Towards a Framework for Pedestrian Simulation for Intermodal Interfaces

João Emílio Almeida, Zafeiris Kokkinogenis, Rosaldo J. F. Rossetti
Artificial Intelligence and Computer Science Laboratory (LIACC)
Department of Informatics Engineering (DEI)
Faculty of Engineering of the University of Porto (FEUP)
Porto, Portugal
e-mail: { joao.emilio.almeida, pro08017, rossetti }@ fe.up.pt

***Abstract*— The dynamics of pedestrians have received less attention in transportation systems when compared to cars and other transportation means. However, its importance is inarguable and, recently, a lot of effort on research was put into this field. The use of Agent-Based Models (ABM) and known techniques such as the Social Forces Model (SFM) has fostered this most recent application field. Several models are already available for crowd simulation, but the validation of such models is a critical issue. Methodologies for behaviour elicitation and validation in social simulation models are needed. In this paper, a new framework to tackle these problems is proposed. Based on research made for more specific applications, concerned with buildings' evacuation, a methodological approach to develop a simulator for pedestrian's dynamics consisting of five main tasks is proposed hereafter. The tasks are: 1) "Reference Models and Benchmarks"; 2) "Pedestrian Sensor Fusion"; 3) "Serious Games for Pedestrian Behaviour Elicitation;" 4) "Behaviour Mining," and 5) "Agent-Based Modelling and Simulation of Pedestrian Elicitation of Emergent Dynamics," a Decision Support Tool aimed at the study and analysis at pedestrian dynamics in the urban context, specifically for helping planners to develop the new generation of buildings and cities.**

Keywords - pedestrian simulation; pedestrian dynamics; pedestrian behaviour elicitation.

I. INTRODUCTION

The study of pedestrian dynamics in urban context, both outdoors and indoors, has been a hot topic of research that boosted in the past years. Some researchers found out that whilst the dynamics of traffic is studied in several scientific areas, pedestrian dynamics is still not completely known and applications demanding this sort of expertise exist and are eager for such knowledge [1].

Millions of travellers use every day public transportation infrastructures such as trains, planes, boats, buses and private cars. Having this is mind, we have the necessity to design and implement the spaces where people move in their daily activities. These spaces must provide safety and comfort to their users. The issues that pedestrian simulation tries to address are related to the individual behaviour and the emergent dynamic resulting from the interactions among them. From this point of view, pedestrian simulation can offer to urban planners the tools to tackle the problems mentioned above, namely the safety and comfort of transportation spaces, such as airports, train and bus stations, or other intermodal interfaces [2, 3,4].

These dynamics gain much more relevance when we consider the interactions of pedestrians with traffic flows. Some models exist for traffic simulations where the interactions between various vehicles coexisting in the same network are simulated [5]. The pedestrians are an important aspect to consider in such simulations, so is the correct modelling of their behaviour and movement, as well as their interaction with vehicles [6, 7, 8].

Simulation is a recurrent solution for testing scientific hypotheses and theories about complex domains, such as pedestrian simulation, as well as to test design strategies and to create phenomena about which theories can emerge [9]. The use of simulation models is a surrogate for systems, which are too expensive or even impossible to test otherwise [10].

One of the purposes for the use of simulation is training and entertainment [11]. Recently, one trend among the simulation community is to use the concept of Serious Games (SG) as a means for training and decision-making. SG can be used as 3D immersion environment suitable for testing real users' behaviours in synthetic scenarios [12]. The idea behind using SG in the traffic dynamics context is to take advantage of existing and tested technology, such as game engines, for the aforementioned purposes, namely, training [13,14].

This paper aims to present the research developments of a framework for Simulation of Pedestrian Simulations for Intermodal Interfaces, based on a project coined "Simulation of Pedestrian Elicitation & Emergent Dynamics" (SPEED).

The remainder of this paper is organised as follows. Section 2 presents some background and related work in the field of pedestrian simulation for traffic and urban environment, including the use of Serious Games. Section 3 is used to introduce the proposed framework architecture, the SPEED, whereas in Section 4, the tasks to accomplish such realization are detailed. Finally, conclusions are drawn, pointing future work and developments in Section 5.

