Neural Computing and Applications (2023) 35:7207–7220
https://doi.org/10.1007/s00521-021-06412-w

S.I. : NEURO, FUZZY AND THEIR HYBRIDIZATION

ANFIS for prediction of epidemic peak and infected cases for COVID-19 in India

Rajagopal Kumar[1] · Fadi Al-Turjman[2] · L. N. B. Srinivas[3] · M. Braveen[4] · Jothilakshmi Ramakrishnan[5]

Received: 27 February 2021 / Accepted: 17 August 2021 / Published online: 21 September 2021

Abstract

Corona Virus Disease 2019 (COVID-19) is a continuing extensive incident globally affecting several million people's health and sometimes leading to death. The outbreak prediction and making cautious steps is the only way to prevent the spread of COVID-19. This paper presents an Adaptive Neuro-fuzzy Inference System (ANFIS)-based machine learning technique to predict the possible outbreak in India. The proposed ANFIS-based prediction system tracks the growth of epidemic based on the previous data sets fetched from cloud computing. The proposed ANFIS technique predicts the epidemic peak and COVID-19 infected cases through the cloud data sets. The ANFIS is chosen for this study as it has both numerical and linguistic knowledge, and also has ability to classify data and identify patterns. The proposed technique not only predicts the outbreak but also tracks the disease and suggests a measurable policy to manage the COVID-19 epidemic. The obtained prediction shows that the proposed technique very effectively tracks the growth of the COVID-19 epidemic. The result shows the growth of infection rate decreases at end of 2020 and also has delay epidemic peak by 40–60 days. The prediction result using the proposed ANFIS technique shows a low Mean Square Error (MSE) of 1.184×10^{-3} with an accuracy of 86%. The study provides important information for public health providers and the government to control the COVID-19 epidemic.

Keywords Corona-virus disease 19 (COVID-19) · Edge artificial intelligence · Machine learning · Cloud data

✉ Rajagopal Kumar
rajagopal.kumar@nitnagaland.ac.in

Fadi Al-Turjman
fadi.alturjman@neu.edu.tr

L. N. B. Srinivas
srinival@srmist.edu.in

M. Braveen
Braveenmani@hotmail.com

Jothilakshmi Ramakrishnan
jothilakshmiphd@gmail.com

1 Department of Electronics and Instrumentation Engineering, National Institute of Technology, Chumkedima, Dimapur, Nagaland 797103, India

2 Artificial Intelligence Engineering Department, Research Centre for AI and IoT, Near East University, Nicosia, Mersin 10, Turkey

3 Department of Information Technology, School of Computing, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur, Chennai 603203, India

4 Department Computer Science Engineering, VIT, Chennai 600127, India

5 Department of Mathematics, Mazharul Uloom College, Ambur, India

1 Introduction

The pandemic Corona-Virus Disease 19 (COVID-19) is one of the major problems faced by the world today. COVID-19 is a harmful infectious disease that spreads from human to human affecting the human lungs and causing Severe Acute Respiratory Syndrome (SARS) and sometimes leads to death [1]. COVID-19 pandemic initially started from Wuhan, Hubei province in China in December 2019. The deadly disease COVID-19 has been named after the disease Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which emerged in 2002 [2]. Later knowing the severity of the COVID-19 disease, the World Health Organization (WHO) declared the widespread of COVID-19 as an emergency pandemic throughout the world [3]. As of June 4, 2020, there have been 62,87,771 confirmed cases, with 3,79,941 mortality cases reported globally. Many nations have declared it a national emergency to avoid the spread of COVID-19 and prescribed lockdown for containment of COVID-19 [4]. Several researchers have identified that COVID-19 mortality is caused due to cytokine storms [5]. As of today, there is no exact medicine for COVID-19. The medicine found for a similar virus has been utilized as a treatment against COVID-19 based on clinical trials [6]. Hence, there is no medicine or particular treatment for curing COVID-19, prevention is the only possible cure, and the prevention is more effective by predicting the spread of COVID-19 [7, 8].

Several kinds of research have been conducted to study the spread of COVID-19 using an Artificial Intelligence (AI) technique. In which, the study uses past data, and the region is mathematically analyzed to predict the future spread of COVID-19. In [9], Machine Learning (ML) technique has been developed to handle past data and predict the spread of COVID-19. In [10], cloud computing and AI-based methodology have been developed to process the health care system. AI-based Computed Tomography (CT) scan for predicting COVID-19 has been developed to monitor the conditions of COVID-19 patients [11]. Alibaba has developed AI-based methodology to predict the COVID-19 spread over China; the analysis shows 98% accuracy in real-time testing in China [12]. An AI-based system has been developed to identify the appropriate vaccines for patients [13]. The developed system also accelerates the quick heal based on genome sequences. Machine learning and cloud-based techniques have been developed to predict the growth of COVID-19 pandemic [14]. In [15], developed an AI tool to detect COVID-19 patients using the thermal sensor of the mobile phone. AI-based early detection of high-risk COVID-19 patients has been developed [16]. The developed tool uses an AI tool complained of scan images of the patients to identify the risk factor. An improved Adaptive Neuro-Fuzzy Inference System tool has been proposed to accelerate the prediction based on the different regions [17]. A regression model has been developed to estimate the growth of COVID-19 infection based on the rate of growth of cases outside China [18]. Rohit Salgotra et al.[19] proposed a prediction model using genetic programming (GP) and the prescribed model developed confirmed cases (CC) and death cases (DC) among three states such as Maharashtra, Gujarat, and Delhi with entire India. Grinberga-Zalite et al. [20] discuss the flexibility to meet out the food requirements during and after COVID-19 crisis. Intissar et al. [21] propose a mathematical assessment for the COVID-19 using SEIR model. Rasheed et al. [22] proposed a mathematical approach in determination of temperature variation between two factors which is needful for COVID-19 pandemic. Agarwal et al. [23] proposed in-silica analyses and reverse vaccinology technique for the development of COVID-19 vaccination.

The improvement in an expert system made the prediction accurate based on the past data. The expert system comprises fuzzy logic and artificial neural network systems. Adaptive Neuro-fuzzy Inference System (ANFIS) is the combination of fuzzy logic and artificial neural network. ANFIS has a higher application with accurate prediction [20]. Chronic kidney disease (CKD) diagnosis and prediction in early-stage using ANFIS have been developed [21]. The method uses a Takagi–Sugeno type ANFIS model to predict the Glomerular Filtration Rate (GFR) values as the biological marker of renal failure. ANFIS-based heart disease classification and prediction of suitable medicine have been developed [22]. The developed model has proved 92.30% forecast in the patient's heart disease degree. A Healthcare monitoring system to classify Cardiovascular and respiratory diseases using ANFIS has been developed [23]. Hence, the rule formation is simple and has higher accuracy; ANFIS can be used for predicting a profound epidemic disaster. Kumar et al. [24] discuss the machine learning algorithm for COVID-19 estimation for lung infected patients. Jeon et al. [25] developed an LQR controller based on fuzzy logic for wind turbines. In this study, a fuzzy-based system has been used to control the performance of the wind turbine. Riahi-Madvar et al. [26] have proposed an improved technique for predicting pollutant dispersion coefficient in rivers. Nabipour et al. [27] have developed ANFIS model to estimate climate change on wind power generation system. Baghban et al. [28] have developed ANFIS-based Swarm Concept Model for Estimating Relative Viscosity of Nanofluids. Soft computing techniques are getting popular for their widespread applications in various filed [29, 30].

