attention and Bayes inference, 5th National Technology Conference in Electrical and Computer Engineering, 2021, https:// civilica.com/doc/1281540
[36] Babaian, Vahidah and Madiri, Shaghaigh and Behlgardi, Seyedah Kausar, Classification of images using deep neural networks, The 5th National Conference on the Application of New Technologies in Engineering Sciences, Torbat Heydarieh, 2018, https://civilica.com/doc /1202833
[37] Transfer Hashing: From Shallow to Deep, IEEE Transactions on Neural Network and Learning Systems (TNNLS), 2018
[38] Harri Valpola. From neural PCA to deep unsupervised learning. In Adv. in Independent Component Analysis and Learning Machines, pages 143–171. Elsevier, 2015.arXiv:1411.7783.
[39] Learning Common and Feature-Specific Patterns: A Novel Multiple-Sparse-Representation-Based Tracker. IEEE Trans. Image Processing 27(4): 2022-2037 (2018)
[40] Aaron vandenOord, NalKalchbrenner, Pixel Recurrent Neural Networks, international Conference on Machine Learning, New York, NY, USA, 2016 ,2016, arXiv:1601.06759v3
[41] Jamishid Bagherzadeh, Hasan Asil, A review of various semi-supervised learning models with a deep learning and memory approach, Iran Journal of Computer Science, 2018
[42] Alex Krizhevsky, IlyaSutskever, and Geoffrey E Hinton. Imagenet classification with deep convolutional neural networks. IN Advances in neural information processing systems, pages 1097–1105, 2012.
[43] Christian Szegedy, Wei Liu, YangqingJia, Pierre Sermanet, Scott Reed, DragomirAnguelov, DumitruErhan,
[44] Andrej Karpathy, George Toderici, SankethShetty, Thomas Leung, Rahul Sukthankar, and Li Fei-Fei. Large-scale video classification with convolutional neural networks. In IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2014.
[45] Christian Szegedy, Wei Liu, YangqingJia, Pierre Sermanet, Scott Reed, DragomirAnguelov, DumitruErhan, Vincent Vanhoucke, and Andrew Rabinovich. Going deeper with convolutions. ArXiv preprint arXiv: 1409.4842, 2014.
[46] M.M. Javidi Fatemeh Sharifizadeh Fatemeh Sharifizadeh," A Modified Decision Templates Method for Persian Handwritten Digit Recognition a Modified Decision Templates Method for Persian Handwritten Digit Recognition", Journal of American Science, 2012