AOPD Assignnment 1 Report - Luke Davoli (s3782747)

Model and Parameters

The agent-based model created for the Assignment 1 uses NetLogo to understand the spread of the Coronarivus Disease (COVID-19) under different circumstances in a population. Beginning with a very simple existing model that tracked the spread of a disease throughout the community, over the course of a series of tasks the model was enhanced and extended to account for more real world variables. These extensions include travel between home and public places, different stages of the disease such as incubation, an asymptomatic and infectious period all the way through to recovery, likelihood of travel and travel intervention based on whether or not an individual is wearing a mask.

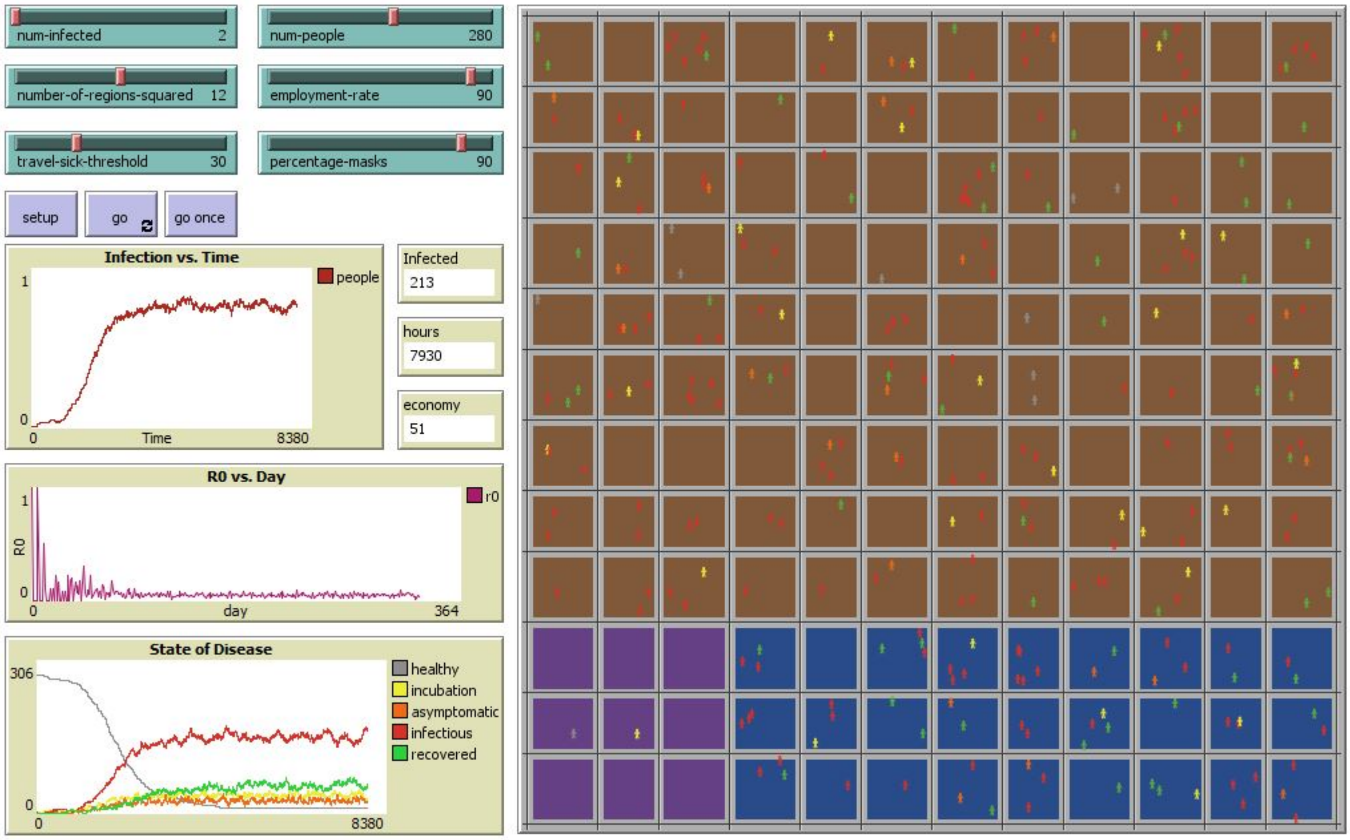
The environmment is divided into homes (brown), shops (purple) and workplaces (blue). All individuals begin at home and possibly travel to public places at certain times each day. A specified amount of individuals begin the simulation infected, and the disease gradually spreads through the population.

