INTELLIGENT TARGET LEARNING AND RECOGNITION USING NEURAL NETWORKS

Ali Raza, Assistant Manager (Tech), Ali Zaidi, Assistant Manager (Tech), Zaim Nazir, Assistant Manager (Tech),
Maritime Technologies Complex, Systems Division, Karachi

Abstract— In this paper, an Intelligent Target Recognition System is presented which has the capability of feature extraction as well as classification for accurate results. Target Recognition has evolved as a challenge for the researchers and scientists especially for those who are in the field of Defense. Machine Learning Techniques and Neural Networks are found to be accurate and efficient method for the tasks which involves classification and recognition processes. The classification performance of the Neural Network very much depends upon the number of attributes being considered and analyzed. The more attributes supplied to the Neural Network, the more accurate results are noticed. But this is only true when we are dealing with small number of data. Neural Network tends to loose its simplicity and the Network becomes more complex if the data is huge. To cope up with this problem, Principle Component Analysis (PCA) Technique, also termed as Dimension Reduction Technique is applied. This technique ensures that less dimensional data is sent to the input of Neural Network without ignoring or suppressing the important attributes of the data which are necessary for the Recognition Process. Neural Network involves the process of training the network and then validating as well as testing them for efficient classification. In this paper, Neural Network namely Feed Forward Back Propagation (FFBP) Neural Network along with other techniques are used for analysis and classification of data and conclusions are made according to the results evolved.

I. INTRODUCTION

This paper will introduce an Intelligent Target Recognition System and provide a detailed analysis of the techniques used with experimental results. Automatic identification and classification of far fetched targets in noisy environment can be a challenging task. Identification performed by human, may take a lot of time and there may be some issues of accuracy involved in it if the user/operator is not well trained or experienced. And if the Data set contains many attributes or dimensions, then the task to manually identify a target could prove to be a heavy workload even for a human expert.

Target Recognition failure may result in uncontrollable events and disasters when it comes to play in defense applications. Therefore, if we analyze this problem by using Neural Network techniques, the system becomes capable of predicting the characteristics of the target efficiently and proves helpful to cope up with the problem of Target Recognition Failure.

The two major factors of Target Recognition process are Features extraction and classification [1]. Feature extraction is critical in intelligent target recognition. The feature extractor should be able to discriminate between the useful and the unwanted data, to be further processed in classification. There are many problems faced by former approaches of target recognition techniques based on Artificial Intelligence [2]. It requires a large amount of database to compare the characteristics of the target and fails when new circumstances or changing environment is encountered by the system. Neural Networks can intelligently classify the targets and are capable to learn from the new circumstances which ultimately results in an efficient and reliable system.

II. PRELIMINARIES

A. *Target Recognition*

The process of Target Recognition is illustrated in Fig.1 and generally involves:

- Detection of the data received from the target.
- Removing the noise from the data by preprocessing.
- Discriminating between the useful part of the data and clutter (which is not required and will only provide resistance in prediction of the target).
- Feature extraction from the processed data in order to provide basis for classification.
- Classification of the target in question, based on the extracted features.
- Supervised learning which involves establishment of a rule by which we can classify new observations into one of the existing classes.

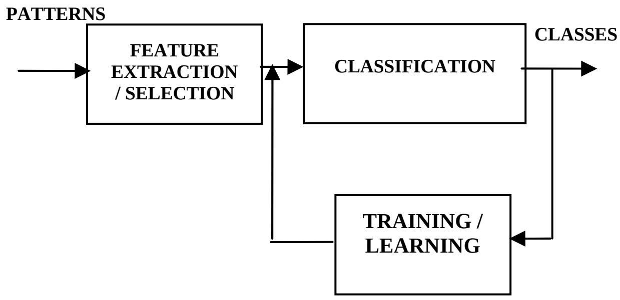

FIG 1: Block Diagram illustrating Intelligent Target Learning and Recognition [3]

B. Feature Extraction

Feature Extraction is an important preprocessing step to reduce the complexity of the data by reducing its dimensionality. In the process of Target Recognition, Feature Extraction has to be implemented with great precision in order to preserve the important components of the data which are necessary for the classification. The process of feature extraction and selection has become very important especially in applications for which datasets with tens or hundreds of thousands of variables are available [4]. Feature Extraction involves extracting the information which is mandatory for detecting the target and to ignore those attributes of data which are not useful for classification and are just acting as noise for our system.

