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A Computational Intelligence Approach to Detect Future Trends of COVID-19 in France by Analyzing Chinese Data

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ABSTRACT

Aims Due to the terrible effects of 2019 novel coronavirus (COVID-19) on health systems and the global economy, the necessity to study future trends of the virus outbreaks around the world is seriously felt. Since geographical mobility is a risk factor of the disease, it has spread to most of the countries recently. It, therefore, necessitates to design a decision support model to 1) identify the spread pattern of coronavirus and, 2) provide reliable information for the detection of future trends of the virus outbreaks.

Materials & Methods The present study adopts a computational intelligence approach to detect the possible trends in the spread of 2019-nCoV in China for a one-month period. Then, a validated model for detecting future trends in the spread of the virus in France is proposed. It uses ANN (Artificial Neural Network) and a combination of ANN and GA (Genetic Algorithm), PSO (Particle Swarm Optimization), and ICA (Imperialist Competitive Algorithm) as predictive models.

Findings The models work on the basis of data released from the past and the present days from WHO (World Health Organization). By comparing four proposed models, ANN and GA-ANN achieve a high degree of accuracy in terms of performance indicators.

Conclusion The models proposed in the present study can be used as decision support tools for managing and controlling of 2019-nCoV outbreaks.

Keywords Coronavirus; Pandemic; Artificial Neural Network; Genetic Algorithm

CITATION LINKS

[1] Epidemiological characteristics of novel coronavirus infection: A statistical analysis of publicly available case data [2] Geographical distribution of 2019-nCov cases [3] Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China [4] FDA-A scalable evolutionary algorithm for the optimization of additively decomposed functions [5] Particle swarm optimization [6] Imperialist competitive algorithm: An algorithm for optimization inspired by imperialistic competition [7] AI-driven tools for coronavirus outbreak: Need of active learning and cross-population train/test models on multitudinal/multimodal data [8] The role of augmented intelligence (AI) in detecting and preventing the spread of novel coronavirus [9] Short-term power load forecasting by neural network with stochastic back-propagation learning algorithm [10] Performance of neural networks in managerial forecasting [11] Insights into neural-network forecasting of time series corresponding to ARMA (p, q) structures [12] A comparison of artificial neural network and time series models for forecasting commodity prices [13] Time series forecasting using neural networks vs [14] Artificial neural networks-a review of applications of neural networks in the modeling of HIV epidemic [15] Comparison of AI techniques for prediction of liver fibrosis in hepatitis patients [16] Dengue confirmed-cases prediction: A neural network model [17] A comparison of normalization techniques in predicting dengue outbreak [18] Prediction of dengue outbreaks in Sri Lanka using artificial neural networks [19] Neural network diagnostic system for dengue patients risk classification [20] Kyasanur forest disease classification framework using novel extremal optimization tuned neural network in fog computing environment [21] Palivizumab prophylaxis during nosocomial outbreaks of respiratory syncytial virus in a neonatal intensive care unit: Predicting effectiveness with an artificial neural network model [22] Applying wavelets to short-term load forecasting using PSO-based neural networks [23] A genetic algorithm tutorial [24] A combination of hidden Markov model and fuzzy model for stock market forecasting

Introduction

Wuhan City, China, suffered from a novel contagious primary atypical (viral) pneumonia at an alarming rate in December 2019. Since then, it has been identified as a zoonotic coronavirus, similar to SARS and MERS coronaviruses, and named 2019-nCoV or COVID-19. From December 2019, to 19th March 2020, the confirmed cases of 2019-nCoV in the world have been reported 206445 with a mortality rate of 8766 persons. Growth in the confirmed cases in Wuhan, even after closing the market and stopping the exports of China, and then international scope provides convincing evidence of the ever-increasing rate of human-to-human transmission which is intensified by geographical mobility [1]. Nowadays, cases of 2019-nCoV have been confirmed in many parts of the world [2], including Asian countries, the United States, and Europe. Special measures have been taken by the whole world, especially China, Italy, Spain, and Iran to prevent an outbreak of COVID-19, whose effects have been already apparent. The geographical expansion of the virus to the whole world opens up an opportunity for the study of future worldwide trends in the spread of the virus. The confirmation of the human-to-human transmission of COVID-19 [3] makes it highly important to assess the transmissibility of and to detect future worldwide trends in the outbreak of COVID-19. Accordingly, the objective of the current study can be expressed in twofold: 1) At the first stage, it tries to detect the trend of COVID-19 outbreak in China at a specified duration based on publicly available data on the worldwide epidemic of 2019-nCoV, and 2) then, it proposes a validated model for detecting future trends in the spread of the virus in France. So, it may provide a suitable decision support tool for crisis management in France. The availability of reliable Chinese data as well as the similarity of the trend of the virus outbreak in France and China, especially in the early stages, are the main reasons for choosing these two countries.

