Multi-agent simulation of Coronavirus contamination on public transport

Victor Geraldo Gomes[1], Gray Farias Moita[2]

[1]*Post-graduation Program in Mathematical and Computational Modelling*
Av. Amazonas, 7675, Nova Gameleira, Belo Horizonte, Brasil
victor@pontobrsistemas.com.br
[2] *Post-graduation Program in Mathematical and Computational Modelling*
Av. Amazonas, 7675, Nova Gameleira, Belo Horizonte, Brasil
gray@dppg.cefetmg.br

Abstract. Since the beginning of 2020, we are experiencing a worldwide pandemic of the coronavirus. Since then, health authorities around the world have tried to prevent people from infecting themselves with this virus. In Brazil, states and cities plan and take decisions to restrict movement or release some activities to return to normal operation. As noted, these are decisions that can, on the one hand, harm the economy and the citizen's interpersonal relationships and, on the other, lead to overcrowding of hospitals, health chaos and more deaths. For this work, a computer simulator was developed where, together with a mathematical model and multi-agent systems, it was sought to show contamination situations in real environments. The simulator has an interface where it is possible to visualize people moving in a pre-established environment. The objective of this work is to add to the studies already in progress, bringing more data and information that can help to improve policies and actions to combat the pandemic.

Keywords: Coronavirus, pandemic, social isolation, multi-agent system, simulation.

1 Introduction

Gain prominence, in the current debate about the COVID-19 pandemic, the criticism to the social isolation strategy. This is founded, essentially, in the idea that economic impacts of isolation are bigger than your benefits in public health terms. It´s argued the possible restriction of social contact should be directed for the risk groups of this pandemic, which is, people over 60 years of age or which are carrier of the cronic diseases. As a result, the rest of society should return to normal as soon as possible, in order to reduce the economic impacts of this sudden stop in your new form [1,2].

The defenders of the normality return argue that the deaths caused from Covid-10 as a proportion of the total population are smaller than the deaths from other diseases or social processes, like murders and traffic accidents. And, by logical imposition, if the economy isn´t used to stopping due to such problems, would not be barred by the effect of an even less lethal virus [1,2].

The present research searched, since a simplified way, similar the movement, interaction and contact between people and risk of contamination by the new Coronavírus (Covid-19). By and large, the idea was the simulator were able to represent a model, and that is capable to imitate operational and human behaviors from a real system, thus allowing extract data and information of this controlled and isolated system. It will be used a multi-agent system to simulate people movement in a closed place [2].

2 Methodology

The building process of a based model on agents begins since the creation of a conceptual model in which the basic requirements are identified. After defining the agents, the next step is specify their behavior. One might begin with a generic conduct and, gradually, adjustments can be made for becoming the agent´s behavior more adherent to reality [2,4]. This work was used the Java programming language. In terms of data structure, each agent is represented with a Java language object.

It can be called “agent”, each one of the active entities of a determined system, and according to the environment term, passive entities. Information are received by a agent, reasoning about the environment and all other agents involved, determining which actions to take, and which goals to pursue. Therefore, this individual is an active entity, this is, able to master your actions, differently to the static notions, such as modules, set of rules and knowledge bases.

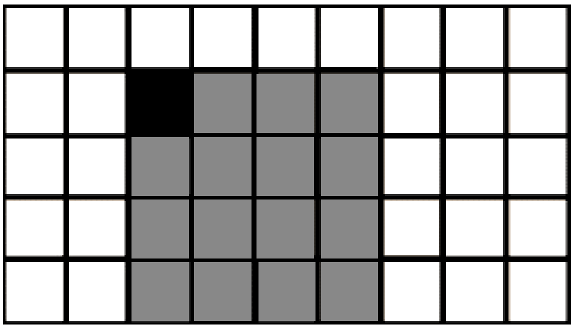
A possible definition is proposed since it considers the agent as a entity, real or abstract, which is able to act about itself or its environment, disposing a partial representation of this environment, where, in a multi-agent universe, it can communicate with other agents, whose behavior is consequence of your observations, knowledge and interactions with other agents [2,3].

