Data Driven Modeling and Simulation – Project: Working with an Agent-based Model of COVID-19 dynamics and interventions

1 The Project

During the project, you will work with a real model of COVID-19 dynamics and interventions that was already used to inform policy decisions (e.g., in the US, UK, and Australia), and as part of numerous research studies. For example, in one particular study the test-trace-quarantine strategy was investigated based on data from Seattle, WA.

The project will enable you to apply and deepen what you learned in the lectures and exercises. Moreover, you can put your problem solving and coding skills to work, as well as your teamwork and time management skills.

To complete the project successfully (and thus to be admitted to the exam) you have to complete all the milestones below. For each milestone, write a report of approx. 3-6 pages using the Springer LNCS LaTeX template. The reports should include all relevant visualizations of experiment results, links to your code and instructions on how to execute it, and references if further literature was consulted. Send your reports to pia.wilsdorf@uni-rostock.de by 23:59 CET of the deadline date. At the end of the semester (on 28.01.2022), you will present your main results in a short talk to your peers and tutor.

If you get stuck, don't hesitate to contact your tutor for help.

2 Milestones

22.10.2021 **Find a Group:** Form a group of 2-3 students. If you don't know anyone, or missed the kickoff meeting, you can use the Blubber in Stud.IP to connect with other students. Then write the tutor (pia.wilsdorf@uni-rostock.de) an email with all the names of your group members (1 email per group). Please also inform the tutor if there are any changes in your group's composition during the semester.

05.11.2021 **Literature Work:** Read the paper "Covasim: an agent-based model of COVID-19 dynamics and interventions". Summarize a) what is the modeling paradigm and how is it different to traditional SIR models, b) what

are the model parameters and how were their values determined, c) how is the intervention "physical distancing, masks, and hygiene" implemented, and d) how is the intervention "vaccines and treatments" implemented.
Using this model, a simulation study was conducted, investigating the test-trace-quarantine strategy for the Seattle, WA region. Read the paper "Controlling COVID-19 via test-trace-quarantine" and summarize a) what was the objective of the simulation study, b) what data were used to calibrate the model, c) how was the calibration conducted, d) what simulation experiments were conducted with the calibrated model, e) what are the main results of the simulation study.

19.11.2021 **Reproducibility:** Reproducibility of experiment results is crucial for increasing the validity and credibility of simulation models. ACM therefore encourages scientists to publish their software artifacts alongside their papers. The artifacts are then evaluated by an independent reviewer who awards badges for the "degree" of reproducibility.
For the Seattle simulation study, the software artifact was published at both GitHub and Zenodo. Try to reproduce the paper results (i.e., all main plots) using this artifact. Then, assign the appropriate reproducibility badges to the artifact. Explain in detail the reasons for selecting/not selecting a badge.

03.12.2021 **What-if Analysis:** Familiarize yourself with the Covasim code. You will find installation instructions and tutorials here. One important feature of Covasim are the various pre-implemented interventions, which can be customized as needed to assist in the policy making process. Analogously to the tutorial, implement an own set of what-if scenarios to show how either the type, strictness, timing, or combination of interventions affects the dynamics of the pandemic. Since we are dealing with a stochastic model, run 100 simulation replications (runs) for each what-if case and plot the mean trajectories with 90% confidence interval bands.

31.12.2021 **Sensitivity Analysis and Experiment Design:** Since its first appearance, the SARS Coronavirus type 2 has developed several variants due to changes/mutations in the virus's genes. Some of these mutations greatly alter the properties of the virus and change the dynamics of the pandemic, e.g., due to an increased transmission or higher lethality (more severe disease). Apply a global sensitivity analysis (SA) using the Method of Morris with at least 4 model parameters and quantify their impact on the model outcome ("number of death"). In your analysis include at least one model parameter, from which you expect a small impact and at least one parameter, from which you expect a strong impact on the mortality. What is worse - a mutation yielding a virus variant with a higher lethality or a higher contagiousness? Repeat the analysis using another SA method that is based on a Latin Hypercube sample, and present and interpret the results. For your analysis you can use one of the available sensitivity analysis libraries in Python, such as

SALib (https://salib.readthedocs.io/en/latest/). Remember to run multiple replications per design point as the simulation is stochastic, and document your code carefully!

14.01.2021 **Calibration:** In Covasim, you can load demographic data and case data for a specific location, as demonstrated here. Find a case data set from Germany (plus corresponding demographic data). Calibrate the model to this data using mean squared error as a distance measure and optimization methods from the scipy package, as demonstrated here. Compare at least two different optimization methods regarding their performance (convergence, runtime). In your report, also explain how these methods work, and why you see this behavior. Then, re-run the what-if experiments and the sensitivity experiments you conducted with the pre-calibrated model during the previous milestones. How have the results changed?

28.01.2022 **Presentation:** Prepare some slides (e.g., using PowerPoint or LaTeX) and *present the most interesting results* from your project to your peers and tutor. The talk should be *approx. 5 min per person*, so you might not be able to present everything from the reports. We plan to do the presentations as an in-person meeting on *28.01.2022, 11:15–12:45 CET, AE22-SR109*.