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Evacuation Simulation in University Buildings using Multiagent System

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Abstract—In this paper, we propose an evacuation simulation in university buildings using multiagent system. In the proposed system, two cases (a) classroom hours and (b) outside classroom hours are considered. In the simulation, each agent recognizes the environment and decides own escape route using the Dijkstra method, and moves to the entrance of the building. Based on the behavior of agents, the average time for escape, the maximum time for escape, the rate of the agents who can escape to the entrance in the limited time, the average speed, and coordinates of agents are output. We carried out a series of computer experiments in order to demonstrate the effectiveness of the proposed system and confirmed that the proposed system can realize evacuation simulation.

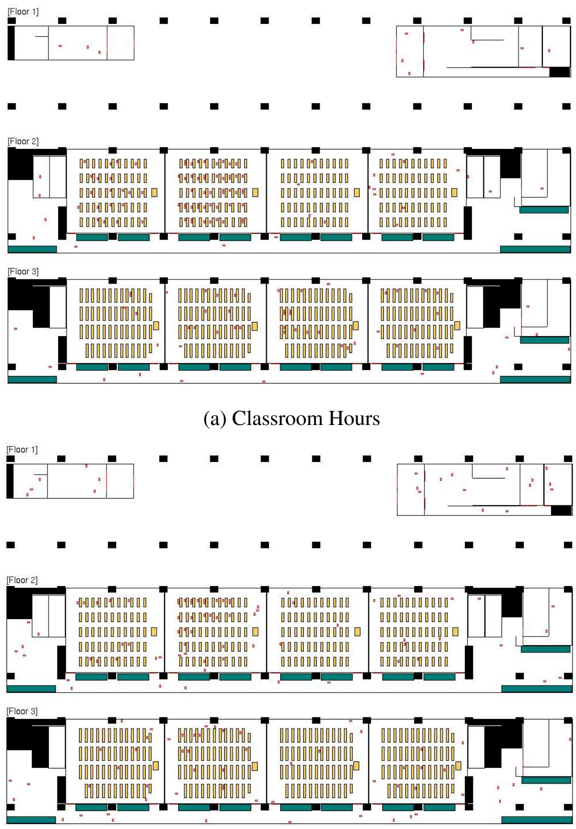
1. Introduction

Recently, we have proposed the office layout plan evaluation system using evacuation simulation with communication among agents[1][2]. In this system, the office layout plan generated by the office layout support system using genetic algorithm[3][4] and the conditions for agents are given, and then the agents move under the conditions. Based on the behavior of agents, the evaluation on the maximum time for escape, average speed, the number of agents who could not reach entrance and so on are carried out. Although this system can realize the evacuation simulation in the office which has only one floor, it can not realize the evacuation simulation in the building which has plural floors.

In this paper, we propose the evacuation simulation in university buildings using multiagent system. In the proposed system, two cases (a) classroom hours and (b) outside classroom hours are considered. In the simulation, each agent recognizes the environment and decides own escape route using the Dijkstra method[5], and moves to the entrance of the building. Based on the behavior of agents, the average time for escape, the maximum time for escape, the rate of the agents who can escape to the entrance in the limited time, the average speed, and coordinates of agents are output.

2. Evacuation Simulation using Multiagent System

Here, we explain the proposed evacuation simulation in the university buildings using multiagent system.



(b) Outside Classroom Hours

Figure 1: An Example of Initial Position of Agents.

2.1. Initial Setting

(1) Initial Position of Agents

In the proposed system, two cases (a) classroom hours and (b) outside classroom hours are considered. In the simulation which assumes the classroom hours, most of agents are assigned in front of the desk of the classroom. In the contrast, in the simulation which assumes outside classroom hours, the agents are assigned randomly.