In this study, the aforementioned objectives are accomplished by applying ANN (Artificial Neural Network) whose reliability is ensured by implementing GA (Genetic Algorithm) [4], PSO (Particle Swarm Optimization) [5], and ICA (Imperialist Competitive Algorithm) [6] for the network training. The results obtained from four proposed models are also compared and the most effective ones are proposed.

ANN (Artificial Neural Network) is a satisfactory substitute for econometric models. It is set up for a wide range of applications such as data classification, function approximation, and pattern recognition under a learning process. This intelligent method can be a substantial help for detecting and analyzing processes with non-linear or even unknown functional forms. Artificial intelligence tools have been developed to predict the spread of coronavirus [7], also AI (Augmented Intelligence) plays an important role in detecting, preventing and spreading Coronavirus [8]. ANNs have been widely utilized for short-term forecasting [9]. By applying an appropriate training process, ANNs are well capable of establishing complex and nonlinear relations among different parameters/variables by applying historical data. Considerable empirical researches on ANNs confirmed their superiority to conventional methods for estimation processes [10-13].

ANN comes into wide use in the modeling of HIV worldwide epidemic [14]. Artificial intelligence methods are also used for hepatitis patients [15]. It has been repeatedly utilized for estimating the number of confirmed cases with Dengue in Singapore [16] and Sri Lanka [17, 18], also the neural network tool is even used to diagnose Dengue [19]. The neural network has also been used in many diseases, such as Kyasanur Forest Disease [20]. In addition, an accurate estimate of the rate of Palivizumab in neonates has been made by ANNs [21]. Therefore, Artificial Neural Network proves widely applications to model virus worldwide epidemics.

Evolutionary algorithms such as GA (Genetic Algorithm), PSO (Particle Swarm Optimization), and ICA (Imperialist Competitive Algorithm) have recently become an important subject of stochastic techniques to search the solution space with the aim of optimization [5]. Several researchers have made an improvement in the learning and structure of the neural network for short-term forecasting by implementing the evolutionary algorithms successfully [22]. Accordingly, the present study also uses the evolutionary algorithms for the network training and it makes a comparison between the results obtained by different models.

Materials and Methods

In this section, a two-phase research methodology is presented in details.

Data Collection

Data are derived from statistics released by the European center for disease prevention and control on the confirmed cases of COVID-19 (European Centre for Disease Prevention and Control data). They have been updated to March 18, 2020, for developing the proposed model.

Experiment

Phase 1: Detecting the behavior of the virus outbreak in China

In the first step, input and output data must be provided to develop an ANN for detecting the trend of COVID-19 virus outbreak in China. This way, its future trend is much easier to be forecasted. For this purpose, the number of people infected with the virus on a certain day (day D) is considered as the output of the system (Y1; Figure 1). The numbers of detected patients in one, two, three, four, and five days before day D are taken into account as the input of the ANN

(X1 to X5; Figure 1). Data are derived from the number of people infected with coronavirus in China from January 1 to March 18, 2020, and they are normalized between -1 and 1 (Table 1). Then, they are divided into two sets of training (80%) and testing (20%) data. Matlab R2017a software application is used for coding.

Figure 1 shows an architectural design of the proposed ANN model. Given that hidden layers have to be considered for the detection process, a three-layer neural network is taken into account. Seven neurons are also used in the hidden layer of the MLP (Multilayer Perceptron) neural network. The MLP neural network produces the best results in practical testing. Diagram 1 indicates the obtained results from two, three, four, five, six, seven, and eight neurons. As Diagram 1 shows, a seven-neuron hidden layer is preferred. The same process is repeated for other models (GA-ANN, PSO-ANN, and ICA-ANN).

