Evacuation Simulation Considering Fire Spread and Occupants Distribution

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Abstract. A fire simulator and an evacuation simulator are used separately to diagnose the safety of a large building. However, it is hard to diagnose the safety of a building using them, because they don't reflect the movement of pedestrian under fire. This study suggests an evacuation simulation considering the movement of pedestrians and fire spread. it applied the fire spread data of the fire dynamics simulator (FDS) to the floor field model (FFM) and models that a pedestrian recognizes a fire and takes a detour to a safe route. Simulations were performed under various scenarios and it was showed that the number of evacuees at each exit varied by the presence and location of fire as results.

Keywords. Indoor Evacuation, Floor field model, Simulation, FDS

1. Introduction

A fire simulator and an evacuation simulator are generally used independently to diagnose the safety of a large building in the situation of evaluation. An evacuation simulator is used to estimate the required safe egress time (RSET), which is the time required for people in the building to move to a safe location on foot. A fire simulator is used to calculate the available safe egress time (ASET) which is the time before the fire affects pedestrians. The safety of a building is diagnosed by comparing these two indices (Kim & Jeon 2015). However, it is difficult to accurately diagnose the safety of a building using a fire simulator and an evacuation simulator independently, because this method does not reflect on the movement of pedestrian under fire spreading situation.

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This study proposed an evacuation simulation considering fire spread and the movement of pedestrians simultaneously. The proposed evacuation simulation was based on coupling method describing evacuation of occupants while avoiding fire spread by combining the fire spread data of FDS (McGrattan et al. 2013), a fire simulator, with an FFM, a pedestrian model. We used IndoorGML data corresponding to the first floor of the actual campus building as the experimental space and placed occupants in experimental space by using occupants distribution data. Experiments were conducted on general condition and two fire conditions.

2. Methodology

2.1. Floor field model

FFM is a pedestrian model which models the micro-scale movement of pedestrian (Burstedde et al. 2001). FFM is based on a two-dimensional Cellular Automata model. An agent is located upon a cell and determines the movement by interacting with only eight cells around itself. Factors affecting the movement of agent are presented in the form of a floor field which is constructed by cells. Representative floor fields in FFM are static floor field (SFF) which shows the distance to the exit and dynamic floor field (DFF) which shows the influence of other agents. An agent determines the next cell to move by calculating the SFF and DFF values of surrounding cells at each time step.

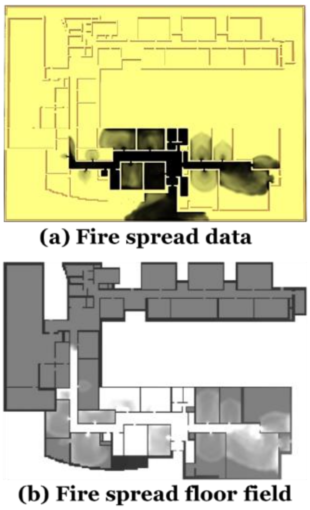


Figure 1. Fire spread in FDS and FFM

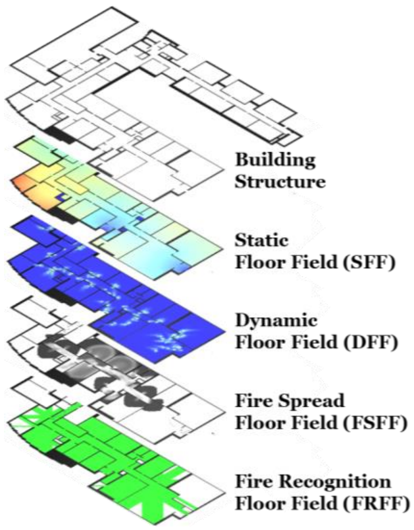


Figure 2. Structure of the improved FFM

This study proposed the improved FFM by adding a fire spread floor field (FSFF) and a fire recognition floor field (FRFF). Fire spread data are calculated by FDS and they store heat, density of smoke and field of view in seconds. FSFF is generated from fire spread data and refers to the fire spread at certain height. FSFF is updated every second to describe fire spread. Figure 1 (a) shows a fire spread data in FDS and (b) shows FSFF in FFM.

Although FSFF visualizes fire spread, agent can't realize fire before the fire arrives in eight adjacent cells. Therefore, this study made FRFF, which refer a space where agents can visually identify fire. FRFF is generated by the expansion of field to the eight-way directions from cell where heat and smoke exist in FSFF. Expansion of field on each direction proceeds only for the walkable cells and it ends when an unwalkable cell appears. When FSFF is renewed every second, FRFF is renewed through the above processes. *Figure 2* shows the structure of the improved FFM including FSFF and FRFF.

2.2. Detour algorithm

In the improved FFM, agents entering FRFF take a detour to avoid the effects of fire. The detour algorithm describes process of exit selection in the graph data structure of IndoorGML. The graph data forms a hierarchical relationship with cell data. The space is divided into subdivisions and each subdivision becomes a node. The edge means connectivity between nodes and stores the distance between nodes. When fire breaks out, the edge stores the distance along with risk weight. For risk weight, edge belonging to FRFF has W and edge belonging to FSFF has W^2. The value saved in edge is evacuation cost and it is renewed along with spread of fire. *Figure 3 (a)* shows graph data in normal and *(b)* shows graph data when fire exists. When an agent enters FRFF, a detour to the exit with minimum evacuation cost is calculated by Dijkstra algorithm.