The Netlogo interface may be utilized by the user to adjust a range of parameters. Amongst these parameters are the number of people in the population, the amount of individuals that begin the simulaiton infected, the number of regions that the environment is divided into, the employment rate of individuals in the population, the likelihood of an individual to travel when sick and the percentage of the population that wears a mask.

The NetLogo interface also provides the user the opportunity to track specific metrics and data of the model as it runs. Included in these data points are the total number of individuals infected, hours passed since the beginning of the simulation, the strength of the economy as a percentage of the population that contributes to the economy (travels to work or the shops) each day, the R0 (rate of spread of the disease through the population) and the amount of turtles currently in each state of the disease (healthy, incubation, asymptomatic infectious, symptomatic infectious and recovered).

Calibration

For most realistic results the number-of-regions-squared and num-people parameters should be scaled in proportion to one another so that homes are neither unrealistically over-crowded nor mostly empty. An example of a good balance may be 12 and 280 for each value respectively, giving homes roughly between 1 and 6 inhabitants with a few empty. The number of turtles that begin the simulation infected is not vital, so for a fuller picture of the entire process of spread I prefer to begin the simulation with 2 turtles infected. At this population level and volume of workplaces, setting the employment-rate to 90 provides a realistic crowd size in workplaces. A travel-sick-threshold of 30 gives individuals a 70% chance of travelling to shops or workplaces when sick, which in a pre-Coronavirus world makes sense as most people would not be held back by what they believe to be a common cold, carelessly leaving the house to spread it through the population. Most people are happy to comply with the need to wear a mask in order to leave the house, so a setting of 90 for the percentage-masks parameter keeps the model stable and responsive.



Sensitivity

The model is very sensitive to most drastic changes in parameters, however remains stable for most small changes with some notable differences.

An increase in the the number of people in the population without increasing the amount of regions leads to overcrowding, which while it does increase the R0, does not lead to a huge leap in rate of spread as infected individuals are still relatively well isolated in each of their homes and transmission between homes is rare. Decreasing the amount of regions is a more serious problem for the model, as undercrowding drastically reduces the likelihood that the disease spreads between homes and it is likely the disease does not survive or remains low.

Decreasing the rate of employment has a strong impact on the likelihood of the disease to spread, especially if the initially infected turtles do not work and live alone, or live with turtles who are also unemployed. Lowering the employment-rate parameter thus produces unpredictable results, as the simulation must pass the initial hurdle of first spreading to new people, after this anything is possible and the model may behave as normal with a slightly lower than normmal rate of spread.

An increase in the travel sick threshold is another highly impactful change, demonstrating the sensitivity of this parameter. An increase to a value of 90 makes chances of leaving the house when sick vanishingly small, and decreases the rate of spread drastically due to the reliance on asymmptomatic transmission for the disease to spread between households.

The percentage-masks parameter is a double-edged sword: while a lack of masks will certainly increase the amount of transmission between individuals within their homes, individuals without masks may not leave home, so transmission outside of home is likely to decrease. For a population with a high mask wearing percentage the opposite is true: transmission becomes very unlikely but there is more opportunity for transmission between households as more individuals are able to travel to public places.

