TRANSP-OR EPFL

Semester project: Modeling Individual Activity Schedules and Behavior Changes in COVID-19 Using Metaheuristic Optimization

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Professor: Michel Bierlaire
Supervision: Cloe Cortes Balcells and Fabian Torres

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1 Project description

The outbreak of the COVID-19 pandemic has significantly impacted the behavior and activity plans of individuals worldwide. When facing restrictions or directly affected by the virus, people tend to alter their behavior, leading to changes in their planned activities. To accurately model the spread of COVID-19 using activity-based epidemiological models, it is essential to consider a network that includes all the facilities where people meet each other. Failing to do so may result in a substantial overestimation of infection rates. Additionally, when specific types of activities are restricted by governmental measures, individuals often choose to substitute them with alternative activities. Unfortunately, existing agent-based models either provide a limited sample of the network or lack the flexibility to incorporate activities outside individuals' desired schedules, such as those that can be shortened, expanded, or removed. Moreover, activity-based models that permit such flexibility are often computationally intensive and impractical for application in sizable populations like Lausanne, which consists of approximately 150,000 individuals.

The primary objective of this project is to develop an innovative approach that addresses these limitations by using a metaheuristic optimization technique already developed by TRANSP-OR lab, to generate personalized activity schedules for individuals. We will use synthetic population data including information about individuals' characteristics and a comprehensive activity network with coordinates for each facility. The proposed methodology aims to create schedules that optimize a given utility function for every individual. This utility function will consider individual preferences, activity durations, and the impact of COVID-19 restrictions on activity choices.

The expected outcomes of this project include a novel framework that provides insights into how individuals modify their behavior and activity plans during periods of COVID-19 restrictions. By integrating a comprehensive network and allowing individuals to select activities from outside their desired schedules, the proposed model will contribute to more accurate and comprehensive epidemiological models. The output of this model will be used as an input for the Interdisciplinary Behavioral Model (IBM) developed by the TRANSP-OR lab. This model integrates individual behavior into both epidemiological and mobility models by combining interdisciplinary research. It integrates epidemiology, mobility, and behavioral modeling, to create a comprehensive model that considers individual-specific behavior in the context of testing, infection levels, and daily activities. Policymakers can leverage these models to make informed decisions regarding the implementation of restrictions and the development of effective risk mitigation strategies.

2 Main deadlines and general information

This project is a semester project assigned to one student. The student will submit a report and present his work at the end of the semester (following EPFL's submission deadlines).

- Official starting date: 19th September 2023
- ECTS: 12 (around 18h a week)
- Duration of the project: 17 weeks, excluding the week of Christmas
- Delivery date: 10th January 2024
- Final presentation: still to decide, but probably 12th January 2024

The main deliverables are the following:

- Midterm presentation: it should last 15-20 minutes and should include slides.
- Report: the final report and any developed code will be handed on the official submission date, at 12 (noon).

The report is expected to satisfy EPFL's requirements for both quality and plagiarism. The code handed in must be documented and well-structured. This means that anyone needs to be able to run the code and reproduce the results in the analysis.

3 Specific objectives and deliverables

The main objectives and deliverables for this project are the following:

1. **Literature review:** The student should become familiar with the different agent-based models and if a link with COVID-19 has been done in the literature, and deliver a literature review.
2. **Methods and data:** We will work with the MATSim synthetic population which includes individuals' characteristics and activity network data for the target region. There will be a

big task on preprocessing XML inputs to pandas dataframes. We will provide scripts with similar examples if needed. A proficiency level in Python language is required for this project. As methods, we will use metaheuristic algorithms such as genetic algorithms or simulated annealing.

3. **Applications and analysis:** This project involves several key components to develop an activity-based model. To achieve this, the project will follow the following steps:

   - Define Utility Function: Formulate a utility function that accounts for individual preferences, activity durations, and the influence of COVID-19 restrictions on activity choices. The student does not need to calibrate this. He will find something similar from literature, or use 'expert knowledge to define it, and in future work, these parameters will be calibrated by the TRANSP-OR lab and replaced.
   - Metaheuristic Approach: Employ a suitable metaheuristic algorithm to optimize the utility function and generate personalized schedules for individuals. We will consider the algorithm implemented in C by the TRANSP-OR lab, and the student will modify it accordingly to be used as an input generator for the IBM model.
   - Simulation and Evaluation: We will use the generated schedules within the IBM model to simulate the impact of di↵erent restrictions and behavior changes on infection rates. For this reason, the student will have to adapt the IBM in order to make it compatible with his activity schedule generator. Finally, we will evaluate the performance and accuracy of the proposed model by comparing the results with other existing models or empirical data.

By structuring the project into these stages, it ensures a systematic approach toward achieving the goal of generating a synthetic population.

4 Work philosophy

The project objectives and deliverables are set out in Section 3. The student is advised to write up the main findings from each step of the research plan. This will form the body of the final report and allow for progressive feedback on the work. It is the responsibility of the candidate to prepare in due time (before) the material for the midterm and final presentations, as well as handing in of the final report.

5 Supervision

The project will be supervised by director Michel Bierlaire (professor), main supervisor Cloe Cortes Balcells (Ph.D. student), and co-supervisor Fabian Torres (Postdoctoral Researcher). The role of the supervisors is to provide guidance in the literature review, modeling, and interpretation of results. The collaboration will be structured as weekly meetings in which the student will discuss the ongoing work and approaches to use and feedback/discussions on the work and approaches to use.

Signatures

____________________ Michel Bierlaire

____________________ Pierre Alexis Hellich

____________________ Cloe Cortes Balcells

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____________________ Fabian Torres

Date 20.07.23 Place Lausanne