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Simulating Covid-19 Disease Spread to Determine How Disease Prevention Influences The Disease Spread Rate

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Abstract
Avoiding mass gatherings is a healthcare approach that enables social distancing and attempts to keep sick individuals apart from healthy individuals to limit the risk of disease transmission. To stop the spread of COVID-19, several workers are employed to check body temperatures and identify masks in public spaces and buildings premises. For each entrance scanning, a temperature checking device is installed. However, there is always a chance for human error while reading values. This study uses simulation to deliver a realistic representation of a real-life situation. Anyone who is unaware of the realities of a pandemic or how speedily a disease could spread will benefit through a simulation. The objectives of this study are to simulate disease spread using GAMA platform for two prevention steps that avoiding mass gathering and forbid infected people from entering places and to display the disease spread rate of the disease through graph/chart within the simulation. People, primarily adults, have been observed to be negligent and perplexed by the contemporary discussions, prompting them to second-guess their choices. Most people are unaware of the importance of maintaining prevention steps everywhere they go. GAMA Platform is used to develop and test the simulation. The simulation contains a calculation for the spread rate as well as a graph to display the changes in population. Through this simulation, the user gets a complete picture and comprehend how taking the prevention steps impacts the spread rate. As a result, individuals are able to distinguish between how quickly diseases spread with and without disease prevention. After testing, the results show that the average number of cycles for the people to get fully infected in a space of 500 people is approximately 30664 cycles while it took only 8407 cycles with a space of 2500 people. Then, it took only 3026 cycles for another space with 2500 people and 200 infected people. To conclude, when prevention steps are enabled, the disease spread rate is slower.
Keywords: disease spread simulation; GAMA platform.

1. Introduction

Coronavirus disease (COVID-19) is a contagious disease caused by the SARS-CoV-2 virus. The virus can spread from the infected person's mouth and nose to small particles of liquid when the infected person coughs, sneezes, talks or breathes. These particles range from larger respiratory droplets to smaller aerosols. It is not possible to know exactly what will happen when a pandemic occurs in the world. A lot of countries did not pay attention to the COVID-19 epidemic at the beginning of its emergence. In the worst-case scenario, several months later, nearly 29 000 people died worldwide while the total number of cases are more than 2.4 million .

Avoiding mass gatherings is a healthcare approach that enables social distancing and attempts to keep sick individuals apart from healthy individuals to limit the risk of disease transmission. Public health authorities and governments face huge issues as a result of mass gatherings. Infectious diseases have historically been disseminated throughout the world at sporting, religious, musical and other mass gatherings. Furthermore, the evidence base for virus transmission during mass gatherings is still expanding and needs to be more substantial. In addition to the significant public health dangers at mass gatherings, managing the increased media attention as well as public and political views and expectations is a major issue for COVID-19. Instead of understanding the risks and the measures that can be used to lower that risk, decisions about the risks of mass gatherings can be influenced by panic, confusion, and a desire to avoid looking foolish [1].

Many countries recommend their citizens to keep at least one metre distance from others. The CDC recommends people to have at least 6 feet or 2 metres distance from other people. This is because, the higher the close contact with other person, the higher the risk of getting infected. However, people especially adults are shown to be negligent and perplexed by the continuous controversies, causing them to second-guess their decisions. A lot of people do not understand the importance of social distancing everywhere they go [2].

To stop the spread of COVID-19, several workers are employed to check body temperatures and identify masks in public spaces and buildings premises. For each entrance scanning, a temperature checking device is installed. However, there is always a chance for human error while reading values. Despite higher temperature readings or lack of masks, many people are frequently allowed entry. A manual scanning device fails in the face of large crowds. The objectives of this study are to simulate disease spread using GAMA platform for two prevention steps that avoiding mass gathering and forbid infected people from entering places and to display the disease spread rate of the disease through graph/chart within the simulation.

. The simulation will be built and tested in GAMA Platform. The simulation will include the calculation for the spread rate and graph to display the change in the population. The simulation will be tested based on two different situations which are different distance to get infected and different total number of people in a specific space. The results will be recorded from the output display.

This research is important to show the imitation of a real-life situation. The simulation is useful for people to understand the impacts of social distancing better since it is being visualised in front of their eyes. This simulation is also important to predict the outcome of this situation rather than waiting for the real-life situation to happen. Furthermore, the responsible authority for handling COVID-19 issue can benefit from this simulation to make important decisions such as determining how many people can be allowed in a room. They can also experiment to compare and differentiate the changes when some of the variables are manipulated.

