COMP90083 Computational Modelling & Simulation

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Assignment 2

Report

THE UNIVERSITY OF MELBOURNE

Group 19

Wentao Hao	**1096215**
Jingjin Li	**1077008**
Zongcheng Du	**1096319**

Introduction

Influenza and seasonal infectious diseases can have serious negative effects on health and the economy. The results have shown that those kinds of infectious diseases are spread through contact between people. Therefore, public health professionals show that the spread can be slowed, if people practice "social distancing" by avoiding public spaces and generally limiting their movement.[1]

This year for example, Covid-19 outbreaks all over the world and result in public places closing. It is reasonable to think that policies like lockdown or forced quarantine would be effective in slowing down the spread. However, Harry Steven [1] did a simulation experiment that proved it is impossible to completely seal off the sick population from the healthy. This also shows that shutting down all the public places is not a sustainable approach. What's more, public services such as schools are in a socially dense environment, and school-based outbreaks usually precede and promote the spread of seasonal and pandemic influenza throughout the community.

Although closures of schools can effectively reduce the spread of influenza, they are destructive and are currently only recommended for pandemics. Therefore, lessening the impact of pandemics via public health interventions is critical. Assessing the feasibility of implementing other social distancing practices in K-12 schools as a first step in seeking an alternative to pre-emptive school closures [2]. After conducted 36 focus groups with education and public health officials across the United States, they found out that due to the limited daily implementation and the use of personalized timetables in primary schools, it is generally believed that in-school practices in primary schools are more feasible than in secondary schools and shortening the school week and the school day was considered the most feasible. This shows how changing the school time schedule may have a positive impact in reducing the contact between students.

Other than changing the school time schedule, wearing a mask, increasing hand washing and class suspension is the first line of defence against such threats because it can be implemented quickly. These types of interventions are designed to reduce the number of effective contacts between individuals in the community [3]. Using an individual-based computer simulation model to track the connection between school children in the stereotyped school environment, they demonstrated how school-based alternative disease interventions have the potential to be as effective as traditional school suspensions without causing a corresponding labor force and economic impact [4].

From above, we can see that besides forced quarantine, an important way to protect students from virus spreading is to reduce contacts through non-pharmaceutical intervention strategies. One of the strategies we think of is to longer the break time between one class and the other if the two classes are in the same classroom. The break time between two classes in the same classroom is called stagger recess time. Let's assume there are two groups of students (group A and group B). Students in group A take class A and students in group B take class B. Class A and B are in the same classroom but have different time intervals. Class B will start right after class A finishes. Normally the stagger recess time is around 10 minutes which is very short, so a lot of students from group B would come 5 minutes earlier before the last lecture is over and gathered to wait outside of the classroom. As soon as the lecture is over, the students from class A would swarm out while the students that were waiting outside packing in. This obviously highly increases the contact between these students from two groups. Thus, this project is to find out how effective is increasing stagger recess times between lectures within the classroom in reducing contact rate on campus. Besides, this project also aims to find the optimal capacity of a classroom with 100 seats during the epidemic.

Model Design

1. Purpose and patterns

The model aims to explore issues related to epidemic control methods, such as Covid-19 in a Semi-closed environment like classrooms or campus. Specifically, will increasing stagger start and dismissal times between lectures within the same classroom reduce contact between people when students and lecturers are back on campus? The model draws on the theory of the human-to-human transmission of the virus. The parameters of the model do not represent a specific disease or a specific school. Therefore, it is only a hypothesis and simulation of a conventional epidemic disease. Specific parameters do not represent actual life results.

2. Entities, state variables, and scales

The model has two kinds of entities: people and square patches of land. The patches make up a square grid landscape of 71 by 101 patches. Persons are characterized by their location, described as the patch they are on. Persons' locations are in discrete units, the x and y coordinates of the centre of their patch. Patch size and the length of one-time step in the simulation are not specified because the model is generic, but when real landscapes are used, a patch corresponds to 1m by 1m which is the usual seat size of a classroom in a campus. In the model, the length of one time step is not specified, but should be the time that it takes a person to move a patch.

3. Process overview and scheduling

There is only one process in the model, movement of the persons. On each time step, each person moves once. People who are having a lecture in the classroom aren't allowed to move. They stay in the seats until the end of class.

4. Design Concept

The number of contacts is expected to change and vary in an unpredictable way based on the duration of stagger time and the total number of agents. Meanwhile, this data might also vary unpredictably if the probability of agents going to the classroom changes. The probability represents the chance of the agent wandering around or heading towards the room at the current tick.

