Agent Based Model for COVID Report

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Introduction

In 2019 the novel coronavirus, ultimately named COVID-19 had drastic effects on the world, originating from China, the “first reported cases by officials” [1] of the virus was in the Wuhan province of China. From there the virus has spread globally and has been declared by the World Health Organisation as a global pandemic.

COVID-19, is a novel coronavirus, meaning that it branches from a family of other coronaviruses, for example the SaRs virus in 2002. Symptoms of COVID-19 range between “fevers, cough, sore throats and shortness breath” [4]. The virus also has an incubation period (asymptomatic period) where victims can have the virus contained in their system without any symptoms at all. COVID-19’s incubation period has been one of the challenges that has contributed to containing the virus. Alongside the incubation period, COVID-19 also spreads via surfaces and droplets which can remain on surfaces between “2hrs to 9 days” [5] making “good hygiene” and “physical distancing” [2] 2 important roles in combating the virus since there is currently no available vaccine.

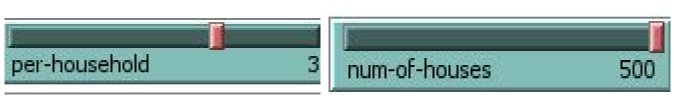
Due to COVID-19, this model aims to investigate the spread of COVID-19 in a community and population and how strategies can be implemented to influence the basic reproduction number of the COVID-19 virus alongside economic growth.

The model is based on the “Spread of Disease” [7] model which has been implemented with netlogo, however differs by introducing containment policies, scheduled movement strategies and the observations of economic growth against r0.

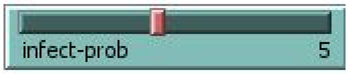
Model Parameters

The model consists of variables of parameters which can be altered and changed to observe different variations of the model and how they differ.

The num-infected parameter controls the initial amount of people which are infected by the virus, this parameter increments in values of 1 and has a maximum value of 200..



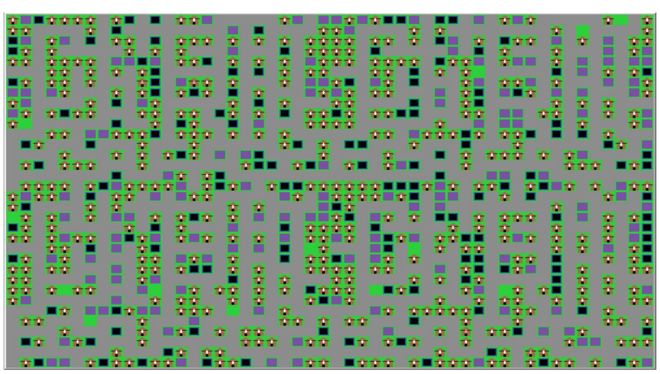
per-household and num-of-houses are the parameters which ultimately determine the population size on the map, population of people will be determined by the num-of-houses multiplied by the ratio per-household.



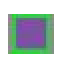
This parameter controls the probability in which the virus spreads, this value is converted into a probability by dividing 1 by the infect-prob as it indicates the range in which a random value can be selected.

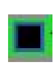
The surface-duration parameter can be changed by the observer, to match the desired time that the infection stays on the surface of areas. The units of this parameter are in hours which is proportional to each tick of the model.

The variation parameter controls which movement strategy will be implemented among the people on the map. The Schedule variation will be the default strategy, whereas the restricted movement policy will limit the movement of people based on their infected state. If people are infected and start showing symptoms, they are isolated at home for 7 days before they are allowed out again.