(2) Impassable Space/Space Where It Is Hard to Pass

In the proposed system, impassable spaces and spaces where they are hard to pass are generated randomly. The number of the these spaces is determined randomly based on the floor size. And the positions of these spaces are determined randomly, and each area is set as the square

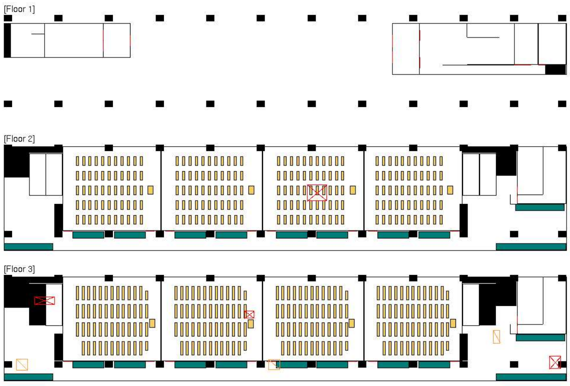


Figure 2: Impassable Spaces/Spaces Where They Are Hard to Pass.

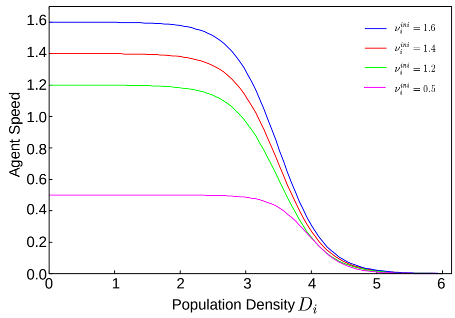


Figure 3: Relation between Population Density and Agent Speed.

whose length of each side takes 1~3(m).

Figure 2 shows an example of impassable spaces and spaces where they are hard to pass.

2.2. Evacuation Simulation

The action of agents can be divided into the following three cases.

(1) Recognition of Environment

(2) Decision of Escape Route

(3) Movement

(1) Agent Speed

The speed of each agent is determined based on the population density. In the proposed system, based on the population density, the following three cases are considered.

(a) Normal Area ($D_i < 1.5$)

(b) Crowd Walking Area ($1.5 \leq D_i < 6.0$)

(c) Difficulty Walking Area ($6.0 \leq D_i$)

where D_i is the population density around the agent i.

The speed of the agent i, v_i is given by

$$v_i = \begin{cases} \left(\dfrac{1.0}{1.0 + \exp((D_i - a_{v1})/\varepsilon_{v1})}\right) v_i^{ini}, & (v_i^{ini} = 0.5) \\ \left(\dfrac{1.0}{1.0 + \exp((D_i - a_{v2})/\varepsilon_{v2})}\right) v_i^{ini}, & (\text{otherwise}) \end{cases} \quad (1)$$

where v_i^{ini} is the speed in the normal area, a_{v1}, a_{v2}, ε_{v1} and ε_{v2} are the coefficients. In the proposed system, v_i^{ini} is set to $1.4 \pm 0.2 (m/s)$ randomly. And, the agent who is in the space where it is hard to pass is assumed as an injured agent, and its speed v_i^{ini} is set to $0.5(m/s)$. In Eq.(1), a_{v1} is set to 3.95, a_{v2} is set to 3.5, ε_{v1} is set to 0.29, and ε_{v2} is set to 0.35.

The speed of the agent i in the space where it is hard to pass v_i^D is given by

$$v_{max}^D = \begin{cases} v_{max}^D, & (v_{max}^D < v_i) \\ v_i, & (\text{otherwise}) \end{cases} \quad (2)$$

where v_{max}^D is the maximum speed in the space where it is hard to pass.

Figure 3 shows the relation between the population density and the agent speed.

(2) Recognition of Environment

In the proposed system, each agent can see 360-degree views, and can obtain the information on impassable spaces and spaces where they are hard to pass.

(3) Decision of Escape Route

(3-1) Information

In this system, agents decide own escape route based on the information about (a) layout, (b) impassable spaces and (c) spaces where they are hard to pass. In the proposed system, each agent is a student. So, each agent knows the layout such as the position of room and furniture.

(3-2) Path Candidates

In the proposed system, nodes (Fig.4(a)) and path candidates (Fig.4(b)) are set on the floor.

