AN AGENT-BASED SIMULATION MODEL OF EVACUATION IN A SUBWAY STATION

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Abstract: The purpose of this study is to build an agent based simulation model of evacuation behaviors at platforms in a subway station in order to mitigate the damage when a disaster occurs. To accomplish this purpose, we need to understand subway passengers' behaviors. It is difficult to reenact the scene of disasters and evacuation drills spend too much time and money to conduct them often. So we model a subway station platform as a complex adaptive system on a personal computer. Feature of research is that we consider the influence of smoke on the evacuee's range of vision and walking speed. Using an agent-based framework which can express several characteristics of evacuee's type such as young/old persons, we construct and simulate the model of evacuee's behaviors more realistically than earlier studies.

Keywords: Agent-based approach, evacuation model, Multi-agent simulation, pedestrian, crowd dynamics

1 Introduction

Tokyo's subway is one of the major transportation means and a lot of people use it every day. So it is important to plan countermeasures for subway safety. Earthquakes, fire and terrorism are main danger to subway. Japan has frequent earthquakes and it is often said there will be a great earthquake in the near future. A great earthquake hit Hanshin-Awaji (Kobe) January 17, 1995 and we realized the danger of fires after the earthquake. In addition, Feb. 2003, a catastrophic accident happened at subway in Desion South Korea. In this case, one of the factors enlarging the damage was smoke from a fire. Smoke extended rapidly, so evacuees had a limited view of evacuation route. Such a fire may break out at other subway stations when a great earthquake or other types of disasters break out.

The purpose of this study is to build an agent based simulation model of evacuation behaviors at platforms in a subway station in order to mitigate the damage when a disaster occur. To accomplish this purpose, we need to understand subway passengers' behaviors. It is difficult to reenact the scene of a disaster, and evacuation drills spend too much time and money to conduct them often. So we model a subway station platform as a complex adaptive system on a personal computer.

The components of this model are (I) group of evacuee, (II) passage, (III) stairs, (IV) evacuation sign board, (V) smoke, (VI) exit. (See Figure1 and 2).

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2 Research approach

2.1 KK-MAS

In this research, we use KK-MAS (Multi-Agent Simulator) developed by KOZO KEIKAKU ENGINEERING Inc. Innovative Information Technology Dept. KK-MAS is a tool to understand for "Complex system" and "multi agent model”, like Swarm (Santa Fe Institute) or StarLogo (The MIT Media Laboratory). A feature of this simulator is VBA (Visual Basic for Application) based language.

2.2 Intended Space

We construct our model based on a real subway station and express it by KK-MAS (See Picture 1 and Figure 1). In this research, we choose a subway station in Tokyo and construct our model from its arrangement of station premise. This station's characteristics are as follows.

1. It consists of three basements in the underground.
2. The second basement is one side home for the going uptown.
3. The third basement in the underground is one side home for the going downtown.
4. The examination of tickets is set up by the first basement in the underground.

This station has a good view of platform because of the platform doesn't include station stalls/ kiosks etc. which cause walking obstruction and narrowing view.

Picture 1 Snapshot of the base of our model

Figure1 represents the third basement of the subway station, which consists of a platform, an underground passageway, pillars and stairs. One cell is equivalent to 50cm.The platform is 4m×120m so we expressed them by 8 cells ×240 cells. The stairs connect the third basement to the second basement. In this station, the second basement is a platform of up-train and the third basement is down train. This means that track line is one side only in each basement. The examination of tickets is set up respectively near the stairs in the first basement in underground. The width of the stairs is 2.5m. The stairs part was expressed by 10 cells × 5 cells.