 - represents a house

 - represents a shop

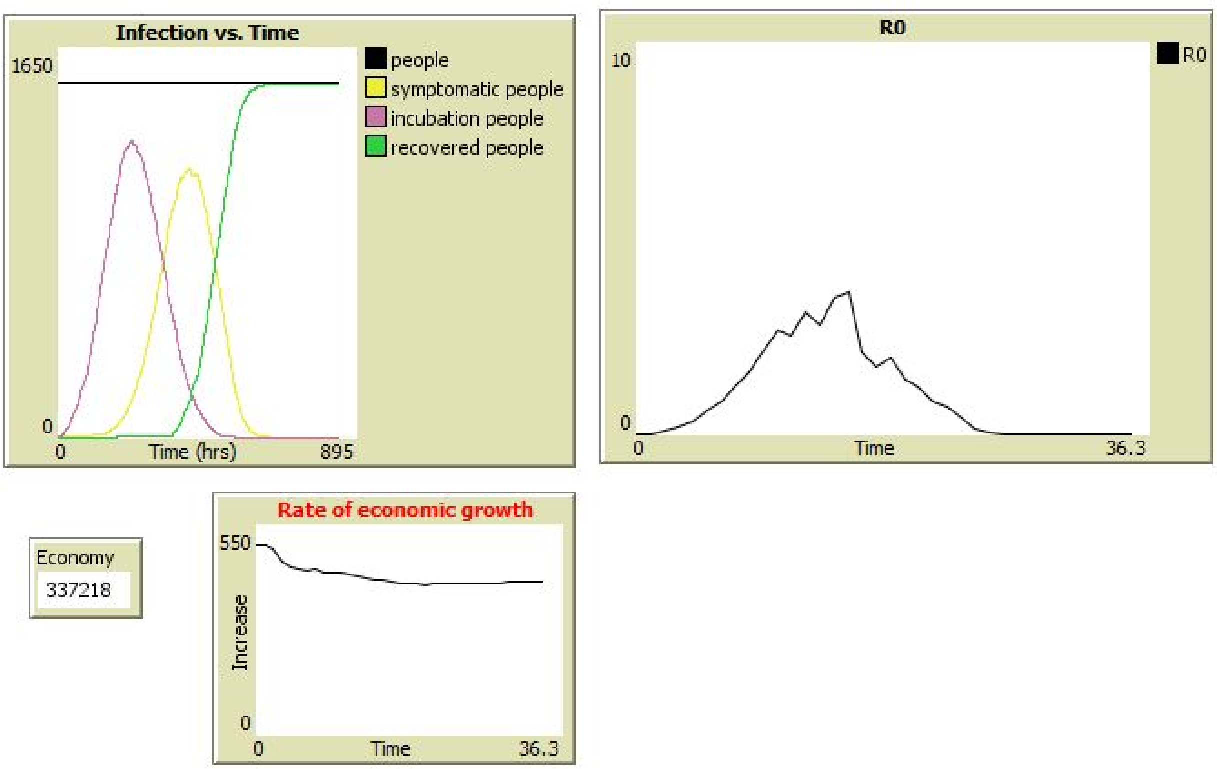
 - represents a workplace

Model Analysis

Model configuration :

- Num-of-house = 500
- Num-of-shops = 170
- Num-of-buildings = 170
- Infect-prob = 5
- Num-infected = 10
- Per-household = 3
- Surface-duration = 24

