A Serious Game for EVAcuation Training

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Abstract—Serious Games are increasingly used as a training and educational tool. Fire keeps claiming a high number of victims. Some authors allege failures during the evacuation process as the main cause that contributes for that number. Fire drills are used to train buildings' occupants for emergency situations. However, fire drills' participants often have prior knowledge of their schedule and as result they are not as focused as they should. Moreover, fire drills require the mobilization of some resources, leading to financial costs. Performing a fire drill will always affect the normal functioning of the place where they take place; for this reason, sometimes they are not performed at all. In some special locations, like hospitals, fire drills are unsuitable. Emergency planning is crucial to prevent and minimize damage and victims. Albeit the improvement on safety measures, many occupants and employers in this type of buildings still lack adequate knowledge and training on how to behave in such hazardous situations. EVA is presented as a possible solution, which is based on the concept of Serious Game that can be used as a training tool for healthcare professionals. A preliminary prototype was developed. A sample of 20 subjects was selected to test it giving promising results. Results also showed that users who had training in fire prevention appear to perform better in the course. Moreover, participants who regularly play computer games overcame easily the game challenges. Further research and development are still to be explored, which are discussed in the concluding part of this paper.

Keywords—Serious Games, Evacuation, Emergency Planning, Building evaluation, Egress.

I. INTRODUCTION

Fire in buildings is always a dramatic situation! Besides the high costs in material damages, it is the effects on the inhabitants that have the major impact [1]. Many fires in complex environments such as healthcare buildings have occurred in recent years, with the correspondent cost of lives; to illustrate the importance of this study, especially on the basis of life costs, some values are presented in Table 1.

To prevent and minimize such hazardous situations, if life costs cannot be avoided at all, planning and education is imperative. Emergency Plans deal with this issue. Fire safety engineers and technicians prepare for each scenario the correspondent actions. These safety measures are patented in the Emergency Plan of the site. To assure the best strategic and tactic plans to deal with the array of possible threats that might arise, such as gas leak, bomb menace, flooding, explosion, and fire, everyone having responsibilities will be asked for their input and must be prepared to react accordingly to the level of emergency. And when the document is ready to be promulgated, public sessions to inform all the professionals that are normally in the building should be taken. At last, fire drills will be performed to evaluate the adequacy of the measures, theoretically devised in the Emergency Plan.

TABLE I MAJOR HOSPITAL FIRES

<table>
<thead>
<tr>
<th>Year</th>
<th>Hospital</th>
<th>Location</th>
<th>Victims</th>
</tr>
</thead>
<tbody>
<tr>
<td>1942</td>
<td>Seaciff Mental Hosp</td>
<td>New Zealand</td>
<td>37 dead</td>
</tr>
<tr>
<td>1950</td>
<td>Iowa, Mercy Hosp</td>
<td>USA</td>
<td>41 dead</td>
</tr>
<tr>
<td>1960</td>
<td>Mental Hosp</td>
<td>Guatemala</td>
<td>235 dead</td>
</tr>
<tr>
<td>1971</td>
<td>Psychiatric Clinic</td>
<td>Switzerland</td>
<td>28 dead</td>
</tr>
<tr>
<td>1994</td>
<td>Southside Regional Med Center, Virginia</td>
<td>USA</td>
<td>4 dead; 3 injured</td>
</tr>
<tr>
<td>1998</td>
<td>Manila Hospital</td>
<td>Philippine</td>
<td>22 dead</td>
</tr>
<tr>
<td>1999</td>
<td>Leningrad Oblast Hosp</td>
<td>Russia</td>
<td>21 dead</td>
</tr>
<tr>
<td>2000</td>
<td>Peking Union Med College Hospital</td>
<td>China</td>
<td>3 dead; 6 injured</td>
</tr>
<tr>
<td>2003</td>
<td>Mental Hospital, Randilovshchina</td>
<td>Belarus</td>
<td>30 dead; 31 injured</td>
</tr>
<tr>
<td>2005</td>
<td>Calderon Guardia Hospital</td>
<td>Costa Rica</td>
<td>18 dead</td>
</tr>
<tr>
<td>2006</td>
<td>Yuanping</td>
<td>China</td>
<td>27 dead</td>
</tr>
<tr>
<td>2006</td>
<td>Hospital No. 17, Moscow</td>
<td>Russia</td>
<td>45 dead; 10 injured</td>
</tr>
</tbody>
</table>

However, fire drills are hardly capable of recreating the truly panic conditions and people tend to take it not as seriously into account. Even when they are carefully planned, as shown in Fig.1, a fire drill may not impose all necessary emotional stress on participants allowing planners to identify drawbacks and issues to be addressed so they could improve certain measures.

