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Coronavirus simulation

DSA assignment semester 1 2020

Report

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1. Abstract

In this investigation we are investigating the effect of government restrictions in slowing the spread of the coronavirus. We will also be investigating how the transfer, death and recovery rate effect the spread and effect of the disease. In addition, we will investigate the effect of having hidden carriers of the disease, and how well they are detected. The effect of initial number of infected people will also be considered. It is expected that higher transfer rates will increase the spread of disease, while a high death rate will quickly eradicated the disease although at a high expense of lives. A high recovery rate, is also expected to eradicate the disease quickly, with minimal loss of life. An increased carrier rate and decreased carrier detection is expected to increase the spread of the disease. A higher percentage of initially infected people is expected to increase the spread of the disease.

2. Background

The simulation was created as a network of people since the disease is most commonly spread person to person, this method was deemed a good way to represent the connections between people and how the disease may spread between connections. People are created in groups, where each member of a group is connected to each other member. There are different types of connection, with more intimate connections providing greater chance for spreading the virus. Since the groups are allocated randomly, they are not always realistic, for example, a group of people living together may have different neighbours.

During the simulation, the government employs preventative measures based on their level of precaution and the spread of the virus. Next individuals apply individual preventative measures, or rebel against the government measures base on their own rebelliousness. Infected individuals automatically apply all individual restrictive measures. Each susceptible person then has a chance of catching the virus from each connection to a carrier or infected person. The probability for this transfer is determined, by the intimacy of the connection, government restrictions, individual restrictions, the transfer rate and a person's vulnerability to the virus, determined by their age and health condition.

A carrier has the chance of becoming a known infection and a chance of recovering based on the level of carrier detection and the recovery rate respectively. The chance for becoming infected happens before the chance of recovering. An infected person has a chance to die and a chance to recover, based on the death and recovery rate respectively. The chance of dying occurs before the chance of recovering, meaning equal death and recovery rates typically yield higher deaths than recoveries. This is somewhat countered by the chance for carriers to recover but no chance to die.

Recovered people have a chance of becoming re-infected, but the chance is only 10% of the chance a susceptible person has. If an infected person dies, all their connections are immediately removed so that they can no longer infect the living.

The simulation runs in successive iterations, where each iteration represents a fortnight. The simulation ends when there is no one left who is infected or a carrier of the disease, when there is no more susceptible people, i.e everyone has been infected, or when a full year has passed.

3. METHODOLOGY

In order to obtain data on a wide range of possible outcomes, a parameter sweep was used to obtain more than 5000 graphs and text files. Due to the excessive random calculations involved in the simulation, results may vary for repeat trials. In order to somewhat mitigate this, the same network was used for simulations with the same initial infection rate.

In order to evaluate the effect of different elements it is necessary to have some way to compare different runs of the simulation. Each iteration in the simulation prints the week number as well as the proportion of the population that falls into each infection category. In order to compare runs, we can compare the statistics from the final iteration. Of particular importance is the week when the simulation finished, the percentage of dead people and the percentage of susceptible people. These results are also represented graphically and can be used to see how the infection rates varied over time.

The command to run a single simulation is:

python3 HealthSim.py -s numPpl %inf trans_rate recov_rate death_rate car_rate car_inf_rate gov_prec

Or if using a file to load the network:

python3 HealthSim.py -s netFile trans_rate recov_rate death_rate car_rate car_inf_rate gov_prec

More information can be found by running the simulation without parameters as shown below:

python3 HealthSim.py

The parameter sweep can be run as follows:

bash paramSweep.sh

Since the parameter sweep completes 5120iterations it takes around 3 hours to complete. (on Dell xps 13-9370-2019) The parameter sweep places the results in a file named paramSweeps, if you run the sweep it may overwrite existing files, make sure to move the old folder if you wish to preserve results. The folder currently contains the results from the parameter sweep with 5120 iterations. If you wish to change to values being swept over, you can change the values of the variables shown below, from the paramSweep.sh file.

```
numPpl=750

lowInf=5          #0.005
highInf=320
multiInf=4

lowTrans=0.1
highTrans=1
stepTrans=0.25

lowRecov=0.1
highRecov=1
stepRecov=0.25

lowDeath=0.1
highDeath=1
stepDeath=0.25

#carrier rate
lowCar=0.1
highCar=1
stepCar=0.25

car_inf=0.5

lowGovPrec=0
highGovPrec=2
stepGovPrec=0.5
```

Different parameters are expected to have an impact on the time and memory it takes to complete the simulation. The number of people is the most obvious factor here. Completing the simulation with more people require more memory to store those people as well as more time to iterate over all the people in the network. This is especially noticeable when creating a network with all the connections between people.