No policy [variation = scheduled] figure 1.1

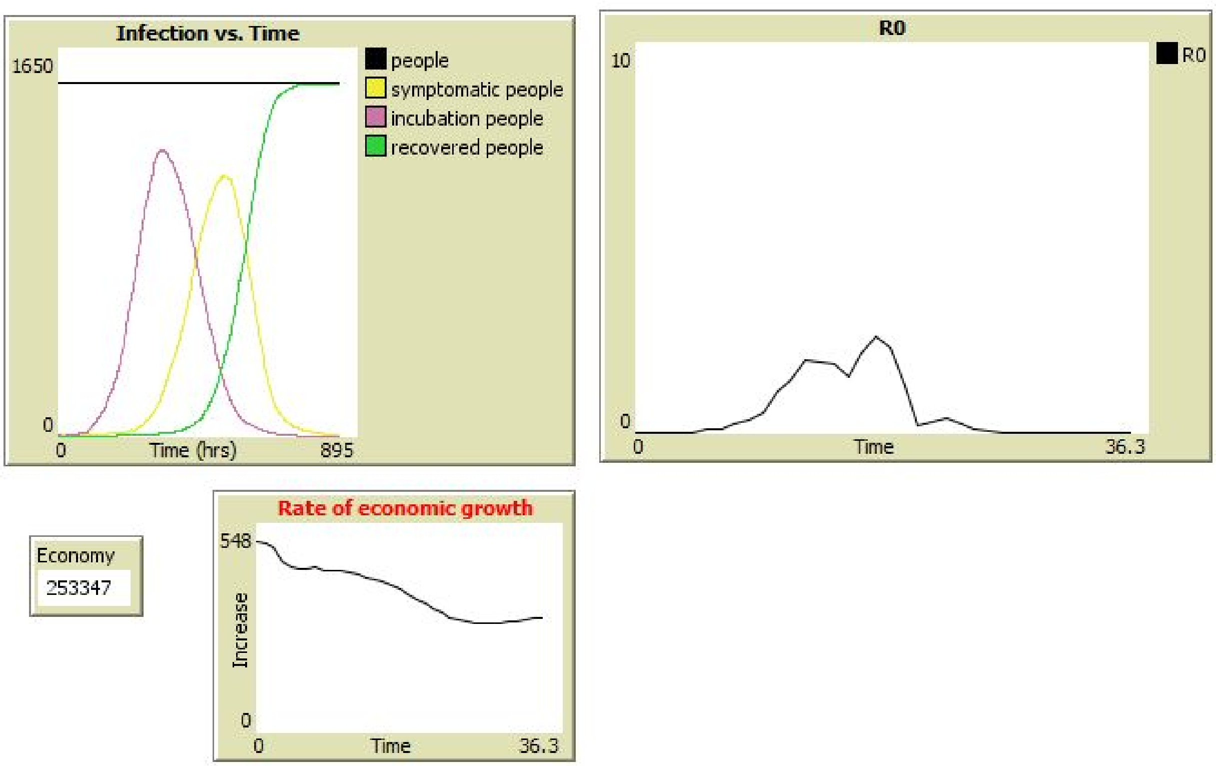


Discussion

When running the default variation of our model, with the parameter configurations above for a time frame of 35 days (7 weeks) we can see that throughout the span of the weeks r0 sits 3.5 at its peak and declines as people recover from the virus building immunity and hence not being re-infected. Through the span of the first initial weeks as the incubation numbers start to rise they correlate with the exponential increase of r0. R0 drops below 1 at the 20 week mark, suggesting that there are no more rising cases at this point.

The rate of economic growth throughout the span of 35 weeks is fairly stable however drops slightly before it re-establishes its stability. The slight drop in economic growth can be suggested by the reduced probability of going out as it lines up with the drastic increase of symptomatic people coming off of the incubation period.

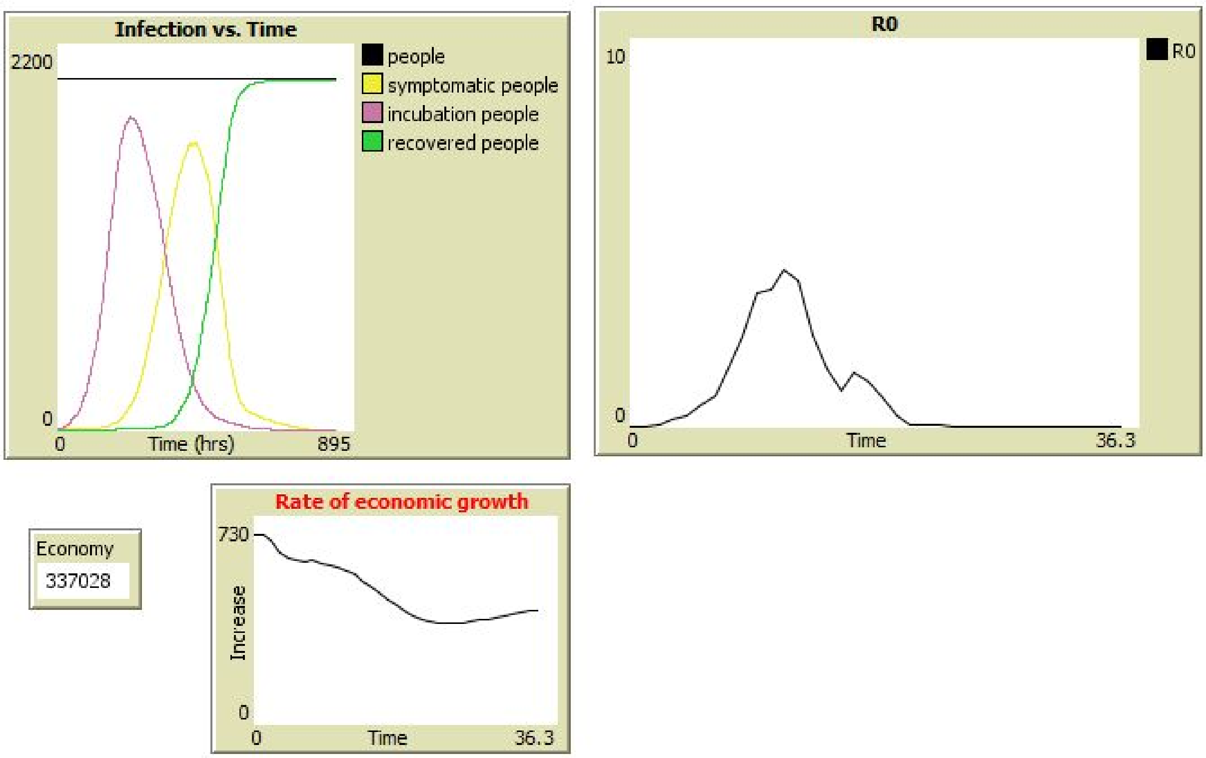
With policy [variation = restricted-movement-policy] figure 1.2



