EMAT10006 Further Computer Programming

GROUP REPORT

Python Simulation of Shoppers in a Supermarket and Covid Susceptibility

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MAY 2021

1 Introduction

In light of the current pandemic, this project seeks to ascertain the effects of supermarket regulations on the spread of covid. The following regulations will be explored: mandatory masks, limiting the number of people allowed in a shop at any one time, one-way layout, time of the year and associated infection rates based on real data. By simulating a shop layout and the passage of shoppers through it, the spread of COVID-19 is predicted.

2 Code Setup

Figure 1 shows how the user inputs, python files and external data feed into the Simulation.py file. Networkx_aldi_layout.py contains the code which creates a graph layout formed with the Networkx module. Networkx _random _path _example.py contains the code which creates the various paths through the shop. Infection _rate _data.py takes the external data from COVID_Bristol_infections.csv and calculates the relevant infection rate for a given month contained within the data. Main.py function calls Simulation.py and outputs animation and plots from the functions Animation.py, Plot_results.py and Results.py. Results.py contains the outputted numerical data used to create the plots and animations. A GUI was also designed

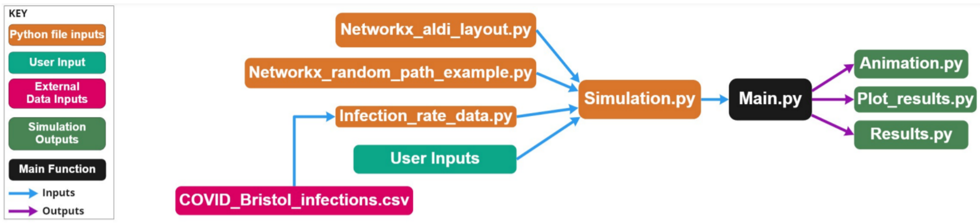

Figure 1: Flowchart of Simulation Inputs and Outputs

as part of the project. The intention for the GUI was to provide an alternative way of running the simulation, using a user interface to allow for easy user inputs. The GUI features a calendar, allowing the user to select a date to base the simulation on.

2.1 Simulation

The simulation is designed with two classes, one updating the whole simulation at each time step, the simulation class, and another which handles the people in the shop at each time step and their characteristics. Each is described in detail within the code submission.

The 3d array representing the shop has 6 layers, each of size 8 x 7, which contain the number of people at each state within the shop. Each layer represents a Covid state:in level 0: number of people at that node who are susceptible wearing a mask, level 1: susceptible and not wearing a mask, level 2: infected wearing a mask, level 3: infected and not wearing a mask, level 4: caught COVID whilst shopping with a mask and level 5: caught COVID in the shop without a mask. The simulation works by moving people around this array, based on inputs from the user regarding infection levels, masks and shop path systems simulating the spread of infection based off of these inputs. The spread of infection is defined by the probability of infection variable which defines the likely hood of a susceptible person catching COVID when in the same space as someone with the infection. The likelihood is corrected based on whether the person is wearing a mask or not to simulate the reduced infection rate caused by shoppers in masks.

The simulation uses a path generator function to give the people being simulated a path. There are a number of path options available: slow, fast and one-way paths. These were created to simulate the policy changes during the COVID pandemic which enforced one way path systems and people to only shop when totally neccersary. It also allows the user to see the effect caused on transmission when people move at different speeds in the shop. Real data was analysed to inform the infection rate of the area. COVID-19 infection levels from Bristol were extracted from (1), and manipulated to estimate a monthly infection rate in Bristol, using the methodology set out from this analysis (2). This allows the user to analyse the different proportions of people that would have been likely to become infected in shops during different times in the Bristol pandemic.

