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Artificial Neural Network Application in Prediction – A Review

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ABSTRACT

The concept of artificial neural network has in recent times found application extensively in the area of prediction or forecasting. Artificial neural network (ANN) is a concept conceived by the biological neural network found in human brain. This concept models the working process of the human brain and is extensively used by researchers in science, technology, engineering and mathematics to solve simple and complex problems with respect to predictions, and pattern recognition. Artificial neural network finds application in various areas including medicine, finance, meteorology, stock market, and cyber security. This work reviews the application of artificial neural network in predictions. A brief introduction to the concept of artificial neural network is presented alongside a detailed review of research works carried out using the concept of artificial neural network for predictions.

Keywords: *Artificial Neural Network, Neurons, Dendrite, Axon, Back propagation, Prediction.*

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I INTRODUCTION

Scientists continue to be relevant in developing and developed economies of the world due to the fact that they help policy makers predict the occurrences, magnitude, and impacts of natural and man-made environmental phenomenal such as global climate change, hurricanes, earthquakes, wood moisture content, and the behavior of toxic wastes [1]. Economic policy makers can now tell the future financial strength of their nation's economy – all thanks to scientific prediction. Prediction in simple terms is telling what the future holds based on observed regular pattern of historical data collected over a period of time.

The government can successfully predict the weather conditions of her country with very high degree of accuracy by using scientific tools used for weather observation. What this simply implies is that rain, wind speed, snow, and cloud cover can be predicted before they even happen [2]. The foreknowledge of weather situations helps the government develop a workable plan with respect to agronomic measures against weather hazards [3]. Artificial neural network model can be very useful in developing supportive statistical plots of concentrate on the trend of weather over a long period of time in a particular area [4]. Prediction of biological activities of molecules from their chemical structures is a challenge in drug discovery. However, it is good news to know that ANN can help solve this bottleneck [5].

The authors [6] conclude that ANN is more appropriate model for forecasting capital markets such as stock and currency. Government institutions, financial institutions, and academic institutions have lost relevant organizational information that is worth billions of naira to individuals and organizations that are not entitled to this information [7]. The ANN concept can be used to identify and classify network activities based on limited, incomplete and nonlinear data sources and as such mitigate the menace caused by the evil players (black hat hackers). Prediction in modern society satisfies two major objectives. Firstly, prediction validates scientific understanding and secondly, it does aid decision making. Over the years different conventional statistical methods (discriminant analysis, and logistic regression etc) have been used by researchers in the field to tell future outcome and their prediction results have been good so far. However, "good" is not enough; for example, the US federal government spend billions of dollars each year on activities involving prediction [1]. This huge expenditure should be justified with better prediction results. To that end, artificial neutral network (ANN), a supervised machine learning algorithm has been adopted by different researchers and applied vastly in varieties of prediction areas. Using ANN to predict future outcomes entails training network to produce the expected result based on observed regular pattern of historical data fed into the network. Why is ANN widely used in prediction? How can a high level of prediction accuracy be obtained using ANN? The objective of this study is to answer these questions.

II. CONCEPT OF ARTIFICIAL NEURAL NETWORK

2.1 How Artificial Neural Network Works

The concept of artificial neural network (ANN) was gotten from the biological neural network that is found in human brain. The human brain is made up of neurons with complex nerve networks. In this complex nerve network, the dendrites are used to receive signal from other neurons and the axons is used to send signals to other neurons. The human brain serves as a model for researchers in the field of computer science who try to mimic the working principle of the brain to perform computational operations. The ANN consists of interconnected processing units called node and this node is the same with the neuron of the human brain. The connecting link between these artificial nodes is similar to the axon synapse dendrite connections of the human brain [8]. In mathematical terms, the performance of the neuron k can be illustrated as follows:

$$yk = (\sum_{j=1}^{m} Wkj\ Xj\ +\ bk)\ \varphi(.)$$

where X_1 , X_2, … X_n are the input signals (soma); Wk_1, Wk_2, … Wk_n are the Synaptic weights (dendrites); bk is the bias; $\varphi(.)$ is the activation function, and yk is the output (axon) of the neuron. In Figure 1 [8], a neuron k receives more than one input signals X_1, X_2, and X_3 and multiplies each of the input signals by synaptic weights Wk_1, Wk_2, and Wk_3 respectively, sums them and adds a bias bk, and then applies an activation function $\varphi(.)$ to produce an output yk

