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An Experimental Evaluation of Short-Term Stock Prediction in the Nigerian Stock Market using Multilayer Perceptron Neural Network

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ABSTRACT

Stock prices fluctuate, are unpredictable, and this has increased interest in the stock price prediction research. This work aims at predicting stock prices in the Nigerian Stock Market using Artificial Neural Network (ANN). Seven-year data obtained from the Investing Website for ten companies listed as the top gainers in the Nigerian Stock Market were used, having attributes High, Low, Close, Open. The data set was divided into a training dataset (70%), validating dataset (15%), testing dataset (15%), a Multilayer Perceptron Neural Network (MLP) using Levenberg Marquardt algorithm to build, train and test the model. The model generated was used for a short-term prediction, predicting the next days' opening and closing prices. The results from the training model were used for comparison with the testing data to ascertain the accuracy of the model. Results from the data analysis carried out using MATLAB revealed that Multilayer Perceptron neural network technique gives satisfactory output with best validation performance mean square value of 0.0059445 at epoch 20, with R score of 0.94654, 0.92687, 0.8584 and 0.92997 respectively for training, validation, Test and combined set. It has Mean Square Error of 5.92336e-3, 5.94448e-3 and 7.98277e-3 for training, validation and testing respectively; and regression value of 9.97966e-1, 9.97813e-1 and 9.97351e-1 respectively for training, validation and testing.

Keywords: Stock, Neural network, MLP, Feedforward, Backpropagation.

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I. INTRODUCTION

Artificial Neural Network (ANN) is a nonlinear statistical data modelling tool which models the intricate relationships between inputs and outputs or identifies patterns. Stock market analysis and prediction are one of the areas in which past data are to anticipate and predict information about the future. This work employs information from previous years to predict stock prices for ten selected companies that were listed as the top gainers in the Nigerian Stock Market. The selected companies are Dangote Cement, the Custodian Insurance, Oando, Jaiz Bank, Mobil, Royal Exchange, Union Bank, Dangote Flour Mill, Neimeth, and Transcorp. The selected companies are vibrant and have been consistently listed in the top gainers in the Nigerian Stock Market. The most fundamental idea behind a stock is that it represents a share of ownership in a company. Stocks are usually issued by a company when it needs to raise capital for investments as an alternative to borrowing the money [1]. Thus, investors trade capital to make profits for a company share in the future.

1.1 The Stock Market and Stock Exchange Market

A stock market is a systematized market for procuring and trading diverse types of securities such as stocks and bonds [2]. Their primary purposes are to help companies get easy access to capital and pricing, a mechanism to determine the value of a stock or whole company. Buyers and sellers of stocks and other financial instruments meet at the stock market, and shareholders can sell their shares on a stock market and reach a large group of investors who are willing to purchase shares at the lowest price. The stock market is volatile, fluctuating and inconsistent, which makes accurate prediction and guidance a big challenge but accurate forecast can assist investors to anticipate future prices [3]. Buying, selling and exchange of publicly listed financial instruments take place at the Stock Exchange Market. Conventionally, stock exchanges were physical places, often referred to as the floor, where stockbrokers and traders meet to exchange stocks for other stocks or money, in recent times nearly all stock trades take place through electronic communication. Most stock exchanges work as an institution that allows for trading individual stocks and other financial instruments through a near-instant automated trading system. Most stock exchanges use a continuous auction principle, which includes an instant execution of stock orders as the market receives them. By operating with the constant policy and rapid electronic requests, modern-day stock exchanges are driven solely by supply and demand [4].

Investors in the stock market want to maximise their returns by buying or selling their investments at an appropriate time and profitable price, since stock market data are highly time-variant and are generally in a nonlinear pattern. The variation can be either short or long term, short-term price of stock changes rapidly while the long-term price of a stock is more determined by analytical approaches of what the value of the stock really should be. Several factors influencing stock prices include the general economic trend, market influences, the share's industry performance, market sentiment, inflation, political climate and government policies [5]. Some of the issues that arose include difficulty in predicting the future price of stocks, especially with the increase of economic globalisation and the evolution of information technology as well as the inability to deal with uncertain, fuzzy, insufficient data which fluctuate in short periods. Therefore, this work attempts to predict prices of the selected stocks in the Nigerian Stock Market using Artificial Neural Network.

II. RELATED WORKS

Artificial Neural Network (ANN) has been applied to several areas of human endeavour such as medicine, engineering, finance, cyber security, meteorology and commerce for which stock market is one. According to a review by [6], ANN outperforms other prediction techniques due to its unique ability to reduce error of prediction accuracy and give near exact values at prediction.

Artificial Neural network was used to simulate the prediction of stock values of four selected banks in Nigeria in [5], using MATLAB 6.5, the results obtained through post training analysis showed a linear relation between the target output and the network output and the correlation coefficient (R-value) between the target and network output. It concluded that ANN was a good fit for stock market prediction.

Feed forward ANN with back propagation was used in [7] to predict stock prices of three selected banks in Nigeria. The network takes four-day price movement to predict the next day's market trend. The results showed that despite the chaotic nature of Nigeria Stock Market, ANN could successfully predict the market trend without understanding of the market dynamics. The authors concluded that

reasonable profit could be obtained in stock market with ANN, investors can sell stock above their purchase price which may not be the next day.