II. BACKGROUND AND RELATED WORK

Many attempts have been made and examples, both commercial and academic exist [15]. However, modelling pedestrians in both normal and emergency situations is not a trivial accomplishment. The implementation, validation, verification and calibration of such models have revealed tough problems to tackle with [16].

A. Pedestrian models

Although many approaches exist to model the behaviour of crowds with varying levels of realism, three models seem to be the most used [17]. Cellular Automata Models [18] treat individuals as separate objects in an area of finite divisions, the so-called cells. Forces-based Models use mathematical formulas to calculate the position variations of the individual elements through the application of forces. Its most explored subtypes consider Magnetic Forces Model (MFM) [19] and Social Forces Model (SFM) [20].

In a basic level, the pedestrian movement in terms of both kinematic and basic interactions between them and other entities is more or less dealt with the SFM and MFM, described earlier. Problems arise when trying to include the reasoning processes and behaviour aspects into the models [22]. Animals tend to act in a rather predictable way as was stated by Reynolds [23].

Pedestrian models have been use also to assess the safety of urban environments and / or to study behavioural aspects in disasters [25]. Dramatic events have fostered the development of pedestrian simulators and data collection that resulted in boost on this area [1]. However, social science studies are needed to develop these theories, which could then yield more realistic results leading to safer and more efficient building designs [26].

The Multi-Agent Systems (MAS) paradigm [27], a branch of Distributed Artificial Intelligence, is particularly adequate for representing social relations by using behavioural models exploiting emergent behaviour. This sort of structure very much resembles a society of several interacting entities and has inspired much research in the Social Sciences [21]. Indeed, MAS consist of another approach that has been used increasingly by researchers and developers for developing pedestrian simulators [15, 17, 28]. Another way to address these subjects is by using numeric simulations based on mathematical models [29, 30].

Social simulation with ABMS has emerged as a research field where computational methods are applied to Social Sciences with connections to MAS. This kind of approach is particularly adequate for representing social relations on the basis of behavioural models exploiting the emergent behaviour of the system. For these reasons, ABMS has been widely used to simulate pedestrian interactions and crowds in a vast range of different scenarios, naturally including evacuations and risk situations [3, 15, 31].

The computer recreation of humans is a challenge pursued by researchers and developers of different areas ranging from video games to less entertaining purposes such as the ones addressed by Serious Games (SG). Virtual characters with emotions and other social features, reproducing typical human behaviour, are a long-term project from any point of view. Some work has been presented [32] but future work is still a pile of issues to solve and a lot remains to be done.

B. The Serious Games Concept

The SG concept, introduced in the 70's of last century [19] has gained a great prominence in the Digital Games field within the last decade, using appealing software with high-definition graphics and state-of-the-art gaming technology. It presents a great potential of application in a wide range of domains, naturally including social simulation and transportation fields.

SG refers to video games whose application is focused on supporting activities such as education, training, health, advertising, or social changes. Benefits from using SG include: the learners' motivation is higher; completion rates are higher; possibility of accepting new learners; possibility of creating collaborative activities; learn through doing and acquiring experience [33].

There some examples of using SG in the Transportation field, such as a game-engine-based modelling and computing platform for Artificial Transportation Systems (ATSs) with a specific module for creating synthetic population [34]. Authors refer four key problems to be solved in order to implement a complete ATS: modelling, computing, experimenting and parallel management. Using the MAS paradigm each agent-based object includes vehicles, pedestrians, traffic infrastructures and other elements such as buildings and even the weather [44].

C. Agent-Based Pedestrian Simulators

During the last decade the academic community and the industry alike, for both investigation and professional use, developed several simulators mimicking pedestrian behaviour. ABMS is a technique used in many of the aforementioned simulators, thus permitting control of unique individuals with their own characteristics (as it happens in real life) bound together in the same simulation framework. Using ABMS each person is modelled individually allowing microscopic simulation, having the group emergent behaviour resulting from the sum of all singular pedestrians.

