ABMs for the spread of COVID-19

1. Research Question

Coronavirus disease 2019 (COVID-19) was a pandemic, the first case of which was identified in Wuhan city, China, in December 2019 (WTO, 2020). The virus mainly spread in a person-to-person manner, entailing that individuals will be affected by respiratory droplets from the patients who carried the virus. To control this global health issue have the pertinent sectors adopted two primary approaches including wearing masks and social restrictions. On one hand, masks are simple barriers for us to prevent our respiratory droplets from reaching another person (Rader et al., 2021). On the other hand, many countries and local government implemented social restrictions, such as social distancing, working from home, and the shuttering of numerous businesses, to contain the Covid-19 (Andresen and Hodgkinson, 2020).

Therefore, the present study will investigate whether those two preventive measures are valid against the spread of COVID-19. A small society will be constructed to simulate the spread of coronavirus, which will stop simulating when all the population are contracted with the virus. In the Based on different size of the population, the body of people with various status was set according to the appropriate rate. For instance, the model has a default proportion for initial people carrying the virus, initial people with masks, and initial people with active personality (Those parameters could be reset on the interface). In order to resonate this simulation to human society which is also the reason why to use the agent-based modelling, I will integrate some special sub-models into this simulation, for instance, the social pressure of wearing masks which means the individuals have to wear the mask when he or she is surrounded by people with facial masks.

In every tick, the graph of output will calculate some percentages.

1) mask=$\frac{turtles\ with\ [mask?\ and\ not\ healthy?]}{turtles\ with\ [\ mask?]}$ 2) no_mask=$\frac{turtles\ with\ [not\ mask?\ and\ not\ healthy?]}{turtles\ with\ [not\ mask?]}$

3) active=$\frac{turtles\ with\ [active?\ and\ not\ healthy?]}{turtles\ with\ [\ active?]}$ 4) no_active=$\frac{turtles\ with\ [not\ active?\ and\ not\ healthy?]}{turtles\ with\ [not\ active?]}$

It is not precise to make the conclusion if we only observe the trends of the above 4 indicators. So that I apply inferential statistics to verify the results, such as a t-test which is a non-hypothesis statistical test to compare the means of two groups.

2. ODD Description

2.1 Purpose

In the pandemic of coronavirus, this model addresses which kinds of behaviour can prevent people away from the virus. More specifically, we should figure out whether the active people have more probabilities to be infected by COVID-19 than people who have a limited preference to move, wearing a mask is whether an effective behaviour of preventive measures against the spread of the virus.

2.2 State variables and scares

The objects in this model represent people with three dissimilar state variables to describe their status. The first variable of healthy? which is the health status, by which we can change the proportion of healthy people in the beginning. The second variable is whether the people have worn the mask, where TRUE of mask? means this person wearing the mask. The modification of this variable represents the change in the percentage of people with masks. The last variable is defining the active status of people. For instance, if the variable of active? is true, this person would move in a larger range than their counterparts. In this regard, we can change the move_instance on the interface page to adjust this variable.
The model runs at one tick, and the simulation will stop when all the people are infected.

2.3 Process overview and scheduling

This model includes the following actions executed each tick.
Move: In every tick, turtles will pick a random direction and forward 2 unit or move_instance. If the variable of turtles is active, then he will move forward a unit of move_instance which we can set in the beginning.
Take-mask: If an individual is surrounded by the person with masks, he or she will also put on a mask because of social pressure.
Infect: The probability of infection varies when different kinds of people met. For example, the probability of infection rate is 5% when both infected and healthy people wearing masks. On the other way, the probability of infection rate is 90% when both infected and healthy people do not wear the masks. If only one of the infected and healthy people wearing the mask, the rate will keep on the 20%.

2.4 Design concepts

Emergence: The most important output of this model is the proportion of unhealthy people, which is emerging from the different status of individuals. These statuses are (1) mask? And (2) active?
Adaption, fitness-seeking, and prediction are not including in this model.
Sensing: Individuals are assumed to know their own statuses like mask?, active or not, and healthy or not.
Adaptive behaviour: The individual decision is whether to wear the mask, which is a deterministic function of the number of people who wear the masks.
Interaction: When two people with different statuses met, the probability of spreading the virus are also different.
Stochasticity: The direction of turtles to move is random.

2.5 Initialization

We can choose the population from 0 to 200 (i.e., 100), and pick the different proportion of people who is active or not and we can set the number of people with mask in the initial situation (i.e., 20). Last but not least, we set the value of move_instance which is from 2 to 10.

