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Appling Artificial Neural Networks Models in Prediction

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Abstract

In this study we viewed concept of the Artificial Neural Networks (ANN) technology, and displayed its advantages, and its applications, and applied this technology in the prediction in time series, we were use the monthly closing price from Khartoum Stock Exchange index for the period from January 2012 to December 2021, to predict future values, by using software MATLAB R 2013a.

The model building steps were done easily by MATLAB program, which selected the learning algorithm and functions to training the network automatically, we determined the number of layers and decay, the data series were divided to three sets: training, validation, and testing set. Depend on values of Mean Square Error (MSE) and Correlation Coefficient between target values and output values (R), the best forecasting model was selected, that has least (MSE) and high value of (R).

The figure7 represent the predicted values were consistent with the real values of the series showing the efficiency of the model.

Keywords: Artificial Neural Networks, Time Series Prediction, Stock Exchange Index.

1. Introduction

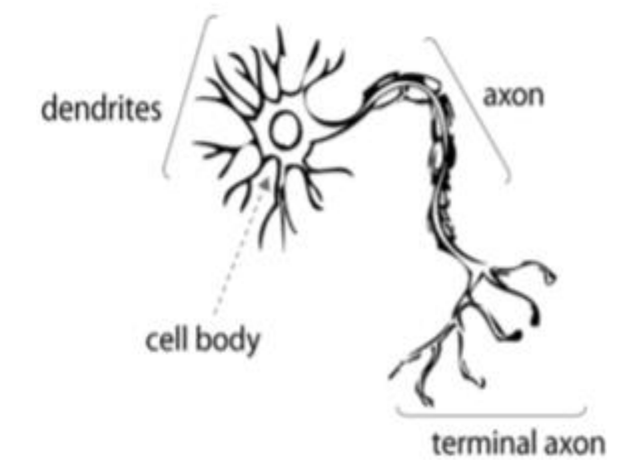
The ability of artificial entities to solve complicated problems is known as artificial intelligence (AI); these systems are frequently taken to be computers or other devices [1]. An Artificial Neural Networks (ANN), which fall under the Artificial Intelligence (AI) methodology, is a data processing model based on the way biological nervous systems, it have enjoyed a recent revival in interest associated with advances in computer technology. Many artificial intelligence experts believe that artificial neural networks are the best and perhaps the only hope for designing an intelligent machine. [2]

Artificial neural networks (ANNs) are used in variety of applications, such as, prediction, on this study we aim to know the extent to which can intelligent models build and develop predictive models of data and data that are in the form of time series, such as stock prices, we shall use monthly closing price from Khartoum stock Exchange index as applying example.

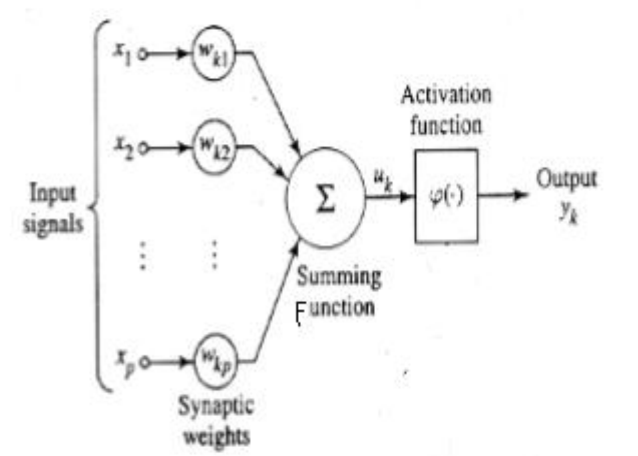
2. Literature Review

2.1 What are Artificial Neural Networks:

Artificial neural networks are popular machine learning techniques that simulate the mechanism of learning in biological organisms. The human nervous system contains cells, which are referred to as neurons. The neurons are connected to one another with the use of axons and dendrites, and the connecting regions between axons and dendrites are referred to as synapses. This cell is illustrated in Figure1 (a) the strengths of synaptic connections often change in response to external stimuli. This change is how learning takes place in living organisms. This biological mechanism is simulated in artificial neural networks, which contain computation units that are referred to as neurons. The computational units are connected to one another through weights, which serve the same role as the strengths of synaptic connections in biological organisms. Each input to a neuron is scaled with a weight, which affects the function computed at that unit. This architecture is illustrated in Figure 1 (b). An artificial neural network computes a function of the inputs by propagating the computed values from the input neurons to the output neuron(s) and using the weights as intermediate parameters. Learning occurs by changing the weights connecting the neurons. Just as external stimuli are needed for learning in biological organisms, the external stimulus in artificial neural networks is provided by the training data containing examples of input-output pairs of the function to be learned. [3]



a. Bilogical neuron, source: Papadopoulos et al..2021 [4]



b. Artificial neuron, source: Simon Haykin 2009 [5]

