Covid Modelling in India

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Abstract

The model was designed to estimate the growth of COVID-19 pandemic in India and its states. Up till now, we have developed a modified Susceptible-Infected-Recovered (SIR) model and combined it with a Susceptible-Infected-Exposed-Recovered-Dead (SIERD) model for the contagion, and we used official data provided by the Indian government up to May 9th, 2020 for quantifying the parameters of this model. The other part of our approach is that we consider all the population to be susceptible, we don't have a metric to determine the number of exposed people in this model. Identifying the infected people's growth, recovery and death rates we use data to optimise Beta values and try to calculate an approximate R_0 value.

INTRODUCTION

Mathematical models can offer a precious tool to public health authorities for the control of epidemics, potentially contributing to significant reductions in the number of infected people and deaths. Indeed, mathematical models can be used for obtaining short and long-term predictions, which in turn may enable decision makers to optimize possible control strategies, such as containment measures, lockdowns and vaccination campaigns. Models can also be crucial in a number of other tasks, such as estimation of transmission parameters, understanding of contagion mechanisms, simulation of different epidemic scenarios, and test of various hypotheses. Several kinds of models have been proposed for describing the time evolution of epidemics, among which we distinguish two main groups: collective models and networked models. Collective models are characterized by a small number of parameters and describe the epidemic spread in a population using a limited number of collective variables. They include generalized growth models , logistic models , Richards models , Generalized Richards models , subepidemics wave models, Susceptible-Infected-Recovered (SIR) models, and Susceptible-Exposed-Infectious-Removed (SEIR) models . SIR, SEIR and other similar models belong to the class of the so-called compartmental models. Networked models typically treat a population as a network of interacting individuals and the contagion process is described at the level of each individual.The evolution of COVID-19 infections in each region, has been modeled via the stochastic susceptible-infected-recovered (SIR) model which is given as,

We use a SEIRD model , where the class of Removed in the SEIR model is partitioned into the Recovered (again labelled with (R)) and Dead (D). Hence SEIRD consider five classes: Susceptible (S), Exposed (E), Infectious (I), Recovered (R) 103 and Dead (D). Their sum, at each time t, is the total number N of individuals in the 104 examined population, i.e. N = S + E + I + R + D. The system of equations in the SEIRD model is given by:

$$\frac{dS}{dt} = -\frac{\beta}{N} SI$$

$$\frac{dE}{dt} = \frac{\beta}{N} SI - \alpha E$$

$\frac{dI}{dt} =- \frac{1}{T} I$

$\frac{dR}{dt} = \frac{1-f}{T} I$

Let β be the average number of contacts that are sufficient for transmission of a person per unit of time t. Then βI/N is the average number of contacts that are sufficient for transmission with infective individuals per unit of time of one susceptible and (βI/N)S is the number of new cases per unit of time due to the S susceptible individuals. Furthermore, let γ be the recovery rate, which is the rate that infected individuals recover or die, leaving the infected class, at constant per capita probability per unit of time.

Where N is the total population, β is the infection rate, a coefficient accounting for the 107 susceptible people get infected by infectious people, α represents the number of days for 108 the transition from Exposed to Infectious (i.e. the incubation rate), TI is the average 109 infectious period and f is the fraction of individuals who die. 110 The system (1) of ODEs is solved by starting from an initial time t = t0 where the 111 values of the populations S(t0), E(t0), I(t0), R(t0), D(t0) are assigned on the basis of the 112 available data at that time and integrated up to a final time T. D is function taken according to the given death rate in India.

The parameters of the model were optimized based on the data obtained for different European regions and India. The criterion for optimization was to simultaneously minimize the square integral error, terminal error and terminal rate error, between the actual data and daily samples of the simulated data. Further, because we have data for more number of days for European countries, we try to use the parameters from those countries and appropriate it on the Indian data which is for a lesser number of days. The assumption is that India may be in the catch game (which, of course, we do not want) if the behaviour of people is taken to be similar. We have to base our predictions based on some gross assumptions under the given circumstances.

