Modeling and Simulation of Fire Evacuation in Public Buildings

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Abstract

The negative consequence of fire, especially fire in public buildings, brings too much of lost in both human and money. The fire evacuation specialists proposed many evacuate techniques, methods and policies adapting to the given building, groups of people, or situations. However, conducting experiments to test these proposed solutions, in the reality, is nearly impossible. Therefore, simulation of fire and fire evacuation to evaluate these proposals is a reasonable solution. This paper proposes an agent-based model for modeling and simulation of fire evacuation in public buildings. The model is implemented and tested using the GAMA agent-based simulation platform.

Keywords: Modeling, simulation, fire evacuation, multiagent system

1. Introduction

The negative consequence of fire, especially fire in public buildings, brings too much of lost in both human and money. The fire evacuation specialists proposed many evacuate techniques, method and policy bay on the given building, groups of people, or situations. However, taking experiments to test these proposed solutions, in the reality, is impossible. Therefore, simulation of fire and fire evacuation to test these proposal is an acceptable solution.

Recently, modeling and simulation of fire evacuation system is one of the most interesting research subjects. Most of proposed models are agent-based modeling and simulation. In which, each agent is autonomy. It could move to other position to meet or interact to other agents to reach its goal. These features of multiagent system are naturally appropriate to the simulation of fire evacuation: an agent could play the role of an evacuee, a fire fighter, a fire evacuation router or some simpler objects such as a fire, a smoke, a water to eliminate fire and smoke, an alarm, an evacuation sign, etc. During fire evacuation, these agents have some actions or behaviors: observe the fire and smoke to avoid them or call the police or to warn others, evacuate themselves or follow other or follow the instructions of fire evacuation routers or policemen, help other to evacuate, help the fire fighter to eliminate fire and smoke, etc. These activities or behaviors could be modeled and realized by using agent technology. That is why most proposed model in the domain is agent-based. For instances, the model of Okaya and Takahashi [1]; Saelao and Patvichaichod [2]; Filippoupolitis [3]; Tang and Ren [4]; Averill and Song [5]; Yi and Shi [6].

In the line with our previous work on modeling and simulation of fire evacuation in public building (Nguyen et al. [7],[8],[9]), this paper proposes an agent-based model for modeling and simulation of fire evacuation in public buildings. The model is implemented in the simulation platform of GAMA (Amouraux et al. [10]).

The paper is organized as follow: Section 2 presents the proposed model. Section 3 presents the allying of the model in a case study. Section 4 is a conclusion and perspectives.

2. Modeling of Fire Evacuation System

2.1 Extension from SEBES model

As mentioned, the model in this paper is extended from the SEBES model (Nguyen et al. [7]). Therefore, the model is called SEBES+.

Inheriting from SEBES model, the SEBES+ has five kinds of agent:

- *fire*: representing fire. The fire agent could propagate within the building space.

- *smoke*: representing smoke. The smoke agent is created from fire agents. It could propagate inside the building space and therefore increase the smoke intensity at a give position by time.
- *alarm*: representing a fire alarm. This agent could detect fire/smoke in its detection range and ring in a ringing duration of time.
- *sign and plan*: representing of evacuation signs and plan. This is a non-movable agent. This provides the information about the direction to emergency exits.
- *evacuee*: representing an evacuee. This agent could see the fire/smoke, hear the alarm, and evacuate to one of the emergency exits by avoiding the obstacles and other evacuees.

The model SEBES+ is added some new kinds of agent for the objective of fire fighting:

- *water/steam*: representing water or water steam to eliminate fire and smoke. This agent is borne from FireFighter water sources or extinguisher.
- *extinguisher*: representing extinguisher device. This agent is put inside the building and its position is noted in evacuation plan. It is used by FireFighter to generate carbon-dioxide to eliminate fire and smoke.
- *fire fighter*: representing fire fighter. This agent play multi role during fire evacuation: fire fighter to bring water and/or extinguisher to eliminate fire and smoke; evacuation router to rout evacuees to move to emergency exits; and act as an evacuee.

The next section will present these new extended agents in detail.