The simulator shows, on its interface, the floor plan of the property where it will be made the people movement simulation, with a view from above this plant. In the simulator, each pixel of screen image always amount to an area 10 x 10 cm in the real world. The environments are presented on a top view [2,5]. Each agent inside the studied place owns a reference in the space, indicating where it is located at simulation given time in the simulations scenery. As well the walls, free areas and doors, an agent location in the simulator will be understood since the combination of the two cartesian planes X,Y (Latitude, Longitude) inside the two-dimensional grid [2,5].

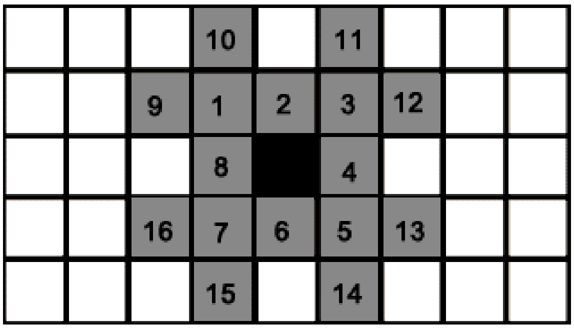
The figure 1a illustrates the occupied pixels by an agent. Every agent will always occupy a area of 4 x 4 pixels (16 pixels) and, converting to unit of measure, each person occupy 0,16 m^2. This dimension is compatible with the average size of an adult person [2,6].

The agent movement occurs within a loop (repetition method). This loop is started along with the simulation and is executed until a certain pre-configured time. The interval between each loop has relation with the agent speed. If the speed agent is 1m/s, the interval to scroll each pixel horizontally is 0,1 second. Each loop, the agent moves, pixel to pixel (occupying always 4 pixels horizontally and 4 pixels vertically), according to the environment and each agent has your speed defined. The agent can move in sixteen directions, according to the Figure 1b. In order to move to the pixel 2,4,6 or 8, it´s made a linear movement (horizontal or vertical), to the pixel 1,3,5 or 7 is a diagonal movement (45º) and, last of all, moving to the pixel 9,10,11,12,13,14,15 or 16 is made a displacement in 22,5º [2,5].

Figure 1 – Pixels occupied by an agent and movement possibility



(a)



(b)

Before each movement, the agent checks the current position and calculate which of the 16 positions will have less distance how far it is intended to move. According to the return, he moves, in case of 16 pixels the agent intend to occupy does not have other agent. 1 pixel to one of these 16 positions. The figure 2 shows a stretch about how is defined the direction that the agent must move. For the proposed model, it is not being considered the possibility of a new way obstruction during the agent´s walking [2,5].

Figure 2 – Movement and contamination algorithm

```
For each movement:

       Current position = (1,1) // Example, it will change with each new movement
       Final destination = (100,100)
       Distance until the final destination = distance between final destination and current position

       If (moving to the position 1 the distance is less than distance until final destination and there is
       not other person occupying those cells)
       {
              Direction will move = diagonally
              Distance until the final destination = distance between final destination and position 1
              Move
              In case of being near some infected person, it can be contaminated
              Wait a moment for the next displacement
       }
       If (moving to the position 2 the distance is less than distance until final destination and there is
       not other person occupying those cells)
       {
              Direction will move = diagonally
              Distance until the final destination = distance between final destination and position 2
              Move
              In case of being near some infected person, it can be contaminated
              Wait a moment for the next displacement
       }
       If (moving to the position 3 the distance is less than distance until final destination and there is
       not other person occupying those cells)
       {
              Direction will move = diagonally
              Distance until the final destination = distance between final destination and position 3
              Move
              In case of being near some infected person, it can be contaminated
              Wait a moment for the next displacement
       }
       ...
       If (moving to the position 16 the distance is less than distance until final destination and there
       is not other person occupying those cells)
       {
              Direction will move = diagonally
              Distance until the final destination = distance between final destination and position 16
              Move
              In case of being near some infected person, it can be contaminated
              Wait a moment for the next displacement
       }

Wait a moment for the next displacement
```