Modelling

The model was Implemented in MATLAB and all the simulation was done in MATLAB too. Implementation of the model was done in a ode solver file which solves the differential equations when initial parameters are given to it in the state files. The conditions and values for the differential equations were-

Death = 0.034; Death rate of COVID-19 (March, 2020)

Pre_infec = 5.2;

f = 1/Pre_infec;

Duration = 14;

β values had to be modified for each state of India and taking data upto April 19th we estimated a line of best fit for cases upto 22nd march(before lockdown) and post 22nd march(post lockdown) we also took into account the 7 day period for symptoms to appear for new cases to keep emerging. This part of the model was put under a policy.m file to take into account social distancing, use of sanitizers, masks and implementation of curfew by the Indian government. The Beta value was fit each day and a trivial approach of taking a mean of the Beta values for to predict future value also applying several supervised machine learning algorithms to estimate the beta value when it’s fed the total of number cases growing each day.

We have used Indian COVID-19 data available. The primary sources of the data are the Ministry of Health and Family Welfare, India (https://www.mohfw.gov.in), https://www.covid19india.org/, and Wikipedia (https://en.wikipedia.org/wiki/2020_coronavirus_pandemic_in_India#Statistics)

Factors Considered-

1. Implementation of Lockdown on 22nd March.
2. Extension of lockdown till 17th May.
3. Relaxation of curfew in states with predominantly green and orange zones post 3rd March.
4. No International flights in and out of India.
5. Total active cases.

R_0 (%) = (Total cases/Total tests) *100= 5.11 %

CFR (%) = (Total death /Total cases) *100= 4.29%

The Beta values are calculated based on best fit upto 29th April and they are taking as constant post april 6th on the assumption that social distancing continues post lockdown. Two different matrices are calculated and put together for the model, time-span1 for the first matrix is taking to be 14 days and the time-span2 is post lockdown period.

$\frac{dy}{dt}$ = [dS; dE; dI; dR; dD]

y represents the solution matrix which provides us the number of Susceptible, Infected, Recovered and Dead values for each upcoming day.

Ode45 is used to solve the system of differential equations in MATLAB.

[t,y] = ode45(odefun,tspan,y0), where tspan = [t0 tf], integrates the system of differential equations y′=f(t,y) from t0 to tf with initial conditions y0. Each row in the solution array y corresponds to a value returned in column vector t.

Simulation and Results

All simulations are done in MATLAB for a period of 300 days to accurately predict the peak and when the number of susceptible individuals become miniscule.The model has been simulated and the parameters have been optimized based on the infection trends obtained for European countries and India (after 15th March, when the infections started to show an exponential trend). This is done in order to demonstrate the possible growth of infections in India, based on the current trend so far (which is an optimistic case), or based on the European trend (which is the case to be prepared for).