There are two groups of agents with different schedules – class A and class B, labelled as blue and yellow respectively. Agents tend to stay away from each other. When an agent enters the room and starts finding a seat, it will move to a random red patch, then it will detect any neighbours of eight patches around it, including the patch it is standing. If there are other agents in this area, it moves to the next random red patch and stays there if it's empty. Initially, class B is waiting in the bottom area, when class A ends, class B will start to go to the classroom based on stagger time duration.

Each agent is aware of how many other neighbouring agents around it. If there are more than one agent nearby, they will move to a new random location to reduce the average contact rate as much as possible.

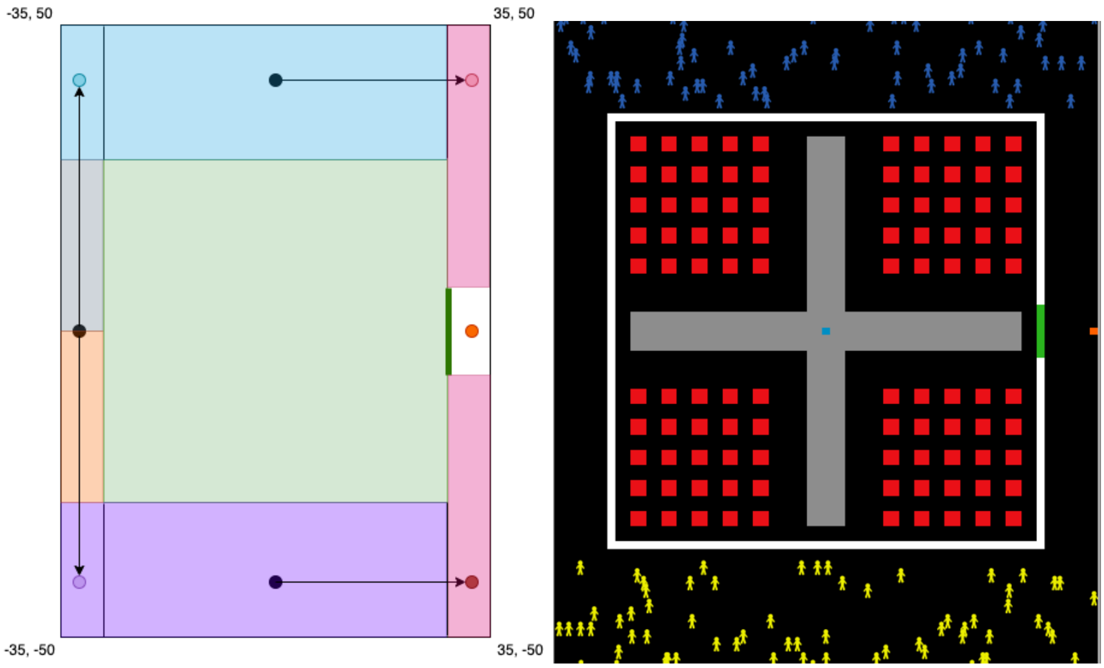

Figure 1. Classroom layout

The area is split into eight parts, and there are five indicators distributed in four corners of the map and the exit. Agents will make decisions on which way to go based on the area color they are currently on to avoid hitting on the wall. The agent will also sense the current tick, when the lecture ends, agents in the room will move out and agents outside the room will start to move in. The movement of agents can be affected by other agents nearby as it tends to avoid the crowd. The length of the lecture is random, it's unimportant to model the actual duration as agents in the room are stationary. The seat each agent takes is also random.

The primary goal for this model is to explore the best strategy to reduce contact rate within the campus. Hence, the total number of contacts and the average contact per person are collected for analyzing and understanding.

5. Initialization

The number of Class A and the number of Class B is initialized when the model is started. The Class A and Class B are two groups of agents with different schedules but in the same classroom. The stagger time between two lectures is determined as a hyperparameter at starting time. In different versions of models, the number of agents and the stagger time are different.

The initial location of the agent in Class A is set to a patch selected randomly in the upper half of the map as well as Class B in the lower half of the map.

6. Input Data

The environment is assumed to be constant, so the model has no input data.

7. Submodels

The experiment sub-model defines exactly whether stagger time affects the total number of contacts. In the first sub-model without stagger time, at the end of the Class A course, Class B immediately flooded into the classroom. Since the size of the door is limited, we set an upper limit for the number of people who can pass through the door at the same time. Both Class A and Class B need to spend a long time near the gate to queue through the door. In the sub-model with stagger time, Class B will wait for a while after the Class A course is over, then move to the gate and queue to enter the classroom. In addition, when a student moves, it will automatically detect whether there are other students in the surrounding 9 pitches. If other students are found, a new direction will be randomly chosen to reduce contact. But the overall direction of movement is towards the classroom.

