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Heuristics for the Intelligent Prediction of Population Growth

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Population growth is a phenomenon that is inevitable in a life course and the components of population growth are fertility, mortality and migration. Because of the impact population growth exact upon the socio- economic nature of a country, it will be wise to know the future size and distribution of it so that adequate measures can be made to forestall possible problems. There are different population models and algorithms implemented to project population growth, ranging from statistical to machine learning models; these model techniques were very suitable in their time, such as the Malthusian theory, which, first and foremost, gives deeper consideration to the exponential growth model, while many implemented classification and linear regression algorithm. Linear regression machine learning algorithms were considered the most effective algorithm for

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population growth projection. This study tends to develop a machine learning model that is data-driven mathematically, capable of implementing the data-independent prediction model equation that was used to predict the impact of the Non-pharmaceuticals approach and pharmaceuticals approach (NPA and PA) in mitigating the spread of the Covid-19 virus, and both models were re-modified to project Nigeria population growth. The data-independent prediction model (DIPM) utilized onset data from the NPA and PA interventions to predict the probability of mitigating the spread of the virus for a specific period. The DIPM has the properties of arithmetic and exponential methods. The fusion of these two properties with the aid of machine learning model has further reveal the data-independent prediction model as a conceptualization technique to reflect how data are processed in an algorithm setting in a concrete world, with the support of the Java array list algorithm, what all the statistical models and supervised machines learning model used in the past studies could not achieve, have been accomplished succinctly. The data independent prediction model is a robust technique for both projection and forecasting future population growth as well as proffer answers to historical issues in mathematical modeling of population expansion.

Keywords: Intelligent prediction; population growth; mathematical modeling; algorithms; machine learning models; Malthusian theory.

1. INTRODUCTION

Projection is the idea of trying to know the future condition of an entity. The use of machine learning has facilitated this curiosity[1]. "Machine learning" refers to a assemblage of methods that let computers learn selflessly from the data; the systems learn on their own rather than following a precise programming pattern, which enables them to function intelligently. As it advances further, it can do better by learning effortlessly and, after that, being able to execute knowledge-related activities. Its learning method is carefully spelt out in that it has a considerable size of data that the computer will overrun in a brute force procedure to reduce the deviation of its prediction from the expected result. The principal motive for applying machine learning is to achieve efficiency and effectiveness in planning. On the basis of this notion, machine learning extends from artificial network procedures and can be regarded as a subset of artificial intelligence (AI). It enables prediction; for this purpose, its basic building blocks are algorithms. It generates data-driven predictions by developing models that discover patterns in historical data and utilize those patterns to generate predictions. Its data acquisition and storage capacities in various fields of scientific research introduce the issue of the tremendous information age. It made available a novel method of reasoning and techniques to analyze and handle problems. Which systematically leads to significant methods of research.[2,3].The main idea behind learning is the tradeoff between bias, variance, and model complexity[4]. Among the many branches of AI, machine learning can integrate data with statistical tools for projection and analytical power to predict results accurately in an intelligent form and intelligently find hidden insights using the supplied data in an automated way[2,5,6,7,8]. It provides a new way of thinking and approaches to analyzing and solving problems, gradually becoming a significant research method. Training of data at every stage with good visualization gives good analysis of data to project and prepare for the unknown to avoid had I know when population growth takes unaware, this ideology gives an insight to the future in preparedness to equip every amenities and the health sector to avoid the loss of lives[9,10,11].

There are primarily three subfields within machine learning: Supervised, Unsupervised, and re-enforcement. One conspicuous difference between the supervised and unsupervised is the appearance of the target variable. In supervised learning, we have a clear direction of what we predict from the stated model. Thus, every record feature or column has its specific label to be predicted. Invariably, unsupervised learning does not have a target variable; each record feature or column is independent and has no specific or fixed pathways to lead them. Supervised machine learning is trained with the data and with pre-labeled features or variables for the model to learn the relationship in the data set. Supervised learning requires more human preparation at the initial process due to the need for adequate labeling; the labeling serves as the ruder to determine whether the pattern recognition is a correct [12] Prediction models.

