CoSiT: An Agent-based Tool for Training and Awareness to Fight the Covid-19 Spread

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***Abstract*—Since the beginning of 2020 and following the recommendation of the Emergency Committee, the WHO (World Health Organization) Director General declared that the Covid-19 outbreak constitutes a Public Health Emergency of International Concern. Given the urgency of this outbreak, the international community is mobilizing to find ways to significantly accelerate the development of interventions. These interventions include raising awareness of ethical solutions such as wearing a face mask and respecting social distancing. Unfortunately, these solutions have been criticized and the number of infections and deaths by Covid-19 has only increased because of the lack of respect for these gestures on the one hand, and because of the lack of awareness and training tools on the spread of this disease through simulation packages on the other. To give importance to the respect of these measures, the WHO is going to try to propose to his member states, training and sensitization campaigns on coronavirus through simulation packages, so that the right decisions are taken in time to save lives. Thus, a rigorous analysis of this problem has enabled us to identify three directions for reflection. First, how to propose an IT tool based on these constraints in order to generalize training and awareness for all? Secondly, how to model and simulate these prescribed measures in our current reality? Thirdly, how to make it playful, interactive, and participative so that it is flexible according to the user's needs? To address these questions, this paper proposes an interactive Agent-Based Model (ABM) describing a pedagogical (training and educational) tool that can help understanding the spread of Covid-19 and then show the impact of the barrier measures recommended by the WHO. The tool implemented is quite simple to use and can help make appropriate and timely decisions to limit the spread of Covid-19 in the population.**

Keywords*—*Multi-agent system; covid-19; CoSiT; modeling-simulation; barrier measures; complex systems

I. Introduction

To sensitize everyone in the fight against the spread of the new virus through the respect of non-pharmaceutical measures while waiting for a pharmaceutical solution to be set up, the WHO in a report entitled "SituationReport-156" [1], recommends through tabletop exercises and textual presentations to its member states, the implementation of educational training and awareness-raising campaigns through seminars and symposiums on the coronavirus (Covid-19). For this purpose it will put at their disposal, different packages of textual simulation, to form and sensitize in the fight against the Covid-19, with the help of textual plans and presentations with slides [2]. At the WHO, for that matter, the Department of Health Security and Preparedness has set up the various table top exercise programs named SimEx (Simulation Exercise) Covid-19 [3] as part of the coronavirus training (Covid-10), which it defines in its 2017 Simulation Exercise Manual [4], as an exercise that uses progressive scenarios, with series of scripted messages to allow participants to consider, the impact of a potential public health emergency on existing plans, procedures and capabilities: in these words that "A TTX (Table Top Exercise) simulates an emergency situation in an informal stress-free environment". Although these plans (non-pharmaceutical measures), in a textual format, are easy to manipulate by individual stakeholders, there are no accessible tools and pedagogical means to train and sensitize all stakeholders on the importance of respecting these measures, as these actors may have different interpretations of these measures and the protocol set up, in an environment where they are geographically distributed and distant from each other, and these training course are only held in the organization's offices around the world, and are purely professional, which considerably restricts listening, and limits training and awareness.

Taking into account the above mentioned observations, and with the increase in contamination, the need for training and sensitization, especially of political decision-makers and populations who are not always able to understand the merits of these measures, is becoming increasingly necessary and important, so that they can make early decisions on the adoption of these measures to save lives. This solution could also be very useful to avoid any misinterpretation of what these textual response plans mean. It is therefore essential to propose an educational tool that can simulate the current reality with all its aspects (particularly social) to understand, control and monitor this disease throughout its life cycle.

The aim of this paper is to contribute to the engineering of coordination and decision making, in a multi-agent universe, and this in the fields of epidemiology, while providing a global approach that takes into account without confusing them and by articulating them, the essential aspects of crisis management: ethical measures (social distancing and wearing of protective masks) and social behavior.

To achieve this, we used the Simple Reflex Agent model to simulate the propagation of the pandemic and to visualize the impact of barrier measures. We then specified and formalized this approach with the UML and AML languages, and documented it with the ODD (Overview, Design concepts and Details) protocol. Then, we proposed a pedagogical architecture, centered on interactive and participative agents, to allow users to play themselves on the existing parameters, according to the context in which they are, and to visualize the results of the simulation in an interface provided for this purpose.

