Analysis and forecast of COVID-19 spreading in India using Nonlinear curve fitting model with machine learning

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Abstract
In this paper, an analysis and forecasting of Indian COVID-19 data is discussed by using scipy optimize curve fitting model of machine learning. We demonstrates the month wise analysis of coming cases, daily recovered cases, death cases and test cases conducted by the Government of India, of COVID-19 from 01\textsuperscript{st} March 2020 to 02\textsuperscript{nd} August 2020, and also forecast for the new cases, recover cases & death cases from 03\textsuperscript{rd} August 2020 to 01\textsuperscript{st} November 2020. Our study show that the total numbers of affected persons due to COVID-19 up to 01\textsuperscript{st} November 2020 will be total cases 13,690,491, recover cases 10,499,593 and death of 129,271.

Introduction
The World Health Organization (WHO) declared COVID-19 (scientifically referred to as the severe acute respiratory syndrome–coronavirus 2 or SARS-CoV-2) a pandemic on 11 March 2020 \cite{1}. This virus had already spread from China to other Asian countries, Europe and the United States. As of 5\textsuperscript{th} July 2020, cases have been identified in 188 countries or regions \cite{2}. It is a respiratory disorder in human having cough, fever and breath problems. The global response to the COVID-19 pandemic has led to a sudden reduction of both greenhouse gas (GHG) emissions and air pollutants \cite{3-5}. This has led to unprecedented enforced and voluntary restrictions on travel and work. On 31\textsuperscript{st} December 2019, China reported to WHO, some persons are infected from pneumonia (caused by a novel coronavirus, currently known as 2019-nCoV) in Wuhan City \cite{6}. Analysis of mobility data from Google \cite{7} and Apple \cite{8} shows that mobility declined by 10\% or more during April 2020 in all but one of the 125 nations tracked. The mobility declined by 80\% in five or more nations.

The first case of COVID-19 in India is found on 30\textsuperscript{th} January 2020, a female student studying at Wuhan city, she belongs to Kerala \cite{9}. After finding more cases, Indian Government has started the lockdown process with many phases from 25\textsuperscript{th} March 2020, so the preventive methods are used during this lockdown to protect the people from COVID-19, such as wearing the mask, hands sanitizing, frequent hand washing, restrictions in travelling, avoid social gathering, staying at home etc. \cite{10}. Indian Government also ordered to close all the schools, colleges, markets and cinema halls during this period. People can only move out in emergency conditions by taking the permission from local authorities. India has very slow growth in the initial stage of COVID-19 pandemic but it increases exponentially later on \cite{11, 12}.

There are many mathematical models and machine learning models given for analysis and prediction of COVID-19 pandemic situation. The spatial distribution and region wise spreading of COVID-19 prediction across the India is given by using Geospatial Approach with the help of GIS Software for distribution and trend analysis till 11\textsuperscript{th} April 2020 \cite{13}. SIER and regression models are used for forecasting for next two weeks on the basis of analysis collected by Johns Hopkins University from 30\textsuperscript{th} January 2020 to 30\textsuperscript{th} March 2020 \cite{14}. The RMSLE calculates the error rate of 1.52 for SEIR model and 1.75 for regression model for above analysis. The time series analysis based on ARIMA are also used for forecast. The time series based study indicates that the number of cases increase exponentially \cite{15}. The linear regression model with machine learning is also used for forecasting and this study used the linear regression, multilayer perceptron and vector autoregression methods for analysis and prediction on the COVID-19 Kaggle dataset \cite{16}. The containment model also used for COVID-19 in India, with prediction for reduction the number of upcoming cases \cite{17}.

There are many more research papers are available not only for Indian but also describes the covid-19 pandemic situations of China, Italy, France and United States, which can be helpful for planning and decision making.
In this paper, a comprehensive nonlinear curve fitting model for analysis and forecast of COVID-19 in India is proposed. This study is divided into two parts; (1) we analyzed the new cases; recover cases, death cases and test cases on daily basis (2) we forecasted the values of news cases, recover cases and death cases weekly by using the nonlinear curve fitting model, The python, Pandas and Scipy optimize curve fitting model are used in our computational work [21].

