NEURAL PREDICTOR DESIGN FOR COVID-19 CASES IN DIFFERENT REGIONS

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Abstract. COVID-19, which emerged in the past years, has affected human life in many different ways. The COVID-19 virus has spread very quickly around the world and has become a pandemic. In many applications, artificial neural networks are used to estimate system parameters in real-time or simulation-based methods. In this study, the daily and total number of cases in Turkey, Italy and India are predicted. Three alternative areas, with or without following rules, are chosen for the COVID-19 cases. For this prediction process, 3 different neural network methods are used: Nonlinear autoregressive neural network (NAR-NN), Adaptive-Network Based Fuzzy Inference Systems (ANFIS) and Autoregressive integrated moving average (ARIMA). The results obtained for 3 different neural networks are given with graphs and tables. The conclusion of this study may be used to improve the precaution for the pandemic.

Keywords: Covid-19, Prediction, ANFIS, NAR-NN, ARIMA.

1. Introduction

Since December 2019, COVID-19 has caused millions of deaths worldwide. In addition, COVID-19 has directly affected the lives of billions of people. This is a new mutated version of the coronavirus family called SARSCOV-2 [1-2]. The disease COVID-19 results in acute respiratory tract infection [3]. The consequences of COVID-19 can be listed as fever, cough, fatigue and death [4]. Studies using cluster analysis correlate long-term post-COVID-19 symptoms, COVID-19 symptoms after hospital admission, and prior medical comorbidities to various profiles of COVID-19 survivors [5].

The disease is fast spreading and has a very varied form. Depending on how well each country can detect instances, there are variations in the total number of confirmed cases worldwide. Controlling the rate of disease spread is necessary to maintain the effectiveness of health services. In order to manage and steer the health system, it is crucial to model the daily number of cases and deaths as well as predict potential future instances. The short- and long-term case can be estimated using artificial intelligence and statistical modeling methods to make the appropriate resource planning for dealing with the outbreak. Therefore, it is possible to properly manage medical resources by calculating the expected disease burden. Additionally, it might suggest actions to be performed to lessen the outbreak [6].

Many different methods such as swab sample and radiology images have been used in the detection of COVID-19 [7-9]. In their study, Kanumuri and Chodavarapu developed a Convolutional Neural Networks (CNN) model for Automatic Diagnosis of COVID-19 Using Radiographic Images [10].

For countries, detection and estimation of the rate of spread and the number of cases are as important as the diagnosis of COVID-19. Many mathematical models have been created and many different artificial intelligence methods have been used to predict the number of cases. Kumar et al. presents an Adaptive Neuro-fuzzy Inference System (ANFIS) based machine learning technique to predict the possible outbreak in India [11]. The method they propose uses the cloud dataset. The prediction shows a low Mean Square Error (MSE) of 1.184×10^{-3} with an accuracy of 86%.

Karcıuglu et al. presents using Auto-Regressive Integrated Moving Average (ARIMA) model for predict of COVID-19 transmission in Turkey [12]. In their results show that the daily number of cases and daily number of deaths are estimated with high accuracy in the ARIMA model. Anne and Jeeva used the ARIMA model to make a short-term forecast of the time series transmission of the exponentially growing COVID-19 outbreak. They performed the prediction process on the total number of cases in a time interval [13].

In their study, Suleiman and Sani aimed to predict the number of cases in Nigeria. They used Nonlinear Autoregressive Neural Networks (NAR-NN) and ARIMA models for this prediction process. They used RMSE, MAE and MAPE as performance criteria. Their results show that NAR-NN give better results [14].

The number of COVID-19 cases were modeled in this study using ANFIS, ARIMA, and NAR-NN techniques, and the model performances of the traditional time series method and neural predictors were compared. COVID -19 case numbers were collected from the web. These data include the number of daily cases, and total cases. The World Health Organization's website provided the dataset, which was used between 10 March 2020 and 22 December 2020 [15]. The number of new COVID-19 cases can be predicted using the proposed model. Forecasts were made with precise accuracy rates for the following 30 days.