2.2 Plotting from the simulation

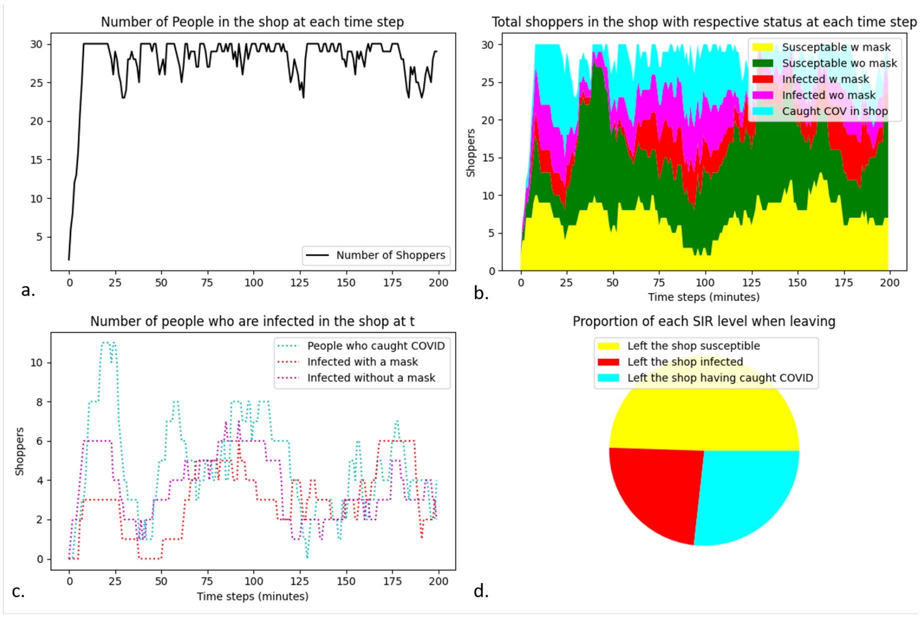

Figure 2: Four graphs from the simulation a. the number of people in the shop at each time step, b. proportion of people of each state at each time step, c. the different numbers of different types of infectious people in the shop at a time step and d. pie chart of the proportion of people who have left the shop with each status

Figure 2 shows the results from the plotting function. Four plots are retrieved from the plotting function. Figure 2a. shows the number of people in the shop at each time step. Figure 2b. shows the proportion of people in the shop at each time step, using a stacked line graph to allow the user to see the proportions of infected and susceptible people in the shop and whether they are wearing masks or caught COVID within the shop. This aims to allow the user to visualise the impact of the variables being adapted within the simulation on the rate of infected. Figure 2c. shows the range of infectious people in the shop at each time step, aiming to capture the trends between the number of infectious people who entered the shop and the number of people who caught COVID within the shop. Figure 2d. shows the proportion of people who have left the shop infected (people who entered the shop infected), susceptible, or people who caught COVID within the shop.

2.3 Animation

There is an animation class which calls both a line animation and a grid animation. The grid animation is a visualisation of the simulation,with a still image of the animation is presented in Figure 3. The grid

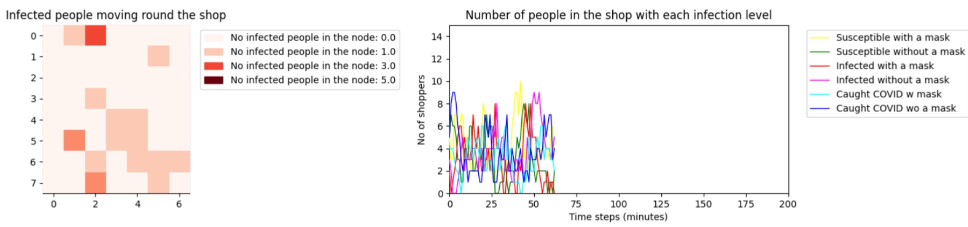

Figure 3: A still image of the animation, the left showing the grid simulation of infected people within the shop and the right showing the line chart of the number of people with each status in the shop at time t

to the left in Figure 3, shows the number of infected people within each node of the shop, in this still image the grid shows the number of infected people in the shop at each time step of the simulation. A red colour map was chosen to align with the red colouring used in the other plotting results relating to the infected people. Infected people animated include all infected people, with and without masks and those who caught COVID within the shop.

The line graph to the right of the grid animation shows 6 lines. These 6 lines represent the number of people at each time step in the simulation that are at each status. It was attempted to produce a stacked plot to better visualise the relationship between the different types of shoppers such as seen in figure 2b. however this was incompatible with the animation package being used. A limitation of the line animation is that the yaxis limit is set to half the number of max shoppers in the shop, this had to be done to allow for the user to see the lines being produced properly, however when there are only one type of shopper in the shop, the line animation would not work. This was a compromise that had to be made.

3 Running the Code

To initiate the simulation, the python code can be ran from the command line, or via a GUI, see Figure 4 for reference. Multiple simulations can be run using the multiplesimulation.py script. See figure 5, change can be followed by 0 (max entry), 1 (duration), 2 (max shoppers), 3 (prob of i) , 4 (chance person wears mask), 5 (level of covid in area).

```
$ python Main.py --help
usage: Main.py [-h] [--max_entry N] [--duration N] [--max_shoppers N] [--month myy] [--path_system N]
               [--level_of_covid P] [--prob_of_i P] [--chance_person_wears_a_mask P] [--plot]

Animate an epidemic

optional arguments:
  -h, --help            show this help message and exit
  --max_entry N         Maximum of N people can enter at once
  --duration N          Run simulation for N time steps
  --max_shoppers N      Maximum number of shoppers in the shop
  --month myy           The month to use to represent the infection rate where 320 is March 2020 (from 320 - 421)
  --path_system N       The type of path system 0 = slow walker 1 = quick walker 2 = one way path system, 3 = mixed
                        scenario
  --level_of_covid P    Probability of any individual in the area being infected
  --prob_of_i P         Probability of any individual getting infected from the shop
  --chance_person_wears_a_mask P
                        Probability of any individual wearing a mask
  --plot                Generate plots instead of animation
```

Figure 4: Illustrating the way to run the code through the command line, showing the help function which displays the arguments available to be changed

```
$ python multiple_simulations.py  --change 0  #run multiple simulations and change variable 0
$ python multiple_simulatons.py --path_system #run multiple simulations looking at the efect of oneway systems
```

Figure 5: Illustrating how to run the multiple_simulation code.