The implementation and simulation of the system was done on the GAMA (GIS and Agent-Based Modelling Architecture) modeling and simulation platform. To validate the obtained model, we defined and simulated several real-life scenarios which revealed results similar to what is observed today.

This paper is organized as follows: in the second section, we propose a review of the literature on infectious diseases, then on the mathematical and computer models existing in the fight against the spread of these diseases, and finally on the educational tools that can play the role of training support in the current context. In the third section, we propose a description and formalization of the agent model we propose as a solution, after which we document it using the ODD protocol. Section four concerns the implementation and experimentation as well as the validation tests through the defined scenarios. The fifth section concerns the general conclusion and outlook.

II. Key Concepts

A. Complex Systems

A system is complex when it is made up of a large number of differentiated autonomous components that interact with each other in a non-trivial way. This system is also characterized by the emergence at the global level of new properties, not observable at the level of components system and by a global operating dynamic difficult to predict from the observation of the constituents and their elementary interactions [5].

B. Modeling - Simulation

Modeling – simulation, first of all, consists of the designing of a model. It is a way of making explicit the complexity of a system to better understand its functioning and to make good decisions [5].

C. Model

A model is a mathematical, or graphic and computerized representation of the objects and the relations between them in a confined zone of the real world. A model can also be viewed as a simplified representation of a complex reality. To be useful, models must be adapted to their objects and be conveniently studied and validated [6].

D. The New Coronavirus

The new Coronavirus named Covid-19 is caused by the SARS-CoV-2 virus, which is spread through close contact with an infected person when small liquid particles are expelled through the mouth or nose of an infected person or when people are in direct or close contact with an infected person. Transmission can also occur in specific settings, particularly in crowded, poorly ventilated indoor spaces where one or more infected persons spend long periods with others. People with the virus can leave infectious droplets when they touch objects or surfaces, such as tables, door knobs and railings. We can then become infected with the virus if we touch these contaminated surfaces before washing our hands [7].

E. Measures to Control the Spread of Covid-19

To limit the risk of contracting Covid-19, the WHO recommends that everyone follows certain basic precautions such as [7]:

- Follow local recommendations.
- Keep at least one meter away from others.
- Wear a mask, in public places.
- Avoid touching surfaces, especially in public places.
- Wash your hands regularly with soap and water or with a hydroalcoholic solution.
- Cough and sneeze into your elbow or a tissue.

In the following, the system that will be modeled will take into account only two of these measures: the wearing of the mask, and the respect of the distancing.

III. Related Works

Several solutions in the field of infectious disease control through mathematical modeling have been well established. Among these solutions, we can mention the one proposed by Kermack and McKendrick in the paper entitled “A contribution to the mathematical theory of epidemics” [8]. The aim was to understand the evolution of the epidemic in large populations of constant size. The application of this mathematical modeling technique was motivated by the need for more accurate predictions of the spread of infections at the population level. This has contributed to a better understanding of the mechanisms of spread to help develop optimal control strategies through public health interventions. In [9], the authors address the problem through a representation in the form of compartments of the various stages of infection. We find several of these compartment models in the literature [10], [11], [12], among which we can cite the SI, SIR, and SEIR models.

The work of Kieczkowski & Grenfell [13], presents a new approach based on an increased interest in modeling the interactions between people in a network with a mixture of local and global interactions, by proposing a stochastic model called Mean-field, to demonstrate that even in the presence of a high level of local correlation their model can succeed. To achieve this, they referred to the work of Watts & Strogatz, [14], in which they analyzed some properties of mesh networks, and showed that they behave like a network model, even for a relatively small mesh parameter.

