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Implementation of Backpropagation Algorithm: A Neural Network Approach for Pattern Recognition

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Abstract—A pattern recognition system refers to a system deployed for the classification of data patterns and categorizing them into predefined set of classes. Various methods used for recognizing the patterns are studied under this paper. The objective of this paper is to study the various techniques for recognizing the complex patterns, identify and implement the best suitable technique with its merits over the other techniques and analyze the result in order to achieve the accuracy in the designed system.

Keywords— Backpropagation Algorithm, Multilayer Perceptron, Neural Network, Pattern Recognition,Supervised Learning,Unsupervised Learning, Error tolerance Factor.

I. INTRODUCTION

A Software design pattern refers to digital information represented in the form of signals like audio, video, voice, image or a character that resembles the real data. Its recognition refers to the process of classifying the patterns into a set of predefined classes based on observations or some priori knowledge of the system. Infact, the domain of pattern recognition is extended to the field of biometrics, detection of credit card frauds, data mining, evaluating audio/video and speech signals, image processing and handwritten character recognition, retrieval of multimedia databases, face recognition, web searching, system security, medical diagnosis, face detection, email spam filtering , etc.

Various approaches are deployed for pattern recognition depending upon the type of pattern selected. These include statistical approach, Syntactic or structural approach, hybrid approach, template matching and Neural Network approach. The statistical approach represents a pattern into a fixed length vector occupying mutually exclusive regions in a d-dimensional space in the spatial view. In this approach, the patterns are classified into different classes using the probability distribution functions for establishing the the decision boundaries in the feature space.

In the Syntactic approach, a pattern is represented as a collection of sub patterns referred to as base patterns and the interconnections among these base patterns are established.The third kind of approach called the hybrid approach is actually a combination of the above two approaches to be used at appropriate stages of pattern recognition.

Eventually evolved the neural network approach which is based on the concept of artificial neurons and their interconnections forming a network used to determine the data patterns through the evaluation of input-output relationships. There are various algorithms defined under this approach for different applications which include Radial Basis Function (RBF) Networks, Self Organizing Map (SOM), Feed Forward Network and Back Propagation Algorithm.

The neural network approach is advantageous over other techniques used for pattern recognition in various aspects. The performance and hence, the efficiency of the network can be increased using feedback information obtained from the difference between the actual and the desired result. This information will then be used to adjust the interconnections between the neurons at the input layer in order to matcht the actual result with the desired one. Additionally, the algorithms defined under this technique have self-organizing, self-adaptive characteristics enhancing the efficiency of the pattern recognition system.

II. LITERATURE REVIEW

According to author Jayanta Kumar Basu ,Debanath Bhattacharyya from Computer Science and Engineering Department of Heritage Institute of Technology, Kolkata , India on "Use of Artificial Neural Network in Pattern Recognition " [1], various methods are used to perform the pattern recognition task however Artificial Neural Networks forms the most commonly used method to recognize the patterns.The algorithms defined under Artificial Neural Networks include feed-forward network, Self-Organizing Map or Kohonen Network ,back propagation algorithm, etc which are used at different stages of pattern identification and classification.In the paper, the basic design of a pattern recognition system was explained along with the related issues involving the definition of pattern classes, sensing environment, pattern representation, feature extraction and selection, classifier design and learning, selection of training and test samples, and performance evaluation.

On the similar ground, the author Sergiy Stepanyuk from Department of Applied Mathematics from Volyn University on "Neural Network Information Technologies of Pattern Recognition" [10] inferred that the main problems in many pattern applications are the presence of abundant features and the difficulty of managing concurrent variations in position, orientation and scaling which clearly indicated the need for more intelligent, invariant feature extraction and

feature selection mechanisms.

The author Lin He, Wensheng Hou and Chenglin Peng from Biomedical Engineering College of Chongqing University on "Recognition of ECG Patterns Using Artificial Neural Network" [11] defined two phases in the artificial neural network: one is the training phase and the other one is the test phase. In case of training phase, the connection weights are automatically adjusted in order to map the input to the corresponding output whereas in the test phase, the already trained network is testing against a sample of random patterns. The ECG Patterns are recognized using three different neural network models which involve the Self -Organizing Map Network, Back Propagation Algorithm, and Learning Vector Quantization.

