Predicting the Direction of Stock Markets Employing Back Propagation in Neural Networks

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***Abstract*— Stock Market prediction is a category of time series prediction which extremely challenging due to the dependence of stock prices on several financial, socio-economic and political parameters etc. Moreover, small inaccuracies in stock market price predictions may result in huge losses to firms which use stock market price prediction results for financial analysis and investments. Off late, artificial intelligence and machine learning based techniques are being used widely for stock market prediction due to relatively higher accuracy compared to conventional statistical techniques. The proposed work employs the steepest descent based scaled conjugate gradient (SCG) algorithm along with the data pre-processing using the discrete wavelet transform (DWT) for stock market prediction. It has been shown that the proposed system attains lesser mean square percentage error compared to previously existing technique.**

Keywords—Stock Market Forecasting, Artificial Neural Network (ANN), Back Propagation, Scaled Conjugate Gradient (SCG), Discrete Wavelet Transform (DWT), Mean Absolute Percentage Error (MAPE).

I. INTRODUCTION

Stock Markets have long remained one of the one avenues on the forefront which is crucial for the operations of most of the top most companies [1]. Several decisions pertaining to investments, shares etc. depend on the behavior of the stocks of a company. The stock price values are often leveraged by financial and investment firms for gaining profits and investing [2]. However, the volatile nature of the stock markets make it a risky proposition. Therefore, estimating the future trends in stock prices is somewhat mandatory for firms analyzing stock prices and aiming to gain leverage. This calls for stock market forecasting or stock market prediction. Stock market prediction is basically a time series prediction problem. Mathematically:

$$\boldsymbol{P = f(t, v)} \tag{1}$$

Here,
P represents stock price
f represents a function of
t is the time variable
v are other influencing global variables

The dependence of stock process over time makes it somewhat predictable under similar other conditions of global influencing variables. However, even the slightest of changes can derail the prediction completely [3].
Statistical techniques are not found to be as accurate as the contemporary artificial intelligence and machine learning based approaches [6]. In this paper, a back propagation based scaled conjugate gradient algorithm is used in conjugation with the discrete wavelet transform (DWT) for forecasting stock market trends. The evaluation of the proposed approach has been done based on the mean absolute percentage error (MAPE). A comparative MAPE analysis has also been done w.r.t. previously existing techniques [4].

II. DEEP LEARNING

Deep learning has evolved as one of the most effective machine learning techniques which has the capability to handle extremely large and complex datasets [5]. It is training neural networks which have multiple hidden layers as compared to the single hidden layer neural network architectures [6]-[7].
The architectural view of a deep neural network is shown in figure 1. In this case, the outputs of each individual hidden layer is fed as the input to the subsequent hidden layer. The weight adaptation however can follow the training rule decided for the neural architecture. There are various configurations of hidden layers which can be the feed forward, recurrent or back propagation etc [8].

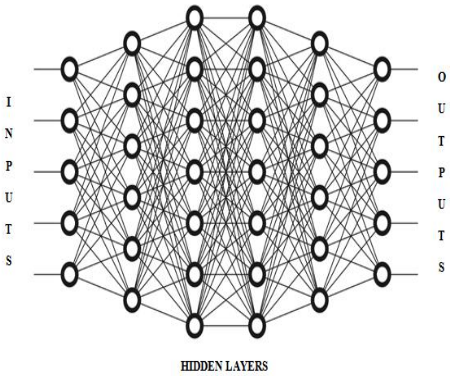

Fig.1 The Deep Neural Network Architecture

The figure above depicts the deep neural network architecture with multiple hidden layers. The output of the neural network however follows the following ANN rule:

$$Y = f(\sum_{i=1}^{n} X_i \,.\, W_i \; + \; \theta_i) \qquad (2)$$

Where,
X are the inputs
Y is the output
W are the weights
ϴ is the bias.
Training of ANN is of major importance before it can be used to predict the outcome of the data inputs.

III. BACK PROPAGATION

Back propagation is one of the most effective ways to implement the deep neural networks with the following conditions [9]:

1) Time series behavior of the data
2) Multi-variate data sets
3) Highly uncorrelated nature of input vectors

The essence of the back propagation based approach is the fact that the errors of each iteration is fed as the input to the next iteration. [10]-[11]. The error feedback mechanism generally is well suited to time series problems in which the dependent variable is primarily a function of time along with associated variables. Mathematically,

$$Y = f(t, V_1 \ldots . V_n) \qquad (3)$$

Here,
Y is the dependent variable
f stands for a function of
t is the time metric
V are the associated variables
n is the number of variables
The back propagation based approach can be illustrated graphically in figure 2.

