International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 20, Issue 3 (March. 2024), PP. 21-30

An Intelligent Dynamic Model of Economic Development with Sustainable Goals

Ashok K Sinha
UST Software India Pvt. Ltd., New Delhi, India

Abstract: *In developing nations there has been an enduring discussion among economists and researchers on defining economic growth and economic development [1-2]. While economic growth, commonly expressed in terms of gross domestic product (GDP), reflects the productivity of natural resources, labor and capital, the economic development encompasses the human development index (HDI) ,a combination of education index(EI) ,health index(HI) and per capita income(PCI) as defined by UNDP in 1990[3].Over the past decades many studies have been done by researchers dealing with modeling of GDP and human development separately ,however no machine learning based computational model has emerged so far to model an evolutionary economic development process integrating the two facets of national economy ,GDP and HDI in a sustainable manner. The model formulation is based on the premise that the deployment of resources, land, labor and capital produces the output GDP impacting human development, and in turn the raised level of output when recycled into the system the economic development keeps on evolving over time with sustainable goals. Based on this framework an intelligent dynamic macro-economic model is developed in this paper with its empirical implementation using deep learning algorithms. Karas sequential model library in Python [4,5] is used in operationalizing the above model with statistical data available from Nitti Aayog ,Govt. of India[7-9] and HDR report of UNDP[10]. Further application of this model is explored to allocate the input resources for achieving the defined target output using inverse dynamic modelling. The solution may not necessarily be optimal, in order to find this a minimum cost resource allocation is obtained by using genetic algorithm, a tool of artificial intelligence [11] . The computational result of model implementation is found to be satisfactory at a level of 95% accuracy. The methodology presented in this paper will be useful in predicting the future economic development and preparing sustainable planning for the national economy. This is a contribution in the field of developing a computational modelling approach to economic study and policy making.*
Key words: *GDP, HDI,GNI,MYS,LFE, ANN ,ML ,GA, AI*

Date of Submission: 23-02-2024 Date of Acceptance: 04-03-2024

I. Introduction:

Economic growth is commonly expressed as the annual rate of increase in the value addition to resources and services, termed as the gross domestic product (GDP) of a country. Sector wise GDP is a measure of productivity; the amount of goods and services produced over a period of time. Their annual plot in India from 1961-2021 is shown in fig.1. GDP is produced by natural resources of a country with the support of human resources, who are engaged in productive and socially useful activities. With conventional wisdom we sometimes take these statistics as the progress of the country. On the other hand, the ability to produce goods and services depends on people's health and education and other indices related to human living standards. These are the components of human capital, measured in terms of human development index (HDI). As defined by UNDP in 1990, HDI is formed by longevity as life expectancy at birth (LFE), knowledge as years of schooling (MYS), and the standard of living as per capita gross national income (GNI). The correlation coefficient among GDP growth and HDI for India as computed from data is 0.28 indicating a weak relationship.

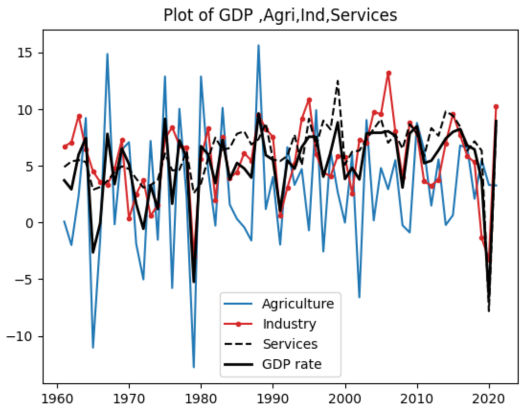


Figure1. Annual Growth rates of GDP,Agri&Allied,Industry and service sectors

The GDP and HDI are not synonym can further be corroborated from one example shown below in table 1 that among developing nations in the year 2021 India with annual GDP growth of 8.18% showing a higher growth in comparison to south Asian neighbor Bangladesh and Sri Lanka, has slipped down in HDI to 132 in comparison to Bangladesh at 129th position and Sri Lanka at 73rd position.

