# Enhanced Model for Recession Forecasting Using Artificial Neural Network

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***Abstract- This aim of this research project is to develop a neural network multi-layer architecture based on back propagation algorithm to predict recession probability in Nigeria. Recession probability forecasting has proven a tedious task for economists, particularly those at investment banks. The motivation for carrying out this study hinges on the drawbacks of the prevalent forecasting methods which include statistical regression analysis or linear models which are strenuous and highly inefficient when dealing with extra-large datasets. Recession as a national economic situation is the result of complex phenomena, whose effects translates into a blend of gains or losses that appear in a market time-series that is usually predicted by extrapolation. Dataset spanning ten years representative of economic recession indicators were analyzed using a feed forward neural network with back propagation algorithm and K-means clustering algorithm. The Object-oriented Methodology was adopted for analysis and implementation was carried out in Google Colab which has Python programming language at its core. The developed system is found to predict an economic recession more accurately when compared with other models, so that adequate economic policies can be made to tackle national economic recession.***

***Indexed Terms- Artificial Neural Network, Recession, Forecasting***

## I. INTRODUCTION

Neural networks are state-of-the-art, trainable algorithms that emulate certain major aspects in the functioning of the human brain. This gives them a unique, self-training ability, the ability to formalize unclassified information and, most importantly, the ability to make forecasts based on the historical information they have at their disposal (Roghani, 2015). An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems function. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurones) working in unison to solve specific problems (Aleksander and Morton, 1995). ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurones. This is also true of ANNs as well (Roghani, 2015).

Hardesty (2017) notes that neural nets are a means of doing machine learning, in which a computer learns to perform some task by analyzing training examples. Usually, the examples have been hand-labeled in advance. Modeled loosely on the human brain, a neural net consists of thousands or even millions of simple processing nodes that are densely interconnected.

Artificial neural networks are forecasting methods that are based on simple mathematical models of the brain. They allow complex nonlinear relationships between the response variable and its predictors. Guoqiang, Eddy and Hu (2008), adds that interest in using artificial neural networks (ANNs) for forecasting has led to a tremendous surge in research activities in the past decade. While ANNs provide a great deal of promise, they also embody much uncertainty.

Simple mathematical models cannot be used to describe exactly certain processes due to their higher complexity (Jorge, Mariana and Pedro, 2010). In fact, most economic or financial interactions cannot be elucidated by a simple stepwise algorithm or a precise formula, particularly when the data are complex or noisy. ANNs allows an accurate description of those kinds of complex processes, offering new advantages over traditional algorithms as the possibility of a model, prediction and optimize results (Jorge et al., 2010).

Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analysis. This expert can then be used to provide projections given new situations of interest and answer "what if" questions (Aleksander and Morton, 1995).

Neural networks take a different approach to problem solving than that of conventional computers. Conventional computers use an algorithmic approach i.e. the computer follows a set of instructions in order to solve a problem. Unless the specific steps that the computer needs to follow are known the computer cannot solve the problem. That restricts the problem solving capability of conventional computers to problems that we already understand and know how to solve. But computers would be so much more useful if they could do things that we don't exactly know how to do.

The field of neural network technology has been extensively studied in the last decade. This has led to considerable research on its use in various scientific applications and to the development of a diverse range of business applications. Consequently, an increasing amount of application efforts have concentrated on their development in the finance sector (Bo and Yakup, 1998).

Roghani (2015) adds that neural networks have been used increasingly in a variety of business applications, including forecasting and marketing research solutions. In some areas, such as fraud detection or risk assessment, they are the indisputable leaders. The major fields in which neural networks have found application are financial operations, enterprise planning, trading, business analytics and product maintenance. Neural networks can also be applied gainfully to recession probability forecasting using correct recession predictors.

The International Monetary Fund (IMF), states that "Global recessions seem to occur over a cycle lasting between eight and 10 years. A global annual real GDP growth of 3.0 percent or less in their view was "...equivalent to a global recession." By this measure, six periods since 1970 qualify: 1974–1975, 1980–1983, 1990–1993, 1998, 2001–2002, and 2008–2009. During what IMF in April 2002 termed the past three global recessions of the last three decades, global per capita output growth was zero or negative, and IMF argued—at that time—that because of the opposite being found for 2001, the economic state in this year by itself did not qualify as a *global recession* (Lall, 2008).