In [1] several commercial pedestrian simulators are referred. Among them it is possible to find Legion, one of the most popular pedestrian simulators within practitioners, used in the design of new metro, railway stations and airports worldwide. SimWalk and STEPS [35] are multi-purpose commercial pedestrian simulators used to plan new urban complex buildings by architects and engineers. Both claim to evaluate safety and comfort of people in urban environments. VISSIM [1] is another microscopic simulation tool for multi-modal scenarios based on the social forces model, allowing real-time simulation in various scenarios, including emergency situations, with 2D and 3D graphics.

From the above we can conclude that the integration of SGs into ATS opens new opportunities for research using game technology for participative simulation, by turning users into active actors in the integrative loop of ATS. Concepts such as Gamification, can further promote social awareness towards future smarter and sustainable transportation systems.

III. SPEED: FRAMEWORK DEVELOPMENT DESCRIPTION

The proposal is to devise a framework able to tackle the issues mentioned above, namely to apply artificial intelligence techniques to safety, risk analysis and comfort of commuters at public transportation interfaces.

For instance, when urban planners decide to build a new subway or train station, airport or some other complex transport facility (see Fig.1), it is imperative to study how the pathways for commuters will be influenced by the environment, other commuters and how all this interactions could affect vehicles' traffic flow.

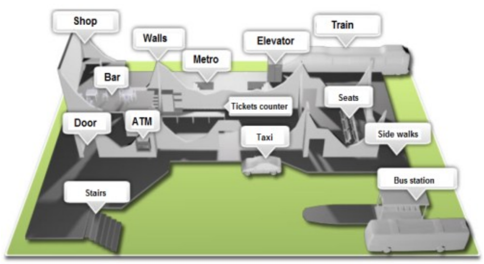

Figure 1. Example of Intermodal Interface (adapted from [15])

A simulation-based decision support tool that combines social simulation, Agent-based Modelling and Simulation (ABMS) and Serious Games (SG) is conceptualized and detailed. In this sense, a player will be immersed in a realistic 3D model environment and its behaviour will be studied. The main interest is not only on the individual based actions, but also how these actions can influence and be influenced by others. The results of this simulated game will provide in depth knowledge that can be used by urban planners, law enforcement forces, and other entities, to implement proper policies and designs.

The methodological approach proposed in this project is formed of five main components describe hereafter (Fig. 2).

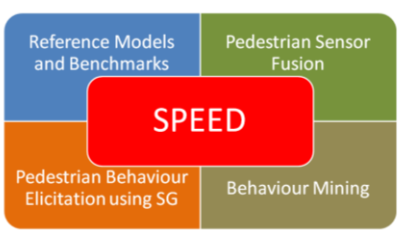

Figure 2. SPEED framework components

A. *Reference Models and Benchmarks*

This task plays a crucial role in the SPEED project development. It consists in looking into the existing approaches for modelling pedestrian behaviour to identify requirements and elaborate reference models and benchmarks. A deep literature review on these reference models is performed, as well as establishing the most suited models to use for validation purposes.

Another important aspect is to identify behaviour patterns and eventual correlation among those patterns; to evaluate the importance of several key issues that might influence behaviour; to identify behavioural aspects of pedestrians with respect of the strategic and tactical levels, i.e. the decision-making process that will result in the effective movement decisions by the pedestrian [24].

By repeating these studies, we reproduce a database of reference models that will be used to validate our proposed approach; a reference dataset with metrics and performance measures, as well as benchmarks. This task will also indentify the measurable characteristics of the human decision-making, which will serve as requirements for the model development.

B. *Pedestrian Sensor Fusion*

The essence of this task is the gathering of data from different sensors providing different types of information yet complementary. The aim is to implement different techniques of data acquisition using multiple sensors such as RFID [36], Bluetooth [43], and WiFi. Final goal is to combine both microscopic and macroscopic technologies for pedestrian data collection.

