

Simulating Cooperative Fire Evacuation Training in a Virtual Environment Using Gaming Technology

Mingze Xi*

Shamus P. Smith†

School of Electrical Engineering and Computer Science
The University of Newcastle (Australia)

ABSTRACT

Fire accidents are one of the most frequently occurring disasters leading to life and property loss. Training for fire escape skills and designing efficient building evacuation plans are increasingly important research topics. Virtual environments (VE) are widely used to support training and simulating human response under emergency situations. However, current VE based training systems have limited intelligent non-player characters (NPC) which are lacking in support of fire science knowledge.

This project will introduce a hybrid method combining gaming technology, agent programming and fire science knowledge to design an evacuation training system for fire wardens. The success of using professional numerical fire simulation tool to support NPC behaviour in virtual environment will provide a new way to enhance the realism of virtual environment by using high fidelity fire data sources.

Index Terms: H.5.1 [INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)]: Multimedia Information Systems—Artificial, augmented, and virtual realities; I.6.4 [SIMULATION AND MODELING]: SIMULATION AND MODELING—Model Validation and Analysis; J.4 [Computer Applications]: SOCIAL AND BEHAVIORAL SCIENCES—Sociology

1 INTRODUCTION

According to the Fire and Rescue New South Wales (NSW) Australia, there are over 6,000 building fires in the NSW area every year. Based on a survey from fire fighters, a large proportion of victims die because they are unfamiliar with emergency fire evacuation plans. People may suffer panic when fire emergencies happen, which will result in delayed evacuation actions and tragic consequences. Fire drills in real world are commonly used for fire evacuation exercises and training. However, it is expensive and not performed under realistic life-threatening or hazardous conditions. These limitations make it hard to provide a suitable environment to practise fire escape skills.

An alternative solution is to use virtual reality (VR). VR technology can help simulate realistic environments for training fire evacuation skills and evaluating building safety levels. There are various tools for fast prototyping virtual environments (VE), for example Virtual Reality Modelling Language (VRML), 3DVIA virtools and modern game engines. Game engines are typically a suite of graphics tools including high efficiency rendering technology which can support the rapid prototyping of virtual scenes, e.g. Smith and Trenholme [8] investigated a virtual fire drill using the Source Engine.

Typically, the participants in a fire emergency can be categorized by their location and evacuation role when the fire emergency happens. Participants inside the building are regarded as evacuees

which contains residents, visitors and safety officers, for example fire wardens, while participants outside buildings are people who have evacuated and professional service staff, for example fire fighters and paramedics. The residents normally are more familiar with the building than visitors. Fire wardens are special type of resident that have the responsibility to give instructions to support evacuation.

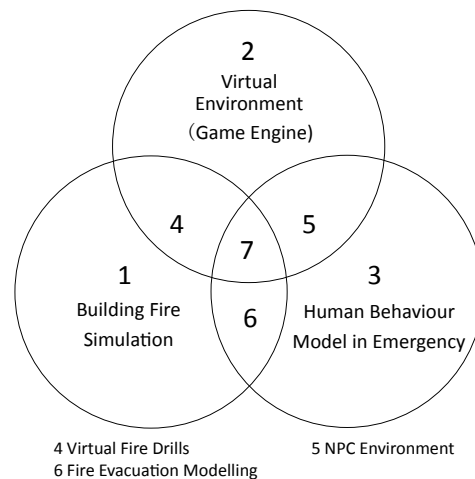


Figure 1: Research topics needed for fire warden training system (area 7)

One research question is what is required to build a good training system for these different characters? Figure 1 describes the main research topics of this project. Previous game engine based evacuation training systems mainly focus on single human player walk-throughs (area 4) or multiple NPCs autonomous evacuation simulation (area 5). Previous studies have reviewed human behaviour in fire emergencies and built various types of human behaviour models [3] (area 3).

How to successfully simulate human behaviours using virtual reality technology has been a long-term research topic. Different from computer controlled characters, real human behaviour is complex, stochastic, highly personalized and easily affected by environment parameters. Normally, artificial intelligence (AI) methods are used to simulate intelligent behaviours of the non player character (NPC) [6] (area 5), but are limited in taking fire science knowledge into consideration, for example toxic gas, smoke and heat. Evacuation models [4], which are also called evacuation simulation tools, are developed by fire scientists and psychologists to simulate fire evacuation activities (Figure 1, area 6). Since the VE method is lacking in fire science knowledge and evacuation mode suffers very limited visual effect and interaction, it is necessary to find a new method that could integrate advantages of the two methods. A possible solution is reusing fire evacuation simulators to support NPC

*e-mail: mingze.xi@uon.edu.au

†e-mail: Shamus.Smith@newcastle.edu.au

behaviour modelling in virtual environments with its fire science knowledge as presented in area 7.

