Week 6
Multiagent Simulation #1

This lab will introduce you to agent-based simulation modeling to work on one of the most critical health crises of our times. You will be creating a simulation of a society that resembles the real world to study the mobility patterns of community and the spread of COVID-19. The central question we are trying to find an answer to through this simulation is, what are the impacts of following social distancing norms in a society and comparing it with a society that doesn't follow these norms.

One of the most prominent impacts of COVID-19 is reduced social gatherings in public places such as grocery stores, parks, and workplaces. This is necessary to control the spread of the virus but it also adversely affects the economy and especially worsens the situation for industries that rely heavily on social gatherings. Needless to point out, the boredom and psychological impacts of staying at home for prolonged periods make it desirable for most people to be able to get back to life as it was.

Simulation (Agent-Based Simulation Modeling)

We create a simple simulation environment to model a community showing the mobility patterns of people in a society using Mesa (An Agent-Based Modeling framework in Python), which is easy to use and is well documented.

The simulation environment contains:

- People, modeled as agents, of two types
    - Initial population 1,000
- Homes
    - Each person is a resident of one home
    - Each home is the residence of four people
    - 250 homes in total to accommodate 1,000 agents
    - If an agent is infected and stays at home, it infects all other agents living in that home as well
- Parks
    - Two parks
- Grocery stores
    - Five grocery stores

In the simulation, agents visit grocery stores and parks. An agent gets infected (with a given probability) if it is in the same location as some other infected agent at the same time step.

Configuration for the simulation

1. **Mobility Patterns Modeling**

One day is one time step for the simulation. For simplification, we assume each agent is only at one place throughout a given time step, so if someone visits a grocery store we can assume that the agent was in the grocery store for that entire time step (i.e. for the entire day).

Refer to the following table for probabilities of mobility across various infrastructure in the society at the start of each day (the probabilities remain constant on and across all days)

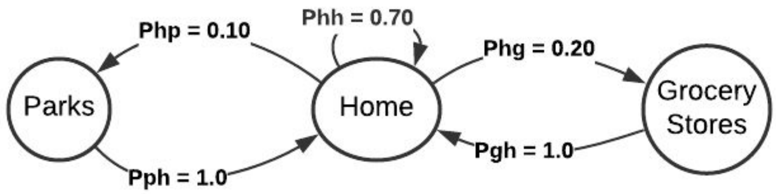

Figure 1. Transition probabilities for agents to visit different places in the society. After each visit to either grocery store or park the agent returns home (in the next time step)

2. Modeling the spread of the virus

Each agent is either infected or non-infected. A non-infected agent transitions to an infected state when it comes in contact with an infected agent. For simplicity, we assume an agent gets infected (i.e., it transitions to the infected-asymptomatic state) on the next time step. Infection has following substates: asymptomatic, symptomatic, critical, cured, and deceased.

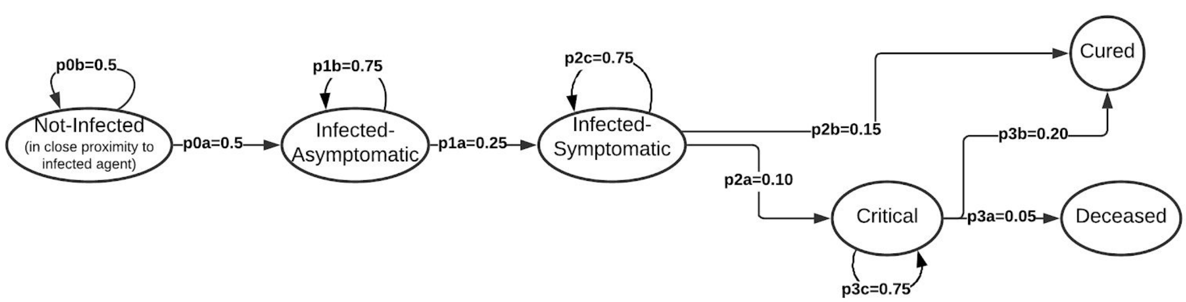

Figure 2. Transition probabilities across various disease states

Lab Tasks

1. Seeding the simulation

Assume three starting states with the following population as infected:

1. 10% as infected (code already in the notebook)
2. 25% as infected
3. 50% as infected

In the simulation, agents (both infected and non-infected) move between places. For each starting state, using your simulation, report the following:

- When does the simulation stabilize (reaches a termination criteria or experiences no further change)? How long will it take to reach that point (report your results in the number of days)?
- When was the infection at its peak?
- How many people die by the time the simulation stabilizes?
- Plot graphs for the spread of the disease based on results from your simulation (with the number of active COVID-19 cases on the y-axis and time steps (days) on the x-axis)

Note that you may need to execute each simulation several times to mitigate the effect of randomness. The above answers could be based on an average of multiple runs.

Assumption: Everyone who is cured develops antibodies and can never get infected again (hence we have a termination criteria for our simulation, when no one has the infection, i.e., when all infected are either cured or deceased).

2. Adding Quarantine Centers

As a measure to contain the virus the authorities introduce '*quarantine center*s' where infected patients can stay until cured (or deceased) and avoid spreading the virus.

- Quarantine center
  - Create one quarantine center for the entire society (Part of code is already in the notebook)
  - Max capacity is 100 (10% of the population)
    - If the quarantine center is completely occupied, infected agent continues to move to other places
    - Cured agents continue to move as before
    - Deceased agents are removed from the center
  - Assume no agent in the simulation gets infected in the quarantine center

Disease State	Probability of going to quarantine center	Explanation
Infected Asymptomatic	$p_{asymp-quarantine} = 0$	Asymptomatic people are unaware of their illness and hence don't go to the quarantine center.
Infected Symptomatic	$p_{symp-quarantine} = 0.20$	20% of the symptomatic patients choose to go to the quarantine center.

Critical	$p_{critical-quarantine} = 1.0$	All critical patients are sent to quarantine centers.

1. Report how your answers change for all parts of question 1 with the quarantine center in place?
2. Did the quarantine center reach its limit of 100 at any time step? If yes, at what time step does it happen? Show your results using a plot.
3. Consider the case where quarantine centers do not have a limit. How do the plots change?

3. Enforcing Social Distancing Norms

To further contain the spread of the virus the authorities have further introduced social distancing norms to be followed (such as wearing mask and practicing social distancing in public places)

To incorporate the impact of following social distancing norms we reduce the transition probability from the state not-infected to infected (p0a=0.5 in Figure 2). We assume it's five times less likely to be infected if one follows these social distancing norms, hence we use p0a = 0.10 and p0b=0.90 with social distancing norms in place.

Answer all parts of question 1 with this setting.

Does following social distancing norms improve the situation? Does it reduce the number of deaths? Use plots to highlight the difference compared to before.

4. Conclusion

- Share other interesting findings you uncover using your simulation.
- How much of an impact did adding quarantine centers (question 1) add and what was the impact of following social distancing norms (question 3) in controlling the spread?
- Based on your understanding of the simulation, identify two influential factors in spreading the virus? Suggest changes to improve the situation based on your analysis.

5. Other Experiments to Try (optional)

- Understanding that elderly population is more vulnerable, how could you include an age attribute to the agent model and refine the disease spread model?
- How could you introduce lockdown measures in the simulated society where only limited visits to grocery stores are permitted and visits to parks are prohibited?