Figure 2 depicts outlines the training procedure of three models GA-ANN, PSO-ANN, and ICA-ANN to detect future trends in the virus outbreak. The details of the forecasting methods (GA, PSO, and ICA) are schematically demonstrated in Figure 3 [5, 6, 23].

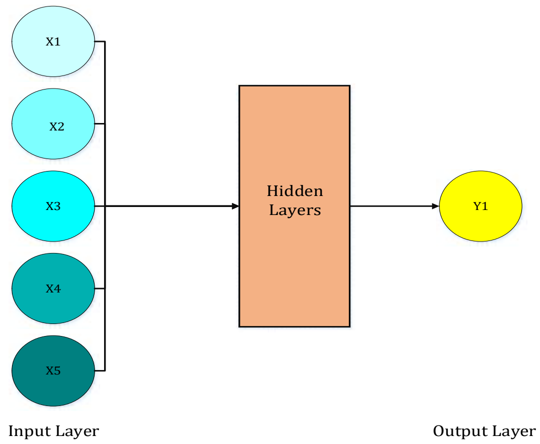

Figure 1) An architectural design of the proposed ANN model

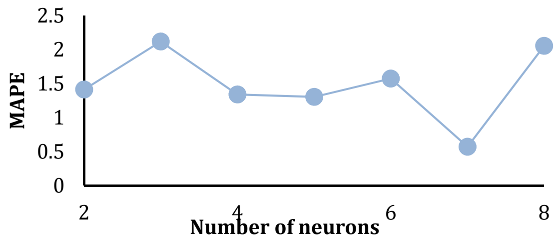

Diagram 1) MAPE vs. number of neurons

Table 1) Normalized data on COVID-19 outbreak in China

Time	Number of patients									
One day ago	-1	-0.998	-1	-1	-1	-0.9971	-0.9975	-0.9971	-0.9967	-0.9855
Two days ago	-0.9978	-1	-0.998	-1	-1	-0.9968	-0.9971	-0.9975	-0.9971	-0.9967
Three days ago	-1	-0.9978	-1	-0.998	-1	-0.9962	-0.9968	-0.9971	-0.9975	-0.9971
Four days ago	-1	-1	-0.9978	-1	-0.998	-0.9974	-0.9962	-0.9968	-0.9971	-0.9975
Five days ago	-0.9964	-1	-1	-0.9978	-1	-0.9941	-0.9974	-0.9962	-0.9968	-0.9971
Total	-0.998	-1	-1	-1	-1	-0.9975	-0.9971	-0.9967	-0.9855	-0.9956

