Prediction of Spread of Covid-19 Infections - A Time-Series Based Approach

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Abstract— Covid-19 has hard-pressed world to handle one of the major health emergencies of modern times. In this scenario, prediction or forecasting the new infections and the rate of death is the need of the hour for effective preparedness in terms of medical facility, vaccinations and other requirements to eradicate the disease from further spread. As on 29th August 2021, according to the Ministry of Health and Family Welfare, Govt of India Sources, a total of 4,37,830 Death cases have been reported in 28 states and 8 union territories. The vaccination to all, proper medical treatment policy, maintaining social distancing, cleanliness and awareness of seriousness about the infection will lead to the end of the current pandemic situation. This paper aims to describe the empirical study of modelling and forecasting time series data of COVID 19 for India. COVID data for the period of 30.01.2020 to 27.08.2021 were collected from the portal of Ministry of Health, Govt of India, analysed by applying Time Series approach and the ARIMA model is used for forecasting. The proposed model is tested using Lag 1 autocorrelation of error (acf1), minmax error and correlation and the obtained results are promising. The proposed time series models proved to be an effective approach as the level of accuracy is close to 96% in case of both infections and deceased rate.

Keywords—Covid 19, ARIMA,

I. INTRODUCTION

A novel microorganism Serious Intense Respiratory Disorder Corona virus 2 (SARS-COV-2) is responsible for the Corona Virus Disease in the year 2019, which got spread all over the globe till today at a rapid rate [1] and WHO announced the epidemic SARS-COV-2 as a pandemic on 11th March, 2020 [2]. The first case was reported at Wuhan City on December 2019 [3,4] and in India it was on 30th January, 2020 [5] in a student who travelled from Wuhan to India. The virus not only infects but also causes deaths by developing lungs infection and other medical complications [6]. In the developed countries like United Kingdom, United States of America, France, Spain, Italy, Germany there was an exponential increase in the number of infections and deaths [7-13].

A major challenge in the detection of this infection is when the individuals are infected without any symptoms (asymptotic category) for several days and it becomes very difficult to monitor the transmission of virus from this category [14, 15]. An epidemic model was developed to identify the human-to-human transmission through the phases of infection i.e. Susceptible (S), Infected (I) and Removed (R) classes and the same was later included with one more phase Exposed (E) [16, 17].

Machine Learning (ML) plays a vital role in solving various complex and real-world problems as per the trends of research [18, 19]. The time series is a sequence of metrics recorded at regular intervals and the interval could be a year (e.g. annual expenses), a month (e.g. passenger traffic), a week (e.g. sales), a day (e.g. climate), an hour (e.g. share trading), few minutes (e.g. call logs), or several seconds (e.g. web traffic)). Day wise recording of these infections and deceased data is available from 30th January, 2021 to till date [20]. Forecasting is the outcome of the time series, which predicts the future values based on the date interval.

Prediction of day wise infections and deaths is the need of the hour as the forecasting assists officials in medical administration. Subsequently, from March 2020 several measures were taken in order to control and eradicate the virus. The measures such as enforcing social distancing, closure of academic institutions, entertainment components, transport, restrict the number of visitors to communal events, suspending religious activities and public meetings. As a consequence, several businesses were closed and many were unable to meet the daily requirements. Initially, the primary objective is to control the spread of the disease, the socio-economic factors of the individual are not considered and also there was no enough data to evaluate, analyse and predict the nature of spread in future.

In the current situation, huge volume of accurate data source is available and hence the forecast of spread of the disease become feasible as it is the need of the hour. The outcome of this prediction also helps in planning the medical and economic status of the society. The reminder of the article is organized as follows: section 2 discusses the related works, proposed time series forecasting is elaborated in section 3, section 4 analysis the results and is followed by conclusion and future scope.

II. REVIEW OF LITERATURE

In this section, the articles related to the proposed model have been reviewed. Hybrid Machine Learning approach is applied for predicting the number of infections and deaths using Multi Layered Perceptron and Imperialist competitive calculation and it was based on the data set of the country Hungary [22]. To design, analyse, evaluate and understand the impact of the pandemic or spreading of infectious diseases without any specific availability of antiviral doses and vaccination is a herculean task. There is a huge requirement of predictive mathematical models those plays multiple roles in controlling the spread of this pandemic [23-27].