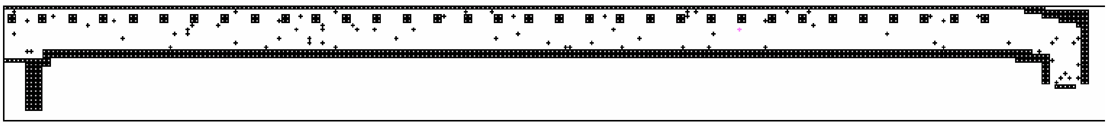


Figure 1 Third basement

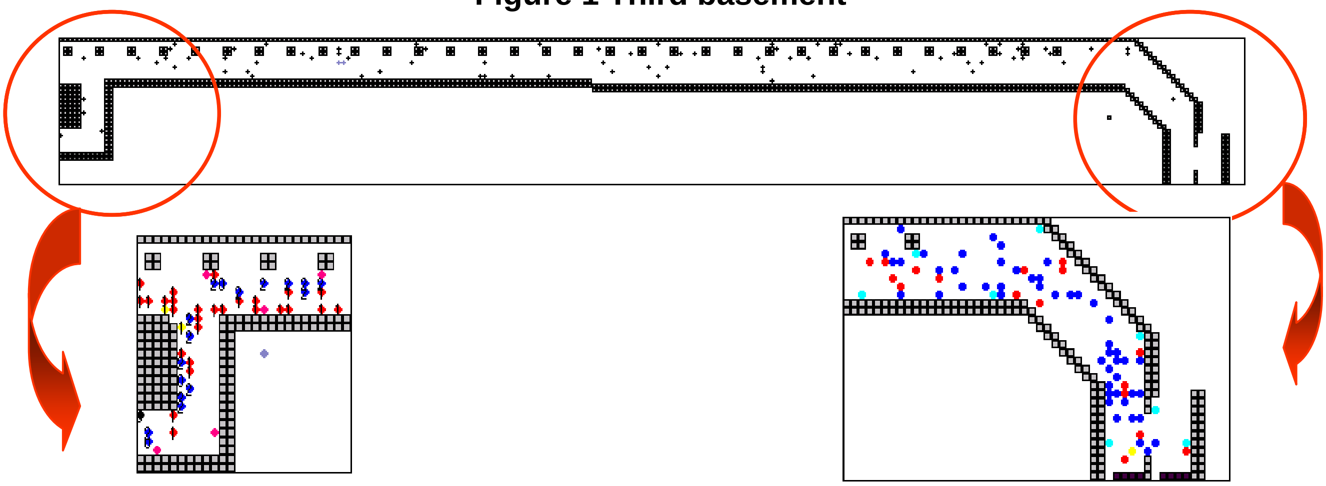


Figure 2 Second basement and enlarged illustration of the second basement exits

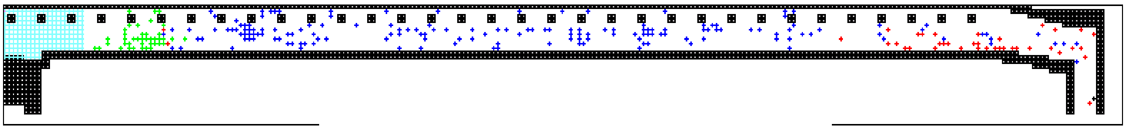


Fig.3 Output screen with smoke

In Figure 3, smoke (light blue part) has been generated from left side. Green, blue and red points show evacuee agents respectively. Blue agent is initial (no informed) state. If a blue agent recognizes smoke, (s)he changes from blue into green. Red agent means (s)he gained information from sign.

3 Evacuation model

3.1 Component

The components of this model are (I) group of evacuee, (II) passage, (III) stairs, (IV) evacuation sign board, (V) smoke, (VI) exit.

(I) group of evacuee : When agents find smoke during walking on the platform, they perceive danger and act evacuation behavior. Evacuee agents are searching surroundings autonomously at the start of escape, and decide the destination. When agents recognize evacuation sign board, they acquire information from it and change their behavior, that means (s)he know the shortest route for an exit and go straight to the exit. When crowd density exceeds a certain degree or agents go up/down the stairs, they change walking speed more slowly. (II) passage: Passage is the room where agents can move. (III) stairs: Stairs are places where the evacuee agents move from the third basement in the underground to the first and the second basement.

(IV) Evacuation sign board gives the evacuee information to the exit. There are two type of evacuation sign board at subway site, but in this research, the sign that displays one side is adopted (see Figure 4-1).

Figure 4-1 Evacuation sign board（one-way）

Figure 4-2 （two-way）

(VI) exit; Exit is evacuee agent's final destination and when evacuees reaches this place, evacuate is completed.

