

Gamifying Evacuation Drills

José Fernando Silva¹, João Emílio Almeida^{1†}, Rosaldo J. F. Rossetti^{1†}, António Leça Coelho²

¹Department of Informatics Engineering

[†]LIACC – Laboratory of Artificial Intelligence and Computer Science

Faculty of Engineering, University of Porto

Rua Roberto Frias, S/N, 4200-465, Porto, Portugal

{ei06123, joao.emilio.almeida, rossetti}@fe.up.pt

²LNEC – National Laboratory of Civil Engineering

Av. Brasil, 101, 1700-066, Lisboa, Portugal

alcoelho@lneec.pt

Abstract— Serious Games have fostered the training methods and are increasingly used for such purposes. A fire in a public building, such as a hospital, care centre or clinic, is by any point of view a dramatic event. Emergency planning is crucial to prevent and minimize damage and victims. Despite 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 Games that can be used as a training tool by safety professionals. A preliminary prototype was developed and some tests were carried out, providing further insights into the human behaviour understanding and presenting promising results. 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; evacuation training; drills.

I. INTRODUCTION

Fire is considered the most dangerous hazard for the occupants of any building. In addition to the high costs in material damages, it is the effects on the inhabitants that have the major impact [1]. Fire has destroyed entire cities throughout history. Some famous examples of total or partial cities destruction are: Rome (Nero fire in 64), London (in years 1135, 1212 and 1666), Lisbon (major earthquake followed by tsunami in 1755), Copenhagen (1795), New York City (1776, 1835), Turku in Finland (1827), Toronto (1849, 1904), Chicago (1871), Boston (1872), San Francisco (1906, earthquake), Thessaloniki in Greece (1917), Tokyo (1923, earthquake followed by tsunami) and Santander (1941). In recent years, after 1900, a great number of victims in building fires took place; some examples are referred in Table 1.

To prevent and minimize such hazardous situations, if fire and terrorist attacks cannot be avoided at all, planning and education is imperative. Emergency Plans deal with this issue. Fire safety engineers and technicians study and implement actions to minimize the number of victims. These safety measures are explicitly presented in Emergency Plans. Occupants of any building must be aware of such plans and be prepared to deal with the array of possible threats that might

arise, such as gas leak, bomb menace, flooding, explosion, and fire. In the same way, emergency responders and building managers must be prepared to react accordingly to the level of emergency. Additionally, fire drills should be performed periodically to evaluate the adequacy of the measures, and to train the subjects that are related to the Emergency Plan.~

TABLE I

EXAMPLES OF MAJOR FIRES AND VICTIMS (XX AND XXI CENTURIES)

Year	Hospital	Location	Victims
1903	Iroquois theatre	Chicago, USA	600 dead
1908	Rhoads Opera	USA	170 dead
1972	Andraus building	S.Paulo, Brazil	16 dead 336 injured
1974	Joelma building	S.Paulo, Brazil	179 dead; 320 injured
1980	MGM Hotel	Las Vegas, USA	85 dead; 770 injured
1988	Chiado,	Lisbon, Portugal	2 dead; 70 injured
2001	World Trade Center	New York, USA	2,749 dead
2003	The Station nightclub	Rhode Island, USA	100 dead
2013	Kiss discotheque	Brazil	230 dead; 160 injured

However, fire drills are hardly capable of recreating the truly panic conditions and people tend to take them not as seriously. Even when carefully planned, 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.

One possible solution to address the aforementioned issues, namely the difficulty of executing the mandatory and periodic Fire Drills, is to use Serious Games (SGs), an affordable and easy way to simulate different scenarios and to train both professionals' and occupants' behaviour. The proposed approach relies on 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. In this work a SG-based platform to train and

evaluate health personnel's behaviour in hazardous situations such as fire is presented.

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 SGs. Section 3 is used to introduce the proposed serious game to train professionals for emergency situations, such as fire, forcing building evacuation. In Section 4, the experimental set-up and some results are presented. We finally draw some conclusions and point out future work and further 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 as well as initiatives [2].