2. Material and Method

The first case in Turkey during the COVID-19 pandemic was discovered on March 10, 2020 [16]. The 287-day Turkish Ministry of Health statistics between the dates of 10.03.2020 and 22.12.2020 were used in this study. The first two coronavirus infections in Italy were reported on January 31, 2020, following the positive tests of two Chinese tourists in Rome. Data from 287 days of WHO data collected in Italy between 10.03.2020 and 22.12.2020 were used in this investigation [15]. On January 30, 2020, the first COVID-19 case in India was reported. The dataset for this study was created using 287 days of WHO data from 10.03.2020 to 22.12.2020 in India [15]. Figure 1 shows the graph of the daily number of cases and Figure 2 of the total number in Turkey, Italy, and India.

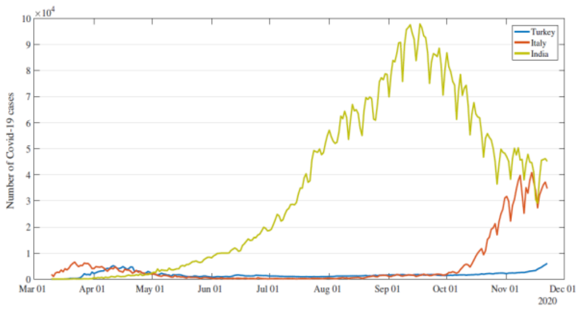

Figure 1: Daily number of cases in three countries

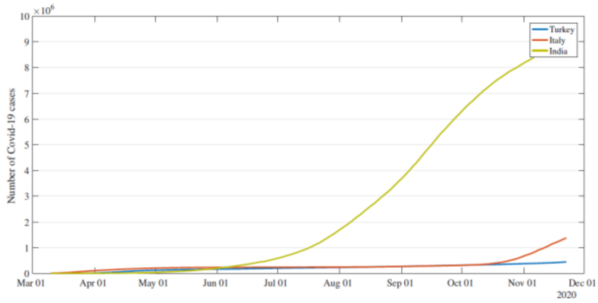

Figure 2: Total number of cases in three countries

ANFIS is a neural network model used in many applications such as prediction [17-18], and control [19-20]. The ANFIS framework was developed by Jang in 1993. ANFIS is a hybrid artificial intelligence method that combines the parallel computation and learning ability of ANNs with the inference feature in fuzzy logic. The basic structure of ANFIS is based on a network structure of Takagi, Sugeno, Kant type fuzzy logic model with neural learning performance [21]. ANFIS has a 5-layer feed-forward neural network. This network structure consists of nodes placed in layers. This system is shown in Figure 3.

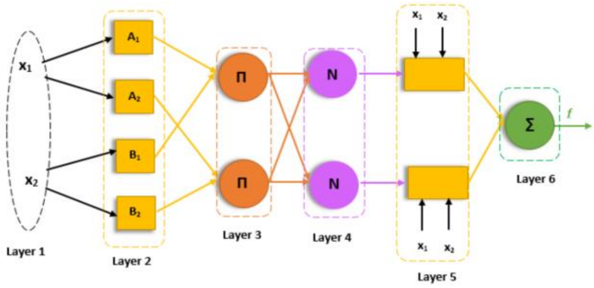

Figure 3: ANFIS Structure [22]

ARIMA is a widely used method among time series estimation methods [23]. ARIMA models are used in many fields such as finance [24], hydrology [25], and energy [26]. ARIMA model has three components [27]:

Autoregression (AR): An autoregressive model derives the regression relationship between a variable that changes based on its previous (or lagged) values.

Integration (I): Integration refers to modeling the differences between raw observations so that the time series can be considered stationary. In other words, the raw values are replaced by the differences between the raw values and the previous values.

Moving Average (MA): The moving average component in the model contains the relationship between an observation and a residual error from the moving average model applied to previous (or delayed) observations.