Fig. 1 Example of a fire drill in the Operating Room of a major Hospital.
One possible solution is to use Serious Games (SGs), an affordable and easy way to simulate different scenarios and to train the professionals’ behaviour. This work mainly relies upon the ability of a SG to involve and immerse the participant in a rather committed manner, as players are usually eager to improve their own performance as the game evolves. We propose a SG-based platform to train and evaluate health personnel’s behaviour in hazardous situations, such as fire.

After this introduction and motivation to the main topic of this research, the remainder of this paper is organised as follows. Section 2 presents some background and related work in the field of Serious Games. Section 3 is used to introduce the proposed SG to train health professionals to handle emergency situations, such as fire events forcing building evacuation, appropriately; this platform was coined EVA. In Section 4, the experimental setup and some results are presented. We finally draw some conclusions and point out future work and developments in Section 5.

II. BACKGROUND AND RELATED WORK

A. Serious Games

The growing interest in the use of games and simulations to support learning is evidenced in the literature, and in recent research projects and initiatives [2].

The term Serious Games as we know today, was first presented long before the introduction of computer and electronic devices to entertainment. In 1970, Clark C. Abt [3] introduced this term of SG with a very close definition to the one we use today, emphasising its ability to have other purposes than entertainment.

Using games for serious ends is not a new idea. Military have been using games in order to train strategic skills for a long time. They called it “war games”. Riegsspiel, from the German word for war game, was a system used for training officers in the Prussian army. The first set of rules was created in 1812 and named Instructions for the Representation of Tactical Maneuvres under the Guise of a Wargame. It was originally produced and developed further by Lieutenant Georg Leopold von Reiswitz and his son Georg Heinrich Rudolf von Reiswitz of the Prussian Army [4].

In general terms, SGs are associated with games for purposes other than entertainment [5]. The major difference between regular video games and serious games is that the latter have education as a primary goal whereas the former focus on entertainment mainly.

Despite this fundamental difference, however, even video games are designed for nothing more serious than mindless entertainment has a learning objective, at least in the beginning: to teach the player how to play the game! These games also implement pass/fail mechanisms no less rigorous than many college entrance exams. This may come as a surprise to many game developers [6].

Christian Loh et al. suggest that games can be used for the rationale for quantitative analysis in games, as well as a method to collect in situ game data for that purpose, using a new design framework known as “Information Trails.” This approach made use of gamers’ actions within the game as the basis for assessment of their learning [7].

B. Evacuation Simulators

Evacuation Simulators are used mainly to test the safety conditions of buildings, concerning the evacuation scenario when some sort of emergency requires that all occupants leave the building as quickly as possible. Parameters include the number and width of exits and stairs, number of occupants and their physical characteristics, such as speed, ability to find the nearest exit, panic behaviour and so forth.

There are several dozens of evacuation simulators [8]. Some of them are the result of academic work, with no support, and most frequently they are not available. A few models are free to the public, such as EVACNET or FDS+EVAC. Others were developed for commercial use (e.g. Pathfinder, Steps, and Simulex) and are available at a considerable cost or on a consultancy basis, where the development company will use it by their own experts [9] and retain the property of the framework. In this latter situation, only the results are provided to the user. The output of these simulators is often used to write a report evaluating and discussing the results, pointing out major drawbacks and suggesting immediate actions to overcome them. Contingency plans can also be considered whenever no corrective measures seem to be available.

One alternative approach for creating the new-generation evacuation simulators is by using the agent-based NetLogo simulation framework with interesting possibilities [14].

C. Use of Serious Games for Evacuation Simulation

Games and simulators can be used for cheaper training rather than using traditional methods. Flight simulators, for instance, do not replace actual flying, but are commonly used for training pilots to react accordingly in certain situations that are hard to reproduce in real life, such as emergency landing. Besides, pilots can practice and gain mileage and these systems are also used to endorse the issuing of flying permits [10].

Imagine now a health care building: a hospital, medical clinic, and psychiatric institution. If users were subjected to simulated scenarios, featuring characteristics of Serious Games, they would be expected to behave in a rather collaborative way, exposing their natural will to maximise their experience in the game (i.e. by gathering as many points as possible). Therefore, being repeatedly subjected to systems such as that will certainly influence individual behaviour in longer term, resulting in quicker reactive responses whenever someone is facing emergency situation in real life.

The use of such tools could possibly save lives by training individuals with simulated scenarios towards the improvement of fire safety consciousness and enhancement of emergency plans. The emotion feelings that a game provide seems to be realistic for the player [11].

This idea is not new. Situations that can hardly be reproduced due to their complexity and exceptionality can be simulated; thus Serious Games can be used to train people and
test strategies. Nagel et al. [12] proposed the use of Serious Games for preparing a scenario of mass evacuation in the situation of a severe flooding. This has happened before in the Netherlands and a group of experts was formed to devise solutions to address that huge problem, helping the government to prepare contingency plans.