1.1 Unsupervised Machine Learning

The technique refers to algorithms that identify patterns in a dataset containing data points that are neither classified nor labeled. The algorithms are permitted to classify, label and group the data points within the data. Unsupervised machine learning tasks infer a function (the existing relationship) to describe hidden structure from unlabeled data [13,14,15]. It is used to deduce patterns in unlabeled datasets.

1.2 Reinforced Learning

The reinforced learning merged supervised and unsupervised methods by applying a dynamic machine learning composition. Yutaka et al. [16] can perceive its environment for interpretation, swing into actions and get educated through the guess method [17,18].

1.3 Population Growth Projection

Population growth projection discloses the future figures of fertility, mortality, and migration of people in a country. Machine learning concepts are currently expanding and favored for predicting future values. In conjunction with the data-independent prediction model, we implemented the Nigeria population growth rate projection, an unsupervised machine learning concept to build the map between base year and population growth.

2. LITERATURE REVIEW

Brintha et al.[19] investigated the population growth of Indian population data using time series forecasting machine learning techniques and analyzed different machine learning algorithms. Mohammad [20] deploys machine learning to predict the population growth rate in a country without historical data. Faith [21] applies various machine learning algorithms to forecast the population growth rate in Turkey. Ahmed [22] predicted the future population of Bangladesh with machine learning to estimate Rofingya refugees. An investigation carried out by Gotelli [23] gave attention to two main tools of projection techniques geometric and exponential methods, and equally thought of including the mortality and fertility as unique components of change. Thomas Malthus, a demographer of British extraction, gave significant attention to the exponential growth model; he studied a large number of demographic data and came to a conclusion that, in the operation of natural population growth, the proportional increase is a constant; the proportional increase is the proportion of the population increase on per unit of time to the total population at that time. Let the total population be P(t) at time t, and let the population growth rate (birth rate subtracted from death rate) be r. According to Malthus's theory, in the activity of natural population growth, r is the increase in the population per unit of time and is directly proportional to the total population. For the fact that population growth constantly increases, it can be regarded as a differentiable constant function. He opined that population increase, if is not commensurate with the food increase, that will spark trouble, more especially if increases in food supply is following arithmetic method while the population increases is following an exponential order, so this lopsidedness could spell doom for the inhabitants of a society and the government, and it is obvious that development will be hindered subsequently.

The National Population Commission (NPC)[24] deploys the Cohort component method, it is a method that is often used to forecast the various demographic variables including gender. It is used too as a plan of action that forecast the population by mimicking the way the population changes with the dictates of population components of change, on the ground of previous information supposition are put together, regarding the trends in the time to come in areas of fertility, mortality and net-migration. Thereafter, the estimated rates are put in an application in the age and gender composition of the population of reference, then replicating it with the thought that people are susceptible to death, that the female gives birth and some persons can change their address. Typical of this method is known as component method. The component approach of forecast of population stick to unit of all the group of persons according to their ages throughout their lifespan with the application of the component of change individually. From the initial population with age and gender, per person has the chance to exit by death as intended by the forecast according to the age and gender. Immediately the mortality is approximated they are deleted from the existing population and living ones continue to aged. Birth rates are estimated among the women procreative population regarding the birth occurrence on yearly basis. Every unit of children giving birth to is also expected to be susceptible to death. Especially, the component method examines both the in-migrants and out-migrant by adding them to the population of reference. Migrants are included, or removed from the population of reference in every vestige of the particular age and gender. This method is replicated on yearly basis of the forecast, which yields the forecasted population by sex and gender, likewise the mortality, fertility and crude death and natural increase and growth rate patterns for every year. Demographers use the component method often times because of its holistic nature of treating variable of population simultaneously. NPC [24]., Simon [25] and Guy J.et al [26] considers Bayesian techniques as a tool for predicting future populations. The primary rationale is the need for incorporating uncertainty in population forecasts, advocated by many authors since the 1980s [27,28,29]. Some techniques have also been developed to bring together aspects of all of these methods, for instance, the parameters from time series models have been constrained according to expert opinions [30,31] or to target levels and age distributions of fertility and mortality. We believe Bayesian methods offer a more natural framework than traditional frequents methods to forecast future population with uncertainty. First, the Bayesian approach offers an explicit, a unified and open process for incorporating data and parameter uncertainty of the model and the model itself, by using probability distributions. Second, it allows the inclusion of expert judgments, including uncertainty, into the model framework. Third, the predictive distributions follow directly from the probabilistic model applied. As a result, probabilistic population forecasts, with more reliable and coherent estimates of predictive distributions, can be successfully acquired. When used together, they may make it easier to quantify prediction uncertainty, which would enhance our capacity to prepare for and comprehend population change.