Fig. (1): diagram of Biological Neuron and Artificial Neuron

2.2 Principles and Development History of Artificial Neural Networks

One way to understand the ideas behind neural computation is to look at the history of this science. McCulloch and Pitts described in 1943 [6] a model of a neuron that is binary and has a fixed threshold. A network of such neurons can perform logical operations, and it is capable of universal computation. Hebb [7], in his book published in 1949, proposed neural network architectures and the first training algorithm. This is used to form a theory of how collections of cells might form a concept. Rosenblatt, in 1958 [8], put together the ideas of McCulloch, Pitts and Hebb to present the perceptron neuron model and its training algorithm. Minsky [9] and Papert demonstrated the theoretical limits of the perceptron in 1969. Many researchers then abandoned neural networks and started to develop other artificial intelligence methods and systems. New models, among them the associative memories, self-organizing networks, the multilayer perceptron and the back-propagation training algorithm, or the adaptive resonance theory (ART), were developed later, which brought researchers back to the field of neural networks. Now, many more types of neural networks have been designed and used [10].

2.3 Advantages of ANNs:

Adaptive learning is the most important advantages of the ANNS systems, Ability to learn how to perform tasks based on information given for practice and introductory experiences. [11]

Neural Networks offer also some useful properties and capabilities like: massively parallel distributed structure, Nonlinearity (An ANN can be linear or nonlinear), Self-Organization, and Uniformity of Analysis and Design.

2.4 Applications of Neural Networks:

Today, artificial neural networks are used in a variety of applications, such as pattern recognition issues, which include issues such as line recognition, speech recognition, image processing, and the like, as well as categorization issues such as text or image classification. [2]

In the medicine and healthcare applications, the ANN can be used in analyzing and diagnosing the symptoms of a pacemaker (electrocardiograph), as well as a trained network that can diagnose the disease and even prescribe medication. [12]

In fact they have already been successfully applied in many fields: industries inspection, financial analysis, time series analysis and forecasting, robot control, weather forecast, risk management, sales forecasting, pattern recognition, electronic noses and many other applications.

2.4.1 Some Studies Used ANNs in Stock Exchange:

(Di Persio and Honchar 2016) [13] Used ANNS for stock price prediction in order to predict financial time series movements and to develop the marketing systems.

(Rezaee, Jozmaleki, and Valipour 2018) [14] Also used ANNs for finical prediction to increase finical performances of stock exchange companies.

2.5 Components of an ANN

There are a large number of different types of networks, but they all are characterized by the following components:

2.5.1 Input Layer:

The input layer of an ANN typically functions as a buffer for the inputs, transferring the data to the next layer. Pre-processing the inputs may be required as ANNs deal only with numeric data. This may involve scaling the input data converting or encoding the input data to a numerical form that can be used by the ANN.

2.5.2 Hidden Layers:

Between the input and output layer, there can be one or more intermediate layers that are called the hidden layers.

A network that contains one hidden layer called (single- layer network), and each network contains more than one hidden layers called (multi-layer network).

There are no standard rules or theories in determining the number of neurons in the hidden layers. [15]

2.5.3 Output Layer:

The output layer of an ANN functions in a similar fashion to input layer except that it transfers the information from the network to the outside world. Post-processing of the output data is often required to convert the information to a comprehensible and usable form outside the network, the number of input and output neurons are determined by the application at hand. [15]

2.5.4 Connecting Links:

They are the communication links between the different layers, they link layers with each other or units within each layer through the weights that are associated or attached to each synapse, and the task of these links is to transfer the signals and data between processing units and layers.

