A Multi-player Approach in Serious Games: Testing Pedestrian Fire Evacuation Scenarios

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Abstract. Serious Games are being increasingly used as a tool for various applications, including social simulation. One of the domains of application is fire safety training and behaviour elicitation. Injuries and fatal casualties having its origin from fires are a concern for fire safety engineers, building managers, and emergency responders. Training building occupants has been a challenge for quite some time. One approach is by classroom education or a more practical way by performing exercises, called fire drills. The former consists of a method for validating evacuation plans and tests what-if scenarios. Another important issue is the lack of human behaviour data; this aspect is often referred to as a drawback to evacuation simulator developers. The elicitation of behavioural knowledge to feed simulators constitutes a critical aspect for which some researchers have proposed the use of Serious Games. This paper addresses these issues in respect to: i) train escape procedures using Serious Games as an educational tool; ii) acquire valuable knowledge using the concept of participatory simulation. A test-bed using Serious Games, developed on the Unity3D framework, implements a multi-player approach taking advantage of its features. The experimental setup is presented and some test results are discussed. Future work is two-fold: expand and refine the scenarios for a wider set of possibilities; perform massive data collection that will be used to feed existing multi-agent evacuation simulators.

Keywords: serious games, fire safety education, evacuation, multi-player, behaviour analysis.

1 Introduction

Fire is considered to be the most dangerous hazard for building occupants [1]. Every year many casualties due to fire occur, some of them resulting in death. A recent example was the fire at the Brazilian discotheque "Kiss", January 27th 2013, resulting in death of 242 people, many of which college students. Such occurrences are many times due to the lack of information and training of the occupants as well as the emergency responders. So, training and education are the best solution to minimize the number of casualties that each year claim the lives of many around the world.

Although fire drills and classroom learning techniques are a possible way to teach fire safety, the use of Serious Game (SG) has been proposed as a good method for training and education [2]–[5]. Indeed, video games has fostered the implementation of SGs with diverse goals other than entertainment [6].

The use of Virtual Reality (VR) based applications for both simulate situations that are too dangerous for exposing real people to and as an aid for training and education is not new [7], [8]. SGs are a good trade-off compromise for the development and rapid prototyping of low-cost VR applications [9]. Unity3D is a successful platform used worldwide for the development of video games presenting high quality graphics, animation and VR features [10].

Another issue is the study of the self-organizing processes associated with building occupants when facing an emergency and having to abandon it, of great importance to assess the safety of the building, pre-defining possible scenarios, and to implement emergency evacuation plans. To help researchers and designers, computer evacuation models were developed for testing what-if scenarios. Most of these evacuation simulators are agent-based. For the intelligent agent behaviour modelling, there is a urgent need of real data to validate and calibrate such models [11].

Our team has been developing SGs aiming to train occupants for the evacuation procedures out of a building facing the presence of fire or other hazardous situations, for some time and having some experiments with good results. For this purpose, we have devised a framework coined Simulation of Pedestrians and Elicitation of their Emergent Dynamics (SPEED) for the elicitation of human behaviour in emergency situations. This framework consists of a methodological approach aiming at the elicitation of human behaviour in hazardous situations, and the use of the collected data to breed and grow an artificial society [12].

One important aspect of the SPEED development consists in having participatory simulation, in which some players interact in the same virtual environment. Taking advantage of the multi-player feature of Unity3D, we envisage a test-bed in which players share the same scenario, having to leave as quickly as possible, as soon as the fire alarm sounds. The experimental setup described in this paper aims to train and educate the players in evacuation techniques as well as elicit their behaviour when facing the urgent need of evacuation from a building.

For the sake of demonstration, we setup a scenario consisting of an auditorium, which has been used in previous experiments, this time using various players simultaneously sharing the same web-based application developed under the Unity3D framework. The final goal is to understand how subjects behave and try to extrapolate their emergent behaviour for fire safety planners and engineers as well as pedestrian evacuation modellers.

The remainder of this paper is organised as follows. Section 2 presents some background and related work in the field of fire safety evacuation techniques, SG and VR, behaviour elicitation and participatory simulation. Section 3 is used to introduce the implementation, whereas Section 4 the experimental setup. Section 5 discusses results from the experiments and tasks to accomplish such a realization. Finally some conclusions are drawn and future works, as well as developments are presented in Section 6.

2 Background and Related Work

Before moving further on the explanation of the experimental setup and the results obtained, it is important to introduce some valuable concepts and subjects underlying this project.

Fire safety training and education

The domain of fire safety is utterly dependent on the human behaviour, both in its origin as well as during its development [13]. Particularly the evacuation process in which occupants must leave whatever activities they are engaged to move as quickly as possible towards the safest and nearest exit. It is commonly noted that the human behaviour is of paramount importance for the outcome of such process [14]–[17].

