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Knowledge Based System for Population Growth Prediction

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Abstract: Projection techniques are commonly employed in mathematical, statistical, and stochastic machine learning models, which rely on randomly generated parameters. However, these models often fail to incorporate crucial and unique factors such as population growth rates and demographics. This study aims to utilize a knowledge-based simulation method that incorporates a machine learning model. Additionally, we will implement a data independent prediction model equation and a data-driven model equation to generate predicted values for the population growth in Nigeria. To enhance the accuracy and consistency of the predicted data, we will employ a Java algorithm optimizer. The resulting predicted data will be valuable for planning purposes and will help overcome the limitations of previous models.
Keywords: Population, Projection, Predicting, Machine Learning, Knowledge base, Growth

1. Introduction

Simulation is the use of models to imitate the real –world process using the computer algorithm to aid in the iteration process, so that the variables interaction within the system with the lead of mathematical analogy to show responses can be achieved. The machine learning model designed using the data independent prediction model to simulate the system with the aid of mathematical model equation to guide the scalability of variables or parameters using Java programming language to act as a facilitator to the perfect integration of all the components and glued them appropriately to produce the expected output from the 2006 census figures used to train the algorithm is our target. For the purpose of proper governance, academia, health, private sectors etc. population prediction and estimation plays a pivotal role for adequate planning and policy formation programme [1]. All stakeholders involved in planning such as sociologist, economist, demographers, and administrators ought to have the true picture of the society composition in areas of age and sex, density, health etc. these indicator are germane for comprehensive administration and factors that are connected to humanistic in nature.[2].

The blueprint of the Software step identification, help to establish the stages of the project involving in the preconceive, inclusion, execution, order and finally adapt a composite structure[3]. Unified Modelling Language (UML) was used in designing the functionalities of the Machine learning Model for the projection of Nigeria Population growth (MLM-PG). UML supports an object orientation, design approach, capturing and representing the integral functionalities of the MLM-PG from an object component perspective. The MLM-PG design present three main UML views: User, Structural (Static) and Behavioral (Dynamic), using three methods: use - case, Sequence diagram and activity diagrams to conceptualize the MLM-PG designed method.

The MLM-PG implementation depicts the functionalities of the MLM-PG. These functionalities show the MLM-PG algorithms. These algorithms are visualized from the Java programming language interfaces and machine learning algorithms. The Java software agents interfaces carters for the algorithms operational methods of the MLM-PG while the Machine learning model interfaces carters for the machine learning operational methods of the MLM-PG**.** The Java algorithm comprises: Initialize component,

Assigner, Separator, Generator, and Concluder while the MLM-PG components interfaces include: preprocessor, Input, Membership, Regulation, Normalization, Fuzzy logic and Output.

Machine learning model is an arrange method which allow the computer algorithm to be taught by the data in an unselfish manner, the systems learn independently instead of being exact in its programming pattern which permit it to perform intelligently. As it advances further it is able to do better by learning effortlessly and thereafter, able to execute activities that are knowledge related. Its method of learning carefully planned in the sense that it has large number of data that the computer algorithm will flip over in a guess procedure so that there will be a minimal departure from the projection estimation outcome. The principal motive of applying machine learning model is to achieve efficiency and effectiveness in regards to planning purposes. Machine Learning, due to the concepts, inherits, some Artificial Network procedures, and it is considered as a miniature of Artificial Intelligence (AI). This allows projection occurrence in a facilitated manner on the basis that its foundation lies on the algorithms, it gives rise to data-driven projection as it cultivate new examples where pattern in a novel way are elicited from previous data and use the method for projection. The technique it used to acquire data and storage capabilities from various discipline of science domain is what introduces volume and variety of data chunk era. It made available a novel method of reasoning and techniques to do an analysis and handle problems which systematically lead to significant method of research.[4], [5]. The tradeoff between bias, variance and model complexity are the primary leading idea of learning.[6]. Machine learning as a subset of Artificial Intelligence, can integrate data with statistical tools for projection and analytical power to predict results accurately in a smart form and intelligently and can also find hidden insights using the supplied data in an automated way. [4]; [7]; [8]; [9].

The Machine Learning is divided into three main categories: Supervised, Unsupervised and Re-enforcement, one conspicuous difference among the supervised and unsupervised is the appearance of target variable. In a supervised learning we have a clear direction of what we are predicting from the stated model, input and output setting. Thus every record or feature or column has its own specific label to be predicted. Invariably unsupervised learning does not have a target variable, each record or feature or column is independent and has no specific or fixed pathways to lead them. The supervised machine learning is trained with the data and with pre-labeled features or variables for the model to learn the relationship that exist 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 if the pattern recognition is correct or not.[10].

In an unsupervised learning method, the algorithm employed by the computer device work to enhance the execution of the training data, and there after able to bring out the relevant generalize pattern or methods that is useful for the subsequent novel data. The unsupervised learning solves the problem of dimensionality reduction in a meaningful compression, big data visualization, structure discovery and feature elicitation.

Unsupervised machine learning technique, is an algorithm that is able to figure out an arrangement among the dataset containing training data that are unlabeled. It is the duty of the algorithm to independently carryout the classification of the training data on its own. Unsupervised machine learning tasks is inferring a function (the existing relationship) to describe hidden structure from unlabeled data. [11]; [12]; [13], [14]. It is used to deduce patterns in unlabeled datasets.