2.5.5 Processing Units (Neurons):

These units perform a process processing data in a neural network, these units are connected in different ways by connecting links, its consist of:

a. **Weighting Coefficients** (w_{ij}):

Each input signal has weight according to input power.

b. **Summation Function**:

Adding the input signals, weighted by the respective weights of the neuron.

c. **Transfer (Activation) Function**:

The transfer or activation function is a function that determines the output value of network after summation of its weighted inputs by summation function. A transfer function gives any real numbers into a domain normally bounded by (0 to 1) or (-1 to 1). Bounded activation functions are often called squashing functions. [16]

d. Outputs Function:

The output is mast often equal to the output of the transfer function, but there some networks in which processing unit modifies the result of the transfer function, and this is done by competing with neighbouring processing units with each other, and competition is usually in the processing units that have greater activation and this competition determines which processing unit will be active or which will output.

It's worth noting here that there is no mathematical law or scientific rule followed to determine the appropriate structure of the network, nor to determine the initial values of the weights, nor to determine the number of times or training to obtained the results (predicted values) which closed to the real value.

2.6 Types of Activation Functions

The activation function, denoted by$\varphi(u)$, defines the output of a neuron, we identify four basic types of activation functions and illustrate in Figure 2.

2.6.1 Threshold Function

In this type of activation function the output is binary valued with the range from 0 to 1, and neurons use this activation function are often referred to as McCulloch-pits model [6], and given by:

$$\varphi(u) = \begin{cases} 1 & if \;\; u \geq 0 \\ 0 & if \;\; u < 0 \end{cases}$$

There also exists threshold functions with other ranges.

2.6.2 Sigmoid Function (Logistic Function)

It is by far the most common form of activation function used in the construction of neural networks, a sigmoid function assumes a continuous range of values from 0 to 1. [5]

$$\varphi(u) = \frac{1}{1 + e^{-au}} \;\; u \in R$$

The parameter a feeling the slope of the function and when a goes across infinity, the logistic function becomes threshold function. [17]

2.6.3 Linear (or Identity) Function:

For the linear activation function have form:

$$\varphi(u) = u \quad , \quad u \in R$$

Or

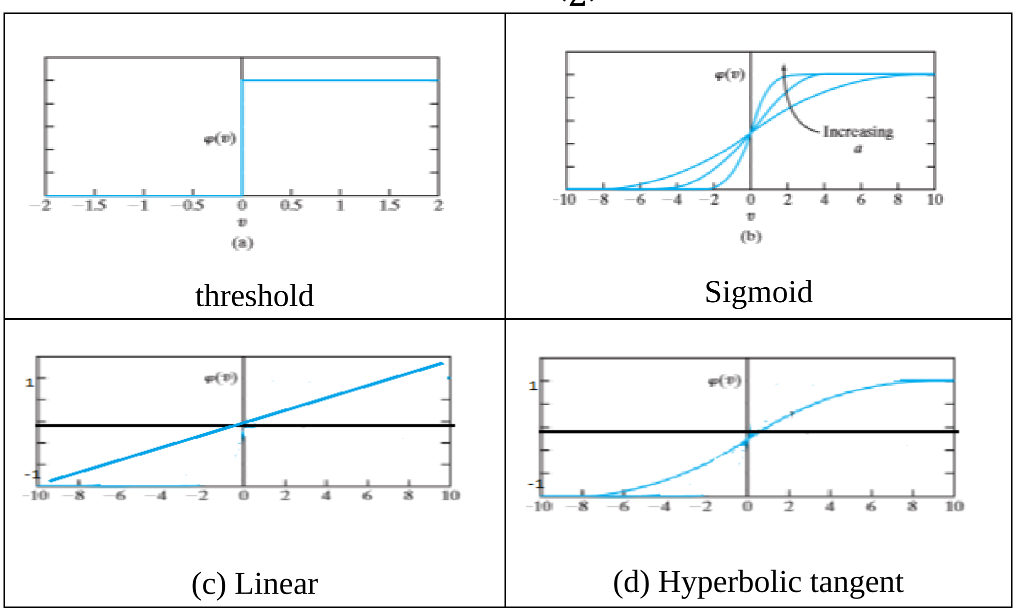
$$\varphi(u) = ku \quad , u \in R$$

Thus, the output signal of a neuron model with linear activation function is equal to its net input. The range of it from $-\infty$ to ∞. [17]

2.6.4 Hyperbolic Tangent Function

It is also sigmoid function with range [-1, 1], [18] and given form:

$$\varphi(u) = \tanh\left(\frac{u}{2}\right) , u$$



threshold | Sigmoid | (c) Linear | (d) Hyperbolic tangent

Figure (2): Diagram of Activations Functions (Source: Simon Haykin 2009) [5]

2.7 Mechanism of ANN

The basic structure of an ANN consists of artificial neurons, that are grouped into layers (input, hidden and output layers) the neurons not only receive input signals put also output information with a particular strength on the input paths to the other neurons through connection weights. All the neurons compute their output using their output function, and then the results may be put through their neighbouring neurons for the next step of processing.

