Stock Prediction Using Artificial Neural Networks

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Abstract

Accurate prediction of stock price movements is highly challenging and significant topic for investors. Investors need to understand that stock price data is the most essential information which is highly volatile, non-linear, and non-parametric and are affected by many uncertainties and interrelated economic and political factors across the globe. Artificial Neural Networks (ANN) have been found to be an efficient tool in modeling stock prices and quite a large number of studies have been done on it. In this paper ANN modeling of stock prices of selected stocks under BSE is attempted to predict closing prices. The network developed consists of an input layer, one hidden layer and an output layer and the inputs being opening price, high, low, closing price and volume. Mean Absolute Percentage Error, Mean Absolute Deviation and Root Mean Square Error are used as indicators of performance of the networks. This paper is organized as follows. In the first section, the adaptability of ANN in stock prediction is discussed. In section two, we justify the using of ANNs in forecasting stock prices. Section three gives the literature review on the applications of ANNs in predicting the stock prices. Section four gives an overview of artificial neural networks. Section five presents the methodology adopted. Section six gives the simulation and performance analysis. Last section concludes with future direction of the study.

Keywords- Artificial Neural Networks (ANNs), Forecasting, Stock Price.

I. INTRODUCTION

Stock market remains one of the major means of investment for investors for at least a couple of decades. The Bombay Stock Exchange (BSE) is one of the India's major stock exchanges and of the oldest exchanges across the world. An attempt is made to predict the closing prices of stock market with reference to Tata Consultancy Services Ltd, Wipro Ltd, Dr. Reddy's Laboratories Ltd and Sun Pharmaceutical Ltd listed under BSE using artificial neural networks. Many scientific attempts have been made on stock market to extract some useful patterns in predicting their movements. This patterns helped researchers in developing many models using fundamental, technical and time series in forecasting the competitive predictions of stock prices for the investors. The Artificial Neural Networks have the ability to discover the nonlinear relationship in the input data set without a priori assumption of knowledge of relation between the input and the output [1], and hence ANNs suits well than any other models in predicting stock prices.

II. JUSTIFICATION OF USING ANNS IN FORECASTING STOCK PRICES

An Artificial Neural Network is defined as a data processing system consisting of a large number of simple highly interconnected processing elements (artificial neurons) in an architecture inspired by the structure of the cerebral cortex of the brain. There are several classes of neural networks, classified according to the learning mechanisms. A network is taught by presenting it with a set of sample data as inputs and by varying the weighting factors in the algorithm that determines the corresponding output states. ANNs are among the most effective learning methods to learn and interpret complex real-world sensor data [2]. The three broadly classified learning methods are supervised learning, unsupervised learning and reinforced learning. There are three fundamental classes of networks namely, single layer Feed forward network, multilayer Feed forward network and recurrent network. The traditional method for solving highly complex problems is by using computing technology in building expert systems. For such systems tasks like financial analysis requires costly programming and maintenance. Moreover in doing so, extracting knowledge from human experts and translate into programming is also tedious. But artificial neural networks on the other hand have automated procedures which lead the learning process rapid. ANNs learn by observing the past data experts' interview is not necessary. An ANN is able to form judgments or achieve stable configuration patterns, even if it is given "fuzzy" or incomplete information [3].

One major application area of ANNs is forecasting and provides an attractive alternative tool for researchers as well as practitioners. The following features of ANNs make them valuable and attractive for a forecasting task.

i. It opposed to the traditional model based methods and it learns from examples and capture subtle functional relationships among the data even if the underlying relationships are unknown or hard to describe. It gives the ability to learn from experience and provides a practical feasible way to solve real world problems.

ii. ANNs can generalize and correctly infer the unseen part of the data even if the sample data contain noisy information with least principle.

iii. ANNs are universal functional approximators and provides a continuous function for a desired accuracy.

iv. ANNs are nonlinear. The real world systems are often nonlinear. The existing nonlinear models are limited in exploiting the explicit relationship for the data series with the little knowledge of underlying law. ANNs have the capacity of performing nonlinear modeling without a priori knowledge about the relationship between input and output variables. Thus ANNs are a more general and flexible modeling tool for forecasting.

III. LITERATURE REVIEW

Artificial Neural Networks are being used for a wide variety of tasks in many different fields of business, industry and science. ANNs are highly flexible function approximators that can map any nonlinear function [4]. One major application area of ANNs is forecasting [5] for example, [6] in predicting the financial failure. Also the study [7] shows the ability of predicting the financial failure one year in advance with the neural fuzzy network model. The ANNs have transferred the learning ability of humans from their experiences into the computer environment which can imitate the functioning principles of human brain [8].