2. Literature Review

2.1 Simulation

As mentioned by Banks, J. [3], simulation is the replica or the imitation of an actual world process or system over time. Models are required for simulations. The model reflects the main features or behaviours of the selected process or system, whereas the simulation shows the model's progression over time. Computers are frequently used to run simulations. According to Srinivasan, B. (2020), simulation is widely used in a variety of areas, including technology modelling for performance tuning and optimization, safety engineering, testing, training, education and video games. Simulation may be used to illustrate the real-world consequences of certain situations and actions.

2.2 Agent-based Model

As mentioned by Grimm, V., & Railsback, S. F. [4], agent-based model (ABM) is a computer model consisting of a group of agents or variables that might change the states in a number of ways. There is a collection of rules that govern the agent's interaction with other agents and it determines the condition of an agent at any given moment. These rules might be either deterministic or stochastic. The condition of an agent is determined by the agency's previous state as well as the state of a group of other agents with whom it interacts.

2.3 GAMA Platform

GAMA Platform will be used for simulation part of this research. GAMA (GIS Agent-based Modeling Architecture) (current version: 1.8.1) is a modelling and simulation development environment for building spatially explicit agent-based simulations. It is created to allow domain experts without programming training or background to model a phenomenon from their area of expertise. GAMA is specially developed for modelers to define spatially explicit and multi-levels models. In particular, it integrates powerful tools coming from Geographic Information Systems (GIS) and Data Mining easing the modelling and analysis efforts. By using GAMA, how rate of the virus spread can be seen easily. Also, charts or graphs can be created in GAMA which can be used for the results [5].

2.4 Disease Spread Rate

Disease spread rate/spread rate indicates how much of a population is infected. It is used to determine the frequency with which new cases of infection develop within a population over a certain time period. Equation 2.1 is equation for the disease spread rate.

Spread rate=(the number of infected people)/(the total number of people)

The number of infected people equals to the number of cases identified in a study or location while the total number of people equals to the number of all people in the study or location which include both infected and susceptible people. Since the number of infected people is always less or equals to the total number of people, the range of spread rate is from 0 to 1. If the spread rate is 0, it means that no one is infected whereas if the spread rate is 1, then everyone in that space is infected.

2.5 Overcrowding

Gray, A. [6] states that overcrowding, also called as crowding, is a situation in which there are more individuals in a given space than is considered safe and healthy. Overcrowding can exist in a house, in public spaces or on public transportation. It can happen suddenly or on a regular basis. Increased physical interaction, sleep deprivation, lack of privacy, and poor personal hygiene standards are among the negative effects of overcrowding on quality of life. Overcrowding relates to people's psychological response to density, whereas population density is an objective measure of the number of people living per unit area. However, statistical reporting and administrative definitions of crowding rely on density data and do not normally take into account people's experiences of congestion.

3. Methodology

3.1. Research Design

To build the simulation, firstly, variables such as number of people, number of infected people and size of the space will be declared. The susceptible people are assigned to wander around in the space and transform into infected people when they come in contact with other infected people. For example, if the initial number of infected people is two, then the number will multiply and form a chain reaction since the infected people will come in contact with susceptible people. The speed of the species (people) as well as the number of species can be controlled within the software. The colour of the initial infected species will be red while the susceptible species will be green. When a red species comes in contact with a green species, the green species will change its colour to red indicating that it has been infected. Hence, it will begin to infect other green species. The simulation is also designed to stop when the spread rate is 1 which means 100% of the population is infected. To observe the time taken for the entire population to get infected, the number of cycles it takes to become 100% infected will be recorded. The number of cycles will be displayed at the top of the output display. In this research, how manipulating the total number of people in a space and manipulating the number of infected people in a space influence the spread rate are tested. There are three different scenarios that were tested. For Scenario 1, there are 500 people scattered around in a 5000 m by 5000 m space indicating that there is no mass gathering happening. 500 people in a space indicates that the room is not fully filled and people are physical distancing.

However, bigger number of people such as 2500 people in a space indicates that the room is almost full. Scenario 2 denotes the testing of 2500 people in the same space size as Scenario 1. The only variable that are not similar between Scenario 1 and Scenario 2 is the total number of people. This will allow us to [illegible] the disease spread in a space with mass gathering happening compared to space with no mass gathering. The number of infected people in Scenario 1 and Scenario 2 is fixed at 20.

Next, Scenario 3 will have 2500 people in the same space but with 200 infected people instead of 20. Since 200 is a larger number compared to 20, it is associated with real-life situation where supposedly a lot of infected people were allowed to enter a place together with other non-infected people. Results from Scenario 3 testing will be compared to the results of Scenario 2 since Scenario 2 has the same total number of people which 2500. This means that the comparison between these situations will tell us if different number of infected people would influence the spread rate.