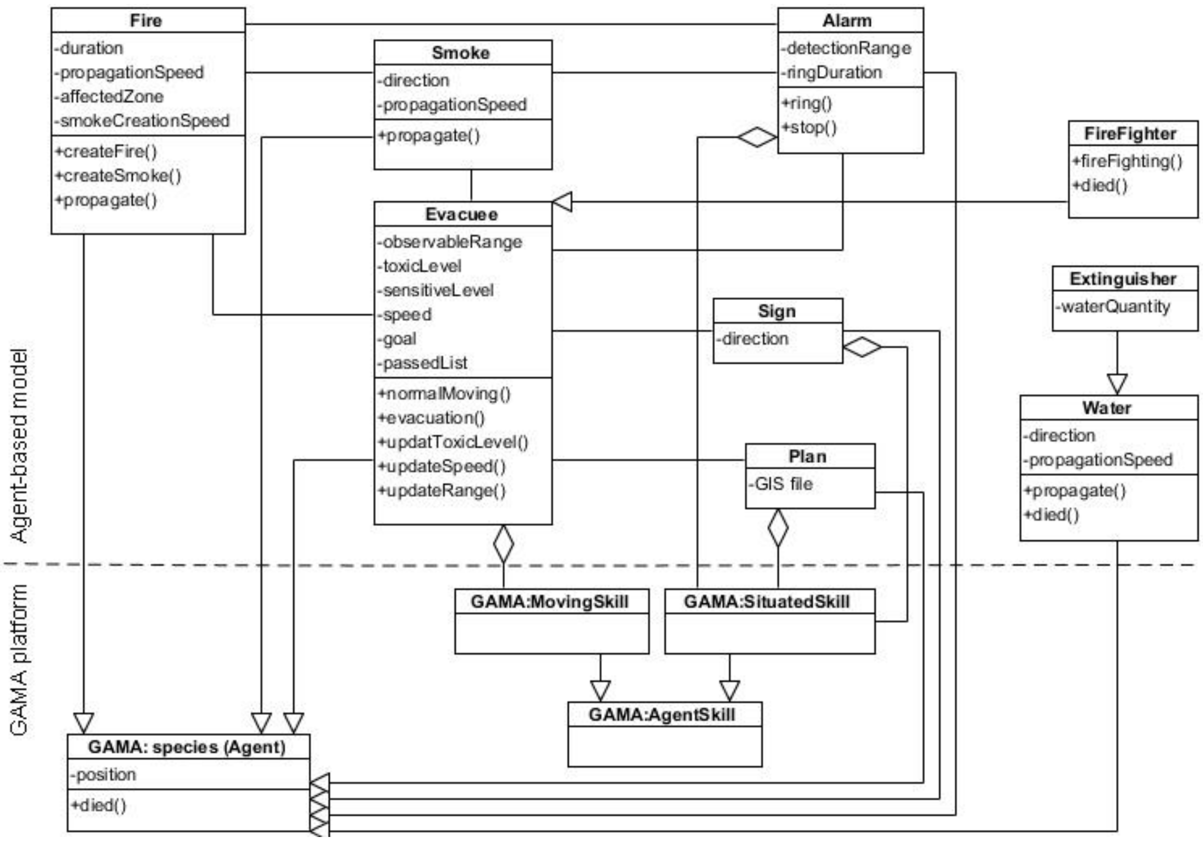

Fig. 1 Extended class diagram of SEBES+ from SEBES model.

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2.2 Water agent

2.2.1 Attributes

- *power*: the ability to eliminate fire and smoke of it.
- *range*: the effected zone of it. It could eliminate fire and/or smoke if these agents go inside its zone.
- *direction*: the direction of propagation.
- *propagationSpeed*: the speed to propagate of this agent.

2.2.2 Actions

- *propagate*: it propagates in its direction inside the building.
- *died*: it will be died after eliminate fire and/or smoke. The elimination rate is 2:1: two water agents could eliminate a fore or a smoke agent.

2.3 Extinguisher agent

2.3.1 Attributes

- *waterQuantity*: the amount of water or carbon-dioxide which could be generated by this agent when used. This could be recharged by fire technician.

2.3.2 Actions

- *propagate*: it propagates in the direction made by the fire fighter.
- *died*: it will be died after using all water quantity.

2.4 FireFighter agent

2.4.1 Attributes

This agent is inherited from *evacuee* agent, so it has all attributes and activities of that agent. It also has some new added attributes:

- *objective*: the object of the fire fighter during fire evacuation. It could be assigned a value of: evacuating, fire fighting, people routing, people helping.