In this project, we will reuse fire evacuation models to generate evacuation plans and scripts of NPC behaviours. Then a game engine will be reused to build highly realistic virtual environments, receive the rewritten evacuation scripts and test the evacuation performance. A new human behaviour model to describe detailed human behaviours with interaction function will be build.

2 STATEMENT AND MOTIVATION OF RESEARCH

There are several fire evacuation training systems in various scenarios such as nuclear plants [2], aircraft [7] and university buildings [8]. Mól and Carlos [5] used a game engine to build and simulate evacuation planning and made comparison between simulation result and real fire drill results, but the NPC in this system is limited in social awareness. There is limited guided evacuation in current evacuation training systems, while big buildings with dense populations normally have at least one safety officer or fire warden who will guide people when emergency situations happen. The influence of fire warden behaviour is normally regarded as leadership influence, which is a very important factor that will influence the evacuation in a emergency situation [1].

A guided fire evacuation training system in virtual environment requires three key elements, realistic 3D virtual environment (buildings), participants (human player and NPC) and fire science knowledge. Finite State Machine (FSM) is one way to model NPC behaviours, but suffers a rigid decision making process, while a real human could make the decision considering social factors. Multi-agent system (MAS) has been widely accepted as a new method to model and simulate human behaviours in emergency evacuation [6]. Most agent-based simulation systems in virtual environment are able to simulate basic behaviours, for example, target finding, target recognition and rescue pathway finding. However, only few of them have taken fire science knowledge into consideration.

Another significant factor in a evacuation training system is the interaction function, which is the key advantage of virtual environment against any other types of simulation environment. With interaction support, we can realise the training process with communication between human participants and NPC. However, how to coordinate fire wardens, human player evacuees and NPCs will be a challenging problem. In this project, only two types of participants, human controlled fire wardens and computer controlled evacuees (NPC), will be considered. The interaction considered here contains interactions among the evacuees and interactions between fire warden (human player) and evacuees.

A valuable 3D fire evacuation training system should not only provide realistic visual effects, but also have scientific data support for agents to generate realistic decisions. Limited by computing requirements, high code complexity and domain knowledge, it is difficult for computer science researchers to add professional fire knowledge into virtual environments. Similarly, fire science researchers may also come across difficulties in visualising their data in realistic 3D environments. Thus a hybrid approach across these disciplines will be necessary.

3 SYSTEM DESIGN AND HUMAN BEHAVIOUR MODELLING

This research will develop virtual environments using computer game engines and build a new NPC human behaviour model. We will model and script the social behaviours of different characteristics, for example fire wardens, staff and students, using agent programming technology. Previous research indicates that agent models can simulate social behaviours with low cost and high fidelity. A framework of agent-based behaviour will be created to realise the interaction between different participants.

The nature of this system is a computer game level (map) created by a game engine that can be run in a computer game environment.

In this system, fire evacuation models are used to generate plans and rules for NPC-based human behaviour model. The final human behaviour model would be able to make decisions and find pathways with fire science knowledge support from fire simulation models.

4 EVALUATION

Time factors and AI behaviour realism are used to evaluate the usefulness of the training system. For the time factor, we will make comparisons between *ideal exit time* which is calculated from existing evacuation model simulations, and the *evaluation exit time* which is observed from the experiments when human players co-operate with NPCs to evacuate the same scene. The comparisons can be used to evaluate the performance (reliability) of our training system. Previous experiments showed that high graphic realism might not be compulsory for all VEs, but may influence the user interest [9]. We intend to explore the influence of NPC actions, either rational or irrational actions on training results. Also, the cooperation between fire-warden (human player) and evacuee (NPC) will be evaluated.

5 DISCUSSION AND FUTURE WORK

The training system described in this paper is not a final application, but an introduction of a new method that may contribute to the knowledge gap of interdisciplinary research. Building a cooperative fire warden training system by reusing game engine and fire evacuation simulation model is an example of using this method to enhance the realism of virtual environment applications by building professional knowledge database from third party software.

Currently, we are analysing the results of simulation models. We proposed to build the structure of the agent based framework as a next step. Future work will explore the possible use of this method to build VE applications other than fire evacuation, for example flood evacuation and earthquake evacuation.

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