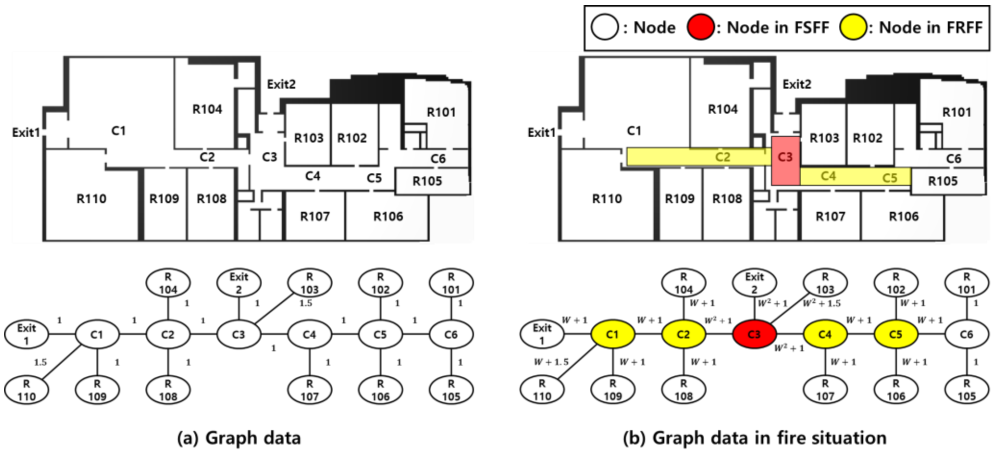


Figure 3. Graph data in normal and fire situation

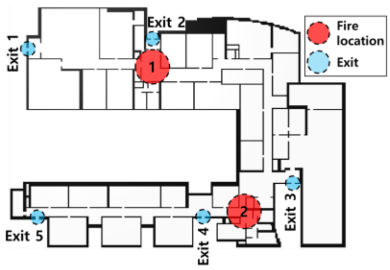
2.3. Occupants Distribution

In this study, occupants distribution located in the actual building was counted and used as agents distribution for the evacuation simulations. This study divided space into subdivisions based on graph data of IndoorGML and installed people counting sensors on the entrance of subdivision spaces. Sensors collect occupants distribution data by checking people's accesses. *Figure 4 (a)* shows subdivision spaces of the experimental space and *(b)* are infrared beam type people counting sensors.

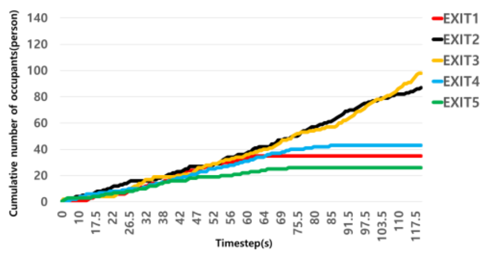
(a) Subdivision spaces

(b) People counting sensors

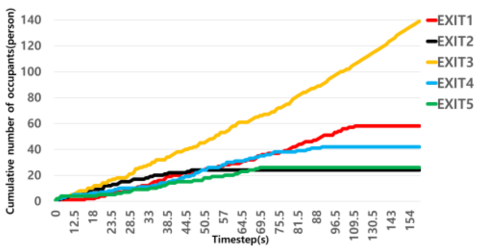
Figure 4. Subdivision spaces and people counting sensors



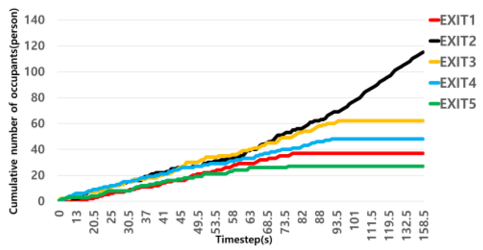
(a) Simulation environment with fire location



(b) Situation 1: Evacuation without a fire



(c) Situation 2: Evacuation when a fire initiated at location 1



(d) Situation 3: Evacuation when a fire initiated at location 2

Figure 5. Simulation environment and results of evacuation simulation

3. Evacuation simulation suing EgresSIM

Evacuation simulations were performed by using EgresSIM (Nam et al. 2016), a cellular automata-based evacuation simulator. The 21st century building, on the University of Seoul, served as the site for simulations. *Figure 5 (a)* is the IndoorGML data corresponding to first floor of the 21st century building. Agents were placed by occupants distribution data obtained from sensors in an experimental space. Simulations were conducted under three scenarios. Scenario 1 was a case without a fire. Scenario 2 was when a fire initiated at location #1 on *Figure 5 (a)*. Scenario 3 was when a fire initiated at location #2 on *Figure 5 (a)*. Results of simulation are shown as *Figure 5 (b), (c), (d)*. Graphs in *Figure5* mean cumulative number of occupants per exit by time.

4. Conclusion

In this study, an evacuation simulation is proposed considering fire spread and pedestrian movement simultaneously by using FFM and FDS. Simulations were performed under various scenarios by using EgresSIM. When the results of simulation were compared, the number of evacuees at each exit varied a lot due to the detour of agents and the evacuation time of each exit clearly increased or decreased. If the evacuation simulation relates to real-time occupants distribution data, it is expected that evacuation simulation can be applied to real-time evacuation route planning.

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