A first study has been carried out using the UWB technology [36]. Here, kinematics related data have been collected and analysed to track pedestrian trajectories in closed spaces, as it is depicted in Fig. 3. In [43] authors have compiled a literature review about using Bluetooth technology in monitoring pedestrian activities in public transportation interfaces.

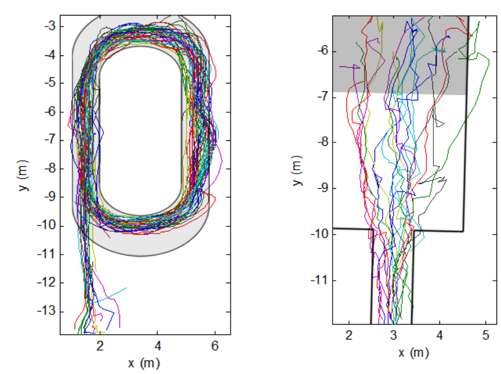

Figure 3. Tracking pedestrian paths using UWB [36]

The pedestrian data will be acquired aiming to observe various measurable facets of the pedestrian behaviour and kinematics. Proper techniques will thus be developed in order to infer useful information regarding moving and behaviour patterns.

The necessity to data fusion from different sources is to enhance the characteristics of each sensor to perform in a given field and compensate its limitations by complementing it with readings from other type of sources. The sensor fusion will unfold in two directions: gathering data related to individuals and groups. For individual measurements, RFID technology will determine the position in space and speed to record movement patterns for an individual, whereas Bluetooth sensing will allow us to define origin-destination matrices and moving times. For group dynamics, videocameras shall be used through the implementation of appropriate video processing techniques to analyse not only kinematics, but also behavioural patterns. As kinematic information can be considered the average heading (e.g. speed and moving time) of a given group, behavioural information can be related to anthropological and emotional reactions. Results will populate a database.

C. *Serious Games for Pedestrian Behaviour Elicitation*

The use of Serious Games (SG) has the following goals: i) the implementation of a Serious Games platform to train and analyse human behaviour while acting as pedestrians in buildings and other public areas; ii) to collect a wide range of different metrics of the player to be later used in the process of mining behaviour; iii) to define and implement monitor agents that elicit behaviour of players during the game, on a seamless basis.

To accomplish the aforementioned goals, the main idea is to adapt a game engine to serve as the basis for the implantation of our SG platform. The platform will support the rapid prototyping of 3D models of the environments to be simulated in the games, recreating real-world buildings. This action will give the player a more realistic perception of the environment. The platform will also support multi-player games and human-in-the-loop simulation as well. During the game, the player will interact with other virtual entities (implemented as agents) through his avatar. This concept aims to help understanding how a player may influence and be influenced by the actions of its peers and, also, by the surrounding environment.

These variables of the player's behaviour will be monitored during the game, generating a huge amount of logs for further analysis. The data acquired will then be used to populate the dataset referred in the last sections. Aggregate performance will be constantly monitored, so the influence of each variable on the emerging behaviour of the system as a whole will be permanently analysed. All this information will feed the behaviour-mining task, described in next section.

Figure 4. EVA: Serious Game for training EVAcuations [37]

Preliminary works towards the development of the framework used the SG concept in the Unity3D game engine to develop a virtual evacuation simulator. Following this research line, a sounder SG for training evacuation procedures was implemented (see Fig.4) and established the peer-designed agent concept [40]. On the pure simulation side, NetLogo was tested for rapid prototyping [41].

D. *Behaviour Mining*

Behaviour elicitation will be feasible through two basic mechanisms: i) adaptive agents interacting with the player, during the game, will learn with player's attitudes, adapt to them, and try to influence forthcoming decisions; and ii) behaviour mining techniques to infer pedestrian decision making process from game logs.

Decision making process is projected over three components: 1) operational, dealing with the kinematic behaviour of the subject; 2) tactical, related to the sensorial state of the subject; 3) strategic, correlated with cognitive behaviour and higher-level decision-making process, such as pathfinding.