Another similar model was analyzed by Boccara & Cheong, [15], where individuals were allowed to change places on a two-dimensional network. Thus, they proved that when the interactions between the agents are over a long-range, it causes a very fast spread of the epidemic in the population. In the work of Kieczkowski [13], the authors studied the effects of local spatial correlations of a temporal epidemic spread as a function of the increasing proportion of global contacts in a cellular automaton (CA) model. They deduce that even in the presence of high local correlations, the model (Mean field types equations) can be quite suitable if the contact rate is treated as a free parameter. They conclude that the contact rate reflects not only a microscopic and epidemiological situation, but also a complex social structure, including short and long term contacts following a hierarchical structure of the society. Among the works that are based on this small-world network principle, we can mention [13], [14].

While these approaches (compartmental and stochastic) rely on mathematical models and representations to propose solutions in the field of epidemiology, the Agent-Based approach is relatively new and more powerful, more realistic in simulating the spread of diseases and predicting the impacts in the population and especially regarding the effectiveness of interventions. According to [16], this model is classified as a solution to model complex social interactions in a real world.

In the same perspective, in [17] authors present an Agent-Based approach for modeling dynamics of contagious disease spread. The aim here was to overcome the limitations of different approaches, such as cellular automata and classical epidemic models. In this paper the authors also allow the modeling of interactions between individuals, which facilitates the study of specific spatial aspects of the spread of epidemics and to address the stochastic nature of the epidemic process. In [18] authors present a tool, EpiSimdemics which is different from the other systems and allows to simulate the propagation of contagious diseases. According to this work, all of these simulators have been widely evaluated and used in dozens of large-scale public health studies.

Among the computer tools used in the fight against Covid-19, the literature informs us that several tools are already available for this purpose, among which: The most powerful computer in the world Fugaku [19], that works particularly at the molecular level, and at the macroscopic level. In addition, the MODSIR19 project [20] developed within the framework of research for the fight against Covid-19, allowing to model the various factors which influence an epidemic, and to visualize the effects on a graph, according to the R0 factor. It also allows to better predict the evolution of the pandemic, to simulate the number of hospitalizations, the needs in resuscitation beds, and the effects of confinement and de-confinement, and is also for pedagogical purposes. Learn to fight: "Good practices when treating patients", on the other hand, is a digital training simulator for the management of patients with the symptoms of Covid-19 [21]. Another powerful tool is the COMOKIT which is a GAMA model on the evaluation and comparisons of policy responses to the Covid-19 [22] pandemic. Its goal is to help policymakers and researchers answer questions such as: Does closing schools decrease peak transmission? What is the impact of wearing masks on the dynamics of the epidemic? How long should a lockdown ideally last?

However, with the increase in the number of cases from day to day, several public health organizations and mainly the WHO have found it necessary to train and sensitize people on coronavirus through various training and sensitization packages through so-called tabletop exercises (TTX) [2]. Although this training is necessary to sensitize and train decision-makers and individuals to curb the spread of the virus. The means and tools of the training set up by the WHO remain a hindrance, and a limit as to the objectives to be reached, for several reasons. Firstly, these simulations are done on paper and through presentations, there are no specialized software tools for this. Secondly, it is restricted to the members of the organization and takes place only in its premises around the world, which reduces the target to be reached. Third, it is targeted and concerns only one category of people. Moreover, the actors being geographically distributed, each of them can have a different interpretation of these measures, and more seriously, the disease changes phase each time and new measures must be adopted each time. Thus, proposing a computer simulation tool for educational purposes to train and raise awareness on the measures prescribed by the WHO becomes an urgent task.

Our work will consist in conducting an in-depth study on the impact of these measures in the fight against the virus, by looking at the training through simulations proposed by the WHO.

IV. Proposed Model

A. Analysis and Design

To answer the questions raised by the literature, we propose a solution to create an educational, simple, interactive, participative and generalist computer tool that can help in the fight against infectious diseases. This tool named CoSiT (Covid-19 Simulation Tools) is based on the GAMA (GIS and Agent-based Modelling Architecture) modeling and simulation platform and follows a set of principles and requirements as follows :

- It is first and foremost an educational tool for training and raising awareness on the importance of respecting barrier measures in the fight against the spread of Covid-19.
- It is also and above all an interactive and participative tool.
- CoSiT is based on the so-called non-pharmaceutical measures prescribed as part of the fight against Covid-19, to produce simulations of our daily lives and to visualize the results obtained in an interface provided for this purpose.
- CoSiT is based on a detailed and realistic representation of the impact of barrier measures in controlling the spread of Covid-19 in the environment of our choice.
- CoSiT is generic, flexible and applicable to any case study.
- CoSit is open and modular enough to support interdisciplinary cooperation.
- CoSiT provides easy access to small-scale training, experimentation and sensitization, making it easy to explore its parameters.