2. Literature Review

Population growth projection applies the components of demographic variables such as fertility, mortality and migration of people of a country. Currently, Machine learning concepts are most growing and popular for predicting future values. Therefore, in the Nigeria population growth rate projection problem, we deploy the data independent prediction model, an unsupervised hybrid prediction model concept to build the map between base year and population

growth. This study adopted the design of machine learning model and simulation method, this hybrid foster strength. [15], attested that simulated environments is fitting for test and validation of defined classes of expert methodology. Both agreed that in the typical world phenomenon simulation result obtained could give a better perspective of how the real world scenario would perform. Based on the order of succession before the development of machine learning model for the prediction of Nigeria population growth, some interpretable predictive models were develop for the prediction of population growth in many countries such as Turkey [16].

The fragmented model applied some classification and statistical blending tools, such as Autoregressive Integrated Moving Average (ARIMAL) [17] they employed different classifiers algorithms of machine learning techniques in the analysis, there was neither machine learning model development nor simulation method. The prediction impacts of distancing from one person to the other that may curtail the covid-19 rate of spread, with the use of data independent prediction model was applied, [18]. Although the existing research have initiated an appropriate technique with the aim of predicting the population growth, the fundamental issue of simulation methodology to help us analyze the behavior of the developed machine model and understand how the system work are persisting issues needing prompt attention. The developed machine learning model was implemented and the components were glued together with Java algorithm to predict the Nigeria population figure from 2007-2032.

Materials and Methods

Population projection gives a picture of what the future size and structure of the population by sex and age might look like, it is based on knowledge of the past trends, and future assumptions made for the three components of population dynamics: fertility, mortality and migration.[19];[16].

Three population projection approaches are used to illustrate its change, linear change, exponential change and geometric change. The two main methods of projection are mathematical and Cohort component method. Mathematical method of projection uses the exponential, linear and logistic to illustrate their outcome.

Cohort -Component method computed as:

$$P_{t+n}=P_t+B_{t,t+n}-D_{t,t+n}+M_{t,t+n} \quad \text{.....(i)}$$

Exponential projection equation: r = [ln (Pi/Pb)]/(Y).....(ii)

Exponential projection method does not consider external factors in inclusiveness

Computed as Pt = (Pi) (e^{rz}).....(iii)

Linear projection equation: (Arithmetic growth model)

The incremental increase is determined for each decade from the past population and average value is added to the present population along with the average rate of increase. Hence, the population after nth' decade is

Arithmetic: **Pb= P+ b X + {b(b+1)} Y .....(iv)**

Arithmetic: $\mathbf{Pb} = P + bX + \frac{b(b+1)Y}{2}$ ..... (v)

Where, Pb = Population after n^{th} decade

G = Average increase,

H = Incremental increase.

The linear projection method assumes that in the future a population would change by same amount over a given period. As occurred during the base year.

Logistic projection equation: Y = a/ [1+b(e^{-hx})] .....(vi)

Computed as Pi= (a)/[1+(b) e^{ht})] .....(vii)

Projection method needs to be accurate, reliable and verifiable, for it to be accepted, especially when our interest is both about interpretability and predictability, statistical tool must not be used solely, rather we need a more robust and analytic technique to achieve that, this is why this study pitch a tent with a more evolving and more encompassing predictive software, which is machine learning method, (Unsupervised) to project population growth of Nigeria, because population data is key to many developmental programmes.[20];[21].

Population projections are relevant for many aspects of public life and are especially important for population policies. And there are many projection models for predictions [22].This study has adopted the data independent prediction model to project the Nigeria population growth and compared the result with the existing model. The existing models used for covid-19 prediction for mitigating infection spread was remodified to project Nigeria population growth

$K(\theta) = Pe^{pt}$.....(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),

$pi = [\alpha e - \eth(t)]$ (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 prediction.

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 modelformat to describe the functionalities of the system and thereafter simulate the model with secondary data from the National Population commission. And compare the output value with the existing value to ascertain the model accuracy, hence, equation (3).

The modified model in equation (3,), reads the population projection model.

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

$^{\phi}$= growth rate ……(i)

t = represent the distant future of choice ……(ii)

The Existing model equation of data independent prediction

$K(\theta) = Pe^{pt}$.....(1) NPA Method

$pi = [\alpha e - \eth(t)]$ (2) PA Method.

$\beta [\lambda e^{-\phi(t)}]$.....(3) population growth model re-modified

The machine learning component and the data independent prediction model were simulated using the java programming language an object-oriented programming. The datasets were optimized using the Java Array list optimizer, passed the machine learning model for training. The optimized and trained components/ features were converted into a Java library file using the following flow chart steps to predict the data making projection to be unsupervised machine learning or knowledge based unsupervised model, which can be turned to any direction of interest of the researcher, such as with different percentages of growth in any year or can be accommodated to predict the population values or onset data. This flexibility made the data independent prediction model it unsupervised.

4 Results And Discussion

The result of its projection output are shown in figure 1-figure 6.