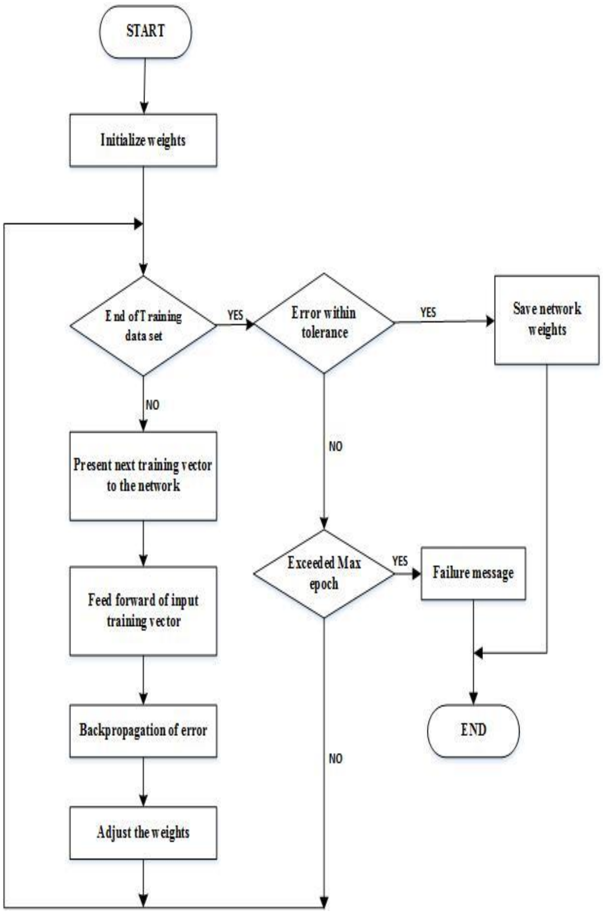

Fig.2 Concept of Back Propagation

In case of back propagation, the weights of a subsequent iteration doesn't only depend on the conditions of that iteration but also on the weights and errors of the previous iteration mathematically given by [12]:

$$W_{k+1} = f(W_k, e_k, V) \qquad (4)$$

Here,
W_{k+1} are the weights of a subsequent iteration
W_k are the weights of the present iteration
e_k is the present iteration error
V is the set of associated variables
In general, back propagation is able to minimize errors faster than feed forward networks, however at the cost of computational complexity at times. However, the trade off between the computational complexity and the

performance can be clearly justified for large, complex and uncorrelated datasets for cloud data sets [13].

IV. GRADIENT DESCENT BASED TRAINING

The gradient descent algorithms (GDAs) generally exhibit:

1) Relatively lesser memory requirement
2) Relatively faster convergence rate

The essence of this approach is the updating of the gradient vector g, in such as way that it reduces the errors with respect to weights in the fastest manner. Mathematically, let the gradient be represented by g and the descent search vector by p, then [14]:

$$p_0 = -g_0 \qquad (5)$$

Where,

g_0 denotes the gradient given by $\frac{\partial e}{\partial w}$

The sub-script 0 represents the starting iteration

The negative sign indicates a reduction in the errors w.r.t. weights [15].

The tradeoff between the speed and accuracy is clearly given by the following relations [16]:

$$W_{k+1} = W_k - \alpha g_x, \;\; \alpha = \frac{1}{\mu} \qquad (6)$$

Here,

w_{k+1} is the weight of the next iteration

w_k is the weight of the present iteration

g_x is the gradient vector

μ is the step size for weight adjustment in each iteration.

There are several ways to implement the back propagation technique in the neural networks [17]. One consideration however always remains that of the least time and space complexity so as to reduce the amount of computational cost that is associated with the training algorithm. The essence of the scaled conjugate gradient algorithm is the fact that it has very low space and time complexity making it ideally suited to large data sets to be analyzed in real time applications where the time is a constraint. The training rule for the algorithm is given by [18]:

$$A_0 = -g_0 \qquad (7)$$

A is the initial search vector for steepest gradient search

g is the actual gradient

$$w_{k+1} = w_k + \mu_k g_k \qquad (8)$$

Here,

w_{k+1} is the weight of the next iteration

w_k is the weight of the present iteration

μ_k is the combination co-efficient

V. THE DISCRETE WAVELET TRANSFORM

The wavelet transform is an effective tool for removal of local disturbances. Stock prices show extremely random behavior and local disturbances. Hence conventional Fourier methods do not render good results for highly fluctuating data sets. Mathematically, the wavelet transform can be given as [19]