A Neural Network is fed with a dataset for the training process. If this dataset's each component is of high dimension, that is contains a lot of attributes, then it becomes very hard for the network to perform fast calculations and the network becomes complex. And this complexity also affects the classification accuracy. The high dimensionality of the dataset becomes a serious problem to classification. To improve the classification process, it is necessary to go through the process of Feature Extraction before feeding the data in the Neural Network.

Feature Extraction Techniques such as Neural Discriminating Analysis (NDA) and Principal Component Analysis (PCA) extracts information from the data which is necessary for classification and reduces the dimension of the data efficiently for accurate classification and efficient Neural Network.

C. Classification In Target Recognition

After Feature Extraction, the process of classification is performed for detecting the target. The process of classification involves discriminating between several objects and to generalize them in several classes.

When training the network and going through the learning process, a distinction can be made between supervised and unsupervised learning for classification. In Supervised learning for classification, each training data is labeled according to the class of events that the data represents [5]. Perceptron and Multi-Layer Perceptron (MLP) are such models which involves Supervised Learning for Classification.

While in Unsupervised learning for classification, each dataset is not accompanied with its class label [6]. It models the structure of the data either in the form of probability density function or by structuring the data in form of cluster centers and widths. Gaussian Mixture Models and Kohonen Networks are such models which involves Unsupervised Learning for Classification.

The process of classification is an important step in the Target Recognition Technique. The performance of this process is highly dependent on the quality of the target features used [7]. So it may require a lot of computation if the data in hand is huge and high dimensional. On the other hand the performance demand of Target Recognition in the field of Defense continuously requires new and innovative techniques to be developed for high accuracy and low error rate. The ever increasing number and sophistication of modern weapons and war vehicles has resulted in demand of such a Target Recognition System which is fast enough to compute and analyze the incoming data while continuously learning from the new events or objects encountered by it. Extremely efficient and fast system is needed in order to meet these real-time data processing requirements.

Neural Networks have shown some promising results where computing large data in real-time environment is required. They can efficiently perform the classification of targets buried in noisy, cluster rich incoming signals.

D. Dimension Reduction Technique

When the dataset is small with less attributes, the classification performance of several Neural Networks is very efficient and the Network itself is very simple. But when we have to consider large high dimensional data then the classification performed by the Neural Networks according to this data is usually not that efficient and the Network becomes very complex due to large number of attributes of the data [8].

So for better classification of high dimensional data, it is usually considered to apply some techniques which could reduce the dimensions of data while preserving important components of it which are mandatory for efficient classification. Dimension reduction techniques like PCA (Principal Component Analysis) or NDA (Neural Discriminating Analysis) or several other preprocessing techniques may be applied for reducing the attributes of the sonar data for better classification and simple Neural Network. In this paper, PCA (Principal Component Analysis) Technique is used for Dimension Reduction.

E. Principle Component Analysis (PCA)

PCA (Principal Component Analyses) is a way of detecting patterns in a data and identifying the similarities and dissimilarities [9] in it. PCA is a very helpful technique of detecting several patterns in those data which cannot be easily represented and analyzed graphically.

When patterns are identified in a data by using PCA, it's easier to reduce the dimensions of data without much loss of information. Principal Component Analysis involves:

- Computing the Eigen Values and Eigen Vectors from the original Data
- Deciding which Eigen Vectors are significant and forming a Feature Vector
- The Eigen Vector with the highest Eigen value is termed as Principle Component of the data set
- The higher the Eigen value, more significant will be the corresponding Eigen Vector
- Forming a new coordinate system based on the Feature Vector
- Mapping data to the new space
- Reduce complexity of data by reducing its dimensionality

Forming the Feature Vector and extracting the most important components of the data is the task which could be easily and efficiently performed by applying PCA (Principle Component Analysis) Technique. In almost all the Target Recognition systems, it's very important to extract feature vectors efficiently for accurate classification [10]. The Eigen values computed by this technique help in the formation of a Feature Vector which contains the most important attributes of data which are required for accurate classification.