Each inputs $(x_1, x_2, \ldots\ldots, x_i)$ being connected to neuron j with weights $(w_{k1}, w_{k2}, \ldots w_{ki})$ attached which may have either a positive or a negative value associated with it. Positive weights activate the neuron while negative weights inhibit it. The neuron sums all the signals it receives, with each signal being multiplied by its associated weights on the connection.

$$u_k = \sum_{j-1}^{m} w_{kj} x_j$$

This output (u_k) is then passed through a transfer (activation) function, to give the final output (o_j) the transfer functions can be selected by the user.

The learning algorithm works by minimizing the error between the output and the target (actual) by propagating the error back into the network. The weights on each of the connections between the neurons are changed according to the size of the initial error. The input data are then fed forward again, producing a new output and error. The process is reiterated until an acceptable minimized error is obtained. [15]

2.8 Network Architectures:

In general, we may identify three fundamentally different classes of network architectures:

2.8.1 A single-Layer Feed-Forward

A network is feed-forward when the connections in the network are directed forward, from the input layer towards the next layer and never in the other trend or connections within the same layer. [19] A network has a single layer of artificial neurons, if the input layer is straight projected onto the output layer. [17]

(That is mean there is no hidden layers in the network) A single layer – feed forward is a simplest neural network.

2.8.2 Multi-Layer Feed-Forward

The multi-layer feed-forward is development of the single layer network, where used to for much more difficult and complicated problems can not be solved by the single layer method or consume more time. It formation from the most important three part in any networkers which are an input layer of neurons, one or more hidden neurons layers and an output neurons layer. [20]

2.8.3 Feed-Back Network

In the Feedback ANN systems, content addressable memories are used, learning neural networks using a feedback process is by comparing the output of a network with the output that is desired and expected. The difference between these two outputs is used to change and modify the weights of the connections between the network units. [2]

2.9 Learning Processes

Learning is the weight modification process of an ANN in response to external input, there are three types of learning:

2.9.1 Supervised Learning

In supervised training style, comparison between actual outputs and desired output of an ANN, therefore it attempts that desired solutions are known for the training data sets. This consists reduce error with the passing time by adjusting the weights input until acceptable network accuracy is reached. [21]

It is also referred to as Learning with a teacher, we may think of the teacher as having knowledge of the environment. [5] It is by far the most common type of learning in ANNs [15].

2.9.2 Unsupervised Learning

It is sometimes called self-organized learning and requires no explicit output values for training, and there is no external teacher or critic to oversee the learning process. [5]

2.9.3 Reinforcement Learning

It is a hybrid learning method in that no desired outputs are given to the network, but the network is told if the computed output is going in the correct direction or not. [15]

2.10 Learning Algorithms

There are many learning algorithms (rules) in common used, the two most popular ones are: the delta rule and the back propagation algorithm. The learning procedures have to select the weights $\{w_{ij}\}$ and the 'biases' $\{\alpha_j\}$ which is usually taken to be one by minimizing the error. [22]

2.11 Model Selection Criteria (Performance Measures)

Although there can be many performance measures for an ANN forecaster like the modelling time and training time, the ultimate and the most important measure of performance is the prediction accuracy it can achieve beyond the training data.

An accuracy measure is often defined in terms of the forecasting error which is the difference between the actual (desired) and the predicted value. [23]

The most frequently used are:

The mean absolute error (MAE) $= \left|\frac{y_i - \hat{y}_i}{n}\right|$

The mean squared error (MSE) $= \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}$

The mean absolute percentage error (MAPE) $= \frac{1}{n}\sum_{i=1}^{n}\left|\frac{y_i - \hat{y}_i}{y_i}\right|$

Where y_t: *actual values* , $\hat{y}_t$: *is predicted value*, n: *series size*

The efficiency of prediction model was determined also by utilize the correlation coefficient (R). [21]