Increasing the rate of initial infection will likely have a similar effect on the time creating the network, but to a lesser extent. It should have no adverse effect on running the simulation itself or on the memory used.

Increasing the transmission rate will increase the number of people infected and may decrease the time taken since, everyone may get infected and the simulation will end. It also decreases the number of susceptible people who are a more time expensive operation. It is not expected there will be any impact on memory usage.

Increasing the recovery rate could increase or decrease the amount of time. Like susceptible people, recovered people are an expensive operation to run in terms of time. However, increase the recovery rate means that the simulation may end early due to the eradication of the disease. It is not expected to impact the memory usage.

Increasing the death rate is likely to reduce the time taken and memory used. This is partially because there is greater possibility for the simulation to end early since all infected people have died. The more significant reason is that the connections held by a dead person are removed, freeing memory and meaning there are less connections to iterate over, effectively reducing the time taken. Additionally, dead people do not require calculations in terms of changing infection status.

Changing the carrier rate is unlikely to affect memory usage but it may increase the amount of time taken to complete the simulation since a higher carrier rate means the infections are detected later and it takes longer for restrictions to be put in place. This means the virus would not be quenched for a longer time meaning the simulation must run more iterations. It is also possible that this increase in the spread of the disease decreases the time taken by allowing all the susceptible people to become infected and so to end the virus early.

The carrier to infection rate is not expected to affect the memory, but it effectively determines how well the virus is being detected. This is expected to have similar effect to that of increasing the carrier rate, where the simulation could go on longer since, the virus is harder to eradicate, but it may go quicker by infecting everyone.

Changing the government precautions is also unlikely to affect memory usage, but it is likely to have an impact on the time taken to complete a simulation. A low level of government usage may allow the virus to run rampant and infect everyone, ending the simulation early. The same could be said for a high level, of government precaution, where the virus could be eradicated early since its harder to spread. Both high and low levels could also have the adverse effect of increasing the time taken by delaying the domination or eradication of the virus respectively.

4. Results

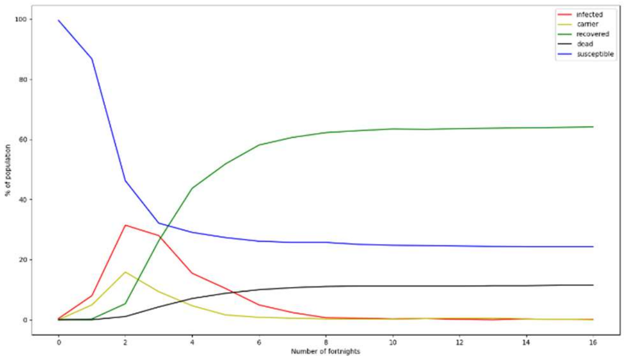
INVESTIGATE each one with 4 graphs in a 2x2 table, use the percieved accurate params, and then the variation for that particular param

4.1. Government precaution

The following graphs, and corresponding final statistics are the results from what is perceived to be the most realistic situation with the government precaution varying. This perceived most realistic situation is as follows:

- Population:	750
- Initial infection rate	0.4%
- Transfer rate:	35%
- Recovery rate	60%
- Death rate	10%
- Carrier rate	35%
- Carrier to infected rate	50%

Government Precaution: 0.0

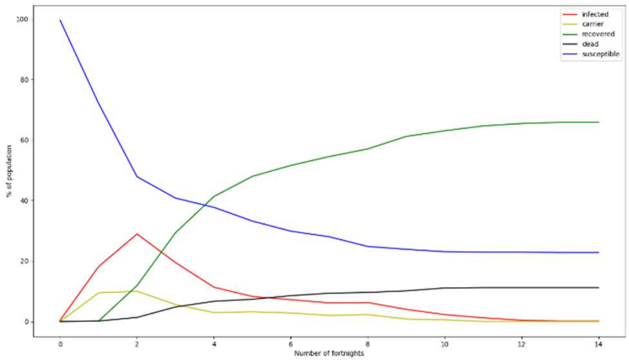


Week 34:

Statistics:

Infected: 0.00 %
Carrier: 0.00 %
Susceptible: 24.27 %
Recovered: 64.27 %
Dead: 11.47 %

Government precaution: 0.5

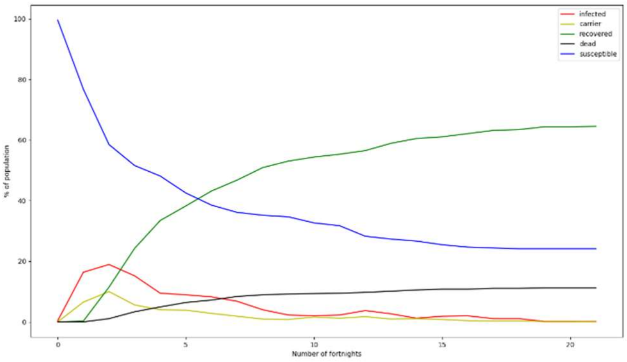


Week 30:

Statistics:

Infected: 0.00 %
Carrier: 0.00 %
Susceptible: 22.80 %
Recovered: 65.87 %
Dead: 11.33 %

Government precaution: 1.0

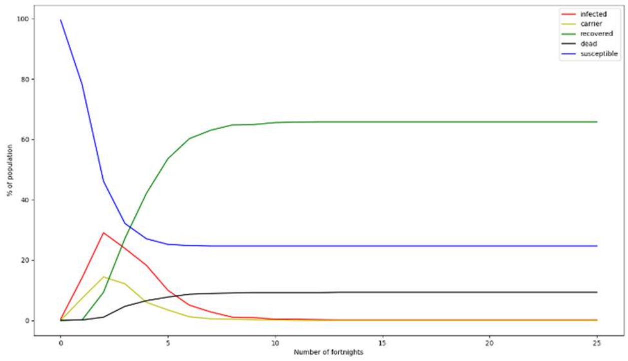


Week 44:

Statistics:

Infected:	0.00 %
Carrier:	0.00 %
Susceptible:	24.13 %
Recovered:	64.53 %
Dead:	11.33 %

Government precaution: 1.5

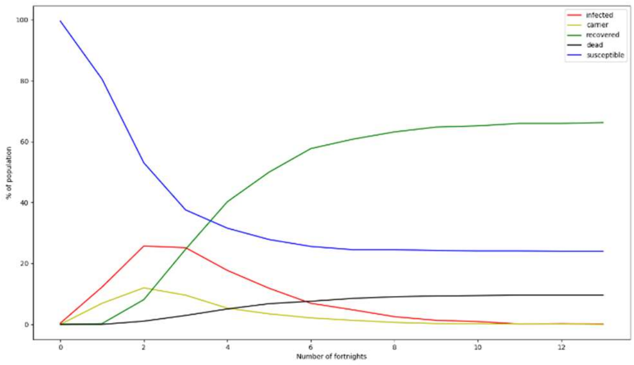


Week 52:

Statistics:

Infected:	0.13 %
Carrier:	0.00 %
Susceptible:	24.67 %
Recovered:	65.87 %
Dead:	9.33 %

Government precaution: 2.0



Week 28:

Statistics:

Infected:	0.00 %
Carrier:	0.00 %
Susceptible:	24.00 %
Recovered:	66.40 %
Dead:	9.60 %

The government precautions seem to have the effect of slowing down the spread of the virus. This can be seen in the decreasing sharpness in the drop of the percentage of susceptible people, and the increase in the number of weeks before the virus is eradicated. While the number of people left uninfected remains much the same, seems to decrease slightly. This may just be due to the random nature and variability of the simulation, but it may also reflect the increase in time, giving people a greater opportunity to recover.

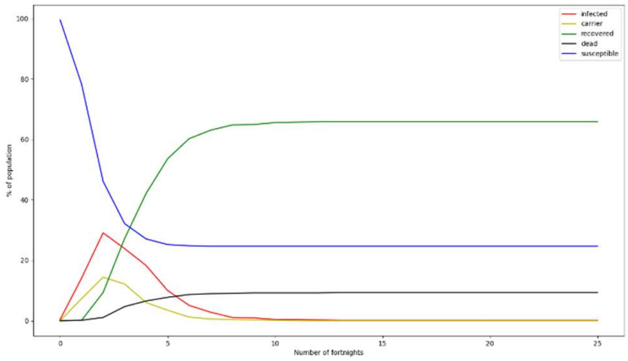
4.2. Initial infection rate

The non-varying parameters are as follows:

- Population: 750
- Transfer rate: 35%

- Recovery rate 60%
- Death rate 10%
- Carrier rate 35%
- Carrier to infected rate 50%
- Government precaution 1.5

Initial infection rate: 0.4%

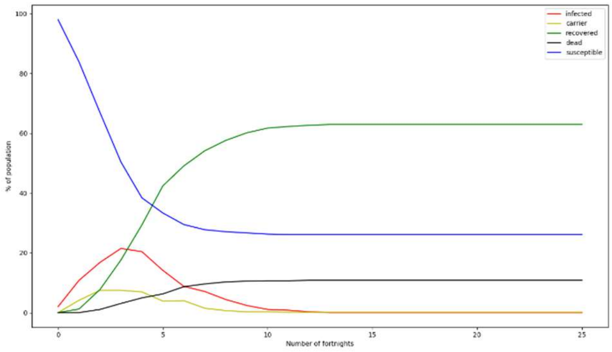


Week 52:

Statistics:

Infected: 0.13 %
Carrier: 0.00 %
Susceptible: 24.67 %
Recovered: 65.87 %
Dead: 9.33 %

Initial infection rate: 2%

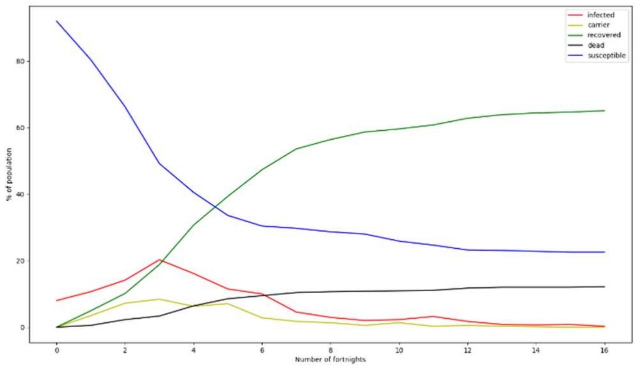


Week 52:

Statistics:

Infected: 0.00 %
Carrier: 0.13 %
Susceptible: 26.13 %
Recovered: 62.93 %
Dead: 10.80 %

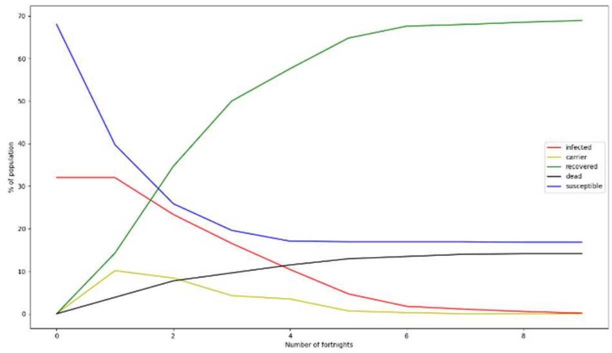
Initial infection rate: 8%



Week 34:

Statistics:

Infected: 0.00 %
Carrier: 0.00 %
Susceptible: 22.53 %
Recovered: 65.33 %
Dead: 12.13 %



Initial infection rate: 32%

Week 20:

Statistics:

Infected: 0.00 %
Carrier: 0.00 %
Susceptible: 16.80 %
Recovered: 69.07 %
Dead: 14.13 %

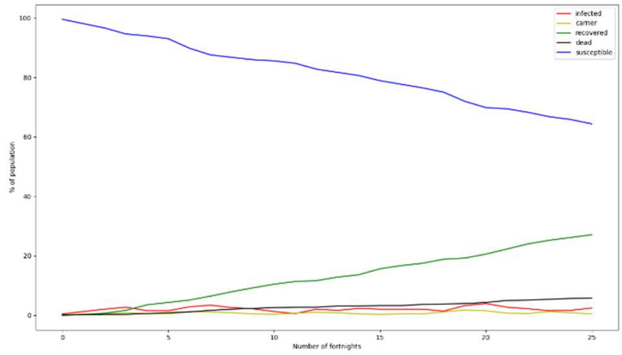
There seems to be a strong correlation with the decreasing number of susceptible people and increasing percentage of deaths. This is likely just because more people are infected and therefore more have a chance to die. The finishing time appears to be somewhat random with the first two graphs showing the disease almost eradicated but continuing for weeks with just a very small amount of people infected.