There are a quite number of studies on modeling stock prices using Artificial Neural Networks and the examples include [9], [10], [11], [12], and [13]. Many more works on forecasting stock market volatility using neural networks are found in [14], and [15] The results determined by using ANNs are better than the results determined by linear and logical regression models [16], [17] and [18]. Also a study on financial prediction by using ANNs [19] provided results with an average failure of 3%. A Multi-Layer Perceptron model [20] with macro-economic indicators used to forecast Istanbul Stock Exchange even at the time of financial crisis generated a signal with a correctness ratio of 73.7% which shows the ability of ANNs in prediction. The study [21] shows that Artificial Neural Networks outperform the adaptive exponential smoothing method in the forecasting of the market movement. The existence of the nonlinearity and volatility of the financial market is propounded by many researchers and financial analysts [22]. ANNs are well suited for problems whose solutions require knowledge that is difficult to specify but for which there are enough data or observations [23]. Stock price movements are affected by many macroeconomic factors including political events, general economic situations, investors' expectations, institutional investors' selections and psychological factors [24]. The designing of ANNs and selecting definite parameters are less or more subjective and it is highly important in achieving the network's performance [25]. Moreover, as not much work has been done on forecasting the Indian stock market using Artificial Neural Networks, this study attempts to predict stock prices of companies under selected sectors and companies listed under Bombay Stock Exchange (BSE).

IV. ARTIFICIAL NEURAL NETWORKS

We just recall that the notion of Neural Network is eminently suited for approximating Fuzzy Controllers and other types of Fuzzy Expert Systems. The concept of Artificial Neural Network (ANN) begins with the functions of human brain. Human brain consists of approximately 10 billion neurons (nerve cells) and 6000 times as many synapses (connections) between them [26]. ANN as inspired by biological nervous systems, process information supplied, with a large number of highly interconnected processing elements (neurons). ANN may be considered as a data processing technique that maps or relates some type of input stream of information to an output stream of data [27].

ANN consists of neurons (nodes) distributed across layers. The way these neurons are distributed and connected with each other defines the architecture of the network. The connection between the neurons is attributed by a weight. Each neuron is a processing unit that takes a number of inputs and after processing with an activation function called transfer function yields a distinct output. The most commonly used transfer functions include, the hardlimit, the purelinear, the sigmoid and the tansigmoid function.

The following features of Fuzzy Neural Networks distinguish them from their classical counter parts.

i. Inputs are Fuzzy numbers
ii. Outputs are Fuzzy numbers
iii. Weights are Fuzzy numbers
iv. Weighted inputs of each neuron are not aggregated by summation. But by some other aggregation operation.

Definition 1

A neural network is a computational structure that is inspired by observed process in natural network of biological neurons in the brain. It consists of simple computational units, called neurons that are highly interconnected. Each interconnection has a strength that is expressed by a number referred as weight.

Definition 2

The bias defines the value of the weighted sum of inputs around which the output of neuron is most sensitive to changes in the sum.

Now we proceed on to define the notion of Neural Network. In Neural Network bias plays an important role. So we take the bias as an input with value – 1 and its corresponding weight is the sum of the average of the other input weights. The class of sigmoid function S_β, defined by the formula

$$S_\beta(a) = (1 + \exp\{-\beta a\})^{-1}.$$

Then, the output of the neuron is defined by

$$Y = S_\beta\left(\sum_{i=1}^{n} W_i X_i - \theta\right)$$

where β is a positive constant (Steepness parameter), θ is called the bias of the neuron, since θ the bias is considered as an input, $x_0 = -1$ and the associated weight $w_0 = \theta$. The quantities X_i and W_i denote the inputs and weights respectively.

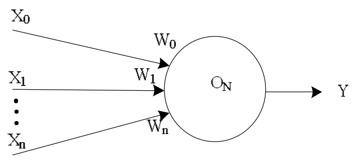

Figure 1. Model of a Neuron

The following table displays the transfer function displays the function and the range of values they accommodate.

