COVID-19 predictive models in two different situations

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1. ***Problem statement and basic model***

In this study, we will use GAMA to simulate the trend of covid-19 spread in Lauttasaari under two different human behaviors: free daily travel and compliance with home quarantine policy. After these two kinds of curve is calculated, it will be compared to the peak time and the largest number of infections. Some people think is not necessary for home quarantine. What would be the impact on the spread of the virus if people were to follow strict home quarantine policies and go out less often? Whether the virus can be brought under control quickly, or slow down the growth of the number of people infected.

The model is divided into two pieces. Frist we refer to the *SIR* model in GAMA toy models: Epidemiology. The spread of virus includes three steps: susceptible, infected and recovered. But for covid-19, we adds a new exposed on the basis of *SIR* model. Susceptible people will experience the incubation period at the beginning, and symptoms will appear after a period of time, and patients with incubation period may also be infectious. In order to define the movement of people in cities, we refer to another movement of people in the road traffic models under tutorials. (https://gama-platform.github.io/wiki/RoadTrafficModel_step3). In the original model of movement of people, agents have two different objectives "working" and "resting" correspond to the movement of go to work and go home. In our model, we set four objectives correspond to the movement of go to work, go to sport do other activities and go home. And we also refer to the idea of controlling people's movement through time in the original model.

2. ***Model simplification***

The SEIR model divides the population into four classes: *S* for the susceptible, *E* for exposed, *I* for infected, and *R* for the recovered or removed. This is illustrated in Figure 1 immunization moves individuals from S section to the R section. The model is based on serval assumptions (Stroyan, 2009). The first assumption is that all individuals of the population must fit into one of the Categories (*S, E*, I or *R*). The second assumption is that the population is large and relatively fixed. The last assumption is that population is well mixed so that every individual has the same chance to contact with others.

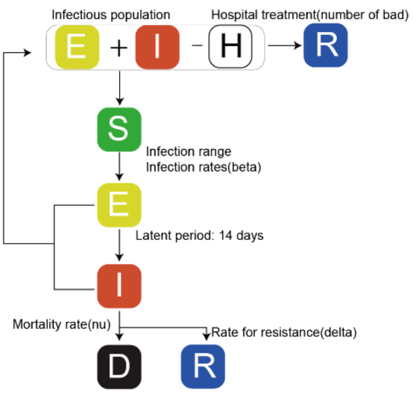

Figure 1

People's daily activities are complex and changeable. In order to simplify the model, we only consider four kinds of daily activities. Working hours in Finland are based on data from the Internet, and we also set a fixed starting time for sport in our model. In addition, the durations of people's different activities are also random within a certain range and the destinations of people's activities are also restricted to the nearest ones.

3. Model description

At the beginning, we set the initial Susceptible number is 5000 and exposed is 10. One will have 0.5 percentage to be spread when he is exposed to the virus carriers. The latent time is 2 weeks and hospital will begin to recover the infected people after 10 days the first infected appear. And it will only recover 100 people because of the limited beds.

Our first step is to edit different building types in GIS, including residential buildings, commercial buildings, green space, office schools, supermarkets, and other places such as church, library, gym. The starting locations of activities of each agent in one day are randomly distributed in residential buildings, and different other types of buildings correspond to different destinations of activities. We also set four objectives including "relax", "work_study", "sport" and "active" to define the activities of each agent. We specify the starting and ending times of a day and specific start points for all agents to perform different activities. The starting time of all agents varies randomly between 2am and 10am, and the ending time varies randomly between 6pm and 2am. At 7am and 7pm, all agents will start from their respective starting locations to the park nearest to them for sports activities and the sports activities will continue randomly for 0-2 hours. At 9am and 13pm, all agents will start from their respective starting locations to the office and school nearest to them for work and study activities and the work and study activities will continue randomly for 0-4. All agents will be engaged in other activities between the beginning and the end of the day except for 7am, 9am, 13pm and 19pm. We set up that each agent can engage in 1-3 other activities in a day and the duration of each other activities is randomly between 15 minutes and 2 hours. After each agent has completed all tasks of the day, the objective of all agents becomes "relax" and they return to the location of home.