Vikas et al [32] study future population forecasting in India using the geometrical model to census population data. In this model, the average increase in future population forecasting every ten years is computed using historical census data. To determine the population in the next ten years, this increment is added to the current population. Thus, it is assumed that the population is increasing at constant rate. Next was the use of Graphical model representation In this process, the populations of last few decades are correctly plotted to suitable scale on graph. The population curve is easily expanded to accommodate future population growth. This expansion calls for meticulous execution as well as the right knowledge and discernment. The most effective method of using this process is to extend the curve by comparing with population curve of some other population having the growth condition. Another technique was the Comparative Graphical model. In this process the census populations of India already developed under similar conditions are plotted. The curve of past population of the India under consideration is plotted on the same graph. The curve is extended carefully by comparing with the population curve having the similar condition of growth. The advantage of this process is that the future population can be predicted from the present population even in the absence of some of the past census report—these various geometrical methods as suitable for the growth pattern. The fourth method was the Master Plan Model. The big and metropolitan cities are generally not developed haphazardly, but are planned and regulated by local bodies according to master plan. The master plan is prepared for the city's next 25 to 30 years. According to the master plan, the city is divided into various zones: residence, commerce and industry. The population densities are fixed for various zones in the master plan. From this population density, the total water demand and wastewater generation for that zone can be worked out. With this method, it is straightforward to access the design population precisely. Lastly was the Logistic curve Model. This process is used when the growth rate population as a result of births, deaths, and migrations takes place under everyday situations and it is not subjected to any extraordinary changes like epidemics, war, earthquakes or any natural disasters, etc. The population follows the growth curve characteristics of living things within limited space and economic opportunity. If the population of India is plotted concerning time, the curve so obtained under normal conditions looks like an S-shaped curve and is known as a logistic curve.

Jabrayilova [33] developed an intelligent demographic forecasting system using fuzzy time series model. The author analyzed things that affect economic changes and how they are interconnected with demographic processes. According to the author, the study's main aim is to develop an intelligent demographic forecasting system that supports demographic situation management decisions based on predictions. To achieve this aim, the author modeled and develops a demographic prediction technique. The author adopted a fuzzy time series for estimating model parameters. The analysis of this series involves constructing a mathematical model of time series of observation of real processes.

Folorunso, et al, [34] used controlled Artificial Neural Network technique to predict the population of Nigeria. Their prediction was done using training, validation, and test dataset in their research, Population Prediction Using Artificial Neural Network. Their study employed the artificial neural network for population prediction (ANNPP), which handles the inconsistent and incomplete nature of data, often experienced in mathematical and demographical models while carrying out population prediction. Three major dynamics of population changes (fertility, mortality, and migration) were considered in the input dataset. Vikas et al, [32], Applied Mathematical Modeling to project the population growth of India. While, Nusrat Rahima et al, [35], uses mathematical growth model to explore and determine an effective and plausible mathematical growth model to predict the future population growth of India. Poogodai [36] uses regression models to study the accuracy of population forecasts. It also looks at how population size and growth rate affect projection mistakes. Caleb Robinson, et al, [37] used the deep learning model to create high resolution population estimations from satellite imagery in the USA, to answer the question where do people live and how many people live there. Fasagba Irewole et al, [38] deploy Statistical package for social sciences (SPSS) Multiple linear regression to obtain the equation to model the population projection in Nigeria.

3. RESEARCH METHODOLOGY AND SYSTEM DESIGN

The study adopted the design of machine learning model. Which intend to apply data independent prediction model, based on onset data using the 2006 conducted census data as the input data presented to the machine learning algorithm to project the Nigeria population growth.

Conventionally, the projection model requires exploiting the data set to infer more information regarding the variable of interest. The data independent prediction model (DIPM),is the projection technique we are using in this study, in conjunction with the machine learning model conceptualization, for the reason that the prediction model by convention can exploit the dataset to deduce more information regarding the variable of interest, such as the growth rate, and time index of the census data, its algorithm can detect uncertainties on demographic composition and social-economic characteristics of the data and analyze the historical data, the model was re-modified from the covid-19 model equation to population prediction model.