To do so, we followed the following process as shown in Fig. 1.

Fig. 2 gives us an overview of the structure of the model to be implemented in the form of a UML class diagram.

In Fig. 3 we can see the AGR representation with AML of our model.

The design of the simulation environment is done upstream of the simulation according to the plan of the place where we

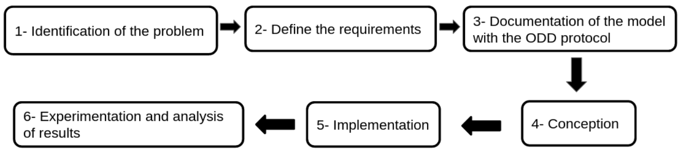

Fig. 1. Solution Implementation Process.

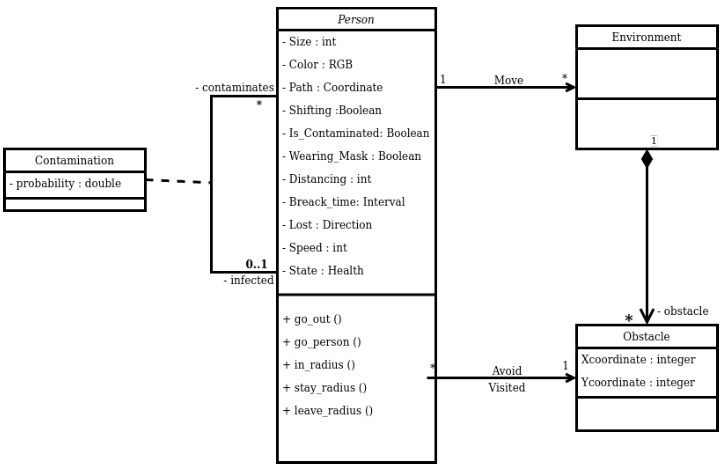

Fig. 2. Overview of the Model Structure in the Form of a UML Class Diagram.

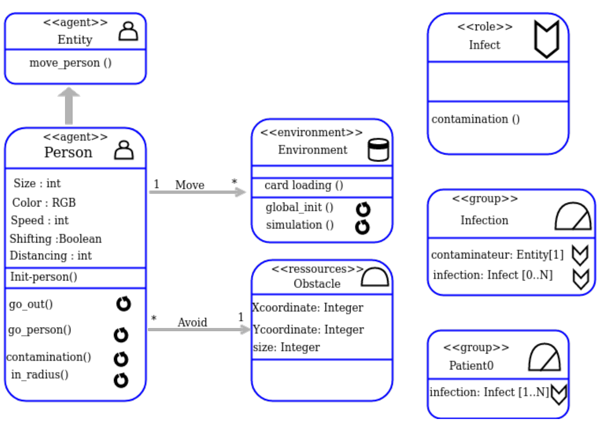

Fig. 3. AGR Representation with AML of the Model.

want to define a scenario, to do this, we have defined some basic rules.

Fig. 4 shows the design of the simulation environment. It is after this step that the file can be exported in CVS (Comma Separated Values) format and imported into our model as a simulation environment.

B. Model Description using ODD Protocol

To describe the model that we propose as a solution, we have used as a tool, the ODD protocol [23], [24].

1) Overview :

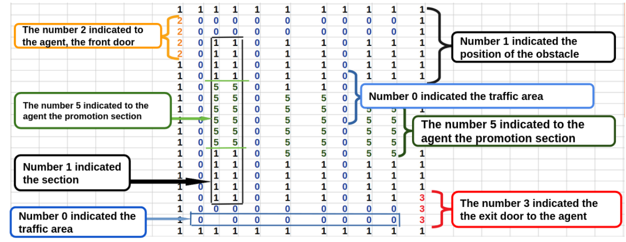

Fig. 4. Design of the Simulation Environment using Libre Office Calc Spreadsheet.