Feedforward multilayer perceptron and Elman recurrent network were used in [8] to predict stock value based on historic stock share value. The results showed that MLP neural networks outperformed Elman recurrent Neural network and linear regression methods. An autoregressive neural network predictor was used to predict future stock returns in [9]. Experiments with real data from the National stock exchange of India for six companies from 02-01-2007 till 22-03-2010 were employed to examine the accuracy of this method. The result was not impressive accurate, the study rather suggested that neural networks should be employed to improve the performance accuracy of the prediction. The neural network toolbox in MATHLAB was used in [10] to forecast stock prices in capital market for different combinations of data and input parameters. Their results showed that MLP neural network gives a satisfactory output that was found to be comparable to the expected output. The suitability of neural network with time series to predict exchange rate in foreign exchange market was examined in [11]. It examined exchange rates between USD/EUR, JPN/USD, USD/GBP using time-series prediction with neural network. A hybrid technique based on genetic algorithm and simulated annealing was used to improve the accuracy of the prediction of an artificial neural network in [12]. Adaline Neural Network (ANN) and modified Particle Swarm Optimization (PSO) were combined in [13] to forecast stock prices. The hybrid technique uses stock market fluctuations as a factor and PSO to optimize and update weights of Adaline representation to depict open price of Bombay stock exchange. The hybrid scheme offers superior performance in terms of mean absolute percentage error when compared with other models such as interval measurements, Chaotic Multi Swarm Particle *Swarm Optimization (*CMS-PSO) and Bayesian-ANN. Three neural network learning algorithms: Levenberg-Marquardt, Scaled Conjugate Gradient and Bayesian Regularization, were used in [14] to predict stock prices and their performances compared. The results showed that Bayesian Regularization outperformed the other two in terms of accuracy, however, it took more time (in days) to train over a large dataset. ANN and ARIMA (Autoregressive Integrated Moving Average) models were adopted for forecasting Nigerian Stock Market Returns in [15] and their performances were compared. ANN showed superior performance in terms of smaller RMSE (Root Mean Square Error), MAE (Mean Absolute Error and NMSE (Normalised Mean Square Error) compared to ARIMA.

This present work, modelled a short-term price prediction of some selected stocks in the Nigerian stock market using a Multilayer Perceptron Neural Network (MLP) with Levenberg-Marquardt algorithm. The stocks were select randomly based on their impressive performance over some period of time. Levenberg-Marquardt algorithm was chosen due to its rapid training (taking a few hours), its ability to efficiently solve slow convergence problem and produce excellent results [14].

III. METHODOLOGY

The study adopts the multiperceptron artificial neural networks for prediction of stocks due to its impressive reporters in the literature.

3.1 Artificial Neural Network

An Artificial Neural Network (ANN) is an information processing model that arose from the desire to artificially stimulate the structure and functioning of the biological nervous system, the brain [16]. It is made up of a large number of highly interconnected processing elements working together to give problem-specific solutions, and these elements are called neurons [17]. ANN is used for applications specific to the needs like pattern recognition or data classification through a process called Learning. The field of ANN was discovered in the 1940s by Warren McCulloch and Walter Pitts who showed that with such networks we could compute any arithmetic or logic function. The first practical application of ANN was made in the late 1950s on the perception [18].

3.2 The Neural Network Model

Artificial Neural Network (ANN) consists of nodes or units that are connected by direct links and every link has a numeric weight. As depicted in figure 1, a bias **b** is to set the actual threshold of the activation function.

The neurons are the basic information processing unit of any neural network and are made up of:

1. A set of links with weights w1, w2, w3, w4…, wn. The weight matrix can be expressed as in equation (1).

$$w = \begin{matrix} w_{11} & w_{12} & w_{13} & . & . & . & w_{1n} \\ w_{21} & w_{22} & w_{23} & . & . & . & w_{2n} \\ w_{31} & w_{32} & w_{33} & . & . & . & w_{3n} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ w_{m1} & w_{m2} & w_{m3} & . & . & . & w_{mn} \end{matrix} \quad (1)$$

2. A linear combiner function for calculating the inputs with the weights, v_i

$$v_i = \sum_{j=1}^{n} \mathrm{w}_{ij}\mathrm{x}_j \quad (2)$$

3. An activation function, e.g. Sigmoid (or logistic) function denoted as

$$\varphi(\mathrm{x}) = \frac{1}{1+\exp(-x)} \quad (3)$$

where x is the input vector

The i[th] output o_i of the network is obtained as in equation (4)

$$o_i = \gamma(v_i) = \gamma(\sum_{j=1}^{d} \mathrm{w}_{ij}\mathrm{x}_j) \quad (4)$$

v_i denotes the ith linear combiner, γ = activation function, x_j = input neuron j o_i = output of the hidden neuron *I*, W = weight matrix, η = rate of learning i & j = input from unit into unit is denoted 'x_{ji}'

Therefore, by adjusting the weight matrix, the Neural Network learns. According to the basic structure of the neural network, the input data fed into input layer and the output data are collected at the output layer.