The development of machine learning model, and the simulation methodology to validate the performance of the model, using the data independent prediction model which combines the exponential and Arithmetic properties, is designated as hybrid. These combination distinguished the implemented method and depute it as high-level model because, the marrying of the two techniques makes the model very robust and superior to the existing model, the results will be more reliable and accurate as the deployed model is poised to balance the excesses of each other, and come up with dependable and verifiable results. The data-independent prediction model, which comprises of both the Non-Pharmaceuticals concept approach and pharmaceutical approach is presented in equation (1.) and (2)

$$\mathbf{K\ (\theta) = Pe^{pt}} \quad \ldots\ldots \qquad \ldots\ (1)$$

The NPA model in equation 1 is known as data independent prediction model (DIPM), is clearly a non-pharmaceutical concept applied to predict the probability of safety from Covid-19 infection using the social distancing values.
While the equation (2),

$$pi = [\alpha e - \mathrm{ƃ}(t)] \quad \ldots \qquad \ldots.\ (2)$$

The Pharmaceutical approach model (PA) came into inception when the vaccines for the Covid-19 infection started arriving. Data from both models were utilized to combat the Covid-19 infection to a standstill. The data from both models were geared towards projection.

Okwonu, et al, [39] and Santosh, [40]. This study reformulate the data-independent prediction model to suit the population projection model because the model has the properties of arithmetic and exponential method, which is dependent on onset data or base data, and extends from such value using the embellished parameters with the automation of Java programming language, using machine learning model format to describe the functionalities of the system and thereafter simulate the model with secondary data from the 2006 conducted census. And compare the output value with the existing value to ascertain the model minimal error. Hence, equation (3)

The modified model in (3), reads the population projection model which is the crux of the study.

$$\beta\ [\lambda e^{-\phi(t)}] \qquad (3)$$

The equation 3 model possesses the characteristics of arithmetic and exponential properties, and the fitting parameters are:

β = starting population
λ = denotes tuning parameter for prediction control and
e **=** is the exponential constant (2.7818). Then, the following are defined

(i) ϕ = growth rate
(ii) t= represent the distant future of choice

<u>Keys</u>

IL: Integration Layer
PL: Processing Layer
SL: Storage Layer
AL. Analytical Layer
VL: Visualization Layer
AV: Actual Value

3.1 User Interface

The user interface provides a platform for users of the system to enter the required features for population projection**.**

3.2 Dataset component

The dataset component consists of dataset from the National Population Commission and is formatted into four columns, base figure, multiplier, growth rate, and time index represented by the mathematical equation of the model.

3.3 Java Array List Algorithm:

The Java Array list component optimized the population growth rate by performing feature extraction and selection and utilizes the value encoding techniques where each value is considered according to their role in the layer Jbutton, Jlabel, Jlayer etc. in the JArray list .The Java Array list module contains the initialization phase, the assigner, separator, generator, concluder and preprocessor phases.

3.4 Initialize Phase

In this phase, the data set is entered into the frontend. Is a method that NetBeans swing designer utilize to initialize components (set as defaults values) as a method it can be called within anytime you wants to use it, it is called inside the constructor to control the parameters you passed through your Graphical User Interface editor of NetBeans. It is a connector between the GUI Editor and Java. Removing it will disable the link between the functionality that NetBeans supplied to work with the components

3.5 Assigner Phase

The assigner allocates task value to each respected data point, helping to find an avenue to attain ease optimality. There is different assigner method in existence, we have adopted and implemented the pattern by Mohammed et al, 2012, though used in the health data regarding tumor dataset, we reformed it and use it in the population data projection.

$$\text{Assigner} = ƌ^*\ Error + \pi \frac{|n| - |j|}{|n|} \qquad (4)$$

Where

|n| is the entire features
|j| is the selected number of features
ƌ* are outside features

error rate = Av - pg/n

Where
Av: the actual number in the dataset
pg: the projected number set aside in dataset
n: the surplus number or difference between the actual value and projected in dataset

We adopt the Mohammed et al, [41] though was applied in the health dataset we find it useful in this data projection problem at hand.