2.4.2 Actions

Beside activities extended from *evacuee* agent, this agent has some new added actions:

- *fireFighting*: this includes several actions which could be executed in any order: moving to extinguishers position to get it to use, using extinguisher to eliminate fire and/or smoke, routing people to evacuate as quick as possible to the emergency exits, helping people to safety evacuate.

3. Case Study

3.1 Choice of Public Building

In our case study, we apply the proposed model for the building that Préventex used in their case study.

Préventex was the first joint sector-based association created in the private sector under the Act respecting occupational health and safety. On October 22, 1981, the Board of Directors of the Commission de la santé et de la sécurité du travail (CSST - the Quebec Health and Safety Commission) adopted resolution A-170-81 that was to lead to the creation of the joint sector-based association of health and safety for the textile and knitting industry.

The evacuation plan of the building is presented in the Figure 2. It is composed of three zones (Source : http://www.preventex.qc.ca/images/ documents/info/en/evacuation.pdf):

- Zone A: This zone is composed of a coffee room , a waiting room, and an emergency door. There are five extinguishers in total in this zone.
- Zone B: This zone is composed of a reception room, a coffee room, stairs doors and enter door. There are totally five extinguishers and three emergency doors in this zone.
- Zone C: This zone is composed of an office room, WC, and two laboratories. There are totally six extinguishers and three emergency doors in this zone.

3.2 Choice of Simulation Platform

On the platform of the simulation, the model is developed on the simulation platform GAMA (Amouroux et al. 2007). GAMA provides a simulation development environment for building spatially explicit agent-based simulations. It enables: (i) to use arbitrarily complex GIS data as environments for the agents; (ii) to run simulations composed of vast numbers of agents; (iii) to conduct automated controlled experiments on various scenarios, with a systematic, guided or ‘‘intelligent’’ exploration of the space of parameters of models; and (iv) to let users interact with the agents in the course of the simulations.