The evolution of COVID-19 has been analysed by computing the fractional order dynamical system on an assumed population [29] and the computation system is based on the discretisation of the domain and the short memory principle. The impact of isolation strategy was studied by applying stochastic model of SIQR and simulated the dynamics of the virus [28].

In a recent work by Gao W (2020), the population is divided into subgroups like susceptible, exposed, infected, deceased and the behaviour of these groups are analysed over a period of time [30]. The authors have also worked on fractional calculus to study the impact of Covid – 19 and applied factional natural decomposition technique to understand the dynamic behaviour of the virus. This work involves highly complicated mathematical computations when compared with machine learning approaches. Non pharmaceutical intervention approach has been applied to reduce the spread of the disease; a collection of population is divided into six groups on which the mathematical model is built by coupled differential equations [31]. The principal objective of this work is only to reduce the impact of the virus, whereas the research article assists in predicting the spread of the virus.

Researchers also focused on investing about the possibility of reducing the spread of the virus without lockdown [32] in which quarantine plays a vital role and the methodology applied is using differential equations. Several deep learning approaches also have been proposed in order to forecast and predict the impact / spread of this pandemic across different global regions. There are studies discussed about the containment of the virus[38-46].

III. TIME SERIES BASED FORECASTING

The data set for the proposed model covers the period from 30th January 2020 to till date [20]. The data consists of the day wise information of infected, deceased and in medication and it includes the information about district wise and state wise. In the proposed work, date wise data is considered for the prediction using the time series approach. A detailed exploratory analysis is carried out and is demonstrated in Figure 1.

The trend shows that due to the fear and precautionary measures taken by the Government there is no significant rise in case of infections and deceased. After major relaxations made and the impact of second wave, there was a huge increase in the infections during the period from March to June 2021. However, during this period the vaccination campaign started on a mammoth scale and many have been vaccinated in the age from 18 years onwards. Inspite of all these proactive and preventive measures, there is an increase in the number of infections. The objective of this study is to forecast about the next possible wave using the time series analysis models.

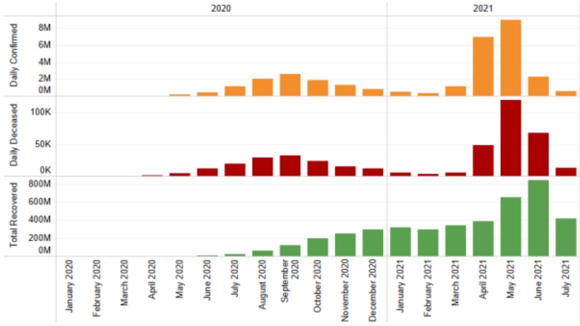


Figure.1. Monthly Impact of Covid-19 in India for the period January 2020 to July 2021

Time series forecasting is broadly classified into Univariate Time Series and Multivariate Time Series. If the Prediction is based on the historical data, then it is referred to as Univariate and if the predictors used are other than the series then it is Multivariate. The proposed work is based on the historical data and hence the applied time series approach is univariate and the model applied is “Auto Regressive Integrated Moving Average (ARIMA)”. The source of data is continuous and not seasonal, no random information exists and so the forecast of Covid 19 infections can be modelled using ARIMA approach. The terms that characterise the ARIMA model is order of the auto regressive (p) i.e. refers to the time or period or lags, order of the moving average (q) i.e. lagged forecast errors, and the number of differencing required to make the time series stationary (d). Depends on the complexity of the series, computation of more than one ‘d’ is required. If the time series is already in stationary mode, then the value of d is set to zero.

A pure AR (Auto Regressive) model the variable Yt is a recursive function and is represented in Equation (1).

$$Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_p Y_{t-p} + \varepsilon_t \qquad (1)$$

where,

Y_{t-p} – lag p of the series

β_p – coefficient of the lag p for model estimation

α - Intercept

ε - Error Rate

Similarly, MA (Moving Average) depends on the forecast errors and is given in Equation (2).

$$Y_t = \alpha + \varepsilon_t + \phi_1 \varepsilon_{t-1} + \phi_1 \varepsilon_{t-1} + \ldots + \phi_q \varepsilon_{t-q} \qquad (2)$$

Where, the error terms are the errors of the AR model of the respective lags and the errors values are calculated is given as:

$$Y_t = \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_0 Y_0 + \varepsilon_t$$

$$Y_{t-1} = \beta_2 Y_{t-2} + \beta_3 Y_{t-3} + \ldots + \beta_0 Y_0 + \varepsilon_{t-1}$$

The combination of AR and MA leads to the development of the model ARIMA and is expressed in Equation (3).

$$Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots + \beta_p Y_{t-p} + \varepsilon_t + \phi_1 \varepsilon_{t-1} + \phi_1 \varepsilon_{t-1} + \ldots + \phi_q \varepsilon_{t-q} \qquad (3)$$

The expected or predicted value is computed as the sum of a constant, linear combination on lags of the predictor variable (of up to p lags) and the linear combination of lagged forecast errors (up to q lags) and the values of p, q and d is to be determined.