To train and educate building occupants it is usual to perform evacuation exercises also called fire drills.

Fire drills and building evacuation

Fire drills are mandatory in many countries. They are performed to test emergency plans but also to educate building occupants in fire escape procedures. Teaching fire safety skills is an important issue to diminish the number of casualties and increase the level of safety.

Serious Games are a powerful tool to catch the attention of the participants, who otherwise would consider those exercises fastidious and boring, only carried out if forced by some disciplinary obligation (professional, academic or to avoid some kind of penalty). Also, the fire drill or emergency scenario can be more realistic without creating situations of danger to the trainees or building occupants. Data stored by the computational tool can also be used for statistic purposes, or to validate and calibrate computer models.

The Serious Games Concept

Serious Games has gained a great prominence in the field of Digital Games within the last years, by using high-definition graphics and state-of-the-art appealing animation software [18]. It presents a great potential as a tool to be used for other purposes rather than mere entertainment. Applications have a wide range of domains, naturally including social simulation, where data collection of player attitudes can be later used for statistical analysis, and behavioural pattern recognition.

Contrary to the primary purpose of entertainment in traditional digital games, SGs are designed with a more serious purpose with respect to the outcomes reflected in changes to the player behaviour [19].

A game is an artificially constructed, competitive activity with a specific goal, a set of rules and constraints that is located in a specific context [20]. SGs refer to video games whose application is focused on supporting activities such as education, training, health, advertising, or social change. Freitas [21] has identified a set of benefits from combining SGs with other training activities: i) the learners' motivation is elevated; ii) completion rates are higher; iii) possibility of accepting new learners; iv) possibility of creating collaborative activities; v) learn through doing and acquiring experience.

Other aspects that draw video game players' attention are fantasy elements, challenging situations and the ability to keep them curious about the outcomes of their possible actions [22].

Using Unity3D and Photon Unity Network to implement the Serious Games

The SGs used as example in this research was created using the Unity3D game engine. Unity3D was selected due to its main characteristics: i) powerful graphical interface that allows visual object placement and property changing in runtime (especially useful to rapidly create new scenarios from existing models and assets and quick tweaking of script variables); ii) the ability to develop code in JavaScript, C# or Boo; iii) simple project deployment for multiple platforms including the Web, which makes it possible to run the game on a Web browser, a feature that is particularly interesting for massive data collection. This last aspect is something that we aim to explore in a near future.

The Photon Unity Network framework was used to implement the network component of the game, making the multiplayer implementation much easier as the server is already setup.

Multi-player

Multi-player is a game mode concept in which it is possible for two or more players to play in the same game at the same time. Classically it is used for cooperatively play (team-based games), or head-to-head competition (famously known as deathmatch). There are usually two modes: split screen in which the users play on the same system and share the screen, or via a Network, which can be local (LAN) or on the web via game servers.

3 Implementation

The implementation of the Serious Game, coined EVA[23], was made using the web-based deployment version of Unity3D. For the multi-player game mode, we used the Photon Unity Network (PUN) which creates a set of "rooms" where the players are connected (see Fig.1) via a network, either local (LAN) or over the Internet, through game servers. Fig.2 shows a screenshot of one experiment with more than one player.

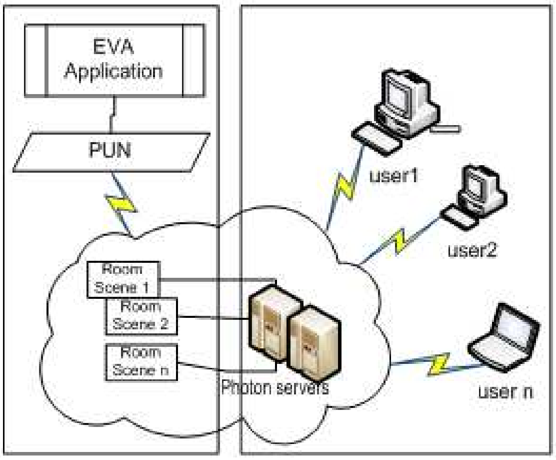


Fig. 1: Implementation architecture

4 Experimental Setup

The Office Room Scene

Fig. 2: Screenshot of Experiment 1 with two players in action simultaneously

This scene consists in subjecting the users to five different case scenarios. Each scenario took place in a virtual office room with the real time interaction of various players. The experiment starts when the player is spawned in the office room and starts hearing a fire alarm. Each player has then to find the exit of the building; however, each scenario had small differences that made each case special.

First scenario

In this scenario, after getting to the door of the office, the user cannot see any emergency exit sign that indicates which direction to take (left or right). The results obtained can shed a light on how people react in these types of situations which lacks any emergency signs is pointing out the right direction (see Fig.3 left).