Table 1. Comparison of GDP and HDI components of few Asian Countries in 2021

HDI	Country	HDI	GDP growth per Capita	LifeExp LFE	Mean year school MYS	GNI growth perCapita
Rank		Value		years	Years	USD (PPP)
73	Sri Lanka	0.782	2.40	76.4	14.1	12,578
129	Bangladesh	0.661	5.71	72.4	12.4	5,472
132	India	0.633	8.18	67.2	11.9	6,590

source: UNDP Human Development Reports

Normally the rise in per capita GDP should impact HDI positively, and this added human capital should raise productivity. But what is so striking is that despite this expected pattern, in developing countries there is still great variation between GDP and broader measures of living standards. For example, in 2021 Guinea and Nigeria have essentially close HDI at 0.46 and 0.53 despite the fact their per capita GDP is 1189 USD and 2066 USD respectively. The cross-country developing experiences have subsequently led us to recognize that the GDP growth and human development of a nation are being treated differently. However, both the terms together constitute the development of a country. With inherent time lag in the system the composite behavior of socio-economic system of a country can be modelled by a dynamic input-output feedback system as shown in fig.5. By dynamic we mean the behavior that changes over time and the term feedback implies recycling of output such that the system keeps on evolving in a sustainable manner. This paper presents the formulation and implementation of an intelligent macroeconomic computational model for prediction and further application in developmental planning.

II. Literature survey:

Dudley Seers, the first Director of IDS, suggested to include more social-relevant measures like poverty, unemployment and inequality while defining the development of a nation [12] Development includes social and economic progress and for achieving this it requires economic growth. Scientists have attempted to model economic growth and development using machine learning. Yoon worked with gradient boosting and random forest machine learning classifier [13]. MAPE and RMSE method are taken into consideration for the purpose of measuring accuracy of the model, however, it does not consider the HDI component and hence unable to model the development properly. Gordon in his paper on "A new method of estimating potential real GDP growth: Implications for the labor market and the debt/gdp ratio " has developed a new method of calculating potential growth rate of GDP [14]. This method concludes that disharmony in rapid unemployment decline and sluggish actual output growth rate employs remarkably a slow growth rate in potential real GDP without discussing the implication on human development.

Emsia and Coskuner in his paper on" Economic Growth Prediction Using Optimized Support

Vector Machines" have developed a hybrid model for predicting economic growth using Genetic Algorithm and Support Vector machine algorithms in an optimal manner [15]. This model is successfully used to predict the GDP growth rate of Turkey. However, its implications on human development has not been considered. In fact, the economic growth process is dynamic in that the effect of resources are visible over a time period. Over the past decades, many studies [16,17] have been done dealing with modeling of GDP, however, dynamic model using machine learning has not been fully explored for modelling of national economic development. Although studies are reported but they are not dynamic. Ghiassi et al [18] have estimated public expenditure of South Africa for budgetary planning using machine learning, however it needs to explore further application of machine learning approach for predicting and planning of economic development of a country. Another work by Gharte et al [19] is able to predict the GDP growth using three supervised learning methods like gradient boosting, random forest and linear regression with satisfactory performance, however, without considering the time lag between the resource allocation and the impact on economic growth and human development. Most of the real-life systems are nonlinear in their input-output relationship [20,23]. With rapid development of neural networks and their cross-field applications data-base training has been widely used[24-26]. In the present paper multilayer neural network architecture has been used for implementation of a dynamic economic system model of developing nation with case study of India.

III. Theme of the proposed work:

In the background of the above research works, the theme of this paper is to develop an intelligent dynamic macroeconomic model of national economy in a sustainable framework. The whole development of models constitutes of three sub-models:

(i) **Dynamic Model of Economic Development**: A sequential data-based model of Indian economy is developed with agriculture and allied sectors, industry and services as inputs and GDP, GNI and LFE and MYS as outputs. This is a forward input-output model used for sequential output predictions.

(ii) **Resources Allocation Model:** This model estimates the input resources for a target output of GDP, GNI LFE and MYS as the composite vector of economic development. This is an inverse modelling exercise which learns from past data.

(iii)**Optimal Resource Planning:** In policy planning we need to find an optimal strategy in sustainable environment so as to achieve the desired output .An optimal solution is obtained by using artificial intelligence (AI) based genetic algorithm [21,22] .The result yields an optimal set of input resources given the target output of the system

IV. Economic Development System in India :

Two main constituents of economic development in developing nations are the GDP growth and the human development index.

4.1 Factors of GDP growth:

The sector wise share of GDP in India can be classified into three conventional groups as given below with the percent allocation of groups and sub-groups for year 2020-21 shown in fig 2.

(i) Primary sector (Agriculture&Allied) comprising of agriculture,forestry,fishing with a total share of 20.19% .