A. Short term forecasting Model for COVID 19

Time series is a set of observations as COVID 19 active cases obtained by measuring a single variable regularly over a period of time. Time series forecasting is used for short-range forecasts such as COVID active case rates. Exponential smoothing is a method of forecasting that uses weighted values of previous series observation. ARIMA models provide more sophisticated methods for modeling trend and seasonal components than do exponential smoothing models to predict future values. ARIMA model, introduced by Box and Jenkins (1970), was frequently used for discovering the pattern and predicting the future values of the time series data. Hosking (1981) introduced a family of models, called fractionally differenced autoregressive integrated moving average models, by generalizing the 'd' fraction in ARIMA (p, d, q) model. Tsitsika et al. (2007) forecasted the monthly pelagic production of fish species in the Mediterranean Sea during 1990-2005 using univariate and multivariate ARIMA models. Kristiansen T (2012) forecasted Nord Pool day-ahead prices using ARIMA model. This paper considered the sequential stages: identification, estimation, diagnostic checking and forecasting used by Box-Jenkins.

1) Identification

This stage basically tries to identify an appropriate ARIMA model for the underlying stationary time series on the basis of Sample Auto correlation Function (ACF) and Partial Autocorrelation Function (PACF). In COVID 19 active case series is non-stationary and is first transformed to natural log and then one can easily identify the possible values of the regular part of the model.

The Bayesian information criterion (BIC) is a criterion for model selection among a finite set of model. The model with minimum normalized Bayesian Information Criterion (BIC) was chosen to prove it mathematically [Jai Sankar T, (2014)]. The various ARIMA (p, d, q) models like (0,0,0), (1,0,0), (1,0,1), (0,0,1), (2,0,0), (2,0,2), (0,0,2), (0,2,0) are executed and from this , ARIMA model (0, 1, 13), which was chosen as the best model based on its low BIC values.

2) Estimation

In this stage, point estimates of the coefficients are obtained by the method of maximum likelihood by Srinivasa Rao Rallapalli et al, (2012) [35]. Associated standard errors are also validated, suggesting which coefficients could be dropped. Model parameters were estimated using SPSS software and the results of estimation are presented in Table 2 and the R value was 0.991. Hence, the most suitable model for COVID 19 cases was ARIMA (0, 2, 0), as this model had the lowest normalized BIC value, good R and better model fit statistics (RMSE and MAPE). The fit measures of the model are presented in Table 1. The results of this model show that the predicted data is close to the actual COVID 19 case data available.

TABLE 1 PRECISION OF THE COVID 19 PREDICTION BY ARIMA MODEL

ARIMA Model (p,d,q	R^2	Root Mean Square Error (RMSE	Mean Absolute Percentage Error (MAPE)	Normalized BIC value

)		)		
0,1,1 3	0.99 6	5344.9 00	12.465	17.223

3) Diagnostic Testing

The article also examine whether the residues of the model gone into white noise process or not. After the model is finalized, re-estimation and diagnostic checks are applied again until the coefficients are reasonably statistically significant and the residuals are random as shown in Figure 2.