Methodology

The nonlinear regression is a powerful technique to fix a broad range of values in nonlinear manner. The nonlinear regression determines the values of parameters that minimize the sum of squares of the distances of the data points (least square method) to the curve. Generally this method is used when experimental values are Gaussian in nature. The nonlinear regression procedure adjusts these values and produce new values to make curve fitted. We use exponential function to fit our data in this model [22].

\[
y_n = \alpha \times \exp(\beta \times x_n),
\]

where \(\alpha\) and \(\beta\) are constants and have the values for new cases: 1741.833, 0.233, for recover cases: 854.028, 0.250 and for death cases 163.097, 0.155 respectively. These values are calculated by Scipy optimize curve fitting model of machine learning based on number of weeks \((x_n)\) with respect to previous values available. The function may be defined as [23]

\[
\text{scipy.optimize.curve_fit(f, xdata, ydata, p0=None, sigma=None, absolute_sigma=False, check_finite=True, bounds=\text{-inf, inf}, method=\text{None}, jac=None, **kwargs)},
\]

where ‘f’ is the model function, ‘xdata’ is independent array object, ‘ydata’ is dependent array object, ‘p0’ is initial guess for the parameters, ‘sigma’ determines uncertainty in ‘ydata’, ‘absolute_sigma’ is a Boolean value to sense and the estimated parameter covariance, ‘check_finite’ to check the input array for value error etc., ‘bounds’ represents lower and upper bound on parameters, ‘method’ to used for optimization (least square), ‘jac’ computes the Jacobean matrix of the function with respect to parameters as a dense array like structure, ‘kwargs’ keyword arguments passed to optimize method. This function returns ‘popt’ an array of optimal values for the parameters, ‘pcov’ provides variance of the parameter estimate in 2-dimensional array. Following function used to perform the curve fitting:

\[
\text{popt, pcov = curve_fit(func, xData, yData, initialGuess)}
\]

initial Guess = [1.0, 1.0]

Analysis And Forecasting

We have analyzed four points of COVID-19, new cases; recover cases, death cases and test cases daily basis as shown in Figure 1-5. The dataset created by Max Roser, Director, “Our World in Data” and his team members used for COVID-19 new cases, death cases & test cases analysis and forecasting [11]. For recover cases analysis & forecasting we have used dataset created by Johns Hopkins University Center for Systems Science and Engineering [12].
The analysis for date wise new cases are shown in Fig.(1a), (2a), (3a), (4a), (5a) for the month of March, April, May, June and July. Similarly date wise recovered cases are shown in Fig.(1b), (2b), (3b), (4b), (5b) for these months. Fig. (1c), (2c), (3c), (4c), (5c) has date wise death cases and in Fig.(1d), (2d), (3d), (4d), (5d) shows date wise test cases performed by Indian Government.

In month of March, India has 1,248 total new cases, 120 recover cases, 32 death cases and 29,663 tests are performed but in April, 31,799 total new cases, 1,845 recover cases, 1,042 death cases and 795,313 test cases. In month of May, 149,093 total new cases, 82,784 recover cases, 4,090 death cases and 2,906,826 tests are performed with continuous growth. In month of June, 384,697 total new cases, 256,060 recover cases, 11,729 death cases with the highest number of death cases 2,003 on 17\textsuperscript{th} June 2020 and 4,871,627 tests are performed and in month of July, 1,072,030 total new cases, 746,462 recover cases, 18,854 death cases and 10,224,316 tests are performed.

We analyzed the data on week's basis and made the prediction for new cases, recover cases and death cases as shown in Figs. (6a), (6b) and (6c) respectively. Using the nonlinear curve fitting model these figures show that the forecasting for new cases, recover cases and death cases are increasing exponentially by using nonlinear curve fitting model. The actual values are represented by the blue dots and predicted values are represented by red line. After inserting the corresponding values in curve fitting model, for the prediction of new cases and recover cases the value of $x_n$ is increased by 0.5 and for death cases it is increased by 0.25.