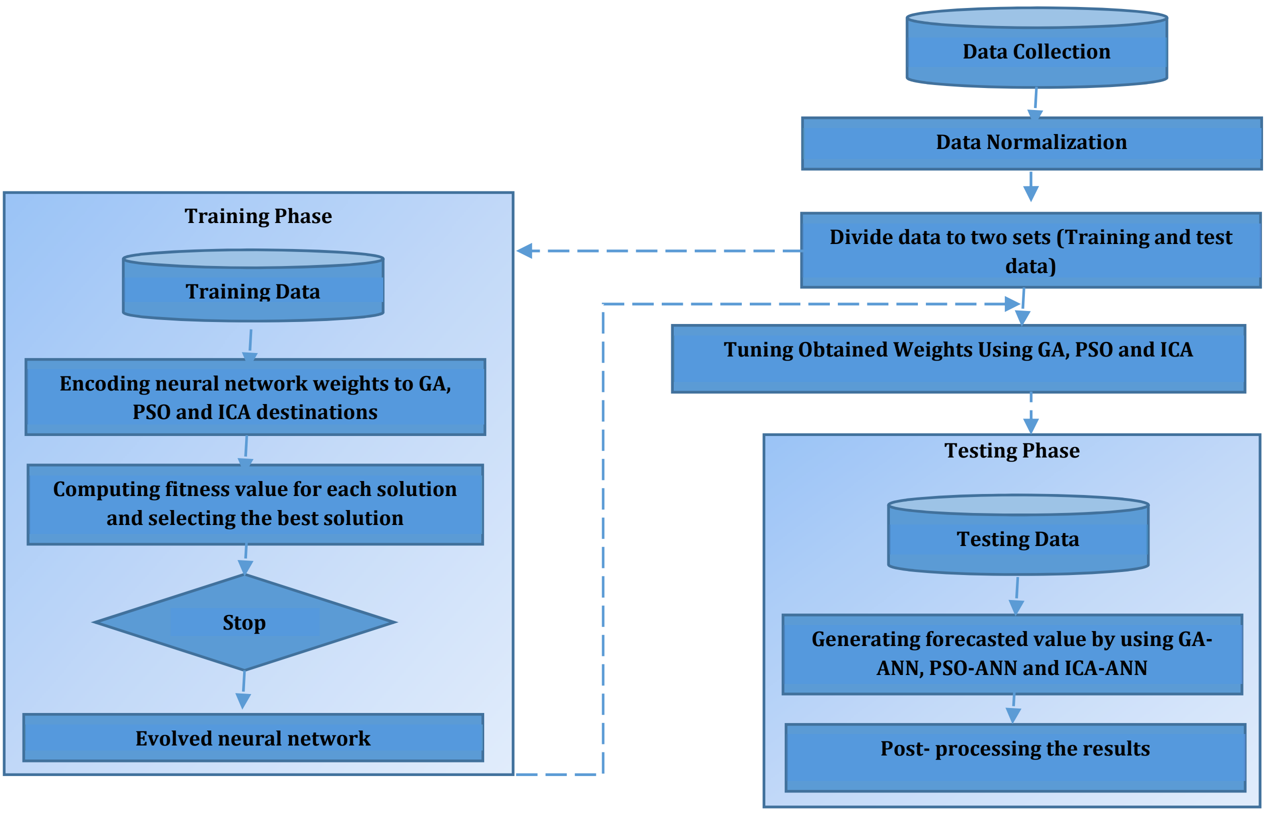

Figure 2) Flowchart of GA-ANN, PSO-ANN, and ICA-ANN

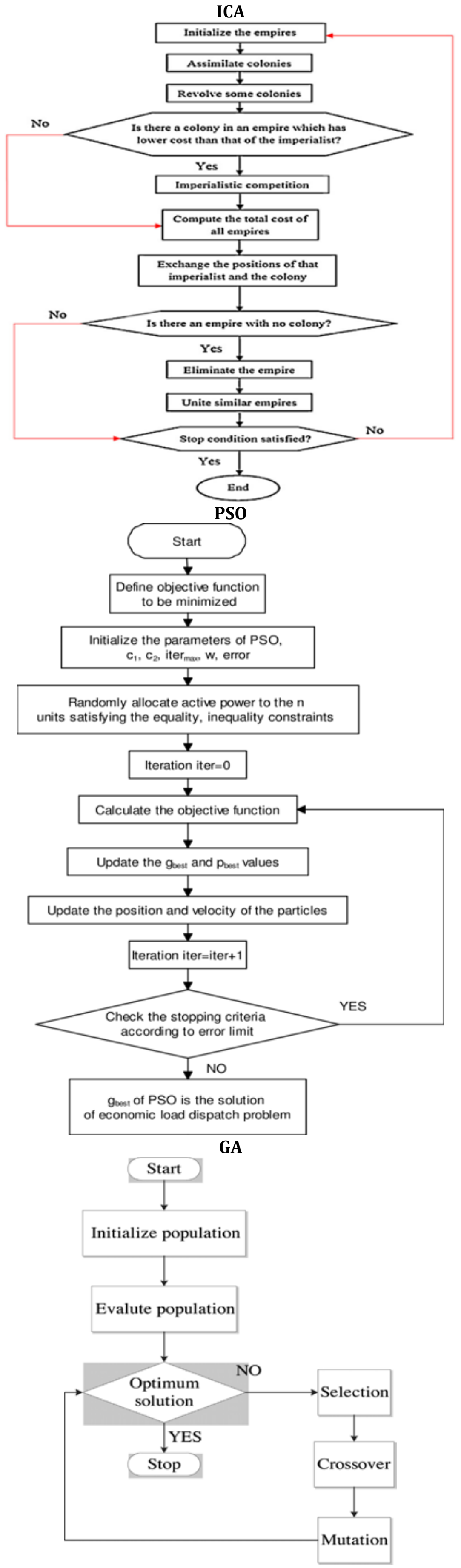

Figure 3) The applied Forecasting Method

MAPE (Mean Absolute Percentage Error) is used to make a comparison between the performance of four proposed models. MAPE is defined by the following statement:

$$MAPE = 100 \times \frac{1}{n}\sum_{i=1}^{n}\frac{|Y_i P_i|}{Y_i} \quad (1)$$

Where P_i and Y_i are the estimated and the real values, respectively. The number of observations is also indicated by n. MAPE results obtained from all the cases are shown in Table 2 (the parameters of each model are obtained by testing a wide range of valid values under a trial-and-error process). Hassan [24] mentioned that models with the lowest rate of MAPE statistical error are more advantageous.

Table 2) MAPE statistics for all proposed models

Model	MAPE
ANN	0.4788
GA-ANN	0.4064
ICA-ANN	2.7782
PSO-ANN	5.1394

Table 2 shows the results from a comparison between four models, as the outputs of their best performance in 20 independent runs.

As shown in Table 2, ANN and GA-ANN models have a higher level of accuracy than PSO-ANN and ICA-ANN models. Diagram 2 indicates the performance and accuracy of each network for two sets of training and testing data.

Table 3 shows how each algorithm detects the outbreak of COVID-19 in the next 30 days (from 18 May 2020) in China. ANN and GA-ANN models detect a declining trend in the spread of the virus for the next days. Whereas two other models observe an accelerating trend in the rate of the spread after a short-term declining behavior.

Diagram 3 shows prediction of proposed models on COVID-19 outbreak in China.

Phase 2: Detecting the behavior of the virus outbreak in France

Future trends in the spread of the virus are now detected in France with a similar pattern of spread. Given that only 21 days have passed from the date on which the first case infected by the virus was confirmed in France to March 18, 2020, data from the first 21 days of virus spread in China are considered to recognize the similarity between the patterns of spread in two countries (note that the trend in spread began on January 1, 2020, in China). Diagram 4 plots the similarity between the patterns of spread in two countries on a graph.

Given the population size of two countries, a correction factor of 3.5 is also considered to use the data from China for detecting the future trend of the virus spread in France.

Low available data for France makes it possible to use the China data for training, testing and simulating the network by which future trends of the virus spread can be forecasted and a possible deadline set for the spread. ANN is used for the detection of future trends in the spread of the virus in France, due to the high accuracy and a low error rate in testing and training data in the case study of China.

Based on the assumption that China and France exhibit a similar pattern of spread and the data from China can be used for France, future trends of the virus spread in France are plotted on Diagram 5. As shown in this Diagram, the crisis is over in France in the next five weeks. It requires that France follows effective policies, such as social distance techniques, implemented in China along with providing a high volume of health facilities and equipment.

Diagram 5 shows the prediction of ANN on COVID-19 outbreak in France. Given that the trend in serious outbreak continued about 70 days in China, it can be said that China's experiences may enable France to shorten the time period by 50 days.