(3-3) Route Decision

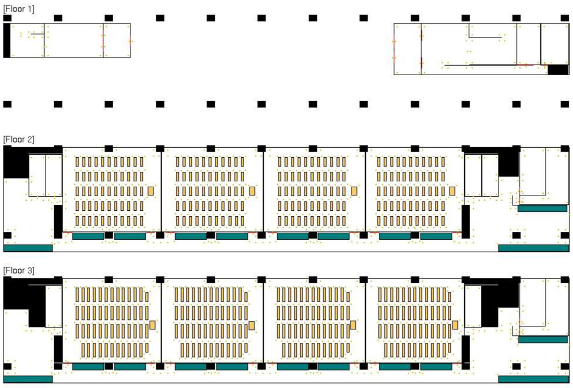
The agent decides own route to the entrance by the Dijkstra method[5] considering the information on impassable spaces and spaces where they are hard to pass. The agent i uses the costs from node n_1 to n_2 ($d_{n_1 n_2}^i$) in the Dijkstra method.

The cost from the node n_1 to the node n_2 for the agent i, $d_{n_1 n_2}^i$ is given by

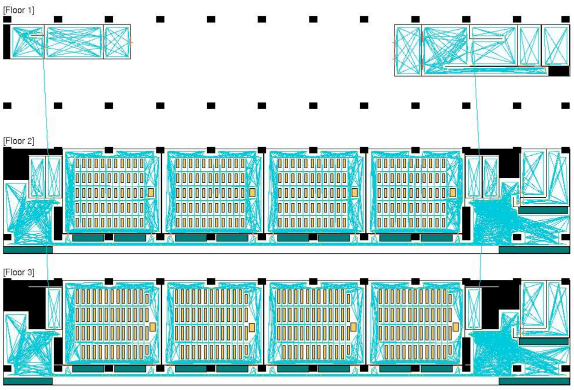
$$d_{n_1 n_2}^i = \begin{cases} \infty, & \text{(There is impassable space on the path between the nodes } n_1 \text{ and } n_2.) \\ \alpha d_{n_1 n_2}, & \text{(There is space where is hard to pass on the path between the nodes } n_1 \text{ and } n_2.) \\ d_{n_1 n_2}, & \text{(otherwise)} \end{cases} \quad (3)$$

where $d_{n_1 n_2}$ is the distance between the node n_1 and the node n_2 and α ($1 < \alpha$) is the coefficient. In Eq.(3), the cost is set to ∞ when there is an impassable space on the path between the nodes n_1 and n_2, because agents can not move on the path between the nodes n_1 and n_2.

Each agent decides the escape route to the steps to the downstairs or the entrance of the building. If there are plural steps to the downstairs or the entrance, each agent selects the shortest route from all routes. If there is no route to the downstairs, the agent searches to the route to the up-



(a) Setting of Nodes



(b) Path Candidates

Figure 4: An Example of Path Candidates.

stairs. If the agent can not find any route to the downstairs, the upstairs or the entrance, it gives up to find the escape route and stops there.

2.3. System Output

The following four items are output based on the movement of the agents in the proposed system.

(1) Time for Escape

(a) Average Time for Escape

In the proposed system, the average time for escape $E_{ave-time}$ is calculated as follows.

$$E_{ave-time} = \frac{\sum_{i \in C_{escape}} T_i}{N_{escape}} \tag{4}$$

where C_{escape} is the set of the agents who can reach the entrance, N_{escape} is the number of the agents who can reach the entrance, and T_i is the time for escape of the agent i.

(b) Maximum Time for Escape

The maximum time for escape $E_{last-time}$ is calculated as follows.

$$E_{last-time} = \max_{i \in C_{escape}} T_i \tag{5}$$

(2) Rate of Agents Who Can Escape in Limited Time

The rate of the agents who can escape to the entrance in the limited time $E_{escape-rate}$ is given by

$$E_{escape-rate} = \frac{N_{escape2}}{N_{all}} \tag{6}$$

where $N_{escape2}$ is the number of agents who can escape in the limited time, and N_{all} the number of all agents.

(3) Average Speed

The average speed $E_{ave-speed}$ is calculated by

$$E_{ave-speed} = \frac{\frac{\sum_{i \in C_{escape}} D_i}{N_{escape}}}{E_{ave-time}} = \frac{\sum_{i \in C_{escape}} D_i}{\sum_{i \in C_{escape}} T_i} \tag{7}$$

where D_i is the distance of the escape route of the agent i.

