COMP90083 Assignment 1: Overview, Design Concept and Details

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1 Purpose

To gain insight into the effect that the immunity rate can have on the spread of the COVID-19 virus throughout a high density population.

2 Entities, State Variables and Scales

There are two types of entities: people and square patches of land. The "world" is a square grid made up of 25 x 25 patches. Each person is characterised by their location, age (old or young) and four boolean variables regarding their infectious status (susceptible, infectious, immune or dead). A person's location is described by their x and y coordinates in the world, a continuous value between [-12.5, 12.5]. The simulation continues until there are no people in the infectious state. The patch size and duration of one timestep are generic, but in the context of a real-world setting, try to emulate 25m by 25m and one day, respectively.

3 Process Overview and Scheduling

During each timestep, the following procedures are executed:

- Check if all people are not infected
  - If they are, stop simulation
- Move all people one step in a random direction
- Transmit infection
  - May occur when a susceptible and infectious person are on adjacent patches
- Infected person either lives or dies if they have surpassed their infectious period
- Those that live become either immune or susceptible
  - Governed by the immunisation chance variable
- Assign all agents with their relevant colour (susceptible = blue, infected = red, immune = green, and dead people are removed from the simulation)
- Update the counter variables

4 Design Concepts

The basic principle addressed by this model is the concept of immunity; how the proportion of recovered individuals that become immune to the virus effects the overall consequence of the virus long term. This concept is addressed by demonstrating the variance in outcomes (death toll, timeline of virus, percentage of people infected at least once, number of infections per person) that emerge as a result of varying the chance of immunity after one survives the infection. A high density population has been used to simulate this (average 60 interactions per person per day) as it is more conducive to realistic results (see report for further explanation). The agents have no adaptive behaviour or objective; there is no conscious change to their behaviour according to the state they are in.

There is no prediction or learning in the model. Agents do not sense any characteristics of other agents. Agents undergo one type of interaction with other agents; infected agents can infect susceptible agents.

Stochasticity is used to represent multiple aspects of the model which are subject to randomness. The initialisation of the model employs several stochastic procedures. The direction each agent moves at each time step is uniformly distributed. As for transmission, a person's susceptibility could depend on the strength of their immune system or the extent to which they were exposed to the infected individual upon transmission. The change of state submodel includes several stochastic procedures to simulate this randomness. There are two collectives in this model, old and young. The system behaviour is observed primarily by tracking the death toll, but also the lifetime of the virus, the percentage of people infected more than once and the average number of infections per person.

5 Initialisation

The model is initialised with four thousand people, each of which begins at a random location. Each person has a 15% chance of being initialised as elderly (older than 65). Each person also has a 5% chance of being initialised as infectious. Those that are initialised as infectious are also assigned a random amount of time for which they have been infectious, which is uniformly distributed between 0 – 14 days. Each person has an infectious time which is a random variable, normally distributed around mean 14 days and standard deviation 3.5 days.

6 Input Data

There is no input data, as the environment is assumed to be constant.

7 Sub Models

There is one sub model which handles transition between the four states:

- The chance that one becomes infected when nearby an infected person is Bernoulli (p = 0.0075)
- The chance that an old person dies after their infectious period is Bernoulli (p = 0.1)
- The chance that a young person dies after their infectious period is Bernoulli (p = 0.01)
- The chance that a person who survives an infection becomes immune is Bernoulli (p = immunity chance)

8 Parameter Table

While some parameters were chosen from literature, others were chosen empirically so that the model dynamics simulate the real world.

Parameter	Value	Reason for choice of value	Reference
Chance of being over 65	15%	Represents a typical population	[2]
Chance of death if over 65	10%	Inference made from academic article	[3]
Chance of death if under 65	1%	Inference made from academic article	[3]
Chance of contracting virus if exposed to it	0.75%	Chosen empirically such that the proportion of people that contract the virus at least once is around 60%, emulating an Indian slum	[1]
Number of people in simulation	4000 people	Chosen empirically such that the proportion of people that contract the virus at least once is around 60%, emulating an Indian slum	[1]
Average infectious period	14 days	Chosen empirically such that the spread of the virus was realistic (did not quickly converge to zero)	

Figure 1: A summary of the parameters chosen, the reason they were chosen, and references

References

[1] Rupam Bhattacharyya, Ritwik Bhaduri, Ritoban Kundu. (2020). *Reconciling epidemiological models with misclassified case-counts for SARS-CoV-2 with seroprevalence surveys: A case study in Delhi, India* medRxiv 2020.07.31.20166249; doi: https://doi.org/10.1101/2020.07.31.20166249

[2] Hatekar, Neeraj & Rode, Sanjay. (2003). *Truth about Hunger and Disease in Mumbai: Malnourishment among Slum Children*. Economic and Political Weekly. 38. 4604-4610. 10.2307/4414196.

[3] Ashleigh R. Tuite, David N. Fisman, Amy L. Greer. (2020). *Mathematical modelling of COVID-19 transmission and mitigation strategies in the population of Ontario, Canada* CMAJ 2020. doi: 10.1503/cmaj.200476; early-released April 8, 2020