3.2 Time and agent' walking speed

One step is equal to 0.4 seconds. In this case, average moving distance of one second becomes 1.25m. Incidentally, free walking speed is at least 0.75m/second, so this value is included within the range. Evacuee agents come to have a narrow view when they enter in smoke and their moving speed become to slow. When evacuee agents existed in the other evacuee agent's view, that agent follows after the other one. Moving speed change from 1.25 m/s to 0.5m/s.

This simulation model considers crowd density and agent’s walking speed. The number of agents in neighborhood1 in Figure 6 links to agent’s walking speed and its speed was fixed considering Figure 5. We wrap up them as Table1.

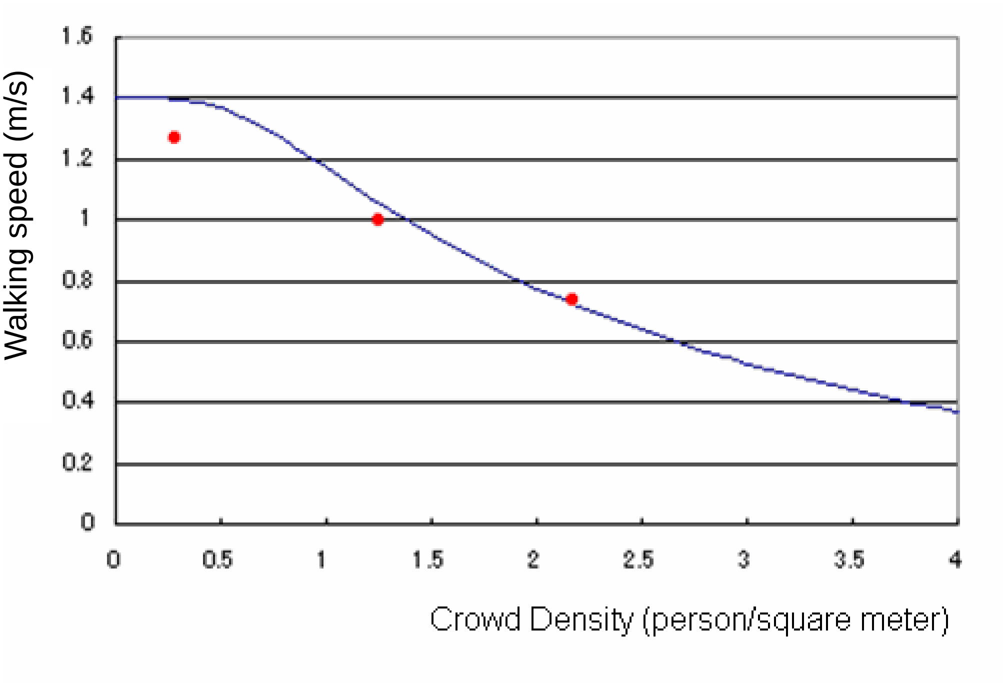


Figure 5 Relation between crowd density and walking speed

Table1. Agent’s walking speed

Congestion degree or where agent is?	Walking speed (m/s)
One or two agents in neighborhood1	1.25
Three or four agents	1.00
Five or six agents	0.75
Seven or eight agents	0.50
In stairs	0.50
In smoke	0.375 - 0.50