Fig. 3: Screenshot of a case scenario with no emergency exit signal (left); and with the emergency sign pointing to the left (right).

Second scenario

This time around there is an emergency sign that indicates the user to take the left to get to the emergency exit. This scenario has the objective of studying the level of attention that people have in panic situations (see Fig.3 right).

Third scenario

The third scenario was designed to study the risk factor of the users, meaning that we wanted to analyse what would happen when the users see that the emergency sign communicates that to get to the exit the left path must be taken, but said path is blocked by a cloud of smoke (see Fig.4 left).

Fig. 4: Scenario with a cloud of smoke blocking the exit (left) and a fire (right).

Fourth scenario

This scenario is very similar to the previous one. The objective here is to study what is the user reaction when faced with a dangerous situation. In this case, when confronted with a wall of fire blocking the path to the exit indicated by the emergency sign. This scenario illustrates a case that is simpler to test virtually rather than in the real world (see Fig.4 right).

Fifth scenario

In the final scenario of the first experiment, crowd influence was tested. The user sees that despite the emergency sign depicting the exit to the left, there is a crowd of people running to the right (see Fig.5).

Fig. 5: Scenario with a crowd running in the opposite direction of the emergency exit sign

The cinema auditorium scene

In this scenario, as with the office room scene, we want to study how the interaction between players influences the choice for an emergency exit. However, as this scenario presents itself with a lot more space, we can run the experiments with a larger number of players at the same time. The experiment starts when a player is connected to a multiplayer session, then the player is placed in front of a random chair in the cinema auditorium. A fire alarm is then heard and the player has to find a way out. There are two exit points, the emergency exit, located near the movie screen and the auditorium's entrance where moviegoers enter the room (as we can see in Fig. 6 and 7).

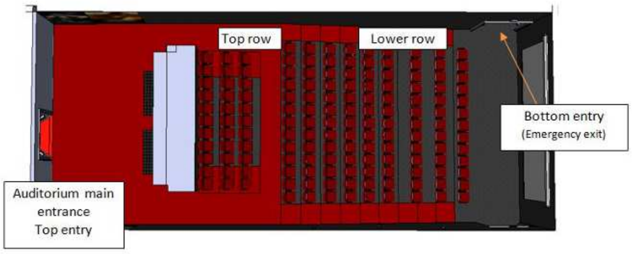


Fig. 6: Screenshot of a schematic representation of the cinema's auditorium

As with any other common cinema auditorium, it is characterised by a certain inclination and steps of stairs, which may cause difficulties in the evacuation process.

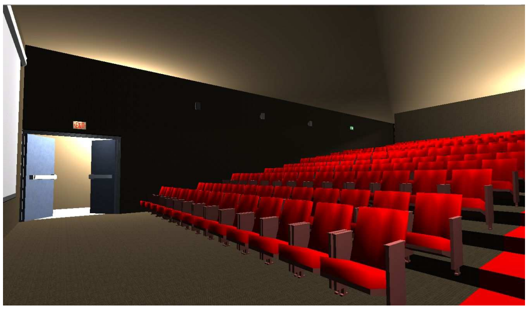


Fig. 7: Another perspective of the auditorium.

The game genre: First Person Player

First Person Players (FPP) are characterised by placing players in a 3D virtual world which is seen through the eyes of an avatar. When playing, user has the feeling of being actually on the location site, moving around, and giving the best possible sensation of immersion.

The controls for the SG presented to the children follow the common standards for the FPS genre, using a combination of keyboard and mouse to move the character around the environment.

5 Data collected and results analysis

In a previous experiment, a group of 19 children from a local elementary school were selected to play the SG. Their main characteristics are presented in **Table 1**. All of them were used to interact with computers, tablets and video games. In fact, almost all said having at least one game console at home (e.g. Playstation, PSP, Nintendo, Wii).

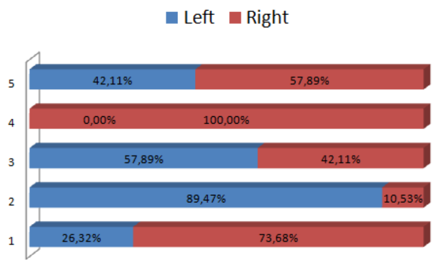
Table 1. Population sample's characteristics.