4.3. Transfer rate

The non-varying parameters are as follows:

- Population: 750
- Initial infection rate 0.4%
- Recovery rate 60%
- Death rate 10%
- Carrier rate 35%
- Carrier to infected rate 50%
- Government precaution 1.5

Transfer rate: 10%

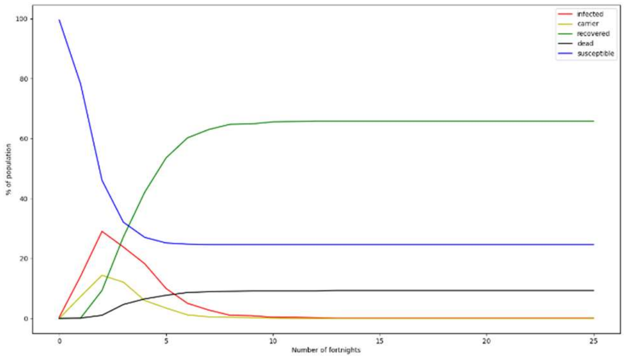


Week 52:

Statistics:

Infected:	*0.80 %*
Carrier:	*0.40 %*
Susceptible:	*63.87 %*
Recovered:	*28.93 %*
Dead:	*6.00 %*

Transfer rate: 35%

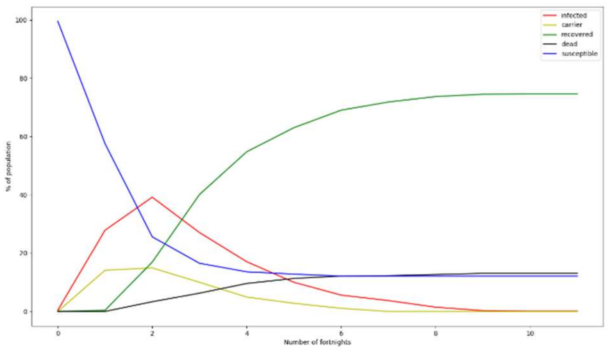


Week 52:

Statistics:

Infected:	*0.13 %*
Carrier:	*0.00 %*
Susceptible:	*24.67 %*
Recovered:	*65.87 %*
Dead:	*9.33 %*

Transfer rate: 60%

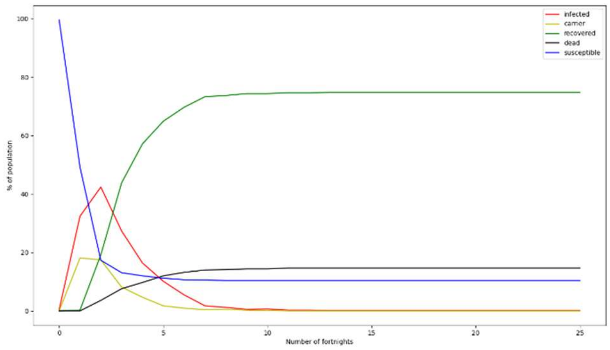


Week 24:

Statistics:

Infected:	*0.00 %*
Carrier:	*0.00 %*
Susceptible:	*12.13 %*

Transfer rate: 85%



Week 52:

Statistics:

Infected:	*0.13 %*
Carrier:	*0.00 %*
Susceptible:	*10.40 %*

Recovered: 74.80 %
Dead: 13.07 %

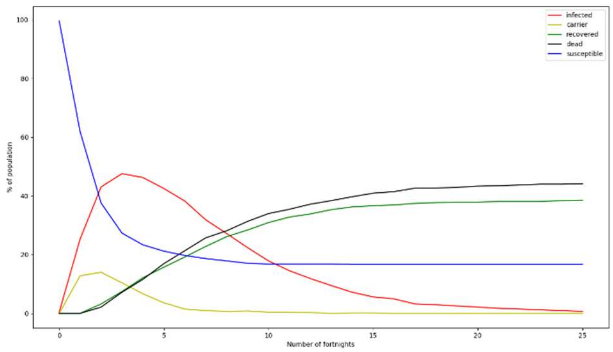
Recovered: 74.80 %
Dead: 14.67 %

There is clearly a correlation between the transfer rate and the number of people who remain susceptible. The transfer rate increases the spread of the virus which allows more people to recover and die, and less people to never become infected.