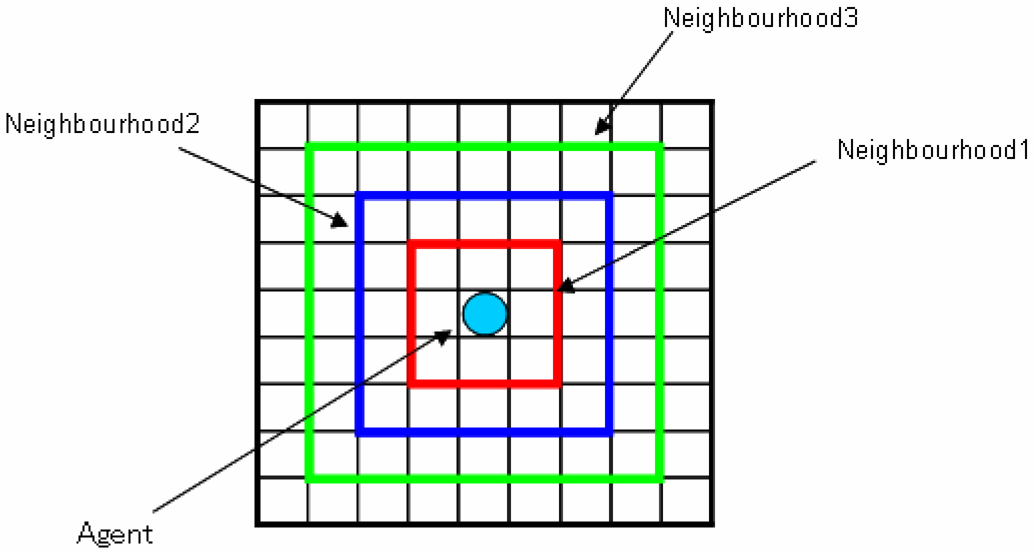


Figure 6 Definition of neighborhoods of agent

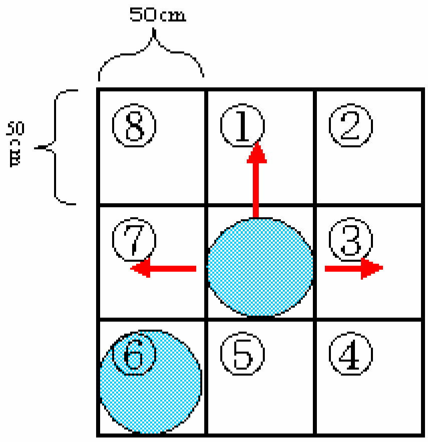


Figure 7 Migratable cells of agent

If agent faces direction of 1 in Figure 7, migratable cells of the agent is 1, 3 or 7 (red arrows direction).

3.3 Destination setting algorithm

In initialization phase, agents walk in an ordinary way. But as it has already described, when agents observe smoke from fire, evacuee agents observe their surroundings to begin to evacuate, and decides the destination. We show the algorithm in Figure 8.