(ii) Secondary sector(Industry) comprising of manufacturing ,electricity,gas ,water supply,mining and quaryying with a total share of 25.92% .

(iii) Tertiary sector(Services) comprising of public administration,defence,finance , real estate, transport and communication with a total share of 53.89% .

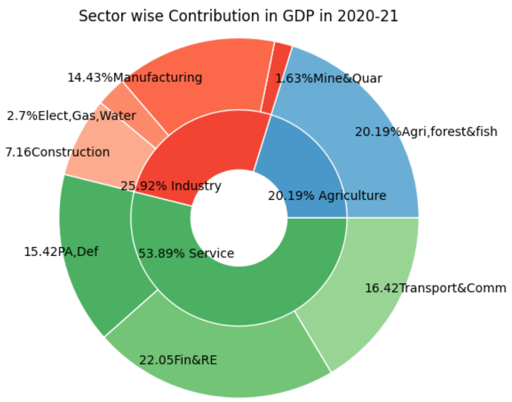


Figure 2. Share of different sectors in GDP of India for year 2020-21

Source :Ministry of Statistics and Program Implementation India,IMF World economic Outlook

[https://statisticstimes.com/economy/country/india-gdp-sectorwise]

This indicates that the service sector is the major contributor in Indian economy, industry comes next followed by agricul[redacted]ture sector. This has been the trend of these groups of sector over the years in Indian economic growth as shown in fig 3.

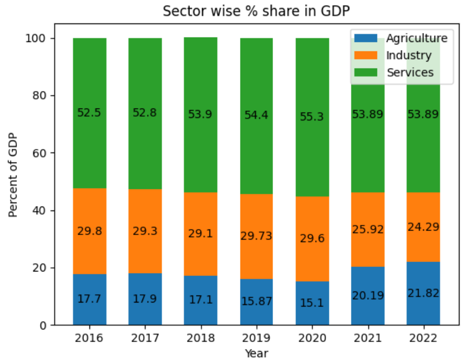


Figure 3: Trend of sector wise % share in GDP.
[Source: PIB Ministry of Finance, Govt. of India, statistics times.com]

As is evident from the above plot, among various resources agriculture, industry and services sectors have major contribution in national economy. In this paper these sectors are identified as the potential factors of economic growth in India.

4.2 Factors of human development : For a long time, a country's level of development was typically measured using economic statistics particularly the per capita gross domestic product(GDP) until UNDP in 1990 realized that GDP alone was inadequate for assessing country's overall development. This measure did not always reflect the quality of human development or the life of average citizens. When we study the economic development in a sustainable environment we should also evaluate the factors of human development such as measure of quality of life as per capita gross national income(GNI), health in terms of life expectancy (LFE) and education in terms of mean years of schooling (MYS) as parameters of sustainable goals of development. All these parameters are the components of human development index HDI ; their plots are shown in fig.4.

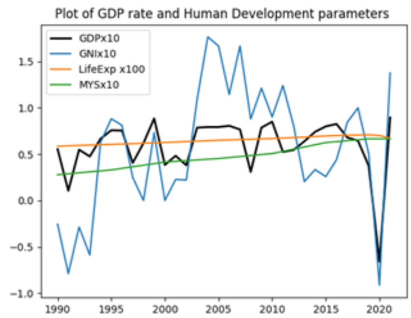


Figure 4. Plot of Human Development parameters of India[Data Source : UNDP HDR report]

.

V. Methodology of the proposed Economic Development Model:

5.1 Model Architecture: Most real-life applications involve nonlinear systems. These types of systems do not satisfy the additivity and superposition principles which make them complex to model and analyze. The model of the national economy is one such example of a real-life nonlinear system, whose modelling ever remains a challenge in identification of its structure and estimation of its parameters. In absence of an accurate structural knowledge of the system components and their interaction ,the black-box approach of system modelling is found to be operationally convenient [23] .The modelling is done based on input-output experimental data .With the rapid development of neural network methods and a trove of big data in recent years neural networks with optimized training and loss function can be used to learn the structure of the system .

A multivariate nonlinear dynamic system model is described by a graphical representation as shown in figure 5 where the state vector is dependent on its past value and the exogenous inputs. The state vector is directly measurable, and it maps to output vector with identity matrix eq.(2) .