In this paper, a profound analysis is carried out in India to predict the possible COVID-19 outbreak using Adaptive Neuro-fuzzy Inference System (ANFIS)-based machine learning technique. Generally, Machine learning models are deployed for feature prediction that involves risk and also for epidemic analysis [24]. The country India has been chosen in this analysis as the COVID-19 cases get rapidly increases across the states of India and have a higher population rate. Predicting the spread of COVID-19 at the right time could help the government to prevent the spread of COVID-19 and would save thousands of souls. The proposed ANFIS-based prediction system tracks the growth of epidemic based on the previous data sets fetched from cloud computing. The proposed technique not only predicts the outbreak but also tracks the disease and suggests a measurable policy to manage the COVID-19 epidemic. The obtained prediction shows that the proposed technique very effectively tracks the growth of the COVID-19 epidemic. The ANFIS is chosen for this study as it has both numerical and linguistic knowledge, and also has ability to classify data and identify patterns. The proposed technique not only predicts the outbreak but also tracks the disease and suggests a measurable policy to manage the COVID-19 epidemic. The obtained prediction shows that the proposed technique very effectively tracks the growth of the COVID-19 epidemic. The result shows the growth of infection rate decreases at the end of 2020 and also has delay epidemic peak by 40–60 days. The prediction result using the proposed ANFIS technique shows a low Mean Square Error (MSE) of 1.184 × 10–3 with an accuracy of 86%. The study provides important information for public health providers and the government to control the COVID-19 epidemic. The paper is organized as follows, Materials and methods with data preprocessing have been discussed in Sect. 2, Proposed ANFIS prediction technique and the developed ANFIS architecture is given in Sect. 3, Sect. 4 discusses the result, and Sect. 5 concludes the proposed research.

2 Materials and methods

In this study, the data set has been created by combining the data collected for COVID-19 for India through cloud computing and local data collected based on population, active cases, lockdown status, and previous medical records. Meanwhile, from the dataset, the data are being separated as a training dataset and testing dataset. Further, the training data has been classified as error data, change in error data, and predictable data. The classified dataset is given as input to the ANFIS-based AI technique. The block diagram of the developed prediction using ANFIS technique is shown in Fig. 1. ANFIS has been selected in this study because the complexity of decision-making is less with simple if-then rules and has high accuracy in prediction [17, 31, 32]. In this study, the Takagi–Sugeno model has been developed to predict the spread of COVID-19 for India. India has been chosen because India is the second-largest populated country, and recent research indicates that COVID-19 spreads rapidly across India. Through the analysis, a suitable solution can be formed and can prevent the spread of COVID-19 [33, 34].

2.1 Data collection and processing

The data collected for the assessment has been listed in Tables 1 and 2

The COVID-19 data sets for India, fetched from the cloud, are listed in Table 1 from the date of the pandemic. As of June 5, 2020, 2,36,621 cases with 6,621 deaths have been reported in India for COVID-19. Furthermore, for the assessment, a separate dataset has been identified based on total population, population density, age factor, CVD and diabetes patients, smokers, transport usage, and health care facilities as local data. The details of the local data set have been listed in Table 2, collected from the local corporation, and the Ministry of Health and Family Welfare, Government of India. The data sets are combined based on time, and a new dataset is created for assessment.

The new dataset is given as input to the ANFIS AI technique. The process for the prediction is shown in Fig. 2. The input dataset has been modified based on time, and the data has been split into training data and testing data. Among that train, data is initialized for clustering, and the parameter setting has been done. In the parameters set, the iteration count, limits, population, and the objective function are fed. The ANFIS completed its training when it reached its maximum iteration or when it reaches the objective function [35–37]. The training dataset has been used for performance evaluation with the test dataset. The new predicted dataset has been finally obtained as the output from the ANFIS system.

3 Developed anfis technique to predict COVID-19

The ANFIS controller has been trained using back-propagation methodology through the least-square estimation method. Figure 3 depicts the architecture of the developed ANFIS, which consists of two inputs and one output. The developed ANFIS model is to make rapid decisions and to predict the spread of COVID-19 cases in India. The developed ANFIS has two inputs; they are COVID-19 data and local data. The spread estimation is the output. In the developed prediction model, the ANFIS first-order Sugeno

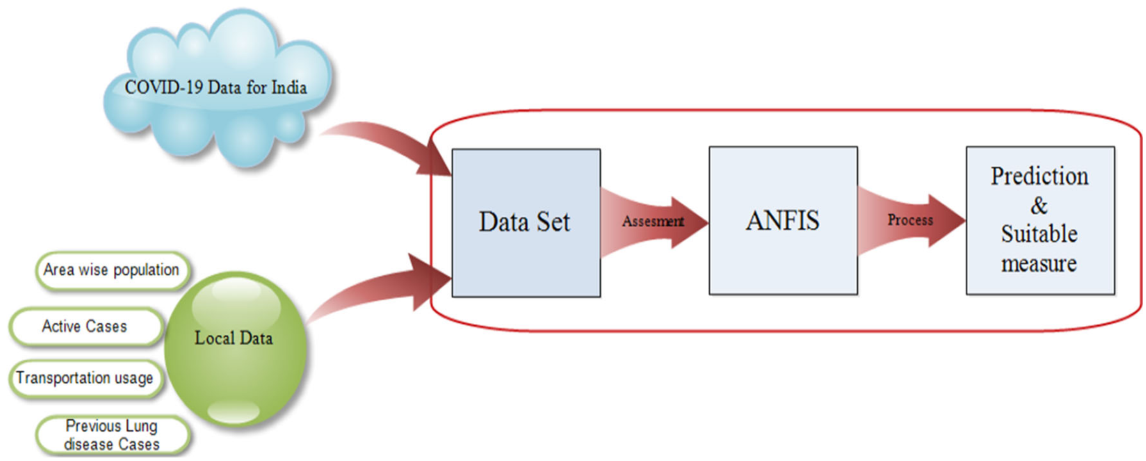

Fig. 1 The architecture of the proposed COVID-19 prediction using ANFIS

model as well with fuzzy IF-THEN rules of Takagi and Sugeno type has been used [17, 38, 39]. If x is A and y is C then,

$$f_1 = p_1 x + q_1 y + r_1 \quad (1)$$

3.1 Training the ANFIS controller

The ANFIS model consists of five layers, as shown in Fig. 3. The architecture of the developed ANFIS system is shown in Fig. 4. The layers of the training functions are described as follows,

3.1.1 First layer

This layer consists of two input nodes, input 1 and input 2 as variables (MFs). This layer transforms the input values x & y to the next layer, and every node in this layer is considered as an adaptive node where e1 and e2 are the error function fed to node i to separate linguistic variable Ai (i.e., A1, A2, A3, A4, A5, A6, A7, A8, and A9) and Bi (i.e., B1, B2, B3, B4, B5, B6, B7, B8, and B9) as the input. The input is linked with this node function, and Oi is the output layer of layer 1. Here nine trapezoidal Membership Functions (MF) with maximum = 1 and minimum = 0 has been used, and the mathematical function is given as,

$$O_i^1 = \mu A_i(e_i) \quad (2)$$

where i = 1, 2…9.

