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Improving Image Classification Result using Neural Networks

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Abstract: *Image classification is among the complex processes which depend on several factors. In this paper, the most common existing methods for image classification are compared first and different structures of multilayer Perceptron (MLP) and Radial Basis neural networks (RBF) are then reviewed for classification. Finally, they are compared to non-neural algorithms. The function obtained by using the proposed method enjoys better results as compared to other methods and it has the best result among other methods with respect to accuracy with an average accuracy of 98.84%.*
Keywords: *Image Classification, MLP Neural Network, RBF, KNN*

I. Introduction

In the recent years, several methods have been presented for image classification. Some of these methods include minimum distance, maximum similarity, and support vector machine (SVM). The main steps in image classification involve determining the appropriate classification system, choosing the appropriate approach for classification, post-classification processing and accuracy assessment [1].

A successful classification requires an appropriate classification system and sufficient training samples. Another method which is widely used in image classification is the use of a neural network which includes error back-propagation networks as well as RBF. In this paper, we modify classification accuracy by MLP. The results show that the proposed method has the best answer among the referred algorithms. Order of the contents of paper is such that SVM method which has been already used for classification in previous articles is discussed in section II. The proposed algorithm which is based on back-propagation neural network is presented in section III. Simulation and comparison of the obtained results are described in sections VI- VII. Finally, the conclusion obtained from the paper is presented in section VIII.

II. Image Classification Methods

1. Support Vector Machine (SVM)

SVM is a multivariable machine learning system developed by Vapink [2]. An appropriate method for data classification includes SVM which uses learning methods with supervisor for data classification. SVM is a means for estimation of classification which uses machine learning theory, in the manner that the main idea of SVM is to maximize the margin between the two classes and to minimize the error. In this method, the two classes are separated by using a linear boundary. A number of learning points with the minimum distance to decision border can be considered as a subset to define decision boarders and as a support vector. Learning set is in terms of $\{(x_i, y_i)\}_{i=1}^{N}$ with any input for $y_i \in \{\pm 1\}$. SVM algorithm is calculated as (1) for $\varepsilon_i \geq 0$.

$$\text{minimize} = \frac{1}{2}\|w\|^2 + c\sum_{i=1}^{N} \varepsilon_i \qquad (1)$$

Where C is a parameter which is adjusted by user and ε_i measures the difference between $a(x_i, w)$ and y_i [3].

2. K NEAREST NEIGHBOR (KNN)

Classification K nearest neighbor is the most common and most appropriate method for classification due to a high understanding and lack of any need to making any hypothesis on the data. In this classification, the sample existing in the test set belongs to a class with the highest number of votes among k of its nearest neighbors. Euclidean distance is used to calculate the nearest neighbor of a sample which is in terms of the following relation.

$$d_{eucl}(x,t) = \sqrt{\sum_{i=1}^{m} d_{eucl}^{i}(x,t)} \qquad (2)$$

If the amounts are continuous, the amount of d_{eucl} will be calculated as follows:

$$d^{i}_{eucl}(x,t) = (a_i(x) - a_i(t))^2 \quad (3)$$

Two major disadvantages of this method are as follows where Determination of k amount by user which is one of the important points of KNN method and All the nearest neighbors of test sample are considered with the same degree of importance [4].

3. Neural Network Classification

The book "Classification Algorithm" which was written in 2003 by Landgrebe describes different image classification algorithms. In the recent years, advanced classification approaches such as artificial neural networks, fuzzy sets and expert systems which are highly used in image classification have been introduced. Classification approaches are classified in terms of with and without supervisor, parametric and non-parametric, soft and hard (fuzzy) classification and pre-pixel approaches. Neural networks are in terms of pre-pixel algorithms [1].

Neural network is an important means for classification. Researches show that neural networks can be a substitute alternative for traditional classification methods. Neural networks are used for classification in industry, trade and science. In most papers, multilayer perceptron neural networks (MLP) are used for classification. A comparison between neural networks and traditional classification methods which are generally in terms of statistical methods shows that neural networks for classification are in terms of linear methods and free models while statistical methods are linear and based on the model [5].