The model is described by a difference equation as

$$X(k+1) - X(k) = ff[U(k),r(k)]$$

$$\text{or} \quad X(k+1) = fw[X(k),U(k),r(k)] \qquad \ldots \qquad \ldots \qquad [1]$$

For identity mapping, output Y(k+1) = X(k+1) … … [2]

Y(k+1) = fw[Y(k), U(k),r(k) … … [3]

r(k) is the random error term in the state model.

where k is the discrete instant of time, $X \in \Re^n$, $\mathbf{u} \in \Re^m$, $\mathbf{y} \in \Re^r$ are the state ,input and output vectors respectively . $\mathbf{f}w: \Re^n \times \Re^m \rightarrow \Re^n$ is a continuous vector valued state transition mapping function .

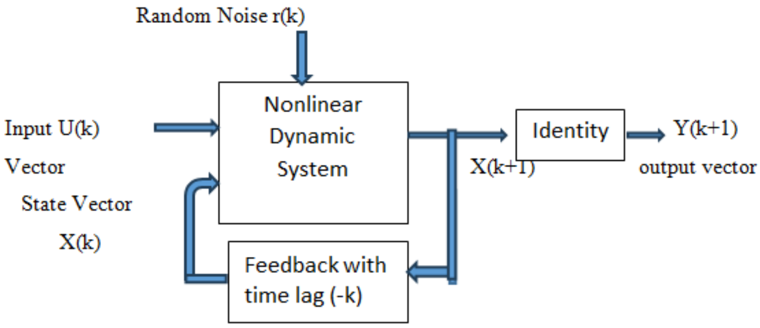


Figure. 5 Multivariable nonlinear dynamic system with state feedback

The modelling task remains to find the nonlinear function fw in eq.[1] from sequential data on input and output variables. This paper selects MIMO neural network architecture with multiple hidden layers for implementing the data-based model. The basic schematic diagram of neural network is shown below in figure(6). In absence of knowledge about exact system structure feature vector is not known . This multilayer MIMO neural network has potential for computing the feature vector from input data through hidden layers. Its architecture works better in nonlinear complex systems.

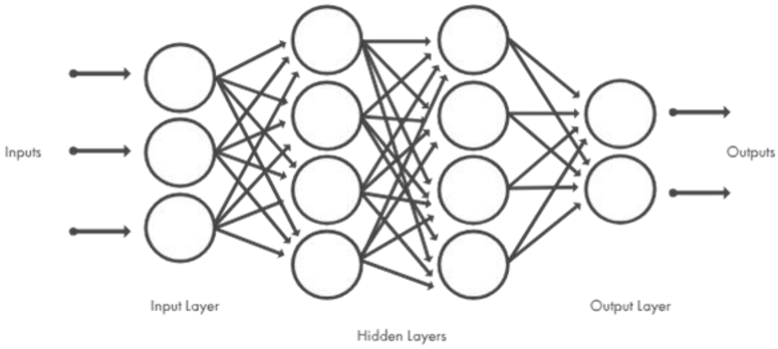


Figure6. Schematic diagram of a sequential neural network

The neural network architecture is built using sequential Keras model[6] .The modelling task can be accomplished in the following steps:

1. Define the model architecture: Sequential Keras models is selected for modelling the system. Keras is one of the most popular Python libraries which provides various tools to deal with neural network models.
2. Decide the number of hidden layers and number of nodes in the hidden layers.
3. Based on the number of class labels, assign number of neurons in the output layer.
4. Train the model with sequential data.
5. Evaluating model performance.

5.2 Model Formulation:

5.2.1 Nonlinear Dynamical System of National Economy: With input and output variables defined in equations [4,5], the black-box diagram is shown in fig.7.

The input vector U comprises of per capita growth rate in agriculture, industry and services which find significant contribution in Gross Domestic Product (GDP). The output vector Y comprises of per capita growth in GDP, per capita growth in GNI, life expectancy LFE and mean year of schooling MYS.

U = [U1, U2, U3] where U1 is the growth rate in agriculture & allied AG … …. [4]

U2 is the growth rate in Industry ID

U3 is the growth rate in Services SR

Y = [Y1 Y2 Y3 Y4] where Y1 is GDP per capita growth rate … … [5]

. Y2 is GNI per capita growth rate.

Y3 is the LFE life expectancy in years

Y4 is the mean year of schooling MYS.