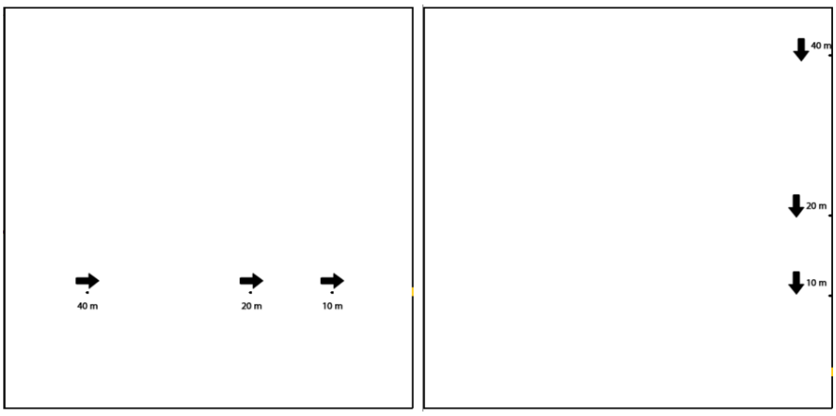
The algorithm calculates the contamination chance of a person is to determined distance from other. For such, the simulator uses the Java random method. For monitoring the contamination between people, it was used the JADE framework. The JADE provides to facilitate the multi-agent systems development, is developed, as the simulator, at Java. If the contamination chance is 13%, for example, the method returns a random number between 0 and 1000, diving by 10. In the case of this returned number is less than or equal to 13, the person will be infected by the virus [2].

3 Results found

For the created models validation, it is necessary the completion of some trials. Some trials are more simple, however not less important to test and assess your model. The proposed test has goal to verify if the specified displacement linear speed is equal to actually calculated speed in a simulation and the distance really crossed by the agent from your initial position to the exit door [2,5].

Initially, it will be considered two displacements : a straight line in the environment which displacement ideal route also behaves as straight line in the moving environment, considering a view from above, from left to right (horizontal movement) and other simulation also being a straight line in the environment, where the agent moves from top to bottom (vertical movement). Bother can be viewed at Figure 3. In the horizontal movement, only it is altered the position of the agent´s column, while in the vertical movement is changed the height until the agent is at the same height of the exit door and, once time being, he will move horizontally to leave the environment. For this, an alone agent at a room and without intern obstructions (in order to avoid the other agent´s influence or fixed obstacles) of 50m wide and 50m length will move to the exit. The simulations are perfomed with the agents being to a exit distance of 10m,20m and 40m from the exit [2,5].

Figura 3 – The positioned agents representation at different distances from the exit



The results of table 1 indicate that it is not mistake in the speed calculation during the movement in straight line. This way, considering the acrossed distance in regards to time, it has the exact value of the initially configured speed to each agent. It is realized each agent scroll ,beyond the initial distance when it was in the door, 0,1m. It happens because it is considered escape from the ambience after the agent does all the door crossing, which is, he scrolls, for example, 40m to the door and more 0,1m for being totally out of the environment [2,5].

Table 1 - Comparison between the specified and calculated displacement speed

Distance and total period – Shift in straigh line

	Initial distance from the door (m)								
	10			**20**			**40**		
Speed (m/s)	Travelled distance	Evasion period	Ideal evasion period	Distance travelled	Evasion period	Ideal evasion period	Distance travelled	Evasion period	Ideal evasion period
0,5	10,1	20,2	20,2	20,1	40,2	40,2	40,1	80,2	80,2
1,0	10,1	10,1	10,1	20,1	20,1	20,1	40,1	40,1	40,1
1,5	10,1	6,73	6,73	20,1	13,4	13,4	40,1	26,73	26,73
2,0	10,1	5,05	5,05	20,1	10,05	10,05	40,1	20,05	20,05

