COMPARATIVE ANALYSIS OF ARTIFICIAL NEURAL NETWORK'S BACK PROPAGATION ALGORITHM TO STATISTICAL LEAST SQURE METHOD IN SECURITY PREDICTION USING NIGERIAN STOCK EXCHANGE MARKET

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Abstract

Statistical analysis has often been used in predicting financial operations in Nigerian economy. In this work, artificial neural network was used to predict movements in stock prices in Nigerian Stock Exchange market. Studies were carried out for the prediction of stock index values as well as daily direction of changes in the index. A network was designed using Back Propagation Algorithm (BPA) to predict stock index values and prices in the exchange for a period of 90 days. The data collected during this period was processed using the BPA algorithm to get an output such that the error between the actual indices and prices, and the computed output was brought to minimum. About 90% of the data was used for the actual training while the remaining 10% was used as test data. The same data was also processed using the Least Squares (LS) method. The results show that BPA algorithm has superior performances in terms of the accuracy of prediction over the LS method. This result of the study is useful to stock market operators.

Introduction

The paper focuses on predicting the value of stock shares traded in the Nigerian Stock Exchange using Back Propagation Algorithm (BPA) of Artificial Neural Network (ANN). In Nigeria, evaluation, estimation and prediction are often done using statistical packages such as SAS, SPSS, GENSTAT, MATLab, etc. Most of these packages are based on conventional algorithms such as the least square method, moving average, time series, curving fitting, etc. The performances of these algorithms are not robust enough when the data set becomes very large.

For an example, when the moving average algorithm in time series was implemented using a programming language with a set of data and, outputs were generated and compared to the outputs obtained from GENSTAT using the same data, the two results were not the same when the data set becomes very large. Also, the beginning and end of the time series data are lost in moving averages. Moving averages in statistical methods can generate cycle that is not present in the input data. Algorithm that implemented the multivariate least square method in statistical packages is not efficient when the data set becomes very large (Vancoillie A).

To overcome this somewhat, BPA algorithm has now been widely proposed by the research community to predict large set of data. The idea of using BPA algorithm to predict large data set has assisted in deriving precise result from imprecise data. Neural Networks are self training systems that imitate the work of human brain. It can be defined as entirely new paradigm in computing that are based on replicating the function and the structure of human brain. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems.

Data model

The input parameters that affect the stock market index value are as follows:

- previous day stock index value according to closing price
- quantity of stock index values
- daily changes in index values
- corresponding values of stock share index value traded in Naira.

The number of companies used for the study was 35. The first 30 companies' stock data collected were used for training while the last 5 companies' data were used for testing after training. Experimental data were gathered directly from Nigerian Stock Exchange website (www.nigerianstockexchange.com) for a period of 90 days. For the data model, back propagation neuron model and least square method were applied.

Statistical methods and artificial neural network

The usual statistical methods for estimation, evaluation and predicting are least square, move averages in time series, linear regression, etc. We used Least Square algorithm as our statistical method, and employed Back Propagation Algorithm as the Artificial Neural network model. Back propagation algorithm was employed due to its multi-layer perception structures.

Least square method

The least squares regression of y on x is $y = a_0 + a_1 x$ where a_0 and a_1 are obtained from the normal equations:

$$\sum_{i=1}^{n} y_i = a_0 n + a_1 \sum_{i=1}^{n} x_i$$

$$\sum_{i=1}^{n} x_i y_i = a_0 \sum_{i=1}^{n} x_i + a_i \sum_{i=1}^{n} x^2{}_i$$

which yield

$$a_0 = \frac{\left(\sum_{i=1}^{n} y_i\right)\left(\sum_{i=1}^{n} x^2{}_i\right) - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} x_i y_i\right)}{n\left(\sum_{i=1}^{n} x^2{}_i\right) - \left(\sum_{i=1}^{n} x_i\right)^2}$$

$$a_1 = \frac{\left(n\sum_{i=1}^{n} x_i y_i\right) - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{n\sum_{i=1}^{n} x^2{}_i - \left(\sum_{i=1}^{n} x_i\right)^2}$$

Similarly, the least square line of *x* on *y* is given by $x = b_0 + b_1 y$

The standard error of estimate *y* on *x* is $S_{y,x} = \sqrt{\frac{\sum_{i=0}^{n} (y - y_{est})^2}{n}}$

This equation is written as $S^2_{y,x} = \frac{\sum_{i=1}^{n} y^2 - a_0 \sum_{i=1}^{n} y_i - a_1 \sum_{i=1}^{n} x_i y_i}{n}$ for easy programming.

Back propagation (learning algorithm)

The learning algorithm of a neural network can either be supervised or unsupervised. A neural network is said to be learning supervised if the desire output is already known. During the learning of supervised method, one of the input patterns is applied to the network input layer. The pattern is propagated through the network to the network output layer. The output layer generates an output pattern which is then compared to the target pattern. Depending on the difference between output and target, an error value is outputted. This outputted error indicates the network's learning effort which can be controlled by the imaginary supervisor. The greater the computed error value is, the more the weight will be changed.