Economic development is a dynamic process. The input resources U consumes time to yield the output Y. The output in return impact the economic system by way of making more investment in agriculture, industry and services through GDP and changes in the quality of human resources through GNI , LFE and MYS. This dynamic system can be described by a first order difference eq.(1) .Its graphical representation is shown in fig.7.

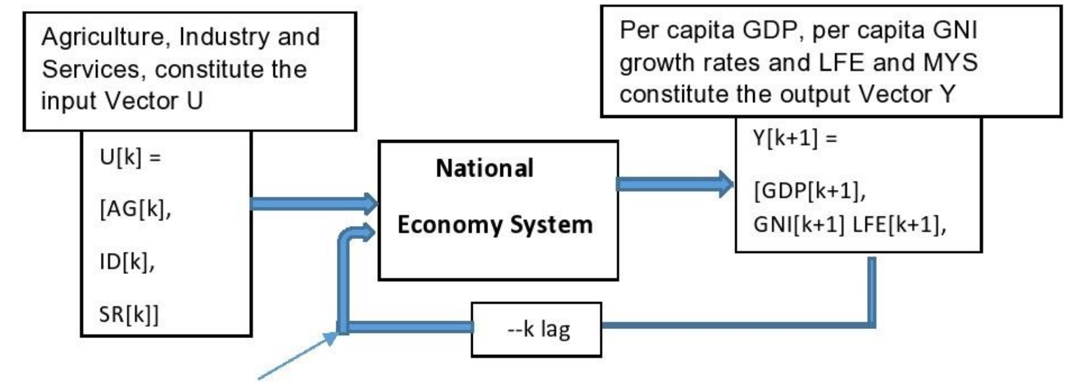


Figure 7: Dynamic economic development model

The architecture of the proposed model in based on multiple-input multiple-output (MIMO) neural network[6]. A Karas sequential algorithm is a method in artificial intelligence to find the relationship between past input and output data of a system in a layered and adaptive manner [6]. The ANN used in this work comprises of input layer ,hidden layer and output layer ; there may be one or more inter-connected hidden layers as shown in fig8.

The proposed dynamic model comprises of input layer with 7 features [AG, ID, SR, GDP, GNI, LFE, MYS] at instant k and output as [GDP[k+1], GNI[k+1], LFE[k+1], MYS[k+1]] at the next instant (k+1). The dense layers are configured as 3 hidden layers with 64 and 32 nodes and the output as 4 nodes with activation function at each node. The data-based economic system learns the state transition function using sequential data. Each of the neurons of the dense layers receives input from all neurons of the previous layer. At its core, it performs dot product of all the input values along with the weights for obtaining the output.

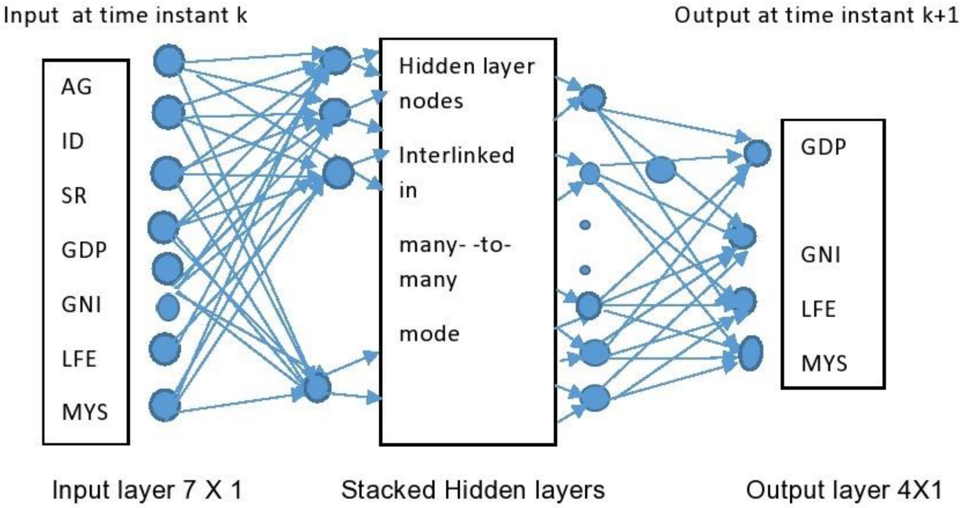


Figure 8 MIMO Neural Network Architecture

5.2.2 Resource Allocation Model: Inputs are estimated for given target output using inverse modelling [4]. Inverse Model is defined as [U(k)] = fi [Y(k+1), Y(k), q(k)] ……. ………. [6]
Where Y(k+1) is the target output vector, U(k) is the current input, Y(k) is the current output vector and q(k) is the random error. The problem is to find the input vector U(k) so as to achieve the target output Y(k+1) from the known current output Y(k). The inverse model is operationalized using MIMO neural network with Keras sequential model algorithm [6].