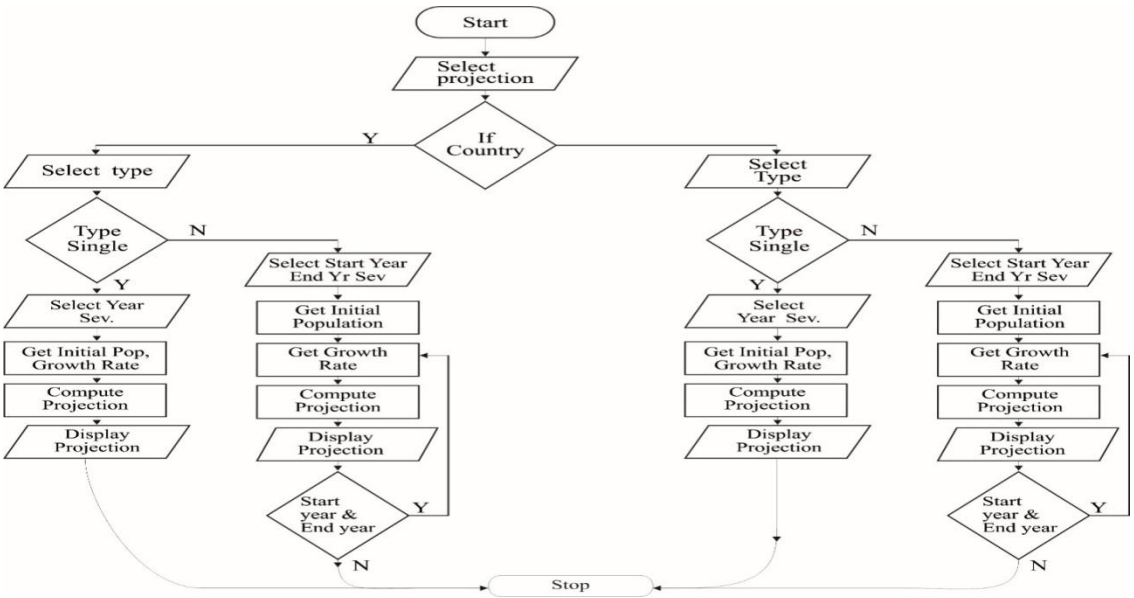

Figure 1. The flow chart for the machine learning model for the projection of the 2006 conducted census population.

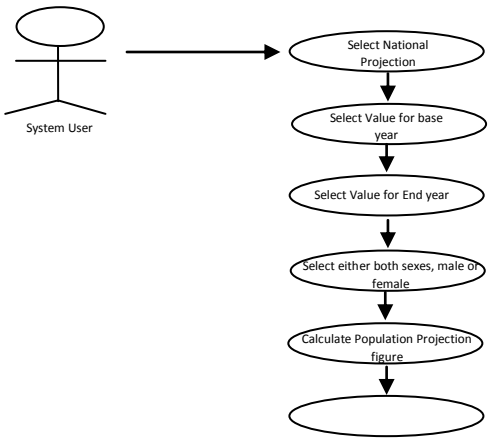

Figure 2.Machine Learning Model -PG USECASE for Calculating National projection.

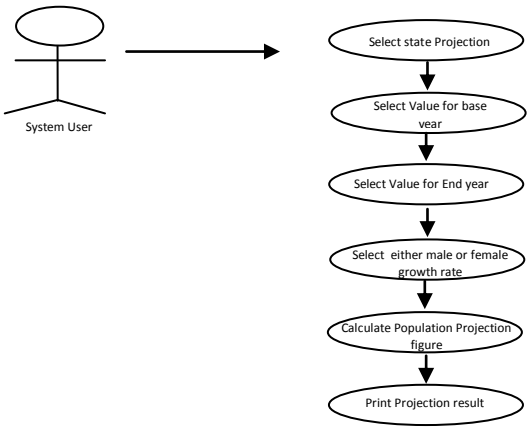

Figure 3 Machine Learning Model -PG USECASE for Calculating State projection

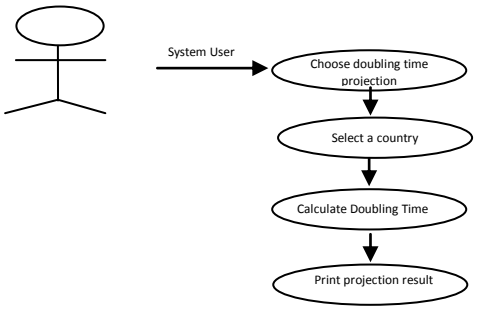

Figure 4 Machine Learning Model -PG USECASE for Calculating of Doubling Times

Figure 3. Projection Sequence DiagramFigure. 5. Sequence diagram for Projection

The projection sequence diagram identifies the users as the main object and other interacting objects .these objects includes user, decision variable, membership values and projection result. These objects interact through synchronous message exchange recourse to each time slot, activation and lifeline