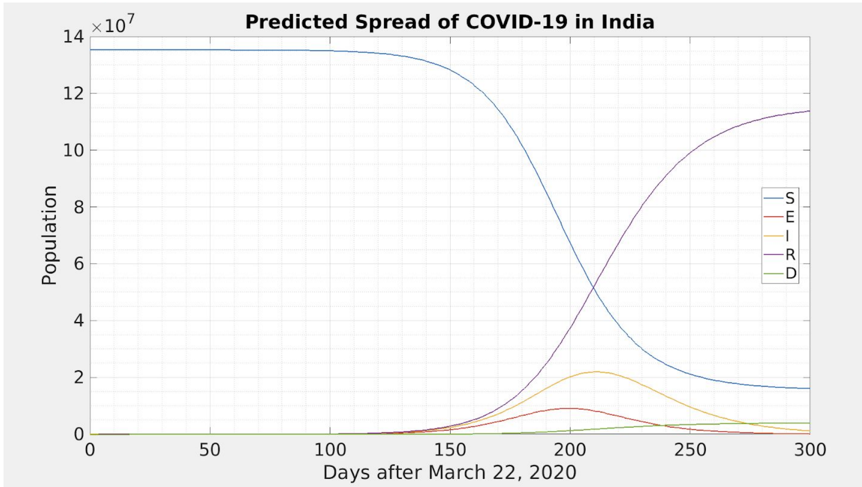

Fig 1. Simulation of growth in India over 300 days most March 22, 2020

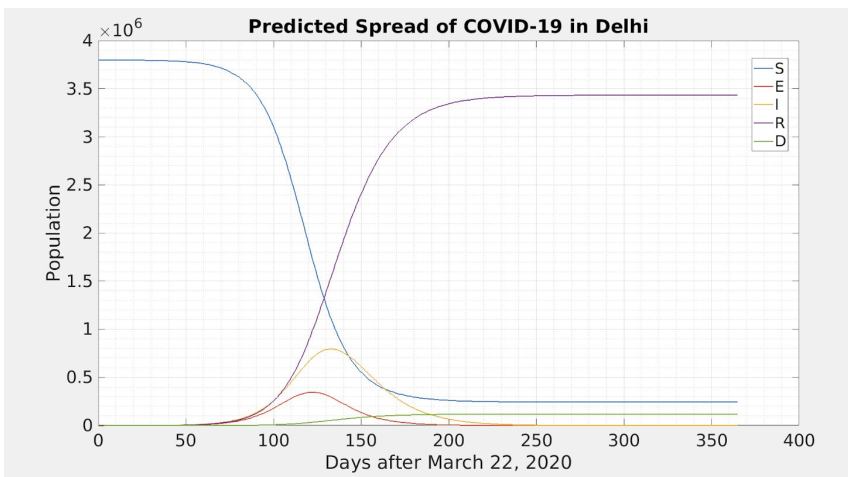

Fig 2. Simulation of growth in Delhi over 300 days most March 22, 2020

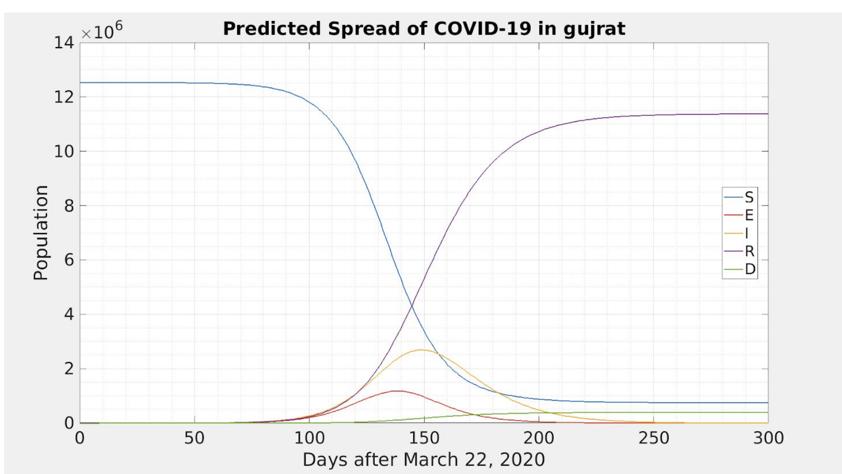

Fig 3. Simulation of growth in Gujrat over 300 days most March 22, 2020

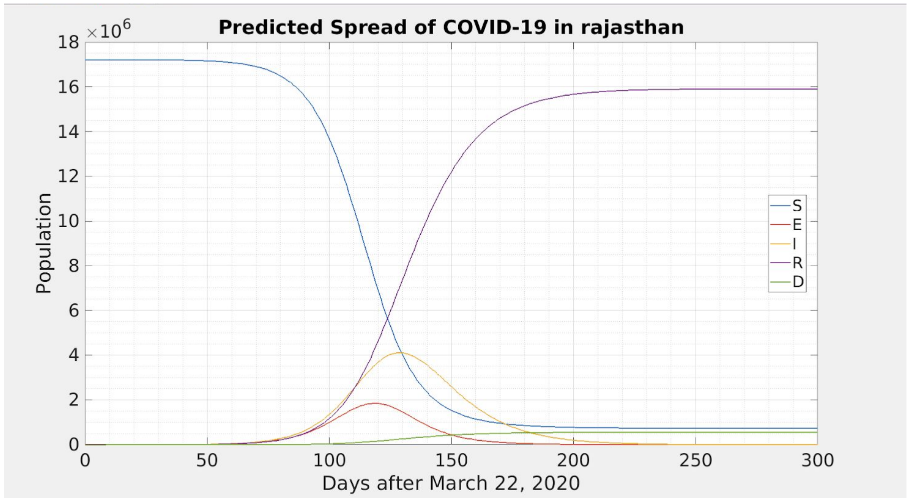

Fig 4. Simulation of growth in Rajasthan over 300 days most March 22, 2020

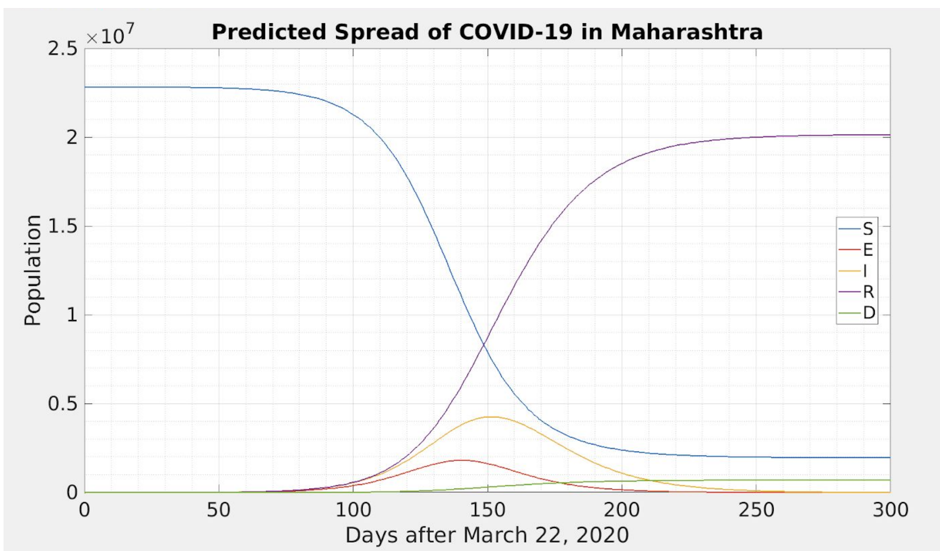

Fig 5. Simulation of growth in Maharashtra over 300 days most March 22, 2020

The infection peaks at about 20 million in India according to this. Several of the top states who are hardest hit by the virus have also been modelled to display peak, also here are some state wise comparisons of the results from the model vs the actual number of cases