ARIMA (p, d, q) models have 3 parameters. p represents the degree of autoregressive (AR) model. d represents the degree of difference taken to make the series stationary. q indicates the size of the moving average window.

The last neural network model used in this study is NAR-NN. NAR-NN is a form of ANN fitting used to assess potential input variable estimations in the future. The NAR-NN facilitates the forecast of future time series estimations. A re-feeding care of tool, which allows an anticipated worth to serve as a contribution for new expectations at later points in time, was used to support it by its history foundation [28-29]. The training process of the ARIMA model are carried out with historical data called time delay [30].

In this study, two different performance criteria, Mean Square Error (MSE) and R^2, are used. R^2 is a statistical regression model. R^2 is a measure that represents the proportion of the variance for a dependent variable that's explained by an independent variable [6]. In Equation 1 where n is the number of samples, P is the predicted value and A is the actual value.

$$R^2 = \frac{1-\sum_{i=1}^{n}(P_i - A_i)^2}{\sum_{i=1}^{n}(P_i)^2} \tag{1}$$

The average difference between predicted and actual values is known as the MSE. Better models have low MSE values.

When the MSE value is zero, the prediction model is said to be error-free [31].

In Equation 2 where n is the number of samples, P is the predicted value and A is the actual value.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(P_i - A_i)^2 \tag{2}$$

3. Simulation Results

In this study, the number of the daily and total confirmed COVID-19 cases in Turkey, Italy and India for 287 days (10 March 2020-22 December 2020) have been used for all forecasting models. Prevalence of the COVID-19 are estimated for the next 30 days with NAR-NN, ARIMA and ANFIS models.

In Figure 4, and 5 prevalence of COVID-19 was submitted with three forecasting model for Turkey. In Figure 6, and 7 prevalence of COVID-19 was submitted with three forecasting model for Italy. In Figure 8, and 9 prevalence of COVID-19 was submitted with three forecasting model for India. All figures show that all forecasting models successfully predict the prevalence of the COVID-19 pandemic. However, ANFIS showed a better performance compared with NAR-NN and ARIMA depending on different model performance criteria.

Table 1. ANFIS, ARIMA, and ARIMA Model Performance (R^2 and MSE)

	MSE			R^2		
	ANFIS	ARIMA	NAR-NN	ANFIS	ARIMA	NAR-NN
Turkey Daily Positive	0.0130	0.0133	0.0135	0.99954	0.99861	0.99892
Turkey Total Confirmed	0.0134	0.0198	0.0172	0.99841	0.95621	0.97325
Italy Daily Positive	0.0121	0.0134	0.0126	0.99869	0.99622	0.99815
Italy Total Confirmed	0.0100	0.0110	0.0100	0.99921	0.99912	0.99915
India Daily Positive	0.0101	0.0198	0.0102	0.99988	0.99447	0.99912
India Total Confirmed	0.0335	0.0421	0.0374	0.95529	0.93541	0.95230

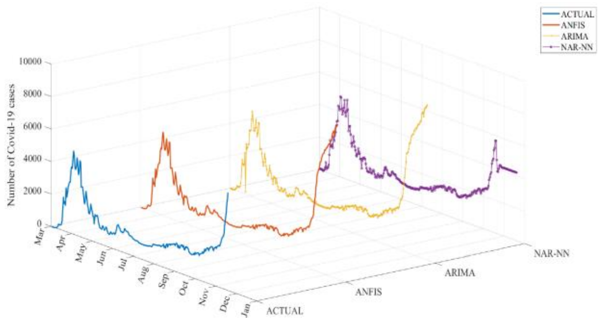

Figure 4: Prediction of daily positive cases and forecasting for the next 30 days for Turkey.