Discussion
When running the model with the restricted-movement-policy variation, we can see that r0 peaks at 2.5 and drops drastically at the 17th week due to the restriction of movement when people begin to adopt as they gain symptoms. R0 depletes as everyone recovers hence the contact between susceptible and infected people approaches 0.

Looking at the economic growth, we can see that the growth is on a steady decline as we increase in the number of infected individuals, it can be inferred that due to our suppression of movement for those who have been infected, those who have been infected can not work, hence reducing the economic growth of the community.

Increasing population size [variation = restricted-movement-policy, per-household = 4] figure 1.3



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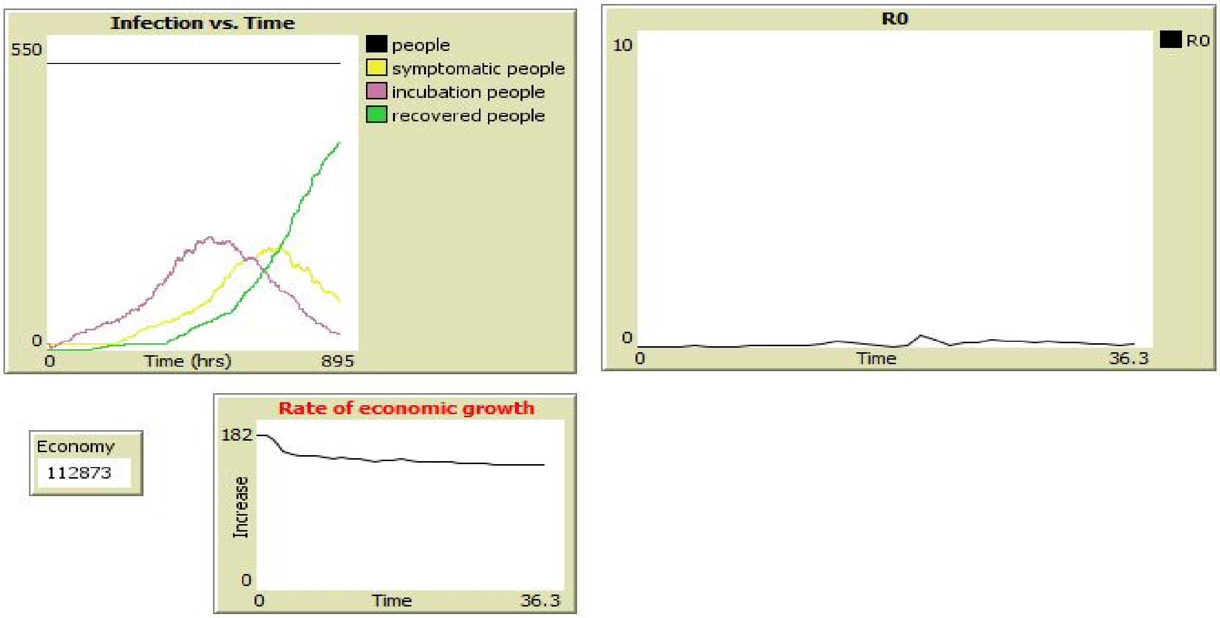
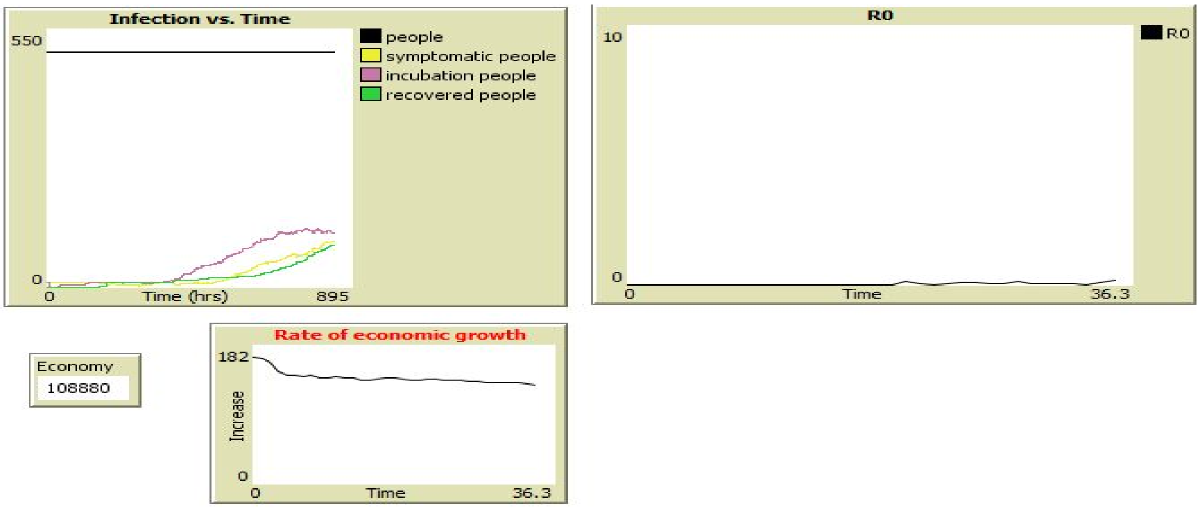
Decreasing population size [variation = scheduled , per-household = 1] figure 1.4