$$Z\,(S,P) = \int_{-\infty}^{\infty} z(t)\,((S,P,t))dt \qquad (9)$$

Here,

S denotes the scaling operation

P denotes the shifting operation

t denotes the time variable

Z is the image in transform domain

z is the image in the spatial domain

The major advantage of the wavelet transform is the fact that it is capable of handling fluctuating natured data and also local disturbances. The DWT can be defined as [20]:

$$W\Phi\,(Jo, k) = \frac{1}{\sqrt{M}} \sum_n S(n).\Phi(n)_{jo'k} \qquad (10)$$

The entire methodology can be understood using the system flowchart depicted below.

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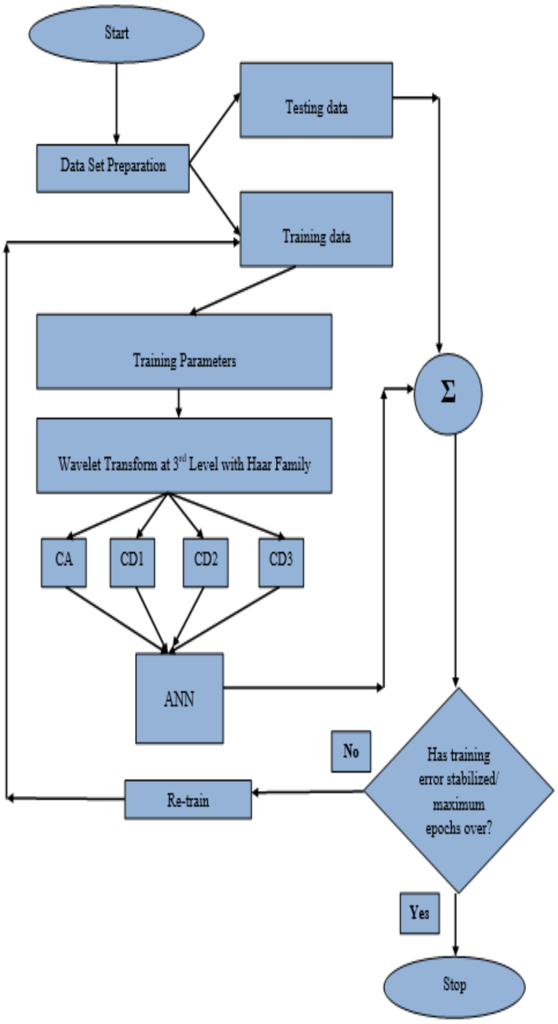

Fig.3 Flowchart of Proposed System

The data is divided in the ration of 70:30 for training and testing data set bifurcation.
The final performance metrics computed for system evaluation are:
1) Mean Absolute Percentage Error (MAPE)

$$MAPE = \frac{100}{M}\sum_{t=1}^{N}\frac{E-E_t|}{E_t} \qquad (11)$$

Here E_t and $E_t^{\sim}$ stand for the predicted and actual values respectively.
The number of predicted samples is indicated by M.

2) Regression
The extent of similarity between two variables is given by the regression where the maximum value is 1 and the minimum is 0.

VI. RESULTS

The results have been evaluated based on the following parameters:

1. (MAPE)
2. Regression
3. MSE w.r.t. the number of epochs

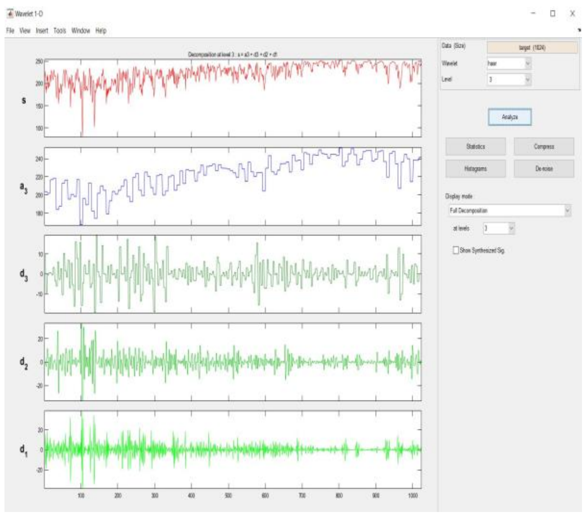

Fig.4 Decomposition of Data at level 3 using Haar Wavelets

The figure above depicts the Haar wavelet decomposition of the stock data at level 3.