5.2.3 Optimal Resources Planning: Optimal resources in sustainable environment need to be estimated for a specified target. This optimization is based on a classical evolutionary algorithm called genetic algorithm [21]. GA works on a population of several solutions, each characterized by a set of features. The fitness function is the cost of achieving the target proportional to the error square shown in eq.7. The optimal solution is the one that fits the criterion. It is formulated as the problem of finding the input U by minimizing the error between the given target output and the model generated output at instant (t+1)

Minimization of (target Y(k+1) - fw [(Y(k), U(k)) **2
Subject to all U's => 0 … …. [7]

VI. Data Sources:

Statistical data on percent growth in agriculture, industry, service sector and per capita GDP in India have been collected from Ministry of Statistics and Program and Implementation [7,8] .Time-series data from 1961 to 2020-21 are plotted in fig 1.These data are used for development of economic model . Data on educational index MYS and health index LFE are collected from HDR report compiled annually by UNDP. Data are plotted over the years from 1990 to 2021 as shown in fig 4. The sector-wise GDP growth are shown in fig.[1-3] .

VII. Implementation and results:

The proposed dynamic macroeconomic development model is implemented in three steps: in the first step operationalization of the model equation [3] is accomplished using data on sector wise share of GDP in India collected from Project and Implementation Ministry, from year 1961 to 2021.The sector wise time-series data are plotted as shown in fig 1 . Human development data are plotted in fig4.

The model in implemented using keras sequential model configured with 4 dense layers or hidden layers ,the input layer with 7 inputs nodes and the output layer with 4 nodes .The summary result of keras model is shown below .

The summary of the sequential neural network using Keras library in Python is given below:

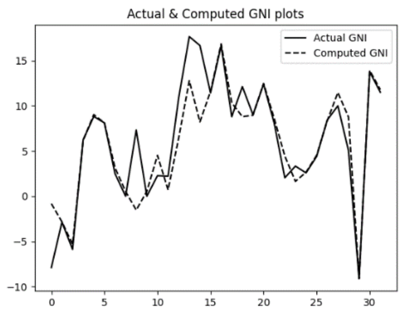
Model summary:

Python libraries used:
from tensor flow. keras import layers, models.
from keras. Layers import Dense
from sklearn. model_selection import train_test_split
from sklearn.metrics import mean_squared_error
from keras.models import Sequential ,model_from_json
Model configuration:
Model: "sequential"

Layer (type)	Output Shape	Param
dense (Dense)	(None, 64)	512
dense_1 (Dense)	(None, 32)	2080
dense_2 (Dense)	(None, 16)	528
dense_3 (Dense)	(None, 4)	68
flatten (Flatten)	(None, 4)	0

Total params: 3,188
Trainable params: 3,188
Non-trainable params: 0

Step 1. The model is trained for 10000 iterations and the result after validation is shown in plots in[fig9a,9b,9c,9d].The plots of root mean square error ,loss and accuracy are shown in fig.7e.The converged value of accuracy is 95% which is very satisfactory.



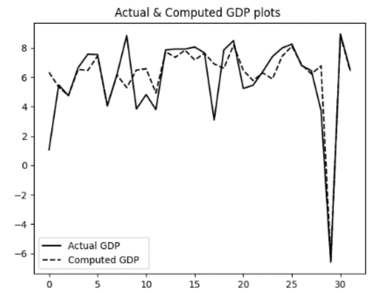
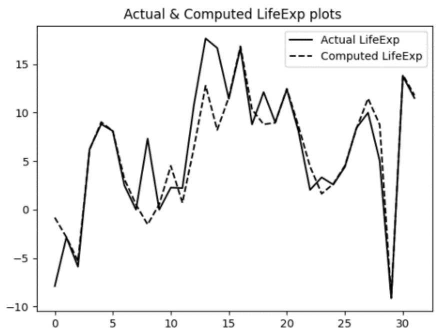