The term Serious Games was first presented long before the introduction of computer and electronic devices to entertainment, in 1970, by Clarck C. Abt [3]. This term had a very close definition to the one we use today, emphasising on its ability to have purposes other 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 already, in the so-called "war games". Riegsspiel, from the German word for war game, was used for training officers in the Prussian army. The first set of rules was created in 1812. It was originally produced and developed further by Lieutenant Georg Leopold von Reisswitz and his son Georg Heinrich Rudolf von Reisswitz of the Prussian Army [4].

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

However, even video games are designed for nothing more serious than mindless entertainment. 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. 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.

There are many evacuation simulators [8, 14]. Some of them are the result of academic work, with no support, and most frequently they are not available to the general public. A few models are free to a restricted public, though. Others were

developed for commercial use 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 client. 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 important issue is the collection of pedestrian data to validate and calibrate the models used by evacuation simulators [13]. Indeed, validating behaviour models is a very complex task, to which very specific data is crucially important.

C. Use of Serious Games in 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].

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 emotional feelings that a game can provide are very 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, and 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 Nederland, and a group of experts was formed to devise solutions to address that huge problem, helping the government to prepare contingency plans.

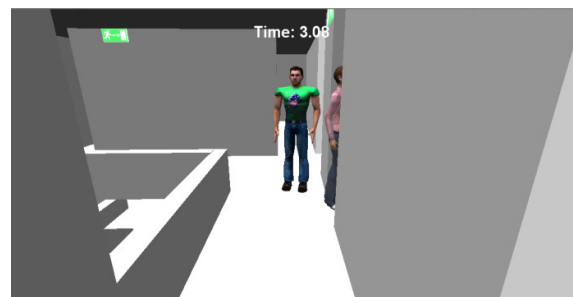


Fig. 1 ModP3D Serious Games evacuation simulator [15].

One implementation addressing the aforementioned issues, using the First Person Shooter (FPS) game genre, has been tested in our laboratory [15, 16] showing promising results (see Fig.1). 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, the user has the feeling of being actually on the location site, moving around, and experiencing the best possible sensation of immersion.

III. TRAINING EVACUATION USING SG

The EVA Serious Game is a prototype using Unity3D, developed to accomplish the aim explained before, i.e., to simulate the evacuation scenario as realistically as possible, allowing us to use this tool for training building occupants. It was named using the three initial letters of evacuation. It is also a reference to the first woman on Earth, Eve (that is *Eva* in Latin languages, such as in Portuguese). This name was chosen to emphasize the pioneering approach to use SGs for training emergency procedures.

As for Unity3D, it 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 set-up scenario was built using a large three-floor building imported from Autodesk's Revit. The 3D model was converted into the Unity3D game engine, and some furniture was added to increase the realms and give a more realistic, almost photo-quality, ambience. Then, a character using the FPS game genre was created. The scenario selected was to recreate a health care facility. For such a purpose, furniture resembling a ward was used.

The player has to navigate the game character through pathways until reaching the outside where they are safe. Our aim is to reproduce a recurrent situation when a staff member is steering a patient in a wheelchair to his ward.

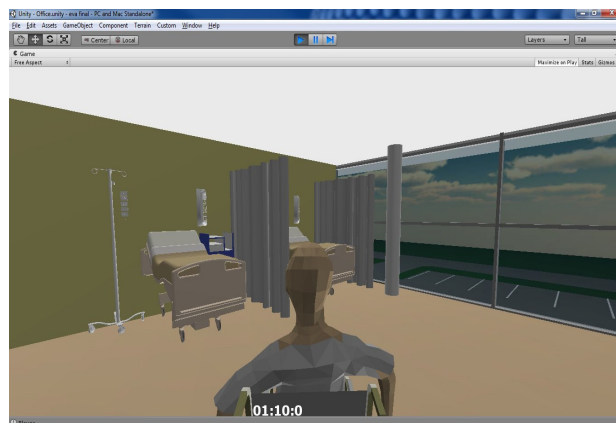


Fig. 2 Screen view of the implemented SG showing the building interiors.

When the game starts, the player is instructed to push the patient baptized Mr. Adam, in a wheelchair, towards his ward (see Fig. 2). The player has no idea of what will happen after that. Suddenly, the fire alarm bells start ringing. The player is asked what he should do in such a situation. Possible answers include: a) nothing; probably it is a false alarm; b) wait for

security personnel instructions; 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 decision has to be made: will the player bring Mr. Adam or not? This is another option that will be recorded.

