# Simulating the airborne transmission of coronavirus for a network of rooms

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## 1 Introduction

Coronaviruses are a family of viruses that cause illness in humans and animals. Different types of virus have been found in people, and are responsible for the SARS, MERS and COVID-19 epidemics. COVID-19 can be transmitted very easily from person to person, via aerosols. The largest particles, including visible splatters of spittle fall fast, whereas the smallest aerosols, invisible to the naked eye, can be carried and linger in a room for a number of hours. This can lead to the spread of the virus in poorly ventilated indoor settings where people tend to spend longer periods of time. This is particularly applicable to both office spaces and restaurants. This work aims to simulate the airborne transmission of COVID-19 by aerosols within a population.

In order to simulate the airborne transmission within a population, the work aims to simulate both the transmission within a room, and the effect of individuals travelling between rooms across a network. The simulation is carried on a network level for individual days, and at a room level for each hour of the day. This is to allow individuals to be placed into rooms at the start of the day, where they interact with others in that room. At the start of the next day, certain individuals may move room, potentially spreading COVID-19 to other parts of the network. In order to develop the idea, pseudo code for the work was designed and can be seen in Figure 1. The code allows a number of inputs from the command line, with key examples shown in Table 1.

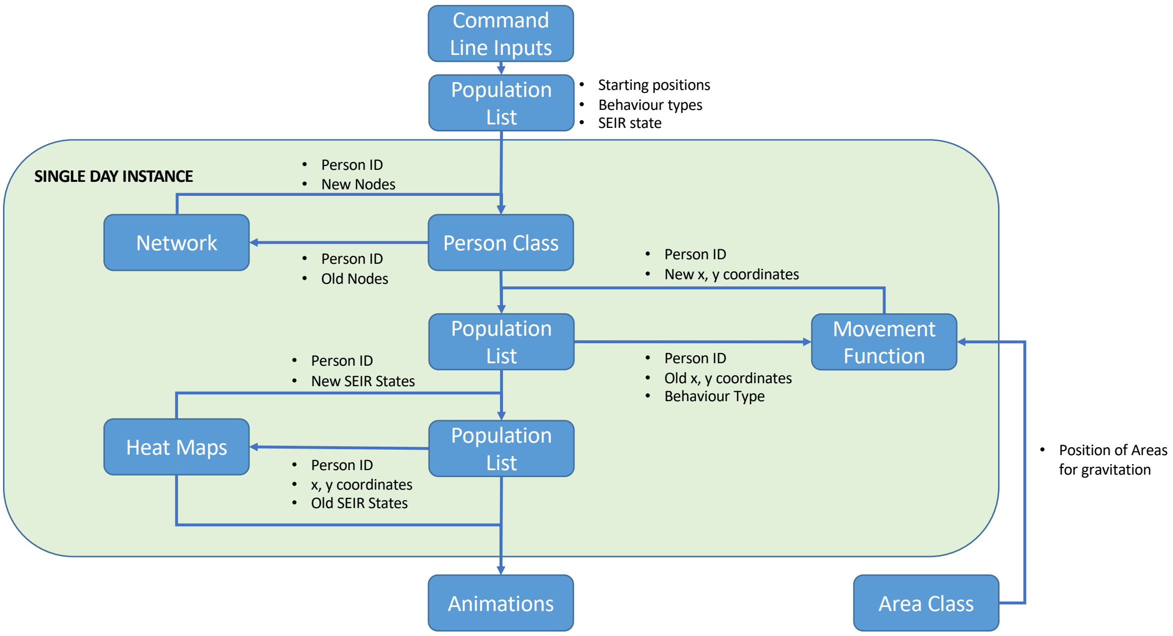


Figure 1: Sudo Code for the Model

Table 1: Example Command Line inputs to the code

| **Input** | **Detail** | **Default Value** |
|---|---|---|
| number | Size of population | 50 |
| cases | Number of initial infected people | 1 |
| distance | Probability of following two meter social distancing | 0.8 |
| mask | Probability of wearing a mask | 0.5 |
| rooms | Number of rooms to simulate | 3 |
| travel | Proportion of people that move between rooms | 0.5 |

# 2 Method

## 2.1 Network Setup

A network was created to simulate the impact that different measures could have on reducing the spread of the virus through a population. To do this, people are placed into rooms across the network at the start of the day, where they interact with others. At the end of each day, people randomly move around the network, but only to connected rooms. This allows the connectivity of the network to influence the speed of the spread. An example of a fully connected, 5 room network with 50 people is shown in Figure 2. A travel parameter has also been implemented that can reduce the number of people travelling between rooms. This is designed around limiting movement to key workers, or showing the effect of some people not following lockdown measures. Another measure implemented is a limit on a number of people in a room, as has been put in place in shops and restaurants in the lockdowns. When people move around the network, the code will iterate until no room has more people than the number of people divided by the number of rooms plus three.