Fig9a GDP plot in forward model **Fig9b GNI plot in forward model**



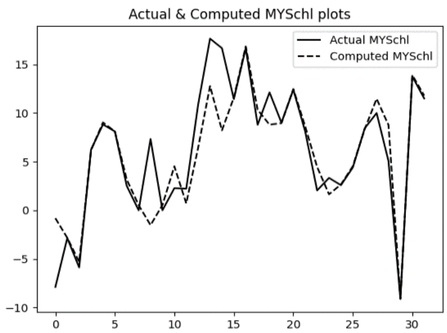
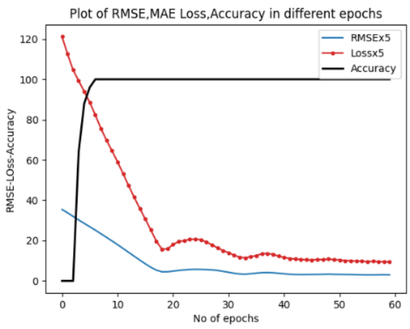


Fig9c Life Expectancy plot in forward model **Fig9d Mean Year in schooling in forward model**



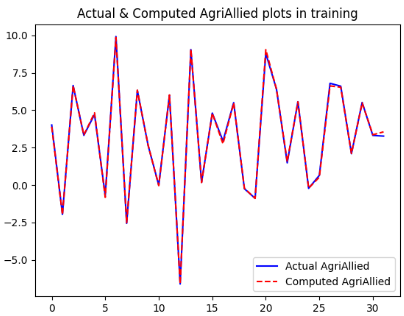


Fig. 9e RMSE,Loss,Accuracy in forward model **Fig.10a AgriAllied Plots in inverse model**

Step2. The second part of this work is the resource allocation model formulated using eq.(6). and implemented using keras sequential model based on the past data .

Configuration of Keras sequential model is:

```
model = Sequential()
model.add(Dense(28,input_dim=n_inputs,kernel_initializer='he_uniform',activation='sigmoid'))
model.add(Dense(14, activation='sigmoid'))
model.add(Dense(n_outputs, kernel_initializer='he_uniform'))
model.add(layers.Flatten())
```

.The graphical results of model training are shown in figure 10a,10b,10c with plots of actual and computed output .

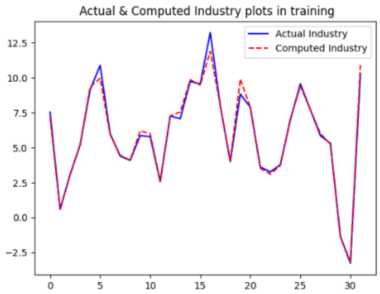


Fig.10b Industry plots in inverse model

Fig10c Service sector plot in inverse model

Fig.10d Loss and accuracy in inverse model

Step 3. The next part of this work is formulated as an optimization problem in which the objective function is to estimate the model inputs in equation [1], while maximizing the fitness function for a specified target output set forth by planners for future years. The constraints are the non-negative input variables. The genetic algorithm in Python is used for optimal resources planning [20,21] . The computational results obtained for two sample cases are:

(i) For achieving the target of 10% rise in GDP growth,5% rise in GNI , 2% rise in LFE and 2% rise in MYS from base year 2021,the optimal solution obtained for inputs is 2.72% rise in Agri&Allied ,12.98% rise in Industry and 3.21% rise in Service sector .This requires proportional investment in these input sectors .

(ii) For achieving the target of 15% rise in GDP growth,10% rise in GNI , 2% rise in LFE and 2% rise in MYS from base year 2021,the optimal solution obtained is 1.05% rise in Agri&Allied ,13.50% rise in Industry and 2.31% rise in Service sector .This requires proportional investment in these input sectors .

The optimization model is operationalized satisfactorily using genetic algorithm.

VIII. Conclusion:

This paper successfully presents the development of an artificial intelligence-based methodology for developing a dynamic macro-economic model for developing nation like India. The work demonstrates how economic growth and human development together contribute to a country's development in a sustainable manner. The accuracy of dynamic models is quite satisfactory at 95% in model building. The methodology explores a quantitative approach to optimal allocation of resources for achieving an assigned target of economic growth as GDP, together with human development components as LFE and MYS. The present work successfully demonstrates how genetic algorithms of artificial intelligence could be used for optimal planning of resources. This is a contribution in the field of computational approach to economic study and policy making. This dynamic macroeconomic model may be useful in predicting and planning economic development with specified sustainable goals.