For each situation, the simulation will be tested three times and the average number of cycles taken to get fully infected will [illegible]. The calculation for spread rate will be included within the simulation codes as the results will be displayed at the output display. Within the simulation, the codes for a chart will written so that it can display the changes in the population in the output display. The type of graph that will be used is line graph.

3.2. Disease Spread Simulation

The simulation code starts with global species. The global species is the world species. All the global attributes, actions and behaviours are declared under this species. This is where all of the unknown variables are defined. In this initial code, the number of people is set to be 500 whereas the number of infected people is 20. The space size is 25 million m2 (5000 m x 5000 m). The formula for spread rate is added within the codes and it is set to update every time one person gets infected. The simulation is set to stop or end when the spread rate reaches 1.

In global species, the variables such as total number of people and number of infected poeple are declared. In this model, the total number of people is declared as nb_people while the initial number of infected people is declared as nb_infected_init. During Scenario 1, nb_people is set to 500 while nb_infected_init is 20. During Scenario 2, nb_people will be changed to 2500 whereas nb_infected_init is fixed. For Scenario 3, nb_people remain 2500 while nb_infected_init is 200. The size of the room or space is fixed as a square with sides of 5000 metres by using ‘geometry shape’. Inside init function, people agent is be created and assigned its number as nb_people while ‘ask’ function will put number of infected people among all people. The variable is_infected being declared true is in order to susceptible species get infected. The simulation will stop when the spread rate reaches 100% which is spread_rate = 1.0. ‘Reflex end simulation’ is used to stop the simulation.

```
model DiseaseSpread1
global {
    int nb_people <- 500; //number of people
    int nb_infected_init <- 20; //number of infected people
    geometry shape <- square(5000 #m); //space size
    //assigning variables to its values
    int nb_people_infected <- nb_infected_init update: people count
(each.is_infected); //infected population is updated
    int nb_people_not_infected <- nb_people - nb_infected_init update: nb_people -
nb_people_infected;
    //spread rate: gets updated everytime someone gets infected
    float spread_rate update: nb_people_infected/nb_people; //spread rate formula
    init{
        create people number: nb_people; //assigning agent to its value
        ask nb_infected_init among people { //puts infected people among all
people
            is_infected <- true;
        }
    }
  reflex end_simulation when: spread_rate = 1.0 { //the simulation will stop/end if spread
rate = 1
        do pause;
  }
}
```

```
species people skills:[moving]{  //assigning people to its behaviour (moving)
    bool is_infected <- false;
    init {
        speed <- 250.0;     // speed of people in m/s
    }
    reflex move {
        do wander;  //people are assigned to wander around
    }
    reflex infect when: is_infected {
        ask people at_distance 10 #m { //people get infected when the distance
is 10 m
            if flip(0.05) {
                is_infected <- true;
            }
        }
    }
    aspect circle {  //poeple's shape
        draw circle(10) color: is_infected ? #red : #green;  //colour change from
green to red
    }
}
```

Figure 1 Global species in GAMA Platform

Regular species can be declared with the keyword ‘species’. A species defines its attributes, actions and behaviours and aspects. This part of the code allows the species people to have its own behaviour in this simulation. People species is set to wander around the space with the speed of 250 ms-1. The speed is set to 250 ms-1 so that the simulation can run and end faster in real time. The people species is also set to get infected if it comes in contact with other infected people in the radius of 10 metres. It will also have circle as its shape and will turn from green (susceptible) to red (infected) when it is infected.

When declaring people species, the behaviour of the species can be written to act a certain way. ‘Skills: [moving]’ is to define the species’ behaviour to move on the space. ‘Bool is_infected’ is set false at first so that the species does not get infected at first. The speed of the species is 250 ms-1. The species is assigned to wander around using ‘do wander’. The species will get infected at the distance of 10 metres when it comes in contact with infected species. ‘Flip’ is used with if function to make the species infected if it comes in contact with infected species. Now, the Boolean for is_infected is true. The species’ shape is a circle with size 25 by using ‘aspect circle’ and ‘draw circle(size)’. The colour of the shape is set to be turn from green to red when it is infected.

```
experiment main type: gui {
	output {
		monitor "Infection Rate" value: infected_rate; //display infection rate in monitor
		display map {
			species people aspect: circle;
		}
		display chart_display refresh: every(10 #cycles) {   //graph
			chart "Disease Spreading" type: series {
				data "susceptible" value: nb_people_not_infected color: #green;
				data "infected" value: nb_people_infected color: #red;
			}
		}
	}
}
```

Figure 2 People species in GAMA Platform

Experiments are usually declared at the end of the file. They start with the keyword 'experiment'. They contain the simulation parameters and the definition of the output which includes displays, monitors or inspectors. A monitor is set to constantly display the updated spread rate value in the output. Therefore, the change in spread rate can be seen in the monitor section of the output. A graph named "Disease Spreading" will show the information on both susceptible and infected people. The y-axis of the graph will display the number of people while the x-axis will display the number of cycles. Time in this simulation is recorded as number of cycles which will be displayed in the output. The plots for susceptible people will be in green while the plots for infected people will be in red. The plots altogether will form a line graph at the end.