Where
Av: the actual number in the dataset
pg: the projected number set aside in dataset
n: the surplus number or difference between the actual value and projected in dataset

We adopt the Mohammed *et al*, (2012) though was applied in the health dataset we find it useful for insight purposes in this data for projection problem at hand.

3.6 Separator Phase

Separator functions used in Roulette Wheel, (RWS), implemented in the health sector, Razamin et al.,[42] in determining dataset allocation is adapted, it is like an Array, ArrayList is a java class been a mother of all functionalities in Java, It does all the required procedure in Java programming, such as add, delete, concatenate, divide, store data, decides, allocate data etc. it has numerous features. Where data points are required to be utilized, like initializing, allocations, and probability cases, it is like a vector in C++, etc. The separator get the allocated data points to be projected in a complete number, and extends it with the aid of a function such as multiplication using the exponential and the provided variables such as growth rate and time interval to be projected, it is sensitive to the data trends. Once the data is provided with the accompanied variable of the projection, it takes it up from there. Every other internal function within the constructor is called within to achieve the required output as outlined in the equation 3.

$$\beta\ [\lambda^{e}\text{-}\phi(t)] \quad (5)$$

The equation 3.model possesses the characteristics of arithmetic and exponential properties, and the fitting parameters are:

β = starting population
λ = denotes tuning parameter for prediction control and
***e* =** is the exponential constant (2.7818). Then, the following are defined

(i) ϕ = growth rate
(ii) t = represent the distant future of choice

i. PROCEDURE::doseparator
ii. START_OF do separator: PROCEDURE
iii. //initialize a real number precision variable that holds the entire number of all PG_ Dataset
iv. PG_Assignersum:=0.00 // Assignersum of all PG_datapoint
v. for loop_counter:=0 to row-1
vi. START for loop_counter
vii. Assignersum:= Assignersum+PG_Assigner[loop_counter}
viii. Loop_counter:=loop_counter +1
ix. END for loop_counter //round the Assignersum to 2d.p
x. Assignersum:= ROUND(Assignersum,"2dp' // time interval of PG_ datapoint
xi. For loop_counter:= 0 to row-1
xii. START for loop_counter
xiii. PG_timeinterval:=PG_ Assigner[loop_counter]/Assignersum
xiv. Loop_counter:=loop_counter +1
xv. END for loop_counter//cumulative projection value for
xvi. PG_dataset with initialized variable value to zero
xvii. For loop_counter:= 0 to row-1
xviii. START for loop_counter
xix. PG_cumdatapoint[loop_counter]:=
xx. 0+PG_cum_projection[loop_counter]
xxi. Loop_counter:=loop_counter+1
xxii. END for loop_counter
xxiii. //separatorPG-datasetfor concatenating with cumulative
xxiv. projection loop counter set to 0
xxv. n:=0 //cumulative _projection_counter
xxvi. //initialize an array to hold popul.with all PG _ cumulative dataset
xxvii. Population []:=0 to row -1
xxviii. //initialize arrays to hold both PG_dataset from PG_Population
xxix. PG_dataset1:=R[row] // firstPg_dataset
xxx. PG-Dataset2:=S[row] //secondPg_dataset
xxxi. PEPEAT UNTIL n>number_rows
xxxii. START REPEAT UNTIL BLOCK
xxxiii. //PopulatePG-datasetarrays with Random _Population_dataset
xxxiv. R[n]:=RANDOM_POPULATION_DATASET()
xxxv. R[n]:=RANDOM_POPULATION_DATASET()
xxxvi. for loop_counter:= 0 to (number_rows
xxxvii. STARTPG_dataset1for loop_counter
xxxviii. IF(R[n]>=cumprojection[loop_counter] AND
xxxix. R([n]<cum_projection[loop_counter+1])
xl. START IF BLOCK
xli. PG_dataset1[loop_counter]:= loop_counter
xlii. END IF BLOCK
xliii. Loop_counter:=loop_counter+1
xliv. ENDPG_dataset1for loop_counter
xlv. For loop_counter:= 0 to)number_rows/2) -1
xlvi. STARTPG_dataset2 for loop_counter
xlvii. IF(S[n]>=cum_projection[loop_counter]AND S[n]<cum_projection[loop_counter +1])
xlviii. START IF BLOCK
xlix. PG_DATASET2[loop_counter]:=loop_counter
l. END IF BLOCK

li. loop_counter:=loop_counter +1
lii. ENDPG _ dataset 2 for loop_counter //increment loop counter, two SeparatedPG_dataset
liii. n:=n+2;
liv. END REPEAT UNTILL BLOCK
lv. END_OF doSeparator:PROCEDURE

