AGENT-BASED SIMULATION OF PEDESTRIAN EVACUATION IN VIRTUAL GEOGRAPHIC ENVIRONMENT

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KEY WORDS: Pedestrian Evacuation, Agent-based Modeling, Virtual Geographic Environment, OpenSimulator

ABSTRACT: Agent-based model has found great interest in simulation of pedestrian evacuation since it better represent the intelligent and self-organized behavior patterns of pedestrians. However, model validation and the user's cognitive perspective have always been the two challenges in agent-based simulation. Therefore, this paper presents an approach to implement agent-based simulation of pedestrian evacuation in a virtual geographic environment (VGE) allowing interactions between avatars and agents, which extends the conventional agent-based modeling by adding human dimension. To test the approach, a pilot experiment has been carried out based on OpenSimulator. Since the avatars would perform close-to-real-life behaviors when a high sense of presence is achieved, such a study is useful for designing and validating agent-based simulation of pedestrian evacuation and helpful to understand pedestrian behavior from a first-person perspective.

1 INTRODUCTION

Sufficiently realistic simulations of pedestrian evacuation has found great interest in the fields of pedestrian management and minimizing human costs during disaster (Murakami *et al.* 2002). It is believed that setting up pedestrian behavior rules on a microscopic scale will better represent the intelligent and self-organized behavior patterns of pedestrians (Bing *et al.* 2005) than macroscopic methods (Golledge 1997). Some earlier research has studied the mechanism of such behavior patterns as the social-force model (Helbing and Molnar 1995; Helbing *et al.* 2000). These models have mainly focused on the dynamics of flow from the physical perspective, which can explain the mechanism of collision rather well but neglect the effect of individualism. With the rapid growth of agent-based technologies since early 1990s, it is found that the agent population can be composed heterogeneously by individuals with different characteristics and more researches have adopted agent-based model in the research of pedestrian behavior (Murakami *et al.* 2002, Braun *et al.* 2003, Ali and Moulin 2005, Pelechano *et al.* 2007).

When simulating pedestrian evacuation with agent-based models, there are two challenges to be addressed. One is how to specify the parameters involved in the model and how to verify the simulated result, especially for the emergency when real data is hard to assemble (Pelechano *et al.*, 2008). The other challenge is the user's cognitive perspective. So far, agent-based simulations are predominantly presented in single user environment and the majority of the outputs are movie based (Crooks *et al.* 2009). In this way, users can only perceive the simulation from a bird's-eye view. Although similarly realistic looking agent-based models can be created through 3D visualizing technology, it is lack of the feeling of immersive and communication between user and the model.

Virtual geographic environment (VGE) is an immersive 3D virtual environment, where users can obtain an immersive feeling and interact with objects in the virtual world through their avatars. This is an important aspect in the use of VGE in general for agent-based model, as behind avatars are people who can interact with the synthetic model environment, adding another dimension to the level of possible analysis and outcomes such as trajectory records for model validation (Crooks *et al.* 2009). Moreover, the immersive environment allows the user to observe the simulation through a first-person perspective by becoming one of the agents in the simulation (Fishwick 2009). Even though, it is rather surprising that computer-controlled agents are currently almost completely missing from such virtual environment, let alone interaction between agents and avatars (Ullrich *et al.* 2008).

The purpose of this paper is to explore the approach to simulate pedestrian evacuation in VGE using agent-based model. The research is expected to be useful for designing and validating simulation of pedestrian evacuation and helpful to understand pedestrian behavior form a first-person perspective.

The rest of the paper is organized as follows. Section 2 describes the potential of VGE as a simulation environment and the developed framework. In Section 3, we demonstrate this developed system by a preliminary example of pedestrian evacuation. Section 4 concludes the paper and introduces our future work.