Results and Analysis

As I progressed through each task, R0 undoubtedly decreased as opportunities for transmission become more and more limited. In the beginning, the rate of spread would begin high and gradually decrease as more and more of the population was already infected and the amount of healthy turtles that could be infected became outnumbered by the already infected turtles. With the introduction of isolation into regions such as homes, shops and workplaces, allowing only travel between them at random intervals, the R0 plummeted. This was only furthered by the introduction of stages of disease, preventing turtles from spreading the disease at any point during their time infected. On the other hand, the ability for turtles to recover allowed the R0 to eventually stabilize as turtles oonce again became available for infection and may once more contribute to the rate of spread. Once a majority of the population becomes infected in this model, the R0 stabilizes at a low level as turtles recover and are re-infected. Throughout the rest of the model's development R0 remained low, further factors preventing travel such as the sick-leave-threshold and mask wearing slowing down the ability of the disease to spread even more.

The economy value is calculated as a percentage of the population that contributes to the economy each day by leaving home to contribute to the economy by visiting the shops or working. The intervention introduced prohibited travel to individuals who refuse to wear masks. At it's minimum value (30) the lack of people able to leave home leaves the economy very weak, hovering at around 20% strength. However it is highly unlikely that more than half the population refuses to wear a mask in order to leave home. A much more realistic value such as 90% mask wearing individuals results in a thriving economy which seems to hover at aropund 60% strength, while also limiting the amount of transmission taking place between turtles while out in public. R0 is mostly similar in both cases of a high mask wearing percentage and a low mask wearing percentage.

COVID-19 ABM ODD Description

Overview

Purpose and Patterns

The purpose of the COVID-19 Agent Based Model that I have produced is to gain a better understanding of and illustrate how the Coronavirus disease spreads through agents in an environment under a range of different circumstances. It aims to test whether mechanisms such as population density by location, travel between locations and interventions such as masks have a noticeable and/or important impact on the rate of spread through a population.

There are a number of patterns that are of concern to the model. Amongst these are a larger population density allowing for the disease to spread more quickly, a decrease or increase in the strength of the economy and rate of transmission in the disease in correlation with the amount of people leaving their home each day to travel to shops or workplaces, as well as the percentage of the population wearing masks reducing the rate of transmission.

Entities, state variables and scales

There are a number of entities that interact with one another in the Agent-Based Model. The most important, the agents, are represented as individuals or people in a population. These people can appear in a number of different states as they come into contact with the virus, carry it and recover from it. Another important entity are the patches of the environment, which may be either a home (brown patches), a shop (purple patches) or a workplace (blue patches), divided by grey patches that serve as walls/roads.

Each of the entities included in the model require a range of state variables to track important information about their attributes and behaviour.

State Variables of People:

- infected?: A true/false value that denotes whether or not the person is currently carrying and infected with the disease. This is set for an arbitrary number of the turtles in the model during setup and gradually grows or decreases as the model runs.
- worker?: A true/false value indicating whether or not the person has a job and will travel to work on some days. This is set to true for an arbitrary number of turtles based on the input from the user of the model in the 'employment-rate' parameter.
- home-patch: The home patch variable is set for all turtles randomly to the coordinates of a brown patch during setup. This patch is the patch that turtles return to following a visit to the shops or travelling to work.
- workplace: Should a person decide to leave home for work, they always travel to the same dedicated blue 'workplace' patch, which belongs to a workplace block they may move around in while at work.
- hours-worked-today and hours-shopped-today: An integer value counting the ticks people have spent at either location, as they will need to know how long they have been at the shops or work so that they may return home after a certain amount of time.
- infectious?: A true/false value that dictates whether or not the carrier turtle infected with the disease is currently infecting other turtles.
- infected-hours: An integer value counting the amount of hours a turtle has been harbouring the virus.
- incubation-hours: A predefined integer value for each turtle that denotes how long they will carry the virus without exhibiting symptoms
- asymptomatic-hours: the amount of hours a turtle will harbour the virus for before becoming infectious yet asymptomatic
- recovery-hours: A predefined integer value for each turtle that denotes how long they will carry the virus for before recovering
- chance-travel-sick: An integer value between 1-101 that denotes a turtles likelihood that a turtle will leave home when sick. Turtles will leave home sick if their chance of leaving is greater than the user set travel-sick-threshold.
- mask?: A true/false value that denotes whether or not a turtle wears a mask.

