Parameter Estimation for SIR-Type Models of COVID-19 Over Short and Long Terms.

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Introduction & Motivation

- COVID-19 puts our society into a “new normal” where the new policies affect the lives of many around the world.
- Scientists produce mathematical models with the ambition to forecast the dynamics of the outbreak of the SAR-Cov-2 virus and its variants.
- One of the applications of these models is the allocation of therapeutic facilities such as ventilators.
- The primary purpose of the present project is to introduce an accurate parameter estimation of the model to assess the solver’s reliability in comparison with available data.
- The result of this project will help with the parameter tuning of the SIRW2 which is believed to have positive predictions on the dynamics of COVID-19 outbreaks in the long term.

Methods & Approach

- A critical aspect of the reliability of the predicting models is the tuning of the parameters. In this project, we tuned our parameters using a library in Python called Py-BOBYQA.
- We utilized Python to integrate and graph our models with respect to time. With Py-BOBYQA, we assigned our models the initial values for our parameters, then we minimized the differences, or the errors, between the estimated data points through our model and the actual data to find parameters that best fit our models with the observed data.
- We generated our artificial dataset by different predicting models, then we cross-checked the validity of our method by tuning parameters for those models.
- Our approach through the help of Py-BOBYQA library is efficient and reliable.

Results

We successfully tuned the parameters for the SIR and SIRE models with the Py-BYBOBA library:

$$\frac{dS}{dt} = \gamma N - \gamma S - \beta\frac{SI}{N}$$
$$\frac{dI}{dt} = \beta\frac{SI}{N} - \omega I - \gamma I$$
$$\frac{dS}{dt} = \omega I - \gamma R$$

$$J = \frac{1}{2}((S_{observed} - S_{measured})^2 + (I_{observed} - I_{measured})^2 + (R_{observed} - R_{measured})^2)$$

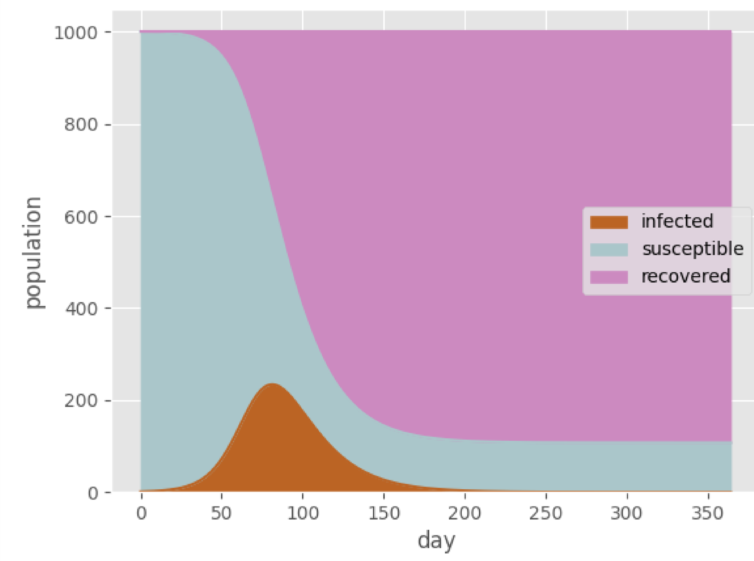

Figure 1: SIR Model to Predict and Generate Data.

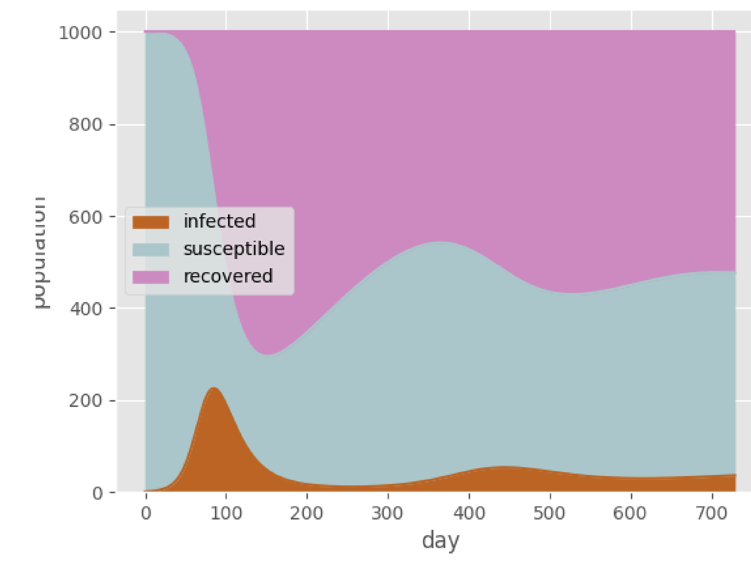

Figure 2: SIRE Model to Predict and Generate Data.