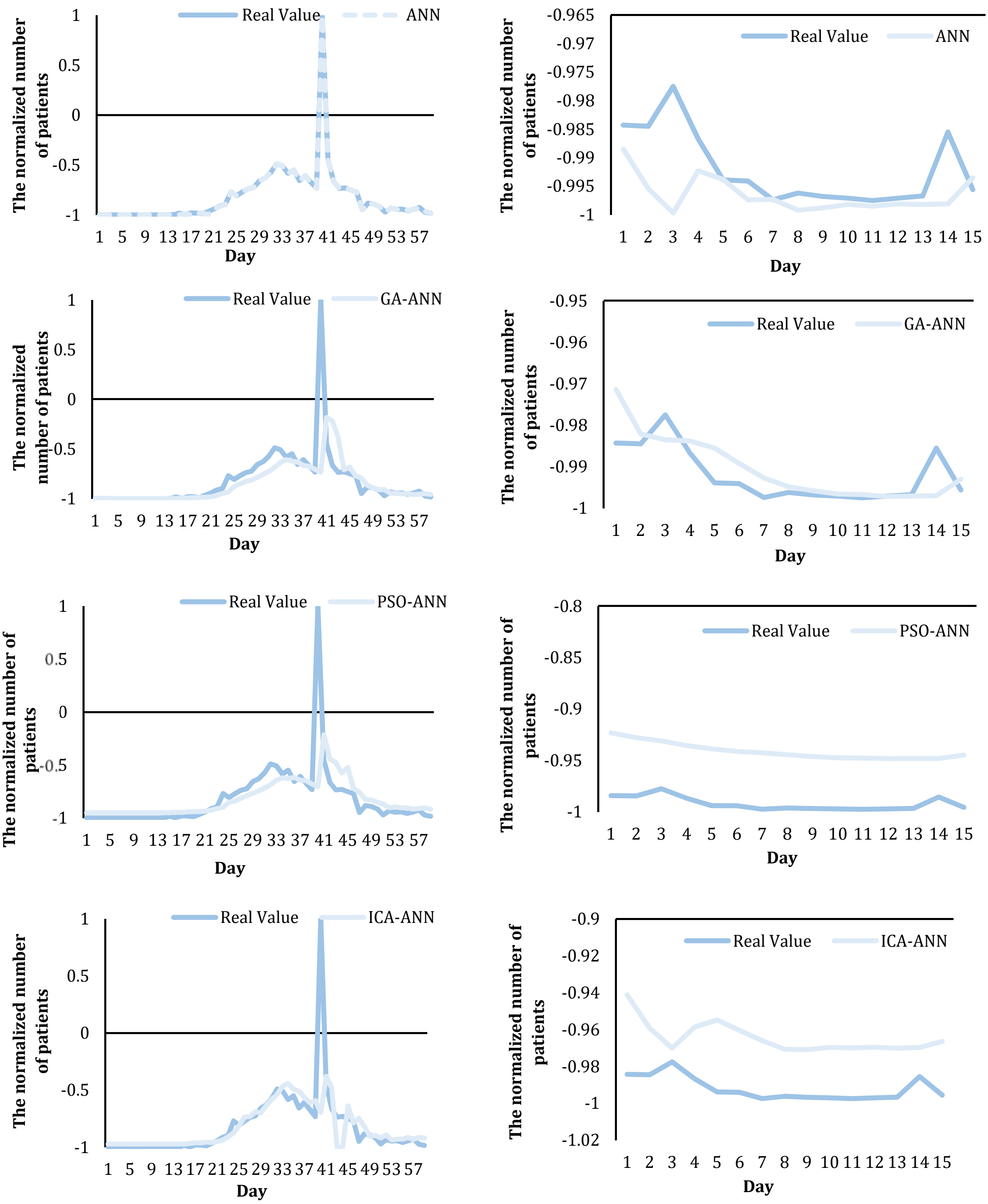

Diagram 2) Experimental results of all proposed models

Table 3) Prediction of proposed models on COVID-19 outbreak in China

Day	ANN	GA-ANN	PSO-ANN	ICA-ANN
1	-0.9963	-0.9926	-0.9314	-0.9545
2	-0.9975	-0.9925	-0.921	-0.937
3	-0.9972	-0.9936	-0.9103	-0.9191
4	-0.9991	-0.9933	-0.8998	-0.9006
5	-0.9988	-0.9938	-0.8883	-0.8828
6	-0.9986	-0.9941	-0.8799	-0.8618
7	-0.9985	-0.9943	-0.8727	-0.8412
8	-0.9986	-0.9946	-0.8661	-0.8184
9	-0.9984	-0.9948	-0.86	-0.7942
10	-0.9984	-0.995	-0.8546	-0.767
11	-0.9984	-0.9951	-0.8499	-0.738
12	-0.9984	-0.9953	-0.8457	-0.7053
13	-0.9984	-0.9954	-0.842	-0.6697
14	-0.9984	-0.9956	-0.8387	-0.6304
15	-0.9984	-0.9957	-0.8357	-0.5884
16	-0.9984	-0.9958	-0.8331	-0.5443
17	-0.9984	-0.9959	-0.8308	-0.5009
18	-0.9984	-0.996	-0.8287	-0.461
19	-0.9984	-0.9961	-0.8269	-0.4282
20	-0.9984	-0.9961	-0.8253	-0.4041
21	-0.9984	-0.9962	-0.8238	-0.3884
22	-0.9984	-0.9963	-0.8226	-0.3778
23	-0.9984	-0.9963	-0.8214	-0.3692
24	-0.9984	-0.9964	-0.8204	-0.3609
25	-0.9984	-0.9964	-0.8195	-0.3527
26	-0.9984	-0.9965	-0.8187	-0.3456
27	-0.9984	-0.9965	-0.818	-0.34
28	-0.9984	-0.9965	-0.8174	-0.3354
29	-0.9984	-0.9966	-0.8168	-0.3314
30	-0.9984	-0.9966	-0.8163	-0.3276