3.1.2 Second layer

In this layer, the input variable received from layer 1 undergoes weight updation for the membership function and acts as fuzzy sets. The nodes of the second layer are non-adaptive [40.41]. The function of this layer is to multiply the layer 1 signals and to give the output product. The mathematical expression is given as,

$$w_j = \mu A_i(e_1) \times \mu B_i(e_2) \quad (3)$$

where i = 1, 2…9 and j = 1, 2…81. The output of this layer signifies the rule strength.

3.1.3 Third layer

In this layer, the neurons in each node undergo identical conditioning using the fuzzy rules. The computation is carried out relating the layers in the node with the fuzzy rules set. Weights are being calculated for every node in this layer, and this layer is non-adaptive. Each node calculates the weight based on the rules to strengthen. It is based on the weights in node to the ratio of weights of the rules. The mathematical function is given as,

$$w_j^* = \frac{w_j}{w_1 + w_2 \ldots w_{81}} \quad (4)$$

where j = 1, 2… 81. The outputs of this layer are normalized firing strengths.

3.1.4 Fourth layer

This layer is a defuzzification layer; and provides the output values that undergone fuzzy rules. The nodes of this layer are adaptive, and mathematical function is given as,

$$O_j^4 = w_j^* f_j = w_j^* (p_j e_1 + q_j e_2 + r_j) \quad (5)$$

The rule base is given as,

If e1 is A1 and e2 is B1 then f1 = p1e1 + q1e2 + r1.

If e1 is A2 and e2 is B2 then f2 = p1e1 + q2e2 + r2.

.

.

.

Table 1 COVID-19 dataset for India

Date	Total cases	Total deaths	Total cases per million	Total deaths per million
2020-01-30	2	0	0.002	0
2020-01-31	1	0	0.001	0
2020-02-01	1	0	0.001	0
2020-02-02	3	0	0.002	0
2020-02-03	2	0	0.001	0
2020-02-04	4	0	0.003	0
2020-02-05	3	0	0.002	0
2020-02-06	3	0	0.002	0
2020-02-07	3	0	0.002	0
2020-02-08	3	0	0.002	0
2020-02-09	3	0	0.002	0
2020-02-10	3	0	0.002	0
2020-02-11	3	0	0.002	0
2020-02-12	3	0	0.002	0
2020-02-13	3	0	0.002	0
2020-02-14	3	0	0.002	0
2020-02-15	3	0	0.002	0
2020-02-16	3	0	0.002	0
2020-02-17	3	0	0.002	0
2020-02-18	3	0	0.002	0
2020-02-19	3	0	0.002	0
2020-02-20	3	0	0.002	0
2020-02-21	3	0	0.002	0
2020-02-22	3	0	0.002	0
2020-02-23	3	0	0.002	0
2020-02-24	3	0	0.002	0
2020-02-25	3	0	0.002	0
2020-02-26	3	0	0.002	0
2020-02-27	3	0	0.002	0
2020-02-28	3	0	0.002	0
2020-02-29	3	0	0.002	0
2020-03-01	3	0	0.002	0
2020-03-02	3	0	0.002	0
2020-03-03	7	0	0.005	0
2020-03-04	7	0	0.005	0
2020-03-05	50	0	0.036	0
2020-03-06	30	0	0.022	0
2020-03-07	33	0	0.023	0
2020-03-08	37	0	0.027	0
2020-03-10	54	0	0.039	0
2020-03-11	56	0	0.04	0
2020-03-12	96	0	0.07	0
2020-03-13	77	2	0.055	0.002
2020-03-14	91	3	0.066	0.002
2020-03-15	97	2	0.07	0.001
2020-03-16	96	2	0.069	0.001
2020-03-17	157	4	0.114	0.003
2020-03-18	149	3	0.108	0.002

Table 1 (continued)

Date	Total cases	Total deaths	Total cases per million	Total deaths per million
2020-03-19	193	3	0.14	0.002
2020-03-20	217	5	0.157	0.004
2020-03-21	271	4	0.196	0.003
2020-03-22	409	4	0.296	0.003
2020-03-23	558	10	0.404	0.007
2020-03-24	545	11	0.395	0.008
2020-03-25	632	9	0.458	0.007
2020-03-26	736	17	0.533	0.012
2020-03-27	799	21	0.579	0.015
2020-03-28	1022	21	0.741	0.015
2020-03-29	1085	31	0.786	0.022
2020-03-30	1163	33	0.843	0.024
2020-03-31	1431	35	1.037	0.025
2020-04-01	1543	38	1.118	0.027
2020-04-02	2533	65	1.836	0.047
2020-04-03	2637	62	1.91	0.045
2020-04-04	3503	80	2.539	0.058
2020-04-05	3846	86	2.787	0.063
2020-04-06	4760	141	3.449	0.102
2020-04-07	4775	119	3.461	0.087
2020-04-08	5967	184	4.324	0.133
2020-04-09	6274	183	4.546	0.132
2020-04-10	7090	232	5.137	0.168
2020-04-11	8482	279	6.146	0.202
2020-04-12	9265	307	6.714	0.223
2020-04-13	9948	343	7.209	0.248
2020-04-14	11,574	370	8.387	0.268
2020-04-15	12,513	415	9.067	0.301
2020-04-16	13,322	451	9.654	0.327
2020-04-17	14,394	460	10.431	0.334
2020-04-18	15,369	523	11.137	0.379
2020-04-19	17,046	534	12.352	0.387
2020-04-20	18,818	579	13.636	0.419
2020-04-21	19,935	637	14.445	0.462
2020-04-22	21,368	690	15.484	0.5
2020-04-23	22,802	722	16.523	0.523
2020-04-24	24,761	755	17.942	0.547
2020-04-25	25,935	832	18.794	0.603
2020-04-26	28,486	873	20.642	0.633
2020-04-27	29,288	920	21.224	0.667
2020-04-28	30,978	996	22.448	0.722
2020-04-29	33,229	1080	24.079	0.783
2020-04-30	34,768	1141	25.194	0.827
2020-05-01	37,036	1220	26.837	0.884
2020-05-02	39,629	1289	28.717	0.934
2020-05-03	42,624	1384	30.887	1.003
2020-05-04	45,086	1445	32.671	1.047
2020-05-05	50,333	1763	36.473	1.277

Table 1 (continued)