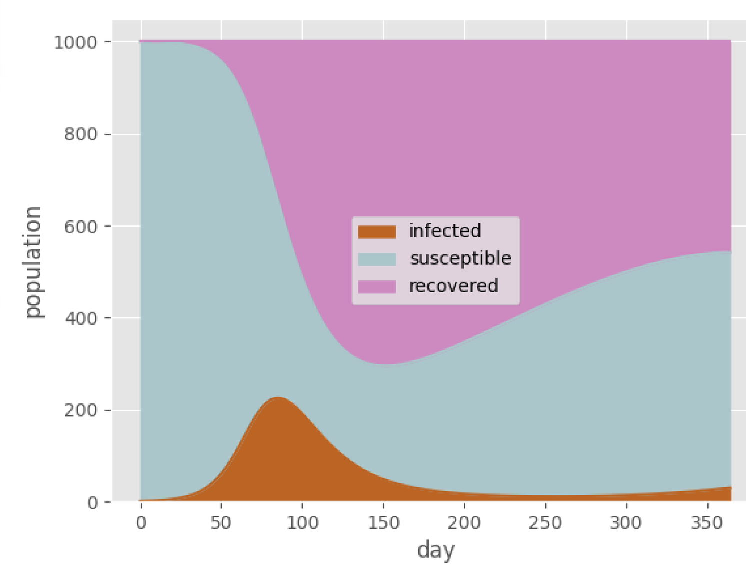

Figure 4: SIRE Model to Generate Data

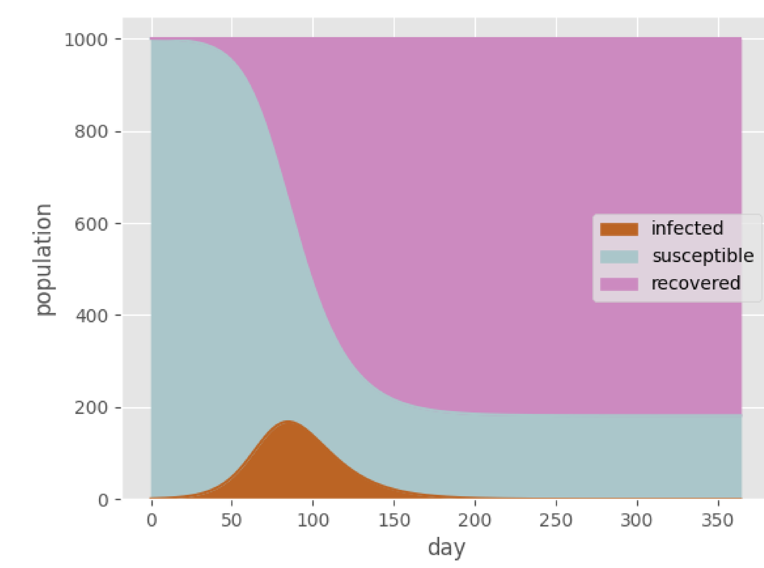

Figure 5: SIR Model to Predict Data

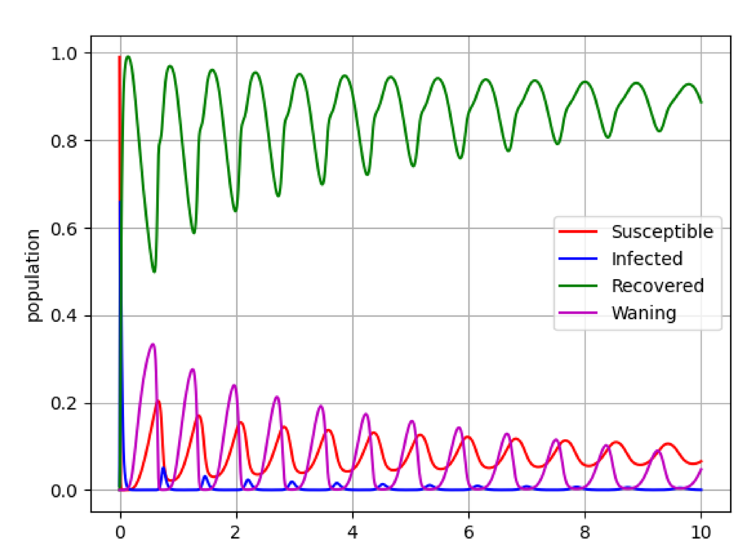

Figure 6: SIRW Model.

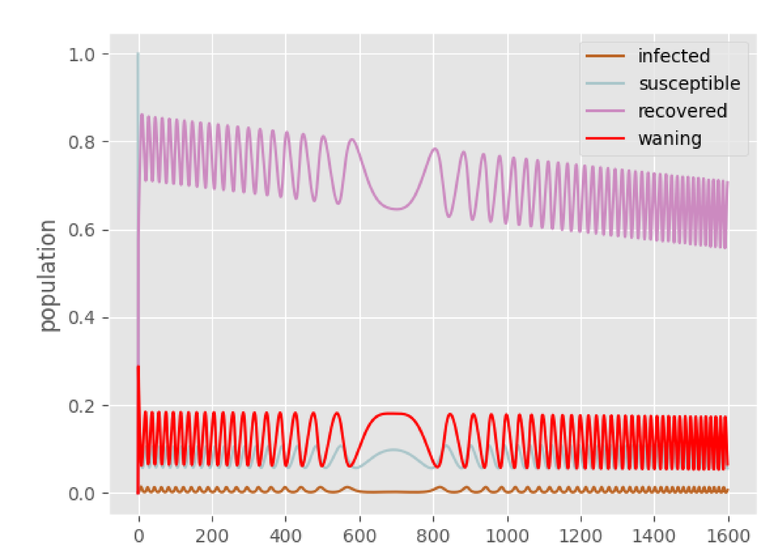

Figure 7: SIRW Model.

As we used a simple model to predict a more complicated dataset, our model could only predict accurately in the short term.

Conclusions & Future Directions

- The Py-BOBYQA can be used to tune parameters for simple models like SIR and SIRE; however, it failed to tune parameters for more sophisticated models like SIRW and SIRW2.
- Our method can only tune three out of five parameters correctly.
- SIR and SIRE models are good for short-term predictions, but their forecasts are unreliable for the long-term goal.
- The goal of this project is to tune the parameters for the SIRW2 model, but the library we used failed to tune the suitable parameters for the SIRW and SIRW2 models. Thus, we are finding alternative ways to solve this issue: The Bayesian Approach and Machine Learning.
- We believe that the SIRW2 model forecasts the dynamics of COVID-19 accurately even for a long-term prediction. Therefore, we are working on the alternatives to tune the parameters for the SIRW model first, then SIRW2.

Acknowledgements

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References:

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