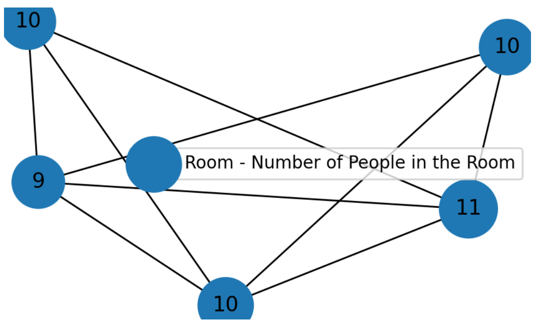


Figure 2: Example network with 5 rooms

## 2.2 Person Class

A Person class was created to achieve the movements and interactions of each person in the room. Since the output of the network setup (Section 2.1) is a data frame, each instance of the person class is created from the tabulated attributes. The attributes needed for the person class are x and y position, room node, whether they follow the two meter rule, and whether they go sit at a table or not. Once each individual person is initialised, the move function is applied to them. This contains nested functions to produce the movement of each person. There are two main conditions that each person can follow if specified: a two meter social distancing rule, and a condition for a person to 'gravitate' towards the table and take a seat there. They then have a 50% chance of getting up and leaving the table every iteration. The table can be located at different places, and the area radius can by changed by user input. In practise this creates an area that people will move towards and stop at in the room. This has the aim of showing if people congregate in a room it increases the risk of infection.

## 2.3 Modelling COVID-19 Particle Concentration in the Air

The principle behind creating 'heat maps' of the rooms is to simulate the main form of COVID-19 transmission as an aerosol. Infectious individuals are designated as point sources at 100 degrees Celsius, lowered to 50 for those designated as mask wearers. A simple roll and addition of the array map simulates concentration dispersion. This allows other individuals to contract the disease by being in proximity of space to where an infected individual was recently, and so physical contact is not required. The inclusion of a decay rate for the temperature of the whole heat map simulates the settling of aerosol particles to the floor over time. At the start of each day the shared spaces are considered to be disinfected as aerosols are given time overnight to settle in still air. The "temperature" of the location an individual resides is used to provide an estimate for their likelihood of infection at that point in time, with a minimum threshold to the required concentration for infection to be viable.

# 3 Scenario Analysis

In order to show the impact of different COVID-19 restrictions, the code has been simulated for 3 different scenarios to represent different levels of national restrictions, which are: no restrictions, half-measures lockdown, and full lockdown. In order to model the different national restrictions, three rooms, with a total of 50 people across the network were modelled. A number of parameters were then varied as shown in Table 2.

The population status at the end of the simulation is shown in Figure 3. It can be seen that as restrictions increase, there is a flattening of the curve for people that are infectious. This is shown by the maximum number of infectious

Table 2: Input parameters varied between running scenario simulations

| Parameter | No Restrictions | Half-Measures | Full Lockdown |
|---|---|---|---|
| *Probability of following two meter social distancing* | 0 | 50% | 100% |
| *Probability of wearing a mask* | 0 | 60% | 95% |
| *Proportion of people that move between rooms* | 100% | 80% | 30% |
| *Room Member Limit* | OFF | ON | ON |
| *Gravitate to table Probability* | 30% | 10% | 10% |

people reaching a peak of almost 40 people in the no limits scenario, but the peak in the full lockdown is much lower at less than 20 people.

It is noted that the deceased curve does not show the expected trend of reducing deaths as restrictions are increased. However, whether a person is deceased is calculated using a random value, and so it is expected that running multiple simulations and taking the average of the values may be more likely to show the trend expected.

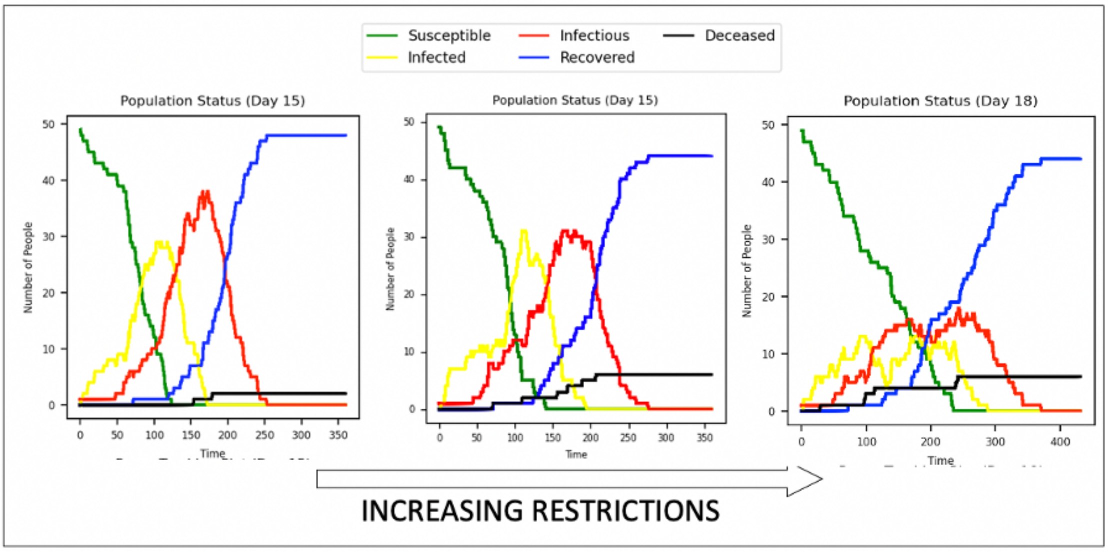


Figure 3: Population status for each of the three levels of national restrictions

Figure 4 shows the simulation midway through a run at 8 days for each of the levels of national restrictions simulated. Figure 4 (a) shows a high density of coronavirus in the air for the no restrictions scenario, while Figure 4 (c) shows the impact that masks and other restrictions have for reducing airborne transmission in the full lockdown scenario.