3.2 Feedforward Multilayer Perceptron (MLP) Neural Network with Back Propagation Algorithm

In **Feedforward Multilayer Perceptron,** the information flow is unidirectional; a unit sends information to other units from which it does not receive any information. There are no feedback loops. They are used in pattern generation, recognition, and classification. They have fixed inputs and outputs; Figure 2 shows schematic diagram of a **Feedforward Multilayer Perceptron.**

Circles and squares represent neurons in figure 2; the topology is called multi-layered Feedforward neural network, as it comprises of three layers: the input, middle/hidden and the output layers. The names imply the functions of the layers. This network is feed-forward, meaning that only one direction propagates the values, allows value movement from the input layer to the output layer only.

3.3 The Network Architecture

Figure 3 presents the class diagram of the model; the model defines the following classes:

a) DataSet: This is the class that represents the concept of the data set
b) NeuralNetwork: This is the class that represents the concept of neural network
c) Training strategy: This is the class representing the concept of training strategy
d) ModelSelection: This is the class representing the concept of model selection.
e) TestingAnalysis: This is the class that represents the concept of analysis

In the Dataset Class, the following three classes were defined:

a) Variables: This class is used to store information about the variables of a data set.
b) Instances: This class is used to store information about the instances of a data set.
c) Missing values: This class is used to store information about the missing values of a data set.

Neural Network Class also defines the following sub-classes:

a) Probabilistic Layer: This class represents a layer of probabilistic neurons.
b) Principal Component layer: This class represents the layer of principal component analysis.
c) Bonding layer: This class represents a layer of bounding neurons.
d) Multilayer Perceptron: This class represents the concept of multilayer perceptron.
e) Scaling Layer: This class represents a layer of scaling neurons.
f) Unscaling Layer: This class represents a layer of unscaling neurons [19].

3.4 Experimental setup

The network was created and trained with supervised Learning, using Feedforward Neural Networks and backpropagation for each of the ten selected companies with the model, on MATLAB environment. The data used was saved in "comma-separated value (CSV) format". The prediction model involves two stages, the first is the training stage and the other is prediction stage. The training process consists mainly of three steps: Feedforward the input signals, Backpropagate the error and Adjust the weights. The Neural Time Series (ntstool) of MATLAB enabled the data to be imported from the CSV file. The selected data in CSV format was then converted into matrix format. The inputs and the target outputs were normalised in the propagation stage, according to the 'mapminmax' function defined in MATLAB, wherein the mapminmax function was used to match the bounds of the Tan-sigmoid activation function. The normalized input is fed into the nodes of the input layer, each input is multiplied with the associated weight which goes into the neurons of the hidden layer. The neurons of the hidden layer perform similar function as those of the input layer and then then passes its result to the next neuron in the output layer. The output layer also performs same calculation as the hidden layer neurons and the final result (output) is compared to the actual output.

3.5 Training Method

Training is used to gain generalised knowledge about the system under consideration and testing is used to predict (forecast) the system behaviour using the knowledge gained [21]. During training, the weights and biases of the network are iteratively adjusted to minimize the network generalisation errors. When training the model, the Mean Squared Error, Cross Entropy Error, Minkowski Error, Normalised Squared Error, Root Mean Squared Error and Weighted Squared Error methods and methods in the neural network toolkit were taken into consideration.

3.6 The Prediction Stage

The neural network is set for prediction after its training. The imported inputs consisted of the whole historical data time series from (2012-2018) stored in the database as shown in figure 4, except for the last day's prices, while the targets consisted of all the closing prices except for the first day's price. This makes the number of input samples match the target samples evenly. Inputs used are open, close, low and high to represent the opening price, closing price, high price and the low price while the output is the close value. The data set was divided into 70% for training, 15 % for testing and 15% validating the data. Five previous data points were considered for training, with η (0.001) learning rate, two hidden layers, one with 100 nodes and the other with 50 and maximum of 30 epochs. Unipolar Sigmoid activation function with 0.5 was used.

Figure 4 shows the database tables for the selected stocks.
The following classes were defined in the course of implementing the network:

- Probabilistic Layer: represents a layer of probabilistic neurons,
- Principal Components Layer: represents the layer of principal component analysis.
- Bonding layer: represents a layer of bounding neurons.
- Multilayer Perceptron: represents the concept of multilayer perceptron.
- ScalingLayer: represents a layer of scaling neurons.
- UnscalingLayer: represents a layer of unscaling neurons.

The MATLAB script for dynamic time series calculations was applied to the data to create and train the network. The network is used to solve a system of equations and to find four constant states that were variables that were likely to fall into one of the ten states of a stock price for a given day. If the information is used, our data can be used on those equations, and the next stock prices can be predicted shortly. We were able to predict stock prices successfully by this method in the next few days.

IV. RESULTS AND DISCUSSION

4.1 Results

Figure 5 presents the training interface on MATLAB; training of the model stops either when it reaches the specified number of epochs i.e. the number of passes of the whole training dataset completed by the algorithm or when Mean Squared Error (MSE) is rarely improving after certain epochs.

The performance curve of the data sets for different cases is presented in Figure 6. The circle in the performance curve shows the best validation performance of 0.0059445 at epoch 20.