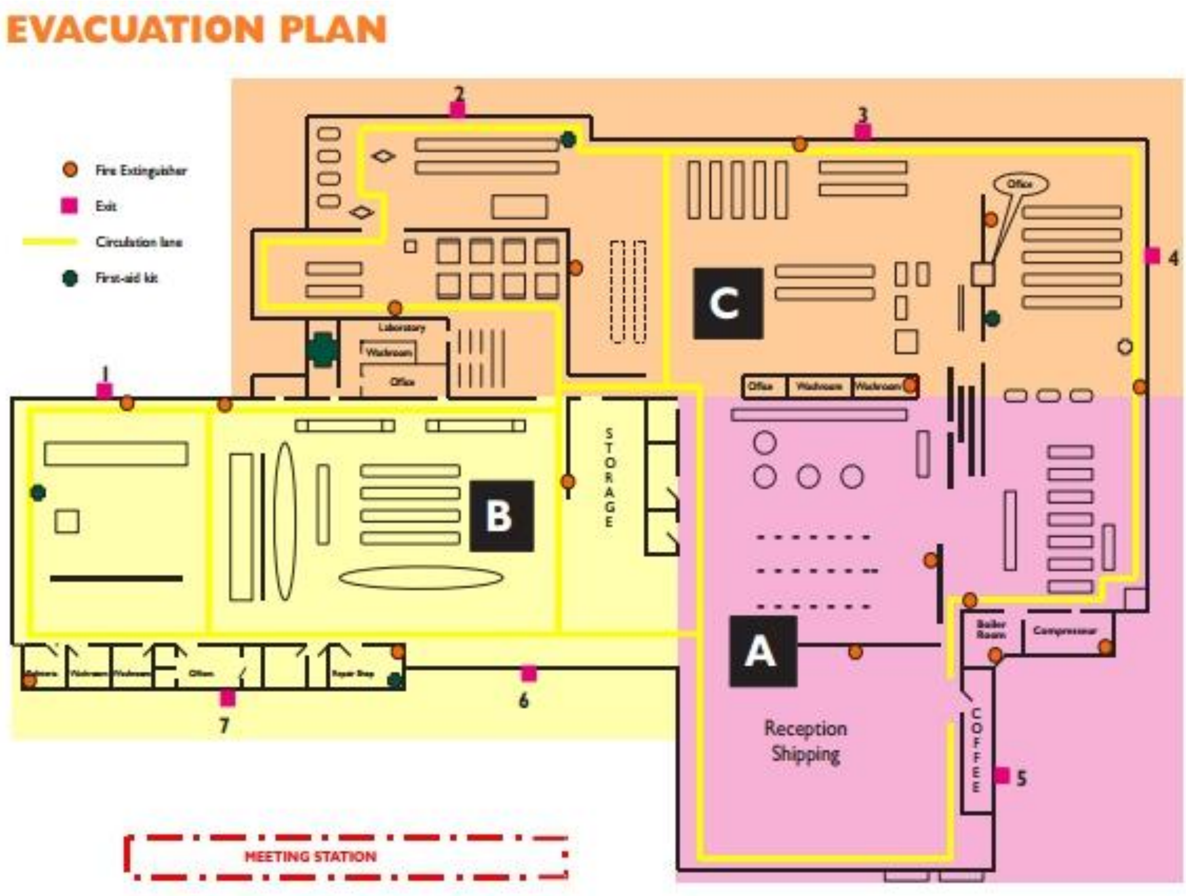

Fig. 2 Evacuation plan of the building based on Préventex's case study.

3.3 Results

3.3.1 Fire and smoke propagation in fighting against water

The propagation of fire/smoke against water/steam is visually presented in Figure 2. In which, fire/smoke agent is presented in gray cycles. Water/steam agent is presented in blue rectangles. The fighting rate of water:smoke is 2:1. It means that two water agents could kill a smoke agent.
The visualization results indicates that the smoke agent number is reduced near the position of water/steam agents.

3.3.2 Evolution of fire and smoke propagation

The evolution of fire/smoke against water/steam is presented in Figure 3: fire/smoke is represented in gray line; and water/steam is represented in blue line.
This simulation indicates that the fire/smoke occurs at the time 100 and grows up gradually. When the fire evacuation system detected the fire in the building, it kicks off the alarm system and the firefighter arrives. They start to puff of water/steam into fire/smoke (at the time 150), and then, the quantity of fire/smoke decreased when the number of water/steam increases (at the time 200). This tendency continues until the fire/smoke if totally eliminated and the firefighters stop their mission at the fire site.