The output also includes a map with the movement of the species and a chart in separate sections. Any species mentioned under 'display map' will show up in the final output. The map will show how the species wander around and get infected while the chart will show the changes in the number of susceptible people and the number of infected people. The chart is named "Disease Spreading". The value of nb_people_not_infected is the number of susceptible people and it is displayed as green dots while the value of nb_people_infected is the number of infected people and it is displayed as red dots. Both green and red dots will eventually form a line graph.

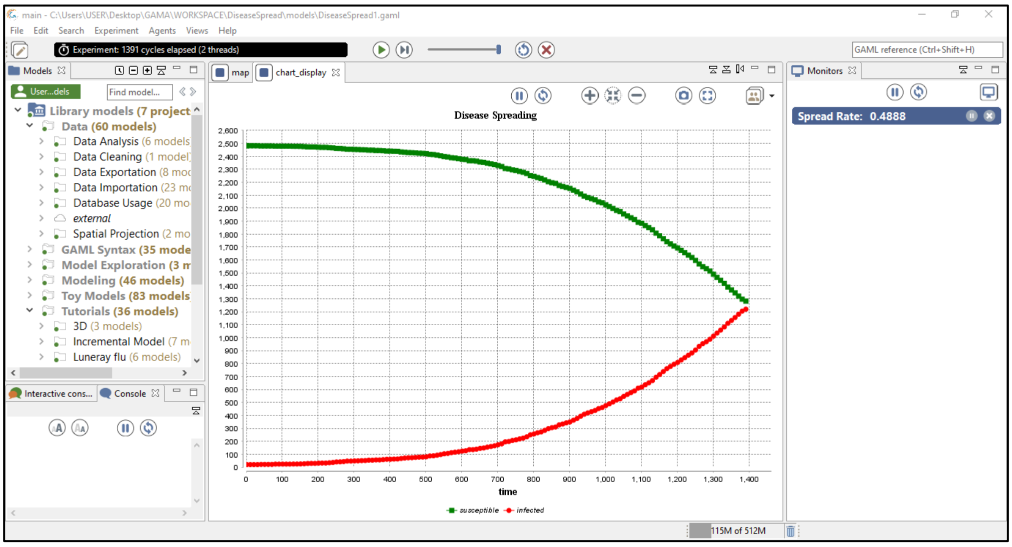

Figure 3 Experiment declaration in GAMA Platform

3.3. Output

The output of this simulation displays a map space with people, a monitor with the spread rate, the number of cycles and the chart.