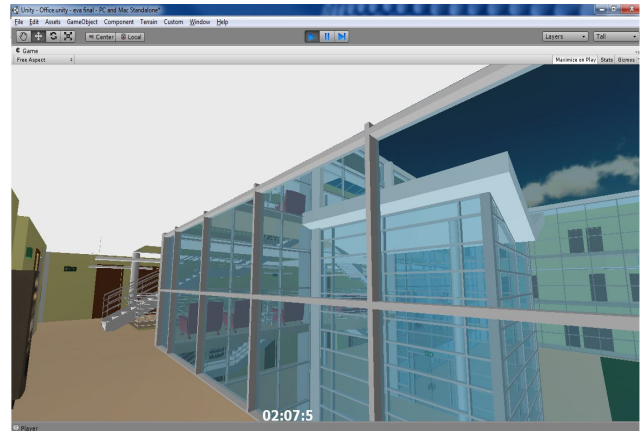


Fig. 3 The player has to find one of the exits of the building.

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 greeted for that achievement, that is, for having rescued Mr. Adam to a safe zone.

Finally, the player is urged to go as quickly as possible to the outside and to find a route to exit the building (Fig. 3). The game will end as soon as the player reaches a valid exit. Total evacuation time is recorded.

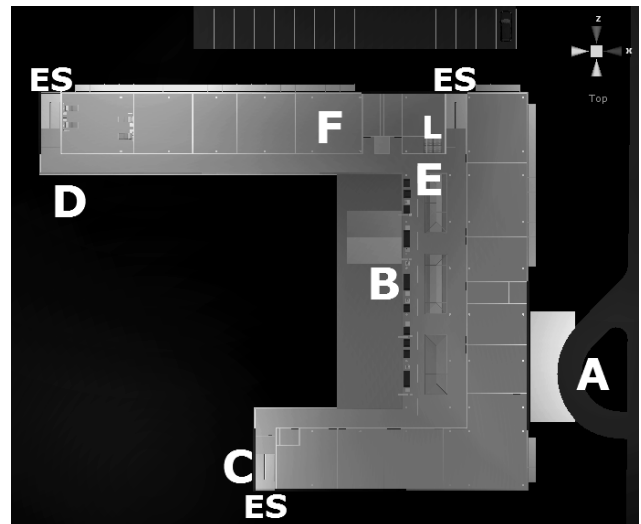


Fig. 4 Building lay-out: A-main entrance; B-back entrance; C-south wing exit; D-northwest exit; E-starting point; F-ward; L-lift; ES-emergency stair.

The valid exits are shown in Fig. 4: (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. The other important elements shown in the map are the Emergency Stairs (ES), the Lift (L), the starting point when the game starts (E) and Mr.Adam's ward (F).



Fig.5 One of the building exits.

The game ends when the player finds one safe exit of the building (see Fig.5). Then, a questionnaire is presented to the player with questions including name, gender, age, occupation, whether they have ever been into a real fire, whether they have previous training in emergency evacuations and participated in fire drills. These answers are necessary to characterise the subject for further statistical analysis.

Our aim with this tool is to have a straightforward way to acquire human behaviour in emergency situations, and also to train procedures. The players' behaviours are saved, for research purposes; it also can be used as an educational tool, to train the correct actions one should take.

IV. EXPERIMENTAL SETUP AND RESULT ANALYSIS

The controls for this game follow the common standards for the FPS genre, using a combination of keyboard and mouse to move the player around the environment. Frequent players will feel comfortable quite soon, with no need for warm-up before the game. 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 participants had no trouble in steering the game character, proving the chosen commands were appropriate. Nevertheless, after a short period of wandering around the building, even subjects unfamiliar with digital games overcome the initial issues, and started controlling their character very satisfactorily.

A. Population Sample

A total of 20 individuals participated in this experiment playing the EVA game. An important number of subjects were students, and many of these, used to play regularly video games. For these, no special instructions were needed.