F. Neural Network

Neural Computing is the technology which is based on networks of "neuron-like" units [11] .The technique of Neural Networks has shown some promising results where the task of prediction and recognition is required. The feature that distinguishes Neural Network from other techniques is the ability to internally develop and learn the algorithms and to continuously improve itself for better classification by adjusting its weights. Their learning capability depends on the network topology, learning algorithm and the problem which is to be analyzed.

The architecture of the neural network involves densely interconnected nodes embedded in layers and an arrangement of interconnected Neurons. These networks also contain simple Computational Units like Summation Unit. The Neural Network topology may consist of two or more layers containing several nodes. The Input Layer accepts the data for learning or testing while the Output Layer generates or transfers the outcomes of the computation performed in the layers which resides between Input and Output Layers [6].

G. Feed Forward Back Propagation Neural Network (FFBP-NN)

The most common learning algorithm of Neural Network which provides efficient learning environment and accurate classification is Feed Forward Back Propagation (FFBP) Neural Network. It consists of an Input layer, Hidden Layer and an Output Layer.

The Structure of Feed Forward Back propagation Neural Network is displayed in figure 2.

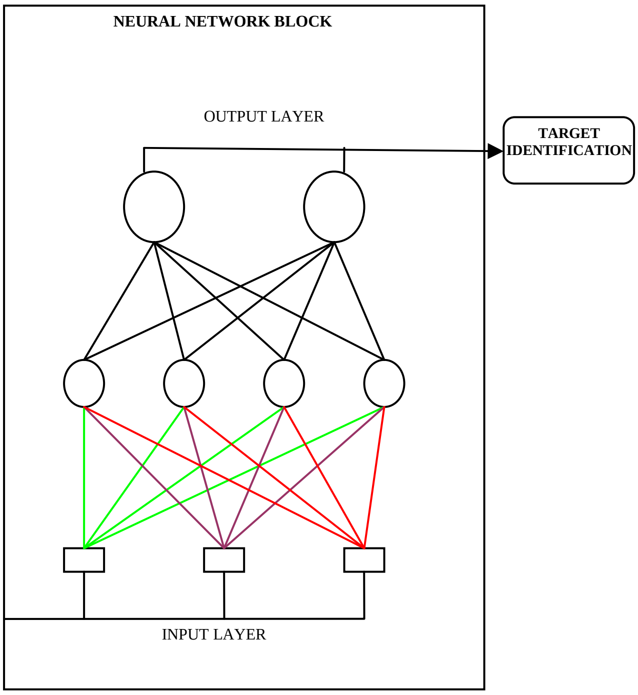

FIG 2: FEED FORWARD BACK PROPAGATION NEURAL NETWORK MODEL

During the training phase of Feed Forward Back Propagation (FFBP) Neural Network, the training dataset is fed in to the Neural Network via Input Layer. The data is then propagated through Hidden layer and comes out of the Neural Network through Output Layer. This process is called the Forward Pass of Feed Forward Back Propagation Algorithm.

The output values originated from the Output Layer are then compared with the actual target output values.

The error between the target output values coming from the Output Layer and the actual output values is calculated and propagated back towards the Hidden Layer. This process is called the Backward Pass of the Feed Forward Back Propagation Algorithm.

In this way, a properly trained Feed Forward Back Propagation (FFBP) Neural Network tends to predict accurately the results of the inputs which it has never seen before. And this Network keeps on adjusting itself during the training phase by comparing the actual and processed

Outputs and forming and efficient Network which can handle undefined inputs with low error rate.