Discussion

By decreasing the population, we can see that r0 never seems to reach 1 and the economic growth of the community drops ever slow slightly as time progresses, the rate of infected people is exponential, however in comparison to a larger population size in the same configuration, it is substantially less. The growth of cases still follows a similar pattern as figure 1.1

Decreasing population size [variation = restricted-movement-policy , per-household = 1] figure 1.5



Discussion
Decreasing the population size, while running the restricted-movement-policy shows that r0 is very low, we can see that economic growth decreases slightly similar to figure 1.4. The drastic factor from this figure is the distribution of cases, where over time the cases of infected people rise by a dilation factor which is much bigger than both figure 1.4 and 1.3.

Conclusion
From the results shown above by the figures, it suggests that population density of the has a large impact of r0 and spreading COVID-19, by implementing a movement policy, we are able to lower the r0 value however this decrease in the r0 is traded by the decrease in economic growth. From figures 1.5 and 1.3 we can see that the movement policy works best in lower population densities, where it is able to dilate the exponential growth of infected people by reducing the movement of infected people. By comparing figures 1.5 and 1.4 in the 35 week time span, we can see that economic growth holds a difference of 3.5% (112 thousand vs 108 thousand) whereas figures 1.1 and 1.2 hold a difference of 26% (337 thousand vs 253 thousand). By applying the policy in lower density populations we can come closer to the economic value and growth of one without, however at the same time, dilate the growth of infections and reduce r0.

ODD

Model Description

Overview

Purpose:
The model is aimed to replicate the spread of COVID-19 in functioning communities and populations through surface based and contact (contact between susceptible and infected individuals) transmission.

Patterns:

Infectious stages and infectious probabilities
COVID-19 is a flu like virus which has become prevalent this year which has been shown to be able to spread via mediums and contact of individuals. A struggle to contain the virus has come from the knowledge that the virus follows stages within an infected individual, hence in the model we have to assume that people can be in phases of the infection; incubation, symptomatic and recovered. In each phase, the chances of infection are assumed to vary, in the incubation period, the virus's chance to spread will be much lower when a person is symptomatic, as the symptoms of COVID-19 heavily impact the way the virus spreads (spreading through droplets and contaminated surfaces). Symptomatic people will have the highest chance of spreading the virus if they are not isolated. People will be assumed to be able to recover, as the population adopts immunity to the virus once all people are infected.

Moving with a purpose
In functioning communities, people move based on the time and schedule, thus we adopt a system where the people agents within the community move at specific times of the day, moving from places on the map based on their current status: working, resting or having lunch. In the night, tendency to work and travel is much less frequent therefore movement in our system only occurs during hours of the day.

Time of virus progression
COVID-19 is a virus which takes days to progress through its phases and become infectious thus
ticks are divided into time in hours and days where each tick represents an hour allowing us to monitor the spread of the virus within the timeframe in which it is prevalent.

