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Integration of Smoke Effect and Blind Evacuation Strategy (SEBES) within fire evacuation simulation

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ABSTRACT

Many fire evacuation models have been proposed in recent years to better simulate such as an emergency situation. However most of them do not respect a recommendation of fire evacuation experts regarding the fact that evacuees should follow the boundaries of obstacles or wall to find the exits when their visibility is limited by smoke. This paper presents an agent-based evacuation model with Smoke Effect and Blind Evacuation Strategy (SEBES) which respects that recommendation by integrating a model of smoke diffusion and its effect on the evacuee's visibility, speed, and evacuation strategy. The implementation of this model enables us to optimise the evacuation strategies taking into account the level of visibility. The obtained simulation results on a realistic model of the Metro supermarket of Hanoi confirm the important impact of smoke effect and blind evacuation strategy on the number of casualties.

1. Introduction

Fire is increasingly a cause of casualties in modern life. For instance, the Myojo 56 building fire in Tokyo (Japan) on September 1st 2001 has killed 44 people and 291 people killed in Mesa Redonda shopping center fire in Lima (Peru) on December 29th 2001. There were also 11 people who died in a fire at the detention center of Amsterdam Schiphol Airport (Netherlands) on October 27th 2005. The Moscow (Russian) hospital fire killed 46 people on December 9th 2006. The Santika Club fire in Bangkok (Thailand) killed 66 people on January 1st 2009. The ABC daycare center fire killed 47 people in Hermosillo (Mexico) on June 5th 2009. The 2010 Dhaka fire was a fire in the city of Dhaka (Bangladesh) on 3rd June 2010 that killed at least 117 people. And this list could infinitely grow up.

The huge loss in these fires leads to at least two important questions: (1) Were people trained to practice the best strategy to fire evacuate? and (2) Were the building designed with the best inside configuration regarding to fire evacuate? These two questions show common issues: how can we assess which strategy is best among the fire evacuation strategies? More specifically, given a particular building which strategy is the best one? The real answer does not exist unless we could experiment in the real environment! One truthful approach is to rely on simulation environment modelling as close as the real world fire evacuation conditions.

Once a fire evacuation simulation model is proposed, it has to comply with at least two modelling points of view. First, from the point of view of fire evacuation experts, the model should take into account the smoke diffusion and its effect on the evacuation, the observable range, the evacuation speed, and the toxic poisoning level of evacuees. In particular, it should

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respect the recommendation of these experts by modelling the movement of evacuees in a limited visibility condition with the strategy of tracking the wall or obstacles. Moreover, the proposed model should accommodate to the model different evacuation strategies in order to see which is the best suitable strategy for a given building. Second, from the point of view of building architecture designers, it should enable to apply with several realistic building evacuation plans (with GIS data) to see which is the best evacuation plan for a given building.

Our objective in this paper is to propose a model for fire evacuation simulation based on agents. This model does not only simulate the effects of fire/smoke on the abilities to move, to observe of evacuees, but also takes into account the given advise of fire evacuation experts, called Smoke Effect and Blind Evacuation Strategy (SEBES). We thus developed this model as a tool which could help fire evacuation training experts to visually demonstrate what evacuation strategy is better in a given environment. Our contribution is thus three-folds:

- First, a proposal of a new agent-based model for fire evacuation simulation is given. This model respects the recommendation of experts in fire evacuation by taking into account their recommendation that evacuees should follow the boundaries of obstacles or wall to find the exits when their visibility is limited due to the smoke.
- Second, an implementation of the proposed model based on an agent based integrated GIS support platform (GAMA [1]) supporting the development of an useful tool for two groups of users:
  - The first group is experts in fire evacuation. They could use this tool as a visual demonstration to illustrate what strategy is the best for evacuees to evacuate by applying all considered strategies into the model and run it, then compare the output parameters to see which is the best among them. This could lead their evacuation training courses to be more intuitive and convince. For instances, in the case study of the Metro supermarket of Hanoi, we compare three strategies of fire evacuation: following the evacuation signs, following the crowd, and following the own's path when evacuees could observe still, and following the boundaries of obstacles and/or wall when their visibility is limited. The simulation results show that following the evacuation signs is the best strategy in that situation.
  - The second group is building architects, constructors, interior designers, etc. They could use this tool to choose the best internal configuration of a given building regarding the effect in fire evacuation by applying their different designs into this model and run it, then compare the output parameters to see which is the best configuration.

This paper is organised as follows: Section 2 presents some related works in the field of crowd evacuation modelling and simulation. Section 3 presents our agent-based model including a Smoke Effect and Blind Evacuation Strategy (SEBES) module for fire evacuation simulation. Section 4 presents the application of our model to a real case study, including two types of scenario: scenarios comparing three bind evacuation strategies, and scenarios comparing three other evacuation strategies in normal condition. Finally Section 5 presents a discussion of the simulation results and some conclusions as well as a discussion about future research.

2. Related works

Recently, there has been an increasing number of models proposed for fire evacuation modelling in buildings. Table 1 summaries a partial collection of recent proposed agent models for fire evacuation. We consider models at two levels:

- At the level of modelling, we consider the modelling of agent types involving a fire evacuation: the evacuees (eV. – column), the group or crowd of evacuees (g/c – column), the fire (fi. – column), the alarm or voice system (a/v – column), and the smoke (sm. – column).
- At the level of optimisation, we consider the optimisation on the building design and the evacuation plan design (de. – column), the optimisation on evacuation strategies in normal condition (visible evacuation strategy – v.e column), and that in limited visibility condition (blind evacuation strategy – b.e column).

More detail, let us analyse at the level of modelling. Evacuee and fire are two objects modelled in most of the listed models. There is only a small number of models modelling the smoke [6,7,12,39]. In these smoke models, the authors took into account the fact that smoke affects the visibility and speed of evacuee. Furthermore, no model does respect a recommendation of fire evacuation experts on the fact that evacuees should follow the boundaries of obstacles or wall to find the exits when their visibility is limited by smoke.

At the level of optimisation, there are many models built to choose the best floor designs or evacuation plan for a given building [3,5,6,10,29,30,35,40]. There are also some models optimised evacuation strategies in normal (visible) condition [25,31,34]. But there is no model to optimise evacuation strategies in limited visibility condition. We do not aim to build a better model of existing over of all aspects but to focus on smoke modelling and taking into account expert recommendations;

Our model will model many kinds of agent: evacuee, fire, alarm, smoke, etc. in which the behaviour of evacuee is modelled based on a recommendation of fire evacuation experts on the fact that evacuees should follow the boundaries of obstacles or wall to find the exits when their visibility is limited by smoke. This enables us to optimise on many aspects: optimise the evacuation plans, optimise the evacuation strategies in both conditions: visible and invisible.