4.4. Recovery rate

- Population: 750
- Initial infection rate 0.4%
- Transfer rate 35%
- Death rate 10%
- Carrier rate 35%
- Carrier to infected rate 50%
- Government precaution 1.5

Recovery rate: 10%

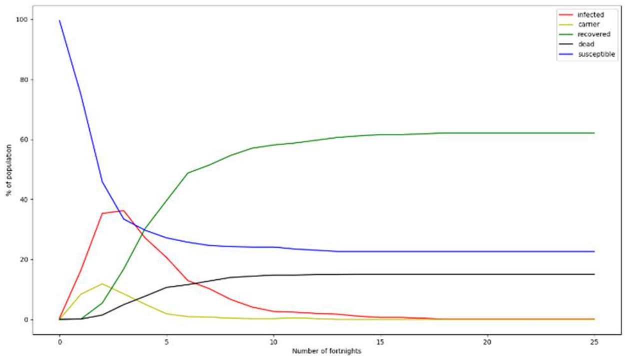


Week 52:

Statistics:

Infected: 0.53 %
Carrier: 0.00 %
Susceptible: 16.67 %
Recovered: 38.67 %
Dead: 44.13 %

Recovery Rate: 35%

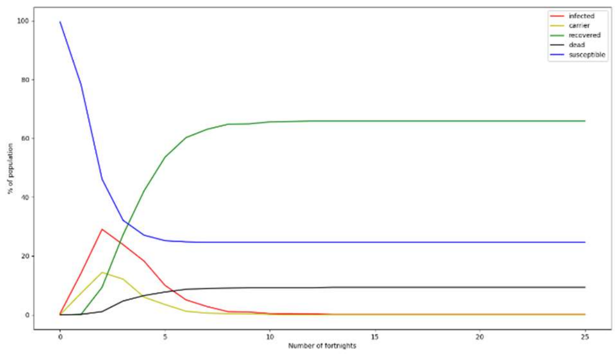


Week 52:

Statistics:

Infected: 0.13 %
Carrier: 0.00 %
Susceptible: 22.67 %
Recovered: 62.13 %
Dead: 15.07 %

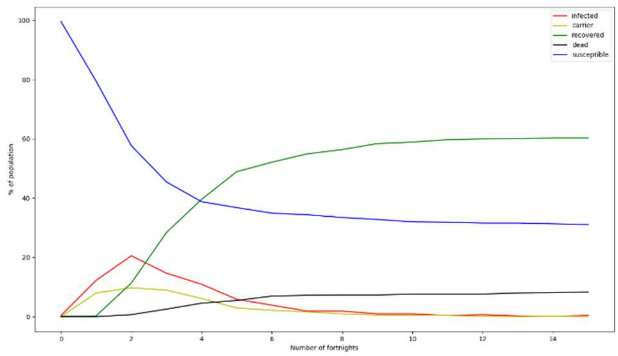
Recovery rate: 60%



Week 52:

Statistics:

Recovery rate: 85%



Week 32:

Statistics:

Infected: *0.13 %*
Carrier: *0.00 %*
Susceptible: *24.67 %*
Recovered: *65.87 %*
Dead: *9.33 %*

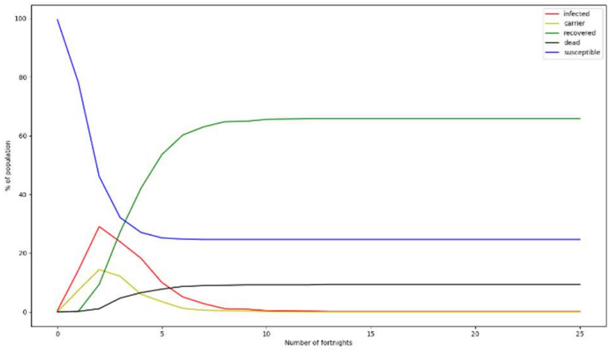
Infected: *0.00 %*
Carrier: *0.00 %*
Susceptible: *31.07 %*
Recovered: *60.67 %*
Dead: *8.27 %*

Clearly increasing the recovery increases the percentage of people who recover. It can also make the simulation go faster by converting more infected people to recovered faster. This is particularly evident in the last run where the simulation ended early and has the least deaths. This decreasing rate of deaths is also a result of increasing recovery, which makes sense since the quicker a patient recovers the less chance they have to die.