In April 2009, IMF changed their Global recession definition to:

- A decline in annual per-capita real World GDP (purchasing power parity weighted), backed up by a decline or worsening for one or more of the seven other global macroeconomic indicators: Industrial production, trade, capital flows, oil consumption, unemployment rate, per-capita investment, and per-capita consumption (Davis, 2009; WHO, 2009).

By this new definition, a total of four global recessions took place since World War II: 1975, 1982, 1991 and 2009. All of them only lasted one year, although the third would have lasted three years (1991–93).

A significant decline in economic activity spread across an economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales is recession (NBER, 2016). One of the main causes of financial recession is failure of policymakers in tighten regulations and the dishonesty of financial institutions (Stiglitz, 2008). Macroeconomic indicators such as GDP (gross domestic product), investment spending, capacity utilization, household income, business profits, and inflation fall, while bankruptcies and the unemployment rate rise. Recessions generally occur when there is a widespread drop in spending (an adverse demand shock). This may be triggered by various events, such as a financial crisis, an external trade shock, an adverse supply shock or the bursting of an economic bubble (Afe, 2016).

Aim and Objectives of the Study

1. To identify leading financial and economic indicators that precursors recession in developing countries and identify performance indicators of a forecast model or algorithm
2. To evaluate an existing statistical/economic model using the identified precursors.
3. To design, implement and test run the enhanced artificial neural network for recession probability forecasting.
4. To evaluate the enhanced machine learning system based on the identified performance indicators.

## II. LITERATURE REVIEW

- Theoretical Framework

Certain theories form the basis of Artificial Neural Networks; these are the basic building blocks. Processing of artificial neural networks hinges on the following: Network Topology, Adjustments of Weights or Learning, Activation Functions.

A neural network consists of nodes (input nodes and neurons, or input nodes and computation nodes), synaptic connections, and functional connections. As far as connection types are concerned, there are two types of neural networks, i.e., feed forward network and feedback network. Feed forward networks are functional mapping networks and usually used for pattern recognition, function approximation and prediction (Haykin, 1994; Yan and Zhang, 2000; Fecit, 2003). Feedback neural networks are used as association memorizers and optimization tools. In a feed forward network, every neuron receives the inputs from the last layer and yields outputs for the next layer and there is not any feedback. A feedback network can be redrawn as an undigraph in which each connection is bidirectional.

In a feedback neural network all nodes are computation nodes, and each node has $(n-1)$ inputs and one output if the total number of nodes is $n$. There are two phases in the workflow of a neural network:

(1) Learning phase. The states of all computation nodes are constant and the connection weights can be adjusted through learning process.
(2) Working phase. Connection weights are constant during this phase and the states of computation nodes change to achieve stable states.

- Architecture of Artificial Neural Networks

The Neuron

The neuron is the basic building block of the neural network. A neuron is a communication conduit that both accepts input and produces output. The neuron receives its input either from other neurons or the user program. Similarly, the neuron sends its output to other neurons or the user program (Chakravarthy, 2011).

a. One-input neuron

The architecture of a one-input neuron is indicated in figure 2.4. The mathematical expression of the one-input neuron is

$y = f(wx + b)$ eqn. 1

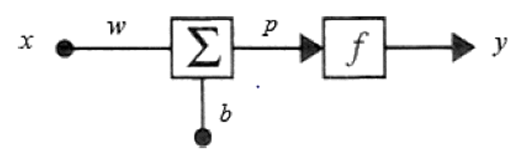


Figure 1: schematics of one-input neuron

Where *w* = the weight of input *x*; *b* = bias; *y* = output; *f* = transfer function. In this expression, the output of accumulator, $p = wx+b$, is also called net input of transfer function *f* . Addition of a bias, *b*, can increase the adaptability of neurons and neural networks.

b. Multiple-input neuron

The architecture of a multiple-input neuron is indicated in Figure 2.5. The mathematical expression of the multiple-input neuron is

$y = f \sum (w_{1i}x_i + b)$ eqn. 2

where $w_{1i}$ = the connection weight of source neuron *i* to target neuron 1,
$i = 1, 2, \ldots, n$; *b* = bias; *y* = output; *f* = transfer function.