Figure 7 presents the Error Histogram which shows the network accuracy. For the target input index, error histogram shows the variation between the predicted value and the actual value. The more the grouping of histogram tends towards 0 (zero), the better the network, a sudden up/down movement in the histogram means that the predicted value varies significantly from the actual value for that input index.

The regression R Values were tested for the cases to measure the correlation between outputs and targets as presented by figure 8. A regression R-value of 1 means a close relationship and 0 a random association. Figure 9(a) and (b) present the graph of the opening and closing prices prediction and the level of accuracy of some of the companies.

The result shows a strong positive correlation between outputs and targets with 0.94664, 0.8584, 0.92689 and 0.92997 repectviely for the traiing, testing, va;idation and oversll sets.

Figure 9 shows sample of the opening and close price prediction for diffenrent days for the selected companies for two comapnies.

The opening and closing stock prediction accuracies of the ten selected companies, using the model, is shown in figures 10.

4.2 Discussion of the Results

For different combinations of data and parameters, the results and outputs obtained for the ten selected companies listed under top gainers in the Nigerian Stock Market are presented in table 1. The network consists of six input layers and one output layer through the experiment; however, the number of hidden layers and neurons in each layer vary.

Normalized Mean Square Error (MSE) along with Correct Direction % and Standard Deviation (SD) were used for comparing the performance of the system. MSE was obtained by squaring the difference between the calculated output and the actual output; however, it was observed that MSE varies with stock prices and thus could not be used for comparison. Normalised MSE was obtained by dividing MSE with the stock price. Correct Direction % alone is not sufficient for the analysis; it was combined with the normalised MSE for comparing neural networks. Standard Deviation (SD) was used to identify the range for the accuracy of the network, and was used along with Correct Direction %.

V. CONCLUSION

This study employed Artificial Neural Network in predicting stock prices of ten selected companies in the Nigeria Stock Market. Historical data obtained from the Investing Website of the companies listed as top gainers in the Nigerian Stock Market were split into three, 70% for training, 15% for validating and 15% for testing. The ANN model comprised six input neurons, one output neuron and two hidden layers for building, training, and testing the network, which was implemented in MATLAB, after which the results obtained formed the model. A web interface was implemented and used for prediction. The predictive model was compared with real-life data, using the ten selected stocks. The performance of the model in prediction stock prices for the ten selected companies were very satisfactory

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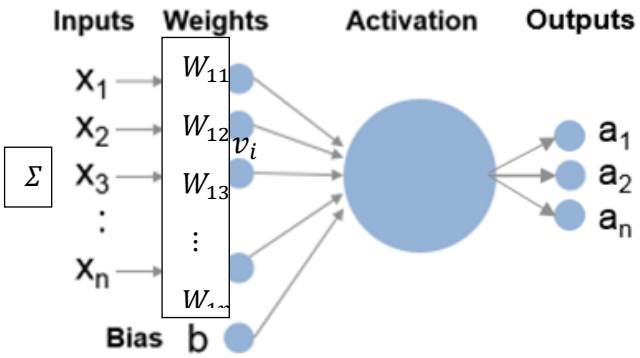

Figure 1: The Model of artificial neuron [19]

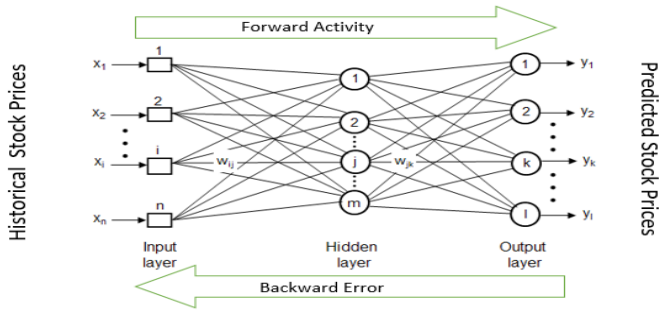

Figure 2: Feed-forward Neural Network with Backpropagation (FFNNB) [18].