The goals for this task are: 1) to devise Behaviour Mining techniques able to infer human behaviour from game logs; 2) to formalise logic models of pedestrian behaviours and synthesise these models into meta-architectures for the pedestrian agents, to be used in the Serious Games development and moreover in the final framework, SPEED.

The methodological approach devised is to use Machine Learning techniques to allow us to infer pedestrian behaviour. Data mining and pattern recognition will be performed on game logs from the SG platform. Pedestrian behaviours will be characterised and classified in terms of the many variables identified previously, as well as the various metrics collected during the game. With this information, meta-architectures for the pedestrian agents will also be defined, which will populate both the game and the simulation environments. The emotional state of the player's avatar will be captured into agent architectures, such as the BDI (belief, desire, and intention) one, to represent his internal state while facing such situations. After these behavioural models have been validated, using the reference models and benchmarks identified in the traditional behaviour analysis, they will populate the game environment, as well as the simulation framework.

E. *SPEED – Simulation of Pedestrian and Elicitation of Emergent Dynamics*

The ultimate goal of this project is to implement a sound and valid Decision Support Tool to aid social simulation of pedestrian interactions within urban context to help architects and engineers when designing the layout of such places. This is also valid for traffic planners to check the interactions of pedestrians and vehicles. Another important aspect to consider is how to analyse issues such as evacuation and/or avoiding overcrowded spaces, helping planners and safety enforcement authorities to develop and/or improve emergency plans for metropolitan areas. The SG can also be used to help fire-fighters and law enforcement authorities to devise improve strategies for rescue teams, for instance.

IV. Integrating Pedestrians and Traffic Simulation

Planning Intermodal Interfaces is a complex task requiring a group of experts collaborating, having different points of view. The experts' team studying urban transportation systems might include the following: traffic managers, public transport planners, urban planners and designers, environmental engineers, politicians, and so forth. Each one of them will try to stress their own perspective according their expertise. When all interested people, together analyse the situation and collaborate to generate a common solution, the expected outcome is likely to be better. Collaboration in such simulation projects is then very much desirable.

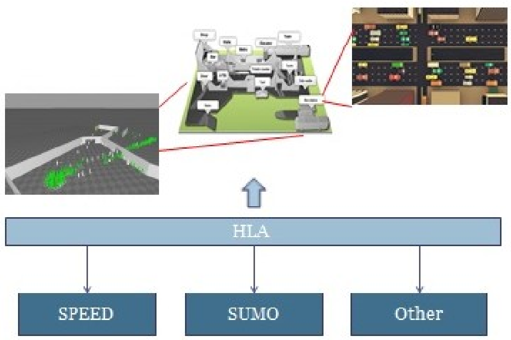

Figure 5. Integrating SPEED with other simulators using HLA

Having in mind the case study of the collaborative traffic and pedestrian simulation we have exposed, would be very much desirable if it were possible to merge different simulation models and/or engines, each of them corresponding to several aspects of the real system. Research in distributed modelling & simulation has originated an IEEE standard for an architectural well-known concept based on the interoperability of different models High Level Architecture (HLA) [38] as it is suggested in Fig.5.

A long-term goal for this research project is the integration of SPEED with different traffic simulators both macroscopic and microscopic, using the HLA concept.

The overall idea is to have a common platform to share models and to integrate different simulators in the same framework. As seen in Fig 6, this concept will allow experts to use merged technologies as if they were a single simulator.

Within the HLA approach, the intention is to bring heterogeneous federates from different simulation domains together to form a distributed intermodal transportation simulation within a virtual environment. The federation consists of the SPEED federate designed to efficiently model pedestrian flow on a detailed microscopic level. This model operates on a virtual intermodal transportation interface space where pedestrian and vehicles entities reside. Vehicles are also brought into the federation by the second traffic federate. Each federates joins the intermodal transportation federation through its respective ambassador as it is depicted in Figure 6.