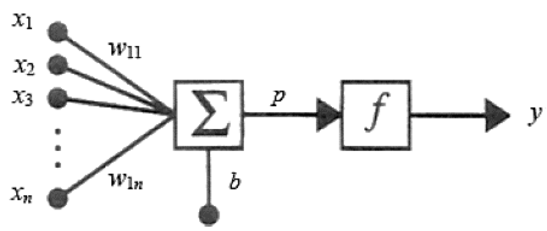


Figure 2: schematics of a Multiple-input neuron. There are *n* inputs for the neuron

The architecture of the multiple-input neuron (*n* inputs) can be briefly represented by a simpler illustration, as indicated in Figure 2.6.

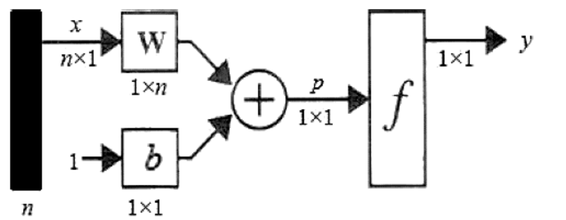


Figure 3: The simpler representation of a multiple-input neuron.

In this representation $x$ is a $n \times 1$ input vector; $w$ is the $1 \times n$ weight vector; $b$, $p$ and $y$ are scalar constant and variables.

- Conceptual Framework

Forecasting is the process of making statements about what will happen in the future based on information that you have at hand. A commonplace example is a meteorologist using maps and scientific data to tell us about the possibility of rainfall, snow fall or sunshine (Egbe et al, 2022). Prediction is making a statement about what you think will happen in the future, often but not always based on experience or knowledge. Prediction is a guess which is based on instinct. For example, a fortune teller makes prediction using a crystal ball. Both prediction and forecasting might refer to formal statistical methods employing time-series, cross sectional or longitudinal data, or alternatively to less formal judgmental methods. Usage can differ between areas of application.

This study builds from its conceptual framework thus:

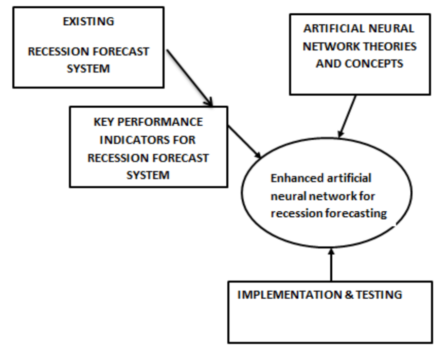


Figure 4: Conceptual Framework of the study

- Key Recession Indicators

The key recession indicators in Nigeria identified in this paper are:

Consumer Price Index, Fuel Pump Price, Money supply (M1), Broad Money (M2), All Share Index, Exchange Rate, Export, Import, Crude Oil Price, Lending Rate. The figure 4 shows the economic indicators at a glance.

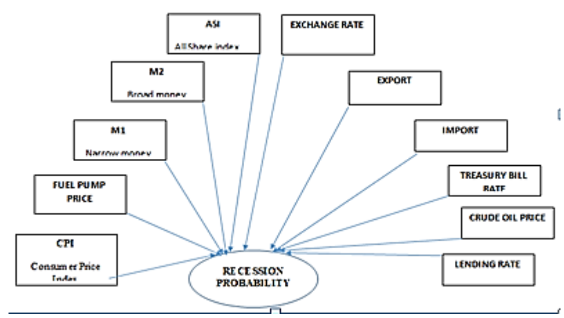


Figure 5: Economic indicators for recession forecasting in Nigeria

- Empirical Framework

Artificial Neural Networks are increasingly finding applications in expertise orientation and the development of applications for a problem-oriented domain (Liao et al., 2012). Several scholars have explored the application of Artificial Neural Networks for series of research analysis and to provide solutions to myriad of problems confronting human race (Alhassan and Lawal, 2015).