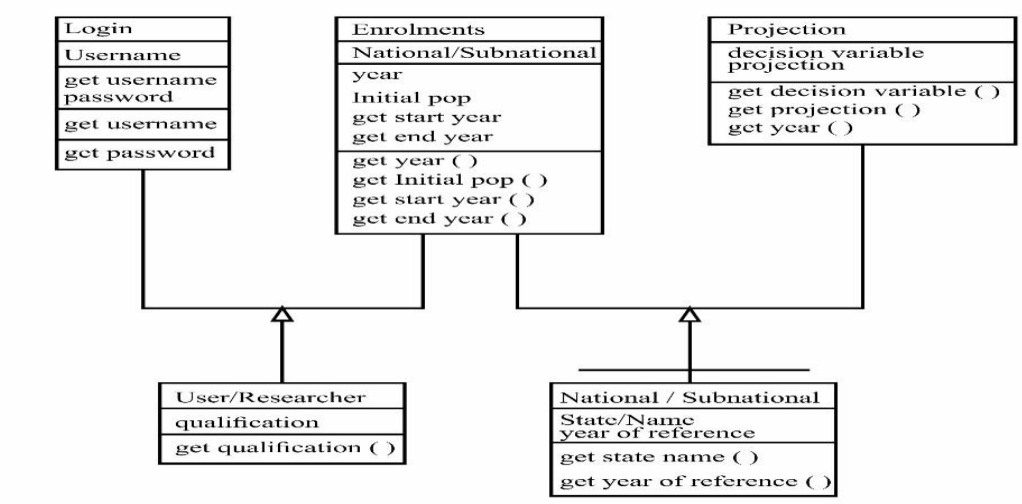

Figure 5 MLM-PG Class Diagram

The user (researcher) will log in into the system by providing user name, and password. These object interact through synchronous message exchange recourse to each time slot, activation and lifeline.

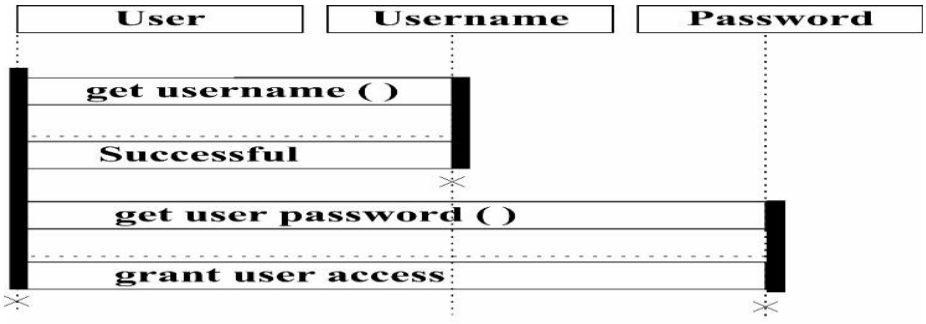

Figure 6. MLM-PG Log in sequence Diagram

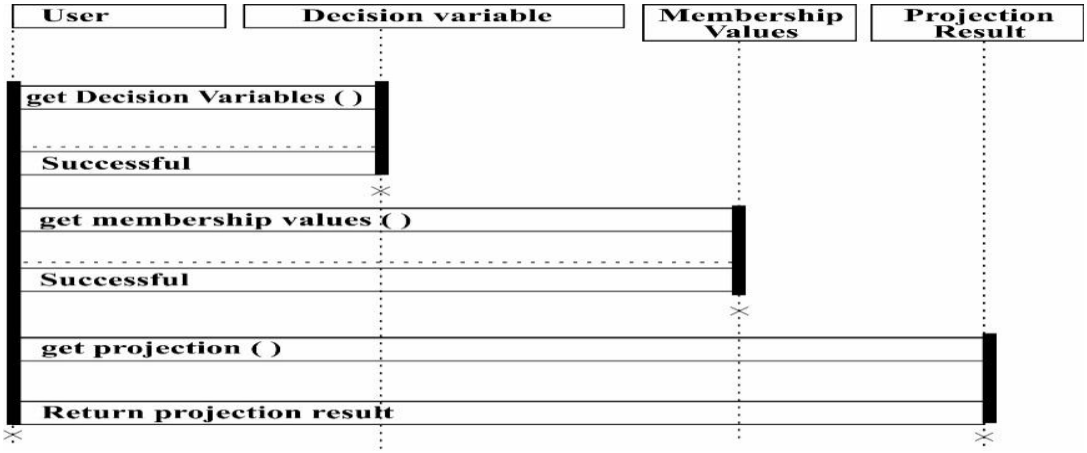

Figure7. MLM-PG projection sequence Diagram

The projection system diagram identifies the data a object interacting with other variables: National projection, base year, end year, both sexes, male or female, calculate, and print projection. These objects interact through synchronous message exchange recourse to each time slot, activation and lifeline.