In the paper "Pattern Recognition Properties of Neural Networks" by author John Makhoul, BBN Systems and Technologies [12], the several pattern recognition properties of neural networks were stated and reviewed especially class partitioning and probability estimation properties. One of the prerequisite criteria of the pattern recognition system is to partition the input feature space into regions, with one region, possibly noncontiguous, associated with each of the classes.

McCullouch and Pitts[8] suggested a computational model referred to as threshold logic for neural networks based on mathematics and algorithms. This model evovled two distinct approaches for neural networks: one based on biological processes in the brain and the other conceptualizing the application of neural networks to artificial intelligence.

Neural network research stagnated after the publication of machine learning research by Minsky and Papert [8] (1969). They pointed two key issues related with the neural networks. The first issue was that the single-layer neural networks were not preferrable for processing the exclusive-or circuit. The second significant issue was that the computers were not efficient enough to effectively cope up with the long processing time required by large neural networks. The Neural network research slowed until the computers achieved a greater processing power.

III. NEURAL NETWORK MODEL

A neural network model is a powerful tool used for various real life applications like time series predication, sequence detection, data filtering, pattern recognition and other intelligent tasks as performed by the human brain.There are various approaches defined under neural network for pattern recognition and depending upon the type of the learning mechanism applied to generate the output from the network, the appropriate approach is selected. The learning can be categorized as Supervised leaning in which the desired result is known to the system i.e. the system is trained with the priori information available to obtain the desired result. If in case the computed result does not match the desired result, then the difference between the two is determined which is used to modify the external parameters required to generate the correct result. The most popular supervised neural network model is Multilayer Perceptron (MLP) which can be used when prior knowledge of the relationships between inputs and targets are known.

If the network is based on the unsupervised learning, then the output is generated based on priori assumptions and observations however, the desired result is not known to the system. Kohonen Self-organizing map/Topology-preserving map (SOM/TPM) network is based on unsupervised learning rule which attempts to learn and analyze the structure of the patten.

The third type of learning is reinforcement learning in which the behaviour of the network is predicted based on the feedback from the background environment though practically, supervised and unsupervised learning rules are more commonly followed for implementation of the network design.

IV. PERFORMANCE ANALYSIS OF THE PATTERN RECOGNITION SYSTEM

The performance of the pattern recognition system depends on the type of approach deployed to perform the identification and classification of the input data patterns. If the network model is based on the unsupervised learning approach, then there is no priori knowledge about the predefined set of classes and the input data is distinguished into groups based on structural characteristics or any other similar characteristics which sometimes can be a tedious task. However, if the model is based on supervised learning approach, then the system developed is more accurate and efficient since the network is already trained with the desired result.Therefor, even in case of mismatch between the computed result and the desired result, the difference between the two is used to adjust and generate the desired result.
On the basis of study of the various systems using the proposed learning rule, the algorithm defined under supervised network model is commonly used in various fields of artificial intelligence systems. One such algorithm is back propagation algorithm which is based on the concept of improving the network performance by reduction of error from the output data.

V. IMPLEMENTATION OF BACK-PROPAGATION ALGORITHM

The MultiLayer Perceptron network based on supervised learning approach is trained using the backpropagation algorithm. This network consists of three layers: input layer, output layer and the intermediate layer i.e. the hidden layer.These layers consists of neurons which are connected to form the entire system. Weights are associated with the connections which marks the signal strength. The weight values are computed based on the input pattern and the error

function back propagated to the input layer. The role of hidden layer is to update the weight functions periodically under its value is minimized or reaches an acceptable or error tolerance factor.