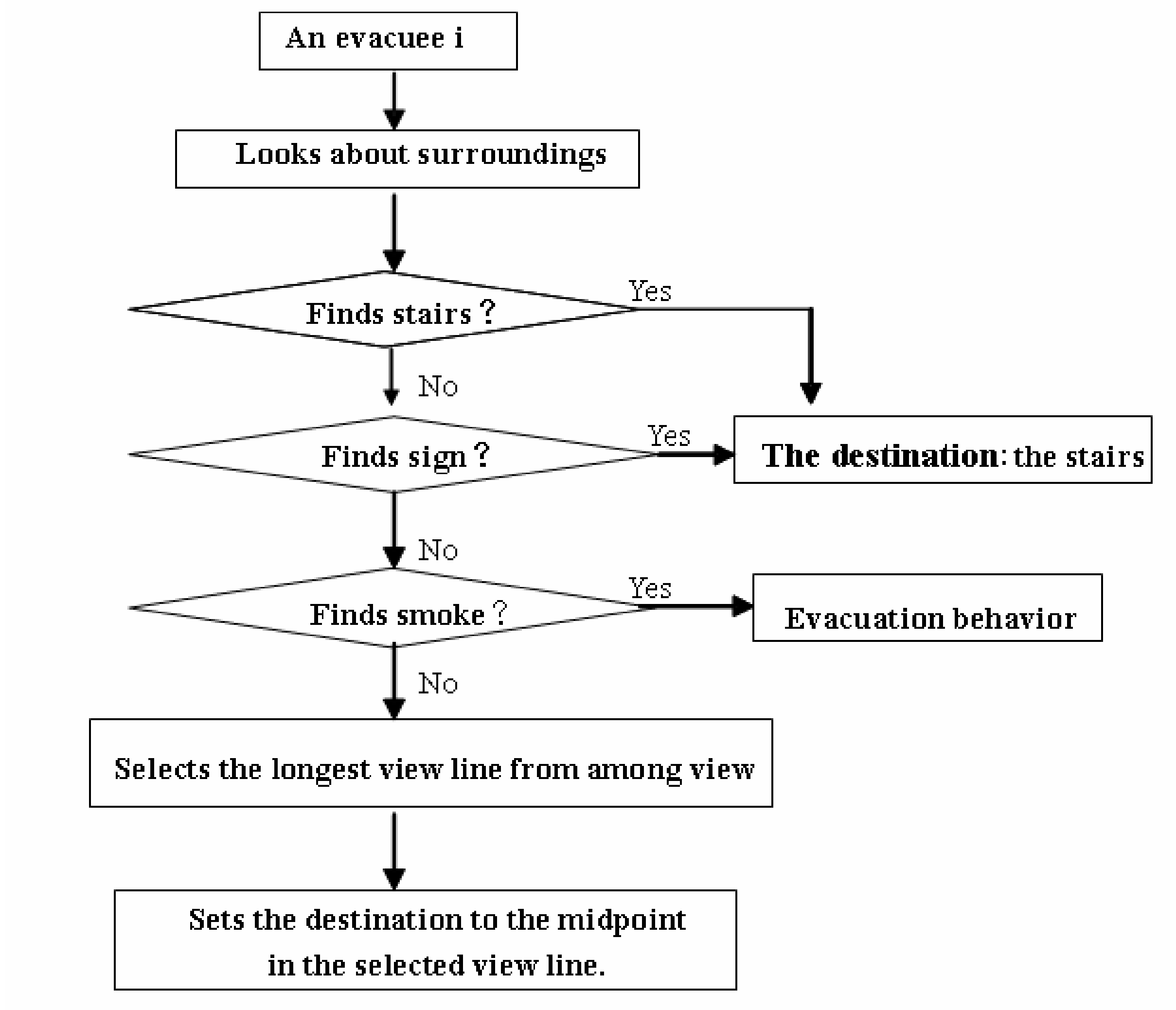


Figure 8 Setting of the destination

When the evacuee agent faces 1, the view line is extended in the direction at which the agent is looking as shown in Figure 9. Agent extends his/her view scope for every one cell, and the agent examine whether there is a passage. When obstacles such as walls exist etc., the search for the direction is stopped and the following direction 3,5, 13 and 15 are examined. The evacuee agent sets the midpoint which is the longest cells of 1 to 15 to the destination. The evacuee agent sets the destination to the midpoint which is the longest cells in the selected view line of 1, 3, 5, 13, 15. The maximum view is set up to 27m. This maximum view can be changed depending on scenarios. When agents discover stairs, the stairs are set to the destination (See Figure 8).

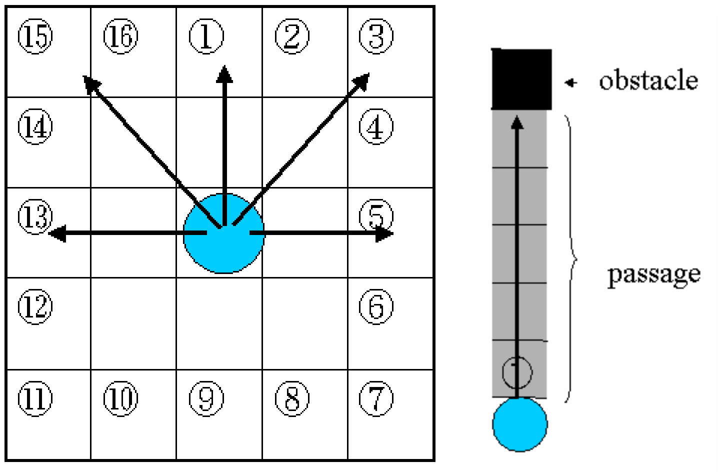


Figure 9 Order of search (Arrow means agent's direction of movement)

3.4 Evacuation algorithm

In case of emergency, people tend to set the short-range objective and to act. For example, people turn in the opposite direction of smoke or follow after other persons, without confirming whether the action is safe. We give thought to above evacuation characteristic features and build them into program algorithm. For instance, when evacuation sign board came into agent's view, information on the stairs place is acquired and the agent advances to the stairs by the shortest route. Information on smoke and stairs position information is passed on to other evacuees when they are coming in the evacuating agent view. And it is possible to give information to evacuee by broadcasting in the subway station.

When a sign enters within 2.5m of an evacuation agent's view scope, the agent obtains the shortest route guidance information to the exit and behaves to the evacuation action immediately.