State Variables of Patches:

- region-x: The region number of a region (block of a home, shop or workplace) in the x-direction.
- region-y: The region number of a region (block of a home, shop or workplace) in the y-direction.
- region-type: The type of region that a patch belongs to, can be one of "Home", "Workplace" or "Shop".

Global State Variables:

- region-boundaries-x and -y: The locations of the region dividers on the x and y axes.
- hours: A count of the amount of hours that have passed since the beginning of the simulation.

- infected-today: An integer value that holds the amount of newly infected turtles in the current 24-hour day.
- infected-y: An integer value that holds the amount of newly infected turtles in the prior 24-hour day.
- economic-contributors: An integer value that counts the amount of people that have left their home to go to the shops or work on any given day.
- economy: a percentage of the population that have left their home to contribute to the economy by working or shopping on any given day.

Process overview and scheduling

Setup:

The simulation environment is divided into regions. Following this the turtles are created, of which an arbitrary amount begin infected.

Go:

1. Each tick begins by executing the spread-infection sub-model in which turtles which updates their infected? state if they are vulnerable to the infection at that particular tick.
2. The agents execute their travel submodel, which asks them to move to either the shops or their workplace if chance allows them.
3. Agents execute their update-infection-status submodel that uses their infected-hours, asymptomatic-hours, incubation-hours and recovery-hours to identify what phase of the disease they currently occupy and update their state accordingly.
4. The agents execute the move submodel that shifts their position in the environment in any given direction.
5. Hours progress, if it is the end of a 24-hour period then graphs/parameters are updated and/or reset

Design

Design concepts

Basic Principle

The basic principle of the COVID-19 model is the concept of rate of spread and how this changes based on the different changes that can be made to the model. For example, the amount of people travelling while symptomatic, density of populations in homes and public spaces, wearing masks, etc. have diverse impacts on the behaviour of the spread throught he population.

Emergence

The most important outcome of the model is the rate of spread that arises as a result of the various parameters and changes that can be made to the model in each run, as well as the resulting state. The simulation may result in a fast and sharp spike in total infections, very quickly encompassing the entire population, while other combinations of parameters lead to infections growing slowly and eventually stabilising at a number far from the total population.

Adaptation

Agents actions are mostly deterministic, other than that they must decide whether they will travel away from home each day. Worker turtles have the opportunity to go to work and then visit the shops on the way home while non worker turtles may only visit shops. This is all down to chance and there is no guarantee that turtles will travel anywhere. It become less likely that a turtle will leave home depending on the size of the travel-sick-threshold set by the user.

Learning

It become less likely that a turtle will leave home depending on the size of the travel-sick-threshold set by the user and the likelihood of each specific turtle to leave home while exhibiting symptoms given that they are currently sick.

Sensing

Agents have an understanding to some degree of the current state of their own infection. They are unaware while in the incubation period and not showing symptoms, but once they are infectious and symptomatic they are able to use their status of infection to inform their decision making. In spite of this, agents are unable to understand the infection status of other turtles in order to avoid them.

Interaction

Direct interaction takes place between turtles when they share a patch. Infected turtles have the opportunity to infect turtles sharing the patch with them, hindered by chance depending on whether they or the turtles they are infecting are wearing a mask. There is no other interaction between agents that prevents any kind of movement or laters their state in any other way.

Stochasticity

The model makes great use of pseudo-random values in a variety of situations. Firstly, all turtles are initialized to a random home patch. They are given a random chance of being employed, with the likelihood of that being determined by the user through the employment-rate parameter. The same goes for the random chance of being a mask-wearer, with the likelihood being determned by the percentage-masks parameter. Furthermore, agent state variables such as the incubation-hours, asymptomatic hours and recovery-hours are all initialized at random based on either a normal or gamma distribution, or a base level plus a random amount. There is a random chance that turtles will travel when sick, as well as a random chance that agents will travel to different locations in the environment at different points in the day. Most importantly there is a differing chance of transmission that is dependent on the individuals involved in a transmission and whether or not they are wearing masks when they come into contact.