Some of the subjects were medicine students, quite used to hospital environments. 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 imagine the problems arising should such an event, as a fire alarm, occur.

The average age of the sample group is 24 years. The percentage of males is 45% having 55% of females. Thirteen are students; of which seven are medicine students. In this group 65% are frequent game players.

B. Results Analysis

The players' behaviours were saved in a log data file. Values saved include: total evacuation time, Mr. Adam's rescue time, the exit the player used, whether the elevator was used during the evacuation, and the answer to the question after the alarm bell starts ringing.

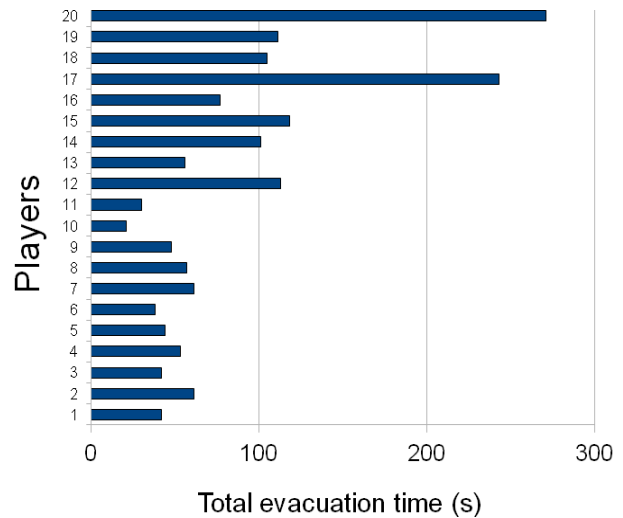


Fig.6 User times for each player

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 (see Table 2) were equally divided, except for two players that chose options a) and b) with one person each, all the others selected either option “c) try to understand what is going on” or “d) leave the building as quick as possible”. In a real situation, both would be acceptable. The interesting part of this questionnaire was to understand if players were prepared to react to such an unexpected event, because no one knew previously that the fire alarm was going to ring.

TABLE II

ANSWERS TO QUESTION POSED AFTER FIRE ALARM

Possible answers	Users' choice
a) nothing; probably it is a false alarm	1
b) wait for security personnel instructions	1
c) try to understand what is going on	9
d) leave the building as quickly as possible	9

Another important aspect was to notice that most of the players decided to push Mr. Adam and rescue him, albeit three left him behind in the ward. This shows that some players behaved in a selfish way, trying to save their lives without thinking on others.

TABLE III

EXITS CHOSEN BY PLAYERS TO LEAVE THE BUILDING

Exit	Users' choice
A-main entrance	4
B-back entrance	10
C-south wing exit	1
D-northwest exit	5

The players had no previous knowledge of the building architecture, so they had no clue on which would be the best exit. Nevertheless, some used the emergency signage as a guide. Results are shown in Table 3. The safest route and preferable one, from the starting point, was the northwest exit (D), but was chosen by only 5 of the subjects (25%). The majority used the back entrance (B) while four selected the main entrance to exit. Only one subject used the farthest away exit, south wing (C).

C. Players' perspective

After the experiment participants were told to relate their experience and give their contributions on how to improve the game.

One of the players confessed that did not follow the exit signs and felt a lot stressed. It was interesting to stress the fact

that acknowledged that had never thought on how to proceed after hearing a fire alarm. This player was one of the six that neither had previous fire safety training or participation in a fire drill. Nonetheless, realised that after playing the game is now more aware of how should behave in such emergency situations.

Other comments regarding the game were made, pointing out improvements to the scenario. Regarding the playability, 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.

V. CONCLUSIONS AND FUTURE WORK

In this paper, we describe some experiments made with a prototype implemented using the concept of serious games, aiming to aid and improve traditional fire drills, especially in complex buildings. The data collected gave us some preliminary results that demonstrated the viability of our proposed approach. It is not intended to replace or avoid the need for on-site drills to train people in emergency situations, with such a SG tool. However, games have proved to be very attractive and an invaluable tool for training. Additionally, our approach has the potential of monitoring players and some performance measures are logged to be further analysed.

The Unity3D game engine was selected because it provided us with a customisable framework and allowed us to recreate a scenario as realistic as possible for the virtual environment.