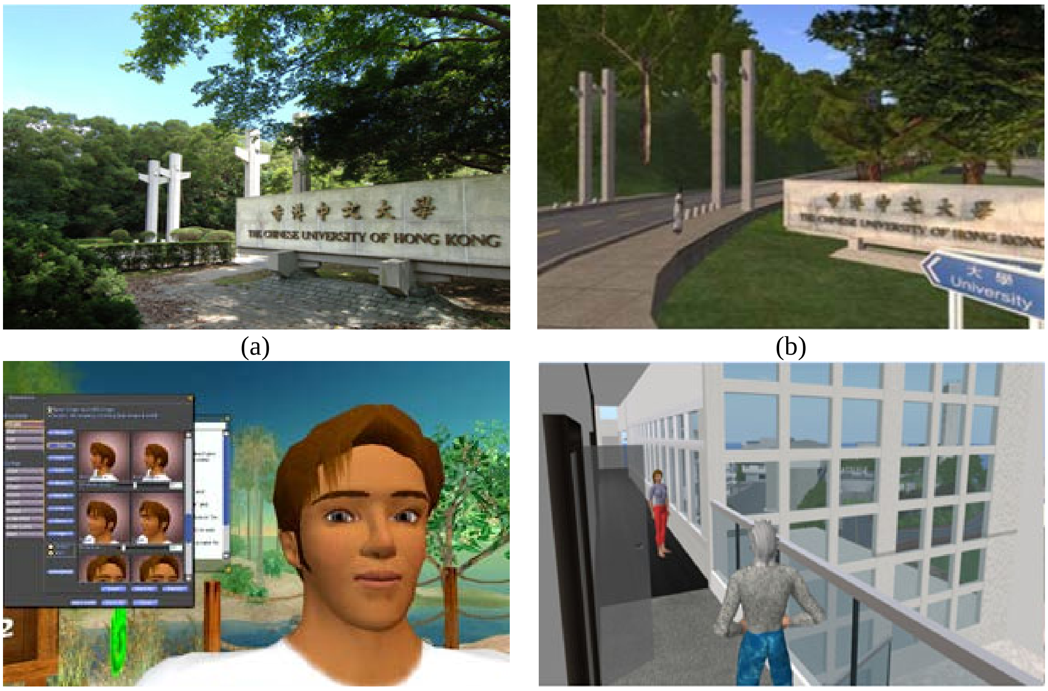
2 AGENT-BASED SIMULATION IN VGE

2.1 VGE as a simulation environment

The structure of a typical agent-based model is composed of agent which is conceptualized as a software entity situated within a part of a simulated virtual environment (e.g., its digital surroundings, other agents, and networked communities) with its own knowledge domain. The agent can interact with the environment, can communicate with other agents, and is capable of performing goal-driven actions (Genesereth and Ketchpel, 1994; Franklin and Graesser, 1997; Hogg and Jennings, 1997; Rana *et al.*, 2000, Castle and Crooks 2006). It is found that the structure of agent-based model is broadly mirrored within virtual environment, where electronic environment is designed to mimic the complex physical space and avatars can interact with each other and with virtual objects.

VGE provides a very rich and dynamic virtual environment corresponding to the physical world and is featured with geographic properties in the real environment (see Figure 1). It is noted that the reliability of simulated agent behavior to a large extent depends on the complexities and consistencies of the environment. A dynamic, rich world, with physical laws and consistent object properties may provide for more fidelity than simpler simulation environments (Veksler 2009). Thus, compared to the 2D simulation environment, the complexity and constraints of VGE may help to improve the simulation, particularly for the indoor environment where multi-layer structure is often involved.

Moreover, VGE could be populated with both user-controlled avatars and software-controlled agents. That is to say the platform of VGE will extend the conventional agent-based modeling by adding human dimension, which leads to a mix of ‘real’ user with simulated agents. The interaction between user-controlled avatars and software-controlled agents is the significance of using VGE, which would highly increase the sense of presence. Once a high sense of presence is achieved, the user behind the avatar would perceive the simulation from a fist-person view and behave as close as possible to real life. Therefore, we can confidently run simulations to study human behavior and use the resulting data both to validate and improve current models (Pelechano *et al.* 2008, Ranathunga *et al.* 2011).



(a) (b) (c) (d)

Figure 1 VGE as a simulation environment: a) a real picture of CUHK, b) a snapshot of Virtual CUHK, c) in VGE users can obtain an immersive feeling through their avatars, and d) avatars could communicate with each other through chatting and gesturing.

2.2 Architecture Overview of agent-based simulation in VGE

Given the advantages of VGE for agent-based simulation we have discussed above, we propose an approach to simulate pedestrian evacuation in VGE using agent-based model. Figure 2 shows how different components are integrated with each other in this approach.

VGE not only provides a closer-to-real-life world representation, but also serves as a platform to implement participatory simulation. This enables software-controlled agents and user-controlled avatars to be co-situated and interact with each other.

Simulated actor agents are created and controlled by the agent-based modeling. Since our approach is based on the multi-agent technology, an agent-oriented design method must be adopted to simulate pedestrian behavior. A realistic simulation of pedestrian evacuation should be able to reproduce the observed phenomenon such as attraction and repulsions between agents, bottleneck effect and lane formation.

The users enter the VGE and achieve a presence in the simulation as avatars via human-computer interaction. As an online virtual environment, VGE can be accessed over the web by many different users who appear as avatars. The avatars can communicate with each other via instant messaging and voice over IP and interact with simulated agents.