Methods

In this experiment, we divide the experiment plan into three stages. The central idea of the experiment is the controlled variable method. We believe that the importance of the contact between Class A and Class B is much higher than the internal contact between Class A or Class B. Because for the spread of disease, the consequences of spread among groups are far more difficult to control than spread within a group. Therefore, in this experiment, we give a lower weight to contacts within Class A or Class B, and a larger weight to contacts in between Class A and B.

In the first stage, we want to know what the optimal stagger time is. We presuppose the number of Class A and Class B. Find the ideal stagger time by comparing the changes in the number of contacts under different stagger times. Of course, when the stagger time is infinite, the number of contacts between people must be minimal. However, in real scenarios, we need to control the stagger time between courses within a reasonably acceptable range. Therefore, in the first stage, what we are looking for is the point where the total number of contacts no longer decreases significantly when the stagger time continues to increase.

In the second stage, we propose a hypothesis. The optimal stagger time does not change with the changes in the number of people in the two groups A and B. This assumption is obviously arbitrary, so our experiment does not represent the situation when the number of people is very small (1-5 people) or very large (greater than 1k). At this time, we explored the impact of changes in the number of people in group A on the total number of contacts when the stagger time and the number of people in group B are determined. Obviously, when the number of people in group A is 0, all contacts are from inside group B. At this time, the total number of contacts is the smallest. But in a real scenario, a course without any student is extremely absurd.

Therefore, what we are trying to find in the experiment is the point that reduces the number of Class A, which can no longer significantly reduce the total number of contacts.

In the third stage, we use the stagger time obtained in stage one and the number of Class A persons obtained in stage two. Study the impact of the number of Class B changes on the number of contacts. In the actual scenario, because Class A and Class B belong to different classes, we assume that the numbers of the two are independent. In other words, we do not consider scenarios where the number of Class A and Class B changes simultaneously.

In the whole experiment, in order to avoid the influence of accidental results on the experiment, we did each experiment multiple times and took the average value.

Results

Scenario 1

The first scenario is that we set class-A and class-B both at 100, then we adjust the stagger time from 0 to 30, then we run the iteration 7 times and calculate the average to avoid any possible noises from the model. The result is shown in Figure 2.

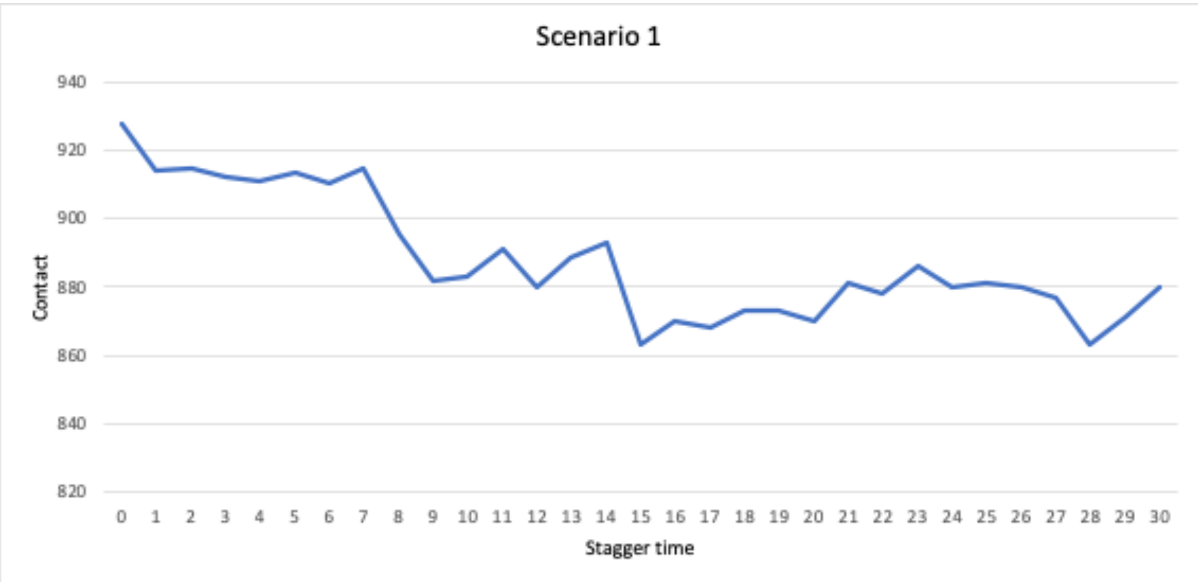

Figure 2. Scenario 1

The contact rate will be around 930 if we do not take any measure. As we gradually increase the stagger time, the total contact does not decrease linearly. Although the main trend of contact is going down, we observed that the contact might even be higher than those who have longer stagger time. This is most likely due to the randomness of the agent's movement when they are going to or leaving the classroom as we set that agent has a 60% chance of going to the destination, 40% chance of wandering around.