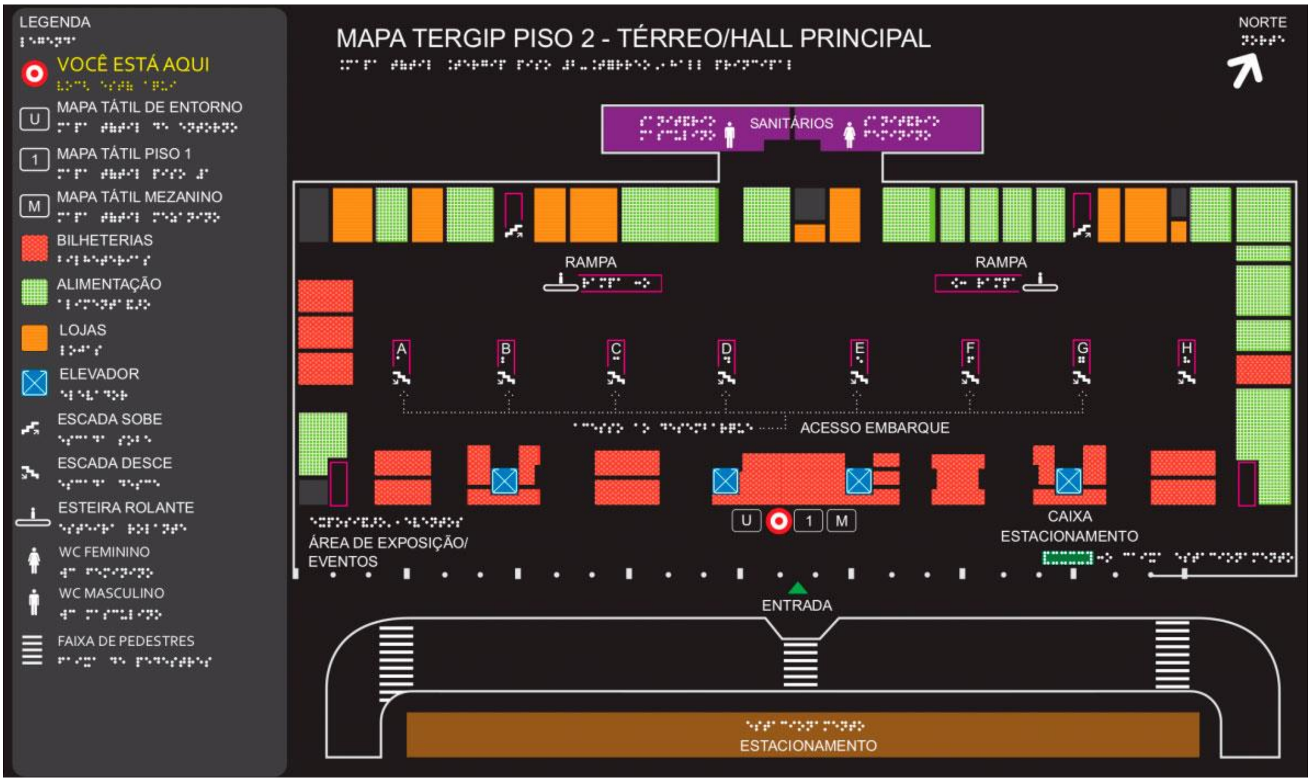
In this study, all the movement and contact simulations were made using the same environment (plant), in the case, The Governador Israel Pinheiro Bus Terminal, in Belo Horizonte (Figure 4). This environment was chosen for having some complexity, a lot of aisles and capacity to many people. The Belo Horizonte´s bus station area is of 45 thousand m2 distributed in three floors (boarding platform, main hall and mezzanine) [7]. For simulating this research, we will use only the main hall (Figure 5) as an area of 4.232 thousand m2.