- **Correlation Coefficient (R).**

A relationship between tow variables, actual values y and predicted values $\hat{y}$. It is a descriptive measure between -1 and +1, defined as follows:

$$R = \frac{\sum_{t=1}^{n}(y_t - \mu_t)(\hat{y}_t - \hat{\mu}_t)}{\sqrt{\sum_{t=1}^{n}(y_t - \mu)^2 \sum_{t=1}^{n}(\hat{y}_t - \hat{\mu}_t)^2}}$$

Where: $\mu_t = \frac{\sum y_t}{n}$, $\widehat{\mu_t} = \frac{\sum \hat{y}_t}{n}$. [21]

2.12 Constructing the ANN Model

Firstly, the data to be used need to be defined and presented to the ANN as a pattern of input data with the desired outcome or target.

Secondly some processes are operated for date like finding the trend, relation between the variables and data distribution

Thirdly, the data are categorized to: training set, testing set and validation set.

Fourthly, the ANN paradigms is determined by selecting the number of neurons in input and output layers, number of hidden layers to be constructed and the number of neurons for each hidden layer.

The next step is selecting the transfer function and determine the evaluation criteria.

Next, the training process is started, it's involves the computation of the output from the input data and the weights. The learning algorithm is used to 'train' the ANN by adjusting its weights to minimize the difference between the current ANN output and the desired output.

Finally, an evaluation process has to be conducted to determine if the ANN has 'learned' to solve the task.

3. Application of ANN

As an application, we shall use the monthly closing price data from Khartoum stock Exchange (KSE) for the period from January 2012 to December 2021, as time series with 120 observations, and made ANN model to predict future values by using MATLAB R2013a program.

3.1 Descriptive Statistic of Data:

Table (1): Descriptive Statistic of KSE Series

Variable	Obs	Mean	Std.dev	Min	Max
KSE	120	7689.915	6530.359	2322.17	20455.31

The simple graph of series in Figure 3 shows that the series is non stationary, and it has trend and random fluctuations. This series follow Nonlinear Auto Regressive model (NAR):

$$y_t = f(y_{t-1} \dots \dots y_{t-d})$$

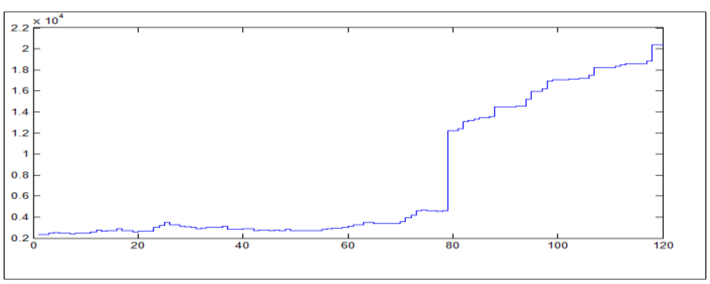


Figure (3): KSE Series Plot, MATLAB R2013a Output

3.2 Modelling Steps

According to model building steps, data series were divided to three sets , then determine number of hidden layers, and numbers of delays (d) , the model of time series have one input layer and one output layer .

The select of learning algorithm and training the network are being automatically with MATLAB program, we can change the deviation the number of hidden layers and number of delays, and return the training network until the results of the prediction were acceptable.

Some changed was done in training parameters, until the results of prediction were accepted, see Table 2 .Training algorithm which used is Levenberg-Marquardt it's one of back error propagation algorithm, the transfer function in hidden layer is sigmoid and output function is linear.

Table (2): Groups Details and Number of Hidden Neurons and Delays

Training set	7%	84 observations
Validation set	15%	18 observations
Testing set	15%	18 observations
number of Neurons in hidden layer		10
numbers of delays (d)		2

The correlation coefficient (R) values and (MSE) values used to evaluate the efficiency of the prediction. Table 3 illustrates that correlation coefficients (R) closed to1, indicate to high correlation between target values and output values.