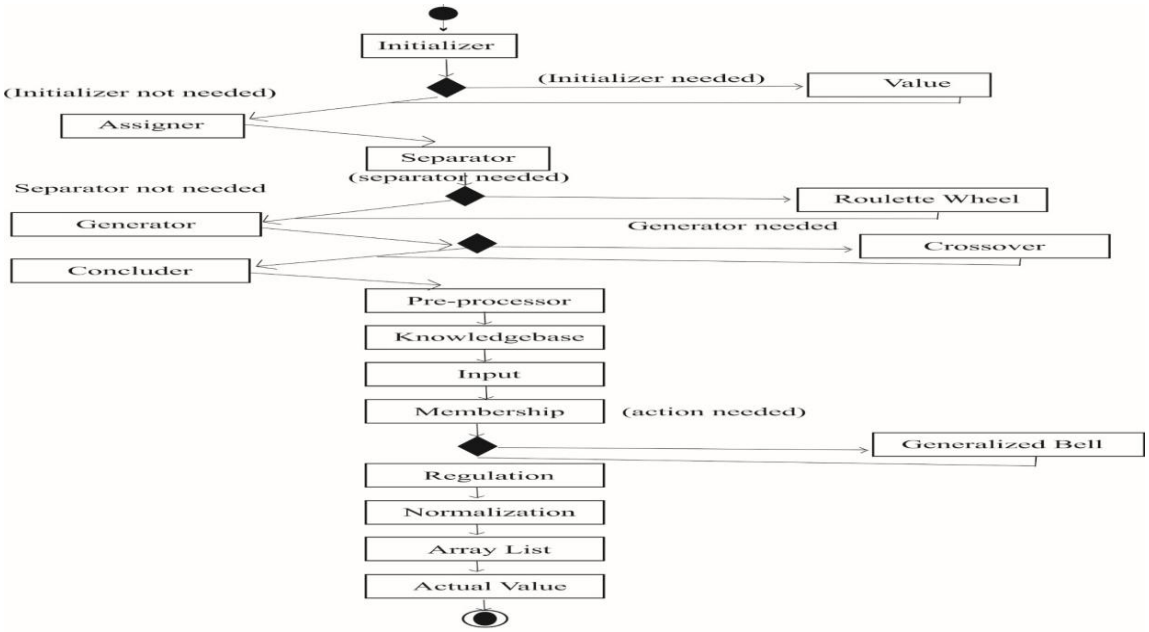

Figure 8.MLM –PG Activity Diagram

Figure 8. Showing the activity diagram for the model functionality.

Figure 6 Activity Diagram of the MLM-PG activity diagram picture the coherent functionality of the MLM-PG utilizing activities, decision points and branches. The arrows in-between the MLM-PG activities identify the transition from one activity to another. The decision point identifies activities with different options. Provided through appropriate branching. On accomplishment of the bracing execution, the flow of execution returns back to MLM-PG activities succeeding the branch.

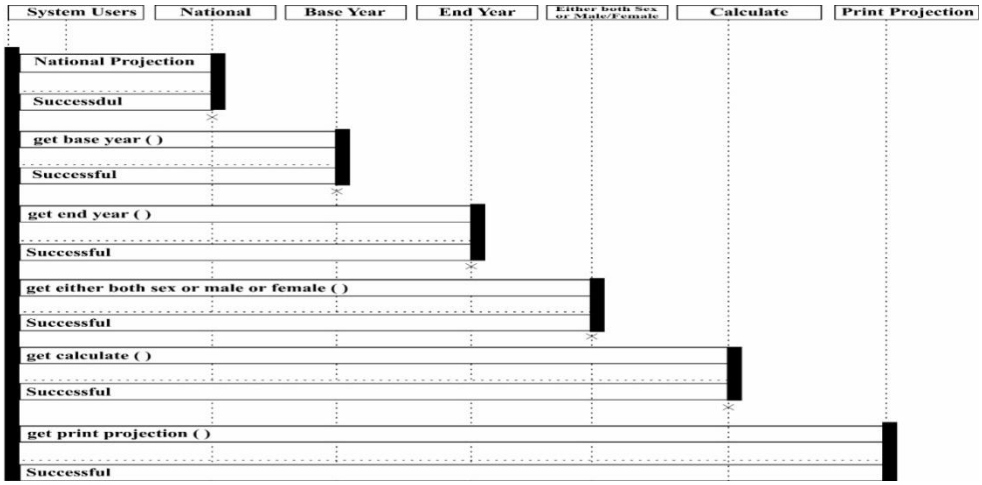

Figure 9. MLM-PG System User Sequence diagram

Class diagram are very germane in Object-Oriented (OO) software development because it initiate a foundation for the software development supplying the information about specific instances relating to instant in time. The class diagram made up the backbone of the object –oriented development and provides a strong basis for the design and implementation of the software. (Genero, 2005). It describes the class attributes and methods used in the Java software comprises of three classes such as login, registration and projection request

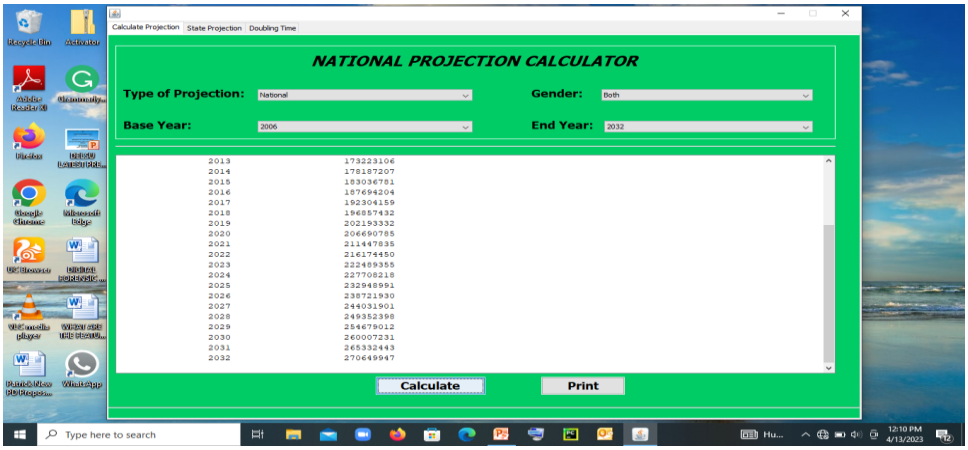

Figure 10. This is the display of the user interface after the projection is accomplished