III. METHODOLOGY

Before importing the sonar data which was taken from the UCI Machine Learning Repository [12], output field was arranged in a separate column so that we can perform further computations easily. The dataset has 208 samples from which 111 patterns were obtained by bouncing sonar signals of a metal cylinder at various angles while the remaining 97 patterns were obtained from rocks. The dataset was divided into two subsets: 50% of the patterns were used for learning and the remaining 50% for validation and testing.

A. *Principle Component Analysis (PCA)*

When we have large high dimensional data then the classification performed by the Neural Networks according to this data is usually not that efficient and the Network becomes very complex due to large number of attributes of the data. So for better classification of high dimensional data, PCA (Principle Component Analysis) Technique is applied in order to reduce the dimensions of data while preserving the important components of it which are mandatory for efficient classification.
The Eigen Values and their corresponding Eigen Vectors for the sonar data is illustrated below:

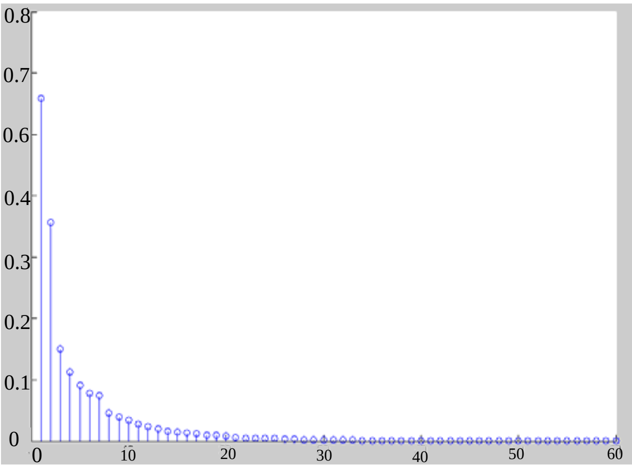

FIG 3: PCA ILLUSTRATION-EIGEN VALUE PLOT OF THE 60 DIMENSIONAL SONAR DATA

From the above plot of the Eigen Values in Fig 3, it can be easily determined which components can be ignored and which dimension is of lesser significance. We can analyze from the above plot that around 20 dimensions are found to be non-zero and the remaining dimensions are just approaching to zero and can be neglected without losing much information.

Analyzing PCA Results

In this section, analysis of the data gone through the PCA technique is done for determining the appropriate number of dimensions to consider for our future experimentation.

Here we will compute some particular number of Eigen Vectors (Dimensions) and will try to regenerate the original data from it. Then we will compare the Original Data and the Regenerated Data so that we can determine any significant losses. The Output plots are shown in Fig.4, 5 and 6 for analysis. Graphs labeled 1 and 2 represents the covariance and Eigen values respectively. On the other hand, graphs labeled 3, 4 and 5 represents Number of Eigen Vectors considered, the Original Data Plot and the Data Plot regenerated from the Eigen Vectors considered respectively.

The graphs shown in Fig. 4 are the outcomes of the PCA technique when applied to the sonar data. The graph labeled 3 shows that 20 Eigen Vectors are considered for this experiment. The graph labeled 4 shows the plot of original data while the graph labeled 5 shows the data regenerated from the 20 Eigen Vectors. By comparing the graphs 4 and 5, we can see that not much data is lost and we could safely consider 20 dimensions out of the original 60 without much bothering about the losses.

In fig 5 and 6, like in fig 4, we have simulated the same measurements but this time number of Eigen Vectors selected are 15 and 10 respectively as can be seen in the graph labeled 3. By analyzing the graphs 4 and 5, we see that the data loss has increased as compared to our previous experiment in which 20 Eigen Vectors were considered.

So by analyzing the above PCA results, it is deduced that considering Eigen Vectors below 20 might compromise the classification accuracy of our Target Recognition System.