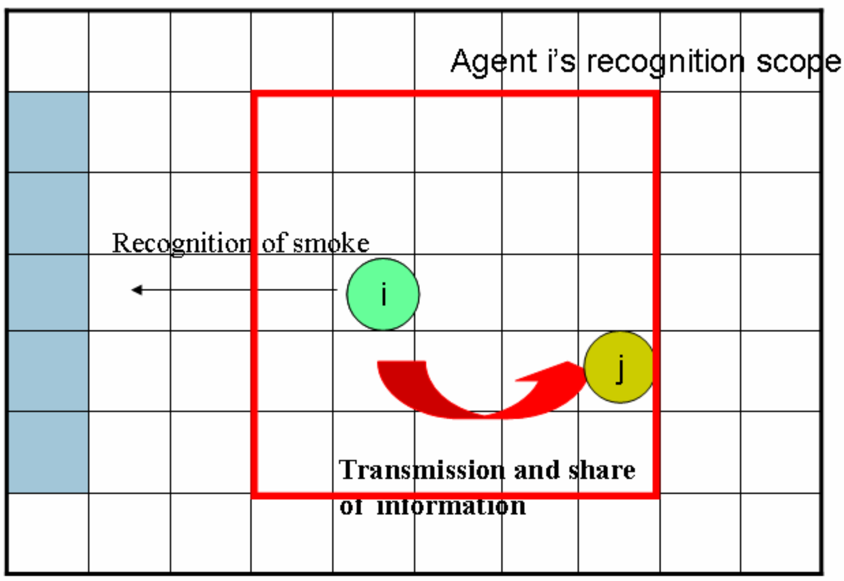


Figure 10 Recognition of smoke and information transmission

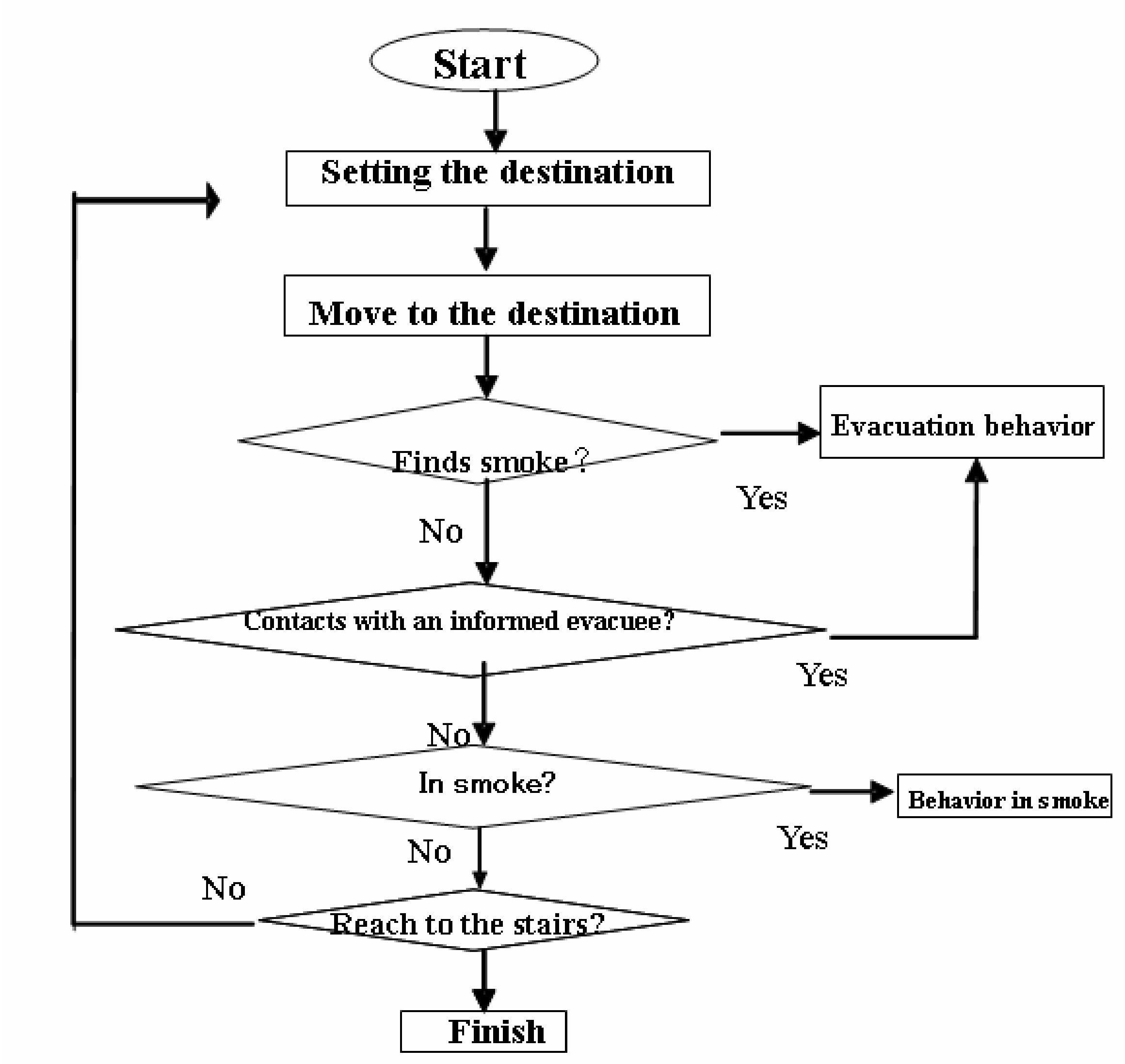


Figure 11 Evacuation algorithm

4 Simulation

4.1 This model's assumption

A fire occurs in a station, the power supply stops, and it changes into the emergency electric power. The station yard dimmed with inflow of smoke and it come to have a narrow view. Depending on scenarios, smoke flows additionally and agent's view is narrowed. Under such assumption, first, we see the influence of with and without smoke. Each scenario does five times simulation and requests the mean value. Initial condition of simulation, we set up 300 agents randomly both the second and third basement in underground.

The spread speed of smoke can be changed with simulator control panel (from 0.5m/s to 5.0m/s in the horizontal).

4.2 Simulation Scenarios and its results

Table2. Scenarios ant its conditions

	Base scenario	Scenario I	Scenario II	Scenario III	Scenario IV
smoke	No	Yes	Yes	Yes	Yes
field of view	27m	2.5m	5m	2.5m	5m
evacuation sign board	No	No	No	Yes	Yes

< Base scenario >

Agent evacuees get a clear view (27m). There is no smoke flow. From the first to 150 steps, the following results were obtained that the number of evacuees decreases suddenly comparatively. This result show that evacuees find the stairs or sign in early evacuation mode and get out immediately. Evacuation completion step is 155.2 seconds on the average.

< Scenario I >

Lighting changes into emergency electric power source, and smoke flows in, therefore evacuees become to be narrow view. Field of vision is set to 2.5m. Smoke is set to flow in from the direction of stairs 2 (See Figure 3). In this setting, the completion time is 228.0 seconds. Like a basic scenario, a decrease of the residual evacuees immediately after the beginning of simulation is rapid. However, increase speed is gentler than basic scenarios. This shows that the evacuees who find stairs or sign boards become smaller than basic scenario because agents have a narrow view.