The projection system diagram identifies the data a object interacting with other Variables: National projection, base year, end year, both sexes, male or female, calculate, and print projection. These objects interact through synchronous message exchange recourse to each time slot, activation and lifeline**.**

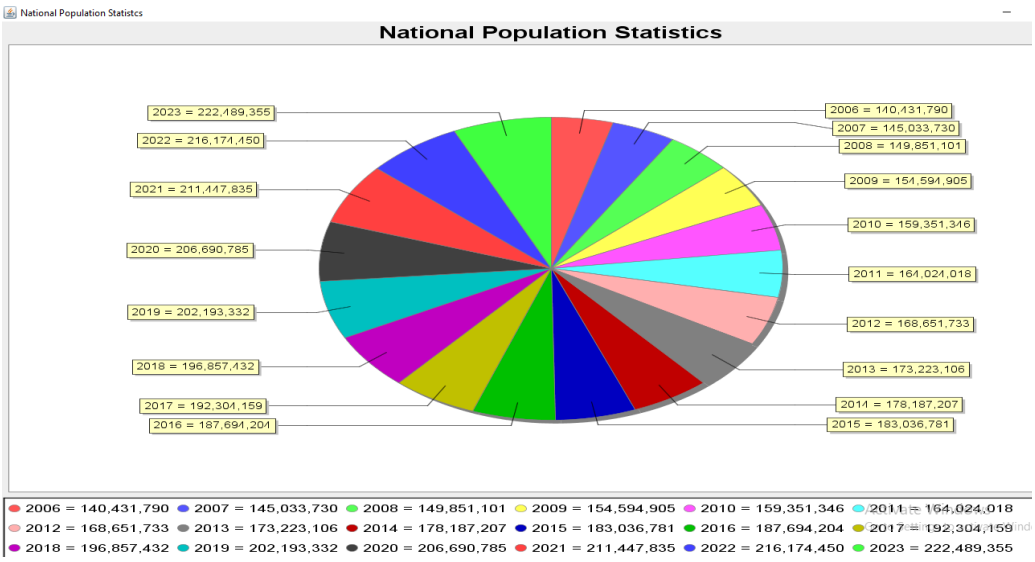

Figure 11. A Pie chart illustrating the different years of projection from 2007-2032

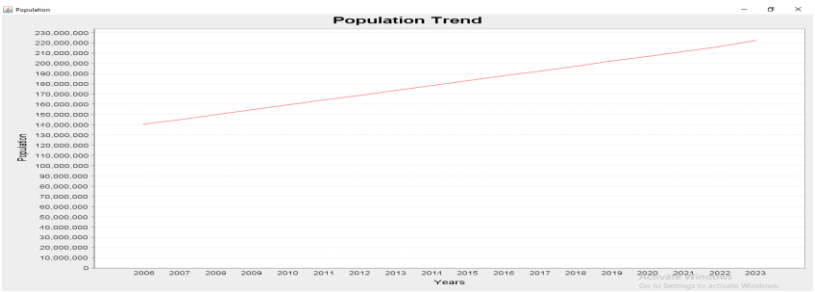

Figure 12. Projected trending, Trends is the Queen of the Projection

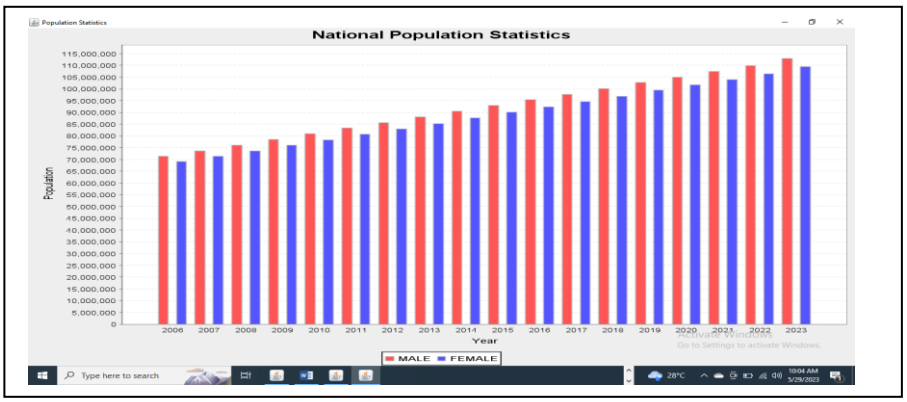

Figure 13. Bar chart further illustrating the galloping percentage of changes over the years from 2007 -2032 as the growth is not endless it grows and retract based on carrying capacity, which naturally constraints exponential growth.