TABLE I: TRANSFER FUNCTIONS

Activation function	Function	Range
Hardlimit	$f(x)=\begin{cases}1, & x\ge 0\\ 0, & x<0\end{cases}$	$\{0,1\}$
Purelinear	$f(x)=x$	$(-\infty,\ \infty)$
Sigmoid	$f(x)=\dfrac{1}{1+e^{-x}}$	$[0,1]$
Tansigmoid	$f(x)=\dfrac{2}{1+e^{-2x}}-1$	$[-1,1]$

ANN basically consists of three layers namely, the input layer, the hidden layer, and the output layer. There exists exactly one input and one output layer and the number of hidden layers may vary from 0 to any number. Weights between the neurons are to be defined after defining the architecture and the transfer function for each neuron. The adjustment of weights is known as training of the NN.

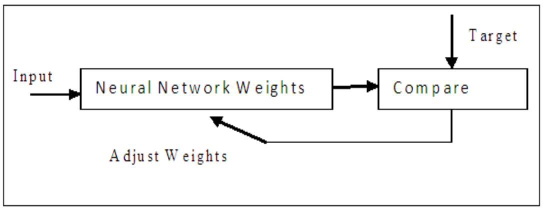

Figure2.Training method in Artificial Neural Network

The training of ANN is shown in Fig 2. Initially, the weights of the network are assigned random values usually within [-1, 1]. Then the input of the first sample is presented to the network which after computation an output is determined. The output thus calculated is compared with the target value of the sample and the weights of the network are adjusted in a way that the error between the outputs and targets is minimized. The common error functions are Mean Square Error (MSE) and Mean Absolute Error (MAE). There are two major categories of training called the incremental and the batch training. In the incremental training, weights are adjusted each time that each one of the input samples are presented to the network where as in the later one, weights are adjusted only when all the training samples have been presented to the network . The weight updating mechanism is known as training algorithm and several such algorithms are available in the literature [28]. They are listed as follows:

i. Gradient descent (Incremental mode)
ii. Gradient descent (Batch mode)
iii. Gradient descent with momentum (incremental mode)
iv. Gradient descent with momentum (batch mode)
v. Gradient descent with variable learning rate
vi. Resilient Backpropagation

The most common algorithm used is backpropagation algorithm which basically propagates errors back during training and using these errors weights are adjusted. Errors in the output determine the errors in the hidden layer which are used as a basis for adjustment of connection weights between the input and hidden layers. Adjusting two sets of weights between the pairs of layers and recomputing the outputs is an iterative process that is carried out until the errors fail below a tolerance level.

The parameters that have to be set for the network training are error function, learning rate, momentum rate and number of epochs. Learning rate parameters scale the adjustments to weights and a momentum parameter is used to overcome local minima. It is to be noted that if the learning rate is made too large the algorithm will become unstable and will converge to the minimum of the error function. If the learning rate is set too small, the algorithm will take a long time to converge. Also number of epochs need to be set in such a way to stop the training before the network is prone to over fit to the dataset hence generalizing ability on unseen data is feasible. Once the training is over, the network is ready for prediction of the problem concerned.

V. ADOPTION OF NEURAL NETWORK IN FORECASTING

The Neural Networks built in this study were designed to produce closing price of stocks for about five days in future. The data used are stocks in the Bombay Stock Exchange namely, Tata Consultancy Services Ltd, Wipro Ltd, Dr. Reddy’s Laboratories Ltd and Sun Pharmaceutical Ltd between the period January 1, 2012 and November 7, 2013. For the neural network part of the study, the data is divided into 70:30, thus 70% of the data is used to train the network and to predict known results from 30% data.
The normalization for the input is done using the formula $x_N = \frac{x - x_{\min}}{x_{\max} - x_{\min}}$, where x denotes the value that should be normalized; x_N denotes the normalized value of x; $x_{\min}$ represents the minimum value of x; $x_{\max}$ represents the maximum value of x. After the normalization the data (stock prices) will be in the range of [0, 1].

The network utilizes the dynamic back propagation model and implements a logistical sigmoid function as the activation function. Using Neuroph [27] and Matlab R2010a the data is analyzed. Inputs to the network are opening price, high, low, closing price and volume of the stocks under study. The network consists of five input neurons, $2n+1$ hidden neurons [28], [29] which are eleven hidden neurons and one output neurons in the three respective layers namely input, hidden and output layers. The number of neurons in the output layer is one as the modeling applied in the study aims to predict one step ahead closing value in the future forecasting and it is used to predict any other future values in the remaining 20% of the data. Although, there are many different ways to construct and implement neural networks for forecasting, most of the studies use the Multi-Layer Perceptron (MLP).