Figure 4 – Belo Horizonte´s Bus Terminal

Source: BH Portal Bus Station [7]

According to BH Portal Bus Station [7], the bus station is responsible for about 10 millions of passenger per year and circulate, on average, 40.000 people a day. Moreover, according to BH Portal Bus Station [7], in march 2020, there was drop of 29% on the departures quantify in regard to March 2019 (decreasing from 19.614 to 13.947 buses) and reduction of 30% on the arrivals number (from 19.317 to 13.744 buses). In regard to passengers flow, the reduction was of 44% on shipment volume (from 353.052 to 196.725 people) and of 43% on landings (from 341.619 to 195.435 passengers) on March 2020, in relation to the same month in 2019.

Figure 5 - Main Hall



Source : BH Portal Bus Station [7]

It was defined 6 simulation scenarios according to Table 2 below. In all simulations, it was distributed 400 people in the environment (BH Bus Station), where, to each simulation, a percentage of people was infected with the Coronavirus (Covid-

19). After putting these people in the environment, in aleatory positions, started the movement with duration of 30 minutes (1800 seconds) [2]. The fixed speed of each person is of 1,66m/s (6km/h) [2,8]. In order a person contaminate other, after analyze 172 studies [9], the simulator considered a chance of 13% to people with distance less than 1 meter and 6,5% to distance between 1 and 2 meters. In both situations, people were without mask. Trying to get closer of a bus terminal environment, for these simulations, consider that half of the people´s environment are waiting the bus (stopped) , and other half will be in movement.