Categorising areas of the map
In our system we allow our environment to be varied, communities vary in the number of houses and businesses they contain (urban and rural areas). The system also incorporates 3 types of areas on the map: homes, workplaces and shops .

Entities, states and scale:

People - Agent

Variable	Variable type and units	Meaning
infected	Boolean	Reports to us whether the person is infected
workp	Patch (coordinate)	The patch in which the person works
p-home	Patch (coordinate)	The patch where the person lives
work-time	Real number ; (hours)	Reports the amount of time the individual is scheduled to work or has left to work
rest-time	Real number ; (hours)	Reports the amount of time the individual has to stay home
lunch-spot	Patch (coordinate)	Where the person will have lunch each day
symptom-time	Real number ; (hours)	The amount of time which the person has symptoms for
recovered	Boolean	Reports to us whether this individual has recovered
isolation-time	Real number ; (days)	The amount of time which the person will isolate for
time-period	Real number ; (days)	The total amount of time which the virus is prevalent within the person
incubation-time	Real number ; (days)	The amount of time the virus incubates within the person
isolating	Boolean	Tells us whether the person is isolating or not

Patches

p-infected	Boolean	Tells us whether the patch is contaminated with the virus
Infect-time	Real number ; (hours)	The amount of time patch is contaminated for

Type-of	String	Indicates what time of environmental agent sits on this patch, eg. house / workplace / shop

Globals

contact-rate	Real number ; (people/tick)	Used to track how many susceptible people come into contact with infected people for R0 calculation
variation	String	Reports the variation in which the model will be run (with or without a policy).
economy-value	Real number ; (arbitrary)	Arbitrary value representing the economic growth and value of the community
infect-prob	Real number ;	This value becomes the chance of infection, eg infect-prob = 4 will have a 1 in 4 chance of infection.
num-infected	Real number ; (people)	Initial amount of people infected by COVID-19
num-of-houses	Real number ; (houses)	Number of houses on the map
num-shops	Real number ; (shops)	Number of shops on the map
per-household	Real number ; (ratio)	The amount of people per home on the map
num-of-buildings	Real number ; (buildings)	Number of buildings on the map
surface-duration	Real number ; (hours)	The amount of time the disease lasts on the on surfaces for the infect-time of the patch.

Scales :

The model runs each tick as an hour and records r0 and time per day off every 24 ticks on the system. The map is a grid of 50x34 of 1x1 square km cubes which equates to 1700 sq km area, which is aimed to mimic a rural suburb density in size. Each person is meant to be smaller, however for the purpose of the experiment, in order to visually illustrate the movement of people, the size of people was factored up. The movement of each person from home to work, was factored to 8 in order to keep the restraints of time realistic as it should take less than 1 tick to travel from home to work within a suburb of 1700 sq km. Times which revolved around the virus were scaled to days (24 ticks per day) in order to scale it towards the amount of time it would take the virus to incubate, show symptoms and recover.

Processes overview and Scheduling

Processes:

The model has been built to illustrate the movement of people and how this spreads the virus. Once the model is setup, each tick cycles through 1hr of the day, each time a tick is passes:

1. Spread-infection: spreads the infection among people that are in contact with each other or are in an area which is contaminated by the virus, along with this, the patch variables infect-time and p-infected are updated based on whether the patch has been contaminated again based on the probability of infection. If people become infected, their variables and states are updated as well. For incubation-times and

2. Recolor: people are recoloured based off of their current state being in incubation, symptomatic or recovered. Since incubation-time, symptom-time are variables we use conditions to filter out those who are still showing symptoms or are in incubations via conditional statements.

3. Move : based on the variation, people will move accordingly based on their current variables and states, if their time is up and they are required to traverse home they will, else they will stay working and vice versa. In the case where the policy is integrated, people will move based on the policy rather than the probability of movement based on their current state (showing symptoms, in incubation or recovered).

4. Calculating contact rate : while the people are moving, the number of people who are susceptible and infected people who are in contact are updated and calculated for the plotting of our basic reproduction number r0.

Design Concepts

Interaction between people and places
Interaction occurs between people who are infected and patches and locations in which they visit. When infected agents interact with patches which may be contaminated with the virus, there is a probability that the patch gets re-contaminated, in this case the patch variables and states are refreshed. Based on the type of person that the patch interacts with, the infect-time and p-infected state of the patch may vary. On the other hand, people who come in contact with patches which are infected, have their variables changed based on the probability of infection and obtain the virus, if they do obtain the virus, the incubation-time of the person changes and their infected state is updated.