Gopal and Chandra (2012) in providing valuable information for accurately predicting the hydrological behavior of watershed which is critical for the planning land use design of civil projects and water resources management used Artificial Neural Net.

Hasan et al., (2014) presents an artificial neural network approach for forecasting electric energy consumption.

The works of Akram, Ziad and Eyad (2011) focused on the network parameters needed in order to get the optimal architecture of an artificial neural network. Many examples were tested and they showed that using one hidden layer with the number of neurons equal to the square of the number of inputs will lead to optimal neural network by mean of reducing the number of training stages (number of training iterations) and thus the processing time needed to train the network. Akram et al., (2011) established that the optimal neural network is the network that can reach the goals in minimum number of training iterations and minimum time of training.

Kiani and Kastens (2006) employed artificial neural networks using macro-financial variables to predict recessions. They modeled the relationship between indicator variables and recessions to 10 periods into the future and used a procedure that penalizes a misclassified recession more than a misclassified non-recession.

Ross (2013) explored the ability of Support Vector Regression (SVR) and feedforward neural networks to predict the 2008 Great Recession when trained only on macroeconomic data from 1978 to 2005. Their performance was compared to that of a standard ARIMA model taken from recent economic literature.
Methodology Adopted and Analysis

In this study, we adopted the Object Oriented Analysis and Design Methodology (OOADM) combined with the agile methodology.

Object Oriented Analysis and Design Methodology (OOADM)

1. Object oriented analysis (OOA): This is the process of defining the problem in terms of objects in the real world with which the system must interact, and candidate software objects used to explore various solution alternatives. The nature of programming objects to real world objects has a big impact here in that all real world objects can be defined in terms of their classes, attribute and operations.
2. Object oriented design (OOD): This is the process of defining the component, interfaces, objects, classes, attributes, and operations that will satisfy the requirement. You typically start with the candidate object defined during analysis, but add much more rigor to their definitions, then you add or change objects as needed to refine a solution. The basic step of system design is shown in Fig. 3.1. This methodology features the unified modeling language (UMLs): Case diagram, active diagram, the architectural design of the system and proposed algorithm.

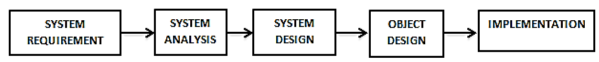

Figure 6: Phases of OOADM

- Agile Methodology

This study also employed the agile software methodology. The agile strategy promotes relatively shorter iterations rather than the formerly popular waterfall methodology's lengthy release cycles. The iterative approach breaks the development process into smaller parts. Each part contains the planning, design, development, and testing steps. Breaking down the objectives into subtasks is an added advantage, allowing the software developer to easily determine how much of the software has been done at any given time. This allows project managers to determine if the project is progressing as planned. When a project falls behind schedule, the agile approach quickly identifies the risk, allowing managers to interact with stakeholders to develop a risk management plan.

- Analysis of the Existing System

Literatures point that intelligent forecasting techniques, such as expert systems, Artificial Neural Networks (ANN), fuzzy logic, have been developed recently, showing encouraging results. Neenwi et al (2013) as presented in Egbe, T.P et al. (2022), analyzed two years representative of economic indices using a feed forward neural network with back-propagation in Matlab 7.0. to forecast stock market in Nigeria. The architecture of the existing system is shown in the figure 6.

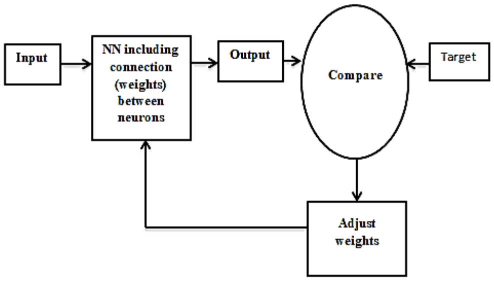


Figure 7: Architecture of the Existing System

- Weaknesses of the Existing System

The simulation results forecasts show that it is possible to consistently obtain forecast-results using information obtained from an artificial neural network indicator. However, the following disadvantages were observed;

1. The convergence obtained from back propagation is very slow and not guaranteed.
2. Time to train NN is probably identified as biggest disadvantage.
3. They used very small sample sets to train, thus model is not very efficient.
4. Back propagation learning requires input scaling and normalization.
5. Back propagation does not guarantee to find the global network minimum. While it does minimize error, there is a chance the weights will be changed to fit a local minimum in the error landscape, but the network will not be optimized.

