10th International Workshop on Innovative Simulation for Healthcare
18th International Multidisciplinary Modeling & Simulation Multiconference

ISSN 2724-0371 ISBN 978-88-85741-65-2 © 2021 The Authors.
doi: 10.46354/i3m.2021.iwish.014

Improving Operational Procedures to Access Industrial Facilities and Urban Areas during Pandemics

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Abstract

Management of population crowds and their access to critical infrastructures is crucial to effectively tackle incidents and avert undesirable situations derived from pandemics. To this end, modelling and simulation combined with serious games emerge as a proper tool to train current and future strategic engineers on this subject. Thus, we propose a simulation-based serious game to devise and improve operational procedures and regulations aimed at preventing access to urban areas and key facilities. The multi-platform application considers three different types of game to explore different situations and evaluate user's proposal to face complex situations. In addition, we are still working on improving user experience and upgrading game mechanics.

Keywords: Education and Training; Modelling and Simulation; Operational Procedures; MS2G, Pandemics

1. Introduction

While we are still dealing with Covid-19 pandemic effects, we must focus on acquiring as much knowledge as we can to anticipate and better face the next global crisis, if any. To this complex task we need data, which has been the great missing during this crisis, but also the proper tools to apprehend the significance of already available data so as to foresee risks and take decisions on them. Thus, decision makers must be thoroughly trained and skilled to cope with complex scenarios that may uncover unexpected consequences on and from people's behaviour. In fact, many perils are just around the corner and could be exposed rapidly and locally. Among others, TIM (Toxic Industrial Material) and TIC (Toxic Industrial Chemical) are currently stored in factories placed in towns and prompt a threat of such kind.

In line with this, we present here an innovative simulator devoted to assessing and improving operational procedures in critical situations aimed at managing population access and control to urban areas and industrial facilities. These critical situations mostly refer to Chemical, Biological, Radiological and Nuclear (CBRN) crises where urgent and efficient response is needed to prevent major casualties and avoid threats (Stolar, 2012). Preparedness is hence the key to tackle incidents and avert the disaster (Mossel et al., 2015).

Along with effective training and technology, regulations and behaviours are the base to these procedures and their implementation in real life. However, we need first to formulate bold hypotheses and test them in some way. Here comes the M2SG (Modelling, Interoperable Simulation and Serious

Games) paradigm (Bruzzone, 2018; Bruzzone et al., 2020a; Bruzzone and Matteo, 2018) that allows simulating them in order to decide whether they can be ameliorated on the grounds of their plausibility and effectiveness. This paradigm proposes the use of serious games based on simulation to leverage benefits from both games and simulations. In this way, we can integrate a immersive experience with engagement and competitiveness (Karshenas and Haber, 2012; Perrotta et al., 2013).

Therefore, the simulation-based game presented here has been developed on Unity3D and proposes the use of a 3D environment and game elements to immerse the user in a realistic world where operational procedures for CBRN crises are designed and assessed. The game involves also intelligent agents (Bruzzone et al., 2020a; Galvão et al., 2012) that simulate the behavior of people during pandemics by introducing unexpected events which user must face. His task would be setting adequate measures and devise strategies to face and make them work in his favor.

2. State-of-the-art

Modelling and simulation have become a widely used tool to comprehend and anticipate complex aspects of reality that otherwise would remain unnoticed. Regarding pandemics, the soaring interest is reflected by the extensive literature (Allen et al., 2008; Bruzzone et al., 2020b, 2020a; De Rooij et al., 2020; Dieckmann et al., 2020; Mao and Bian, 2011; Raybourn, 2014) although the approaches often differ according to the scope and objectives of the research. As of the occurrence of the A/H1N1 influenza outbreak in the spring 2009, the world has turned around to study the social, legal and economic effects that pandemics have all over the world (Araz et al., 2012; Perry, 2018). Out of it, we started to grasp the fact that a proper management of critical decisions may hinder the profound impact of pandemics, but it was not until 2019 with the arrival of COVID19 pandemic that we have fully realised how unprepared we were. To this end, we must focus now on developing proper tools and explore new paths that let us tackle future problems with more nimbleness and effectiveness.