Learning of virus
During the incubation phase of the virus, people are less likely to know that they actually have the virus, so people go along with their daily routine normally, however if they gain symptoms of covid, people learn that they may be sick, and this influences the movement behaviour of the person, reducing the likelihood that they are to go to work or a shop.

Interaction between people and people
The interaction between people, allows for the r0 to be calculated as people who are susceptible to the virus and people who have the virus come into contact, the global variable contact-rate is updated and hence r0 can be produced.

Objective measure of Infection and stage times
The objective measure for incubation-time and symptom is decided via a probability normal distribution with a mean of 7 and a standard deviation of 2 as the incubation time “range between 1 - 14” and has a “median between 5 - 7” [3] , with this normal distribution, the incubation time can be pick randomly and securely within the ranges of incubation time and symptom times of COVID-19.

Observations
The outputs of people and their current states are plotted against time, alongside this we observed the number of days which have passed, and the r0 value as time passes. The number of infected people are also observed and monitored with the economic value of our model.

Initialisation

Initialisation of the model begins with setting the default shapes of agents to their designated type, either being people, houses, shops or workplaces so that they can be drawn later on. Next the map is drawn based on a binary matrix list indicating where buildings can and can not be placed, we iterate through this matrix list and color the patches accordingly. After the map has been drawn the places on the map are initialised randomly on the map, however kept to the constraints of the number-of-houses, num-of-buildings and num-of-shops. People are sprouted from homes with the default location being the home that has sprouted them. Upon being sprouted, people are initialised with one random workplace, a work-time within the range of 6-10 hours, a rest-time of 0 and set in states where they have not been infected or have recovered. Since the lunch spot daily changes, it is defaulted to none. People are then infected based on the number of infected-people and recolored accordingly to visually represent the infected people.

Infected People and default values:

- Incubation-time = floor value of normal distribution with mean 7, std 2
- Infected = true
- Symptom- time = 0

Submodels

The Basic reproduction number:

R0 = transmissibility * contact rate * duration of infectiousness

ref: [6]

This is the model which was used to calculate the basic reproduction number, transmissibility suggests the probability of being infected by a susceptible individual and an infected individual, calculated via the 1 / infect-probability. Contact rate is the rate in which infected and non-infected people come into contact, calculated with the calc-contact-rate function. Duration of infectiousness is defaulted to time-period of the infection of the person.

Citations

[1] Coronavirus disease 2019 (COVID-19) Situation Report - 94
World Health Organisation, 23/04/2020 [online]
https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200423-sitrep-94-covid-19.pdf

[2] Australian Health Protection Principal Committee (AHPPC) advice on reducing the potential risk of COVID-19 transmission in schools
Australian Government - Department of Health, 17/04/2020 [online]

https://www.health.gov.au/news/australian-health-protection-principal-committee-ahppc-advice-on-reducing-the-potential-risk-of-covid-19-transmission-in-schools#:~:text=COVID%2D19%20is%20a,as%20a%20mild%20disease.

[3] Australian Health Protection Principal Committee (AHPPC) coronavirus (COVID-19) statements on 14 May 2020
Australian Government - Department of Health, 16/05/2020 [online]
https://www.health.gov.au/news/australian-health-protection-principal-committee-ahppc-coronavirus-covid-19-statements-on-14-may-2020

[4] What you need to know about coronavirus (COVID-19)
Australian Government - Department of Health, 10/08/2020 [online]

https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert/what-you-need-to-know-about-coronavirus-covid-19#symptoms

[5] Water, sanitation, hygiene and waste management for the COVID-19 virus
World Health Organisation, 03/03/2020 [pdf]
https://www.who.int/publications/i/item/water-sanitation-hygiene-and-waste-management-for-the-covid-19-virus-interim-guidance

[6] Notes On R0
James Holland Jones - Department of Anthropological Sciences Stanford University, 01/05/2007 [pdf]
https://web.stanford.edu/~jhj1/teachingdocs/Jones-on-R0.pdf

[7] Spread of Disease
Netlogo - Uri Wilensky & William Rand, 2015 [Book]
http://www.netlogoweb.org/launch#http://www.netlogoweb.org/assets/modelslib/IABM%20Textbook/chapter%206/Spread%20of%20Disease.nlogo