Date	Total cases	Total deaths	Total cases per million	Total deaths per million
2020-05-06	52,349	1820	37.933	1.319
2020-05-07	56,513	1872	40.951	1.356
2020-05-08	59,732	1989	43.284	1.442
2020-05-09	62,982	2076	45.639	1.505
2020-05-10	66,216	2237	47.983	1.621
2020-05-11	71,365	2303	51.714	1.669
2020-05-12	74,360	2380	53.884	1.725
2020-05-13	77,806	2537	56.381	1.838
2020-05-14	81,725	2683	59.221	1.944
2020-05-15	85,937	2749	62.273	1.992
2020-05-16	89,910	2855	65.152	2.069
2020-05-17	95,914	2992	69.503	2.168
2020-05-18	101,411	3186	73.486	2.309
2020-05-19	106,109	3297	76.89	2.389
2020-05-20	112,361	3443	81.421	2.494
2020-05-21	117,968	3567	85.483	2.585
2020-05-22	124,535	3731	90.243	2.703
2020-05-23	131,755	3857	95.475	2.795
2020-05-24	138,635	4014	100.46	2.909
2020-05-25	145,822	4175	105.668	3.026
2020-05-26	151,915	4313	110.082	3.126
2020-05-27	158,154	4507	114.604	3.266
2020-05-28	164,899	4725	119.492	3.424
2020-05-29	173,265	4881	125.554	3.537
2020-05-30	181,727	5236	131.686	3.794
2020-05-31	190,523	5357	138.059	3.882
2020-06-01	198,927	5624	144.149	4.076
2020-06-02	206,877	5802	149.91	4.205
2020-06-03	216,524	6032	156.901	4.371
2020-06-04	226,223	6335	163.929	4.59
2020-06-05	236,621	6621	171.464	4.798

Table 2 Local dataset for India

Data	Parameters
Population	1,38,00,04,385
Population_Density	450.419 sq km
Median_age	28.2%
Aged- 65_old	5.989%
Aged_70_older	3.414%
Cardiovascular Disease (CVD)_Patients	28.28%
Diabetes_prevalence	10.39%
Female_smokers	1.9%
Male_smokers	20.6%
Public transport usage	42.3%
Handwashing_facilities	59.55%
Hospital_beds_per_thousand	0.53%

If e1 is A9 and e2 is B1 then f81 = p81e1 + q81e2 + r81.

where O4j is the layer-4 output, pj, qj, r are the parameter set in layer-4, Ai and Bi are the fuzzy membership function.

3.1.5 Fifth layer

The fifth layer is the output layer in the ANFIS system. The function of the fifth layer is, to sum up, all the inputs processed by layer-4. This layer also transforms fuzzy results into binary form. The node in this layer is non-adaptive, and the single node computes overall incoming signal to form a summation output. The mathematical function is given as,

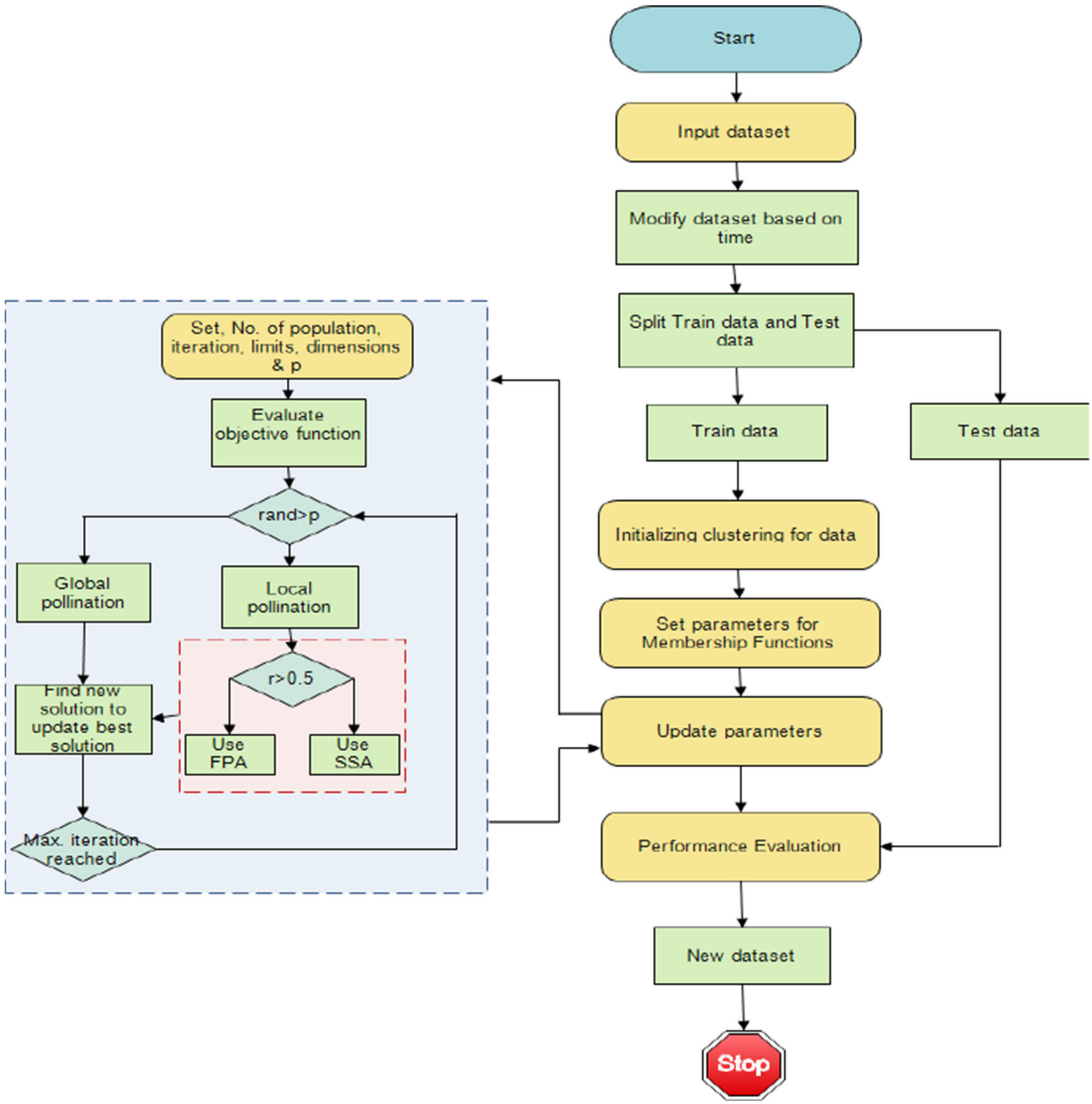

Fig. 2 Flow chart of the proposed ANFIS

$$y = \sum_{j=1}^{81} w_j^* f_j = \sum_{j=1}^{81} ((w_j^* e_1)p_j + (w_j^* e_2)q_j + (w_j^*)r_j) \quad (6)$$

The above training indicates that e1 and e2 have a significant impact on output prediction. A hybrid fuzzy and neural network-based intelligent technique has been applied to develop ANFIS architecture. The ANFIS analysis the parameter, in feed-forward propagation the function signals moves forward till layer-4, and appropriate parameters are estimated using the least-square technique. In back-propagation, the error rate propagates backward, and the weight of the layers is updated using the gradient descent algorithm. In the developed model, the ANFIS consists of 81 rules with 9 membership functions to the input variable. Moreover, the training data used for training is 600, and testing data used are 600. The surface view obtained for the developed ANFIS technique is shown in Fig. 5. The Figure shows the 3-D view, which displays the variation of the output for the corresponding input. The developed ANFIS estimates the COVID-19 across India.