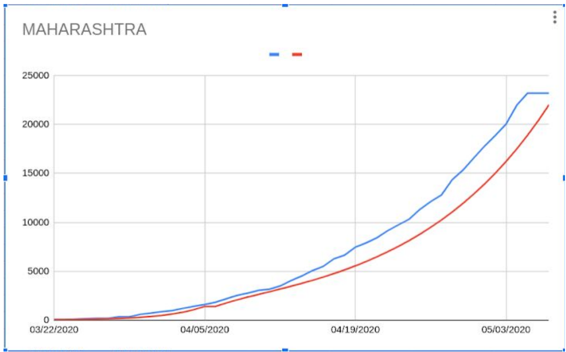

Fig 6. Actual(orange) vs Predicted(blue) cases in Maharashtra

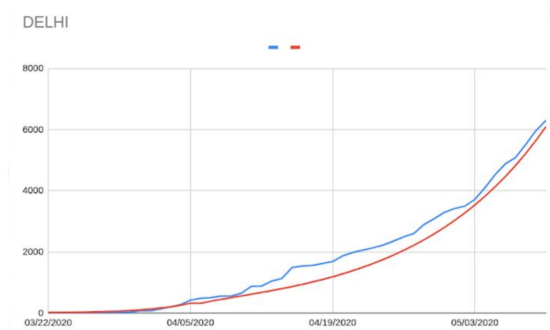

Fig 7. Actual(orange) vs Predicted(blue) cases in Delhi

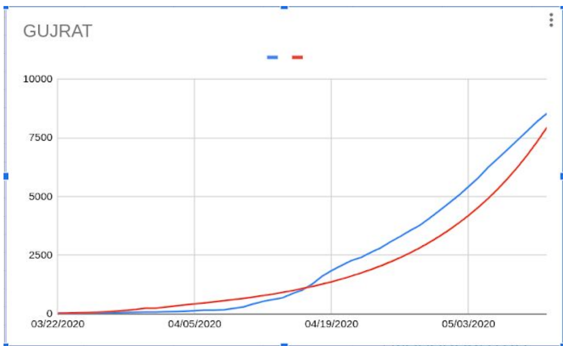

Fig 8. Actual(orange) vs Predicted(blue) cases in Gujrat

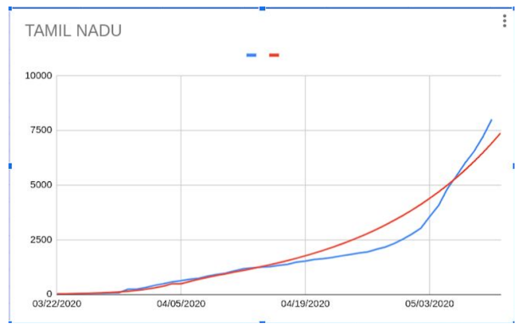

Fig 9. Actual(orange) vs Predicted(blue) cases in Tamil Nadu

The model predicts as we can see a steady growth and has not taken into the number of tests each day and thus does not have any spikes. The accuracy ranged from 80-90% depending on different states. Here are the state wise predictions for the next 60 days(10th May,2020)