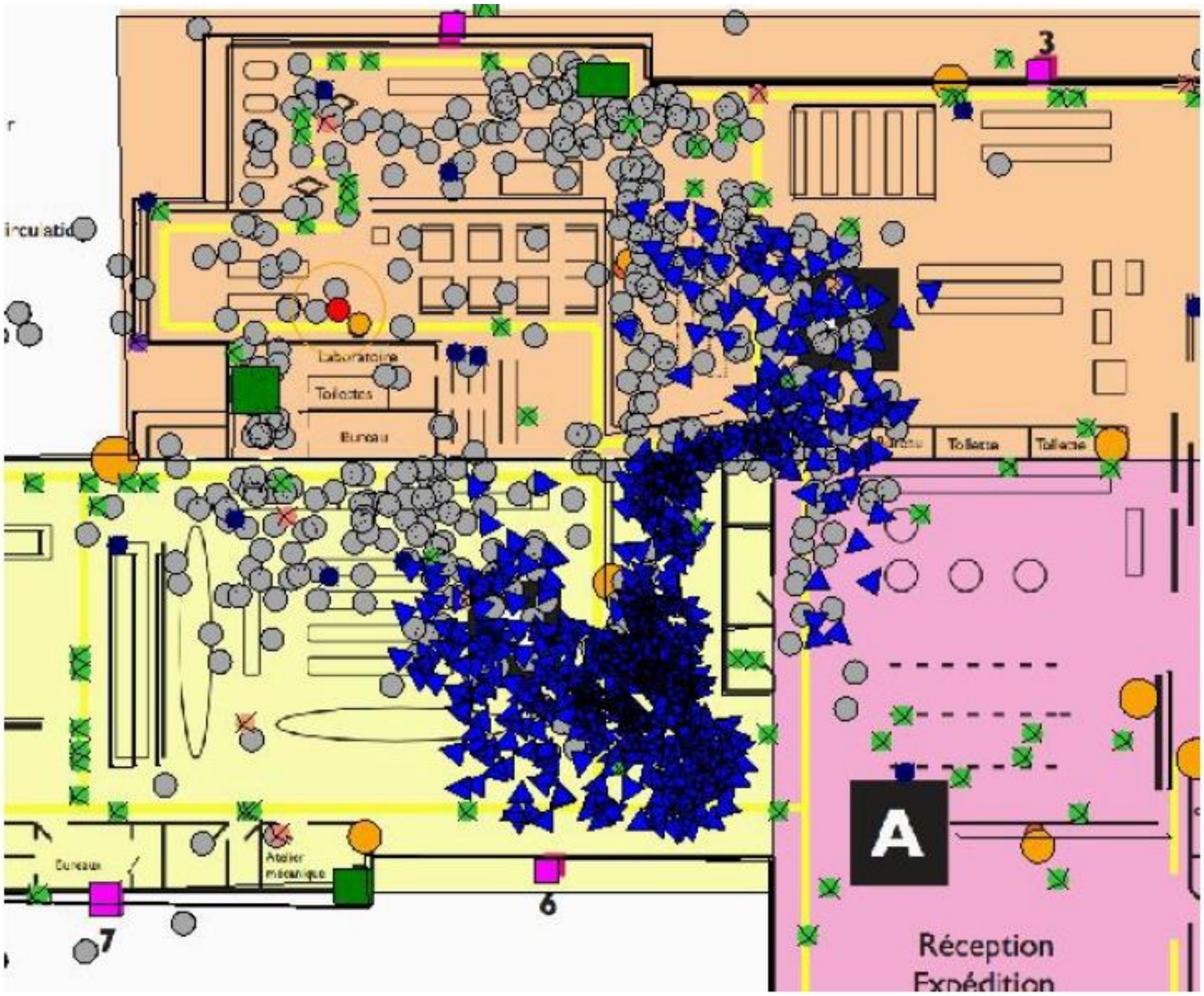

Fig. 3 Visualization of fire and smoke propagation against water.

3.3.3 Evolution of people objective during fire evacuation

We distinguish four kinds of people objective (or activity):

- Working: they are working (black line).
- Circulation lane: They are in the circulation lane to evacuate (yellow line).
- Emergency exit: They arrive at one of emergency exit. (matron line).
- Meeting station: They are safety at the meeting station (red line).

The evolution of the number of people in each activity is represented in Figure 5. At the beginning time (0-200), most of people is in their work. When the fire occurs and the alarm rings, people changes their behavior: they start to regroup in circulation lane to evacuate. So the number of people in circulation line increases. The number of people at emergency exits is proportionally related to the number of people in the circulation lines at previous time. Consequently, the number of escaped people (at the meeting station) increases until there is no more people inside the fire building.

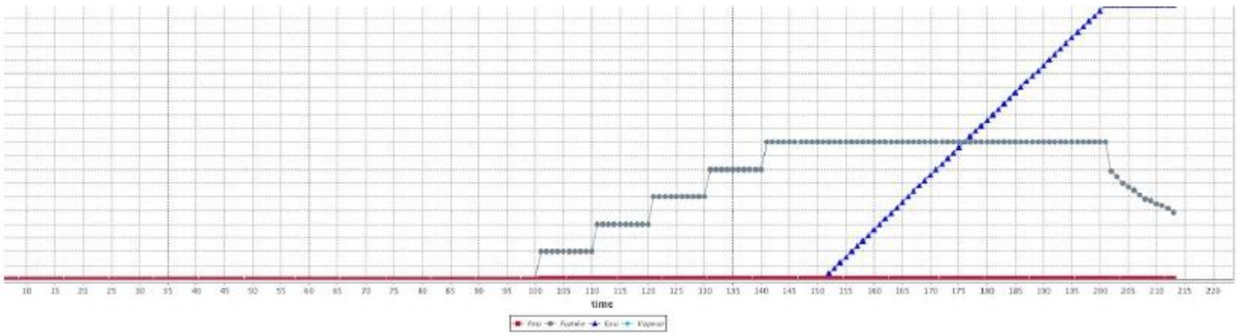

Fig. 4 Evolution of fire and smoke propagation.