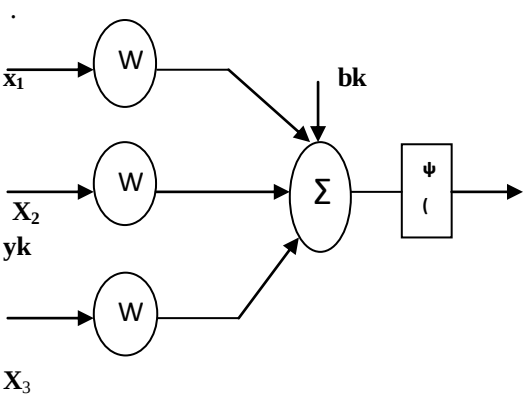

Figure 1: An Algorithm of A Neuron In ANN

2.2 Back-Propagation Analysis

An interesting fact to note about ANN is that they are not programmed explicitly, that is, using the traditional approach of programming but instead they are trained and they learn from experience. This means that a programmer does not determine the values of the weights needed to solve a particular problem; instead the ANN learns the proper weight through supervised training. The most popular and effective algorithm used by researchers to train the ANN is the back propagation algorithm. It is called back propagation because we go one way to the network from the input unit or node through the hidden units and to the output unit (forward pass), and then propagate back from the output unit through the hidden unit and then the input unit (backward pass). Note that within this process session a weight vector (adjusted and measurable input signal) is assigned at random to each link connecting the neuron or node to determine the strength of one node's influence on the other. A desired output is gotten from adjusting the weight vector and threshold vector (benchmark of input signal to expect) .

The adjusting of the weight vector and threshold vector trains the ANN and the ANN does acquire knowledge in much the same way the human brain acquires knowledge from learning from experience. In summary, in back propagation training process, weight vectors are assigned to links at random. Then the actual outputs are compared with the desired outputs (supervised learning process) and errors are calculated. The errors are then propagated back to the network in order to adjust the weight vectors; this process is iterative which continues until the desired output is obtained [8]. Figure 2 [40] illustrate the working process of back propagation algorithm. However, note that X_1, X_2, and X_3 are the input signals (soma); W_1 is the Synaptic weight (dendrite); b is the bias, and h_1, and h_2 are the hidden layers of the ANN model.

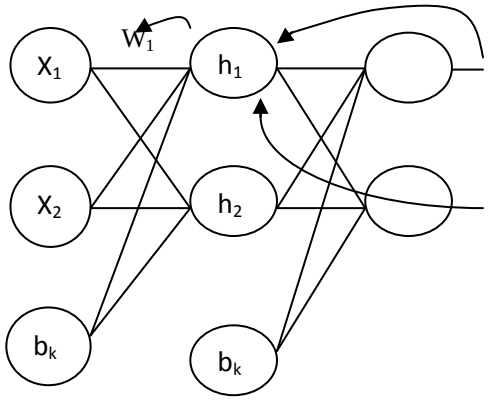

Figure 2: Working Process of Back Propagation Algorithm.

Over fitting can occur when training an ANN model and this should be strongly avoided because prediction results from a model that experienced over fitting appear to be accurate due to reduced mean square error (MSE), while in the real sense it is a mirage. Over-fitting occurs in an ANN model when

the model starts memorizing the training data rather than learning to generalize from the model [9]. To solve the problem of Over-fitting, the number of hidden layers in the ANN model should be increased. Increasing the number of hidden layers and neuron per layer increases the prediction accuracy of ANNs. ANN is widely used by researchers for prediction because of its flexibility to diverse application areas.

III. TYPES OF ARTIFICIAL NEURAL NETWORK

The following are the different types of ANN. They are:

1) **Feed Forward Neural Network:** in the feed forward neural network, there is an information flow in one direction, that is, from the input unit or node via the hidden unit and finally to the output unit [8]. The feed forward neural consists of the following:
    a) **Single Layer Network:** A single layer network is made up of one input unit, hidden unit and of course one output unit.
    b) Multi Layer Network: This type of feed forward neural network has more than one layer of nodes between the input and output nodes.
2) **Recurrent Neural Network:** Recurrent neural networks are not like the feed forward networks because they follow the principle of back propagation. In recurrent networks, information flows in two directions, that is information are fed forward until a fixed value is gotten. Then the error is computed and propagated backwards [37]. The "Elam" and "Hopfield" networks are examples of recurrent network.
3) Stochastic Neural Network: Unlike the regular neural networks, stochastic neural networks are designed by introducing
4) random variables into the network which can be achieved by either giving the network's neurons stochastic functions or stochastic weight [10].