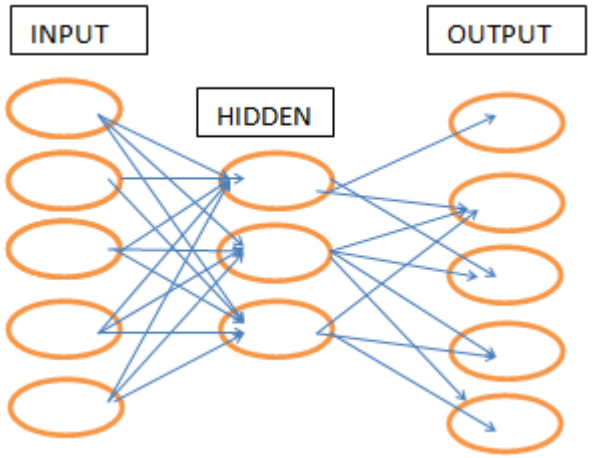

Fig 1 shows the neural network model with 5 neurons in the input layer, 3 in the hidden layer and 5 in the output layer.

The backpropagation algorithm is stated as follows:

1) The backpropagation algorithm operates in two phases: Initially, the training phase in which the training data samples are provided at the input layer in order to train the network with predefined set of data classes. Eventually, during the testing phase, the input layer is provided with the random test data for predicting the applied patterns.
2) Since this algorithm is based on the supervised learning approach, therefore the desired result is already known to the network. In case of discrepancy between the computed result and the desired result, the difference between the two is backpropagated to the input layer so that the connection weight functions of the perceptrons are adjusted in order to bring the error upto the error tolerance factor range.
3) This algorithm operates in either of the 2 modes: Incremental mode in which each propagation is followed immediately by the weight adjustment or batch mode in which the weight updations take place after various consecutive propagations. Usually batch mode is preffered over incremental mode due to less time consumption and less no. of propagative iterations. In this algorithm, a pattern is presented at the input layer.The neurons at this layer pass the pattern activations to the next layer neurons, which is actually the hidden layer. The outputs at the hidden layer neurons are generated using a threshold function along with the activations determined by the weights and the inputs. The threshold (saturation)function is computed as: 1/ (1 + exp(-x)) where x is the activation function value which is computed by multiplying the weight vector with the input pattern vector.
4) The hidden layer outputs become input to the output layer neurons, which are again processed using the same saturation function.
5) The final output of the network is eventually computed by the activations from the output layer.
6) The computed pattern and the input pattern are compared and in case of discrepancy, an error function for each component of the pattern is determined, and based on it the adjustments to weights of connections between the hidden layer and the output layer are computed. A similar computation, still based on the error in the output, is made for the connection weights between the input and hidden layers. The procedure is repeated until the error function reaches the range of the error tolerance factor set by the user.
7) The advantage of using this algorithm is that it is simple to use and well suited to provide a solution to all the complex patterns. Moreover, the implementation of this algorithm is faster and efficient depending upon the amount of input-output data available in the layers.

A.Training Mode: In this mode, the network is trained with the training. txt file in which the patterns are represented in form of 5*7 matrix of binary information showing 1 for the dark spots where the pattern overlaps with any coloum or row of the matrix and 0 for the light spots where there is no overlapping or vice versa.