To measure the performance of the neural network model used, Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD) and Root Mean Squared Error (RMSE) were calculated. Suppose $(a_1, a_2, a_3, ..., a_n)$ are actual values and $(p_1, p_2, p_3, ..., p_n)$ are the predicted values then the MAPE, MAD and RMSE can be calculated by using the formula (1), (2) and (3).

$$MAPE = 100 * \frac{1}{n}\sum\left|\frac{a_i - p_i}{a_i}\right| \quad \text{--- (1)}$$

$$MAD = \frac{\sum|a_i - p_i|}{n} \quad \text{--- (2)}$$

$$RMSE = \sqrt{mean(a_i - p_i)^2} \quad \text{--- (3)}$$

A maximum network error of 0.01, momentum coefficient that ranges from 0.1 to 0.9 and learning rate that ranges from 0.1 to 0.9 has been used in the training. The trained network thus obtained has been tested with randomly selected data from the 20% data set.

VI. RESULTS AND DISCUSSION

Using the developed system to predict the future stock values with the multilayer perceptron an analysis can be done to know the effectiveness of dynamic backpropagation algorithm. By using the past historical stock prices of the selected companies under BSE, we tried to predict stock values for future five days of April 2013 which are compared to the actual values.

Table I displays the comparison between actual values and predicted values of the closing prices of the companies. Also the forecasting errors associated with the predicted values are also shown in the table.

TABLE II. ACTUAL VALUE Vs. PREDICTED VALUE OF STOCK PRICES

Company Name	Date	Actual Value (in Rs)	NEUROPH		MATLAB	
			Predicted Value	Forecasting Error (%)	Predicted Value	Forecasting Error (%)
Tata Consultancy Services Ltd	17-04-2013	1459.20	1496.16	2.53	1444.82	0.99
	18-04-2013	1450.70	1500.10	3.40	1429.40	1.47
	22-04-2013	1425.25	1479.81	3.83	1414.22	0.77
	23-04-2013	1429.60	1475.18	3.19	1404.49	1.76
	25-04-2013	1402.10	1482.02	5.70	1364.85	2.66
Wipro Ltd	17-04-2013	374.95	376.41	0.39	392.50	4.68
	18-04-2013	368.65	367.45	0.32	392.44	6.45
	22-04-2013	339.35	338.83	0.15	392.46	15.65
	23-04-2013	342.75	348.03	1.54	392.40	14.49
	25-04-2013	335.20	404.16	20.57	392.40	17.07
Dr. Reddy's Laboratories Ltd	17-04-2013	1905.00	1890.03	0.79	1891.20	0.72
	18-04-2013	1904.65	1886.30	0.96	1900.21	0.23
	22-04-2013	1884.20	1876.31	0.42	1869.94	0.76
	23-04-2013	1902.90	1889.05	0.73	1900.90	0.11
	25-04-2013	1992.75	1933.62	2.96	1942.64	2.51
Sun Pharmaceutical Ltd	17-04-2013	458.23	477.15	4.13	437.88	4.44
	18-04-2013	458.02	459.75	0.38	439.72	4.00
	22-04-2013	463.55	463.49	0.01	440.23	5.03
	23-04-2013	475.20	472.69	0.53	441.07	7.18
	25-04-2013	487.62	486.87	0.15	441.95	9.37

Table 2 displays the performance of the network adopted in the study.

TABLE III. EVALUATION OF THE NEURAL NETWORK

Input Variables	Network Architecture and Tool used	Forecasting Performance	Company			
			Tata Consultancy Services Ltd	Wipro Ltd	Dr. Reddy's Laboratories Ltd	Sun Pharmaceuticals Ltd
i. Opening price ii. High iii. Low iv. Closing price v. Volume	(5-11-1) (NEUROPH)	MAPE	2.97	4.60	2.10	1.14
		MAD	42.46	15.48	42.98	5.41
		RMSE	47.39	30.94	62.99	8.29
	(5-11-1) (MATLAB)	MAPE	1.86	11.67	2.50	7.54
		MAD	26.85	40.26	51.77	36.57
		RMSE	31.36	43.43	85.65	40.05

Fig. 3, Fig. 4, Fig. 5 and Fig. 6 show the graphical representations of predicted and real closing prices of the companies.