As shown in the chart, the total contact keeps decreasing until stagger time equals 15. After 15, the contact rate does not have significant drop and it’s also the same as stagger time equals 28. Thus, the optimal stagger time we get is 15.

Scenario 2

In terms of the second scenario, we will take the optimal result we get from scenario 1, which stagger time equals 15, and keep class-B as 100, then adjust class-A from 100 to 20. The iteration is also run 7 times. The result is shown in Figure 3.

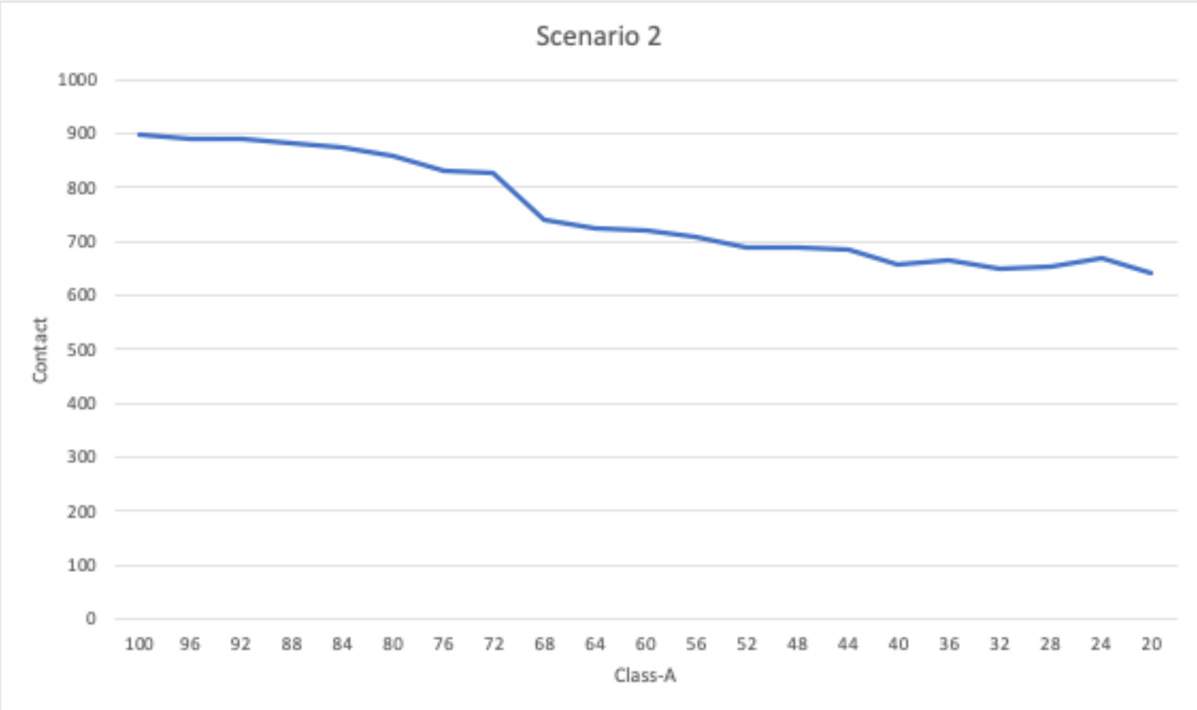

Figure 3. Scenario 2

By keeping the optimal stagger time, we can analyze the optimal number of students in class-A. Contact does decrease gradually, this number drops from 900 to 800 and takes 30 (100 – 70) students in reduction. However, the same number of drop only takes 12 students in reduction (68 – 56) from 800 to 700. When class-A is lower than 56, the drop does not appear very significantly. Therefore, we can conclude that the optimal number for class-A is 60 (our aim is to maximize students in a classroom while minimizing contact as much as possible).

Scenario 3

For the third scenario, we take the optimal result we get from scenario 2, which class-A equals 60, stagger time equals 15, and adjust class-B from 100 to 20 and run for 7 iterations. The result is shown in Figure 4.