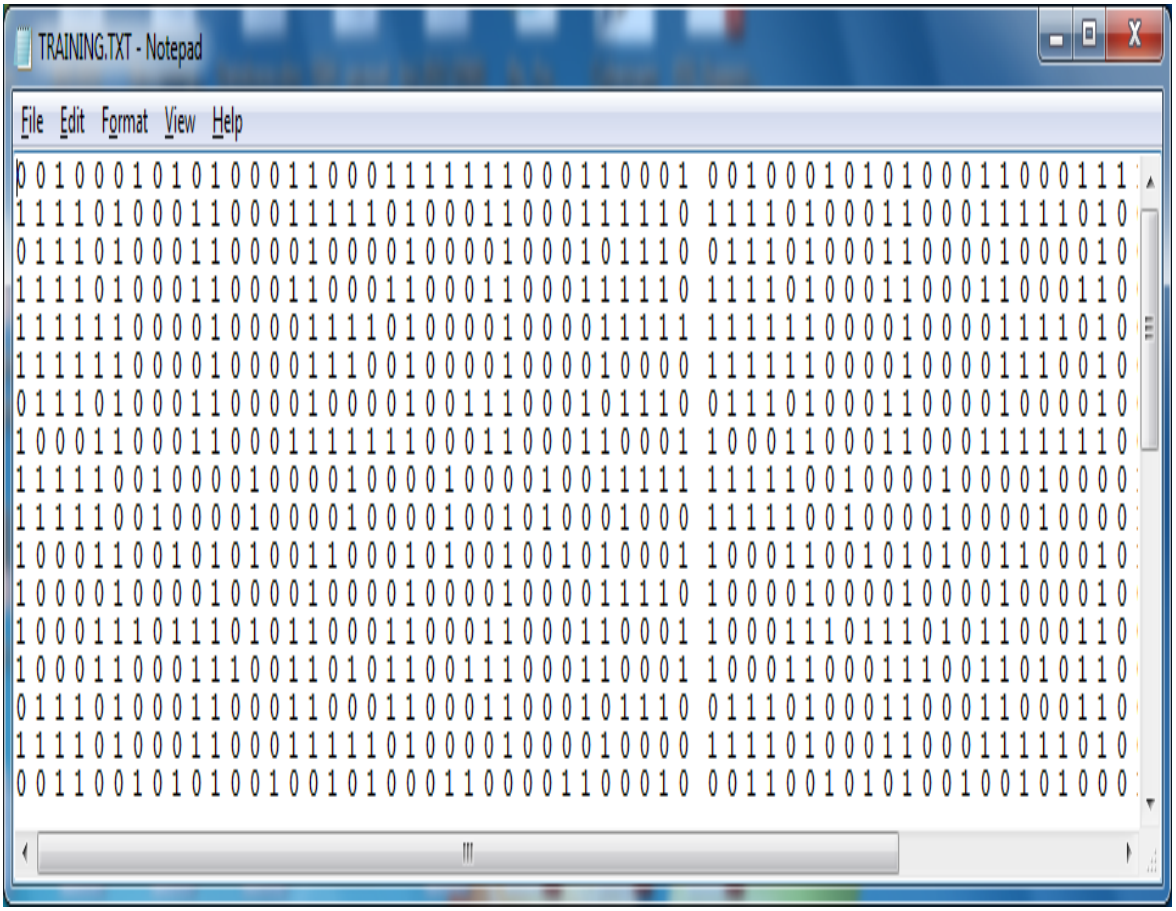

Fig 2. Training.txt File is provided as an input at the training mode

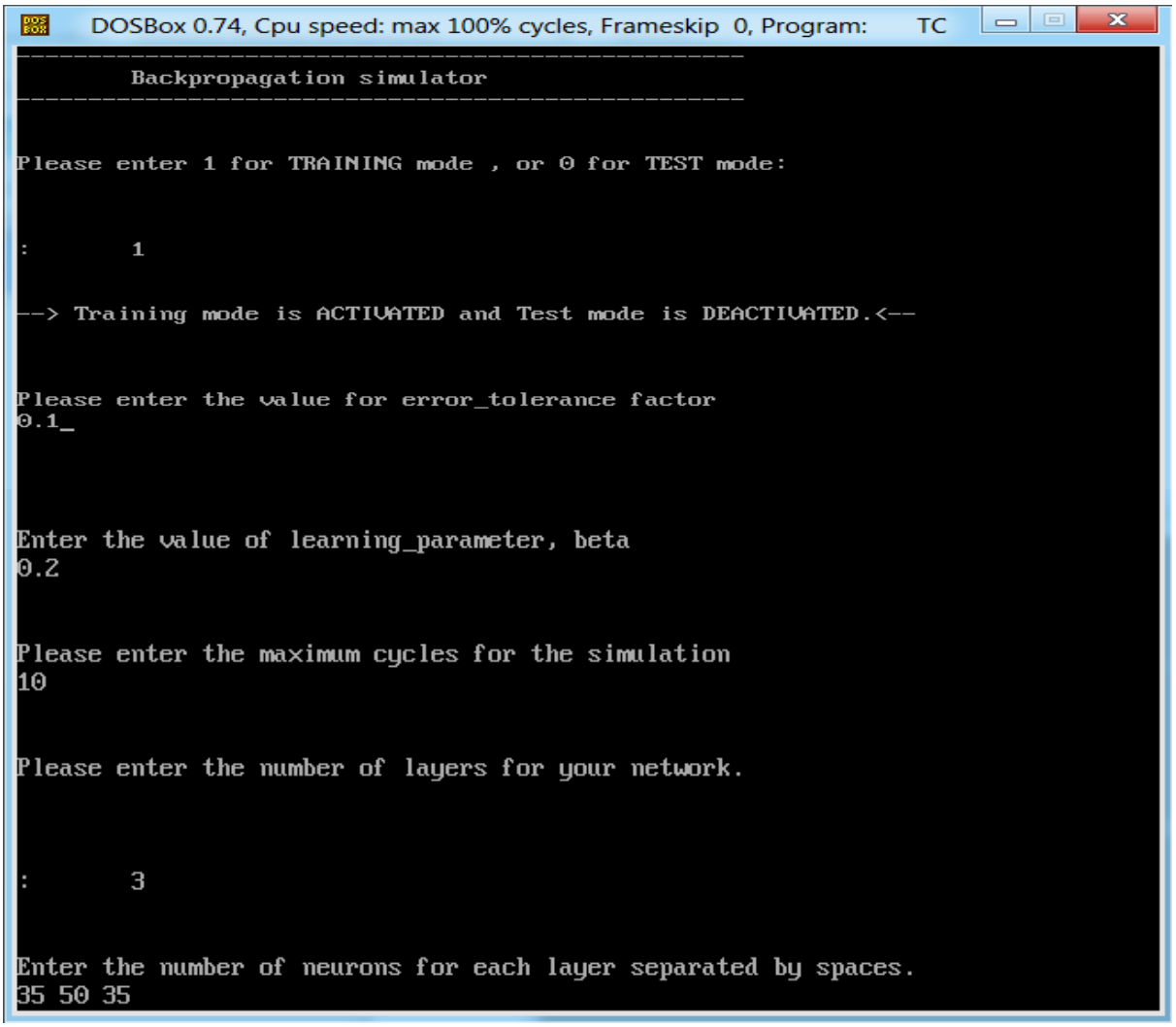

Fig 3. In the given below figure, the value of error tolerance factor and learning parameter along with the no. of simulation cycles , no. of layers in the network and no. of neurons in each layer is selected.