< Scenario II >

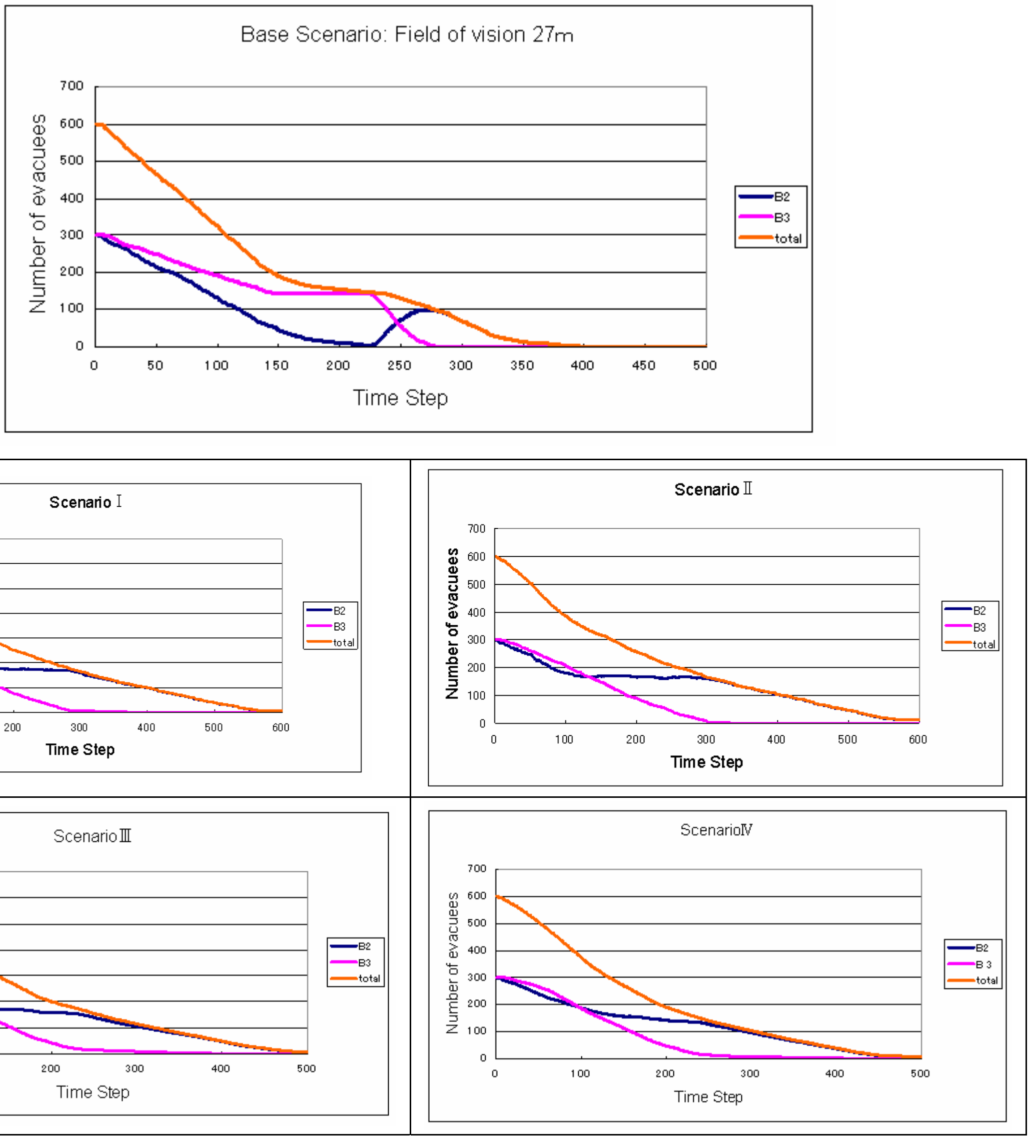
The setting is similar to scenario I and the field of view is changed to 5m. The graph is similar to scenario's one. However, a decrease of the residual evacuee becomes slowly in comparison with scenario 1's graph. The completion time is 221.6 seconds.

< Scenario III>

Information by the sign is added to the condition in scenario I. Owing to information by the sign, a decrease evacuation time decrease efficiently from initial state up to for 150 steps. The completion time is 198.8 seconds.

< Scenario IV>

These results indicate that it is possible to evacuate efficiently according to information by the sign in both scenario III and IV.



1 Step = 0.4 seconds

Figure 12 results of each scenario

5 Conclusion and challenges for the future

Smoke becomes major factor at the disaster, so we try to construct evacuation model considered fire case at a subway station. In this simulation, we focused on the evacuee's view, smoke and distributing information. Moreover, by using the multi-agent simulation, our simulation model visually deal with the difference of evacuee's view, evacuation behavior with and without information. We understand evacuee's behavior corresponding to change in situation at disaster to some degree. In this model, we can express the impact of agents' field of view and evacuation sign boards. Using this simulation, we can point out the effective installation location of sign boards or ventilator exit. It suggests this approach can become a tool for accident prevention. In our model, each agent acquires information from announcement about emergency exits, other evacuee, and recognition of smoke or signs. The person who is well informed of the escape route is not considering in it.

In future task is below. The subway station is a space that various people use, so it is necessary to consider the difference such as behaviors of older people or persons with a physical handicap, and spatial perception. Moreover, the station assumed to be a model in this research has somewhat simple structure that there were the stairs before and behind the platform and no obstacles in the path. We need to develop it to the more compound structure station. It is also necessary to think about the kind of smoke and the difference of how to flow in more detail.

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