Table (3): Mean Squared Error's and Correlation Coefficient's for Three Groups, MATLAB R2013a Output

Group	MSE	R
Training data	566953.11	0.9926
Validation data	74017.31	0.9993
Testing data	208696.66	0.9994

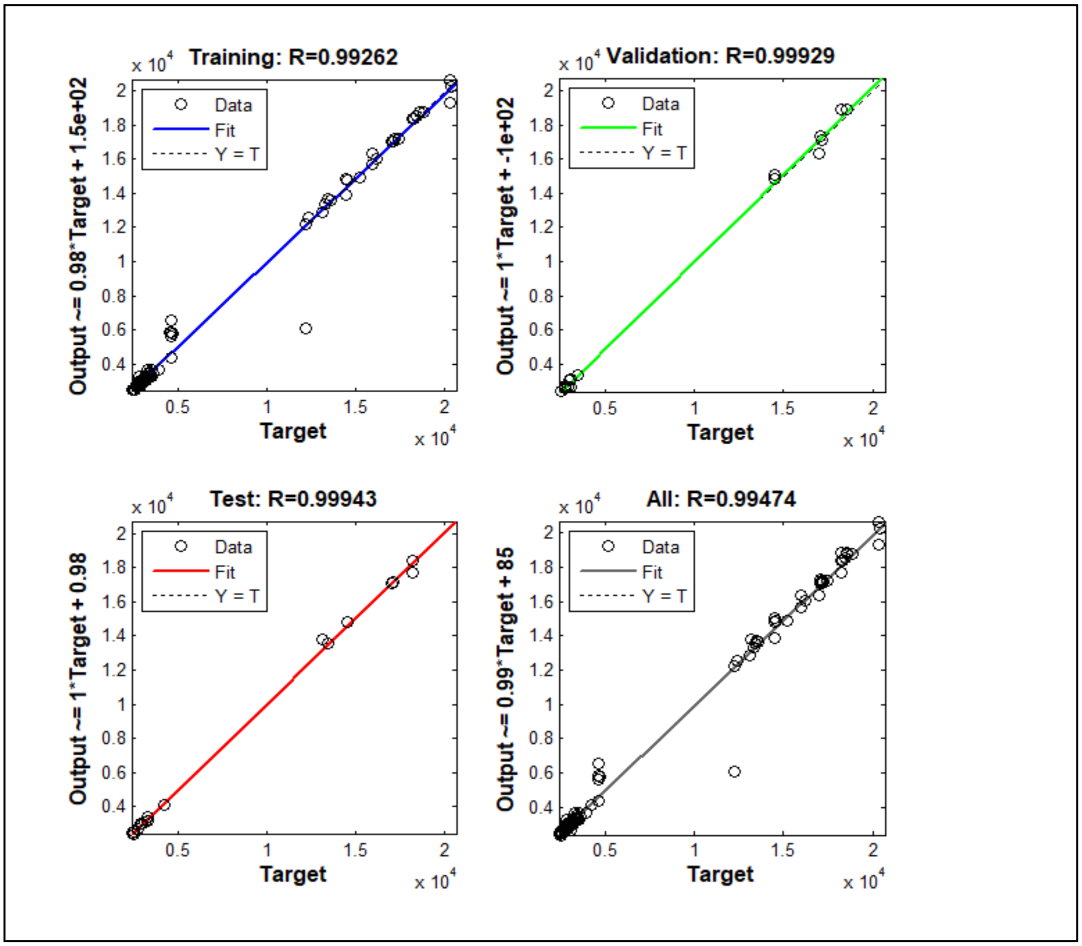


Figure (4): Correlation between Outputs and Targets, MATLAM R2013a Output

The autocorrelation function graphs of the errors series are shown in Figure 5. It can be seen that the errors are not correlated except fourth coefficient. And it has normal distribution see Figure 6. The amounts of Model performance measures in Table 4 indicate to efficient of model.