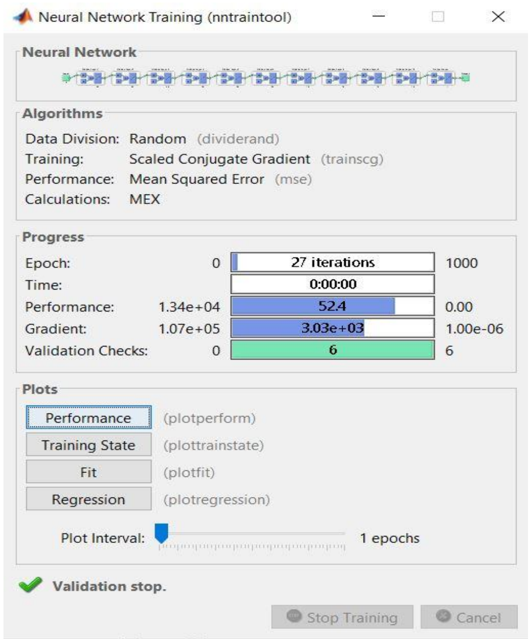

Fig.5 Designed Neural Network

The figure above depicts the training parameters of the deep neural network based on the SCG leaning algorithm.

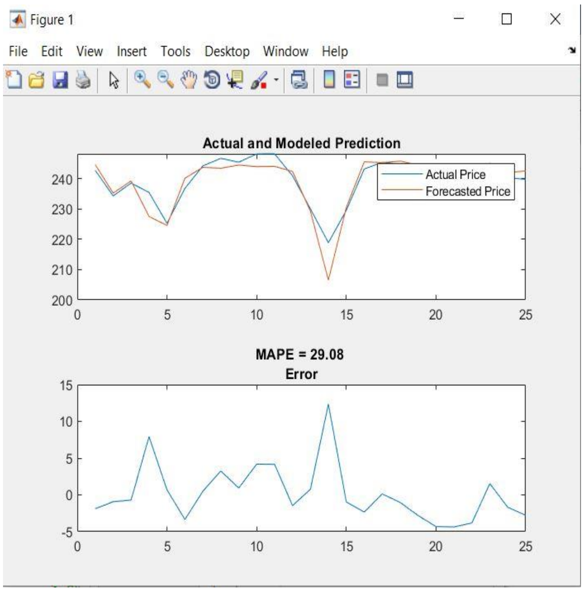

Fig.6 Predicted and Actual Stock Behavior

The figure above depicts the predicted and actual stock behavior.