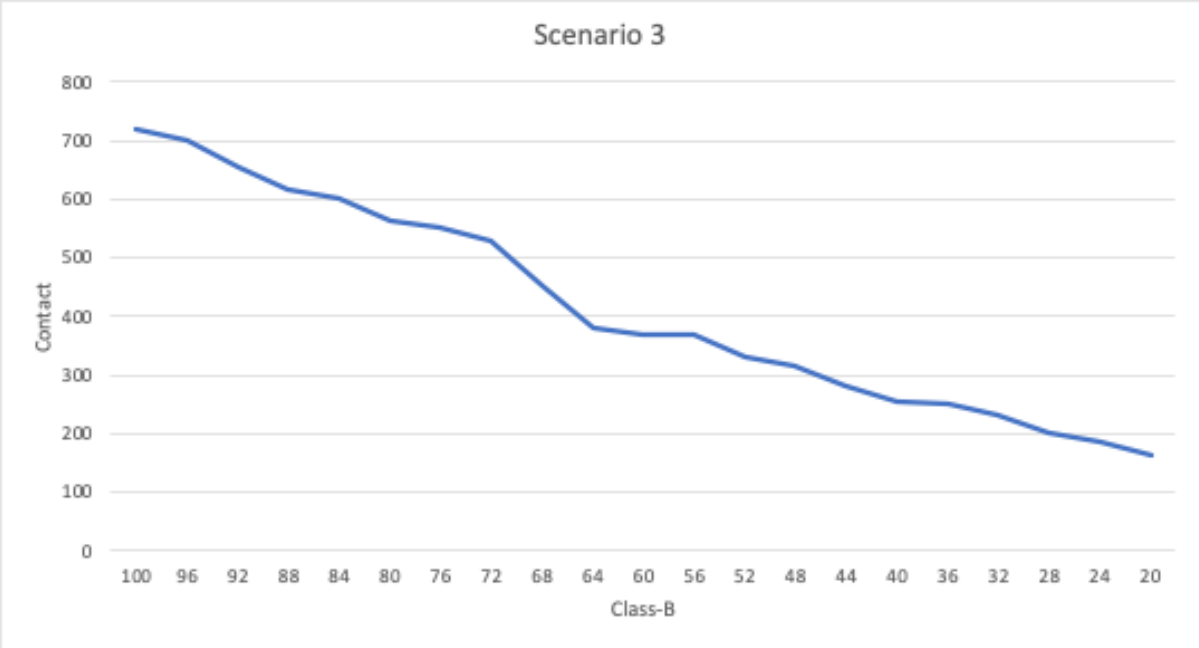

Figure 4. Scenario 3

We perform the same logic as scenario 2, as we can tell from the chart, the largest drop in contact occurs when class-B ranges from 72 to 64. To maximize the number of class-B while minimizing the total contact, we will take 64 as our final result for class-B.

Therefore, the optimal strategy for students with two different schedules in the same classroom will be – 15 minutes in stagger time, 60 students for class-A, and 64 students for class-B.

Discussion

According to the result we get from the model, increasing stagger time does bring notable decrease in student contact, we also found that it is not necessarily the longer the stagger time, the less the contact will be. When the stagger time reaches certain threshold, the result does not have much difference. Therefore, we can conclude that the measure we take to reduce contact rate is the most effective when the stagger time equals this threshold (15) that brings 8% drop. Meanwhile, controlling the number of students in a classroom is also effective by only shrinking the size to 60%.

The current Covid-19 Campus model performs very well in the current classroom context, it simulates students from two different schedules precisely, and gives us an insight of what we can do in pandemic, but only in the classroom context as the university campus is a very complex environment. Due to the time limit of the future, we'd like to simulate more aspects such as students on their way to enter or exit the campus and the transportation involved; students walk across different buildings; and students going different levels in the same building in the future. The logic of the model not only can be used in the university context, but also in every scenario that involves people shifting, such as organization, conference room, office area, barber shop and restaurant.

The overall progress of the project has gone well and on time, but there were few barriers that we have come across. In the beginning, we tried to make the agents avoid hitting the wall by bouncing them back, but it's difficult to determine the direction to bounce towards after hitting the wall as there's no method in NetLogo to control the agent facing north or south. Therefore, we have set 4 indicators at each corner of the map and 1 at the door, agents can now move towards the correct direction without hitting the wall. Secondly, when we tried to make agents sit in an empty seat, the first approach we took is: let agent move to the closest seat within certain radius. However, after several attempts, agents will sometimes gather in the same seat. Finally, we took the simplest approach: let agent move to a random seat, if there are other agents in the current patch or there are other neighbors around it, move to the next random seat until it's empty.

To conclude, throughout the project, the key takeaway is to think in different aspects if the current solution gets stuck. It might be much better to dive in another totally different approach.

Reference

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