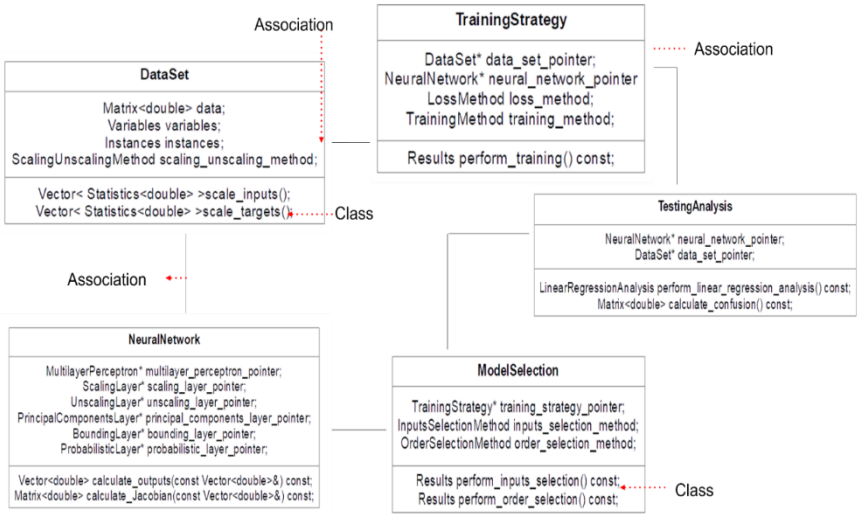

Figure 3: Class diagram of the model stock prediction

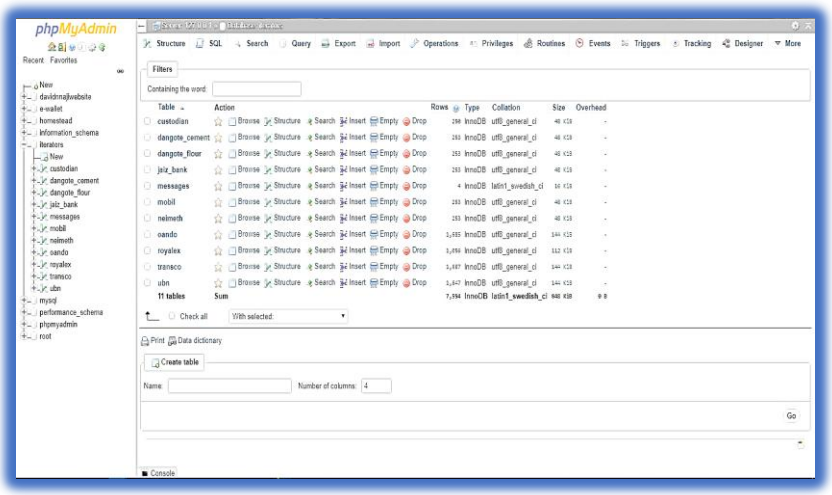

Figure 4: Database containing tables for the 10 selected different companies.

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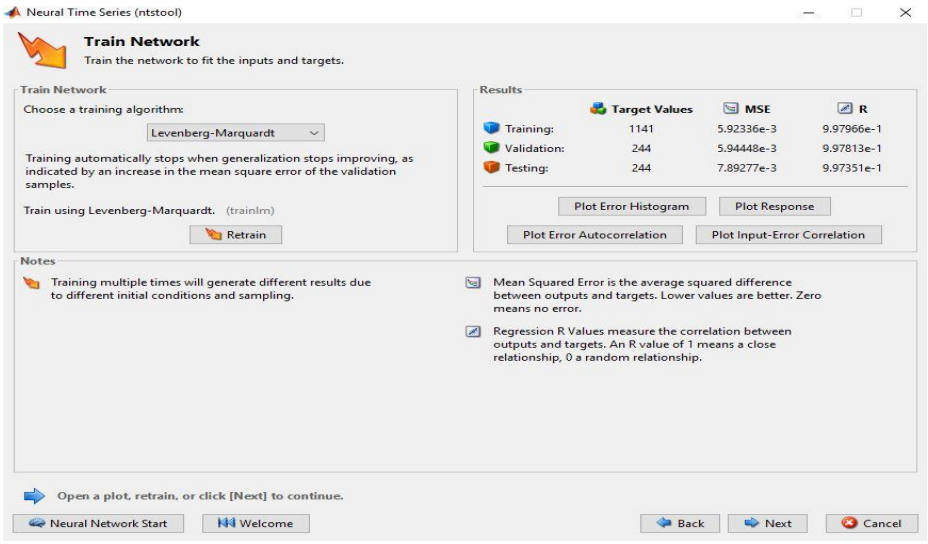