(4) Coordinates of Agents

The coordinates of each agent are output to the file.

3. Computer Experiment Results

In this section, we show the computer experiment results to demonstrate the effectiveness of the proposed system. In this experiment, the layout shown in Fig.1 was used.

We examined in three conditions (1) Classroom Hour (a) (2) Classroom Hour (b) and (3) Outside Classroom Hour. In the conditions (1) and (2), 98 agents were set in the building (See Table 1). And in the condition (3), 117 agents were set in the building.

3.1. Time for Escape

(a) Average Time for Escape

Table 2 shows the average time for escape. As shown in this table, the average time for escape is almost same in the conditions (1)~(3). Strictly speaking, the average time for escape in the classroom hours is longer than that in the condition (3) (outside classroom hours). This is because the agents concentrate around the door of the classroom.

(b) Maximum Time for Escape

Table 3 shows the maximum time for escape. As shown in Table 3, the maximum time for escape in the third trial is

Table 1: The Number of Agents in Each Room.

Condition (1) (Classroom Hour (a))

Room No.	1	2	3	4
2nd Floor	30	0	0	30
3rd Floor	0	30	0	0

Condition (2) (Classroom Hour (b))

Room No.	1	2	3	4
2nd Floor	30	30	0	0
3rd Floor	30	0	0	0

Table 2: Average Time for Escape.

	1st Trial	2nd Trial	3rd Trial
Condition (1)	48.33	48.40	49.89
Condition (2)	46.94	46.77	47.18
Condition (3)	42.00	41.01	44.32

[sec]

Table 3: Maximum Time for Escape.

	1st Trial	2nd Trial	3rd Trial
Condition (1)	72	79	140
Condition (2)	68	64	120
Condition (3)	83	79	143

[sec]

longer than the other two trials. This is because that some agents were set in the space where it is hard to pass, so the speed of these agents were set to $0.5(m/s)$.

3.2. Rate of Agents Who Can Escape in Limited Time

Table 4 shows the rate of the agents who can escape in the limited time (300 steps (= 5 minutes)). As shown in Table 4, in most of the simulations, all agents could escape in the limited time. In the cases where some agents could not escape in the limited time, those agents were set in impassable spaces.

3.3. Average Speed

Table 5 shows the average speed. As shown in Table 5, the average speed is almost same in all conditions.

3.4. Agents in Evacuation Simulation

Figure 5 shows the agents in the first trial of the condition (2). In this figure, agents (red square) move to the steps to the downstairs.

4. Conclusion

In this paper, we have proposed the evacuation simulation in university buildings using multiagent system. In the proposed system, two cases (a) classroom hours and (b) outside classroom hours are considered. In the simulation, each agent recognizes the environment and decides own escape route using the Dijkstra method, and moves to the entrance of the building. Based on the behavior of agents, the average time for escape, the maximum time for escape, the rate of the agents who can escape to the entrance in the limited time, the average speed, and coordinates of agents are output. We carried out a series of computer experiments in order to demonstrate the effectiveness of the proposed system and confirmed that the proposed system can realize evacuation simulation.

Table 4: Rate of Agents Who Can Escape in Limited Time.

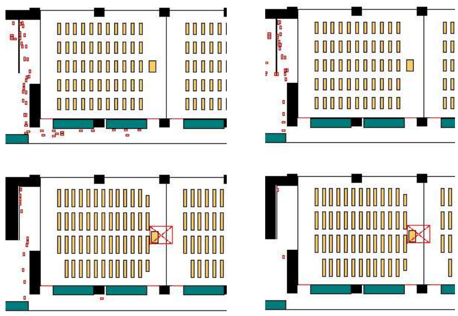
	1st Trial	2nd Trial	3rd Trial
Condition (1)	100	100	100
Condition (2)	97.96	100	100
Condition (3)	100	99.15	99.15

[%]

Table 5: Average Speed.

	1st Trial	2nd Trial	3rd Trial
Condition (1)	1.41	1.39	1.39
Condition (2)	1.41	1.40	1.39
Condition (3)	1.41	1.41	1.37

[m/sec]



(a) 20th Step (b) 30th Step

Figure 5: Agents in 1st Trial of Condition (2).

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