IV. ARTIFICIAL NEURAL NETWORK THEORETICAL MODELS REVIEW ON PREDICTION

4.1 ANN Prediction in Medicine

Seyagh et al. [11] studied the application of support vector machines, artificial neural networks and decision trees for anti-HIV activity prediction of organic compounds. Prediction of biological activity of molecules from their chemical structures is a challenge in drug discovery. In this regard pattern classification has gained attention as one of the methods that can be utilized in drug discovery. In this study, the authors used three classification models for anti-HIV activity, based on pattern recognition methods such as support vector machines, artificial neural networks and decision trees. All the methods gave good results in learning and prediction. The latter results indicated that the three models can be used as an alternative for classification problems in structure anti-HIV activity relationship.

Nakajima et al. [12] investigated which method was best suitable for determining the diagnostic prediction accuracy of coronary artery disease. They compared artificial neural network diagnostic model with conventional quantitation systems. Their result shows that the ANN model had a better prediction accuracy of stress defect as when compared to other conventional quantitation methods. The authors conclude that ANN model is diagnostically accurate in various clinical settings, including that of patients with previous myocardinal infarction and coronary revascularization.

Ahmed et al. [13] used a hybrid of ANN and fuzzy logic (Neuro-fuzzy model) to evaluate its prediction accuracy with respect to Crohn's disease (CD) diagnosis. They achieved a prediction accuracy of

97.67% with a sensitivity of 96.07 and 100% respectively.

Kabirirad et. al. [14] used ANN model to predict heart disease (Coronary Arteries of the heart). The authors used datasets gotten from the databases located in Cleveland, Switzerland, and Hungary. They achieved a prediction accuracy of 98%.

Nan et al. [15] designed an ANN model to predict the frequency of occurrences of AIDS (Acquired Immuno Deficiency Syndrome) and death in China. The authors used historical data (for training their ANN model) obtained from China's largest search engine – Baidu. Three performance indicators were used to validate the performance of their model. Based on their result, they conclude: "ANN methods can lead to a satisfactory forecasting of AIDS occurrences and death regardless of the change in the number of search queries".

The author [16] predicted the HIV / AIDS viral load level over a given period of time. So the author used a multi-layer ANN model with back propagation as the training algorithm for the prediction. He achieved a prediction accuracy of 93.79% and a Mean Square Error (MSE) of 0.0323 which shows that ANN method is a reliable algorithm for the prediction of HIV / AIDS viral load level.

4.2 ANN Prediction in Stock Market

Kaur et. al. [17] compared the prediction accuracy of ANN model and Support Vector Machine (SVM) model across seven major stock markets. The performance indicators used for the evaluation are: Mean Absolute Error (MAE), and Root Mean Square Error (RMSE). The findings of their research suggest that there is significant difference both for MAE, and RMSE across the selected global indices and that ANN model had greater prediction accuracy compared to SVM model.

Kalaiselvi et al. [18] predicted stock price using a multi-layered feed forward ANN model with back-propagation as their training algorithm. The output of their research shows that their proposed prediction ANN model demonstrated an excellent performance in financial time series forecasting.

Chopra et al. [19] investigated the stock market prediction capability of ANN model before and after demonetization in India. The used a multi-layered ANN model with Levenberg-Marqurdt as their training algorithm. Their model achieved a prediction accuracy of 99.9% which depicts a very high efficiency.

Moghaddam et al. [20] investigated the ability of ANN model in forecasting the daily NASDAQ stock exchange rate. The authors used daily stock exchange rate of NASDAQ from January 28, 2015 to June 18, 2015 to train their multi-layered feed forward ANN model. Their model achieved a prediction accuracy of 96.22%.

Shahbaz et al. [6] **in** their survey of Stock Market Forecasting forecasted the shares of Iran Khodro, using ANN, the data collected from the statistics organization of Iran for this survey spans from 1996 to 2004. They used MATLAB Software to simulate their prediction. Their model consists of 3 layers, the first layer includes 22 neurons, middle layer includes 9 neurons, and the output layer includes 4 neurons. The neural network starts to learn, considering the received inputs and data at the output, in their sampling the results repeat every 50 times and the rate of training is regulated on 0.005. They concluded that ANN is an appropriate model for forecasting capital markets such as stock and currency when compared to other forecasting methods such as Arima, because of its superior capabilities of learning, and error minimization.