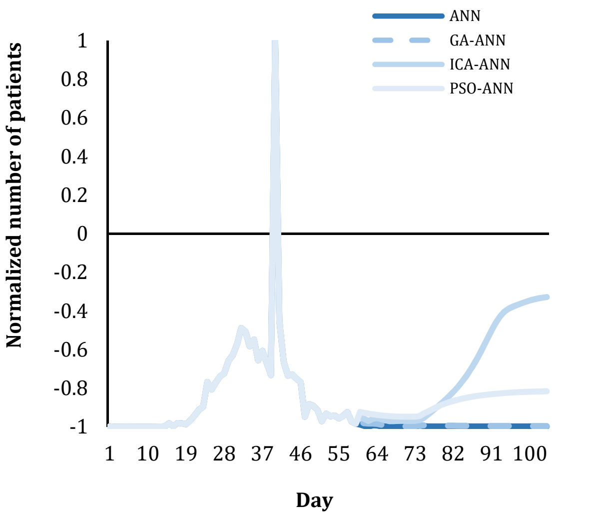

Diagram 3) Prediction of proposed models on COVID-19 outbreak in China

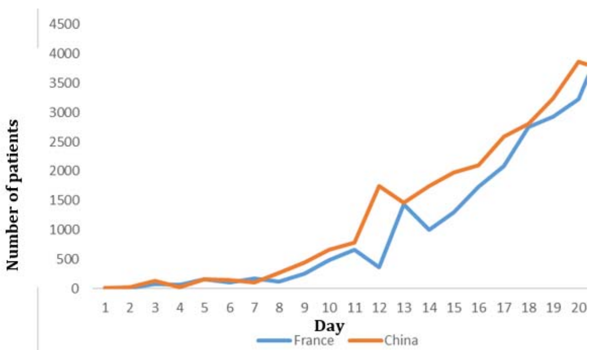

Diagram 4) Similarity between patterns of spread in two countries

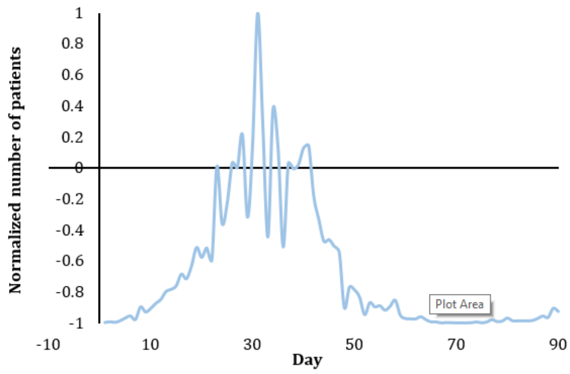

Diagram 5) Prediction of ANN on COVID-19 outbreak in France

Conclusion

The present study used artificial intelligence to detect future trends in the spread of COVID-19 virus in China and France. The results of ANN and GA-ANN models showed that China has brought the rate of the spread under control and France can also control the situation by adopting China's health policy in the next five three weeks. Accordingly, France has an opportunity for successfully fighting against the coronavirus and subsequently saving thousands of people from death, by providing some prevention and treatment China's policies.

The proposed ANN model had a higher level of accuracy than PSO-ANN and ICA-ANN ones whose results indicated an increase in the rate of the spread after a short-term decline. Given that the outbreak of the disease is extremely severe and it is easily transmitted from human to human, all the countries must impose very strict controls on their entrance gates to prevent the spread of the virus again. Since the proposed ANN models achieved a high degree of accuracy in terms of performance indicators, they can be a decision support tool for detecting future global trends of the 2019-nCoV expansion/stopping. As data from Middle Eastern countries, including Iran, is being supplemented by passing time, the development of artificial intelligence-based methods to predict the spread of the virus in these countries is proposed as one of the most important areas of future researches.

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