Figure 5: MATLAB ANN Time Series Interface

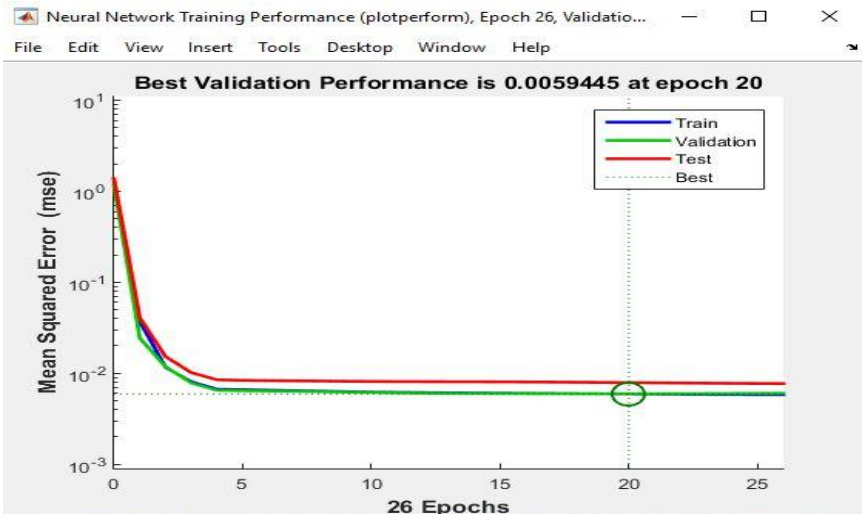

Figure 6: Performance curve of the data sets

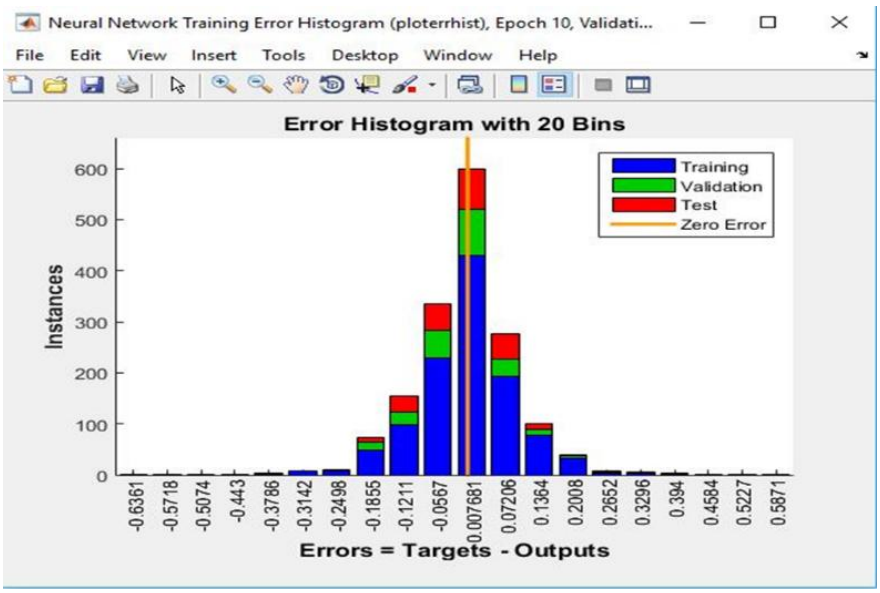

Figure 7: Error histogram.

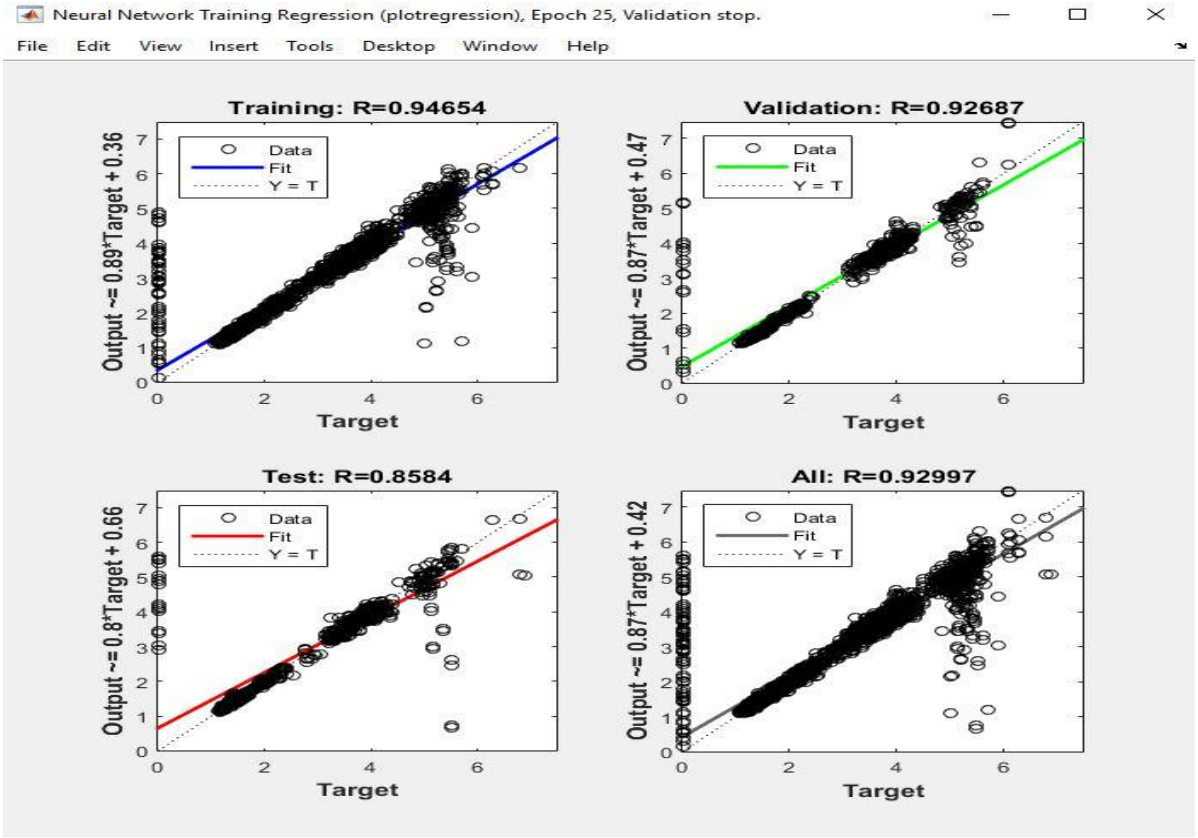

Figure 8: Regression values..