B. *Feed Forward Back Propagation Neural Network*

Here, for the Classification and Target Recognition purpose, Feed Forward Back Propagation Algorithm is implemented in MATLAB on the SONAR Data. The SONAR data is propagated in the Network in two different scenarios. After the making of the Network, the first task performed is to determine the outcomes of the Feed Forward Back Propagation Neural Network by using the original 60 Dimensional Data. The second scenario is propagating the preprocessed Data, i.e. the data on which PCA (Principle Component Analysis) Technique is applied, into the Neural Network and then comparing the outcomes of both the cases.

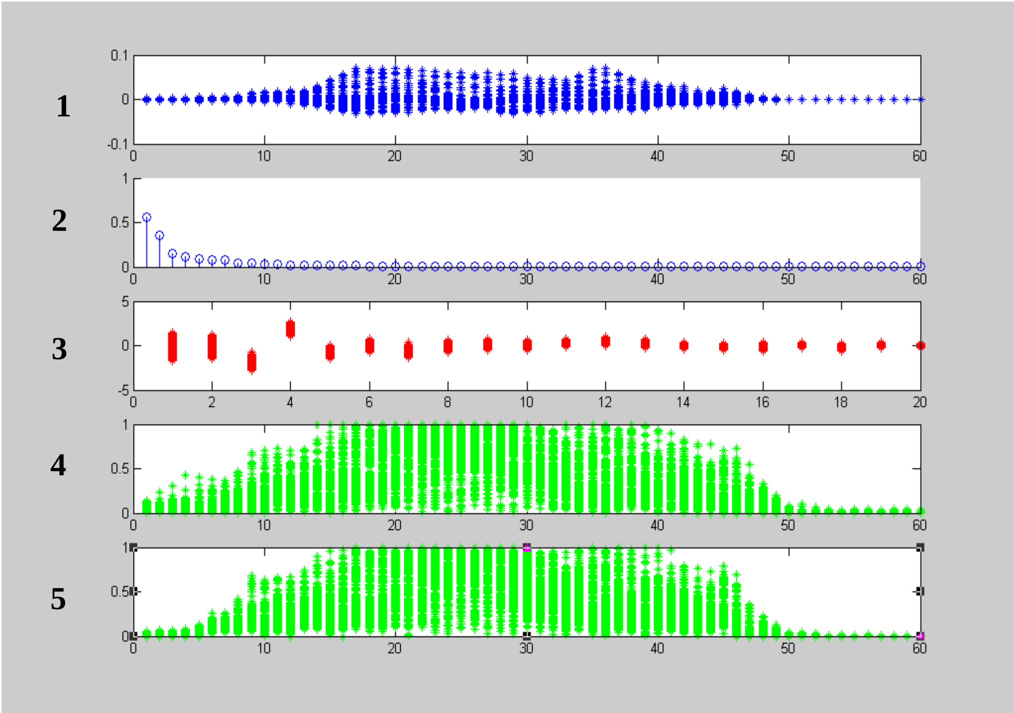

FIG 4: PCA ILLUSTRATION-CONSIDERING 20 EIGEN VECTORS AND FORMING A FEATURE VECTOR MATRIX AND THEN RETRIEVAL OF ORIGINAL DATA FROM IT