Population Pyramid by Age and Sex, 2022 (Medium Variant in Nigeria)

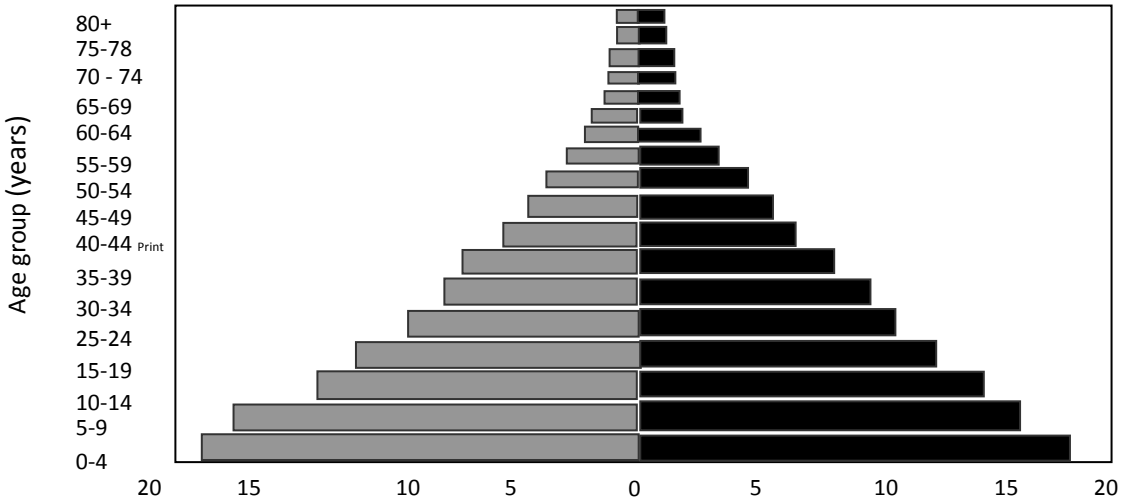

Figure 14: Population Pyramid by Age and Sex, 2020 (Medium) (NPC, (2022)

This is a pyramid showing the age structure of Nigeria population, for the year 2020

Existing Projection By Total Population

Table 1: Nigeria Total Projected Population Distribution by sex, 2007 to 2022

YEAR	Total	MALE	FEMALE
2006	140,431, 790	71,345,488	69,086,302
2007	144,636,162	73,362,818	71,273,344
2008	148,987,688	75,458,773	73,528,915
2009	153,408,431	77,591,819	75,816,612
2010	157,898,421	79,761,798	78,136,623
2011	162,450,998	81,964,681	80,486,317
2012	167,054,454	84,193,850	85,256,694
2013	171,704,412	86,447,718	85,256,694
2014	176,438,990	88,742,943	87,696,047
2015	181,248,792	91,076,923	90,171,869
2016	186,121,277	93,443,245	92,678,032
2017	191,053,912	95,839,254	95,214,658
2018	196,042,933	98,263,945	97,778,988
2019	201,135,262	100,739,423	100,395,839
2020	206,283,338	103,242,979	103,040,359
2021	211,493,324	105,776,862	105,716,462
2022	**216,783,381**	**108,350,410**	**108,432,971**

(SOURCE : NPC, [23])

This display the growth rate for Nigeria from 2007 to 2022 (Annually).

Comparison of machine learning model with the existing population projection growth, compare the actual with the predicted. (Machine Learning Algorithm)

Table 2.

YEAR	ACTUAL POPLATION	PREDICTED POPULATION	ERROR	%ERROR
2006	140,431, 790	140,431,790	0	0
2007	144,636,162	145,033,730	397,568	2.74
2008	148,987,688	149,851,101	863,413	5.80

2009	153,408,431	154,594,905	1,186,474	7.73
2010	157,898,421	159,351,346	1,452,925	9.20
2011	162,450,998	164,024,018	1,573,020	9.68
2012	167,054,454	168,651,733	1,597,279	9.56
2013	171,704,412	173,223,106	1,518,694	8.84
2014	176,438,990	178,187,207	1,748,217	9.90
2015	181,248,792	183,036,781	1,787,989	9.86
2016	186,121,277	187,694,204	1,572,927	8.45
2017	191,053,912	190,505,679	1,250,247	6.54
2018	196,042,933	196,857,432	-544,499	2.77
2019	201,135,262	202,193,332	1,058,070	5.26
2020	206,283,338	206,690,785	407,447	1.98
2021	211,493,324	211,447,835	45,489	2.15
2022	**216,783,381**	216,174,450	-608,931	2.80
2023	……..	222,489,355	000000	000
2024	……..	227,708,218	000000	000
2025	……..	232,948,991	000000	000
2030	……..	260,007,231	000000	000
2031	……..	265,332,443	000000	000
2032	……..	270,649,947	000000	000

Table 3.NIGERIA GROWTH RATE PROJECTION BY Total Population 2007-2032 using Machine Learning Algorithm

YEAR	ACTUAL POPLATION	PREDICTED POPULATION	ERROR	%ERROR
2006	140,431, 790	140,431,790	0	0
2007	144,636,162	144,153,976	-482,186	3.34
2008	148,987,688	148,425,331	-562,357	3.79
2009	153,408,431	152,823,247	-585,184	3.82
2010	157,898,421	156,974,286	-924,135	5.89
2011	162,450,998	161,528,566	-922,432	5.71
2012	167,054,454	166,214,979	-839,475	5.05
2013	171,704,412	171,037,359	-667,053	3.90
2014	176,438,990	175,999,650	-439,340	2.50
2015	181,248,792	180,130,576	-1,118,216	6.17
2016	186,121,277	185,245,507	-875,770	4.73
2017	191,053,912	190,505,679	-548,233	2.88
2018	196,042,933	195,915,219	-127,714	6.52
2019	201,135,262	201,478,365	-343,103	1.70
2020	206,283,338	205,466,295	-817,043	3.98
2021	211,493,324	211,173,909	-319,415	1.51
2022	**216,783,381**	217,040,074	256,693	1.18