- *Purpose:* The objective of the model is to explore, in a low-scale real environment of our choice, the impact of barrier measures in the fight against Covid-19.
- *Entities, state variables, and scale:* The model is composed of a single variable, the human agent, which represents the different people in the considered area with their characteristics and epidemiological status. Each agent is localized in space by its coordinates, and can recognize objects in the environment.
It should be noted that the environment is composed of a set of obstacles which are the objects of the living world, and of agents which are people. It corresponds to a cell of 70m x 70m that can be parameterized.
As for the temporal resolution, the simulation is done by a succession of iterations for which the time step is fixed at one second. This time step is defined in such a way that the displacement distance during an iteration of an agent does not exceed the dimension of a cell. The simulated duration is not defined by default, because it depends on the type of environment and the number of initial agents. This duration corresponds to a day of work and activities.
The simulation is divided into four phases, which are distinguished by the agents' behaviors:
    - A "Life without constraint" phase, which includes two types of agents: "infected and susceptible". A phase of "Life with a constraint of wearing face mask", during which agents are forced to wear the mask. A phase of "Life with constraint, respect of social distancing", during which they must respect a certain distance from each other. And a phase of "Life with a constraint of facial mask-wearing, and respect of social distancing", which combines the two previously mentioned.
    - Several other variables are also defined as parameters of the model: the number of people who can intervene throughout the simulation, the probability of contamination within a population, the measure of social distancing, the simulation environment. The model gives the user the possibility to act on the behavior of the agents before and during the simulation through the activation and deactivation of these barrier measures.

2) Design Elements:

- *Basic Principles:* The aim is to show, through modeling and computer simulation, the importance of barrier measures in the fight against Covid-19. The aim is to provide an educational tool that can be used as a training and awareness support.
- *Emergence:* There is a phenomenon of spatial spread of disease that is conditioned by the movements and behaviors of human agents. **Perception:** Agents can perceive other agents in their vicinity, as well as objects in the world they are in.
- *Interaction:* The only interactions present in the model are the interactions between human agents.
- *Stochasticity:* The model contains some stochasticity in both the initialization and the dynamics. The position of the agents in the space is random on one of the cells. The number of initially sick agents is also chosen randomly. During the simulation, when a new agent is created, its status is chosen randomly according to a probability. Moreover, an agent moves a more or less constant distance but in a randomly chosen direction according to its objectives.
- *Observation:* The main display of the simulator is an environment containing the different types of agents, as well as the obstacles. It is updated at each time step, allowing to visualize the dynamics of the disease propagation. During the simulation, we can observe the evolution of the number of contamination with the help of a curve representing these values as a function of time, and also in textual form for the non-professionals of the domain.
- *Adaptation:* the individual behavior of each agent is a process of adaptation at each time step, it adapts to evolve within its environment and to reach its objectives.
- *Objectives:* the objective of the agents is to move according to the established rules. These objectives are not fixed but depend on the parameters and the scenario we want to simulate.

3) Details:

- *Initialization:* During this phase, we have to define the basic parameters of the simulation such as: importing the simulation environment, creating and initializing the agents, setting the parameters of the behavior of these agents.
- *Input Data:* The main input data is in CSV format previously provided by the user.

V. Implementation

The aim is to develop a tool capable of simulating the propagation of the Covid-19 in a public environment such as supermarkets, bars, or restaurants, and then to display the results obtained in a clear and accessible way for everyone. The solution implemented here is a simple reflex agent-based model, documented by the ODD protocol, implemented, modeled and simulated using GAMA Platform [25]. Its interface has different parts and offers two solutions: the CoSiT1 solution which is an interactive and customizable training environment and the CoSiT2 solution, which is more generalist, and uses the parameters of CoSiT1 to offer on a single screen, all possible results.

The Gama modeling and simulation platform is the one with which we implemented this solution. Fig. 5 gives us a descriptive overview of this solution.