In this sense, (Araz et al., 2012) propose a simulation model along with a tabletop exercise for decision makers to practicing policy implementations in emergency-response scenarios. They combine the interaction and dynamics of traditional tabletop games with the realism provided by the real-time effects of their decisions yielded by simulation models. They argue how multi-media technologies are useful tools to put trainees in decision-makers' shoes and increase their readiness for a pandemic.

Other interesting example of these tools is presented in (Bruzzone et al., 2019) where a virtual laboratory is created under the umbrella of ALACRES 2 project. It is devoted to addressing emergency management and safety in ports through the proposal of M&S (Modelling and Simulation) solutions to predict likely outcomes according to scenario initial conditions. In line with the simulator presented here, the laboratory attempts to identify, test, and validate emergency procedures in the event of crises such as Covid spread.

(Bruzzone et al., 2020a)(Bruzzone et al., 2020a) developed VESTIGE, an agent-based simulator to analyse and evaluate the impact of an epidemic on top of a system of systems (SoS) such as the one of a city. The simulator considers a variety of parameters like age, sex, education, or routines that feature and specify the behaviour of every agent in the model. It also considers the spatial circumstances of individuals as well as the initial conditions of the scenario at issue, that is, the weather, time and temperature. Eventually, is the interaction between them what generates the complex and realistic behaviour of the simulator and the unpredictable outcomes. In this sense, it is user's turn to comprehend and react to them by proposing containment measures like lockdown or suspension of mass gathering events and study their impact on the results.

All in all, (Bruzzone et al., 2014) propose the very combination of modelling and simulation and serious games to face strategic challenges by putting the stress in interoperability. And in fact, that approach is the one followed in the present study. They argue the importance of usability, friendliness on simulators, but also the need for using intelligent agents to achieve more complex behaviors (Bossomaier et al., 2009; Bruzzone et al., 2011; Mao and Bian, 2011). Through them we can get closer to reality and actual interactions while maintain usability and simplicity in the model. Should stochastic parameters be inserted in the model, then most probable scenarios can be investigated, and the serious game will always bring in uncharted paths, so learning is eventually enriched with the more runs the user performs.

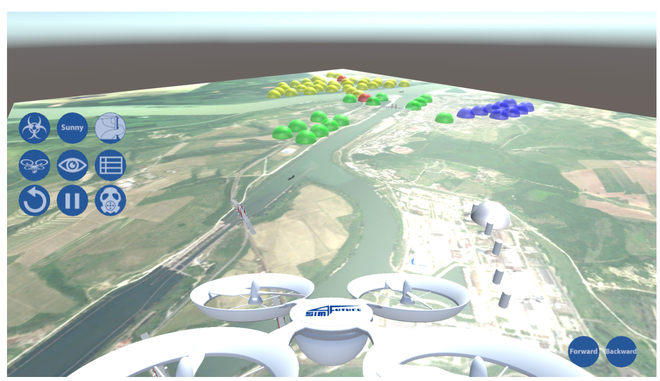

Figure 1. Overview of main scene.

3. Game General Description

The simulation-based serious game proposed in this paper has been fully developed on the videogame engine Unity3D by using OOP (Object-Oriented Programming) in C#. The game is multi-platform, so can be played on different devices, from computer to smartphone and VR (Virtual Reality) being the interface kept mostly equal in all of them. The choice of a videogame engine for its development responds to a twofold purpose: on the one hand, we want to guarantee a high level of interaction and yield immersive environment to ensure a fully realistic experience; on the other hand, we need maximum flexibility to implement new game modes and data input and output, either to consider new scenarios or assess user's performance. The modularity of game engines allows accommodation of these features, and they high degree of reusability greatly facilitates the development of new applications (Bijl and Boer, 2011).