2.6 Input

No time-series inputs are used.

2.7 Submodels

Individuals search and wearing the masks

On every tick, each individual will check the number of people with masks who are surrounding themselves. Assuming that we focus on one individual, “myself”, and defining a circle with a radius of 5 units and the centre point is “myself”, if there are more than 10 people who are wearing the masks, “myself” will also put on a mask.

3. Methodology

We can test the hypothesis with a one-tailed mean comparison test. On this data set which is collected from Behaviorspace by setting different parameters (["initial_people" [100 50 200]], ["initial_active" 20], ["move_distance" [2 2 10]], ["initial_per" 5] and ["initial_mask" 20]). We have two main research objectives: 1) we want to figure out whether the active person has high likelihood of getting the Covid-19 virus than the inactive person. 2) we want to know whether wearing masks is a preventive measure against the virus.

Because those two groups and four sets of observational units are independent, we use two independent-sample-tests. Before testing hypothesis, we assume they have the same variance and unknown common standard deviation. We also employ the pooled estimate of standard deviation.

Figure 1-Pooled estimate standard deviation

$$s_p = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$$

Note: n_1 *and* n_2-sample sizes from population 1 and 2

s_1 *and* s_2-standard deviation of population 1 and 2

Figure 2-Two-sample test statistic

To test $H_0: \mu_1 - \mu_2$ versus an alternative, use the two-sample t-statistic:

$$T = \frac{mean_1 - mean_2}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Under H_0, this statistic has t-distribution on $(n_1 + n_2 - 2)$ degrees of freedom

Note: μ_1 *and* μ_2-the mean of population 1 and 2

Figure 3-Summary statistics

	Mask	No_mask	Active	No_active
Mean	0.7340	0.8106	0.8188	0.7859
Standard deviation	0.3079	0.2648	0.2890	0.2711

3.1 Test of difference in means of patients with masks and without masks

$$H_0: proportion\ of\ patients_{with\ masks} = proportion\ of\ patients_{without\ masks}$$

$$H_1: proportion\ of\ patients_{with\ masks} < proportion\ of\ patients$$

3.2 Test of difference in means of active patients and inactive patients

$$H_0: proportion\ of\ patients_{active} = proportion\ of\ patients_{inactive}$$

$$H_1: proportion\ of\ patients_{active} > proportion\ of\ patients_{inactive}$$

4. Results

4.1 On hypothesis one:

$$H_1: proportion\ of\ patients_{with\ masks} < proportion\ of\ patients_{without\ masks}$$

Firstly, we should calculate s_p.

$$s_p = \sqrt{\frac{(557-1)*0.3079^2+(557-1)*0.2648^2}{557+557-2}} = 0.2312$$

Then we test $H_0: \mu_1 = \mu_2$ against $H_1: \mu_1 < \mu_2$, we can compute the p-value roughly.

$$T = \frac{0.7340-0.8106}{s_p\sqrt{\frac{1}{557}+\frac{1}{557}}} = -9.2743$$

Finally, we can get the table of t-test result:

Value of T	-4.4516
P-value	9.3806 e-6

On this hypothesis with one-tailed mean comparison test, the value of T is -4.4516 and |T|>$t_{1000}(0.0005)$, (The freedom degree equals to 1112, since tables do not include t_{1742}, use t_{120} which is equals to 3.3) so reject H_0 at 0.05% level. This result represents a very strong evidence (p<0.001) of a difference in mean of the proportion between person with and without masks. In other words, although each group of people with or without masks will be affected ultimately in our simulation model, the healthy person with masks will contract the virus much slower than those who are not wearing the masks.

4.2 On hypothesis two:

$$H_1: proportion\ of\ patients_{active} > proportion\ of\ patients_{inactive}$$

Value of T	1.9595
P-value	0.0018

The process of calculation would be the same as hypothesis one. On this hypothesis two, the value of T is 1.9595 and $t_{1000}(0.05)$> T >$t_{1000}(0.025)$, so reject H_0 at 5% level. This indicates some evidence (p<0.01) of a difference in mean of the proportion between active and inactive person. In short, the group of active people will have higher possibility to be affected by Coronavirus.

5. Conclusion

The present study constructed a simulation, in which different individuals were moving in various directions and steps, to predict how the behaviours will influence the spread of Covid-19. After assuming that person with different status (e.g., wearing masks or not) will affect the speed of diffusing the virus, the present study found that social distancing (and other means of inactivating social mobility) and wearing masks are effective measures against the Covid-19 pandemic.

Reference:

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