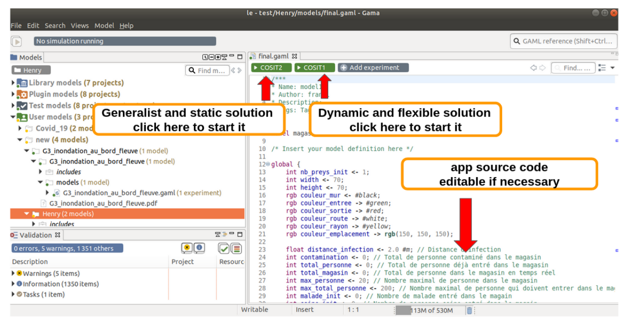

Fig. 5. Gama Modeling and Simulation Platform Uses

The CoSiT1 interface The main requirements implemented in this part are summarized in Fig. 6.

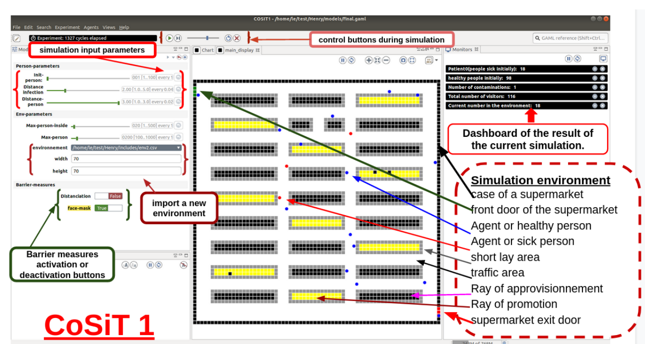

Fig. 6. CoSiT1 Simulation Interface.

The CoSiT2 interface The main requirements implemented in this part are summarized in Fig. 7.

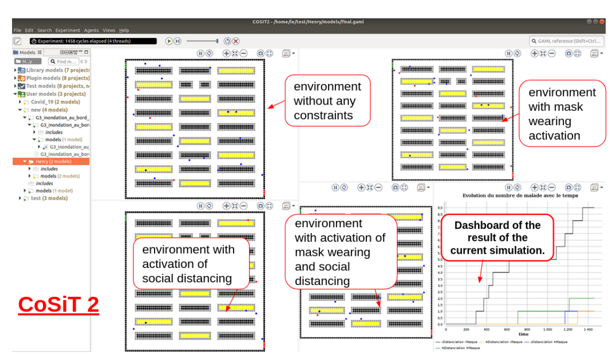

Fig. 7. CoSiT2 Simulation Interface.

VI. Numerical Simulation and Experimentation

In this section, the simulations performed are presented. Table I describes the parameters used and the estimated baseline values.

TABLE I. Parameter Values and their Meanings

Parameters	Estimated baseline values
Distance infection	$[0 - 2.0]$ meters
Maximum persons inside the supermarket	50
Maximum visitor per day	500
Distanciation value	$[0 - 4.0]$ meters
Respect of wearing face mask	Yes/No
Respect for distancing	Yes/No
Probability of infection	0.05
Probability of wearing a face mask	$[0.5 - 1.0]$
Probability of distancing respect	$[0.5 - 1.0]$

A. Experimentation 1: Influence of Wearing a Mask on the Spread of the Virus in a Supermarket

There is scientific debate about their use, one study showed the ability of surgical masks to prevent the exhalation of respiratory viruses. Therefore, the use of masks by the population could reduce peak contamination.

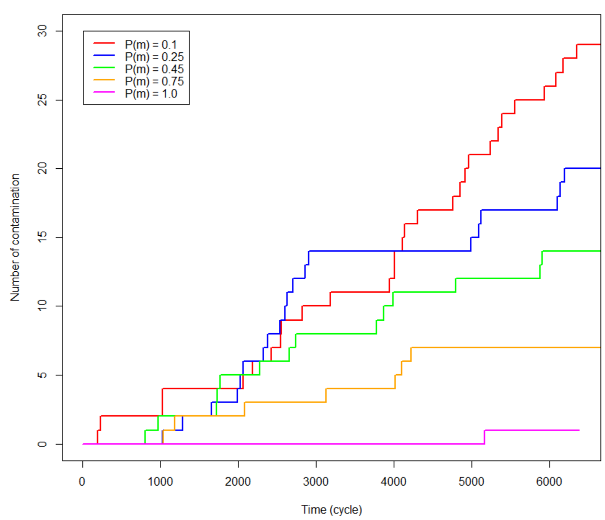

Fig. 8. Several Probability of Wearing Masks are Considered (0.1, 0.25, 0.45, 0.75 and 1) and the Social Distancing is not Respected.