Algorithm 1. The Separator Algorithm for population growth projection

3.7 Generators Phase

Generator institute produces and takes out optimal features from the projection growth rate dataset; Generator takes some random data and attempts to imitate the training data and generate false images; it aims to undercut the discriminator by attempting to generate images that exactly replicate the training dataset. You require a single ArrayList to store the result. At each point, you randomly choose an element from one of the two input ArrayLists with 0.5 probability. You can use a random number generator to choose between 0 and 1, say (Random::nextInt (0,2)). You store the resulting element in the result array List. You don't have to make new array lists if you don't need background data after crossover. Generate synthetic data.

3.8 Concluder/Acceptance Phase

The concluder recognizes a practicable benchmark in terminating the projection of population growth optimization process. Using generation as a concluder standard for projection of population growth dataset was dependent on its adaptive nature**.**

The adaptability provides:

1. Malleability as terminating criterion for any given dataset.
2. Terminating at any given iteration.

3.9 Preprocessor Phase

The pre-processor secures the optimized population growth projection crumbly dataset and transforms it into frizzy appearance in a coordinated form and thereafter stored the dataset in the knowledgebase. Applying the norm of fuzzy pre-processor is dependent on its ability to modify the optimized crumbly values into frizzy coordinated values as against to more approaches. The equation 5 is the standard pre-processor implemented, for crisp values transformation into fuzzy set. The fuzzy value of y' for the population growth projection decision variables D in the ith row is calculated as:

$$\text{Preprocessor} \quad y = \frac{y - \min(D)}{Max(D) - Min(D)} \tag{6}$$

Where:
ý = optimized population growth fuzzy sample decision variable D in the ith data point
y = optimized population growth number of sample decision variable D in the ith data point
min (D) = minimum population projection figure of sample decision variable D in dataset
max (D) = maximum population growth figure of sample decision variable D in dataset

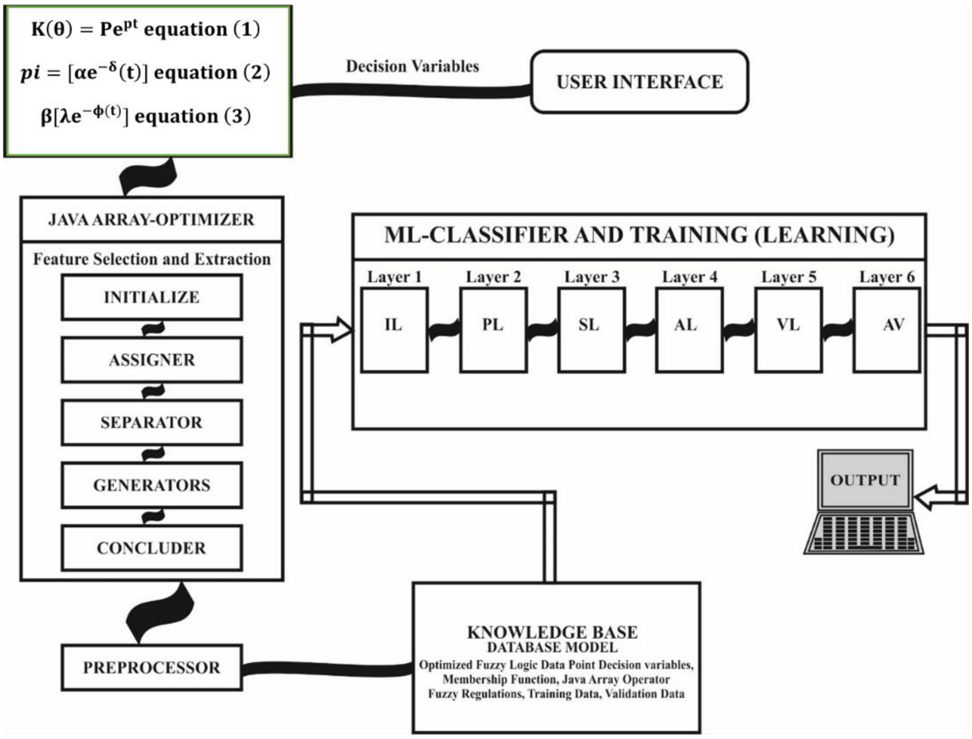
The knowledge domain (KD) obeys repository rule for the operational data which is been processed. This encompasses possessing structured and unstructured knowledge about the problem realm. The database constituents of the KD and sample decision variable values. These constituents or units perform the operational input for the data independent prediction model, as the trainer and using the Java programming language as the main classifier. The data independent prediction model and training block as portrayed in Fig. 1. Layer 1, Layer 2, Layer3, Layer 4, Layer 5 and Layer 6.