4.5. Death Rate

- Population: 750
- Initial infection rate 0.4%
- Transfer rate 35%
- Recovery rate 60%
- Carrier rate 35%
- Carrier to infected rate 50%
- Government precaution 1.5

Death rate: 10%

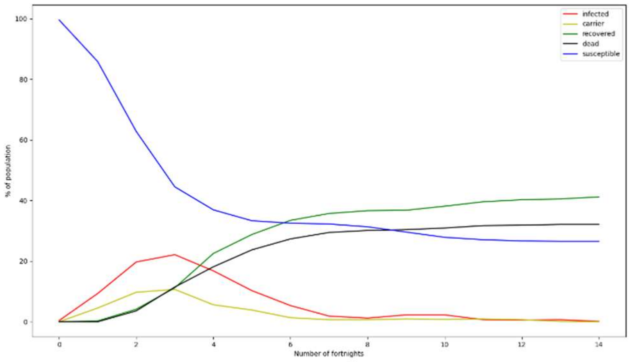


Week 52:

Statistics:

Infected: *0.13 %*
Carrier: *0.00 %*
Susceptible: *24.67 %*
Recovered: *65.87 %*
Dead: *9.33 %*

Death rate: 35%



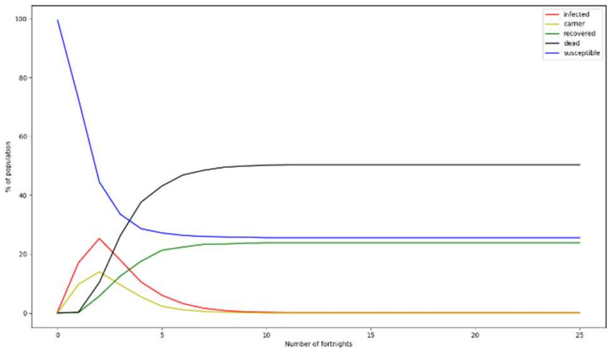
Week 30:

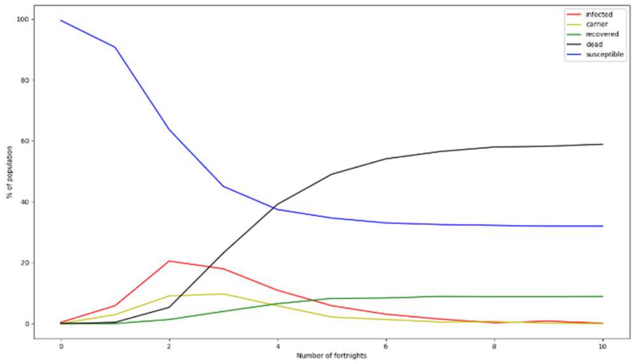
Statistics:

Infected: *0.00 %*
Carrier: *0.00 %*
Susceptible: *26.53 %*
Recovered: *41.33 %*
Dead: *32.13 %*

Death rate: 60%

Death rate: 85%





Week 52:

Statistics:

Infected:	*0.13 %*
Carrier:	*0.00 %*
Susceptible:	*25.60 %*
Recovered:	*23.87 %*
Dead:	*50.40 %*

Week 22:

Statistics:

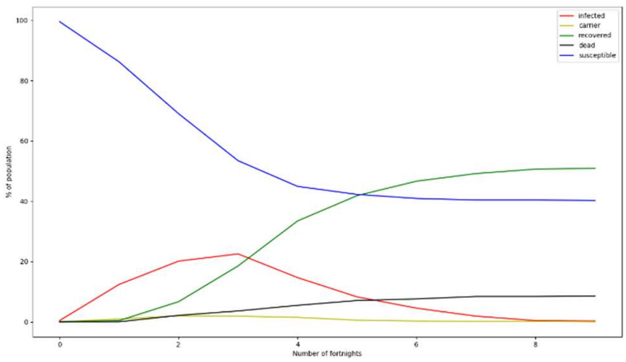
Infected:	*0.00 %*
Carrier:	*0.00 %*
Susceptible:	*32.00 %*
Recovered:	*8.93 %*
Dead:	*59.07 %*

Clearly increasing the death rate decreases the chance of recovery, especially since death is calculated first. It can also cause the simulation to end early as most of the infected people die. The result is that increasing the death rate, can result in less total people infected.