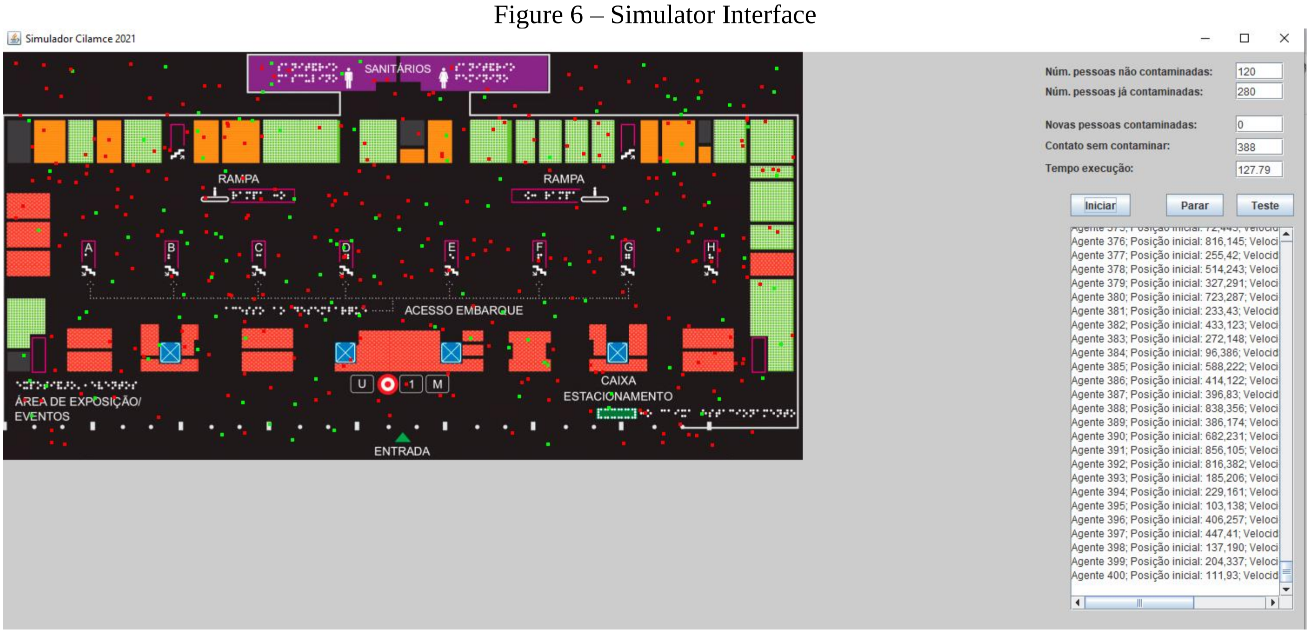
Table 2 - Simulation scenarios

Scenery	Total number of people	Uncontaminated without mask	Contamina ted	Probability of contamina tion less than 1 meter [9]	Probability of contamination at 2 meters [9]
1	400	360 (100 %)	40 (10 %)	13%	6,5 %
2	400	320 (100 %)	80 (20 %)	13%	6,5 %
3	400	280 (100 %)	120 (30 %)	13%	6,5 %
4	400	200 (100 %)	200 (50 %)	13%	6,5 %
5	400	120 (100 %)	280 (70 %)	13%	6,5 %
6	400	80 (100 %)	320 (80 %)	13%	6,5 %

According to the epidemiological bulletin [2,10], the transmissibility of infected patients by SARS-CoV is, on average of 7 days after the beginning of the symptoms, and it is believed the period can be the same for the New Coronavirus (Covid-19). Consequently, on our simulations, a newly infected person could not contaminate other person.

Note that, according to the Table 2, the number of contamined initially was increasing in each simulation. This strategy was adopted objecting to analyze the contamination speed in line with the people number already were with the disease. It was also considered that nobody was using masks during the simulations. The figure 4 illustrates the simulator interface and people positioned in the environment before the outset of simulation for the scenery 1. Realize that the green points mean people uncontaminated by Coronavirus (Covid-19), and the red points are the contaminated agents.

Figure 6 – Simulator Interface



It was made a simulation to each scenery and the results obtained from these simulations are at Table 3. In this same table is possible to realize the percent of new contaminated in regard to people without the disease is very close, some between 45 and 51,3%. It is worth highlighting one infected person can approximate to other in a distance less than one meter, and do not transmit the disease. Being understood contacts without contamination when a contaminated person were less than

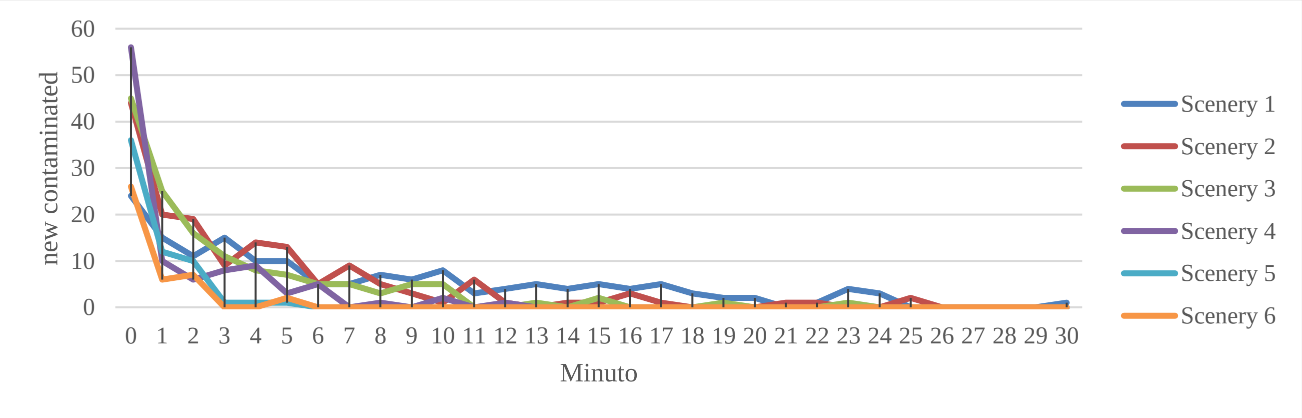
1 or 2 meters from other uncontaminated, but, according to said above, that is why the probability of contamination is only 13% or 6,5% according to the distances [9], these people were not contaminated.