III. Implementation

As we know, type of inputting data and order of data are very important for neural networks so that they will have a close relation with the final results. For this purpose, a series of processes shall first be made on the database so that finally the data is prepared to be applied to the network in two groups, namely learning data and test data. The following steps were taken in order to prepare the aforesaid data.

First step: To make the data uniform, at first total data is changed into numerical data by removing the character data in Classes section of database and replacing that with numbers. The number attributed to each class is presented in table(1).

Second step: As we know, if a feature has a constant amount in all instances, it will have no effect on the network performance. As a result, the third feature called region-pixel-count with a constant amount of 9 was removed at this stage aiming at preprocess of data. In this case, number of features has decreased to 18 features which are in turn useful for the network.

Table 1. Replacing Characters with numbers

Class	Assigned Number
BRICKFACE	1
SKY	2
FOLIAGE	3
CEMENT	4
WINDOW	5
PATH	6
GRASS	7

Third step**:** Then, by surveying each column of features and by finding maximum and minimum amounts, all the data of that column are normalized by passing through a linear function (4), in the manner that after completion of this stage, all the amounts will be placed in the interval of {-1,1}.

$$f = 2\left(\frac{x - \min}{\max - \min}\right) - 1 \quad (4)$$

Fourth step**:** Finally, one-third of all data in which there are equal numbers of each class is considered as learning data and the rest is considered as test data. Moreover, all learning data are rearranged randomly to remove network sensitivity to order of instances.

IV. MLP Network With Back Propagation Algorithm

MLP neural networks are among the most widely used and most common methods for classification of inputs so that Several algorithms have been provided to adjust the parameters of this type of network and Back Propagation algorithm is one of them which modifies the weighs of network by calculating the error in terms of returning and calculation of error of each neuron. As shown in Fig.1, MLP networks are constituted of several sections: inputting section which is directly connected to data, middle layers which are also called Hidden Layers, output layers which are equal to the number of classes in view of number of neurons, neurons which are constituted of Activation Functions and weighs which indicate the degree of importance of one input.

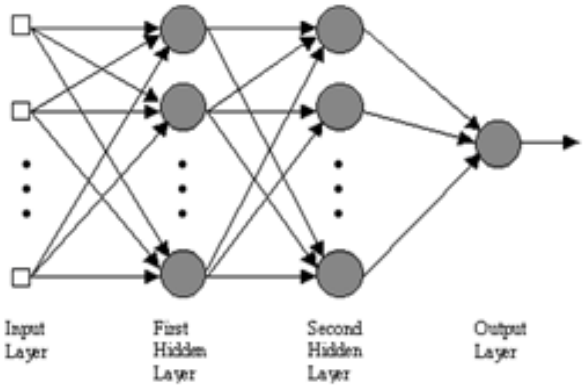

Figure 1. A scheme of MLP network

Moreover, BP algorithm adds another parameter to the aforesaid parameters called Learning rate. Since this type of network and algorithm have equal and predefined principles, the difference seen in the results is due to the difference in the amounts of network parameters and adjusting them by error will result in questioning the type of network. Considering the aforesaid issues, the amounts of parameters are explained.

- Input: number of inputs is always equal to the number of features and here it is 18.
- Number of internal layers: In this paper, number of hidden layers starts from one layer and will finally end in two layers.
- Number of neurons of external layer is equal to the number of classes which is 7 for this database.
- Number of neurons of hidden layers is 5 and 10 neurons for each hidden layer, respectively.

Moreover, in case activator function is Antisymmetric (symmetric against the origin, odd function); learning rate with BP algorithm will be higher. As we know, the standard logistic function has not this form while hyperbolic tangent function with a=1.7159 and b=2/3 coefficients enjoys these conditions [6]. First of all, some amounts should be considered for the weighs to start program performance. It is better that these amounts have zero averages and variance amounts of weighs are equal to $\sigma_w = m^{-\frac{1}{2}}$ (m: number of synoptic relations of a neuron). Here, initial amounts of weighs are selected within an interval of [-0.5 +0.5].