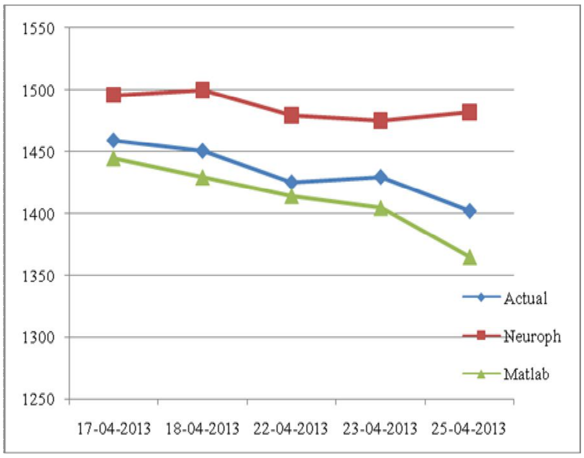

Figure 3. Actual Vs. Predicted Stock Prices of Tata Consultancy Services Ltd

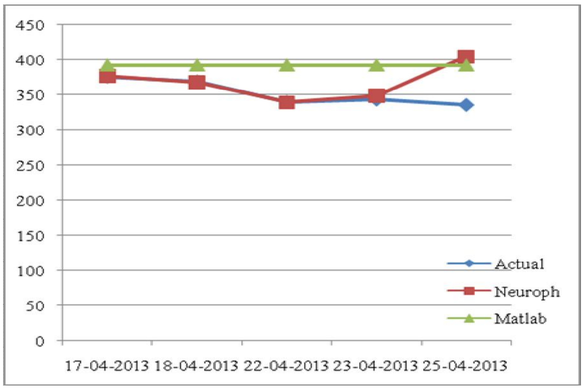

Figure 4. Actual Vs. Predicted Stock Prices of Wipro Ltd

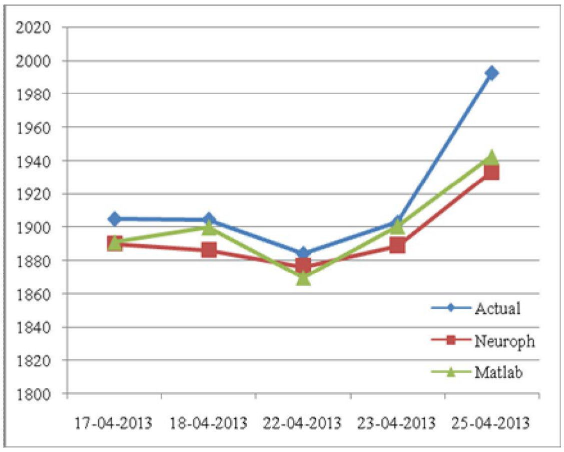

Figure 5. Actual Vs. Predicted Stock Prices of Dr. Reddy's Laboratories Ltd

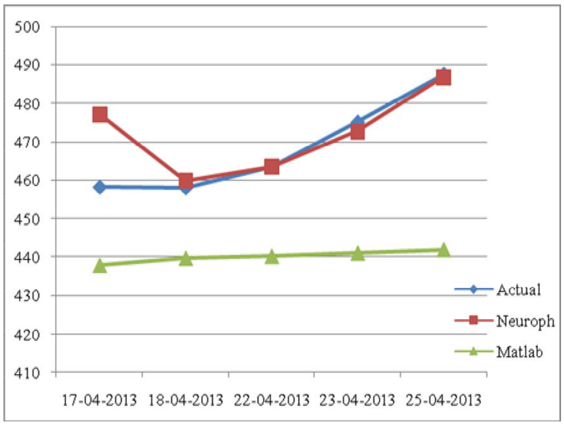

Figure 6. Actual Vs. Predicted Stock Prices of Sun Pharmaceutical Ltd

Fig. 7, Fig. 8 and Fig. 9 display the MAPE, MAD and RMSE comparative graphs of both Neuroph and Matlab respectively.