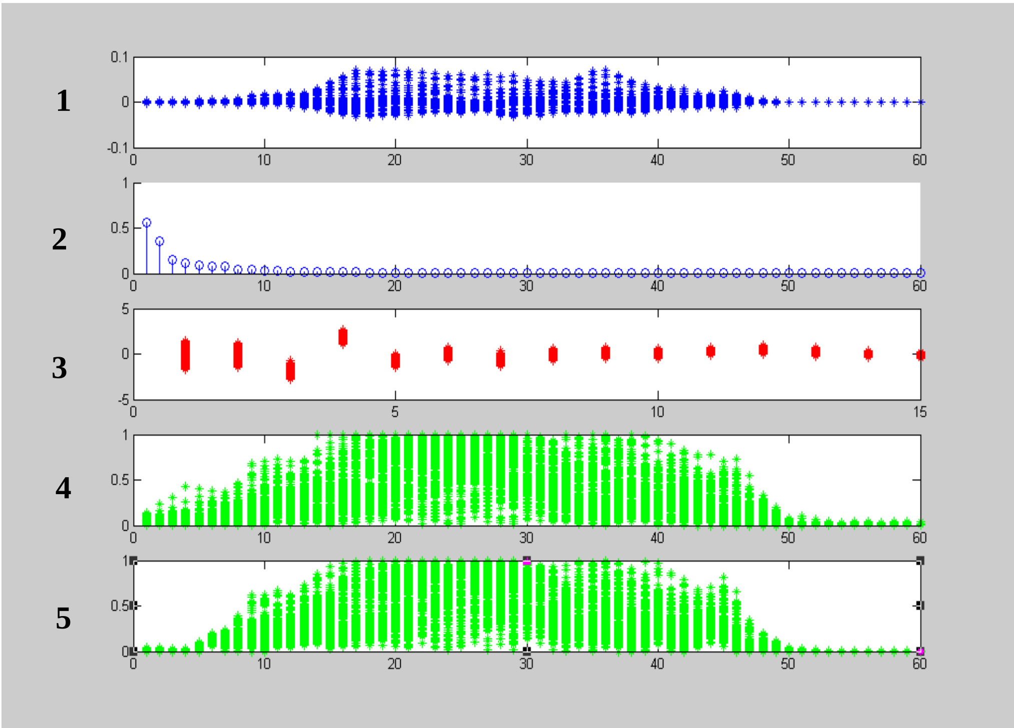

FIG 5: PCA ILLUSTRATION-CONSIDERING 15 EIGEN VECTORS AND FORMING A FEATURE VECTOR MATRIX AND THEN RETRIEVAL OF ORIGINAL DATA FROM IT

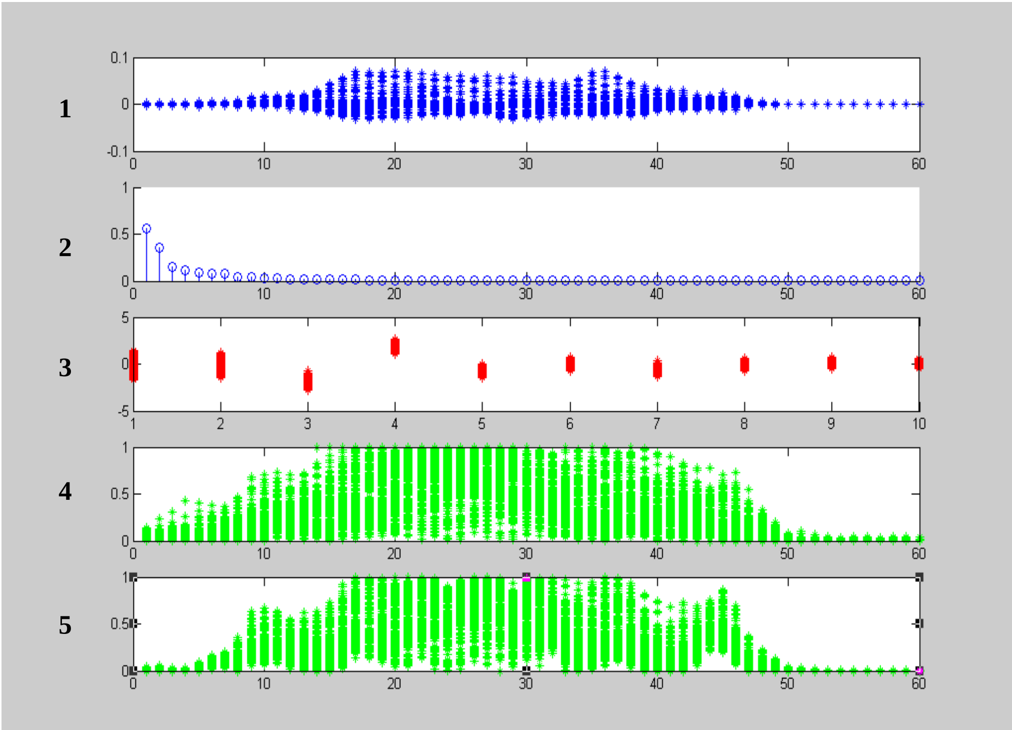

FIG 6: PCA ILLUSTRATION-CONSIDERING 10 EIGEN VECTORS AND FORMING A FEATURE VECTOR MATRIX AND THEN RETRIEVAL OF ORIGINAL DATA FROM IT

