ISSN 2229-5518

Backpropagation Algorithm: An Artificial Neural Network Approach for Pattern Recognition

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Abstract— The concept of pattern recognition refers to classification of data patterns and distinguishing them into predefined set of classes. There are various methods for recognizing patterns studied under this paper. The objective of this review paper is to summarize the methods used **in** various stages of a pattern recognition system and identify the best suitable technique with its advantages over other techniques to recognize the complex patterns along with other real-life applications.

Index Terms— Artificial Neural Network, Backpropagation Algorithm, Multilayer Perceptron, Pattern Recognition, Supervised Learning, Reinforcement Learning, Unsupervised Learning.

1. Introduction

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

There are various approaches used 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. In case of statistical approach, a pattern is represented as a fixed length vector in the spatial view with features that allow the vector to occupy mutually exclusive regions in a d-dimensional space. In this approach, the decision boundaries in the feature space are established using the probability distribution functions which distinguish the patterns from the different classes.

The Syntactic approach focuses on the analogy of the complex pattern i.e. in this approach, the pattern is represented as a collection of sub patterns known as base patterns and the interconnections among these sub patterns are defined.

The third kind of approach is known as the hybrid approach which is actually a combination of the above two approaches to be used at appropriate stages in areas of pattern recognition.

Last but not the least, the neural network approach is based on the concept of artificial neurons and their interconnections used to determine the data patterns through the evaluation of input-output relationships. There are various algorithms defined under this approach like Radial Basis Function (RBF) Networks, Self Organizing Map (SOM), Feed Forward Net work and Back Propagation Algorithm used in various Applications.The neural network technique is advantageous over other techniques used for pattern recognition in various aspects. The performance of the network can be increased using feedback information obtained from the difference between the actual and the desired output. This information will then be used to adjust the connections between the neurons at the input layer so that the actual result matches the desired one. Moreover, the algorithms defined under this technique which have self-organizing, self- adaptive characteristics add to the efficiency of the network for pattern recognition.

2. Literature Review

According to 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],there are various methods used to recognize patterns however Artificial Neural Networks forms the most commonly used method to perform pattern recognition task. Various Algorithms are defined under Artificial Neural Networks like feed-forward network, Self-Organizing Map or Kohonen Network ,back propagation algorithm, etc which are used at different stages of pattern identification and classification.The basic design of a recognition system was explained taking into consideration 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 Recog-

nition" [10] concluded that the main problems in many pattern applications are the abundance of features and the difficulty of coping with concurrent variations in position ,orientation and scale. This clearly indicates the need for more intelligent, invariant feature extraction and feature selection mechanisms. On the basis of reviewed literature open problems such as implementation of neural circuit in recent analog and digital hardware, designing stable neural network models for specific tasks of pattern recognition, associative neural network methods for better resolution of tasks of pattern recognition are defined.

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] stated that the artificial neural network work in two phases: one is the training phase and the other is the test phase. In the training phase, the connection weights are automatically adjusted to map the input to the corresponding output whereas in the test phase, the already trained network is testing against a sample of patterns. Three different neural network models are employed to recognize the ECG Patterns. These include the Self -Organizing Map Network, Back Propagation Algorithm, and Learning Vector Quantization.

In the paper "Pattern Recognition Properties of Neural Networks" by John Makhoul, BBN Systems and Technologies [4], the several pattern recognition properties of neural networks were reviewed especially class partitioning and probability estimation properties .One of the objectives in pattern recognition is to partition the input feature space into regions, with one region, possibly noncontiguous, associated with each of the classes. Given a feature vector that lies in a particular region, the feature vector is classified as belonging to the class corresponding to that region.

McCullouch and Pitts[8] discovered a computational model known as threshold logic for neural networks based on mathematics and algorithms. This model evovled two distinct approaches for neural networks. One approach focused on biological processes in the brain and the other focused on the application of neural networks to artificial intelligence.

Neural network research ceased after the publication of machine learning research by Minsky and Papert [15] (1969). They discovered two key issues related with the neural networks. The first issue was that the single-layer neural networks were not suitable for processing the exclusive-or circuit. The second significant issue was that the computers were not sophisticated enough to effectively handle the long processing time complexity required by large neural networks. Neural network research slowed until computers achieved greater processing power. Also key in later advances was the backpropogation algorithm which effectively solved the exclusive-or problem.