The calculated values of new cases, recover cases & death cases are shown in table 1.
| week no | date from | date to | weekly counting | total counting to date |
|--------|-----------|---------|----------------|------------------------|
|        |           |         | new cases | recover cases | death cases | total new cases | total recover cases | total death cases |
| Actual Values | | | | | | | | |
| 1-14   | 3/1/2020  | 5/31/2020 | 182,140 | 91,849 | 5,164 |
| 15     | 6/1/2020  | 6/7/2020  | 64,485  | 31,996 | 1,765 | 246,625 | 123,845 | 6,929 |
| 16     | 6/8/2020  | 6/14/2020 | 74,294  | 45,950 | 2,266 | 320,919 | 169,795 | 9,195 |
| 17     | 6/15/2020 | 6/21/2020 | 89,539  | 67,398 | 4,059 | 410,458 | 237,193 | 13,254 |
| 18     | 6/22/2020 | 6/28/2020 | 118,398 | 84,527 | 2,841 | 528,856 | 319,795 | 16,095 |
| 19     | 7/6/2020  | 7/12/2020 | 176,388 | 129,038 | 3,406 | 849,550 | 553,468 | 22,674 |
| 20     | 7/13/2020 | 7/19/2020 | 228,065 | 146,616 | 4,142 | 1,077,615 | 700,084 | 26,816 |
| 21     | 7/20/2020 | 7/26/2020 | 307,904 | 217,481 | 2,841 | 1,385,519 | 917,565 | 32,063 |
| 22     | 7/27/2020 | 8/2/2020  | 365,201 | 268,635 | 5,301 | 1,750,720 | 1,186,200 | 37,364 |
| Predicted Values | | | | | | | | |
| 24     | 8/3/2020  | 8/9/2020  | 415,897 | 304,055 | 5,545 | 2,166,617 | 1,490,255 | 42,909 |
| 25     | 8/10/2020 | 8/16/2020 | 467,284 | 344,539 | 5,764 | 2,633,902 | 1,834,795 | 48,672 |
| 26     | 8/17/2020 | 8/23/2020 | 525,021 | 390,414 | 5,991 | 3,158,922 | 2,225,209 | 54,664 |
| 27     | 8/24/2020 | 8/30/2020 | 589,891 | 442,397 | 6,228 | 3,748,814 | 2,667,606 | 60,892 |
| 28     | 8/31/2020 | 9/6/2020  | 662,777 | 501,302 | 6,474 | 4,411,590 | 3,168,908 | 67,366 |
| 29     | 9/7/2020  | 9/13/2020 | 744,668 | 568,050 | 6,730 | 5,156,258 | 3,736,958 | 74,097 |
| 30     | 9/14/2020 | 9/20/2020 | 836,677 | 643,685 | 6,996 | 5,992,935 | 4,380,642 | 81,093 |
| 31     | 9/21/2020 | 9/27/2020 | 940,055 | 729,390 | 7,272 | 6,932,989 | 5,110,033 | 88,365 |
| 32     | 9/28/2020 | 10/4/2020 | 1,056,205 | 826,507 | 7,560 | 7,989,195 | 5,936,540 | 95,925 |
| 33     | 10/5/2020 | 10/11/2020 | 1,186,708 | 936,555 | 7,858 | 9,175,902 | 6,873,095 | 103,783 |
| 34     | 10/12/2020 | 10/18/2020 | 1,333,334 | 1,061,256 | 8,169 | 10,509,237 | 7,934,352 | 111,952 |
| 35     | 10/19/2020 | 10/25/2020 | 1,498,078 | 1,202,561 | 8,492 | 12,007,314 | 9,136,913 | 120,444 |
| 36     | 10/26/2020 | 11/1/2020  | 1,683,176 | 1,362,680 | 8,827 | 13,690,491 | 10,499,593 | 129,271 |

Table 1 Indian COVID 19 forecasting from 03rd August 2020 to 01st November 2020 (weekwise)

**Conclusion**
In this paper, by analyzing the existing COVID-19 data's of 23 weeks (5 months, from 01\textsuperscript{st} March 2020 to 02\textsuperscript{nd} August 2020) and a corresponding model is established, and then the prediction is done for next 13 weeks (3 months, from 03\textsuperscript{rd} August 2020 to 01\textsuperscript{st} November 2020) by using nonlinear curve fitting model. We predicted the total numbers of new cases; recover cases and death cases till 01\textsuperscript{st} November 2020, week wise. Our analysis shows that there will be 13,690,491, COVID-19 cases with the recovery of 10,499,593 cases and the death of 129,271 till 01\textsuperscript{st} November 2020 in India, with the current conditions and having approximate (per week) frequency of 1,683,176 new cases found, 1,362,680 recovery rate and death rate of 8,827 persons. These figures are only mathematical values which are estimated by doing some calculations. But these values can be reduced by using some preventive measures against the COVID-19 disease, such as performing the continuous large number of COVID-19 tests, maintain the social distance to each other, proper wearing the mask etc. The increase in these values will also be stopped when some effective medicine or vaccine of COVID-19 available for use to the effected persons or as needed.

Declarations

Compliance with Ethical Standards

Funding: There are no financial conflicts of interest to disclose.

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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