One implementation addressing the aforementioned issues, using the First-Person-Shooter (FPS) game genre, has been tested in our laboratory [13] showing promising results. FPS are characterised by placing players in a 3D virtual world, which is seen through the eyes of an avatar. This attempts to recreate the experience of the user being physically there and exploring their surroundings. When playing, user has the feeling of being actually on site, moving around, and experiencing the best possible sensation of immersion.

III. EVA: SERIOUS GAMES FOR EVACUATION TRAINING

To accomplish the mentioned above goal, i.e. to simulate the evacuation scenario as realistic as possible, and use this tool for training, we implemented a Serious Games prototype using Unity3D, which was coined EVA. This name derives from the three initial letters of evacuation. It also relates with the first woman known, Eve (that is Eva in Latin languages, such as in Portuguese). This name was chosen to stress the originality and pioneering approach to use SGs for training emergency procedures in healthcare environments.

Unity3D is a successful platform used worldwide for the development of video games, with appealing graphics, in which we can use the FPS game genre.

The setup scenario was built using Autodesk’s Revit. This situation is expected to resemble an important albeit simple task, very common in environments such as hospitals and other healthcare buildings.

The 3D model was converted into the Unity3D framework, and some furniture was added to give a more realistic, almost photo-quality, ambient. Then, a character using the FPS was created.

The player has to navigate the game character through pathways until reaching the outside where she is safe. Our aim is to reproduce a recurrent situation when a staff member is steering a patient in a wheelchair (Mr. Adam) to his ward. This situation is expected to resemble an important albeit simple task, very common in environments such as hospitals and other healthcare buildings.

When the game starts, the player is at location “E” (see Fig. 2), leaving the lift and pushing Mr. Adam’s wheelchair towards his ward at “F”. Suddenly, the fire alarm rings aloud. The player is asked then what should be done (Fig. 3). Possible answers include: a) nothing; probably it is a false alarm; b) wait if it is a real alarm, security personnel will give the alert; c) try to understand what is going on; d) leave the building as quickly as possible.

The option selected is saved for later analysis. Then, whatever the option selected, the player is instructed to leave the building as quickly as possible. At this time of the game, another important decision has to be made: will the player bring Mr. Adam or not? This is another option that will be recorded.

If the player chooses to steer Mr. Adam in his wheelchair towards the exit, when reaching a safe zone, such as a different fire compartment or protected emergency stairs, the total time since the beginning of the fire alarm until that point is registered, and the player is greeted for that achievement, in other words for having rescued Mr. Adam to a safe zone.

Finally, the player is urged to go as quickly as possible to the outside, which demands finding a route to exit the building.
Of course familiarity with the environment will effect the player’s planning for the best itinerary to the way out, as well as will her ability to find and follow exit signs. The game will end as soon as the player reaches a valid exit (Fig. 4), and the total evacuation time is recorded. The valid exits are shown in Fig. 2: (A) is the building main entrance; (B) is the back entrance or an access to back yard; (C) is the exit of the south wing emergency stair; and, (D) is the exit of the northwest emergency stair.

Before the player can actually leave the game, she is presented with a questionnaire including questions such as name, gender, age, occupation, whether she has ever been involved in a real-life fire situation, whether she had previous training in emergency evacuations, and whether she has ever participated in fire drills. This information is necessary to characterise the subject for further statistical analysis, as answers are saved into a database.

During the evacuation process, if the player tries to use the elevator, a warning message is shown (Fig. 5). This way, the player is also taught that during a fire alarm, elevators are not a valid means to exit the building, and stairs should be used instead. Following the same approach, many other safety issues and procedures can be easily translated into instructions popping up during the course of a game, so as to train, warn, and correct behaviours.

This way, the proposed solution in this paper represents a straightforward way to acquire human behaviour in emergency situations, and also to train procedures. It allows gathering information on the way occupants would react if such an event occurred, and also as an educational tool, to train the correct actions one should take or decisions one should make. The data gathered will provide useful insight into people’s behaviour and will also be an important decision-support tool for management and safety personnel to enforce and implement the emergency and evacuation plan.

IV. EXPERIMENTAL SETUP AND RESULT ANALYSIS

The controls for this game follow the common standards for the FPS genre, using a combination of the keyboard and a pointing device (e.g. a mouse) to move the player around the environment. Frequent players will very likely be familiar with such commands and feel comfortable using them quite soon, with no need for warm-ups before the game can actually start. The complete action mapping is as follows:

- **Mouse movement** - camera control, i.e. where the player is looking at;
- W - move forward;
- S - move backwards;
- A - move to the left;
- D - move to the right;
- F – open / close doors.

Most of the participants had no trouble in steering the game character, proving the chosen commands were appropriate and intuitive. Nevertheless, after a short period of wandering around the building, even subjects unfamiliar with digital games overcame those initial issues, and started controlling their character very satisfactorily.