STATE	60 DAY PREDICTION
Delhi	47715
Andhra Pradesh	13567
Assam	128
Haryana	1144
Himachal	983
Chattisgarh	198
Goa	0
Gujrat	118777

Madhya Pradesh	100973
Maharashtra	279539
Jharkhand	984
Kerala	3014
Bihar	7797
West Bengal	13955
Himachal Pradesh	900
Telangana	11398
Tamil Nadu	63558
Karnataka	5178
Punjab	11367

Here are the Beta and R_0 values of certain states, the beta was calculated in python by an algorithm used to minimize the Root Mean Squared Error by feeding actual and predicted values to the system, Beta was selected on the basis where the RMSE was lowest between Predicted y and actual y.

STATE	**Beta**
Delhi	0.29
Andhra Pradesh	0.35
Assam	0.57
Haryana	0.41
Himachal Pradesh	0.61
Chattisgarh	0.63
Goa	0.8
Gujrat	0.31
Madhya Pradesh	0.38

Maharashtra	0.26
Jharkhand	0.42
Kerala	0.51
Bihar	0.44
West Bengal	0.38
Telangana	0.33
Tamil Nadu	0.28
Karnataka	0.43
Punjab	0.35

Discussion

This work has been done on the ongoing COVID-19 pandemic, with a thought of providing a simple yet effective model for prediction of the future growth of the pandemic, and evaluation of lockdown and other preventive measures.

Now, we discuss the impact of curfew/lockdown in India. India announced a strict lockdown on 24 March, when the number of reported cases was 536. India observed Janta Curfew and the public activity since that date has been little to none other than essential services. Assuming the same pattern as Hubei in India as well (although the lockdown in Hubei was more stringent with strict police control over individual movements), we can assume that till April 8 (14 days from lockdown) very little effects of social distancing will be seen. By this date, India has reported patients as many as 5274. This number increases greatly in the next coming weeks, this can be attributed to several regions as people were still moving around post janta curfew for a few days before lockdown was strictly imposed, also the availability of testing kits has greatly risen in the past month as India has started manufacturing it’s own kits. As trains and some other services have now opened if community transmission happens and spreads due to the movement of migrant workers and labourers the number of cases may keep increasing exponentially all of may. However, after April 8, India should start seeing the effects of social distancing (provided it is enforced properly) and the curve should start flattening out. At its peak, India can experience anywhere from 0.5 to 2 million cases considering an exponential growth. A recent study by Mandal et has shown that social distancing can reduce cases by up to 62%. Assuming the uncertainty about the compliance in the enforcement of lockdown, we predict the social distancing effects with reductions of 70% in beta the infection rate. India may have seen fewer COVID-19 cases earlier, but now it is close to becoming one of the worst affected countries in the world. There are many states like Maharashtra, Delhi, Madhya Pradesh, Gujrat, Uttar Pradesh, and Andhra Pradesh, who are at high risk, a lot of the country's red zones also predominantly belong to these states. These states are seeing a huge jump in confirmed

COVID-19 cases in the past few days. On the positive side, Kerala has shown how to effectively "flatten" or even "crush the curve" of COVID-19 cases. We hope India can be free of COVID19 in the next few months.

Conclusion

In this paper, we proposed a SEIRD model for the analysis of the COVID-19 outbreak in India. In our new formulation. We highlight that only a few days passed since restrictions started in India and,maybe in the next few days, the effects of such measures will be more evident, hopefully causing a further decrease in the infection trend. In this case, the previsions shown in this paper should be updated by introducing a new time interval at which the decreasing slope of βt should be easily changed by simply modifying one parameter. The proposed model is flexible and can be quickly adapted to monitor various infected areas with different restriction policies.The situation with the coronavirus pandemic in India is very threatening. The proposed simple method of epidemic dynamics comparison can be used to evaluate the actual situation.

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