Table 3 - New contaminated

Scenery	Were not contaminated	New contaminated	Percent of new contaminated
1	360	162	45,0 %
2	320	159	49,7 %
3	280	140	50,0 %
4	200	101	50,5 %
5	120	61	50,8 %
6	80	41	51,3 %

The figure 7 shows, to each scenery, the evolution of contaminated number along the simulation minutes. As can be seen, the infection number happens in the outset of the simulations.

Figure 7 – Evolution of the new contaminated number



4 Conclusion

This study approached the development of a simulator, through the software in Java Language and communication by framework JADE, using the concept of multi-agents to enable the crowd´s evasion. The challenge on the simulator development was formed due to the necessity to definite accurate parameters of movement minimum distance, agent size, displacement speed, room door positions, among others. The software made able simulations to be validated, as for example, confronting each agent’s evasion time, speed this agent and the distance crossed. The strategy of choosing the creation of a simulation 2D facilitated, for example, by the possibility to get monitoring visually the agent movement until exit doors or the verification one agent will not overlap other.

The challenge was equip the agent´s human aspects, like speed, walking direction and contamination state by the New Coronavirus (Covid-19). The use of plant from the BH Bus Station enabled to have a big and complex environment, with many aisles and stores. These characteristics allowed many agents were included in the simulation e lets, still, several other combinations of initial sceneries.

The multi-agent system choice happened because it is waited simulations try to be the nearest possible from the reality. The multi-agent technology allows the academic community, researchers and study centers can make several simulations, with possibilities from different sceneries and a variety of techniques.

As seen on presented results, the percentage of new contaminated (relation between who did not have Covid-19 and who were newly infected) was close to 50%. It was also perceived this number did not vary a lot because there were already few contaminated initially (in the simulation beginning) with possibility to infect others or so, during the simulation outset, there were already contaminated people and did not find other to transmit the disease.

In an upcoming work could be explored other conditions and variables as: checking the time that the contaminated stayed close to other person uncontaminated, and setting some mininum time that they need to stay next to happen the contagion, altering the status of person from standing to walking and vice versa during the simulation and others.

5 References

[1] Ferrari, Andrés; Cunha, André Moreira. A pandemia de Covid-19 e o isolamento social: saúde versus economia, UFRGS, 2020.

[2] GOMES, Victor Geraldo; MOITA, Gray Faria. A multi-agent approach to simulate contamination with the new Coronavirus. XXXI CILAMCE Iberian Latin-American Congress of Computational Methods in Engineering, Brasil, 2020.

[3] FERBER, J.; GASSER, L. Intelligence artificielle distribuée. In: International Workshop on Expert Systems & Their Applications, 10., 1991, Avignon. Cours n. 9. France: [s.n], 1991.

[4] MACAL, C., NORTH, M. Agent-based modeling and simulation. In Winter Simulation Conference (WSC), Proceedings of the 2009, pages 86-98, 2009.

[5] GOMES, Victor Geraldo. Uma abordagem multiagente para simulações de movimentação de multidões e de evacuação. Belo Horizonte, CEFET-MG, 2019. Dissertação (Mestrado em Modelagem Matemática e Computacional).

[6] STILL, G.K., Crowd dynamics. Department of Mathematics (University of Warwick), 2000, 280 p. Tese (Doctor of Philosophy in Mathematics).

[7] https://www.rodoviariadebelohorizonte.com.br, acesso me 15/07/2021.

[8] MONTEIRO, Walace David; ARAÚJO, Claudio Gil Soares. Transição caminhada-corrida: considerações fisiológicas e perspectivas para estudos futuros, Revista Brasileira de Medicina do Esporte, Vol. 7, Nº 6 – nov/dez, 2001.

[9] ELER, Guilherme. Cada metro de distância reduz o risco de contaminação pela metade, https://super.abril.com.br/saude/cada-metro-de-distancia-reduz-o-risco-de-contaminacao-pela-metade/, acesso em 30/07/2021.

[10] Brasil. Ministério da Saúde. Secretaria de Vigilância em Saúde. Doença pelo Novo Coronavírus 2019 - COVID-19, Brasília, v. 03, fev/2020.