4 Results

An analysis was undertaken to understand the impact on the simulation of varying different parameters. The simulation was run for multiple iterations,varying different input arguments at increments.

4.1 Shop capacity

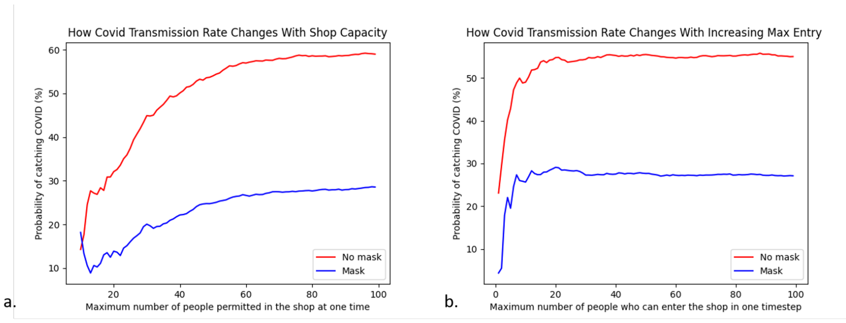

Figure 6: Where a. shows the effect of varying the maximum number of people in the shop on the probability of infected and b. shows the impact of varying the number of people who can enter the shop at one time

Varying the shop capacity variable shows the effect that minimising the number of people allowed in a shop at one time can have on the probability of infection. Figure 6a. shows the steep increase in the probability of infection, converging to around 40%. Figure 6b. shows the probability of catching COVID rising rapidly to a maximum of around 55% when the number of people entering the shop at one time step is maximised. The results from this analysis show the effect that minimising the total number of people in a shop and entering a shop can have on COVID infection risk, due to the decrease in contact between people in the same space.

4.2 The effect of masks and infection rate

The effect of the local infection rate on the probability of infection can be seen in Figure 7a. indicating the increasing risk of infection as the probability of a new shopper being infected tends to 1. This indicates the effect within shops of the local area having a high infection rate, linking to the steep transmission rates observed during the pandemic when infection rates were high. Figure 7b. shows the effect of shoppers wearing masks, indicating the rapid decrease from 70% of people catching COVID to less than 40% when all people wear masks.

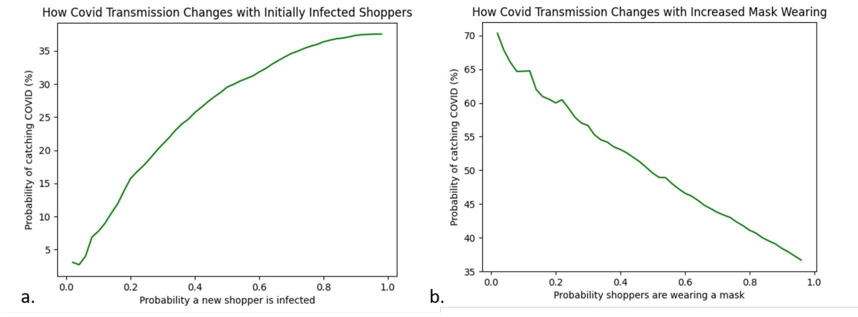

Figure 7: a. shows the effect of varying the probability of someone entering being infected and b. shoppers wearing masks

4.3 The convergence of the model over time

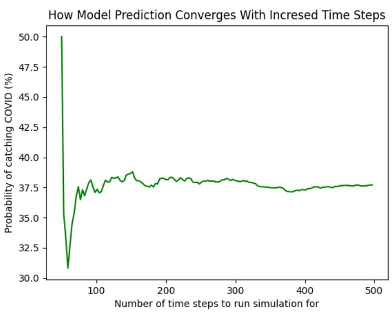

Figure 8: Convergence of the probability of infection as time steps are increased

The model was verified by testing that the simulation converged to a stable probability when run with constant parameters over different time periods. As demonstrated in Figure 8, the simulation converges to a stable probability of 37.5% when run for more than 200 time steps. Evidently the simulation needs to be run for a certain numnber of time steps to allow shoppers to move throughout the shop, at small amounts of time steps, there would be limited interaction between people and only a few people would have moved through the space. This is what ultimately causes the instability in the probability at small time step iterations. Therefore if the model were to be used in the future for real life analysis, it would be recommended to run the model over time periods longer than 200.

References

[1] Bristol Government Website `https://www.bristol.gov.uk/statistics-census-information/the-population-of-bristol`

[2] COVID Statistics Calculation `https://www.nebraskamed.com/COVID/how-to-calculate-covid-19-stats-for-your-area`