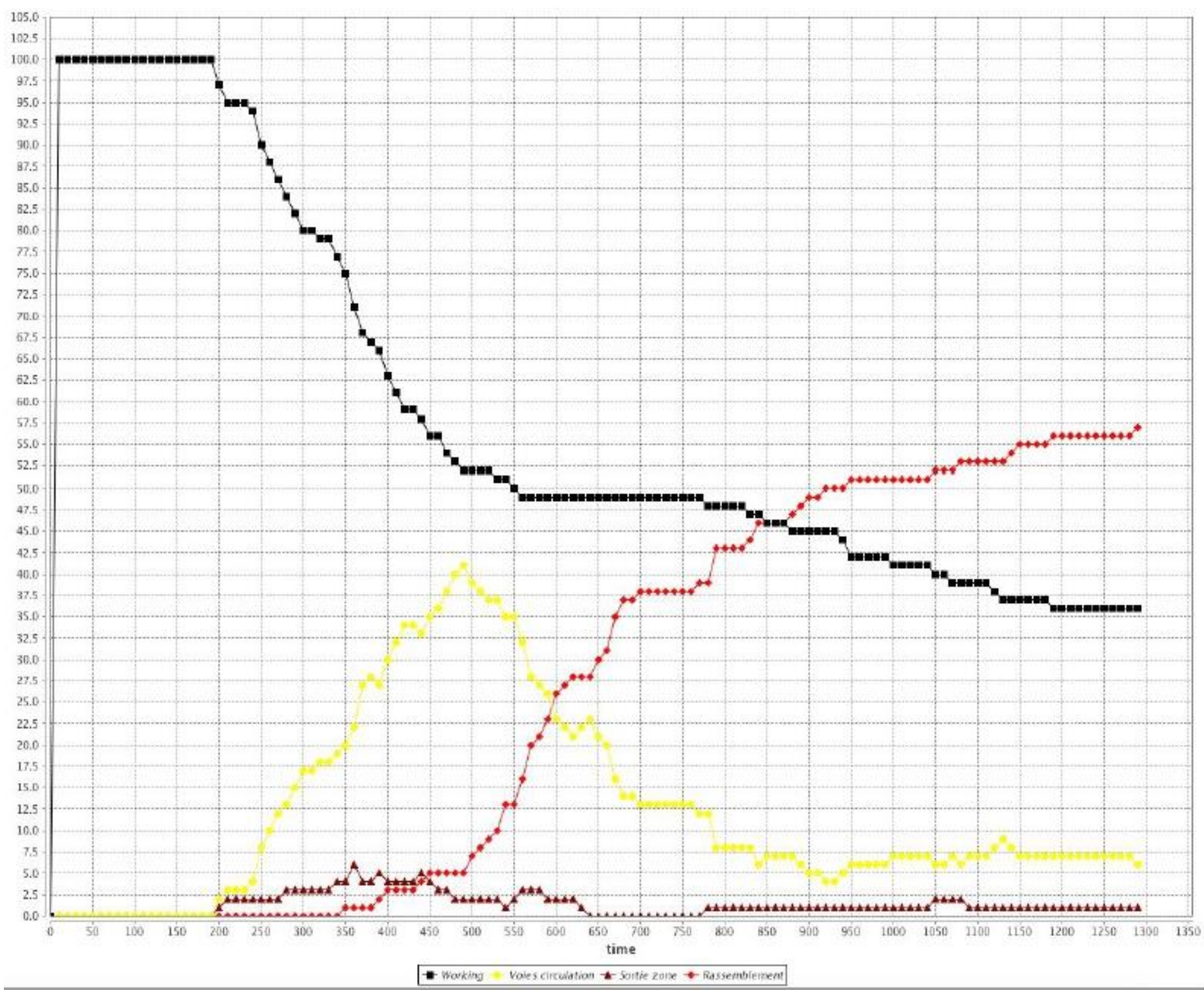

Fig. 5 Evolution of people objective during fire evacuation.

4. Conclusions

This paper presented an agent-based model for modeling and simulation of fire evacuation inside public building, called SEBES+ model. This model is an extension from the SEBES model by adding some new kinds of agent in the system: water or water steam agent to eliminate fire and/or smoke, extinguisher agent to generate water or carbon-dioxide to eliminate fire, fire fighter agent to use water and/or extinguisher to eliminate fire/smoke, to rout and help people in evacuating, etc.

The proposed model has been implemented in GAMA, an agent-based simulation platform and then, tested with some scenarios.

The validation and evaluation of the proposed model, and the testing of some new fire evacuation policy are some of our perspective works in the near future.

Acknowledgments

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