4.3 ANN Prediction in Meteorology

Al-Shawwa et al. [21] designed a predictive model based on ANN concept for the prediction of temperature in the surrounding environment. The following served as input to their multi-layered model; they are natural factors such as proximity from water surfaces, the influence of vegetation, and the level of rise or fall below sea level. The authors trained their model using data from several regions in

the surrounding environment of Palestine and achieved a prediction accuracy of 100%.

Sivaneasan et al. [22] proposed an improved solar forecasting algorithm using a three layered feed forward ANN model with back-propagation algorithm as their training algorithm. They adopted a fuzzy logic preprocessing method and used a training dataset obtained from a clear sky model and a weather station situated in Singapore. The findings of their research suggest that error correction factor coupled with ANN can significantly improve solar irradiance forecast accuracy due to its adaptive error correction ability.

Yadav et al. [23] developed an ANN model to predict rainfall in Uttarakhand region in India. The authors used 10 neurons for the design of their model and they achieved a very low MSE value of 0.00547823 which suggest high prediction accuracy.

Anh et al. [24] designed a hybrid model that consists of a preprocessing method (seasonal decomposition and discrete wavelet transform) and two feed forward neural networks (ANN and Seasonal ANN). Their result shows that both the wavelet transform and seasonal decomposition methods combined with SANN model could satisfactorily simulate non-stationary and non-linear time series related problems such as rainfall prediction. However, wavelet transform along with SANN provided the most accurately predicted rainfall.

Palvanov et al. [25] used a deep convolutional neural network to forecast atmospheric visibility. Their system uses three streams of deep integrated convolutional neural networks which are connected in parallel and trained with three million outdoor image dataset. Based on the finding of their research, they assert that their approach achieved higher prediction accuracy as when compared to classical methods.

The authors [26] used artificial neural networks to predict the PM 10 concentrations as factors determining the occurrence of smog phenomena. They used meteorological data and concentrations of PM 10 to create their network. The data were recorded in 2014 and 2015 at three measuring stations operating in Krakow, Poland under the State Environmental Monitoring. The best results were obtained by three-layer perceptron with back-propagation algorithm. Their neural networks received a good fit in all cases.

Banan et al. [27] used an artificial neural network (ANN) to extract the complex relationships among divergent parameters that have the capabilities to predict O_3 concentrations which serve as an input to meteorological conditions and precursor concentrations. The ANN was trained using samples of daily maximum data provided by the Malaysian Department of the Environment (DOE) over a period of 9 year (2003–2011) in the towns of Gombak and Shah Alam in Malaysia. Furthermore, surface O_3 concentrations from the two locations (Gombak and Shah Alam) were estimated using surface meteorological variable as predictors for the ANN. Based on the results they got, it can be concluded that the relationship between the parameters and the O_3 concentrations are highly complex and non-linear.

Analysis of the regression based model results between Gombak and Shah Alam were evaluated using the ANN. Based on the sample results it was confirmed that Shah Alam has the highest regression result of R = 0.64 in comparison with Gombak station. The inference drawn from their study shows that neural network model consistently gives superior predictions.

Veintimilla-Reyes et al. [28] created a model based on Artificial Neural Networks (ANN) that allows predicting the flow in Tomebamba river, at real time and in a specific day of a year. The input parameters for their ANN model are information of rainfall and flow of the stations along the river. This information is organized in scenarios and each scenario is prepared to a specific area. For their work, they used two scenarios. The information was gotten from the hydrological stations placed in the watershed using an electronic system developed at real time. The

prediction works very good three days in advance. Their research includes two ANN models: Back-propagation and a hybrid model between back propagation and OWO-HWO (output weight optimization–hidden weight optimization) to select the initial weights of the connection. These last two models have been tested in a preliminary research. To measure the effectiveness of their model, it was evaluated based on the following key performance indicators (Mean Square Error, Radial Mean Square Error, EF, CD and BIAS). They achieved a great prediction accuracy that can be useful to avoid floods in the city of Cuenca in Ecuador and beyond.

Abhishek et al. [29] used an artificial neural network (ANN) approach to develop an effective and reliable nonlinear predictive model for weather forecasting. They used different performance indicators to evaluate their model and these performance indicators are; different transfer functions, hidden layers, and neurons to forecast maximum temperature for 365 days of the year. Their study will be useful in developing supportive statistical plots and concentrate on the trend of weather over a long period of time in a particular area.