Figure 1 illustrate the main view of the simulator, where user is presented an overview of a city map with several colourful bubbles that represent units' position range. Every colour refers to a different type of unit, and every unit reproduces specific entity behaviours through an agent-based approach. We can distinguish:

- Green Units. Containment forces in charge of providing healthcare support and decontamination services. They are the basic unit used to keep and hold those suspected of being infected.
- Blue Units: Police Forces that assist Containment ones in cordoning areas and containing infected units. They have limited capability to hold incoming flows of people but are able to move rapidly as they are equipped with cars and motor bikes.
- Grey Units: Military Forces that have a higher capacity to contain flocks of people, although they are slower than Police since they move around by truck. They become available only when user requests their service, which has a negative impact on final score. This way, he is encouraged to cope with the problem just by using normal units and thus optimizing the containment strategy and total cost.
- Yellow Units: Outside user's control, they represent crowds of people that are suspected of being infected but whose state cannot be confirmed. They can use different types of means of transport, so they velocity may vary. User may modify it to vary scenario difficulty but has still to anticipate their movement in order for them not to access the urban area.
- Red Units: Representing infected people, they main objective of the game is to prevent them from accessing the protected area by using all units under user's management. Otherwise, they will have a very negative impact on final score. They can spread the pandemic to other kind of units, including containment ones, so user must keep an eye on unexpected contagion events.
- Autonomous assets: Ships and drones that move around the scene and are in charge of conducting surveillance and reporting user periodically by informing about all unit's states. They have predefined behaviours that cannot be changed, although they may vary according to the difficulty level.

Aside from units, the game considers a set of general parameters that set up the scenario and which some of them may be modified by user:

- Scenario type: as main setting, the game considers four types of scenarios according CBRN perils, that is to say Chemical, Biological, Radiological and Nuclear, being pandemic included in the biological case. This setting has impact of available units, their behaviours and how contamination is spread throughout the urban area and industrial facilities.
- Weather: weather conditions influence speed of all units and accuracy of implemented measures, such as cordoning of areas. They user selects it at the beginning remaining fixed until the end of the run. They include snowy, rainy, foggy, and sunny choices.
- Terrain type: the considered terrain is heterogenous so that it considers from rivers and mountains to roads and countryside. These may affect unit's movement since they can be slowed down or blocked by such kind of elements.
- Area type: the scenario contains a set of critical infrastructures and areas that may be accessed from all kin of units. Apart from having a bearing on final score, the aim of placing them is to request the user full attention to guarantee their security and protect them from people's unexpected behaviour.

Along with all of them, the game considers another two major elements. On the one hand, scenario is based on a medium-size town, so population features different ethnics, cultural backgrounds, and ways of living. On the other hand, the division of the terrain into three main zones: the country border, an intermediate zone, and the urban area which includes the industrial plant (Figure 1). All three connected by bridges which define the only means to access these areas and therefore the critical access that must be monitored and controlled.

Regarding the infection spread, the algorithm evaluates every certain time the percentage of overlapping among infected units and any other force. Then, according to a probability defined beforehand, it calculates the likelihood of this unit to become infected. This probability depends also on the type of unit (protection elements) and transport means (exposure time). Thus, the unit may be infected turning red colour in that case.

Finally, as for the score function, the evaluation is based on several factors which are grouped into rewards (+) and penalties (-):

- Type of unit moved: Every time user makes use of a unit, he incurs a penalty as to the type of unit. For example, military ones are more costly.
- Meters moved: User incurs a penalty every time a unit is moved a meter, varying as to the type of unit.
- Infected and Suspected units' transport type: if units use faster transport means, then rewards are added since game difficult has been increased.
- Percentage of contained units: There is a reward per every infected unit that has been contained, depending on its overlapping surface percentage.
- Infected Units in Town and Industrial Facilities: If the user is not able to contain units and these surpass the sanitaire cordons achieving the town, then there is a substantial penalty added to the final score.

