Data Analytics
Assignment -5

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Implementation

1. I have implemented the SEIRV model using the following recursive equations to get S, E, I, and R each day.

$$\Delta S(t+1) = S(t+1) - S(t) = -\beta(t)S(t)\frac{I(t)}{N} - \epsilon\Delta V(t) + \Delta W(t)$$
$$\Delta E(t+1) = E(t+1) - E(t) = \beta(t)S(t)\frac{I(t)}{N} - \alpha E(t)$$
$$\Delta I(t+1) = I(t+1) - I(t) = \alpha E(t) - \gamma I(t)$$
$$\Delta R(t+1) = R(t+1) - R(t) = \gamma I(t) + \epsilon\Delta V(t) - \Delta W(t)$$

2. I have used the following model for immunity waning as mentioned in the assignment:
   - ΔW (t) = R(0)/30, when t is between 16 March 2021 and 15 April 2021.
   - ΔW (t) = 0 , when t is between 16 April 2021 and 11 September 2021.
   - ΔW (t) = ΔR(t − 180) + εΔV (t − 180), when t is larger than 11 September 2021.
3. As per the instructions given in the assignment, I have computed CIR for each day and also c {bar} (t) and Δi {bar} (t).
4. After computing the above vectors, I calculated the loss function using the below formula and then applied gradient descent algorithm to calibrate the model parameters to match the daily COVID-19 reported cases in Karnataka from 16 March 2021 to 26 April 2021.

$$l(P) = \frac{1}{42}\sum_{t=\text{March 16}}^{\text{April 26}} \left(\log(\overline{c}(t)) - \log(\overline{\Delta i}(t))\right)^2,$$

   The gradient descent algorithm can be described as follows -

$$p(j+1) = p(j) - \frac{1}{j+1}\partial_p l(p(j)),\ p \in P,\ j \geq 0,$$

   Here I approximated $\partial_p l(p(j))$ as $\Delta_p l(p(j))$ i.e. I calculated the gradient wrt to a parameter as the difference in loss after and before perturbing the parameter. To estimate the gradient, I perturb β on either side by ±0.01, perturb CIR(0) on either side by ±0.1, and all other parameters by ±1, and estimate the gradient.

Results -

I have initialized the parameters as follows -

- N , alpha , gamma , epsilon = 70,000,000, 0.172413793 , 0.2 , 0.66
- R0 = 0.20 * N

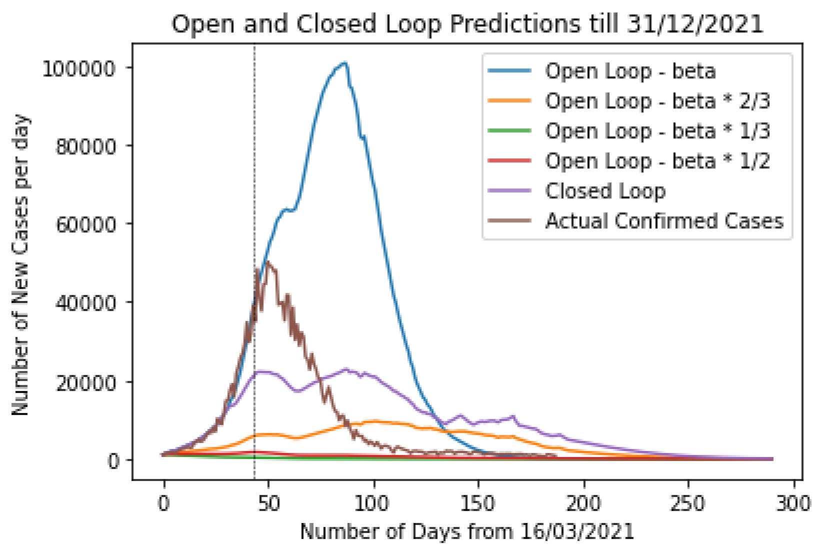
- CIR0 = 12
- E0 , I0 = 0.12 * N / 100 , 0.12 * N/ 100
- S0 = N - E0 - I0 - R0
- Beta = 0.5

After running the algorithm for ~150000 epochs, the loss is reduced below 0.01 and the best parameters I got at loss 0.0099 are as follows :

- BETA = 0.39804954392173675
- S0 = 55832000.00533693
- E0 = 83999.99716872863
- I0 = 83999.99749437576
- R0 = 13999999.999999965
- CIR0 = 14.15799172039157

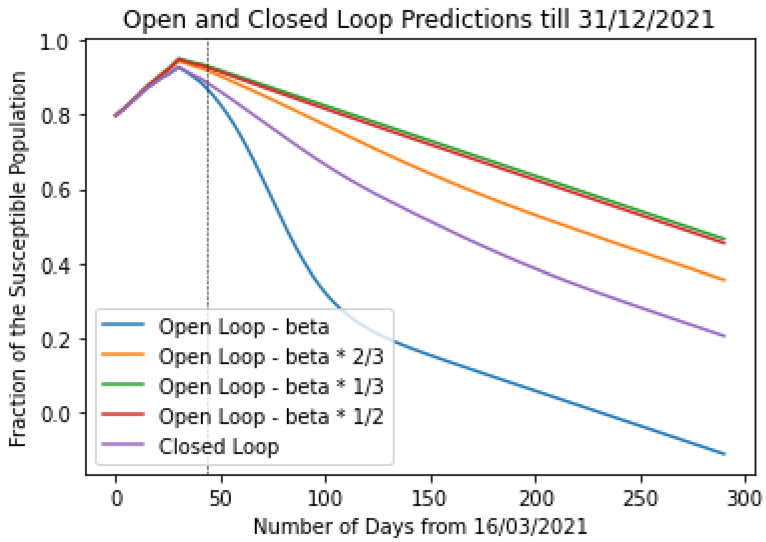
Observations-

Plot 1 - New Cases Per Day



Plot 1 plots the predictions Δi(t) in Open and Closed Loop Case and compare the plots against the actual confirmed cases Δconfirmed(t). The X-axis indicates the number of days passed since 16/03/2021 and Y-axis indicates the new cases per day. Here the brown plot indicates the actual confirmed cases.
We know that by reducing the beta (contact rate) the number of new cases per day should also reduce which can be confirmed from the above plot of Open Loop Prediction whereby by reducing the beta the number of cases per day is also reduced and for a lower value of contact rate, the number of cases per day quickly reduce to zero which indicates if the contact rate is less then the virus won't spread much.
The Closed Loop Prediction is denoted by the purple plot which indicates that if we impose some restrictions like Lockdown etc and control the contact rate then we can prevent the spread of the virus to much extent. We can notice that the peak of the actual confirmed cases is greater than that of the new cases we have predicted in the closed loop case where we have controlled the contact rate.
Note that the dashed vertical line indicates the date 27/04/2021.

Plot 2 - Fraction of the Susceptible Population Per Day



As we can notice in Plot 2 (considering the N fixed), the fraction of the Susceptible Population for the Open loop with Beta is quickly decreasing compared to other plots because of the higher contact rate. In other words, the susceptible population will be exposed to the virus and goes into the next states quickly if the contact rate (beta) is high. That is why we see less decrease in the susceptible population for the lower beta. Note that the dashed vertical line indicates the date 27/04/2021.