In addition to the above items, network learning method can also play an important role in the final results. Basically, Sequential learning method in which weighs are modified after providing each example, will offer better results in this algorithm. Further to this, training is preferred to sequential method in view of operations because it requires less local storage of weighs for each connection. Moreover, searching for a weight space is made randomly by providing instances to the network on a natural basis. This in turn lessens the probability of network to be trapped in the local minimums. This is while in Batch Learning method, weighs are modified after providing all the examples. However, learning speed in both methods depends on the parameter of learning rate. So that learning speed decreases by having a low learning rate and vice versa. Here, learning rate starts from 0.01 and then decreases in the middle of training.

V. Radial Basis Function Network

In fact, this type of network is a special type of MLP network with only one hidden layer which is shown in Fig.2. Moreover, in contrast with BP algorithm, modification of network parameters starts from input towards output. As it is clear from its name, the main kernel of the neurons of this network is developed based on radial functions such as Gaussian Functions (3). Since the number of hidden layers is limited to one layer, the most important parameters of this network are therefore limited to Number of neurons or internal layer kernels, type of activator function in each neuron, Radius and centers of activator functions and weighs.

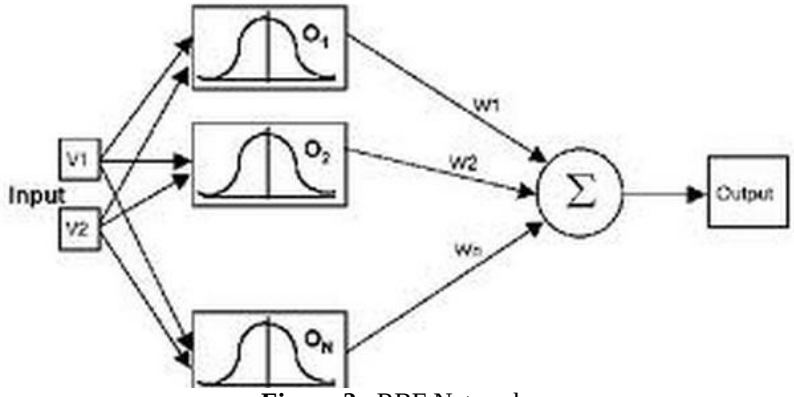

Figure 2. RBF Network

In this paper, RBF networks are tested with 10, 15 and 20 neurons all of which use Gaussian Functions. Moreover, with the initial amounts, the centers are randomly selected from several examples based on which the initial amounts of variance or radius of each neuron are calculated considering (5)

$$\sigma = \frac{d}{\sqrt{2M}} \tag{5}$$

where d is the space between selected centers and M is the number of neurons. Furthermore, initial amounts of weighs are similar to MLP-BP network. Since three parameters are modified during learning process, three parameters are required to determine learning rate. According to the obtained results, the less the learning rate is for the centers, the better the results of the network will be. Here, three initial amounts are considered for the three mentioned parameters according to table(2).

Table 2. RBP Learning rates

Learning Rate	Value
Weight rate	0.001
Center rate	0.0001
Variance rate	0.001

VI. K-Nearest Neighbors Algorithm

As it was said at the beginning, this algorithm is outside of neural networks. In fact, this method acts based on Euclidean distance between the samples. Despite neural networks which have two processes, namely training and testing, this method performs all stages within just one stage. The goal of using this algorithm is to establish a basis for the networks used in this paper. In addition, different nature of this method results in application of a series of different processes in establishing the inputting data. Since the best results obtained by this algorithm were examined in testing the studied database based on K=3 neighborhood, this amount will be considered as a basis for comparison.

VII. Results

1. Image classification database

UCI image classification database is used to check the results of the proposed method. The database has 2310 instances and 7 output classes. Each instance is in terms of a 3*3 area with 19 features [3] .

2. Simulation

Different structures of networks are tested, in the manner that the aforesaid database is used for all of them. Finally, after comparing the results of RBF and MLP-BP networks, the best results of which are compared to the results of KNN algorithm. First of all, accuracy results are provided for 4 different MLP-BP neural networks, so that the first one has one hidden layer with 5 neurons and the second one has the same layer with 10 neurons. This is while by adding another layer to the first and second network with the same number of neurons, the third and fourth networks are obtained, respectively. As seen in Fig.3, the network has offered the Best result among other configurations with two hidden layers each with 10 neurons. However, from practical viewpoint, considering the results of the second network and since it has less layers and less neurons and as a result, it needs a smaller memory, it is preferred to other configurations for implementation in the embedded systems.