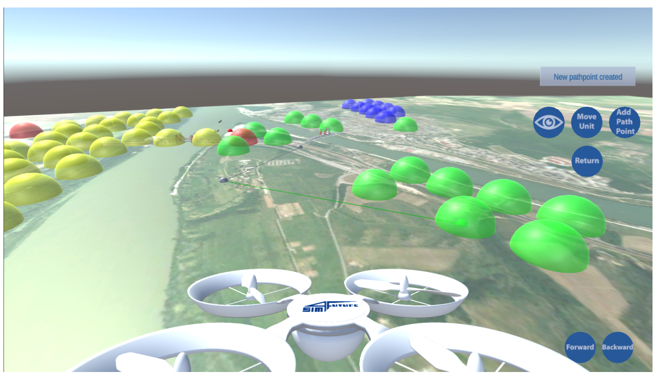

Figure 2. Path configuration of containment unit.

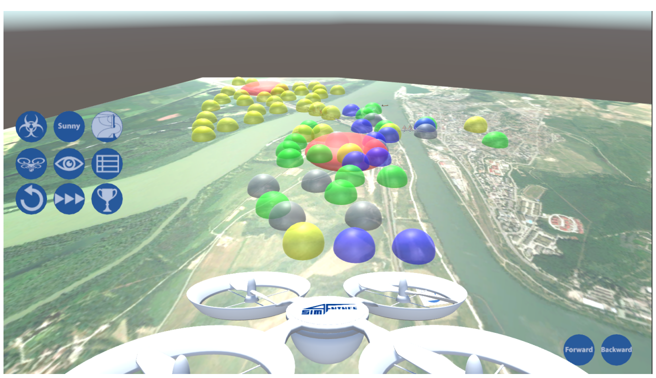

Figure 3. Spread Mode with infected unit range growing.

4. Game Modes

The game considers three game modes whereby user adopts different viewpoints:

- Free Mode: Visualization mode where user acts as a mere spectator and cannot modify scenario conditions. Its main objective is to serve as an introducing scene so the player can understand game main features and get acquainted with controllers and views.
  The mode runs predefined paths for every unit that are also embedded in next modes as base unit paths. We have carefully designed these path strategies so that they come to be a basic operational procedure whose final score is hard to be surpassed. Units path points are defined per time interval and in between motions are interpolated between them. Those can be modified from Unity editor in case of necessity.
- Competition Mode: Sets off on Free Mode basic strategies, but now user performs the designer role. He can select and modify units' paths and velocities (Figure 2), having so an impact on final score. The more units he uses and the longest the path, the higher the cost and hence the lower the score. To design adequate and smart strategies, he must understand properly antagonist units' (suspected and infected) on Free Mode. An important factor to take into account is the fact that units now follow an A* path finding algorithm, so different initial conditions lead to distinct outcomes. Units can be blocked by other units leaving margin to a small percentage of overlapping between them. A small pop up shows final score according to measures adopted.
- Spread Mode (Figure 3): The final mode is similar to the Competition Mode but now it is infected unit's range what increases, thus being now the approach different. The main insight here is understanding that we face a situation where infected unit's location can be blurry or unknown, so user must establish long *cordons sanitaire* to cover the area and contain the problem. In this case, the simulator calculates the overlapping area percentage between growing range and containment units' range and introduces some randomness to decide whether the situation has been handled properly.

5. Conclusions

The simulator-based serious game proposed is aimed at educating people on the development of operational procedures to face and control access to critical areas in case of critical situations prompted by pandemics. The fact that the simulator is presented as a game enrich the experience by means of engaging elements such as an immersive experience and high interaction.

As main insights gained, we foresee the potential of this kind of tools both in education and research, in particular as a decision-support tool in different fields that range from pandemics to contamination issues. We are still on working on improving user interaction and game modes to be more precise and reflect reality with higher accuracy. and reflect reality with higher accuracy.

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