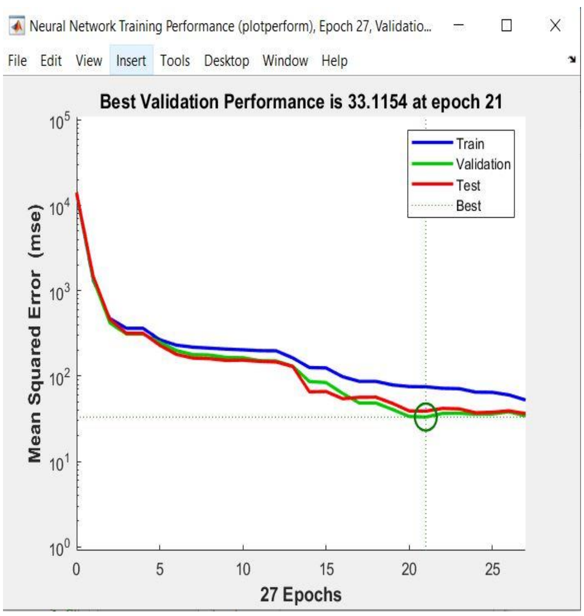

Fig.7 Variation of MSE with respect to epochs

The figure above depicts the variation of the mse w.r.t. the epochs

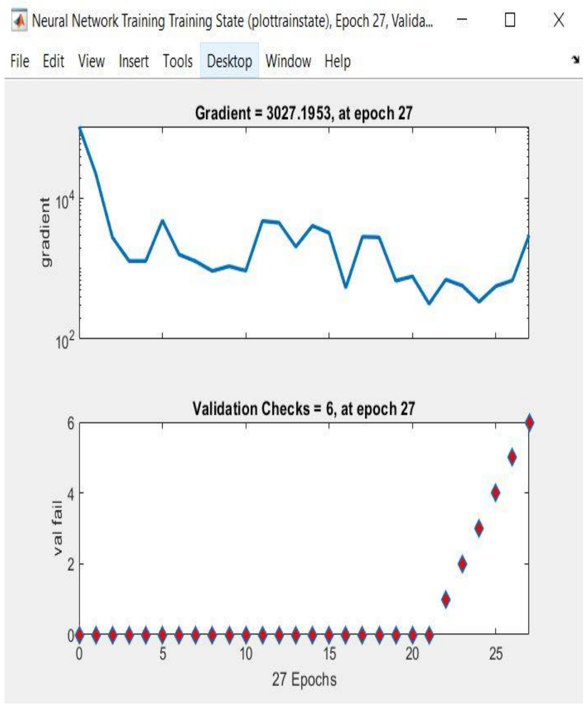

Fig.8 Training Parameters

The figure above depicts the training states as a function of iterations.

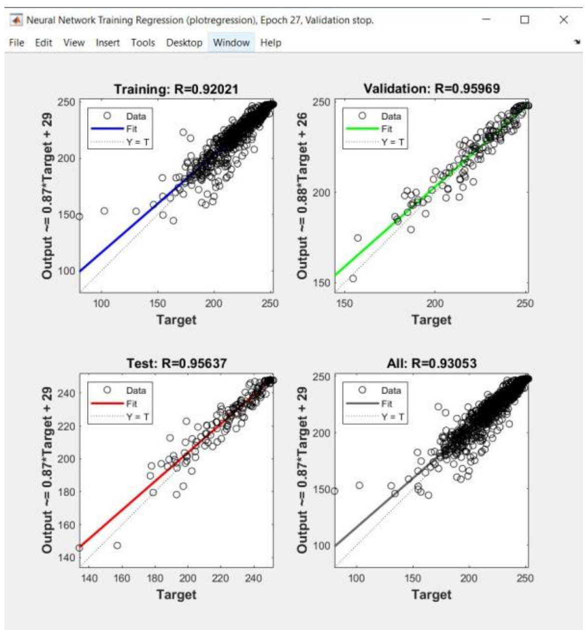

Fig.9 Regression Analysis

From the above figures, it can be concluded that the proposed system attains the following results:
1) MAPE of Proposed work=29.08%
2) Accuracy of Proposed work=70.92
3) Accuracy of Previous work [1]=57%
4) Regression of Proposed work= 0.93 (overall)
3) Number of iterations is 27
A comparative accuracy analysis w.r.t. previous work is given by:

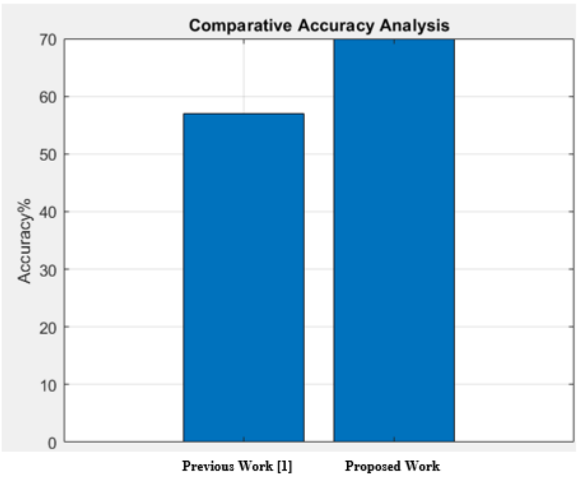

Fig.10 Comparative Accuracy Analysis w.r.t. Previous Work [1]

CONCLUSION

It can be concluded from previous discussions that stock market prediction is a category of time series prediction with high sensitivity and dependence on external factors. Hence it is often challenging to attain high levels of accuracy in prediction. In the proposed approach a back propagation based deep learning model is proposed with a 1-10-1 configuration. The adaptive gradient descent algorithm (GDA) is used to train the neural network. Data pre-processing is done using the discrete wavelet transform. It has been shown that the proposed work attains a mean absolute percentage error of 29.08% compared to a mean absolute percentage error of 57% of previous work [1]. Moreover, the regression is 0.93 at the number of epochs being 27. Thus the proposed system is able to achieve low errors, higher accuracy and relatively low number of iterations. Also the proposed work outperforms previously existing systems in terms of the accuracy for the benchmark datasets used.

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