Collectives

It quickly becomes apparent that due to the design of the regions seperating agents into their homes, clusters of the infection will form clearly within house walls before spreading at work or at shops. In this way families in this model become the main hub for transmission of the virus before carrying it with them in their travels and spreadint it to other family collectives.

Observation

The model is summarised through a series of live plots on the model interface. Important metrics that serve to assist users in better understand the results of the simulation include the R0 plot by day, the state of the disease in each agent as they move from healthy, incubation, asymptomatic, infectious through to recovery. We also observe the total number infected in any state, as well as the strength of the economy as a percentage of the population leaving their homes to contribute to it.

Other Design Principles

Prediction and objectives are not implemented as elements of the model, but are possible candidates for future extension of it. Prediction may involve predicting the rate of spread given a particular set of parameters while objectives may include allowing agents to avoid contracting the virus.

Details

Initialization

The first thing to be set up are the regions that divide the environmment into homes, workplaces and shops, three quarters of which are homes, three sixteenths are workplaces and one sixteenth shops. These proportions were chosen on to give balance to the density of a population in any region at any given time. Due to the frequency with which the agents visit shops and go to work, it would not make sense for the regions to thoughtlessly be divided evenly with a third each, as this would lead to empty shops and workplaces with well overcrowded homes.

Homes are coloured a light brown, with shops a deep purple and workplaces blue. The amount of each region (they remain in the same proportion to each other regardless) may be chosen by the user with the number-of-regions-squared parameter. For example, a chosen value of 12 will provide 12 regions in the x direction and 12 in the y direction for a total of 144 regions, of which 9 are shops, 27 are workplaces and 108 are homes. These are split up using grey region boundaries, patches which do not belong to any region.

We then begin to initialize turtles. Turtles are generated with the shape 'person' as this is what our turtle agents represent, real people. The amount of turtles created is chosen by the user, it may be any number between 2 and 500 using the num-people slider found on the interface. All turtles begin uninfected and uninfectious and are given a random patch to stand on. They are then assigned a home patch and asked to move to it, so that all turtles begin their day at home. The chance-travel-sick variable is set to 101, so that they are certain to leave home (other random factors permitting) as we know that they are not sick.

Turtles are then randomly assigned an employment status, based on the chance chosen by the user through the 'employment-rate' parameter slider on the user interface. If they are chosen to be a worker, they will be assigned a workplace patch that they will travel to if they choose to mmove to work on a particular tick, which is within the confines of their workplace as a whole.

Following this they are given the random opportunity to wear a mask or not, again depending on a chance chosen by the user through a slider on the interface that controls the parameter 'percentage-masks'.

Finally their timeline of stages of the virus is set. This is set before contracting the virus for each agent, and remains the same every time they contract the virus and recover.

The Australian Government's estimation of the incubation period timeline is not exactly precise: "The median incubation period COVID-19 is 4.9 – 7 days, with a range of 1 – 14 days." Thus we assign the turtles an incubation-hours variable value, representing the duration of the period randomly using a normal distrubtion with a mean of 144 hours (6 days) and a standard deviation of 60 hours (2.5 days). This allows for the small chance for an incubation period to be less than 0 hours, therefore in the highly unlikely case that a randomly generated value produced be much more than 2 standard deviations from the norm, values less than 1 become 168 hours (7 days). This means most incubation periods will be within the range of 4 to 9 days with edge cases as low as just a few hours or as high as 14 days.

To the understanding of Harvard Medical School, the presymptomatic period in which individuals are infectious yet not exhibitng symptoms takes place "48 to 72 hours before starting to experience symptoms." As a result agents are assigned an asymptomatic-hours variable which has a value of at least 48 plus a random value between 0 and 23.