To be useful, trajectories of both agents and avatars will be record and analyzed for model validation and spatial cognition. Since the users immerse in VGE and perceive the simulated evacuation from a first-person view, it is expected to observe the same type of behavior as in real life. Therefore, difference between ‘real’ and ‘simulation’ can be drawn from the comparison of trajectories generated by agents and those by avatar, which are useful to investigate uncertainty of human behavior and modify the model.

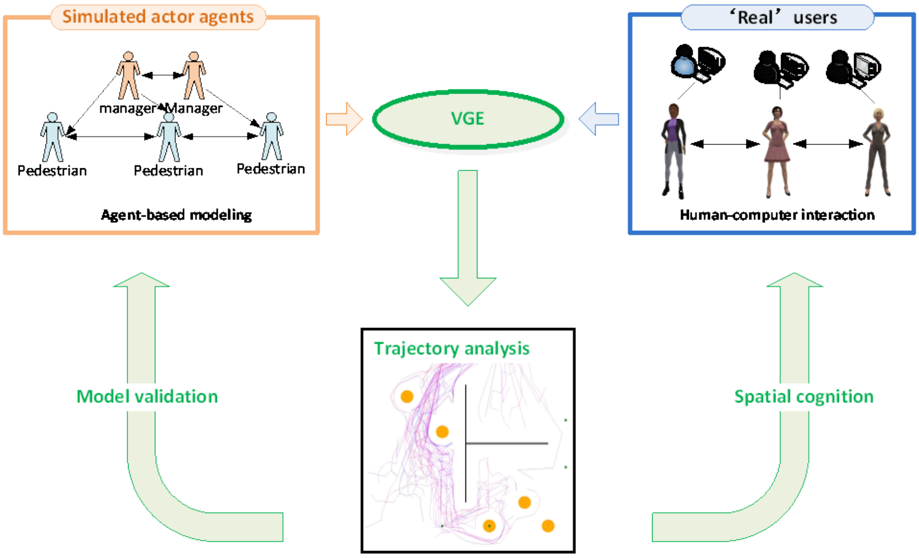


Figure 2 Architecture overview

3 PILOT EXPERIMENT

In order to test the proposed approach we carried out a pilot experiment to simulate pedestrian evacuation from a room a room measuring 10m by 10m with only one exit. At the beginning, the pedestrians are wandering randomly. After a specified time, the alarm is sounded and the pedestrian evacuate from the exit.

3.1 Agent-based pedestrian evacuation model

Figure 3 shows the flow chat of agent-based model for pedestrian evacuation .When the model is started, agents are placed within the room and wander randomly until an alarm is sounded. Once the alarm is activate, all the agents stop wandering and try to move towards the exit. At each model tick (model second), all the agents have the option of moving and simultaneously checking to see if they are at a specific destination. For each agent, if the answer is yes it then checks to see if it is the exit, in which case the agent is removed from the building. If it is not an exit, the agent chooses a new direction to walk based on its line of sight. If the agent is not at its destination, it checks whether it can move to a new location without colliding with other agents. This decision is made by calculating its maximum walking speed, a process based on the density of surrounding agents and their walking speed. When agents have made their move, they remain stationary until the next model tick before repeating the process.

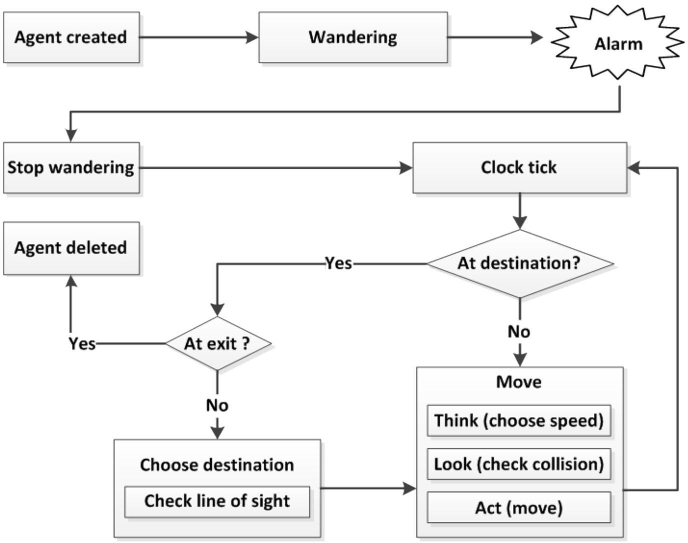


Figure 3 Flow chat of agent-based model for pedestrian evacuation

3.2 Implementation and result

We implement the pilot simulation through OpenSimulator, which is an open source multi-platform, multi-user 3D application server. It is relative easy to build customized virtual environment through OpenSimulator. The programming is done using in-world scripts created using the proprietary Linden Scripting Language (LSL).