3.10 Training Input

The training input acquires operational data held within the knowledge domain and transfers it directly to the consecutive layers. Layer 1 shows four sample decision variables. The indicated variables serve as the input for the data independent prediction model training block.

4. DISCUSSION

The designed machine learning model have applied the data independent prediction model equation based on onset data to predict the Nigeria population growth, as a standard, the prediction model utilize the data set to conjecture more information regarding the variable of interest. Several population models have been used such as statistical bleeding tools, various machine learning algorithms relying predominantly on the historical input data. But our designed machine learning model serves better in accuracy, consistency and unbiased.



Initialization components

Fig. 1. A detailed design of the Machine learning model for projecting Nigeria Population Growth (MLM-PG)

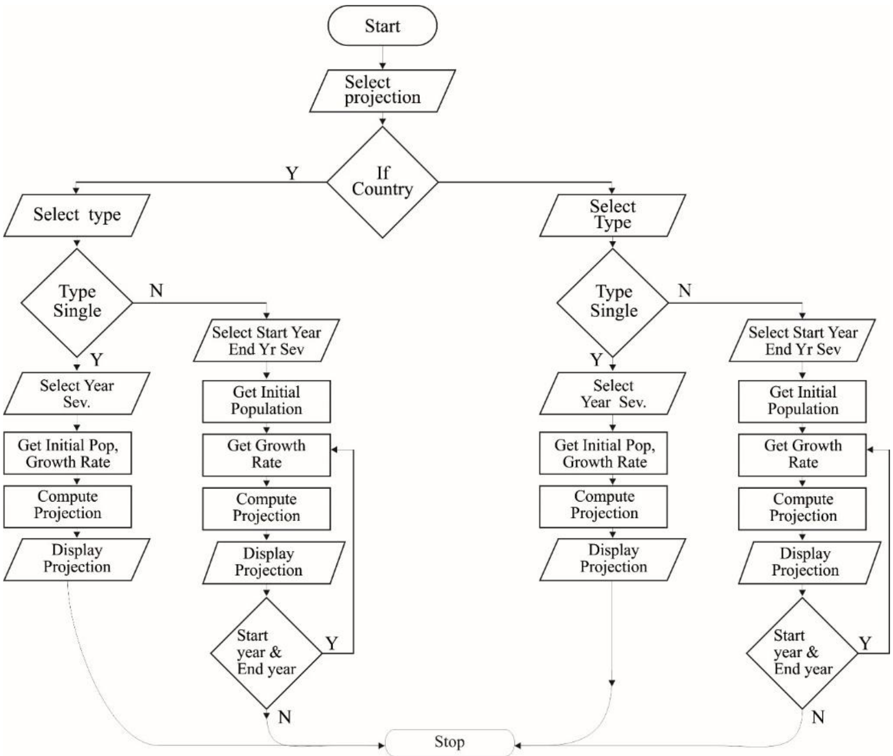


Fig. 2. Flow chart showing the logic that the machine use to learn the logic to carryout the sequential method of the projection of 2006 conducted population census

5. CONCLUSION

The data independent prediction model is a robust technique for both projection and forecasting future population growth as well as proffer answers to historical issues in mathematical modeling of population expansion. In this study, we have design a machine learning model conceptualization on how the data independent prediction model an unsupervised machine learning model characteristics, can project the Nigeria population growth to archive accuracy and consistency.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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