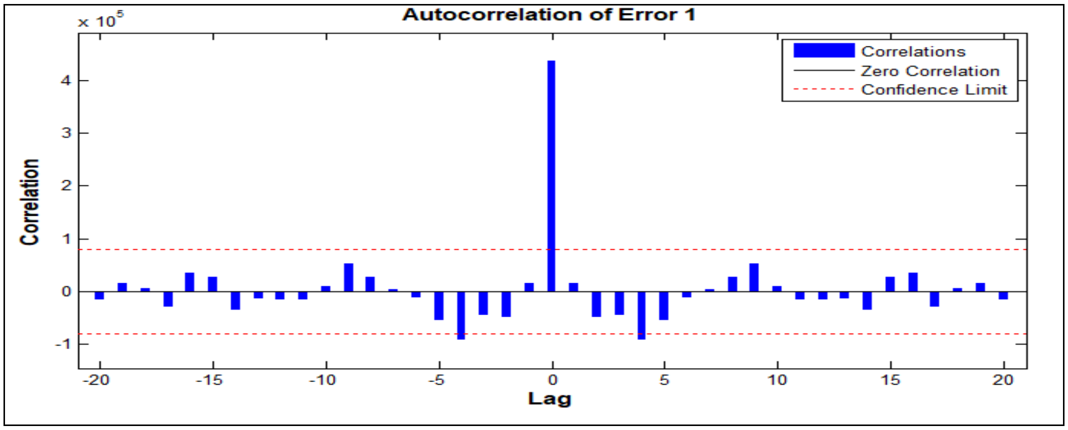


Figure (5): Error autocorrelation plot, MATLAM R2013a output

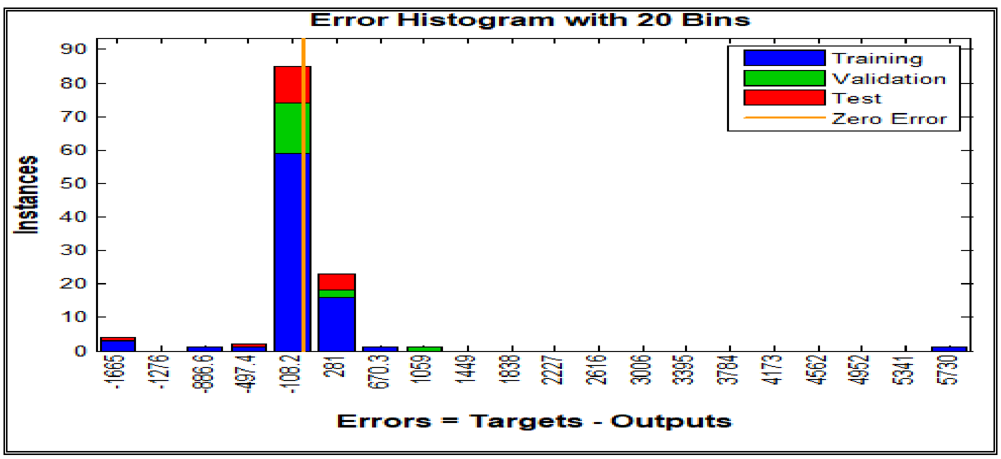


Figure (6): Error Histogram Plot, MATLAM R2013a Output.

Table (4): Model Performance Measures

R	0.9947
MSE	446290.3
MAE	257.2907
MAPE	4.122445

3.3 Forecasting

Table 5 show last 10 predictive values with target values from ANN model, and Figure 7 illustrate the predictive values were consistent with the actual values for the series.

Table (5): Output from MATLAB R2013a Program

time	Actual value	Output value
Jul 2021	18579.68	18795.88
Aug 2021	18579.68	18795.88
Sep 2021	18866.42	18795.88
Oct 2021	20348.91	19312.43
Nov 2021	20349.15	20694.14
Dec 2021	20455.31	20230.62

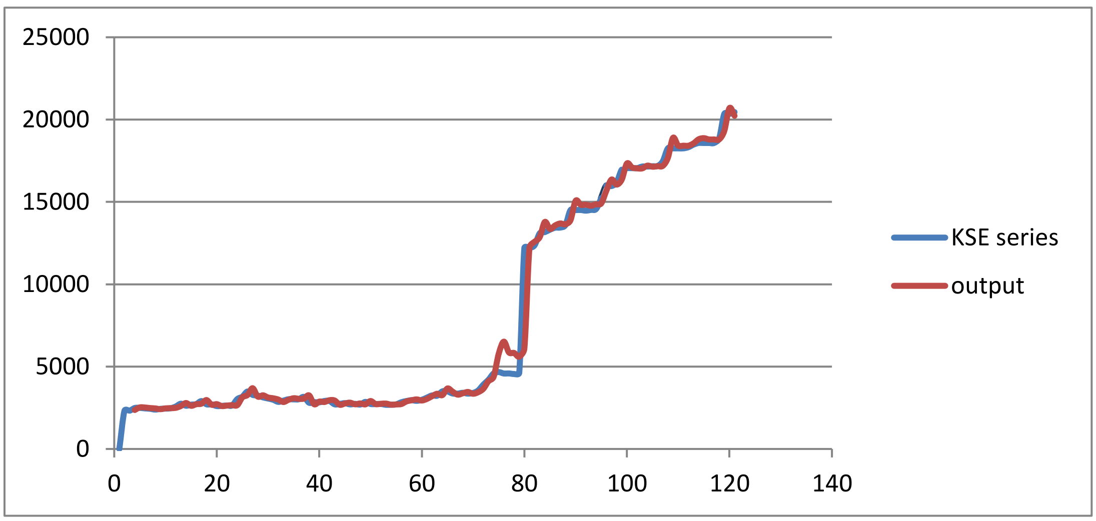


Figure (7): Forecasts Series from ANN Model, and KSE Series, Output from Excel2007 Program