# 4 Future Work

Further development of the network could look at defining the probability of travel for different edges. This could show the impact of measures to keep people at home, and limit the travel to shop, and offices for example. Implementation of more varied behavioural habits could also be considered through additions to the move function. The outputs of the scenarios run, shown in Figure 3, suggest that higher restrictions have little/no impact on reducing the death rate, due to the likelihood of dying being modelled as a probability per iteration an infected person completes. This neglects some complexities of recovery aspects such as the strain of a high spike in cases on hospitals leading to a higher death rate. Future modelling could address methods in which to more accurately represent these features.

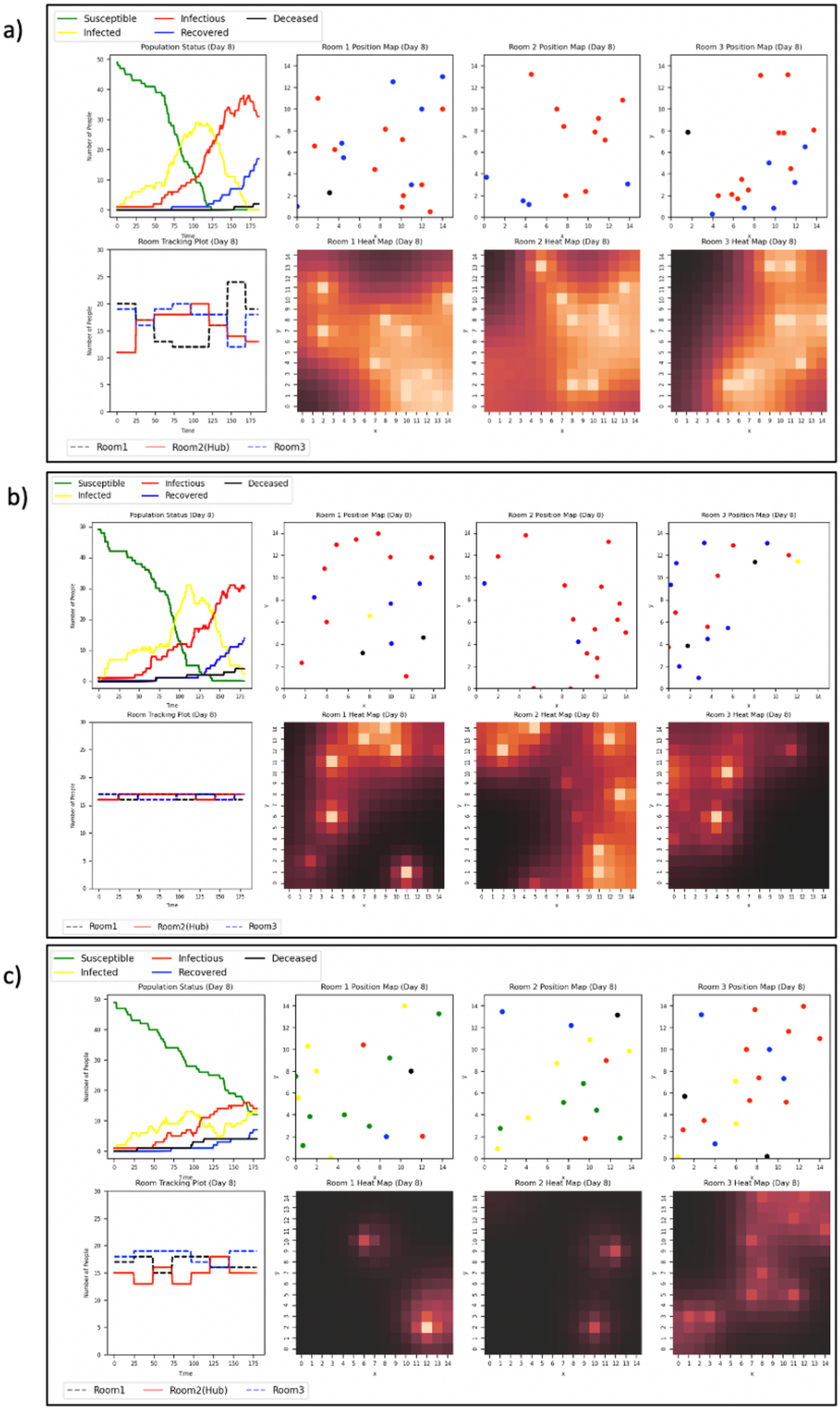


Figure 4: Simulation examples for (a) no restrictions, (b) half-measures, (c) full lockdown