Li et al. [30] simulated three tidal flow systems and a continuous vertical flow system filled with synthetic wastewater and compared the influent and effluent concentrations to examine three important factors. They are: (1) nutrient removal in artificial TF-CWs (Testing Framework for Composite Web Services), and (2) the ability of a back propagation (BP) artificial neural network to predict nutrient removal. The nutrient removal rates were higher under tidal flow when the idle/reaction time was two, and reached 90 ±3%, 99 ± 1%, and 58 ± 13% for total nitrogen (TN), ammonium nitrogen ($NH4^+$-N), and total phosphorus (TP), respectively.

The main influences on nutrient removal for each scenario were identified by redundancy analysis and were input into the model to train and verify the pollutant effluent concentrations. Comparison of the actual and model-predicted effluent concentrations showed that the model predictions were good. The predicted and actual values were correlated and the margin of error was small. The BP neural network fitted best to TP, with an R2 of 0.90. The R2 values of TN, $NH4^+$-N, and nitrate nitrogen ($NO3^-$-N) were 0.67, 0.73, and 0.69, respectively.

4.4 ANN Prediction in Finance

Penpece et al. [31] predicted the sales revenue of grocery retailing industry in Turkey with the help of grocery retailers marketing costs, gross profit, and its competitors' gross profit by using artificial neural network. Artificial neural networks are models which are used for forecasting because of their capabilities of pattern recognition and machine learning. ANN method is used to forecast the sales revenue of upcoming period. According to their results, there are high similarities between forecasted and the actual data; predicted results of their study are bigger or smaller than the actual data for only 10%. Because of this high accuracy, they suggested that companies at grocery retailing industry in Turkey can use ANN as a forecasting tool.

Vochozka et al. [32] used ANN model to predict the exchange rate of Euro against the Chinese Yuan. The objective of their research is to propose a methodology for considering seasonal fluctuations in equalizing time series by means of ANN model on the case study of Euro and Yuan. Based on their result findings, the authors asserted that ANN model has higher prediction accuracy.

Tolo [33] used a recurrent neural network based on Long-Short Term Memory (LSTM) and a Gated Recurrent Unit (GRU) cells to predict future occurrences of financial crises. The authors trained their ANN model with the Jorda-Schularick-Taylor dataset – a historic dataset that contains the crises date and important macroeconomics series of 17 countries over a period of 146 years. They achieved excellent prediction accuracy after extensive sensitivity analysis.

Jahn [34] demonstrated that ANN models are one of the best options when it comes to predicting annual GDP growth rates. They compared their ANN model

with a corresponding linear model in predicting the annual GDP growth rate of 15 industrialized economies of the world over a time period of 20 years. Their result shows that the ANN model achieved a very low root mean square error compared to the linear model; which signifies high prediction accuracy for the ANN model.

The authors [35] developed a multi-layered feed forward ANN model to predict financial crises in the Turkish economy. They used monthly data of 7 well known macroeconomics and financial indicators of Turkish economy during the periods of 1990 to 2014 to train their machine learning model. They asserted that the Turkish economy remains at high risk due to key negative developments and political instability between 2014 to 2016.

4.5 ANN Prediction in Cyber Security

Parveen [36] asserted based on the findings of his research that very high prediction of cyber anomalies is achievable with artificial neural networks.

Fang et al. [37] developed a deep learning framework that consists of two directional recurrent ANN models with long short – term memory. The aim of their research is to solve the problem associated with cyber attack data namely; long – range dependence and high nonlinearity. Their empirical result shows that their ANN model achieved impressive prediction accuracy when compared to classical statistical approach.

Jeong et al. [38] designed a convolutional ANN model to solve the challenge of malware causing destructive effect on PDF files in the cyber space. Their ANN model is developed to decipher high level trends among collectable spatial clues so as to show if malicious activities took place or not. The authors achieved a high level of prediction accuracy.

Rhode et al. [39] investigated if it was possible to predict whether or not an executable is malicious based on a short snapshot of behavioral data. The authors found out that recurrent ANN model were best suited for the experiment. Their ANN model achieved a prediction accuracy of 94% within 5 seconds of execution.

V. CONCLUSION AND RECOMMENDATION

Artificial neural network has really proven to be an important concept in varieties of prediction situations. Recent research works have seen ANN being applied in areas such as medicine, finance, meteorology, stock market, engineering, and cyber security. An advantage which ANN has over other prediction and forecasting methods is it unique ability to reduce the error of prediction accuracy and give predicted values almost equal to ideal values which are thus reliable for adequate decision making. We recommend that researchers who would want to use ANN for prediction should carry out proper data engineering on their chosen dataset for this will solve the issue of over-fitting and thus improve prediction or forecasting accuracy.

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