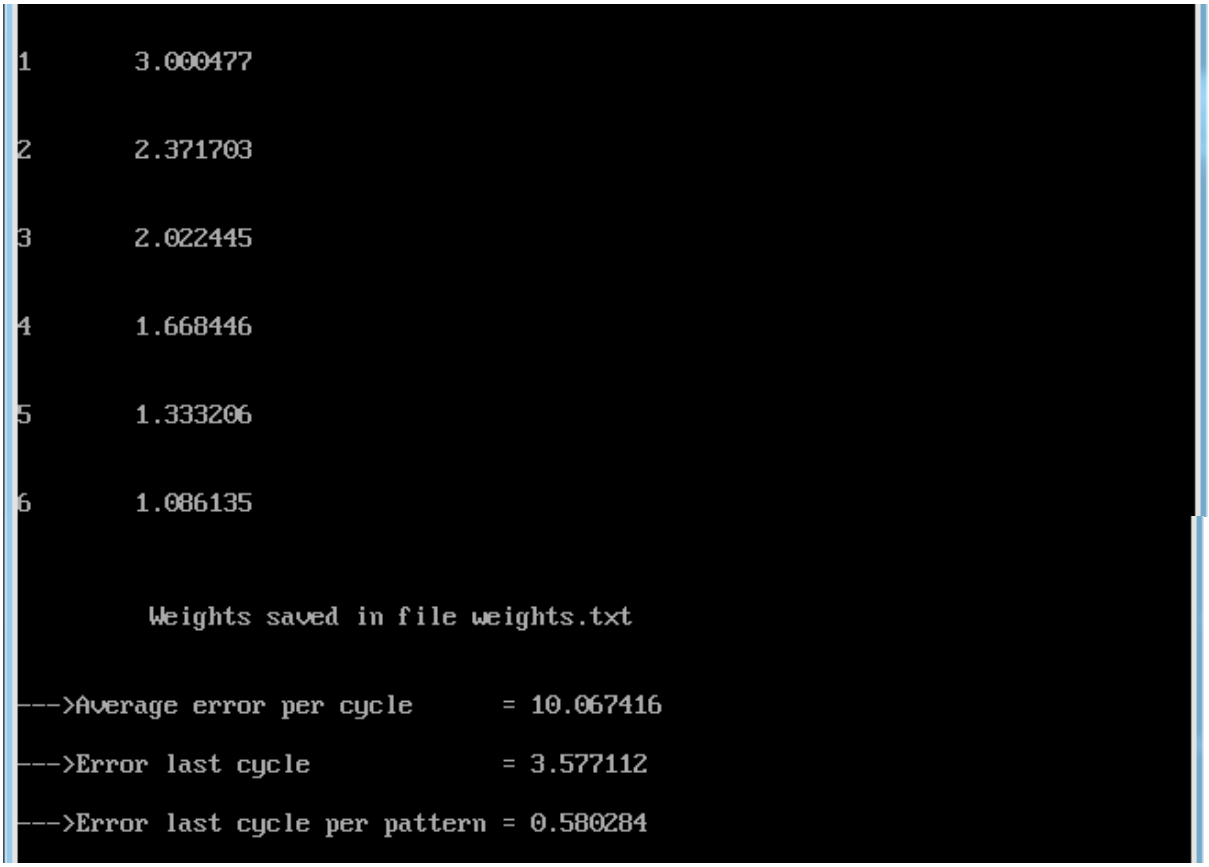

Fig 4. The above given values in fig 2 are used to compute the weight function along with average error per cycle, error last cycle and error last cycle per pattern as shown below and these values are then stored in Weight.txt.

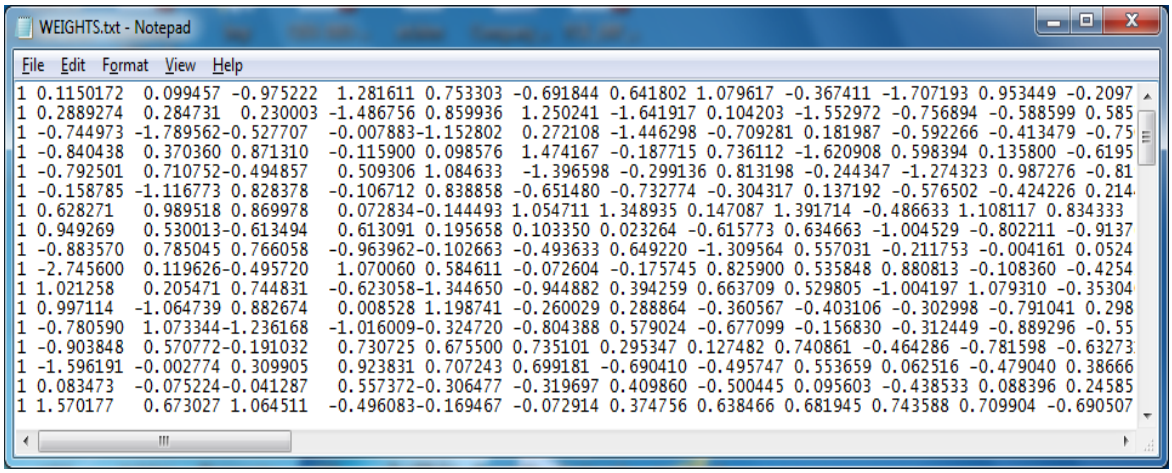

Fig 5. Weights. Txt file is generated as an output of the training mode.

B. Test Mode : In the test mode, the weight.txt file generated during the test mode is given as input to the system along with test.txt file which consists of the pattern to be recognized to the already trained network.