- Analysis of the Proposed System

This study proposed a hybrid model to predict recession probability in Nigeria. The hybrid model comprises a neural network and k-means clustering algorithm. The K-means clustering module was incorporated into the system to enhance the ANN architecture. K-means clustering reduces the dimensions of the input data and then use the reduced dimensions to train the ANN network. This helps to improve the accuracy of the model by reducing the number of inputs and eliminating irrelevant data. The user is expected to enter the input dataset with the required output (target) as shown in the figure 5. The Neural Network initializes the input weight using a random number and also the hidden layer weight with the same random number and threshold constant. It does the neural network calculation using the activation function for the input layer and the output layer, and then it calculates its error by finding the difference between the output and the target. If the error is large enough then the neural network adjust this weight and back-propagates, but if the error is small, it outputs the prediction. Ten years representative of economic indicators were analyzed using a feed forward neural network with back-propagation algorithm and k-means clustering algorithm.

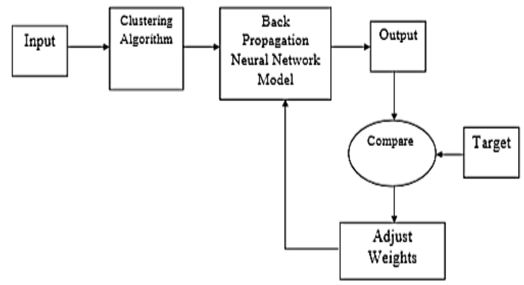


Figure 8: Architecture of Proposed System

- Advantages of the Proposed System

The advantages of the proposed system are as follows:

1. It improves the training rules of backward propagation algorithm, thus arrive at a better prediction with greater accuracy.
2. The proposed system will guarantee and obtain global network minimum using clustering algorithm.
3. It uses very large sample sets to train model efficiently.
4. It uses an Artificial Neural Network, which has the ability to use an arbitrary functional approximation mechanism in learning from observed data.
5. It will reduce time complexity of the train of the hidden layer of backward propagation

- Use Case Diagram

A use case represents the functionality of the system. The figure 6 shows the use case of the proposed system.

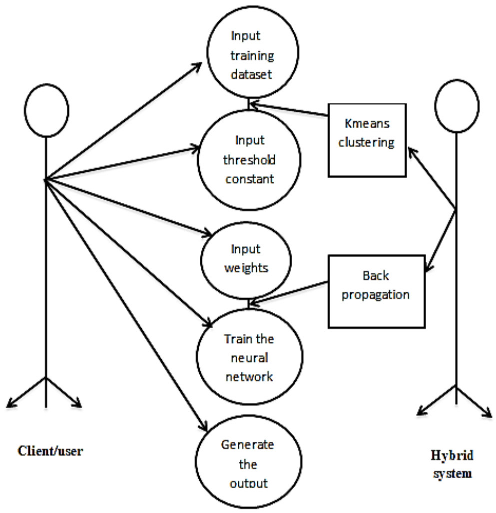


Figure 9: Use Case of the Proposed System.

- Class Diagram of the Proposed System

Class diagram describes the attributes and operations of a class and also the constraints imposed on the system. The figure 7 shows the class diagram of the proposed system.

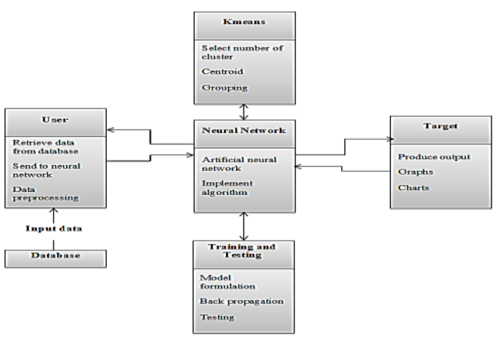


Figure 10: Class diagram of proposed system

- Sequence Diagram of Proposed System

A sequence diagram is a type of interaction diagram because it describes how- and in what order- a group of objects work together.