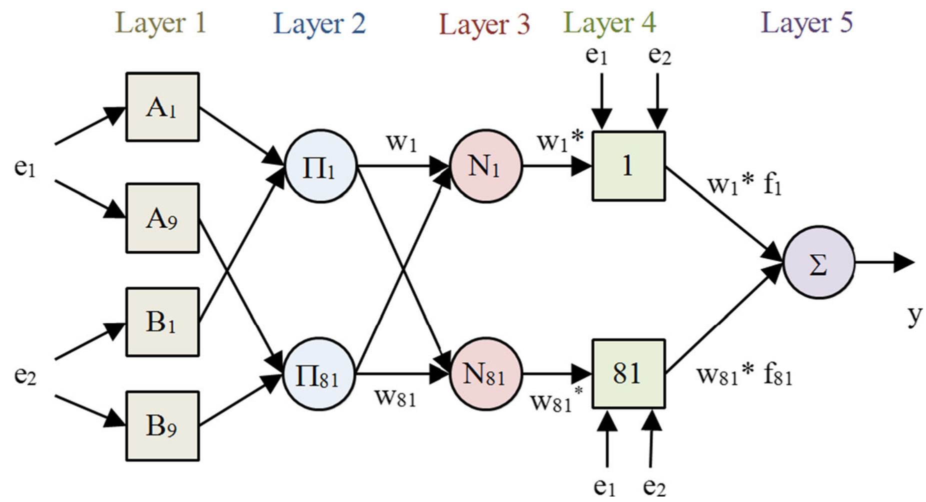

Fig. 3 Structure of the ANFIS controller

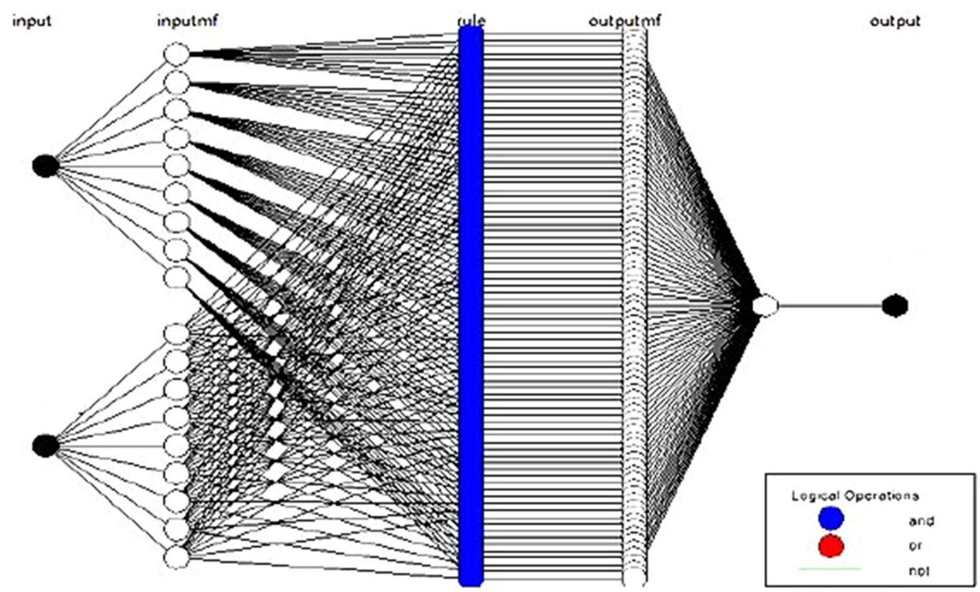

Fig. 4 Architecture of developed ANFIS controller

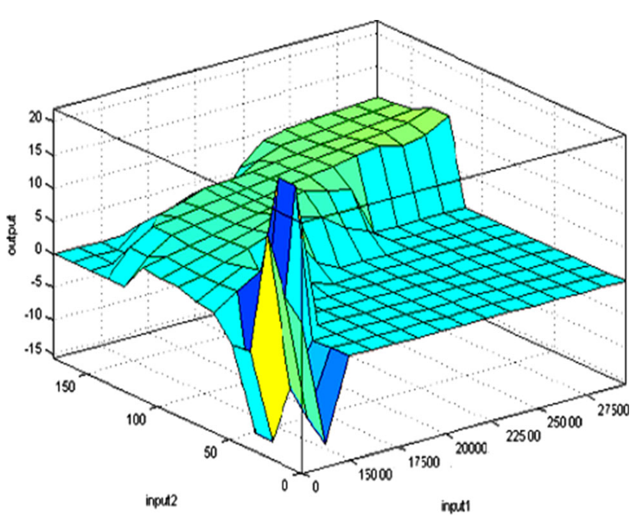

Fig. 5 Surface diagram of the ANFIS prediction controller

4 Results and discussion

An analysis has been carried out to predict the Spread of COVID-19 using ANFIS tool in MATLAB and Google AI. In the analysis, to prove the performance of the proposed ANFIS-based methodology, the proposed technique has been compared with the Multiple Linear Regression (MLR)-based prediction technique. Figure 6 shows the COVID-19 cases in India. From the Figure, it can be seen that the cases increase linearly. Figure 7 shows the COVID-19 mortality cases in India. The mortality cases are increasing day-to-day. The lockdown was implemented on March 22, 2020, and later restrictions in the lockdown were removed due to economic impact on May 3, 2020. From Figs. 6 and 7, it can be observed that the COVID cases get increase later with the liberation given in lockdown.