References:

[1]. Amartya Sen," Development as Freedom",1999
[2]. Dereze Jean and Amartya Sen ,"Economic Development and Social opportunity",1995
[3]. Human Development Index @ https://hdr.undp.org/data-center/human-development-index#/indicies/HDI
[4]. Haykin Simon," Neural Network :A Comprehensive Foundation",Pearson Education, Asia,2001
[5]. Niloy Purkait , "Hands-On Neural Networks with Keras " ,Packt publishing,2019
[6]. Albert Tarantola 2005," Inverse Problem Theory" Siam Publications
[7]. NitiAayog ,Govt. Of India https://ndap.niti.gov.in/
[8]. Sectorwise GDP : https://statisticstimes.com/economy/country/india-gdp-sectorwise.
[9]. Statistical data from Statistics and Program Implementation , Gov. of India
[10]. Human Development Report 2021/2022 by UNDP .
[11]. Eyal Wirsansky ,"Hands-on Genetic Algorithm with Python",Packt publishing ,2020

[12]. Seers, D. The Meaning of Development, IDS Communication 44, Brighton, UK: Institute of Development Studies. (1967)

[13]. Jaehyun Yoon ," Forecasting of Real GDP Growth Using Machine Learning Models: Gradient Boosting and Random Forest Approach" **.**

[14]. Robert J. Gordon ," A new method of estimating potential real GDP growth: Implications for the labour market and the debt/gdp ration ", National bureau of Economic research ,1050 Massachusetts Avenue Cambridge, MA 02138 August 2014

[15]. Emsia and Coskuner ," Economic Growth Prediction Using Optimized Support Vector Machines", Computational Economics ,2016. Springer Science

[16]. Pawar, Pradnya & Padmawar, Vaishnavi & Karande, Akshit. " Gross Domestic Product Prediction using Machine Learning." 08. 2395-0056.July 2021

[17]. Alamsyah, A. and Permana, M. (2018)." Artificial Neural Network for Predicting Indonesian Economic Growth Using Macroeconomics Indicators", 2018 International Symposium on Advanced Intelligent Informatics (SAIN), Yogyakarta, Indonesia, 22-23 August, pp. 15–19. IEEE Xplore. doi: 10.1109/SAIN.2018.8673347

[18]. Manoochehr Ghiassi and Beatrice D. Simo-Kengne " Machine Learning for Economic Modeling: An Application to South Africa's Public Expenditures". International Journal of Public Administration in the Digital Age (IJPADA) 8(1).2021

[19]. Tanvi Gharte, Himani Patil, Soniya Gawade. GDP Prediction and Forecasting using Machine Learning. International Research Journal of Engineering and Technology (IRJET) Volume: 09 Issue: 04. Apr 2022.

[20]. Jaroslava Žilková, Jaroslav Timko, Peter Girovsk**ý "**Nonlinear System Control using Neural Networks",Acta Polytechnica Hungarica ,chap 2 ,equation 1 ,vol 3 ,No 4 ,2006

[21]. Gregory J.E. Rawlins , "Foundations of Genetic Algorithms 1991 "

[22]. Kevin Wayne ,"Algorithms" ,Addison-Wesley Professional , 2011

[23]. Octavio Loyola-Gonzalez "Black-Box vs. White-Box: Understanding Their Advantages and Weaknesses From a Practical Point of View" ,IEEE Access , November 1, 2019.

[24]. Leondes T. Cornelius (Edited by), "Control and Dynamic Systems ",vol 7 of Neural Network Systems ,Techniques and Applications ,Academic Press,1998.

[25]. Ali, Z.; Hussain, I.; Faisal, M.; Nazir, H.M.; Hussain, T.; Shad, M.Y.; Shoukry, A.M.; Gani, S.H. Forecasting Drought Using Multilayer Perceptron Artificial Neural Network Model. Adv. Meteorol. **2017**, 2017, 5681308.

[26]. Soh, Y.; Koo, C.; Huang, Y.; Fung, K. Application of artificial intelligence models for the prediction of standardized precipitation evapotranspiration index (SPEI) at Langat River Basin, Malaysia. Comput. Electron. Agric. **2018**, 144, 164–173.

[27]. Farajzadeh, J.; Fard, A.F.; Lotfi, S. Modeling of monthly rainfall and runoff of Urmia lake basin using "feed-forward neural network" and "time series analysis" model. Water Resour. Ind. **2014**, 7–8, 38–48