4.6. Carrier rate

- Population:	750
- Initial infection rate	0.4%
- Transfer rate	35%
- Recovery rate	60%
- Death rate	10%
- Carrier to infected rate	50%
- Government precaution	1.5

Carrier rate: 10%

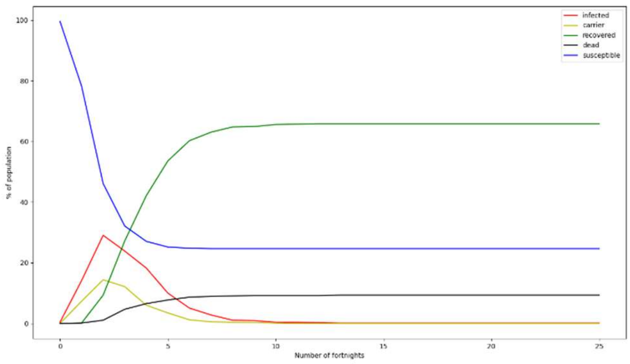


Week 20:

Statistics:

Infected:	*0.00 %*
Carrier:	*0.00 %*

Carrier rate: 35%



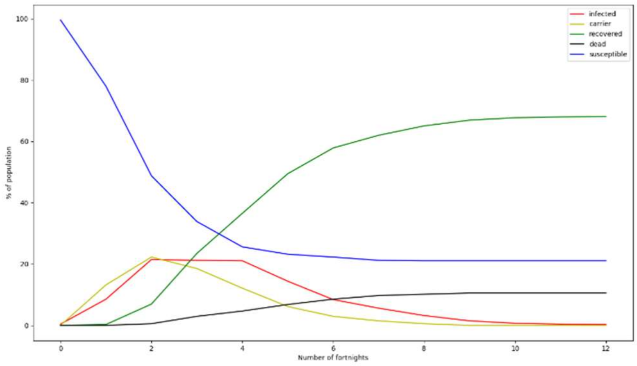
Week 52:

Statistics:

Infected:	*0.13 %*
Carrier:	*0.00 %*

Susceptible: 40.27 %
Recovered: 51.20 %
Dead: 8.53 %

Carrier rate: 60%



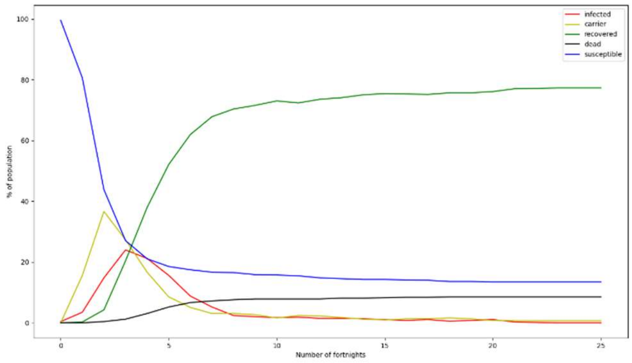
Week 26:

Statistics:

Infected: 0.00 %
Carrier: 0.00 %
Susceptible: 21.07 %
Recovered: 68.40 %
Dead: 10.53 %

Susceptible: 24.67 %
Recovered: 65.87 %
Dead: 9.33 %

Carrier rate: 85%



Week 52:

Statistics:

Infected: 0.00 %
Carrier: 0.67 %
Susceptible: 13.47 %
Recovered: 77.33 %
Dead: 8.53 %

Increasing the rate of infections that are initially carriers seems to increase the recovery rate. This makes sense since carriers have a chance to become fully infected or to recover but have no chance to die. There is also a decreasing amount of people who didn’t get the disease.

5. Conclusion

The results show that a higher transfer rate did aid the spread of the disease and that the higher death rates would eradicate the disease as with higher recovery rates. This was expected. The increase of the carrier rate also increased the spread of disease as expected, It also increased the recovery rate which was unprecedented. Increasing initially infected people also increased the spread of the virus. The increased government restrictions did little to curb the virus, but did manage to slow it down, allowing more people to recover.

The result is that the government does need to put restrictions in place, although this needs to be considered carefully since there are associated economic results. It is also important to try and detect the virus as early as possible. Variable carrier to infection rates wasn’t investigated, but by decreasing the carrier rate it was clear less people were infected with the disease.

This investigation could be significantly extended. Variables could be considered not just individually, but also with their joint effect. The connections could also be made more realistic by trying to add groups of connections that make sense. There is also room for more parameters to be investigated and for the parameters to investigated in more detail with finer increments. The number of connections could also be increased to be more realistic. This was currently not done due to the sharp increase in time to create a network. There could also be some modelling on the social and political pressures that may effect when a government enforces or lifts a restriction.

6. References

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