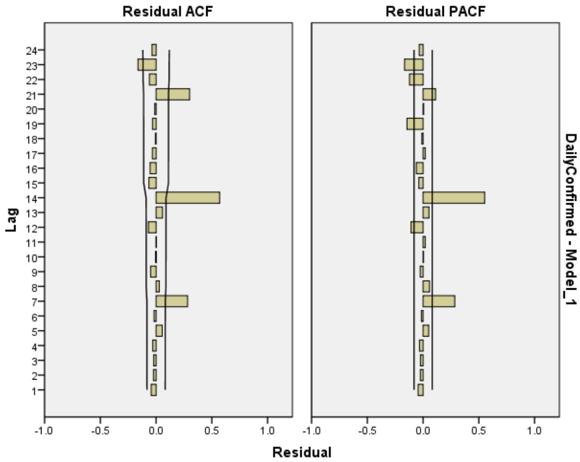


Figure 2. Residuals of ACF and PACF for COVID 19

4) Sensitivity Analysis

In order to make the time series stationary the value of d is to be computed. Differencing the series should be done carefully as it may overfit the series and in turn the model parameters are disturbed. The correct order of differencing is the one in which the stationary series oscillates between the defined mean and the auto correlation function (ACF) reaches to zero. The threshold value for ACF should be less than 1 and if the first lag itself is negative then the series is over differenced. To test the stationary, Augmented Dickey Fuller Test [21] is applied. For the considered data, the ACF test is shown in Figure 3 (a) for the infections and 3 (b) for deceased.

The ACF test shows that the data is not in the weak stationary category and can the level of differencing computed is fit to proceed with the ARIMA model. The number of lags is set to 20 for the proposed model. On identifying the level of difference, the next process is to determine the value of p. The computation of p is shown in Figure 4.

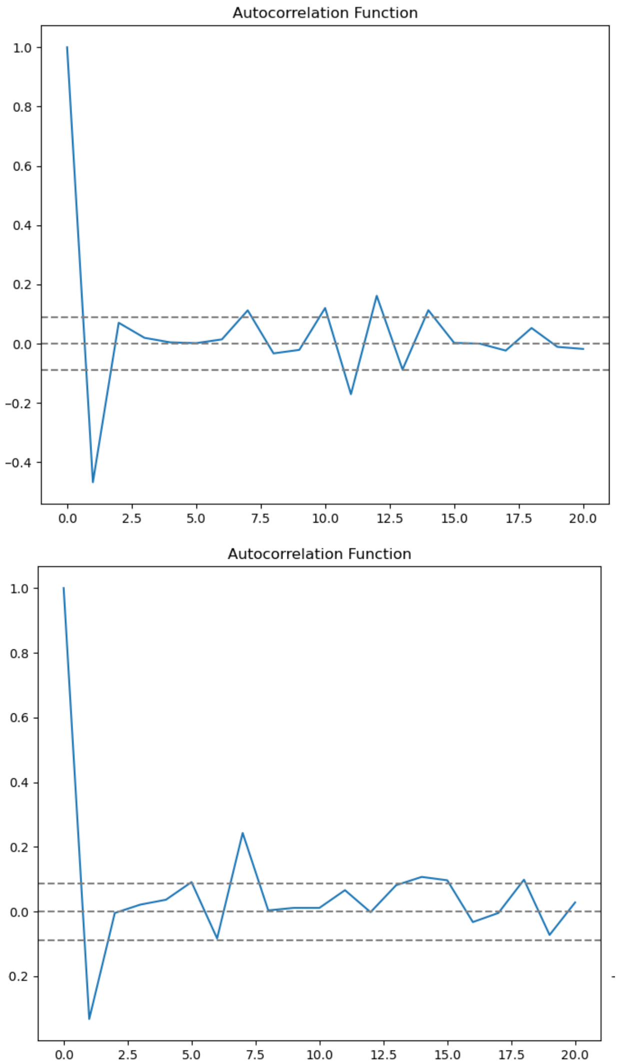
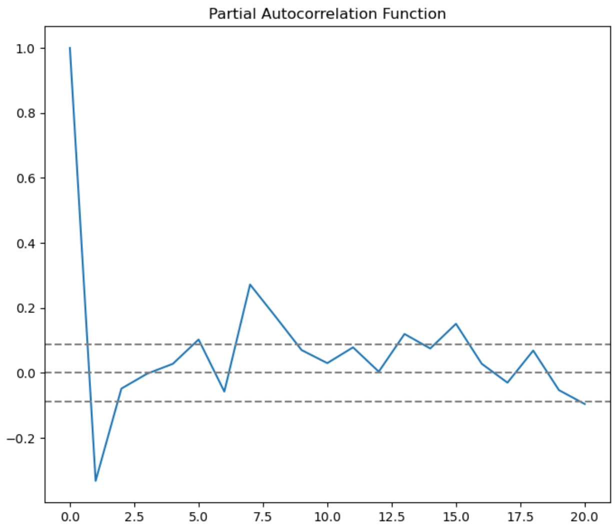
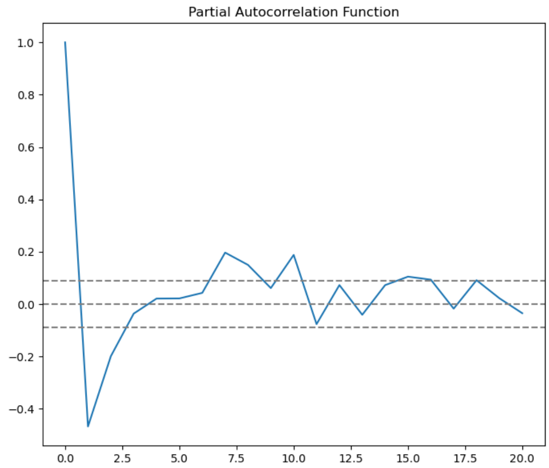