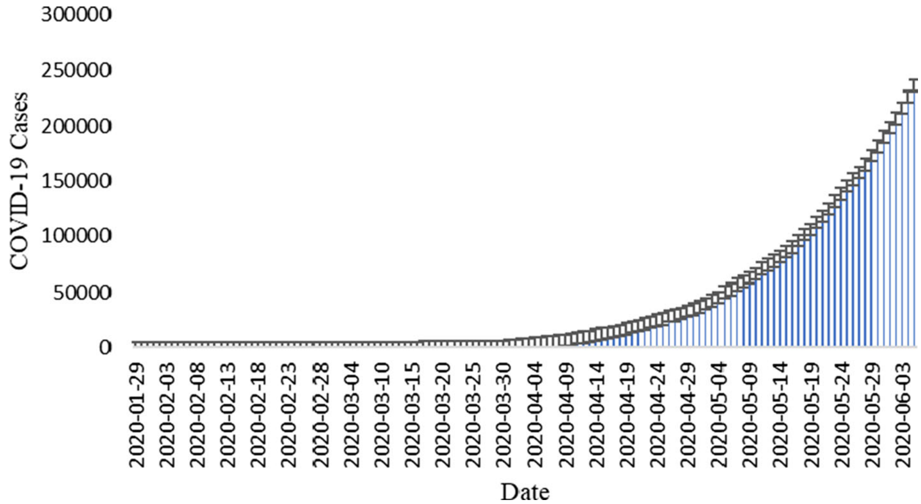

Fig. 6 COVID-19 cases as of June 3, 2020

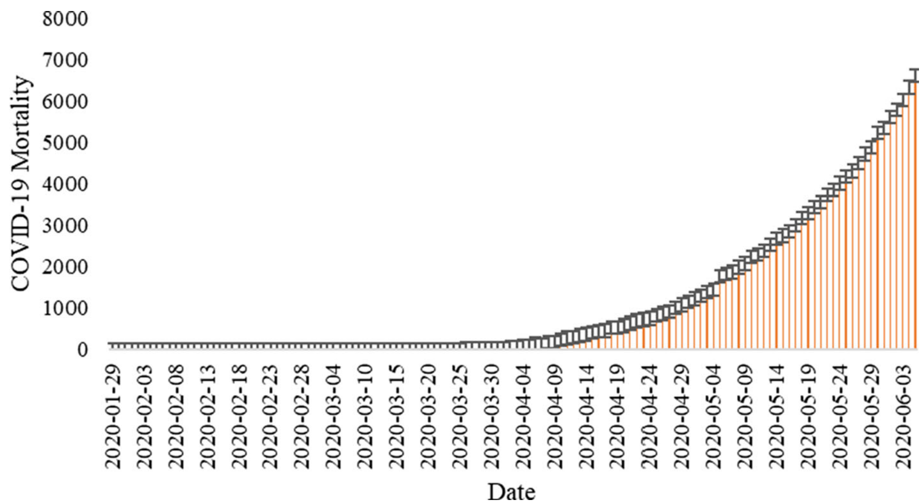

Fig. 7 COVID-19 deaths reported in India

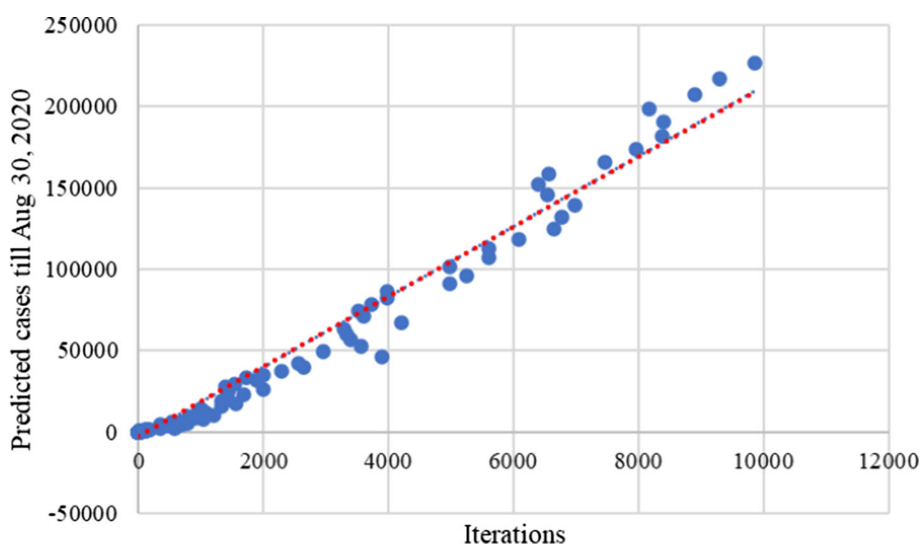

Fig. 8 COVID-19 cases predicted using LR technique

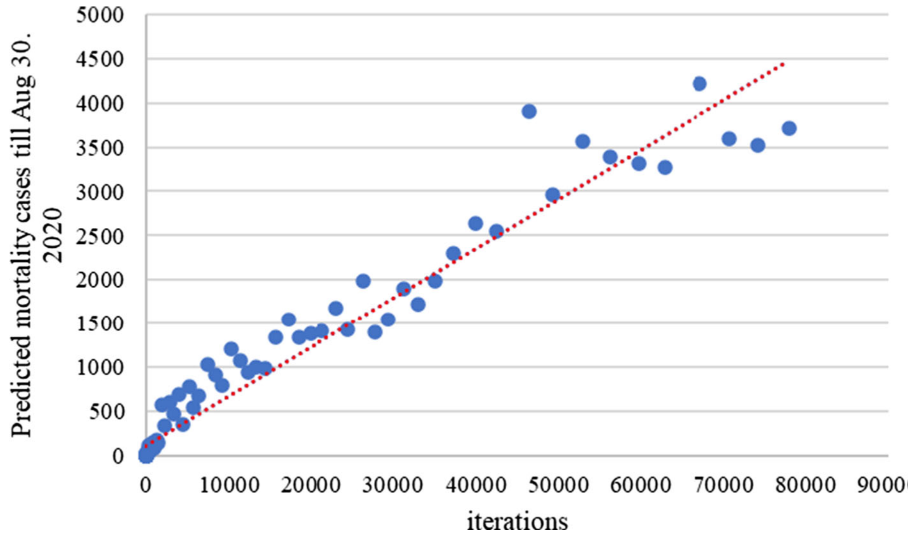

Fig. 9 COVID-19 mortality cases predicted using LR technique

Initially, the Linear Regression (LR) algorithm has been implemented to analyze the prediction rate. Figure 8 shows the predicted COVID-19 cases until Aug 30, 2020, obtained using the LR technique. Figure 9 shows the predicted COVID-19 mortality cases. Further, the MLR prediction algorithm has been implemented to analyze the prediction rate. Figure 10 shows the predicted COVID-19 cases until Aug 30, 2020, obtained using MLR technique. From the Figure, it can be seen that the COVID-19 cases could increase by 13% when compared to the present cases. From the analysis, it also can be predicted that most cases are in the region where the population density is high and liberation is given in lockdown. Figure 11 shows the predicted COVID-19 mortality cases. The analysis predicts that the mortality rate would be less when compared to COVID-19 infected cases.

Furthermore, the new dataset formed with the combined data of COVID-19 and local data has been processed by the ANFIS. In this analysis, other factors such as smoking ratio, lung disease, and pollution data have been included. The obtained prediction is shown the Fig. 12. From the Figure, it can be understood that the COVID-19 cases could increase by 16,00,000 if the present scenario continues. The prediction clearly shows that the cases increase linearly, and the Govt. policy must be changed to prevent the spread of COVID-1.

A comparative analysis has been carried out to evaluate the performance and accuracy of the proposed AI technique. The obtained results have been listed in Table 3 in which all techniques have been trained till maximum iteration reaches. From the analysis, it is seen that the proposed prediction technique takes the lower computation time of 438 s. Further, it uses a rule-based technique, which reduces the complexity when compared to LR and MLR techniques. The P-SVM used in genomic sequence analysis [24] obtained a prediction accuracy of 84% and is