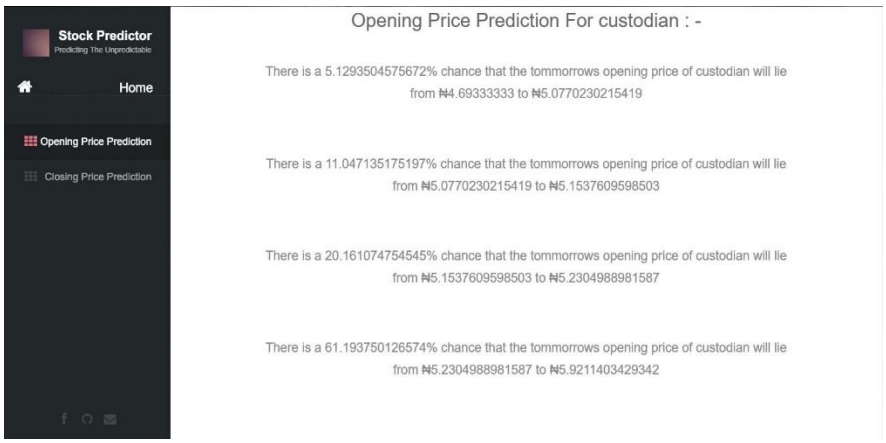

Figure 9 (a): Opening price prediction for the Custodian Insurance

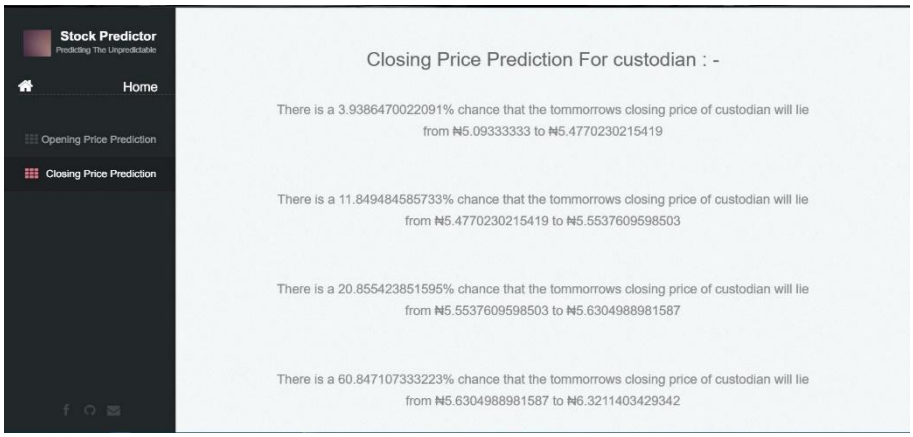

Figure 9 (b): Closing price prediction for the Custodian Insurance

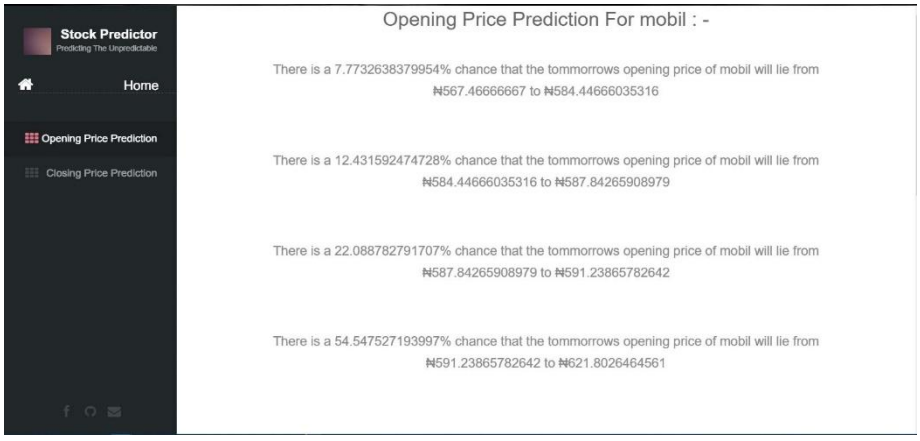

Figure 9 (c): Opening price prediction for the Mobil

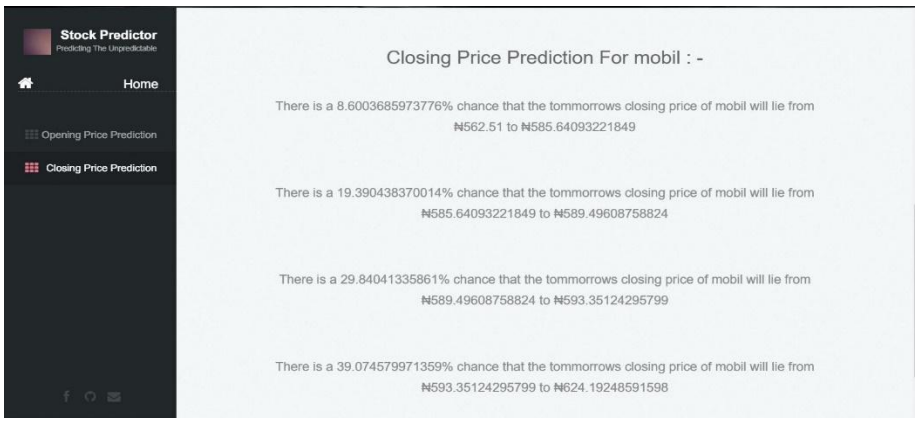

Figure 9 (a): Closing price prediction for the Mobil

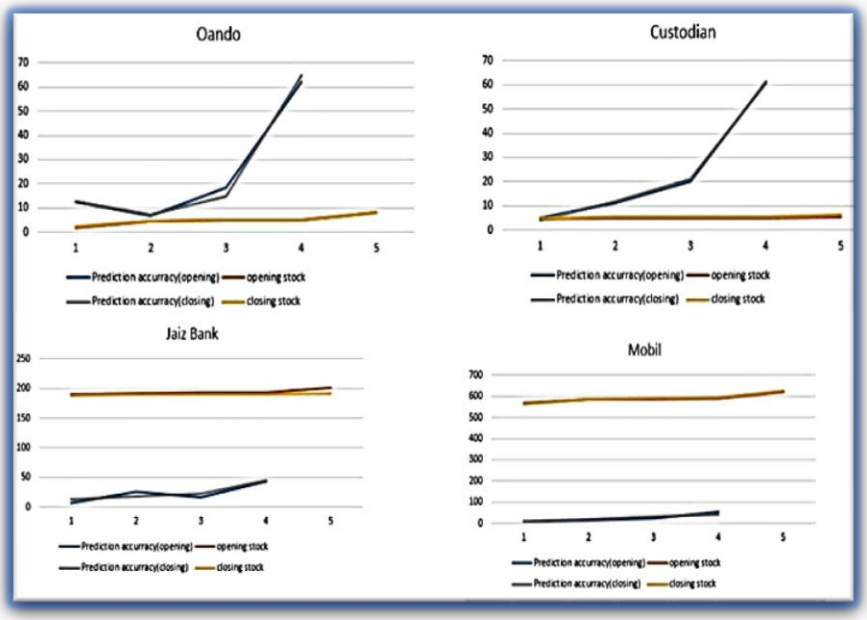

Figure 10 (a): Opening and closing prediction accuracies of four of some the selected companies

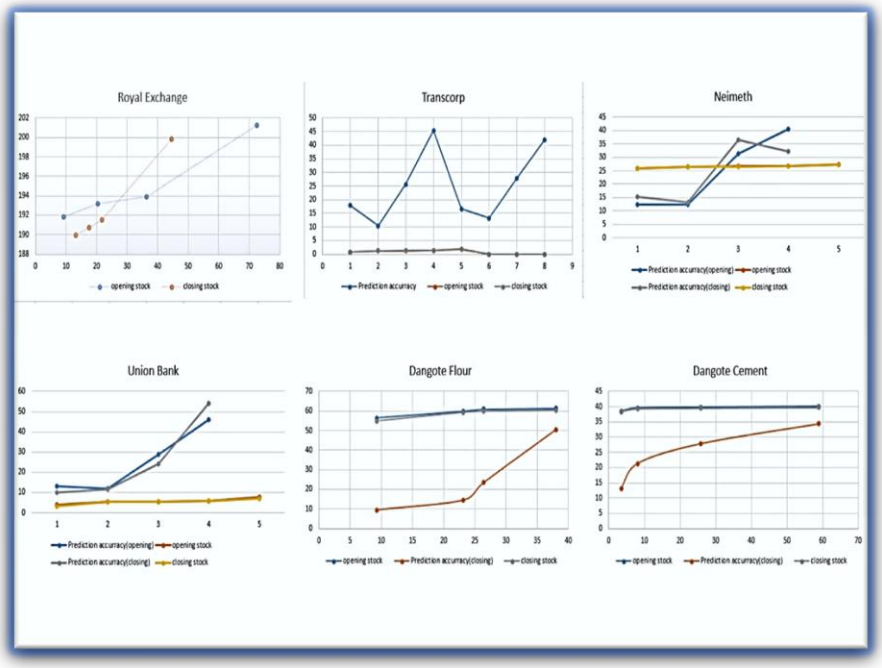

Figure 10 (b): opening and closing accuracies of six of the selected companies.

Table 1: Summary of the Network Size and Accuracy Analysis of the ten selected companies

	Network Size Analysis					Network Accuracy Analysis				
Company	Number of input neurons	Number of output neuron	Number of hidden layers	Number of neurons in each hidden layer	Total Neurons	MSE	Normalized MSE	Correct Direction %	Mean(Error)	Standard Deviation (Error)
Custodian	6	1	3	3	9	177.792	0.14287	52.12	0.7727	13.4676
Unicn Bank	6	1	2	3	6	87.2659	0.1002	30.8511	2.9873	8.8747
Mobil	6	1	7	7	49	2613.62	17.5448	9.04	-42.56	28.3931
Oando	6	1	1	1	1	37.16	0.062	42.55	1.2674	5.9792
Jaiz Bank	6	1	1	1	1	0.7138	0.0097	52.65	0.0497	0.8457
Neimeth	6	1	3	3	9	1.7378	0.0133	56.38	0.1027	1.3177
Dangote Cement	6	1	1	1	1	46.25	0.0579	50	0.1509	6.8173
Transcorp	6	1	1	1	1	103.9	0.0866	43.61	2.0849	10.0043
Dangote Flour	6	1	2	3	6	4.894	0.0496	64.36	0.5567	2.1467
Royal Exchange	6	1	1	1	1	1.4888	0.0155	56.38	0.0623	1.2218