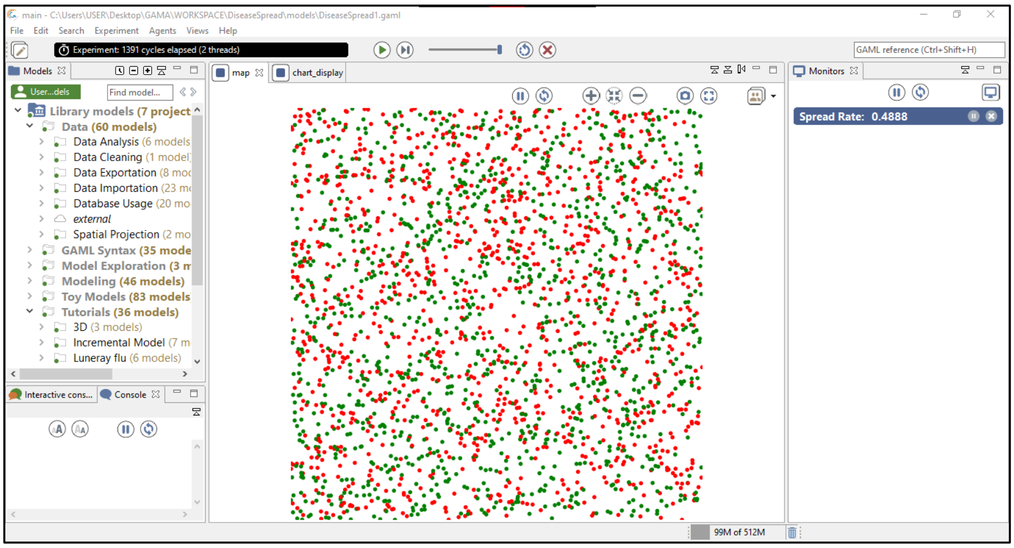

Figure 4 Map output in GAMA Platform

Figure 5 Graph output in GAMA Platform

4. Results and discussion

4.1. Results and discussions

For Scenario 1 (500 people), first attempt, second attempt and third attempt showed 27 067, 31 599 and 33 325 cycles respectively. All three attempts showed results more than 25 000 cycles which indicates that all three attempts in Scenario 1 took longer time to fully get infected.

For Scenario 2 (2 500 people), first attempt, second attempt and third attempt showed 8 728, 8 709 and 7 782 cycles respectively. All three attempts showed results less than 9 000 cycles which indicates that all three attempts in Scenario 2 took lesser time to get fully infected. Table 1 shows all the data that has been collected from the testing of Scenario 1 and Scenario 2. The table includes the number of cycles taken for each attempt in Scenario 1 and Scenario 2 as well as the average number of cycles for those scenarios.

Table 1: Results of Scenario 1 and Scenario 2

Scenario	Number of people	Number of infected people	Attempt	Number of cycles	Average number of cycles
1	500	20	1	27067	$\frac{27067+31599+33325}{3}$ $=\frac{91991}{3}$ $=30663.67$ ≈ 30664
			2	31599	
			3	33325	
2	2500	20	1	8728	$\frac{8728+8709+7782}{3}$ $=\frac{25219}{3}$ $=8406.33$ ≈ 8407
			2	8709	
			3	7782	

The average number of cycles is calculated by adding the numbers obtained from all three attempts, then dividing it by three. The answer is rounded off to the next whole number since the number of cycles cannot be anything other than whole number. The average number of cycles for Scenario 1 is 30 664 whereas for Scenario 2 is 8 407 which is 22 257 lesser compared to Scenario 1. This indicates that the time taken for the people to get fully infected in Scenario 1 is slower than in Scenario 2.

For Scenario 3 (2 500 people with 250 infected people), first attempt, second attempt and third attempt showed 2 844, 3 325 and 2 907 cycles respectively. All three attempts showed results less than 3 000 cycles which indicates that all three attempts in Scenario 3 took the shortest time to get fully infected. Table 2 shows all the data that has been collected from the testing of Scenario 2 and Scenario 3. The table includes the number of cycles taken for Scenario 2 which is taken from Table 1 and for Scenario 3.

Table 2: Results of Scenario 2 and Scenario 3

Scenario	Number of people	Number of infected people	Attempt	Number of cycles	Average number of cycles
2	2500	200	1	8728	$\frac{8728+8709+7782}{3}$ $=\frac{25219}{3}$ $=8406.33$ ≈ 8407
			2	8709	
			3	7782	
3	2500	200	1	2844	$\frac{2844+3325+2907}{3}$ $=\frac{9076}{3}$ $=3025.33$ ≈ 3026
			2	3325	
			3	2907	

5. Conclusion

In Scenario 1, there were 500 people in a 5000 m x 5000 m space which means the people were scattered far apart from each other with no overcrowding. In Scenario 2, there were 2500 people in the same room which means the room was almost full and the people are considered to be having mass gathering. The manipulated variable for Scenario 1 and Scenario 2 is the total number of people in the space. Since the average number of cycles taken for the people to get fully infected in Scenario 1 is 22 257 cycles higher than in Scenario 2, it is clear that the larger the number of people in a space, the faster the disease spread rate. Therefore, avoiding mass gathering is one of the vital steps for disease prevention.

Next, in Scenario 3, there were 2 500 people in the same space as in Scenario 1 and Scenario 2. Both Scenario 2 and Scenario 3 have total number of people who are enabling mass gathering. However, the number of infected people in both scenarios are dissimilar. Scenario 2 had 20 infected people as same as the previous testing while Scenario 3 had 200 infected people which is more than in Scenario 2. Since the average number of cycles taken for the people to get fully infected in Scenario 2 is 5 381 cycles higher than in Scenario 3, the larger the number of infected people in a space, the faster the disease spread rate. In conclusion, avoiding mass gatherings and prohibiting the entry of infected people into a premises should be enforced. Hence, this research will aid people to comprehend better about the importance of prevention steps for disease spread. The objectives of this research have been achieved.

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