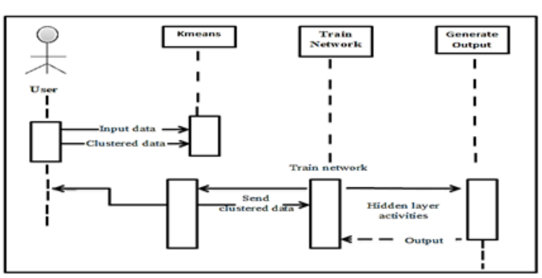


Figure 11: Sequence Diagram of Proposed System

- System Design and Implementation

Control Center/ Main Menu

The enhanced Artificial Neural system (ANN) proposed in this study is composed of the following building blocks as shown in the figure 8.

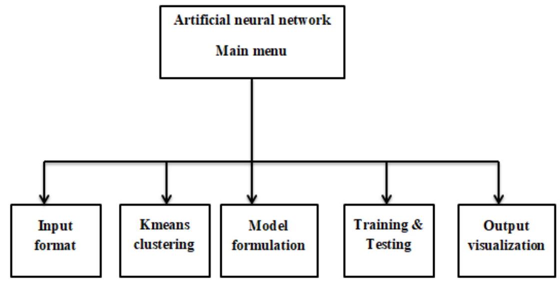


Figure 12: Control Center/Main Menu

- Algorithm

Egbe et al. (2022) proposed an algorithm for training neural network which we adopted in this study. The connection we are interested in is between neuron A (a hidden layer neuron) and neuron B (an output neuron) and has the weight WAB.

1. First apply the inputs to the network and work out the output – remember this initial output could be anything, as the initial weights were random numbers.
2. Next work out the error for neuron B. The error is What you want – What you actually get, in other words: ErrorB = OutputB (1-OutputB)(TargetB – OutputB) The "Output (1-Output)" term is necessary in the equation because of the Sigmoid Function – if we were only using a threshold neuron it would just be (Target – Output).
3. Change the weight. Let W+AB be the new (trained) weight and WAB be the initial weight. W+ AB = WAB + (ErrorB x OutputA) Notice that it is the output of the connecting neuron (neuron A) we use (not B). We update all the weights in the output layer in this way.
4. Calculate the Errors for the hidden layer neurons. Unlike the output layer we can't calculate these directly (because we don't have a Target), so we Back Propagate them from the output layer (hence the name of the algorithm). This is done by taking the Errors from the output neurons and running them back through the weights to get the hidden layer errors. For example if neuron A is connected

as shown to B and C then we take the errors from B and C to generate an error for A. ErrorA = Output A (1 - Output A)(Error B WAB + Error C WAC) Again, the factor “Output (1 – Output).

5. Having obtained the Error for the hidden layer neurons now proceed as in stage 3 to change the hidden layer weights. By repeating this method we can train a network of any number of layers.

- System Flowchart

A system flowchart also known as an activity diagram shows the flow of controls from one activity to another.

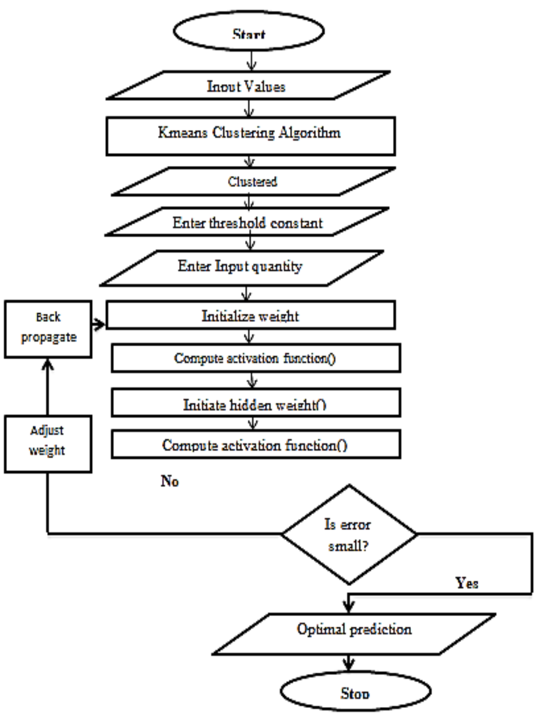


Figure 13: System Flowchart

- System Implementation

To implement this algorithm, Google Colab was used which has Python programming language at its core.