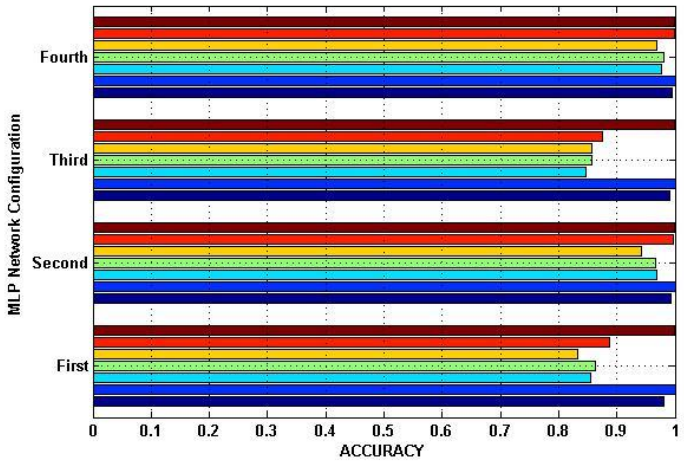

Figure 3. MLP Network Results

The results for three different configurations of RBF network are then described, in the manner that the first one has 10 neurons and the second and third ones have 15 and 20 neurons, respectively. As seen in Fig.4, the third configuration is better in four classes as compared to other configurations and it is a little different with the first and second networks among others, but generally, RBF network with an average accuracy of 84.47% is significantly different with MLP-BP network with an average accuracy of 98.84%, in the manner that in order to prove the function of MLP-BP network, its results are provided in table(3) beside the results of KNN algorithm. By examining the results in table(3), it is concluded that MLP-BP network has had a better function even better than KNN algorithm which is based on Euclidean distance, in the manner that it almost has 100% accuracy in four classes and their minimum for other classes is 96.7%. Moreover, by comparing the results in [3], it can be seen that our proposed method has a better function compared to that method.

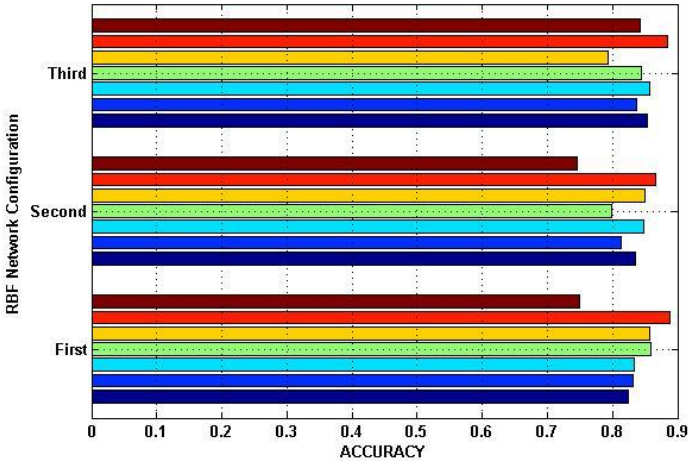

Figure 4. RBF Network Results

Table 3. MLP versus KNN results

		Classes						
		7	6	5	4	3	2	1
MLP	Sensitivity	0.985	1.00	0.845	0.94	0.95	1.00	0.995
	Specificity	0.996	1.00	0.997	0.988	0.97	0.999	1.00
	Accuracy	0.995	1.00	0.975	0.981	0.969	0.999	0.999
KNN	Sensitivity	0.965	1.00	0.86	0.810	0.930	1.00	0.995
	Specificity	0.994	1.00	0.986	0.992	0.961	0.991	1.00
	Accuracy	0.990	1.00	0.968	0.966	0.957	0.992	0.999

VIII. Conclusion

In this paper, a new look is given to image classification using neural networks. Furthermore, by using different networks with variable configurations and also by comparing the results With non-neural algorithms, it is shown that MLP-BP algorithm has a better function as compared to other aforesaid networks. The importance of this issue is further shown by describing data preparation method for the network. In addition, as the future work, we first want to completely apply the preprocessed methods on the database to decrease the number of features if there is any dependency between the features. We also want to use evolutionary neural networks such as genetic algorithms to increase the space for searching for number of layers and number neurons in MLP-BP networks.

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