We select four home stay policies according to the Finland governmental policy: work and study remotely, do exercise at home, set a curfew and limit people's outdoor activities at night and decrease the frequency of going out only if necessary. When we implement the home office policy, agents will no longer move to the locations of offices and schools but stay at the location of their home when it is time to start working and study. Similarly, when we implement the homestead policy, agents will no longer move to their nearest park for sport but stay at home when it is time to start sport. After the curfew we set, the start and end times of the day will be fixed at 6am and 10pm, which means that all agents can only be located in their homes during the night. When we implemented the policy of going out only if necessary, the number of mobile agents is lower some agents will no longer move among all agents.

Differences in infection rates： In the case of free daily travel, the virus will spread freely, and the maximum infection rate will reach 0.36. However, the maximum infection rate will be reduced to 0.12 after the implementation of the policy.

Differences in the growth rates of exposed and infected individuals： In the case of free daily travel, the curve for exposed and infected people is growing faster, leading to a situation that is prone to large-scale outbreaks of infected people, putting enormous pressure on the health system. However, after implementing the policy, the growth rate will be slower, allowing the health system more time to prepare.

Differences in the peaks of exposed and infected individuals： After the implementation of the policy, the peak number of infected patients will be significantly reduced and the peak time will be delayed, which means that the number of hospital beds needed will be reduced and the pressure of treatment caused by the concentrated outbreak of the virus will be reduced. The economic cost of government spending on disease treatment would be reduced.

Differences in the number of uninfected individuals after the outbreak ended： With the implementation of the policy, the number of uninfected people will increase and more people can avoid the risk of being infected by the virus.

4. *Discussion and conclusion*

The Covid-19 pandemic is exerting a1n unprecedented stress on the public health systems of many countries. Under this situation, we implemented a modified SEIR compartmental model accounting for infection from undiagnosed individuals and for different levels of population isolation, to evaluate effects of contacts reduction in the epidemic temporal dynamics. The results of this study shows that a home quarantine has a effect on the spread of the virus and will reduce the number of infections compared to the normal model. In addition, we carried out simulation in a real urban space, and made a simple classification of public space, we could get the result that the number of infections in which public space would be effectively controlled: closing offices and schools was the most effective measure, and reducing the use of parks would slow the spread of the virus.

But in our model, we did not divide the population into different groups, assuming that everyone was equally likely to be infected. This may therefore lead to an underestimation of the actual level of infection. In addition, we assume that Lauttasaari is a closed island, with no access and movement of outsiders, which also makes the infection rate in the simulation lower than the actual situation. However, we chose this option in an attempt to be conservative and our results should be interpreted as the current best-case scenario.

Reference

Nicho, Joanna (2010) "The SIR Epidemiology Model in Predicting Herd Immunity," Undergraduate Journal of Mathematical Modeling: One + Two: Vol. 2: Iss. 2, Article 8. DOI: http://dx.doi.org/10.5038/2326-3652.2.2.8

Stroyan, Keith. "Using Calculus to Model Epidemics." (http://www.math.uiowa.edu/~stroyan/CTLC3rdEd/3rdCTLCText/Chapters/Ch2.pdf).

Leonardo López. Xavier Rodó (2020) " A modified SEIR model to predict the COVID-19 outbreak in Spain and Italy: simulating control scenarios and multi-scale epidemics. "
DOI: https://doi.org/10.1101/2020.03.27.20045005

Data resources

Working time in the European Union: Finland: https://www.eurofound.europa.eu/publications/report/2009/working-time-in-the-european-union-finland. Published by European Foundation for the Improvement of Living and Working Conditions

Oringinal infected individuals simulation data: https://github.com/owid/covid-19-data/tree/master/public/data. Published by European Centre for Disease Prevention and Control (ECDC)

Buildings in Helsinki: Source: Buildings in Helsinki. The maintainer of the dataset is Helsingin kaupunkiympäristön toimiala / Kaupunkimittauspalvelut. The dataset has been downloaded from Helsinki Region Infoshare service on 25.05.2020 under the license Creative Commons Attribution 4.0.

City of Helsinki road map: Source: City of Helsinki road map. The maintainer of the dataset is Helsingin kaupunkiympäristön toimiala / Kaupunkimittauspalvelut. The dataset has been downloaded from Helsinki Region Infoshare service on 25.05.2020 under the license Creative Commons Attribution 4.0.