While information on the time of recovery across cases in generally inprecise, the best estimation of the World Health Organisation is that for "...people with mild disease, recovery time is about two weeks, while people with severe or critical disease recover within three to six weeks." As a result the recovery-hours is generated randomly using the absolute value of a normal distribution. We begin with a base value of 300 hours (12.5 days) minimum to recover, and add the absolute value of the number generated randomly on the normal distribution with a mean of 0 and a standard deviation of 300 hours. In this way, it becomes less and less likely to have recovery times as they grow larger, with most recovery times within the region of 4-5 weeks.

To complete setup, we chose a number of turtles to begin the simulation infected which is determined by the num-infected slider on the interface.

Input data

The model does not use input data to represent time-varying process. Input data does not include parameter values or data used to initialize the model, these parameters are discussed in other sections.

Sub models

Spread Infection

The spread-infection submodel asks all turtles that are currently infected and infectious to infect other turtles on that occupy the same patch as them. An important factor in whether or not the transmission of the infection from the carrier to the contact is whether or not each party is wearing a mask.

While there is limited information available on just how impactful wearing a mask is on defneding against transmission of the virus, we know the order of effectiveness of each combination thanks to this chart from the Michigan Department of Health and Human Services. At highest risk are neither the contact or carrier wearing a mask: in this situation, tranmission in our model is an absolute certainty. If the contact wears a mask but the carrier chooses not to, the risk of transmission is still high, so we have given this situation a 80% chance of resulting in transmission of the virus. In the opposite situation in which a carrier is wearing the mask but the contact is not, likelihood of transmission is significantly reduced: we have given this situation a 50% chance of resulting in successful transmission. Finally if both the carrier and the contact are wearing a mask the rate of transmission is once again significantly reduced, in our model to 20%.

If transmission is successful, turtles sharing the patch with the infected now become infected themselves, with their infected? variable being set to true.

Travel

For a turtle to leave their home and travel to a new location such as the shops or a workplace, they must be wearing a mask and their chance-travel-sick must be greater than the travel-sick-threshold set by the user on the interface. Turtles that are not infected will have their chance-travel-sick set to 101, which is always higher than the threshold and thus will not be prevented from travelling.

Employed turtles (turtles who have worker? = true) have the opportunity to leave their home 5 times each day between 7am and 11am. On each hour they are given 14% chance of leaving for work, giving them a roughly 70% chance of heading to work on any given day. If they do successfully move to work, they are counted as an economic contributor for the day in the economic-contributors count variable. The Melbourne Univeristy of Business and Economics believes the average Australian full-time work week to be 37.5 hours long, so this calculation has been adjusted for part-time and casual workers. Agents in this model work an average of roughly 29 hours a week.

Unemployed turtles are instead given the opportunity to go to the shops on any given day between 7am and 4pm. They are given a 4% chance on 10 opportunities to go the shops for a roughly 40% chance of going to the shops each day. Turtles visiting the shops are also counted as economic contributors. Employed turtles also have a 20% chance of going past the shops on their way home.

While turtles are at the shops or at work their hours-worked-today and hours-shopped-today variables are incremented so that they know when it is time to return home. Turtles at work return home after 6 hours, while turtles at the shops return home after 3 hours.

Update Infection Status

The infected-hours variable keeps a count of how many hours a turtle has spent carrying the virus. The incubation-hours, asymptomatic-hours and recovery-hours discussed previously provide guidelines for when to update a turtles infection status.

Turtles that are infected but have not been infected for longer than their defined incubation period less the amount of hours they will spend infectious yet asymptomatic are coloured yellow. Once they become infectious yet asyptomatic, they progress to orange. In this state they are able to infect other turtles but will still leave home thinking they are not sick. Once a turtle spends enough time carrying the virus they will proceed from the incubation period to the infectious and symptomatic period, coloured red. At this point they are given a random chance of leaving home when sick (chance-travel-sick) that, if less than the travel-sick-threshold, will keep them at home while symptomatic. Finally, once a turtle's infected-hours surpasses its recovery-hours its infected and infectious values are set to false, it is coloured green and it is once again able to leave its home.

Move

The move submodel simply asks turtles to advance forward one patch. If the turtle is facing a wall, the turtle will face the opposite direction before moving.