Our aim is to provide a tool to train people and also to allow building managers evaluate and validate safety plans.

Future work will consider the inclusion of more scenarios and buildings. Also, more tests with an increasing number of subjects and varying situations will be carried out. Another important aspect is the development of a multi-player version of our game and to include other performance measures to study individual and social behaviour. Ultimately the data gathered will provide insights into crowd behaviour, both individually and collectively. This tool will also be an important decision support tool for management and safety personnel to enforce and implement emergency and evacuation plans.

ACKNOWLEDGMENT

This project has been partially supported by FCT (*Fundação para a Ciência e a Tecnologia*), the Portuguese Agency for R&D, under grant SFRH/BD/72946/2010.

REFERENCES

- [1] Almeida, J. E., Rosseti, R., & Coelho, A. L. “Crowd Simulation Modeling Applied to Emergency and Evacuation Simulations using Multi-Agent Systems”. In *6th Doctoral Symposium on Informatics Engineering, DSIE'11*, Porto, 2011.
- [2] Sara Freitas. *Using Games and Simulations for Supporting Learning*. Learning, Media and Technology, 31(4):343–358, 2006.
- [3] Abt, C. *Serious Games*. Viking Press, 1970.
- [4] Origins of the Kriegsspiel, [Online]. Available: http://www.kriegsspiel.org.uk/index.php?option=com_content&task=view&id=15&Itemid=58

- [5] Susi, T., Johannesson, M., & Backlund, P. *Serious games—An overview*. University of Skövde, Technical Report HS-IKI-TR-07-00, 2007.
- [6] Michael, D., Chen, S. *Serious Games: Games That Educate, Train, and Inform*, Muska & Lipman / Premier-Trade, 2005.
- [7] Loh, C. S., Anantachai, A., Byun, J., & Lenox, J. Assessing what players learned in serious games: in situ data collection, information trails, and quantitative analysis. In Q. Mehdi (Ed.), *10th International Conference on Computer Games: AI, Animation, Mobile, Educational & Serious Games (CGAMES 2007)*, July 2007. Louisville, KY, USA.
- [8] Kuligowski, E.D, Peacock, R.D., Hoskins, B.L. *A Review of Building Evacuation Models, 2nd Edition*. NIST Technical Note 1680. National Institute of Standards and Technology, U.S. 2010.
- [9] Kady, R.A., Gwynne, S., Davis, J. A Review of the sources of occupant performance data used in building evacuation models, in *Human Behaviour Fire Symposium*, 2009.
- [10] Ribeiro, J., Almeida, J. E., Rossetti, R. J. F., Coelho, A., & Coelho, A. L. Towards a serious games evacuation simulator. In *26th European Conference on Modelling and Simulation ECMS 2012* (pp. 697–702). Koblenz, Germany 2012.
- [11] Kirriemuir, J., McFarlane, A.: Literature Review in Games and Learning, Futurelab Series, University of Bristol, 2004.
- [12] Nagel, R. Vermeulen, C.: Evacuation a serious game for preparation. http://www.hkvlijninwater.nl/documenten/Evacuation_a_serious_game_for_preparation_BK_BT.pdf. 2010
- [13] Vasconcelos, G. et al. 2012. Using UWB for Human Trajectory Extraction. *24th European Modeling & Simulation Symposium - EMSS 2012* (Vienna, Austria, 2012).
- [14] Almeida, J.E. et al. 2012. NetLogo Implementation of an Evacuation Scenario. *WISA'2012 (Fourth Workshop on Intelligent Systems and Applications)* (Madrid, Spain, 2012).
- [15] Ribeiro, J., Almeida, J., Rossetti, R., Coelho, A., Coelho, L. Using Serious Games to Train Evacuation Behaviour. In: *CISTI'2012 (7th Iberian Conference on Information Systems and Technologies)*, Madrid, Spain, Jun 20-23, 2012.
- [16] Silva, J.F.M. et al. 2013. Preliminary Experiments with EVA - Serious Games Virtual Fire Drill Simulator. *27th EUROPEAN Conference on Modelling and Simulation (ECMS 2013)* (Ålesund, Norway, 2013).