B. Experimentation 2: Influence of Social Distancing on the Spread of Covid-19 in a Supermarket

Like the wearing of masks, maintaining a certain distance has been recommended. The positive effects of such actions are visible on the number of contaminations, depending on whether one practices it or not.

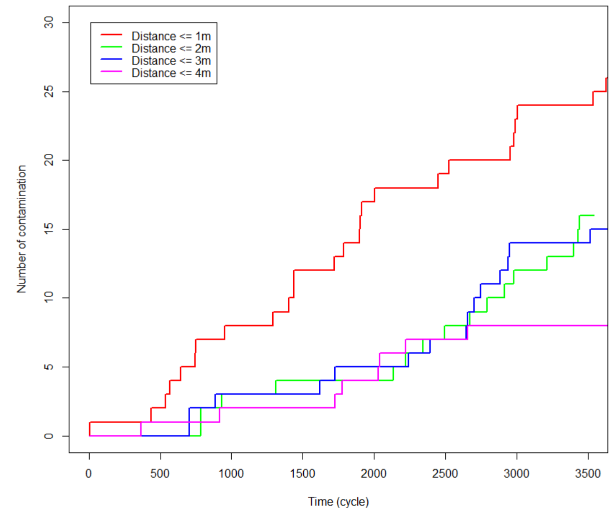

Fig. 9. Impact of Social Distancing.

C. Experimentation 3: Influence of Mask Wearing and Respect of Social Distancing on the Spread of Covid-19 in the Environment

The main objective of this experiment is to find the best protocol that can have an optimal impact on the spread of the pandemic, reducing the spread factor R0. To do this, we decided to simulate a scenario in which the two previous barrier measures are found under the same conditions.

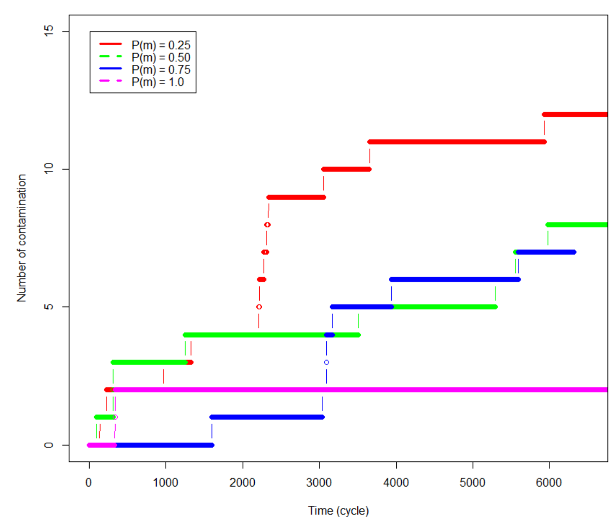

Fig. 10. Impact of Wearing Face-Mask and Respect of Social Distancing. Several Probability of Wearing mask are Considered while the Social Distancing Considered is 2 Meters

As shown in Fig. 10, we start this exploration with the simplest possible scenario, i.e. a free spread of the disease with a percentage of 25% as the probability of wearing a face mask, and 2 meters as the distance measure to be respected.

D. Experimentation 4: Consideration of Promotion Area in the Supermarket Environment

This experimentation attempts to display the dynamics of the pandemic in a supermarket that contains promotion areas.