Neural networks that learn unsupervised have no such target output value. It cannot be determined what the result of the learning process will look like. During the learning process, the units' weight values are arranged inside a certain range, depending on given input values. The paper used supervised learning to predict Nigerian stock exchange market indices because of its ability to use binary number and XOR operation. It also employs generalized delta rule for supervised training. The model receives an input pattern vector from the environment through its input layer and distributes it unchangeable to the first hidden layer of neurons. Unlike neurons in the input layer, those of the hidden and output layers are non-linear units. They receive weighted sum of output from the previous layer as input. The network input for neuron **j** denoted by *network* **j** is define as:

$$network \quad j = \sum w_{ij} O_i \theta_j$$

where θ_j is the threshold or bias for neuron j (it is a constant unit and always set to either 0 or 1. O_i is the output of neuron i connected to neuron j through the interconnection weight W_{ij}. Figure 1 illustrates the simple structure of Artificial Neural Network.

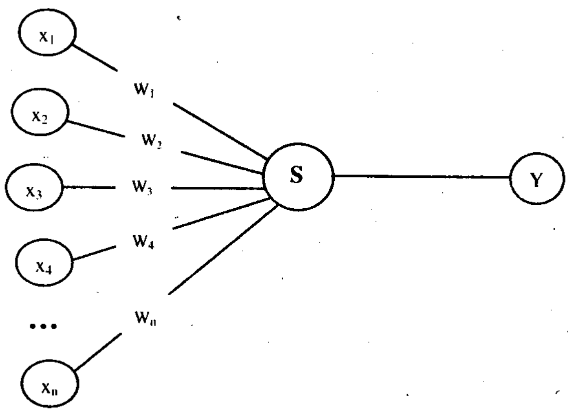

Figure 1. Simple structure of Artificial Neural Network.

In order to produce consistently correct result or output, network weights have to be trained. Back propagation learning algorithm is illustrated as follows:

1. *randomize all network weight to small number e.g. -1 ≤ 0 ≤ 1.*
2. *apply an input training vector X and calculate the ANN_NET signal from each neuron using the standard formula:*

$$\text{ANN\_NET}_j = \sum_{i=1}^{n} x_j w_{ij}$$

3. *apply the threshold activation function to the ANN_NET signal from each neuron as follows:*

$$\text{OUT}_j = \begin{cases} 1, \text{ if } \text{ANN\_NET}_j \text{ is greater than threshold } \zeta_j \\ 0, \text{otherwise} \end{cases}$$

4. *compute the error for each neuron by subtracting the actual output from the target output;*

$$\text{error}_j = \text{target}_j - \text{OUT}$$

5. *modify each weight as follows:*

$$w_{ij}(t+1) = w_{ij}(t) + \alpha x_i error_j$$

6. repeat step 2 through 5 until the error is sufficiently low.

Implementation of back propagation algorithm

Back propagation algorithm as described above was implemented in Java Programming Language. The data was read in sequentially in the order in which they were collected and the maximum and minimum of each attribute obtained, followed by normalization. The programme was written in such a way that the hidden node was increased gradually in other to attain proper convergence. The sigmoid of all inputs to the hidden layers with the bias value multiplied by the randomly generated weight for each unit was computed. To compute the output layer, the summation of the sigmoid from hidden layer was also computed. The update of the input layer with two input nodes was also computed. This involves the product of the learning rate and error of output. After iteration, the corresponding calculated output was closed to the actual output from the data set.

Implementation of least square method

The Least Square Method $S_{y,x}^2 = \frac{\sum_{i=1}^{n} y^2 - a_0 \sum_{i=1}^{n} y_i - a_1 \sum_{i=1}^{n} x_i y_i}{n}$ was also implemented using java programming language and the same set of data was applied as input, taking the same precautions as in the case of the BPA algorithm.

Comparison of back propagation algorithm to the least square method

The back propagation performances are compared to the performances of the least square method. Table 1 shows the two models with average relative percentage errors that were derived from the set of Nigerian stock index values that served as input data to the both least square and back propagation algorithms.

Table 1: Relative percentage errors of Back propagation and least square.

Model	Average relative percentage error (%)
Back propagation with one hidden layer	1.430
Back propagation with two hidden layer	1.486
Back propagation with three hidden layer	1.512
Least square method with 30 companies	2.43
Least square method with 35 companies	3.15

As shown in Table 1, the relative percentage error of back propagation with one, two and three layer is still lower than the Least Square Method, although the efficiency of Back Propagation Algorithm varied with the number of hidden layers. For example, back propagation with one hidden layer had the highest accuracy (1.43). Looking at the table again, the average relative percentage errors calculated between back propagation and least square model showed that back propagation model was superior to the least square method. The prediction models of back propagation were more robust than the least square method. More so, using one hidden layer during the processing performs better than using two or more layers. This also reduces the time complexity of the algorithm.

Conclusion

The work is not saying that statistical formulas are not robust enough to predict or evaluate the data or when the data become large. Most of the statistical packages use conventional algorithms which require approximation for better performances. The work employed back propagation of ANN because it is used to train data for prediction while statistical methods calculate data for prediction, estimation or evaluation. From the results of the two methods (Least Square and Back Propagation Algorithm), it is better to use artificial neural network to predict a large set of data. For example, the average relative percentage errors of back propagation are always lower than the average relative percentage of least square method. This indicates the efficiency of the back propagation algorithm over least square method.

It can be concluded that back propagation as one of the Artificial Neural Networks is a better architecture to evaluate, estimate and predict a set of large data than any statistical methods such as least square method.

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