3. Neural Network Model

A neural network model is a powerful tool used to perform pattern recognition and other intelligent tasks as performed by human brain. The neural network approach for pattern recognition is based on the type of the learning mechanism applied to generate the output from the network. The learning can be classified as Supervised leaning in which the desired response is known to the system i.e. the system is trained with the priori information available to obtain the desired output. In case of this type of learning, if the computed output does not match the desired output, then the difference between the two is determined which is eventually used to modify the external parameters required to produce the correct output. The most common supervised neural network model is Multilayer Perceptron (MLP)

If the network is based on the unsupervised learning, then the output is produced based on priori assumptions and observations however, the desired response is not known. Kohonen Self-organizing map/Topology-preserving map(SOM/TPM) network is based on unsupervised learning rule.

The third type of learning is reinforcement learning wherein the behaviour of the network is predicted based on the feedback from the background environment which also forms a part of neural network design approach however supervised and unsupervised learning rules are more commonly followed for implementation of the network design.

4. Performance of the Pattern Recognition System

The performance of the system depends on the neural network model deployed to recognize the patterns in the input data. If the network model is based on the unsupervised learning mode, then there is no knowledge about the predefined set of classes and the input data is classified into groups based on structural characteristics or any other similarity in the characteristics which sometimes can be a tedious task. However, if the model is based on supervised learning, then the system developed is more accurate since the network is already trained with the desired output.

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.

5. Implementation of Back-Propagation Algorithm

The MultiLayer Perceptron network is trained using the back-propagation algorithm.

i. The network consists of three layers: input layer, output layer and the intermediate layer i.e. the hidden layer.

ii. These layers comprises of the neurons which are connected to form the entire network.

iii. Weights are assigned on the connections which marks the signal strength. The weight values are computed based on the input signal and the error function back propagated to the input layer.

iv. The role of hidden layer is to update the weights on the connections based on the input signal and error signal.

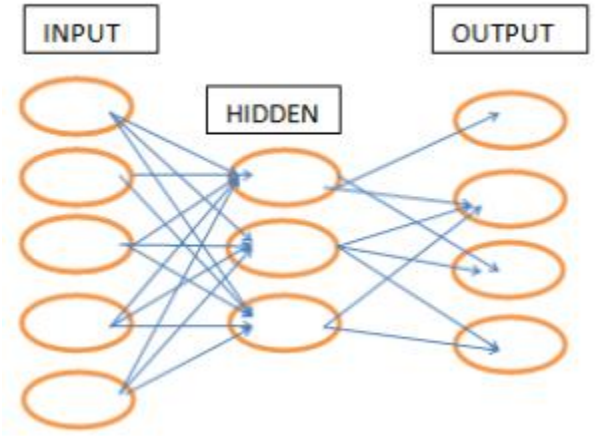

Fig [1] shows the neural network model with 5 neurons in the input layer, 3 in the hidden layer and 4 in the output layer.

v. The algorithm operates in two phases: Initially, the training phase wherein 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 test data for prediction of the applied patterns.

vi. The desired output is already known to the network. Therefore, if in case the computed output does not match the desired output, the difference in the result is backpropagated to the input layer so that the connection weights of the perceptrons are adjusted in order to reduce the error. The process is continued until the error is reduced to a negligible amount.

vii. This algorithm works in either of the 2 modes: Incremental mode in which each propagation is followed immediately by the weight update or batch mode in which the weight updations take place after many propagations. Usually batch mode is followed due to less time consumption and less no. of propagative iterations.

viii. 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.

ix. Moreover, the implementation of this algorithm is faster and efficient depending upon the amount of input-output data available in the layers.

6. Conclusion

Pattern Recognition can be done using various methods but the neural network approach is better in performance than other approaches due to efficient algorithm usage for complex pattern recognition, adaptive learning and better tolerance to fault though more time may be required to train the network for very complex patterns.

7. Future Scope

The neural network methodology is used in various real life applications of data mining, web security, medical diagnosis.This approach 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.

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