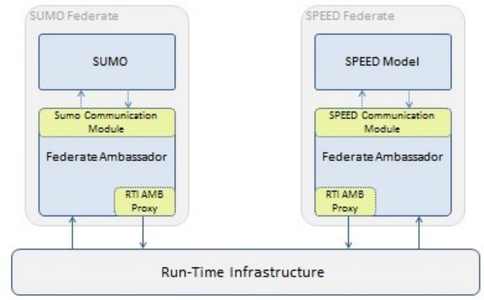

Figure 6. Integrating SPEED with SUMO using HLA

V. CONCLUSIONS AND FUTURE WORK

This paper presents the general design of a framework coined "SPEED," constituting a unique tool for "Simulation of Pedestrian Emergent Evacuation Dynamics." The purpose of such framework is to provide a simulation and training tool that ultimately will help urban planners, architects and engineers to design the next generation of safer cities with reduced costs. Not only, it will be used for validating new and existing building layouts, training occupants using virtual drills, and helping fire-fighters and rescuers to develop plans, rescue strategies, and learn how to deal effectively with crowds during emergencies and critical situations.

To the present date some preliminary results have been achieved. Some promising initial studies using UWB [36], Bluetooth [43], pure simulation [15, 41] as well as SG [37, 42, 45] and the Peer Designed Agent concept [40], were carried out showing the feasibility of the proposal. Further work is ongoing and more results are expected soon.

As for the scientific point of view, this work contributes with an integrated framework for designing and validating behaviour models in microscopic simulations. Indeed much of the scepticism and controversy around behaviour validation can be overcome with the proper methodology. Of course there are issues to be addressed which will be focused in future research.

ACKNOWLEDGMENT

This project has been partially supported by FCT (Fundação para a Ciência e a Tecnologia), the Portuguese Agency for R&D, under grants SFRH/BD/72946/2010, SFRH/BD/67202/2009.

REFERENCES

[1] H. Timmermans, Pedestrian Behavior: Models, Data Collection and Applications. Emerald Group Publishing Limited, 2009.

[2] S. Al-nasur and P. Kachroo, "A Microscopic-To-Macroscopic Crowd Dynamic Model," 2006 IEEE Intelligent Transportation Systems Conference, pp. 606–611, 2006.

[3] E. F. Esteves, R. J. F. Rossetti, P. A. F. Ferreira, and E. C. Oliveira, "Conceptualization and implementation of a microscopic pedestrian simulation platform," Proceedings of the 2009 ACM symposium on Applied Computing - SAC '09, p. 2105, 2009.

[4] N. C. New, L. A. Dixon, J. S. Lott, and J. Wilhite, "Simulation-Based Pedestrian Analysis along Houston LRT Corridors (East End and Downtown)," in ITE 2009 Annual Meeting and Exhibit, 2009.

[5] A. Godara, S. Lassarre, and A. Banos, “Simulating Pedestrian-Vehicle Interaction in an Urban Network Using Cellular Automata and Multi-Agent Models,” in Traffic and Granular Flow’05, Springer Berlin Heidelberg, 2007, pp. 411–418.

[6] C. Premebida, G. Monteiro, U. Nunes, and P. Peixoto, “A Lidar and Vision-based Approach for Pedestrian and Vehicle Detection and Tracking,” 2007 IEEE Intelligent Transportation Systems Conference, pp. 1044–1049, Sep. 2007.

[7] E. Papadimitriou, G. Yannis, J. Golias, “A critical assessment of pedestrian behaviour models”, Transportation research part F: traffic psychology and behaviour, 12(3), pp.242-255, 2009.

[8] T. Wang, “Study of pedestrian-vehicle interaction behaviour by microscopic simulation modelling”, PhD Thesis, University of Southampton, 2012.

[9] X. Pan, C. S. Han, K. Dauber, and K. H. Law, “A multi-agent based framework for the simulation of human and social behaviors during emergency evacuations,” Ai & Society, vol. 22, no. 2, pp. 113–132, Jun. 2007.

[10] A. M. Law, “How to Build Valid and Credible Simulation Models,” in Proceedings of the 2005 Winter Simulation Conference, 2005, pp. 24–32.