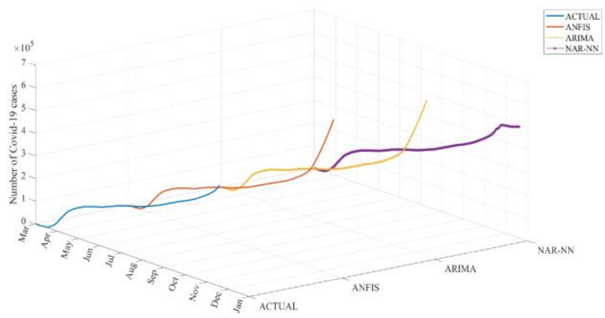

Figure 5: Prediction of total confirmed cases and forecasting for the next 30 days for Turkey.

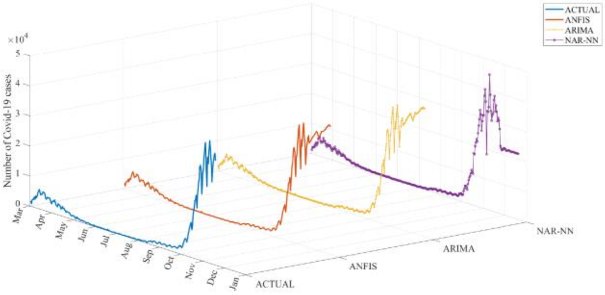

Figure 6: Prediction of daily positive cases and forecasting for the next 30 days for Italy.

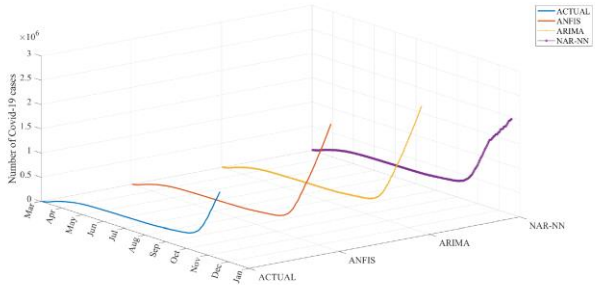

Figure 7: Prediction of total confirmed cases and forecasting for the next 30 days for Italy.

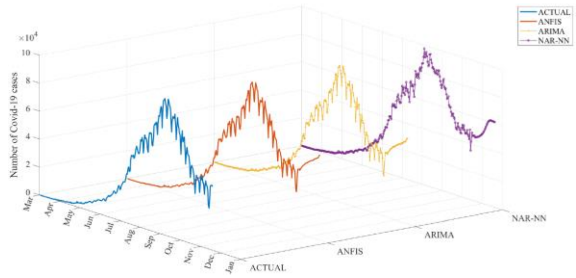

Figure 8: Prediction of daily positive cases and forecasting for the next 30 days for India.

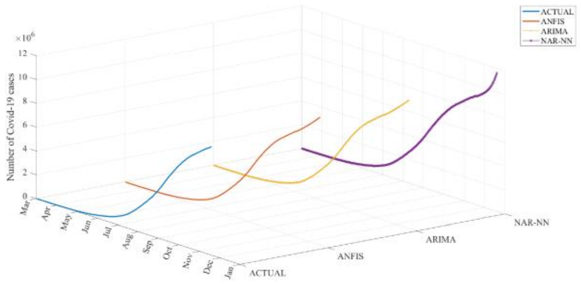

Figure 9: Prediction of total confirmed cases and forecasting for the next 30 days for India.

4. Discussions and Conclusions

In this study, three different neural networks, ANFIS, NAR-NN and ARIMA, were used to estimate the daily and total number of cases in Turkey, Italy and India. All 3 estimators used performed well. Although the 30-day target period for the forecast seemed short, it is vital for the COVID-19 outbreak. Neural networks have been shown to perform better, especially in short-term predictions. However, where the necessary data is available, such short-term forecasts give human experts a good perspective on the COVID-19 pandemic. Because ANN was used in this study on a database that spanned 9 months, as can be seen in Table 1, R^2 values were typically above 0.99. This situation demonstrates that the performance of the suggested model, ANN, is reliable and can provide results that are more accurate when compared to conventional techniques. The simulation results improved and showed that three types of neural predictors could be used in real-time applications such as these virus cases predicting.

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