Implementing FFBP Neural Network Without Applying PCA Technique

Fig 7 shows a block diagram of a Feed Forward Back Propagation Neural Network implemented without applying PCA i.e. all 60 dimensions of the dataset are considered while training, testing and validation of the FFBP-NN.

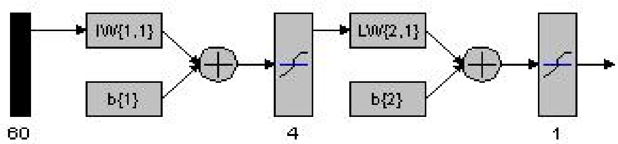

FIG 7: BLOCK DIAGRAM OF THE FFBP-NN WITH 60 DIMENSIONAL SONAR DATA

The performance of the FFBP-NN during the training phase when trained with SONAR data was found to be very efficient. Fig 8 illustrates the performance graph of our FFBP-NN:

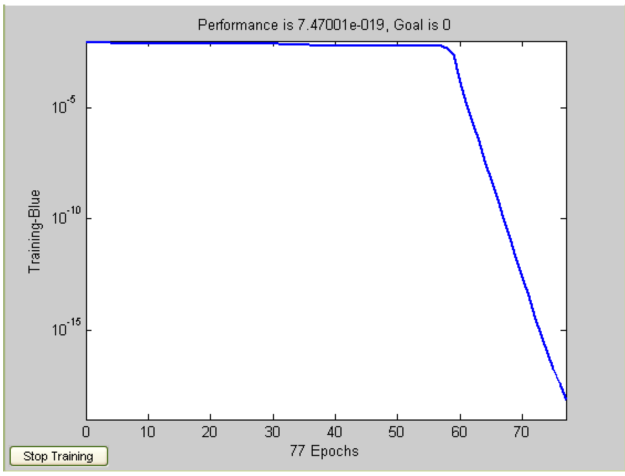

FIG 8: PERFORMANCE OF A FFBP-NN WITH ORIGINAL DATA HAVING 60 DIMENSIONS

Implementing FFBP Neural Network With the Preprocessing PCA Technique

When the dimension reduction technique namely Principle Component Analysis (PCA) was applied to the data set, it was found that the dataset could be transformed from 60 dimensions to 20 dimensions without loosing the important attributes of data which are necessary for optimal classification.

The performance graph of the FFBP-NN during the training phase of the pre-processed data is shown in figure Fig 9.

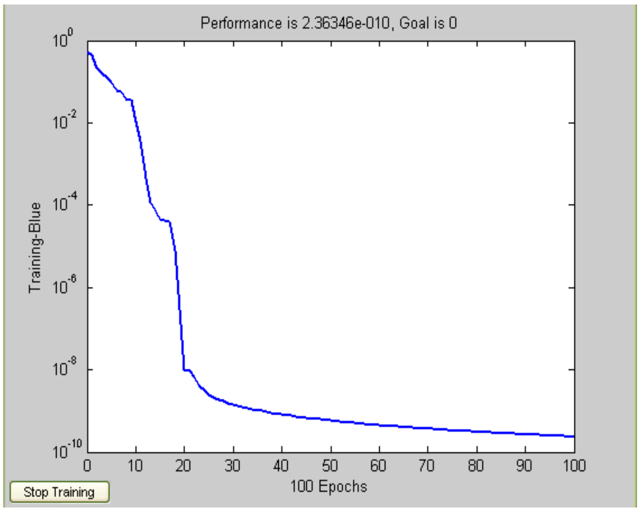

FIG 9: PERFORMANCE OF A FEED-FORWARD BACK PROPAGATION NEURAL NETWORK WITH PCA (20 DIMENSIONAL DATA)