A. Population Sample

To test the previously described prototype, we asked some volunteers to play the game. A total of 20 individuals participated in this experiment playing the EVA game. A considerable number of the subjects were students, and many of them used to play video games fairly regularly. For such players no special instructions were needed.

Some of the subjects were medicine students, quite used to the stressful environments of hospitals. There were also three nurses. For this particular group, this tool has an increased importance for they are aware of the typical daily reality at hospitals and can easily realise the problems arising should such an event, such as fire alarm, occurs.

The average age of the sample group is 24 years. The percentage of males is 45% against 55% of females. Thirteen are students, of which seven are medicine students. In this group 65% are frequent game players, including one
professional poker player. Although this sample is quite small to support strong arguments regarding behavioural issues, as well as to characterise professional profiles and skills of people working in healthcare-like environments, it served the purpose of demonstrating the ability of SGs to serve as an important tool for collecting data and training. A large sample would be necessary for us to implement robust inference methods and analyse data appropriately.

B. Results Analysis

Players’ behaviours were saved in a log data file. Values saved include: total evacuation time, Mr. Adam’s rescue time, the exit used by the player to leave the building, whether the elevator was used during the evacuation, and answers to the questions shown in Fig. 3.

The evacuation mean time to exit the building was 84.6 seconds. If we consider only players that are frequent gamers, this time drops to 63.6 seconds. Fig. 6 shows all evacuation times recorded for the 20 subjects. Two of the players took a lot longer to exit, due to their inability to use the game controls.

The answers to the questionnaire presented to the player after the fire alarm sounds (in Fig.3) were equally distributed, except for two players that chose option A (do nothing; probably it is a false alarm) and B (wait for security personnel instructions), with one person each; all the others selected either to “try to understand what is going on” or “leave the building as quick as possible”. In real-life situations, both are just as valid.

It is interesting to notice that most of the players decided to push Mr. Adam and rescue him, albeit three left him behind in the ward.

C. Players’ comments

Some of the participants were interviewed to report their experience and supply valuable contributions on how to improve the game. They also suggested ways in which the EVA framework could be used to train health care personnel.

One of the players, a medicine student, confessed that she did not follow the exit signs, and felt a lot stressed. But the most important fact to be noticed is that she acknowledged that she had never thought of such events, such as fire and of how to proceed then; she never realised that emergency signs are there to lead people to safe exits, and became conscious that if she were facing a real-life situation she would have a hard time and no clue on how to behave appropriately. This player was one of the six that neither had previous fire safety training nor had participated in a fire drill. Nonetheless, she realised that after playing the game she is more aware of how she should behave in such emergency situations.

Some comments regarding the game were made, pointing out improvements and new ways to increase the realms of the scenario. For instance, the game could be used to train the evacuation of wards, instructing players to move the beds with patients, from the fire zone to a safe place.

Additionally, it was pointed out that the use of a joystick could overcome problems some players experienced with using the keyboard and mouse to steer the game subject. Other interacting devices would certainly improve playability, as well.

V. Conclusions

This paper presents one experiment in which we explore the concept of serious games as an important asset to aid and improve traditional fire drills especially in complex environments such as hospitals and healthcare buildings. Our aim is not to completely replace or avoid the need for on-site drills to train people in emergency situations, such as with the prospect of fire, for instance. Nonetheless, game environments can be very attractive in many different ways, and have proven to be an invaluable tool for training. Additionally, we build our approach on the potential of such a concept to ease and leverage an improved understanding of human behaviour in such situations, as subjects are monitored during their playing the game and some performance measures are logged to allow further analysis. This has demonstrated that, besides a training tool, SGs can be used as an important instrument for behaviour elicitation, leveraging social experiments and simulation of situations hard to control and handle in real life.

Our prototype was implemented with Unity3D, a popular game engine, which provided us with a customisable framework and allowed us to extend it with features of a serious game platform into the virtual environment. We invited some subjects to use the game and collected some preliminary results that demonstrated the viability of our proposed approach. We have then conceived a methodology which is both instrumental as an aid to train people and an invaluable asset at practitioners’ hand to evaluate and validate safety plans, as managers get better understand of users’ behaviour and how to improve their attitude in face of emergencies.

The very next steps in this research include the improvement of the prototype, with the inclusion of more
scenarios and buildings to carry out more tests with an increasing number of subjects and varying situations. We also intend to include other performance measures to study individual and social behaviour; in this particular case, a multi-player version of our game will foster collective behaviour analysis and give us better insight into social aspects and interactions involved whenever crowds are forced to evacuate under elevated anguish and emotional distress. Ultimately, this tool is also expected to be used as an imperative decision support tool, providing necessary and additional insights into evacuation plans, building layouts, and other design criteria to enhance buildings with such a critical use and with many vulnerable occupants as are hospitals.

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