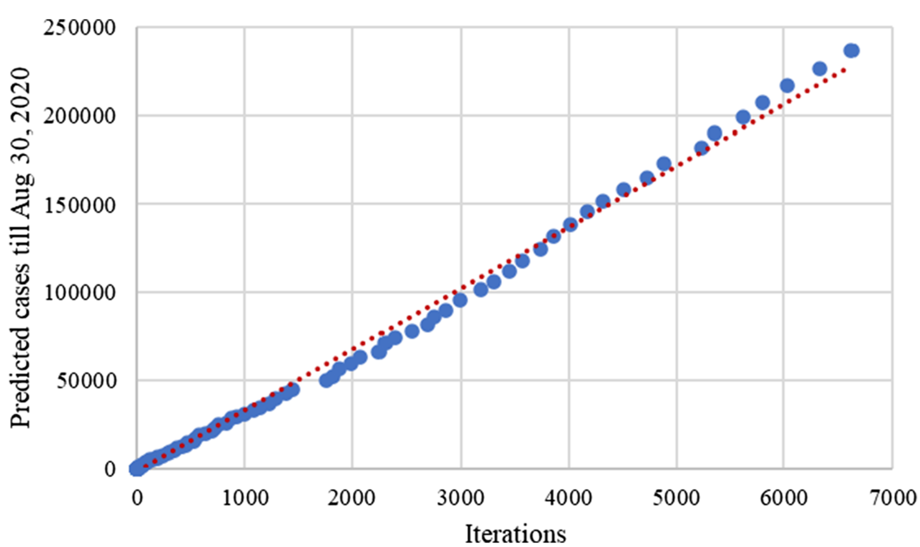

Fig. 10 COVID-19 cases predicted using MLR technique

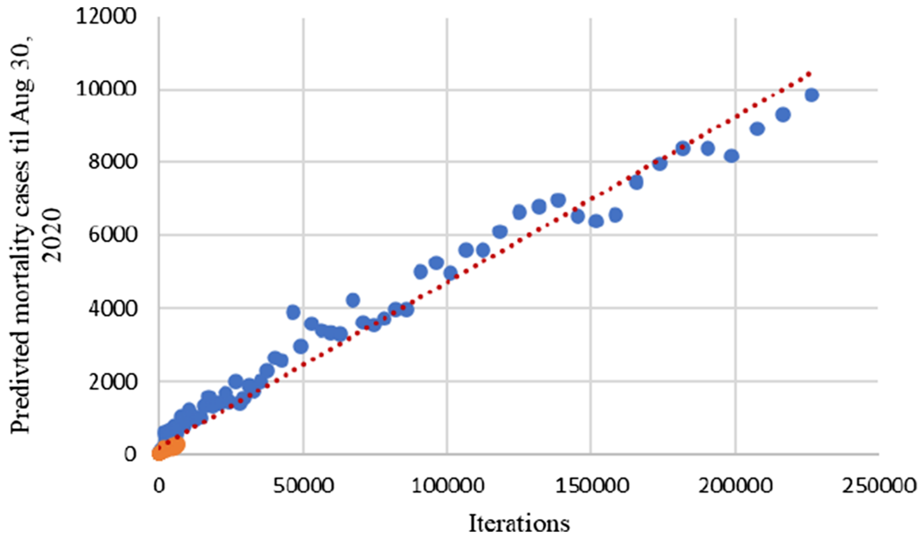

Fig. 11 COVID-19 mortality cases predicted using MLR technique

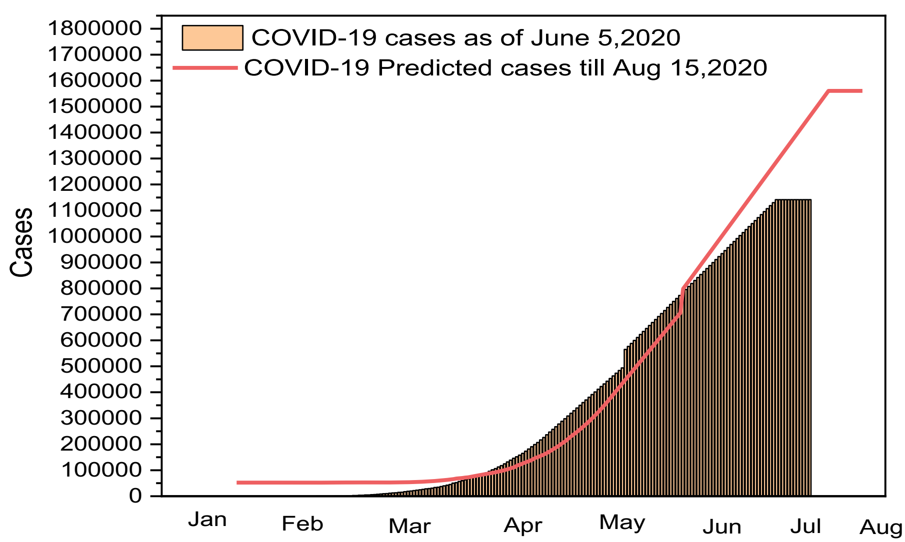

Fig. 12 COVID-19 cases predicted using ANFIS technique

Table 3 Comparative analysis

ML technique				
Measured data	Linear regression	Multiple linear regression	P-SVM	ANFIS
Computation time (Sec)	720	540	475	438
Optimization	Scatter plot	Scatter plot	Rule-based	Rule-based
MSE	1. 843 × 10–3	1.262 × 10–3	1.206 × 10–3	1.184 × 10–3
Accuracy %	83	83.6	84.2	86

also purely rule-based. The prediction accuracy obtained through the proposed ANFIS technique is 86%. Therefore, from the analysis, it is evident that ANFIS-based prediction technique has higher accuracy with minimum computation.

5 Conclusion

An ANFIS-based AI prediction technique has been proposed to predict the spread of COVID-19 in India. In this study, The proposed ANFIS-based prediction system tracks the growth of epidemic based on the previous data sets fetched from cloud computing. The proposed technique not only predicts the outbreak but also tracks the disease and suggests a measurable policy to manage the COVID-19 epidemic. In this analysis, the following observation has been made. The result obtained shows that the spread of COVID-19 continues if the liberation were given to the lockdown. The government of India must reconsider strict lockdown to prevent the spread. The analysis depicts that the COVID-19 cases could reach 16,00,000 at the mid of August. The result shows the growth of infection rate decreases at the end of 2020 and also has delay epidemic peak by 40–60 days. The prediction result using the proposed ANFIS technique shows a low Mean Square Error (MSE) of 1.184 × 10–3 with an accuracy of 86%. The study provides important information for public health providers and the government to control the COVID-19 epidemic.

Declarations

Conflict of interest The authors declare that they didn't get any financial support or influential support to be reported in this paper.