IV. EXPERIMENTAL RESULTS

The experimental results of the Intelligent Target Recognition System are tabulated in Table 1 and Table 2:

Table 1: The Percentage of CORRECT CLASSIFICATION For FFBP-NN ***without using PCA***

CLASSES		**OVERALL**
% Of Correct "mine" Estimation	% Of Correct "rock" Estimation	% Of Correct Classification
93.3%	95.6%	94.45%

Table 2: The Percentage of CORRECT CLASSIFICATION For FFBP-NN ***using PCA***

CLASSES		**OVERALL**
% Of Correct "mine" Estimation	% Of Correct "rock" Estimation	% Of Correct Classification
91.1%	93.4%	92.25%

From Table 1 and 2, it is evident that by applying PCA technique the accuracy of the system is compromised to some extent but the resulting neural network is less complex and much faster.

V. CONCLUSION

Neural Networks are found to be efficient for the classification process in the Target Recognition System. Feed Forward Back Propagation (FFBP) Neural Network produces accurate classification results with the SONAR dataset used while the technique namely Principle Component Analysis (PCA) is used for Dimension Reduction of the data in order to reduce the complexity of the Neural Network.

It can be further concluded from Table 1 and 2, that in case of FFBP-NN, the preprocessing of data for dimension reduction, reduced the accuracy of the system slightly but it also reduced the complexity of the Neural Network resulting in a faster processing of the data.

VI. REFERENCES

[1] Yongzeng Shen, Qicong Wang and Shiming Yu, "A Target Recognition of Wavelet Neural Network Based on Relative Moment Features" IEEE Intelligent Control and Automation , pp-4089-4092, 2004

[2] Gang Liu and Robert M. Haralick "Optimal matching problem in detection and recognition performance evaluation, " Pattern Recognition Volume 35, Issue 10, October 2002, Pages 2125-2139

[3] Engin Avci , Ibrahim Turkoglu, Mustafa Poyraz " Intelligent Target Recognition based on Wavelet Packet Neural network.", Expert System with application 29(2005), pp (175-182), 2005 Elsevier Ltd .

[4] Guyon I., Elisseeff A.: "An introduction to variable and feature selection", Journal of Machine Learning Research 3 (2003) 1157-1182.

[5] "Machine Learning, Neural and Statistical Classification" (Ellis Horwood Series in Artificial Intelligence), Prentice Hall, edited by D. Michie, D.J. Spiegelhalter, C.C. Taylor, July 1994.

[6] Danilo P. Mandic, Jonathon A. Chambers "Recurrent Neural Networks for Prediction", John Wiley and Sons Ltd, Simon Haykin (Editor), 6 Aug 2001.

[7] Emanuel Radoi, André Quinquis, Felix Totir, Fabrice Pellen, "Automatic Radar Target Recognition Using Super-Resolution MUSIC 2D Images and Self-organizing Neural Network", pp-1-4 (2139-2142) , 2001.

[8] Ethem Alpaydm "Introduction to Machine Learning", Massachusetts Institute of Technology Press, 2004

[9] "Handbook of NEURAL NETWORK SIGNAL PROCESSING", CRC Press LLC, edited by Yu Hen Hu and Jenq-Neng Hwang, 2002.

[10] Ruiz-del-Solar, J., Kottow, D. "Neural-based architectures for the segmentation of textures", Proceedings 15th International Conference on Pattern Recognition, vol. 3, pp.1080- 1083, Barcelona, Spain, 3-7 Sept. 2000.

[11] "The Handbook of Brain Theory and Neural Networks", Massachusetts Institute of Technology Press, edited by Michael A. Arbib, pp-1-4, 2003.

[12] UCI Machine Learning Repository [http://archive.ics.uci.edu/ml/datasets.html]