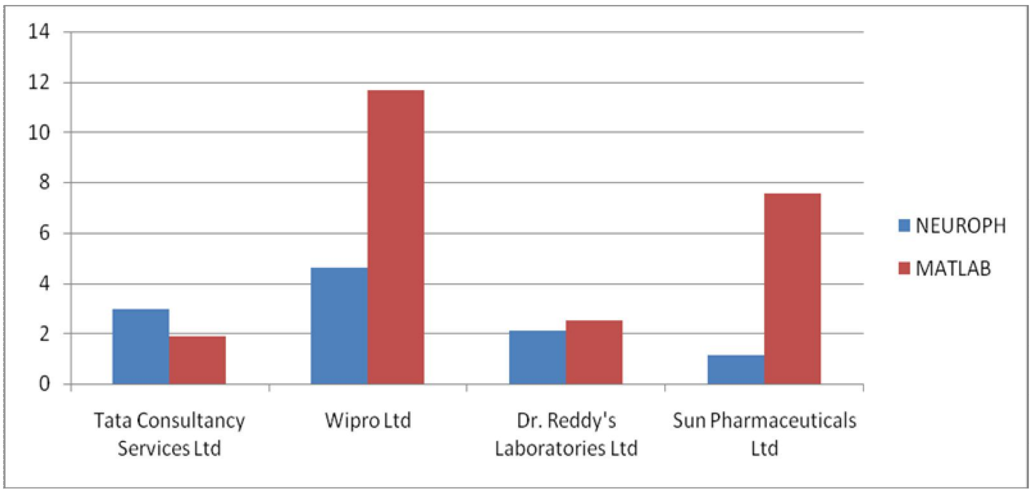

Figure 7. MAPE Comparison of NEUROPH and MATLAB

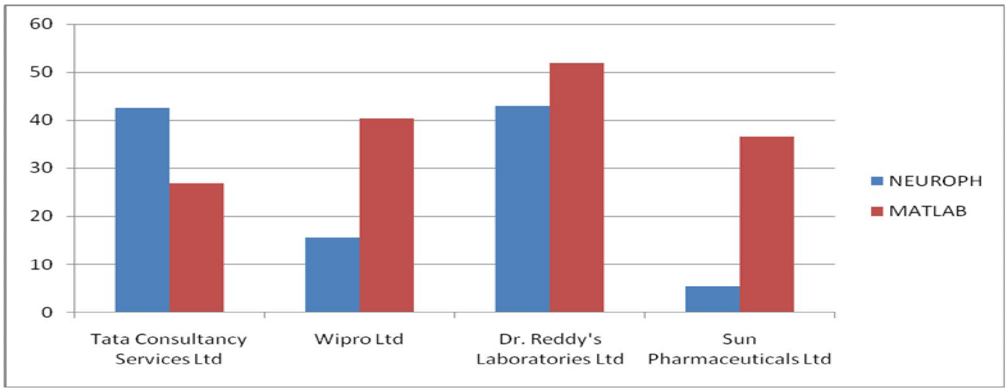

Figure 8. MAD Comparison of NEUROPH and MATLAB

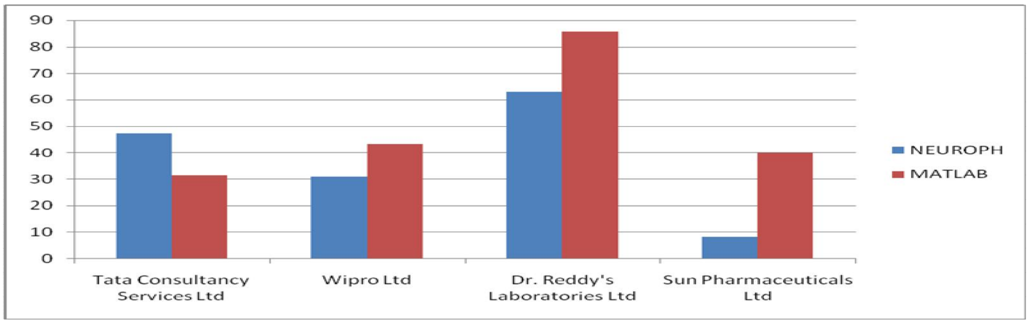

Figure 9. RMSE Comparison of NEUROPH and MATLAB

It is observed that error was high when we take three inputs for prediction and it was minimized when we take five inputs. It is also observed that the accuracy in prediction is more when we take data in continuous dates except in one case in the study.

However it is well known that the performance of ANNs, with respect to forecasting, depends on a variety of factors and the performance of the network constructed in this study cannot be compared easily with the published findings of other studies.

VII. CONCLUSION

In our study a highly flexible non-linear modeling technique ANN has been implemented to forecast the stock prices of selected sectors and companies under Bombay Stock Exchange. The input used in the study is opening price, high, low, closing price and volume of the stocks. The predicted results demonstrate that artificial neural network has been able to predict stock prices with better accuracy if we increase the number of input data.Yet, there is a considerable scope definitely to build on the study attempted in all possible ways to predict the stock prices with higher level of accuracy.

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