References

1. Schwartz DA, Graham AL (2020) Potential maternal and infant outcomes from (Wuhan) coronavirus 2019-nCoV infecting pregnant women: lessons from SARS, MERS, and other human coronavirus infections. Viruses 12(2):194
2. Li YC, Bai WZ, Hashikawa T (2020) The neuroinvasive potential of SARS-CoV2 may play a role in the respiratory failure of COVID-19 patients. J Med Virol 92(6):552–555
3. Sohrabi C, Alsafi Z, O'Neill N, Khan M, Kerwan A, Al-Jabir A, Iosifidis C, Agha R (2020) World Health Organization declares global emergency: a review of the 2019 novel coronavirus (COVID-19). Int J Surg 76:71–76
4. Aleta A, Moreno Y (2020) Evaluation of the potential incidence of COVID-19 and effectiveness of containment measures in Spain: a data-driven approach. BMC Med 18(1):1–12
5. Guo YR, Cao QD, Hong ZS, Tan YY, Chen SD, Jin HJ, Tan KS, Wang DY, Yan Y (2020) The origin, transmission and clinical therapies on coronavirus disease 2019 (COVID-19) outbreak–an update on the status. Mil Med Res 7(1):1–10
6. Gao J, Tian Z, Yang X (2020) Breakthrough: Chloroquine phosphate has shown apparent efficacy in the treatment of COVID-19 associated pneumonia in clinical studies. Biosci Trends 14(1):72–73
7. Zhao Z, Li X, Liu F, Zhu G, Ma C, Wang L (2020) Prediction of the COVID-19 spread in African countries and implications for prevention and controls: a case study in South Africa, Egypt, Algeria, Nigeria, Senegal and Kenya. Science of the Total Environment, p.138959
8. Lotfi M, Hamblin MR, Rezaei N (2020) COVID-19: Transmission, prevention, and potential therapeutic opportunities. Clin Chim Acta 508:254–266
9. Alhazzani W, Møller MH, Arabi YM, Loeb M, Gong MN, Fan E, Oczkowski S, Levy MM, Derde L, Dzierba A, Du B (2020) Surviving Sepsis Campaign: guidelines on the management of critically ill adults with Coronavirus Disease 2019 (COVID-19). Intensive care medicine, pp.1–34
10. Darwish A, Hassanien AE, Elhoseny M, Sangaiah AK, Muhammad K (2019) The impact of the hybrid platform of the internet of things and cloud computing on healthcare systems: opportunities, challenges, and open problems. J Ambient Intell Humaniz Comput 10(10):4151–4166
11. Shi F, Wang J, Shi J, Wu Z, Wang Q, Tang Z, He K, Shi Y, Shen D (2020) Review of artificial intelligence techniques in imaging data acquisition, segmentation and diagnosis for COVID-19. IEEE Rev Biomed Eng 14:4–15
12. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, Zhang L, Fan G, Xu J, Gu X, Cheng Z (2020) Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. The Lancet 395(10223):497–506
13. Patiyal S, Kaur D, Kaur H, Sharma N, Dhall A, Sahai S, Agrawal P, Maryam L, Arora C, Raghava GPS (2020) A web-based platform on COVID-19 to maintain Predicted Diagnostic, Drug and Vaccine candidates
14. Tuli S, Tuli S, Tuli R, Gill SS (2020) Predicting the growth and trend of COVID-19 pandemic using machine learning and cloud computing. Internet of Things 11:100222
15. Maghdid HS, Ghafoor KZ, Sadiq AS, Curran K, Rabie K (2020) A novel ai-enabled framework to diagnose coronavirus COVID 19 using smartphone embedded sensors: Design study. arXiv preprint arXiv:2003. 07434
16. Zhang K, Liu X, Shen J, Li Z, Sang Y, Wu X, Zha Y, Liang W, Wang C, Wang K, Ye L (2020) Clinically applicable AI system for accurate diagnosis, quantitative measurements, and prognosis of COVID-19 pneumonia using computed tomography. Cell 182:1360
17. Karaboga D, Kaya E (2019) Adaptive network-based fuzzy inference system (ANFIS) training approaches a comprehensive survey. Artif Intell Rev 52(4):2263–2293
18. Lau H, Khosrawipour V, Kocbach P, Mikolajczyk A, Ichii H, Schubert J, Bania J, Khosrawipour T (2020) Internationally lost COVID-19 cases. J Microbiol Immunol Infect 53(3):454–458
19. Salgotra R, Gandomi M, Gandomi AH (2020) Time Series Analysis and Forecast of the COVID-19 Pandemic in India using Genetic Programming, Chaos, Solitons & Fractals, Elsevier, Vol.138, 109945
20. Grinberga-Zalite G, Pilvere I, Muska A, Kruzmetra Z (2021) Resilience of meat supply chains during and after COVID-19 Crisis. Emerg Sci J 5(1):57–66
21. Intissar A (2020) A mathematical study of a generalized SEIR model of COVID-19. SciMedicine J 2:30–67
22. Rasheed MAA, Farooque MMJ, Acharya HS, Quadri MSA (2021) Mathematical modelling of the relationship between two different temperament classifications: during the Covid-19 pandemic. Emerg Sci J 5(1):67–76
23. Agarwal A (2020) Using in-silica analysis and reverse vaccinology approach for COVID-19 vaccine development. SciMedicine J 2:96–105
24. Kumar R, Al-Turjman F, Anand L, Kumar A, Magesh S, Vengatesan K, Sitharthan R, Rajesh M (2021) Genomic sequence analysis of lung infections using artificial intelligence technique. Interdiscip Sci Comput Life Sci 13:1–9
25. Jeon T, Paek I (2021) Design and verification of the LQR controller based on fuzzy logic for large wind turbine. Energies 14(1):230
26. Riahi-Madvar H, Dehghani M, Parmar KS, Nabipour N, Shamshirband S (2020) Improvements in the explicit estimation of pollutant dispersion coefficient in rivers by subset selection of maximum dissimilarity hybridized with ANFIS-firefly algorithm (FFA). IEEE Access 8:60314–60337

27. Nabipour N, Mosavi A, Hajnal E, Nadai L, Shamshirband S, Chau KW (2020) Modeling climate change impact on wind power resources using adaptive neuro-fuzzy inference system. Eng Appl Comput Fluid Mech 14(1):491–506
28. Baghban A, Jalali A, Shafiee M, Ahmadi MH, Chau KW (2019) Developing an ANFIS-based swarm concept model for estimating the relative viscosity of nanofluids. Eng Appl Comput Fluid Mech 13(1):26–39
29. Wu CL, Chau KW (2013) Prediction of rainfall time series using modular soft computingmethods. Eng Appl Artif Intell 26(3):997–1007
30. Taormina R, Chau KW (2015) ANN-based interval forecasting of streamflow discharges using the LUBE method and MOFIPS. Eng Appl Artif Intell 45:429–440
31. Bhatt M, Kasbe T (2019) A survey on chronic kidney disease diagnosis using fuzzy logic. In 2019 IEEE International Symposium on Smart Electronic Systems (iSES)(Formerly iNiS) (pp. 252–256). https://doi.org/10.1109/iSES47678.2019.00063
32. Kour H, Manhas J, Sharma V (2019) Usage and implementation of neuro-fuzzy systems for classification and prediction in the diagnosis of different types of medical disorders: a decade review. Artif Intell Rev. pp.1–56
33. Hussain AA, Bouachir O, Al-Turjman F, Aloqaily M (2020) Ai techniques for covid-19. IEEE Access 8:128776–128795
34. Kolhar M, Al-Turjman F, Alameen A, Abualhaj MM (2020) A Three Layered Decentralized IoT Biometric Architecture for City Lockdown During COVID-19 Outbreak. IEEE Access 8:163608–163617
35. Ghiasi MM, Zendehboudi S, Mohsenipour AA (2020) Decision tree-based diagnosis of coronary artery disease: CART model. Comput Methods Programs Biomed 192:105400
36. Kavadi DP, Pathan R, Ramachandran M, Gandomi AH (2020) Partial derivative nonlinear global pandemic machine learning prediction of COVID 19, chaos, solitons & fractals. Elsevier 139:110056
37. Sitharthan R, Sundarabalan CK, Devabalaji KR, Yuvaraj T, Mohamed Imran A (2019) Automated power management strategy for wind power generation system using pitch angle controller. Meas Control 52(3–4):169–182
38. Sitharthan R, Geethanjali M (2014) ANFIS based wind speed sensor-less MPPT controller for variable speed wind energy conversion systems. Aust J Basic Appl Sci 8:14–23
39. Reza Kazemi M, Mosavi A, Shirazian S (2019) ANFIS pattern for molecular membranes separation optimization. J Mol Liq 274:470–476