[11] Ören, T., “Modeling and Simulation: a Comprehensive and Integrative View”. In T. I. Ören, & L. Yilmaz, Agent-Directed Simulation and Systems Engineering. WILEY-VCH Verlag GmbH & Co, 2009.

[12] A. Frey, J. Hartig, A. Zinkernagel, and H. Moosbrugger, “The use of virtual environments based on a modification of the computer game Quake III Arena in psychological experimenting,” Computers in Human Behavior, vol. 23, no. 4, pp. 2026–2039, 2007.

[13] R. Hays, “The effectiveness of instructional games: A literature review and discussion,” Technical Report 2005-004, Naval Air Warfare Center Training Systems Division, Florida, USA, 2005.

[14] J. E. Almeida and R. J. F. Rossetti, “Mapping 3D Character Location for Tracking Players’ Behaviour,” in Fifth Workshop on Intelligent Systems and Applications (WISA 2013), Lisbon, Portugal, 2013.

[15] F. Aguiar, R. Rossetti, and E. Oliveira, “MAS-based Crowd Simulation Applied to Emergency and Evacuation Scenarios,” in IEEE ITSC2010 Workshop on Artificial Transportation Systems and Simulation (ATSS’2010), 2010.

[16] J. D. Averill and D. S. Mileti, “World Trade Center Disaster Occupant Behaviour, Egress, and Emergency Communications,” NIST NCSTAR 1-7, WTC Investigation, 2005.

[17] G. Santos and B. E. Aguirre, “A Critical Review of Emergency Evacuation Simulation Models,” 2004.

[18] A. Shende, P. Kachroo, C. K. Reddy, and M. Singh, “Optimal Control of Pedestrian Evacuation in a Corridor,” 2007 IEEE Intelligent Transportation Systems Conference, vol. 1, no. 2, Sep. 2007.

[19] S. Okazaki and S. Matsushita, “A Study of Simulation Model For Pedestrian Movement,” in First International Conference on Engineering for Crowd Safety, 1993, no. 1, pp. 271–280.

[20] D. Helbing and P. Molnar, “Social force model for pedestrian dynamics,” Physical review E, 1995.

[21] J. E. Almeida, R. Rosseti, and A. L. Coelho, “Crowd Simulation Modeling Applied to Emergency and Evacuation Simulations using Multi-Agent Systems,” in DSIE’11 - 6th Doctoral Symposium on Informatics Engineering, 2011, pp. 93–104.

[22] E. Kuligowski, “Predicting Human Behavior During Fires,” Fire Technology, Nov. 2011.

[23] C. W. Reynolds, “Flocks, herds and schools: A distributed behavioral model,” ACM SIGGRAPH Computer Graphics, vol. 21, no. 4, pp. 25–34, Aug. 1987.

[24] J. E. Almeida, R. J. F. Rossetti, and A. L. Coelho, “Modelling and Simulation of Pedestrian Emergency Evacuation Dynamics,” in MECC 2013 – International Conference and Advanced School Planet Earth, Mathematics of Energy and Climate Change, 2013.

[25] W. Shiraki, H. Inomo, K. Yasuda, H. Aritomo, and H. Ishikawa, “Simulation of pedestrian dynamics at occurrence of disaster using CA-model,” in Intelligent Mechatronics and Automation, 2004, 2004, pp. 191–195.

[26] A. Jalalian, S. Chalup, and M. Ostwald, “Architectural evaluation of simulated pedestrian spatial behaviour,” Architectural Science Review, no. April 2013, pp. 37–41, 2011.

[27] M. Wooldridge, N. R. Jennings, and D. Kinny, “A methodology for agent-oriented analysis and design,” in Proceedings of the third annual conference on Autonomous Agents - AGENTS ’99, 1999.

[28] X. Pan, C. S. Han, K. Dauber, and K. H. Law, “A multi-agent based framework for the simulation of human and social behaviors during emergency evacuations,” Ai & Society, vol. 22, no. 2, Jun. 2007.