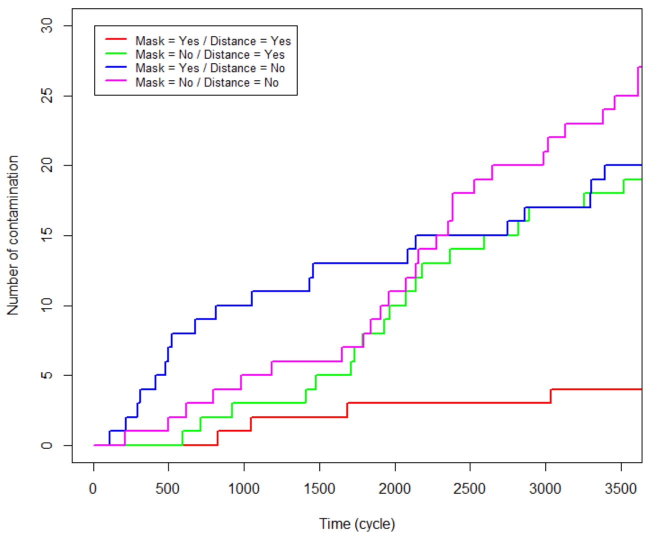

Fig. 11. Impact of Wearing Face-Mask (Yes/No) and Respect of Social Distancing (Yes/No) in the Environment with Promotion Area.

In Fig. 11, we consider a percentage of 25% as the probability of wearing a face mask, and 2 meters as the distance measure to be respected.

VII. Discussion of the Results

In Fig. 8 it can be seen that the use of masks does indeed reduce the peak of contamination. Therefore, recommending the use of face masks would avoid overloading hospitals and intensive care units as much as possible, and would contribute to slowing down the speed of spread of the virus while reducing the R_0 factor. The greatest change was achieved with a face mask probability of 0.75 and above, which avoided the sudden increase in cases that were still noticeable with a face mask probability of 0.5.

As presented in Fig. 9 the social distancing would act on the extent of the propagation. It also shows us that the smaller the radius of propagation of the virus (e.g. 1 meter), the fewer contaminations there are. For large distances, the results show that it is not always obvious to adopt such behavior in society, which justifies the high epidemiological peak when the distance increases. If social distancing also appears to be one of the best ways to reduce the spread of the virus and to relieve the health centers, it raises several questions about the right distance to adopt in order not to be contaminated. As in the case of wearing a mask, the simulations were run several times with a distancing measure varying from 1 to 5 meters.

Based on the results described in Fig. 10, we can compare the two different measures.It seems that these two policies taken individually correlate with the behavior of the individuals according to the environment where they are. On the other hand, these two measures taken together allow us to observe an antagonistic reaction (when the mask does not work, the distancing protects and vice versa, and when both work the protection is of high quality).

The presence of promotion areas has an impact on the spread of the disease as shown in Fig. 11. It appears that even if the supermarket contains promotional areas, the application of the two barrier measures is recommended to avoid the spread of the disease.

VIII. Conclusion and Perspectives

Based on the results obtained in this paper, we confirm that the objectives assigned at the beginning of this work have been successfully achieved. Results clearly show that the adherence to the WHO prescribed barrier measures influences the spread of the virus and is a means of controlling Covid-19, which supports the hypothesis of this research. Public health experts also claim to be already aware of this solution. However, it is not clear what the average distance would be in the general case, and how long it would take to change masks. These factors would therefore deserve to be examined more systematically. The main advantage of CoSiT over the WHO TTX tabletop simulation schemes is that it is user-centered, educational, interactive, participatory, general-purpose, and flexible, with a quick learning curve.

However, making this tool available through a web portal so that it can be accessed and used by all in contexts of their choice, remains a challenge because the GAMA technology we used does not yet allow it.

Therefore, we recommend that technologies for deploying simulation models in the Cloud (online) be explored more systematically to facilitate mass remote training and awareness in real-time when an epidemiological crisis occurs. This would allow everyone to be aware in time of the need to adopt certain measures and would also help policymakers and political actors in making timely decisions to save lives. This solution will also help public health organizations in their training and awareness campaigns in the fight against infectious diseases.

Availability of Materials

For materials request, please find material documentations and source code using Gama Platform by clicking HERE. A video of the implemented tool is available on the following LINK.

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