2023	……..	223,069,193	000000	000
2024	……..	229,265,795	000000	000
2025	……..	231,199,739	000000	000
2030	……..	255,106,730	000000	000
2031	……..	261,564,788	000000	000
2032	……..	268,186,332	000000	000

Comparison between the actual and predicted population (machine learning model)
Edo State Projected Population by total 2007-2032

Table 4

YEAR	ACTUAL POPLATION	PREDICTED POPULATION	ERROR	%ERROR
2006	3,233,366			
2007	3,322,668	3,313,693	-8,975	2.71
2008	3,414,774	3,411,879	-98201	0.03
2009	3,505,653	3,512,975	7322	2.09
2010	3,595,335	3,608,395	13060	3.62
2011	3,683,611	3,713,086	29475	7.93
2012	3,770,141	3,820,813	50672	0.01
2013	3,854,642	3,931,666	77024	0.01
2014	3,944,847	4,045,735	100,888	0.02
2015	4,040,178	4,140,693	100,515	0.02
2016	4,140,181	4,258,271	118090	0.03
2017	4,244,511	4,379,188	134677	0.03
2018	4,353,500	4,503,538	150038	0.03
2019	4,461,137	4,631,419	170282	0.04
2020	4,567,512	4,723,090	155578	0.03
2021	4,672,707	4,854,292	181,585	0.04
2022	4,777,042	4,989,138	-212,096	0.04
2023	……..	5,127,731	000000	000
2024	……..	5,270,173	000000	000
2025	……..	5,314,629	000000	000
2030	……..	5,864,183	000000	000
2031	……..	6,012,638	000000	000
2032	……..	6,164,846	000000	000

Comparison between the actual and predicted population (machine learning algorithm)
Delta State Projected Population by Total Population2007-2032

Table 5

YEAR	ACTUAL POPLATION	PREDICTED POPULATION	ERROR	%ERROR
2006	4,112,445			
2007	4,192,014	4219828	-8,975	2.71
2008	4,275,075	4,344,864	-98201	0.03
2009	4,358,889	4,473,604	7322	2.09
2010	4,443,441	4,595,118	13060	3.62
2011	4,528,537	4,728,436	29475	7.93

2012	4,613,842	4,865,622	50672	0.01
2013	4,699,157	5,006,787	77024	0.01
2014	4,789,960	5,152,049	100,888	0.02
2015	4,885,710	5,272,974	100,515	0.02
2016	4,985,899	5,422,703	118090	0.03
2017	5,090,103	5,576,685	134677	0.03
2018	5,198,675	5,735,038	150038	0.03
2019	5,307,543	5,897,889	170282	0.04
2020	5,416,738	6,014,628	155578	0.03
2021	5,526,218	6,181,707	181,585	0.04
2022	5,636,145	6,353,428	-212,096	0.04
2023	…….	6,529,918	000000	000
2024	…….	6,711,312	000000	000
2025	…….	6,767,924	000000	000
2030	…….	7,467,755	000000	000
2031	…….	7,656,802	000000	000
2032	…….	7,850,635	000000	000

Comparison between the actual and predicted population (machine learning algorithm)

Adamawa State Projected Population by Total 2007-2032

Table 6

YEAR	ACTUAL POPLATION	PREDICTED POPULATION	ERROR	%ERROR
2006	3,178,950			
2007	3,272,473	3,261,973	-10,500	3.22
2008	3,369,841	3,358,627	-11,214	3.34
2009	3,468,075	3,458,145	-9930	2.87
2010	3,567,119	3,552,076	-15,043	4.23
2011	3,666,513	3,655,133	-11,380	3.11
2012	3,765,959	3,761,179	-4780	1.27
2013	3,865,082	3,870,301	-5219	1.35
2014	3,968,062	3,982,590	14528	3.65
2015	4,074,913	4,076,066	1153	2.83
2016	4,185,266	4,191,809	6543	1.56
2017	4,299,284	4,310,838	11,554	2.68
2018	4,417,584	4,433,247	15,663	3.53
2019	4,536,948	4,559,132	22,184	4.86
2020	4,657,314	4,649,373	7941	1.70
2021	4,778,877	4,778,527	350	7.32
2022	4,902,055	4,911,269	9214	1.87
2023	…….	5,047,698	000000	000
2024	…….	5,187,917	000000	000
2025	…….	5,231,680	000000	000
2030	…….	5,772,656	000000	000
2031	…….	5,918,792	000000	000
2032	…….	6,068,627	000000	000

The existing projection method by the National Population Commission, using the spectrum 5 and population analysis spreadsheet software to implement the cohort component model. The comparison between the national total population growth predicted value with the actual population, the results is approximately some few thousands differences from the actual value, precisely in the year 2022, the surplus value is about 257,000, and 608,931 which amount to the percentage error of 1.18%. and 2.8 % respectively while tables 4-6 shows the sub-national totals such as Delta, Edo and Adamawa states respectively, their excess value from the actual population also bask within some few thousands away from the original, with the percentage error of 0.04% , 0.04% and 1.87% respectively. There is a strong quantitative correlation between these two projections, which make our model unbiased.

Conclusion

The projection of the National and some selected sub-national population data was predicted with the data independent prediction model equation in a conceptualized machine learning model which is unbiased and more robust than the existing method, a leverage for the government and users of population data.

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