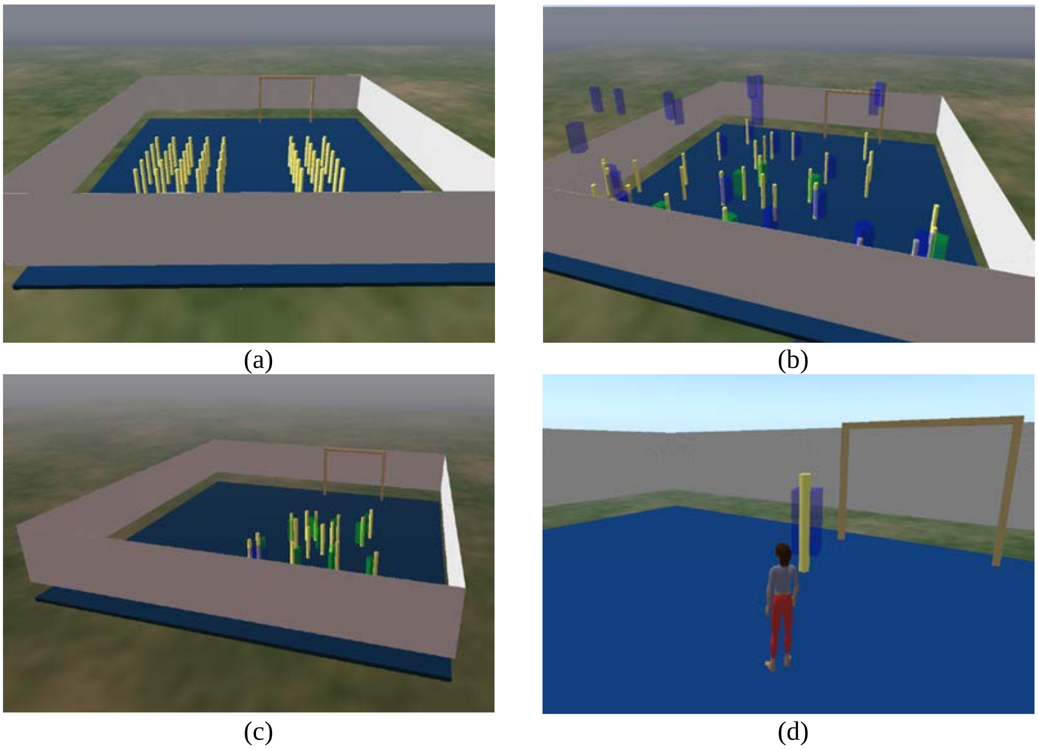


Figure 4 Screenshots of the pilot experiment: a) the initial state of one room measuring 10m by 10m placed with agents, b) the agents are wandering randomly, c) the agents are moving towards the exit when the alarm is sounded, and d) agent awareness of avatar.

As a prove-of-concept, we simplify the pedestrian behavior in this experiment. We assume that all the pedestrians will move straight forward to the exit without collision and the walking speed is only affected by the available space. According to Ando *et al*. (1988), the walking speed is lowest at 0.35m/second when the available space is 0.25m^2/person, and rises almost linearly before plateauing at approximately 1.35m/second when available space is

1.5m^2/person. In order to detect collision, the object named “predicted movement volume” is created for each pedestrian before each movement. The object is presented a transparent cube, which appears blue when created. If no collision is detected, the cube turns green and the pedestrian moves to the next position safely. Otherwise, the cube turns red and the pedestrian tries to figure out a new movement (see Figure 4b).

To incorporating avatars into the simulation, we enable the agent awareness of avatars to demonstrate the possibility of interaction between avatars and agents in VGE. The agents will change its moving direction automatically if an avatar is detected on its way (see Figure 4d).

4 CONCLUSION AND FUTURE WORKS

We have proposed an approach to simulate pedestrian evacuation in VGE using agent-based model. Ideally, this approach will extend the conventional agent-based modeling by adding human dimension, allowing interactions between avatars and agents. Since users could enter the simulated environment as avatars and perform close-to-real-life behaviors when a high sense of presence is achieved, such studies are, in general, useful for designing and validating agent-based simulation of pedestrian evacuation and helpful to understand pedestrian behavior from a first-person perspective.

Our simulation prototype is still in development. Currently, the model is able to simulate the simplified pedestrian evacuation such as collision avoidance and speed variation and enable the agent awareness of avatar. Further works will be done in the near future. One promising advantage of interaction between agents and avatars is role-playing for training, as avatars could play various roles such as evacuees and conductors. Future works will also take account of the technology of trajectory record and analysis for model validation. Moreover, VGE provides networking environment, which allows multiple users to participate the simulation simultaneously, thus leading to a networking digital laboratory for research on pedestrian behavior.

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