[29] S. Al-nasur and P. Kachroo, “A Microscopic-To-Macroscopic Crowd Dynamic Model,” 2006 IEEE Intelligent Transportation Systems Conference, pp. 606–611, 2006.

[30] A. Shende, P. Kachroo, C. K. Reddy, and M. Singh, “Optimal Control of Pedestrian Evacuation in a Corridor,” 2007 IEEE Intelligent Transportation Systems Conference, vol. 1, no. 2, Sep. 2007.

[31] E. Cordeiro, A. L. Coelho, R. J. F. Rossetti, and J. E. Almeida, “Human Behavior Under Fire Situations – Portuguese Population,” in 2011 Fire and Evacuation Modeling Technical Conference, Baltimore, Maryland, 2011.

[32] N. Magnenat-Thalmann and Z. Kasap, “Virtual Humans in Serious Games,” 2009 International Conference on CyberWorlds, 2009.

[33] S. I. de Freitas, “Using games and simulations for supporting learning,” Learning, Media and Technology, vol. 31, no. 4, pp. 343–358, Dec. 2006.

[34] Q. Miao, F. Zhu, Y. Lv, C. Cheng, C. Chen, and X. Qiu, “A Game-Engine-Based Platform for Modeling and Computing Artificial Transportation Systems,” IEEE Transactions on Intelligent Transportation Systems, vol. 12, no. 2, pp. 1–11, 2011.

[35] E. D. Kuligowski, R. Peacock, and B. L. Hoskins, “A Review of Building Evacuation Models, 2nd Edition,” NIST, Technical Note 1680, 2010.

[36] G. Vasconcelos, M. Petry, J. E. Almeida, R. J. F. Rossetti, and A. L. Coelho, “Using UWB for Human Trajectory Extraction,” in 24th European Modeling & Simulation Symposium - EMSS 2012, 2012.

[37] J. F. M. Silva, J. E. Almeida, A. Pereira, R. J. F. Rossetti, and A. L. Coelho, “Preliminary Experiments with EVA - Serious Games Virtual Fire Drill Simulator,” in 27th EUROPEAN Conference on Modelling and Simulation (ECMS 2013), 2013.

[38] IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) - Framework and Rules. IEEE Computer Society, 2010.

[39] J. Ribeiro, J. E. Almeida, R. J. F. Rossetti, A. Coelho, and A. L. Coelho, “Towards a serious games evacuation simulator,” in 26th European Conference on Modelling and Simulation ECMS 2012, 2012, pp. 697–702.

[40] Lin, Raz, et al. "Facilitating the Evaluation of Automated Negotiators using Peer Designed Agents." AAAI. 2010.

[41] J. E. Almeida, Z. Kokkinogenis, and R. J. F. Rossetti, “NetLogo Implementation of an Evacuation Scenario,” in WISA’2012 (Fourth Workshop on Intelligent Systems and Applications), 2012.

[42] J. F. Silva, J. E. Almeida, R. J. F. Rossetti, A. L. Coelho, and S. Paulo, “Gamifying Evacuation Drills,” in Third Iberian Workshop on Serious Games and Meaningful Play (SGaMePlay 2013), 2013.

[43] J. Filgueiras, R.J.F. Rossetti, Z. Kokkinogenis, M. Ferreira, M. Paiva, J.M.R.S. Tavares, J. Gabriel. “Sensing Bluetooth mobility data: potentials and applications”. Presented in 16th annual meeting of Euro Working Group on Transportation, September, 4 - 6, Porto, Portugal, 2013.

[44] L. S. Passos, R. J. Rossetti, Z. Kokkinogenis, “Towards the next-generation traffic simulation tools: a first appraisal”. In CISTI 2011 6th Iberian Conference on Information Systems and Technologies, 2011.

[45] J. Ribeiro, J. E. Almeida, R. J. F. Rossetti, A. Coelho, and A. L. Coelho, “Using Serious Games to Train Evacuation Behaviour,” in CISTI 2012 - 7ª Conferencia Ibérica de Sistemas y Tecnologías de Información, 2012, pp. 771–776.