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E0 259 Data Analytics Assignment-3

M.Tech (AI) 18224

Q2.) **Calibrate model parameters**

We give a brief overview of the data collection process, and the model parameter calibration here. We have:

$$\begin{aligned}
\Delta S(t) &= -\beta(t)S(t)\frac{I(t)}{N} - \varepsilon\Delta V(t) + \Delta W(t)\\
\Delta E(t) &= \beta(t)S(t)\frac{I(t)}{N} - \alpha E(t)\\
\Delta I(t) &= \alpha E(t) - \gamma I(t)\\
\Delta R(t) &= \gamma I(t) + \varepsilon\Delta V(t) - \Delta W(t)
\end{aligned}$$

In this model the values of $\alpha(= 1/5.8), \gamma(= 1/5)$ and $\varepsilon(= 0.66$ or $0.33)$ are known to us via experimental studies. We have to tune the parameters $P = (\beta, S(0), E(0), I(0), R(0), \text{CIR}(0))$, so as to fit the data given in the Excel sheet from 16^{th} March to 26^{th} April 2021. We should note the following definitions immediately:

- S(t) : Susceptible at time t
- I(t) : Infected at time t
- E(t) : Exposed at time t
- R(t) : Recovered at time t

Firstly we show the data filtering process as below (from the excel sheet):

- Compute **reported infections** at time t : $\bar{c}(t)$ = Cases - Recovered - Deceased. It is important to note the segregation here as our model explicitly consists of three states viz. Infected, Recovered and Exposed
- Then we compute $\Delta\bar{c}(t)$ for the given date range, and do time averaging (last 7 days) as specified.

Now we outline our initialization procedure:

- CIR(0) = 12 as specified in the problem.
- I(0) is initialized as : $I(0) = \bar{c}(0)$*CIR(0). This turns out $\approx 0.4\%$ of the total population, which is close to the initial guess discussed in class.

- R(0) = 35% of the total population.
- E(0) = 0.5% of the total population.
- S(0) = N - R(0) - E(0) - I(0). Assuming a closed system.

Our model:

- Computes CIR(t) = CIR(0)$\frac{T(t_0)}{T(t)}$.
- Assigns $\Delta W(t)$ and $\Delta V(t)$ values according to the given information.
- Does a forward discrete run of the differential system with all the computations.
- Computes $\frac{I(t)}{CIR(t)}$ to match with the tabular data. Then computes a time averaged version of $\Delta i(t)$. This would be used to compare with $\Delta\bar{c}(t)$, to minimize the SSE loss.

Tuning Procedure:

- Gradient Descent is run for β and $CIR(0)$ and the initial conditions $R(0), I(0), E(0)$

Below we describe the model parameters and the plots which try to match the data points.The last three parameters indicate % of the total population. Now we show the fitting curve here:

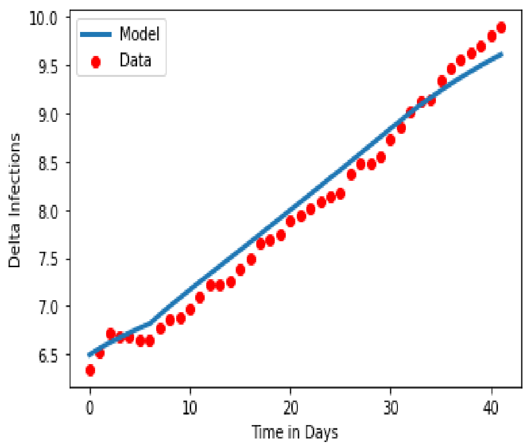

Figure 1: $\Delta i(t)$ from model is fit to $\Delta\bar{c}(t)$ for 42 days, log scale on y-axis

$$\begin{aligned} \beta &= 0.43 \\ CIR(0) &= 12.3 \\ R(0) &= 35\% \\ I(0) &= 0.38\% \\ C(0) &= 0.49\% \end{aligned} \tag{1}$$

Conclusions: We summarize our observations as follows:

- Increasing β resulted in increase of $E(t), I(t)$ more rapidly.
- CIR controls the comparison scale. The whole prediction plots are scaled appropriately when CIR is scaled.
- The initial conditions I(0) and E(0) affect the initial rate of increase in infected cases, with little effect on the later parts of the trajectory.

Q3.) **Predictions after 27^{th} April $\Rightarrow$ 20^{th} September = 146 days**

We introduce vaccination data into the system model. We observed that using a blanket number of 2,00,000 vaccines per day gave rise to negative S(t) values. Hence we decided to use the vaccination data as specified in the **First Dose Administered** column in the sheet. The key-points of the simulation process are:

- $\Delta W(t)$ was taken to be 0 after 15^{th} April and until 11^{th} September. Thereafter $\Delta W(t) = \Delta R(t-180) + \varepsilon \Delta V(t-180)$.
- E(0),R(0) values were chosen as **end of parameter tuning simulation (Q2), i.e 27^{th} April**.
- CIR(0), for start point of 27^{th} April was chosen as CIR(42) from the above simulation (Q2)
- I(0) was computed as $I(0) = \bar{c}(0)$*CIR(0). Here the time index 0 corresponds to the date 27^{th} April.
- S(0) = N - E(0) - I(0) - R(0) to maintain conservation.
- Unlike the earlier figure, here we show the number of people infected at time t (earlier it was change in infections)

Open Loop Control

In open loop control we have fixed β, as computed earlier. We show the comparison plot from dates: 27^{th} April to 20^{th} September 2021.

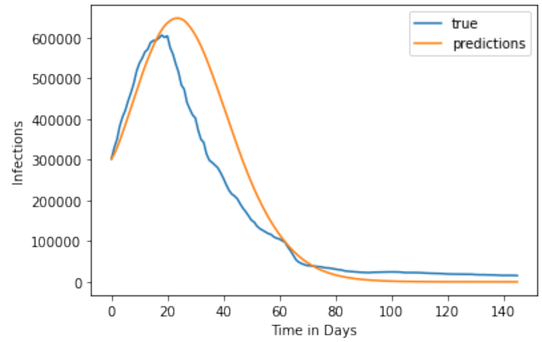

Figure 2: Open Loop Control Predictions

Closed Loop Control

In closed loop control we have variable β, as per last week's average caseload. We show the comparison plot from dates: 27^{th} April to 20^{th} September 2021.

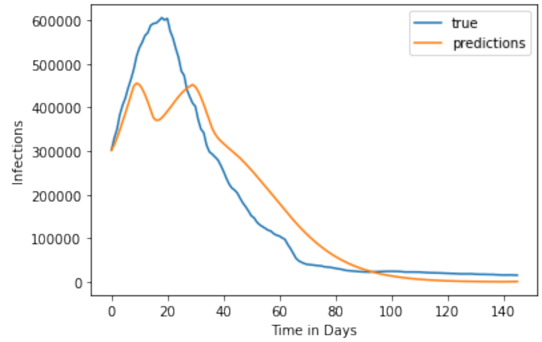

Figure 3: Closed Loop Control Predictions

Conclusions

- In open loop control, we can observe the predicted caseload outnumbers the actual caseload, this maybe due to containment strategies such as lockdown, etc. put in place.
- The dynamic closed loop adjustments enable us to manage the caseload extensively. This is because even with small changes in the contact rate β, we observe large change in the dynamics.