Figure 3. Auto Correlation Function



(a) Infections



(b) Deceased

Figure.4. Partial Auto Correlation Function

In Figure 4, it is observed that the lag1 is significant to proceed with the further calculations. In the next stage, the value of q is computed and it is referred to as the error of the lagged forecast for both the infections and deceased. Figure 5(a),5(b)and 5(c) represents the q component and the level of orders considered is 0, 1 and 2 for the infected cases.

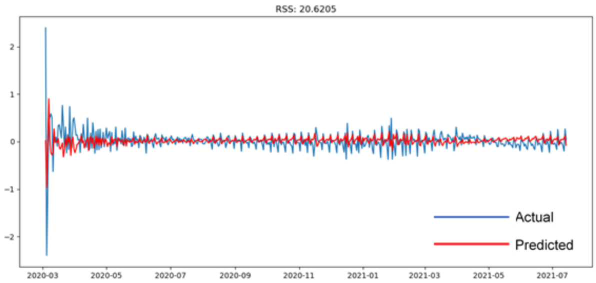


Figure 5(a). q Computation – Order of Differencing 0 (Infection)

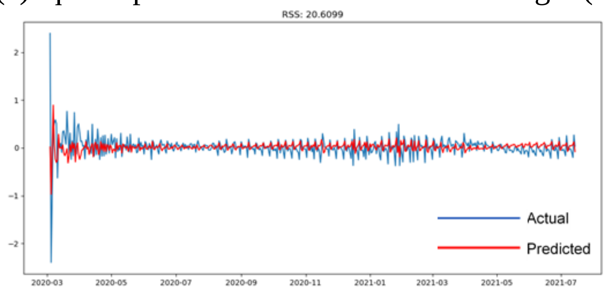


Figure 5(b). q Computation – Order of Differencing 1 (Infection)

Figure 5(c). q Computation – Order of Differencing 2 (Infection)

In the similar manner the Figure 6(a), 6(b) and 6(c) represents the q component and the level of orders considered is 0, 1 and 2 for the deceased cases.

Figure 7(a). ARIMA Model – Infections

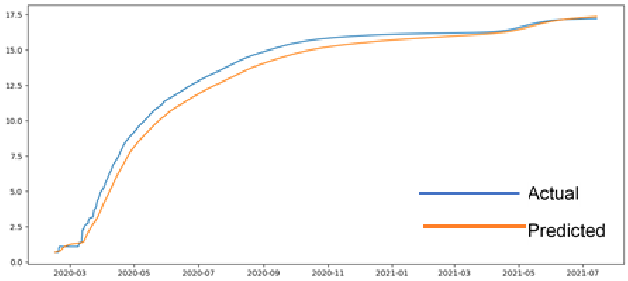


Figure 7(b). ARIMA Model – Deceased

The difference in the prediction of the infections and deceased of the proposed model is close to the actual values. The statement is evident from the Figure 7(a) and 7(b). The correctness of the proposed model is discussed in the following section.

IV. Results and Discussion

The proposed model is evaluated by computing the Root Mean Square Error (RMSE), which is the standard deviation of the prediction errors. Figure 8(a) and 8(b) shows the RMSE error for the infections and deceased cases.