Data	Values
Number of subjects	19 (100%)
Male subjects	9 (47%)
Female subjects	10 (53%)
Mean age	7,58
Age SD	0,96
Left-handed	4 (21%)
1st Grade	2 (11%)
2nd Grade	8 (42%)
3rd Grade	3 (16%)
4th Grade	5 (26%)

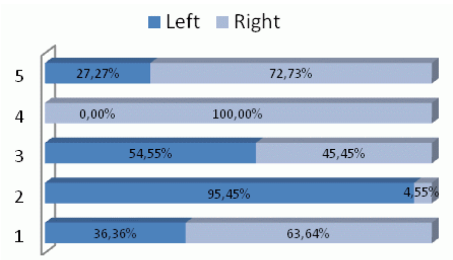
Preliminary results from the experiments

Most subjects prefer the keyboard+mouse combination (15 – 79%) instead of the joystick (3 – 16%). It was noted that the youngest children (6 or 7 years old) attending the 1st or 2nd grade, had more difficulties to understand the SG concept and to interact with it. The children of the 3rd and 4th grades were more comfortable with the computer commands and the SG aim.

The exit-choice scenario was probably the more challenging of the two role plays and the one that kids enjoyed the most. Only two failed to see the emergency sign pointing left; they confessed that were not aware of its meaning. These were the youngest (7 years old) so it is understandable their lack of knowledge.



a)



b)

Fig. 8: a) results in percentage for each exit-choice test scene; b) results of a similar test with a population of adults

Fig.8a) shows the results in percentage of the exit-choice test scenario for the children. Fig.8b) shows results from a similar test with a population sample of adults. Comparing both graphs, it is clear that the results are very similar. Only in scene 5, testing the tendency of following others, we realize that kids are more prone to follow the exit sign (42.11%) than adults (27.27%). Perhaps this fact is due to children are better educated to obey rules than adults. Analytical results are shown in Table 2.

Table 2. Results from the exit-choice scenario.

Scene	Left	Right
1. Tendency to turn left / right	5	14
2.Tendency to follow emergency signs	17	2
3.Tendency to go through smoke	11	8
4.Tendency to go through fire	0	19
5.Tendency to follow others	8	11

Expected results

One of the purposes of this multi-player approach is to analyse and to compare the results with the data collected with the single player version. Added to this, it is expected to extrapolate some players' behaviours when they know they are not alone in the simulation.

So far we have prepared two role play multi-player scenarios for which some experiments can be made in the future, for the purpose of social simulation research.

6 Conclusions and future work

This paper presented the use of SGs to acquire human behaviour when facing the urgent need of evacuating from an unknown building and having to deal with a set of unexpected situations and obstacles. A novel aspect consisted in the implementation of a multi-player component allowing the study of the interaction between players. Results are promising and extremely valuable for fire safety practitioners as well as for evacuation modellers, since data on human behaviour is scarce and much sought-after, particularly for specific groups such as children, elderly or people with disabilities. The knowledge elicited using this methodology might be used by evacuation simulators when trying to model situations.

This method has proved to be useful for data collection as well as training. The subjects that participated in previous experiments, at the end, were taught how they should behave in a real situation, and we are confident that the lessons learned will be hardly forgotten. After the tests, they showed a new confidence and knowledge in fire safety. The multi-player feature, although implemented, was not fully tested at the time of the writing of this paper, due to time constraints and the lack of sufficient concurrent players to test the scenarios. This aspect will be pursued in the future.

Collecting information from the multi-player version of EVA will be the next step of this research. For that, a certain number of users must be chosen as well as observers to collect the data. The massive data collection process using the multi-player feature developed and presented in this paper will allow us to compare them with results obtained from the single player version of the application.

During the course of the implementation of the multi-player framework, new and interesting features and scenarios arose, that are proposed as future work:

- Having different non-playable characters (NPCs) in the scene, each representing different roles. For instance, having people with disabilities, children and the elderly should cause different reactions on the players. For example, what would the player do if an elderly is passed out on the floor?
- Communication between players would elevate the player interaction even more, bringing the simulation even closer to the real world. However, restrictions would have to be placed so that players could only communicate with others only in a certain range around them.
- The implementation of a visual identifier, such as the players' name above the player's head, for example, would allow the testing of situations in which people tend to follow others they know.
- Registering the amount of time the player has been subjected to smoke (reducing visibility) and even fire, would make the simulation closer to the real world. Dying states and animations would be implemented to show that the user failed to escape. This situation would hopefully cause more stress to the individuals being tested, as it happens in real life.
- Currently the player only moves by walking. By implementing a running feature, this could become a limited resource in the simulation, meaning that the player would become tired over time.
- Implementation of a virtual player, whose objective would be to record the game session, making the data analysis much more efficient.

This work has given us the opportunity to use a complex framework for game development, expand an existing application under development at LIACC, the EVA evacuation simulator, by providing the multi-player capability which will permit new scenarios and data collection opportunities.

The ultimate goal of this research is to provide fire safety engineers and building managers with a tool for training and educating fire safety skills, as well as to grant researchers a means for human behaviour elicitation.

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