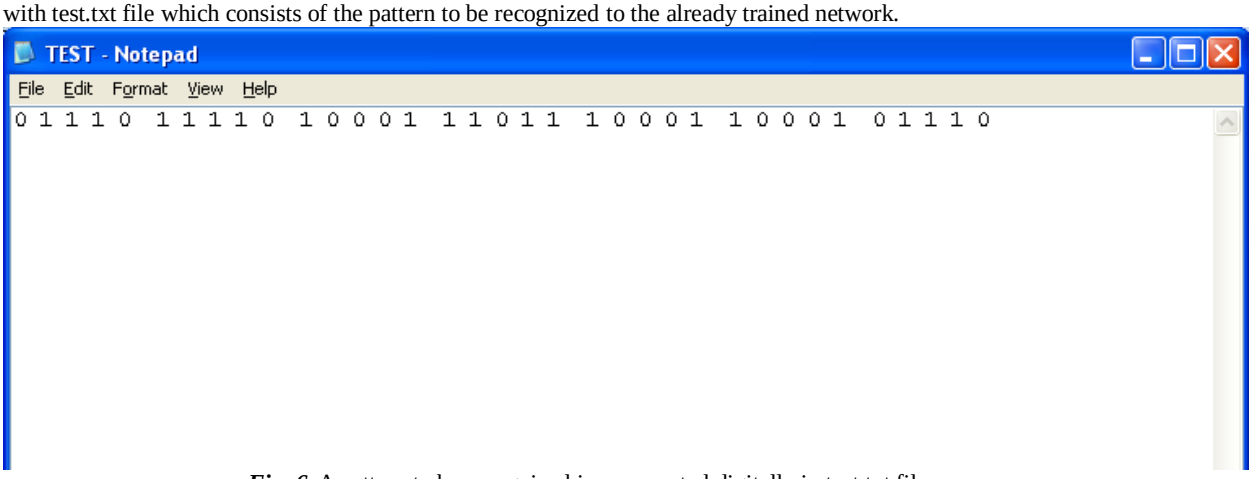

Fig 6. A pattern to be recognized is represented digitally in test.txt file

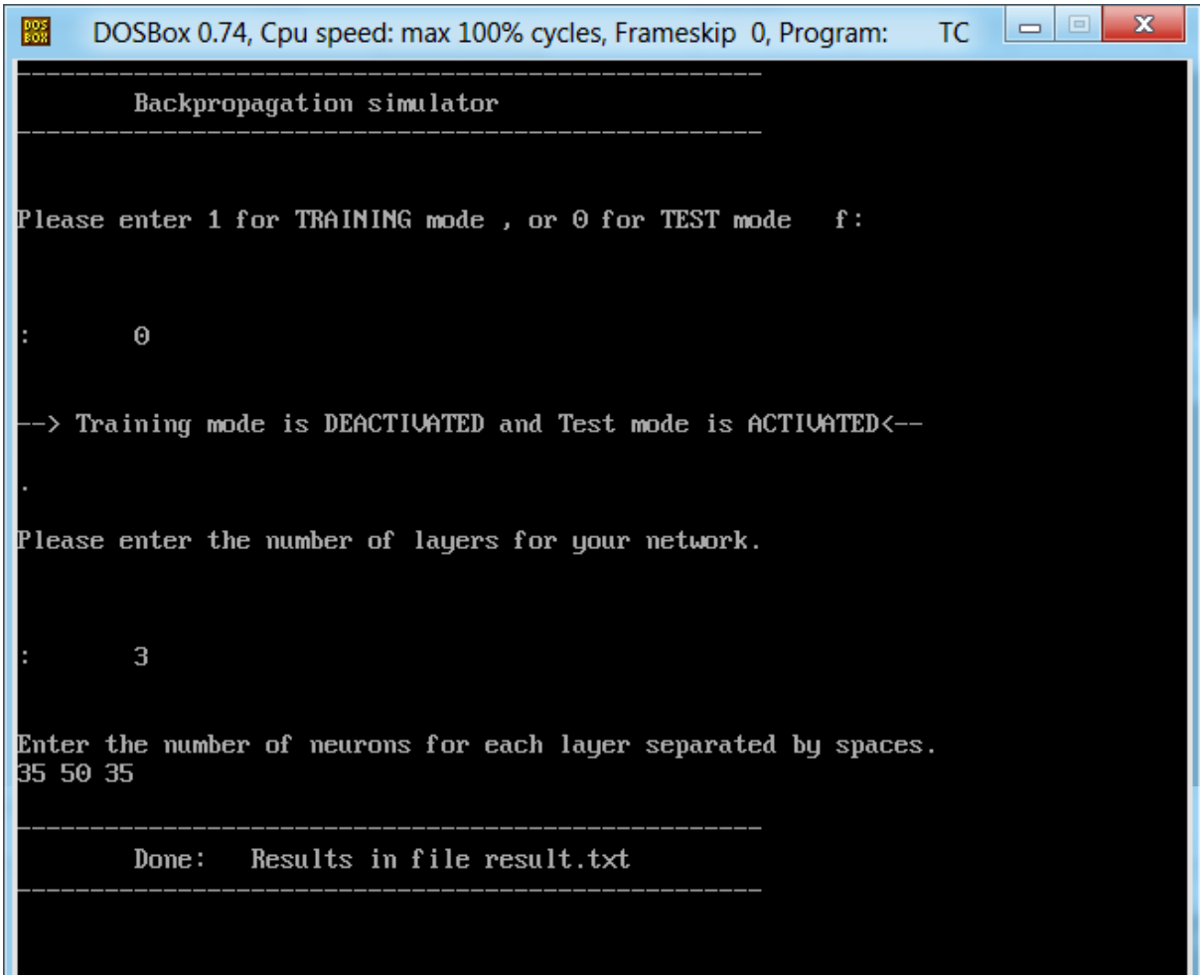

Fig 7. In the given below figure, the test mode is activated in which , just by entering the details regarding the no. of layers and no. of neurons in each layer the threshold function is computed which is saved in result.txt.

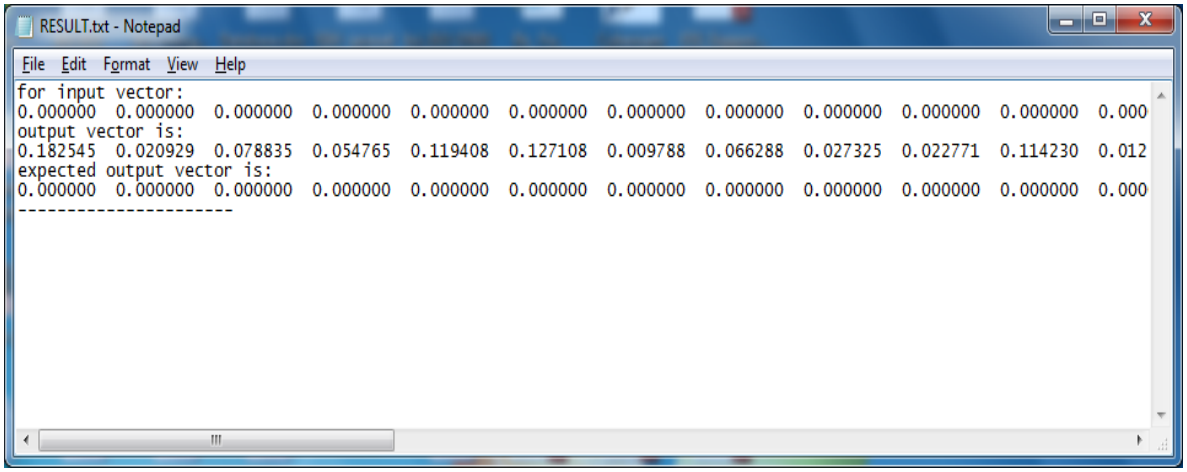

Fig 8. The result.txt file contains the input pattern vector as well as the output pattern vector representation which is matched to obtain the correct result.

VI. RESULTS & CONCLUSION

The backpropagation algorithm repeats the procedure of weight adjustments until the error is reduced to the negligible amount and reaches the error tolerance range.This technique approach is better in performance over other techniques due to high accuracy rate for complex pattern recognition, adaptive learning as well as better tolerance factor to fault even though more time may be required to train the network for very complex patterns.
The actual output vector as well as the expected output vector is provided in the Result.txt file which shows the discrepancy between the two in order to perform the weight updations on the interconnections.

VII. FUTURE SCOPE

The neural network methodology is used in various real life applications including data mining, web security, medical diagnosis, data filtering, sequence detection,etc .This technique works as a sequential learning machine taking the input patterns one by one for recognition but as a future prospect, work will be carried to generate high level networks for recognizing concurrent patterns. Also, the dynamic characteristics of the neurons at the input and the output layers will be explored and taken into consideration in the near future.

VIII. REFERENCES

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