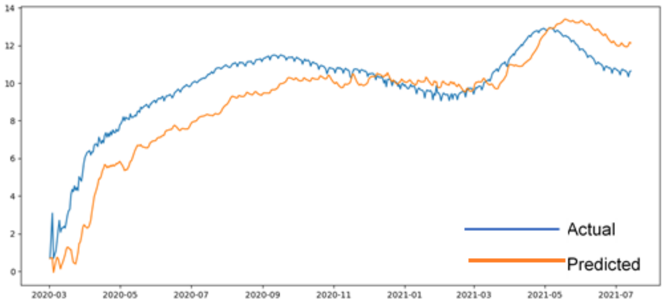


Figure 8(a) Evaluation – RMSE – Infections

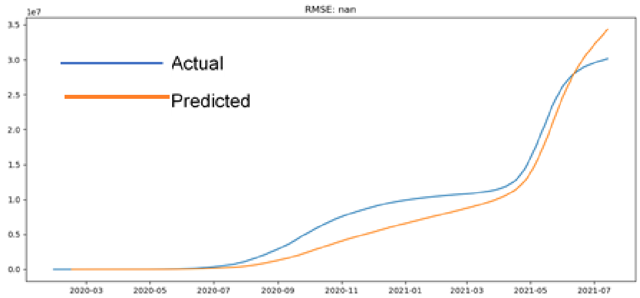


Figure 8(b). RMSE - Deceased

The RMSE is close to the actual and the predicted values. Table 2 and 3 shows the sample of date wise error values of infections and deceased cases for various values of ‘d’ respectively. The sample considered for every month on 3rd day for the period from March 2020 to July 2021.

TABLE 2. RMSE – INFECTIONS (DATE WISE)

Date	d=0	d=1	d=2
03/03/2020	0.023788	0.023788	0.693147
03/04/2020	-0.77154	-0.74776	0.716935
03/05/2020	0.59243	-0.15533	-0.05461
03/06/2020	0.214508	0.059182	0.537821
03/07/2020	-0.0708	-0.01162	0.752329
03/08/2020	0.060515	0.001134	0.052865
03/09/2020	0.074721	0.063937	0.048807
03/10/2020	0.095796	0.013645	0.043164
03/11/2020	0.027205	0.058584	0.027388
03/12/2020	0.052336	-0.018296	0.038504
03/01/2021	0.011041	0.093524	0.072009
03/02/2021	0.046609	0.015081	0.048496
03/03/2021	- 0.047103	0.073046	0.002988
03/04/2021	0.080395	-0.010522	0.070819
03/05/2021	0.003372	0.028962	0.023788
03/06/2021	- 0.003136	0.036255	0.070205
03/07/2021	0.081722	0.016465	0.031181

TABLE 3. RMSE – DECEASED (DATE WISE)

Date	d=0	d=1	d=2
03/03/2020	0.00481155	0.054134924	-0.00388666
03/04/2020	0.073702067	0.000450579	0.075245852
03/05/2020	- 0.073247401	0.083251977	0.033356061
03/06/2020	0.098450114	0.083675204	- 0.011564717
03/07/2020	0.074371625	- 0.007700403	0.068289992
03/08/2020	0.092430621	0.079532417	0.081840783
03/09/2020	0.06080461	0.03277875	0.090663781
03/10/2020	0.011185696	0.07137068	0.011627496
03/11/2020	- 0.096381678	- 0.011515443	0.015357309
03/12/2020	0.077610347	0.025515154	0.013156593

03/01/2021	0.028376412	0.02460982	-0.007783151
03/02/2021	0.046088722	0.073556576	0.026419056
03/03/2021	0.042881945	0.063354407	0.013173732
03/04/2021	-0.029882201	0.035506657	0.043008846
03/05/2021	0.015678442	-0.045205737	0.037915764
03/06/2021	0.022414978	0.059358356	0.074468708
03/07/2021	0.057548858	0.097141596	0.002330914

V. CONCLUSION AND FUTURE SCOPE

This work resulted in predicted the number of infections and deceased using ARIMA model on the considered data set. The proposed time series based prediction of Covid-19 cases results in an accuracy of 91.26% in case of infections and 90.19% for deceased for next one week as per the current data taken in this work. The implemented model is based on the data history of infected and deceased. However, there are other factors those may influence the spread of the disease. This prediction based study is limited to a particular set of parameters, instead of a comprehensive model.

In future researchers can include the features like population, social awareness, measure on social distancing policy, contract tracing, climatic conditions, utilization of public transport systems, location-based movement of individuals shall be considered and models shall be built using Deep Learning algorithms. The study provides evidence on immediate future COVID cases in India, which can be considered for future policy making and formulating strategies for not only managing COVID 19 but also in preventing further spread.

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