- Test Plan

For the purpose of testing the ANN, the variables of interest are randomly divided into two groups in a ratio of 75% to 25%. The 75% will be used for the training set, while the 25% for test set or validation.

- Test Data

The dataset used for testing the ANN comprises economic indicators that precursor a recession obtained from the Central Bank of Nigeria and the Nigeria Bureau of Statistics.

- Results before Applying Kmeans Clustering

The results shown in this section are those obtained before the kmeans clustering was applied. At this stage the dataset were applied as obtained from source without any reduction in frame.

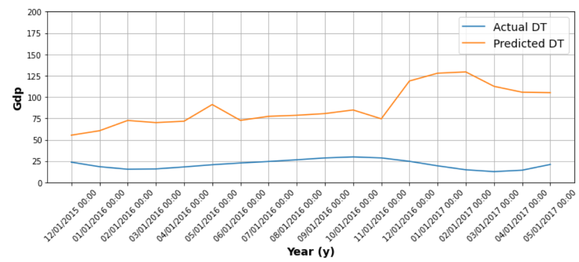


Figure 14: Model Results before Applying Kmeans (Clustering actual and Predicted GDP in one graph)

- Model Results after Applying Kmeans Clustering

This section provides model results after kmeans clustering have been applied. At this stage the dataset have been reduced to contain only variables (economic indices) with strong correlation with the GDP.

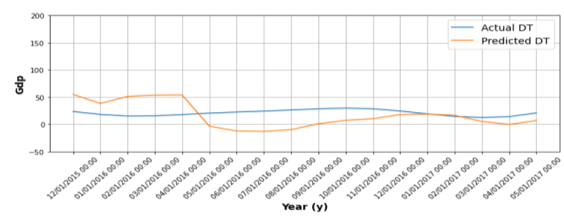


Figure15: Model Results after Applying Kmeans Clustering (Predicted and Actual GDP Plotted On One Graph)

- Model Results Validation

Now that our model has been trained, we can begin evaluating the model’s performance on our validation dataset. There are multiple statistical measurements we can use to measure how well our model has performed. In this research we will be using the following three metrics:

1. Mean Absolute Error (MAE): Provides a measure of the absolute differences between the predicted value and the actual value. In this project the MAE is 2.84 before applying Kmeans but 3.93 after applying Kmeans.
2. Root Mean Square Error (RMSE): Indicates the magnitude of the prediction error. To calculate RMSE using scikit-learn we first need to calculate the mean squared error and then take the square root of it, which can be achieved by raising the mse to the power of 0.5. In this project the RMSE is 3.42 before applying kmeans but 5.15 after applying kmeans.
3. Coefficient of Correlation (R2): Indicates the strength of the relationship between an independent variable and a dependent variable. The closer the value is to 1, the stronger the relationship. In this project the r2 is 0.86 before applying kmeans but 0.52 after applying kmeans.

## CONCLUSION

Predicting recession accurately has always been a challenge to mankind. The Nigerian recession situation is nonlinear; hence it is predictable using neural networks. The use of artificial neural networks (ANNs) in a nonlinear market does not require an understanding of the market dynamics. This is why it is practically feasible and profitable to use machine learning systems like neural networks to predict the behaviour of financial instruments such as recession. In this research work, it was observed that the economic indices used for predicting recession are highly non-linear, stochastic and volatile in nature. In order to overcome the limitations of neural networks, k-means clustering algorithm was integrated to form an enhanced model. Finally, the proposed enhanced network model is found to predict the recession more accurately when compared with other models.

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