4. Conclution

Artificial Neural Networks are very much needed in modern sciences so in order to make more advance development in future. ANNs models have helped researchers to forecast outcomes in many fields of science. This study concluded that the use of ANNs model in the prediction, has a high quality in predicting the future values of stock exchange index, this makes it helpful to determine the fiscal policy of countries.

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Appendage

Data series of Monthly Closing Price from Khartoum Stock Exchange index

date	close	date	close	date	close	Date	Close
Jan-12	2322.17	Jul-14	2859.39	Jan-17	3251.96	Jul-19	14470.84
Feb-12	2324.52	Aug-14	2935.95	Feb-17	3236.01	Aug-19	14518.11
Mar-12	2487.97	Sep-14	3020.13	Mar-17	3497.06	Sep-19	14572.54
Apr-12	2495.5	Oct-14	3011.68	Apr-17	3493.01	Oct-19	15232.65
May-12	2464	Nov-14	3017.64	May-17	3369.05	Nov-19	15985.06
Jun-12	2440.5	Dec-14	3161.62	Jun-17	3361.01	Dec-19	15964.14
Jul-12	2391.87	Jan-15	2808.13	Jul-17	3409.77	Jan-20	16186.24
Aug-12	2435.34	Feb-15	2844.1	Aug-17	3361.01	Feb-20	16960.3
Sep-12	2451.62	Mar-15	2829.94	Sep-17	3401.58	Mar-20	17049.6
Oct-12	2472.09	Apr-15	2913.47	Oct-17	3555.4	Apr-20	17052.5
Nov-12	2577.8	May-15	2912.24	Nov-17	3906.79	May-20	17052.5
Dec-12	2748.26	Jun-15	2709.78	Dec-17	4202.42	Jun-20	17150.23
Jan-13	2625.79	Jul-15	2737.37	Jan-18	4585.46	Jul-20	17150.23
Feb-13	2690.7	Aug-15	2781.73	Feb-18	4668.78	Aug-20	17168.7
Mar-13	2725.56	Sep-15	2707.29	Mar-18	4583.52	Sep-20	17186.33
Apr-13	2907.19	Oct-15	2740.03	Apr-18	4585.52	Oct-20	17472.25
May-13	2710.56	Nov-15	2697.42	May-18	4555.12	Nov-20	18255
Jun-13	2704.94	Dec-15	2858.53	Jun-18	4620.79	Dec-20	18254.48
Jul-13	2605.1	Jan-16	2731.93	Jul-18	12209.96	Jan-21	18254.48
Aug-13	2617.69	Feb-16	2725.49	Aug-18	12209.96	Feb-21	18254.01
Sep-13	2640.21	Mar-16	2735.96	Sep-18	12371.64	Mar-21	18325.01
Oct-13	2641.19	Apr-16	2680.46	Oct-18	13097.09	Apr-21	18481.92
Nov-13	3028.93	May-16	2687.37	Nov-18	13170.06	May-21	18579.68
Dec-13	3178.07	Jun-16	2706.2	Dec-18	13317.41	Jun-21	18579.68
Jan-14	3488.58	Jul-16	2837.97	Jan-19	13436.62	Jul-21	18579.68
Feb-14	3284.4	Aug-16	2910.97	Feb-19	13444.09	Aug-21	18579.68
Mar-14	3241.91	Sep-16	2963.01	Mar-19	13591.24	Sep-21	18866.42
Apr-14	3133.95	Oct-16	2923.01	Apr-19	14501.89	Oct-21	20348.91
May-14	3064.23	Nov-16	2986.86	May-19	14504.04	Nov-21	20349.15
Jun-14	2989.76	Dec-16	3118.93	Jun-19	14510.94	Dec-21	20455.31