A Simulation on Tsunami Evacuation Using a Multi Agent System -The Relationship between Evacuation Behavior and Tsunami Victims-

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SUMMARY:
In this paper, to discuss how to evacuate from a tsunami, a multi agent simulation is employed. In the simulation system, virtual spaces of evacuated area are set and evacuee agents move to evacuation center according to various types of evacuation behaviors. The behavior is determined by parameter settings prepared in this paper, such as, evacuation in confusion, to high altitude, and so on. Additionally, the evacuee agents have some parameters about starting time of evacuation, walking speed and states of agents. As just described, in this paper, various simulations are performed, and the relationship between evacuation behaviors and tsunami victims is discussed.

Keywords: Tsunami, Evacuation behavior, Multi agent simulation

1. INTRODUCTION

The 2011 off the Pacific coast of Tohoku Earthquake and tsunami have caused nearly 20,000 people killed or missing and more than 250,000 building damaged. The moment magnitude of this earthquake is 9.0, wetted surface area by tsunami is about 561 sq km and over 30m tsunami height traces are observed. Although the massive earthquake and tsunami caused heavy damage to human and property, residents have some time for evacuation till tsunami rushes toward them. Therefore, it is important for them to evacuate in an appropriate way (2012).

In this paper, the results of a simulation on tsunami evacuation using a multi agent system (2005) are reported. In this simulation system, a simple model of town block and human agents are prepared. Each agent has criteria on whether evacuation or not, and parameter of moving speed and selection of evacuation route, and variety of evacuation guidance methods are prepared. Therefore, various evacuation behaviors of agents are simulated in the system. Simulations are performed under different parameters, and effects of such parameters on tsunami victims are discussed based on simulation results.

2. TSUNAMI EVACUATION SIMULATION SYSTEM

2.1. Outline of Tsunami evacuation simulation system

This simulation system consists of three models mentioned below.

2.1.1. Evacuated area model
In this simulation system, an evacuated area is assumed to be a common coast of Japan, especially, Kansai region that may be hit by large tsunami is considered as the area model.

2.1.2. Agents model
In this system, agents are assumed to be residents in the evacuated area who evacuate to an evacuation center when a large earthquake generates tsunamis. The agents behave in accordance with their own rules determined by parameter settings in this system. Details of the rules are mentioned later.

2.1.3. Tsunami model
A tsunami model is defined as movements of tsunami and is described as an agent model in this system.

2.2. Settings of virtual spaces of evacuated area

Virtual spaces of the evacuated area are defined as grid pattern spaces consisting of square cells shown in Figure 1. The size of a cell is assumed to be 4m×4m. In consideration of a difference in height, the lower end of the area in Figure 1 is assumed to be at sea level and the upper end is assumed to be at an elevation of 8 meters. There are roads, an evacuation center and sites for buildings in the evacuated area. The evacuation center is assumed to be a park or a school site designated by an administrative organ in the region.

An evacuated area becomes very complicate, when various patterns based on actual layouts of buildings and roads are taken into consideration. Therefore, simplified models of roads and building sites are considered in this simulation system. The definitions of them are mentioned below.

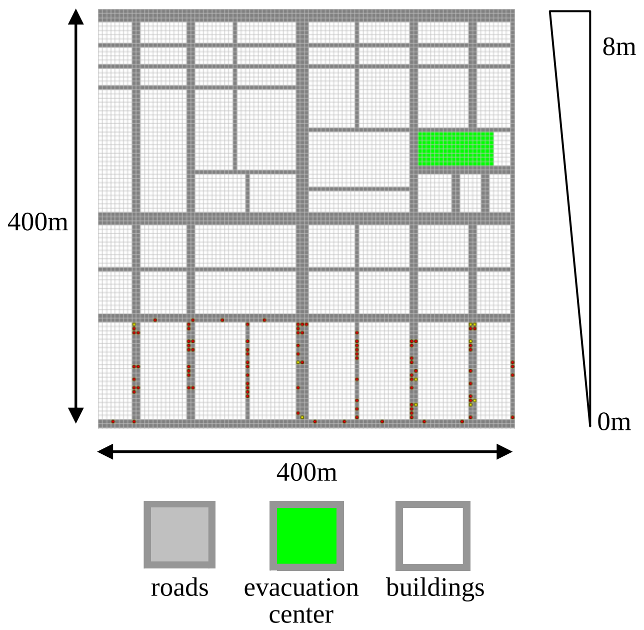


Figure 1. Virtual spaces of evacuated area

2.2.1. Roads
Residents are assumed to go to evacuation center for safety by the roads. In this system, although the roads are not damaged by an earthquake, residents can't go through the roads when tsunami waves will arrive the roads. The road width is assumed to be from 4m (1 cell) at minimum to 12m (3 cells) at maximum. In this paper, barriers on the roads such as cars are not considered for simplification.

2.2.2. Evacuation center
All the residents can evacuate to the evacuation center, and the size of center is assumed to be 28m×68m (7 cells ×17 cells). The center is set at an elevation of 6 meters and is safe if tsunami waves will arrive. Additionally, two buildings for evacuation are placed at lower position than the evacuation center. However, about half of the residents can escape into the buildings, because the buildings size is smaller than the evacuation center.

2.2.3. Buildings sites
Residents can't go through the buildings sites, and the types and/or scales of the buildings are not considered for simplification in this system.

2.3. Settings of evacuee agent model

In this system, an evacuee agent model is defined as ordinary residents in the evacuated area. The number of agents is assumed to be 100, and all the agents are assumed to start evacuating from places less than 2 meters above sea level. The initial positions of the agents are set randomly in the area at from 0 to 2 meters above sea level. The agents can't move outside the virtual spaces of the evacuated area. Table 1 shows parameter settings of evacuee agents, and the details of parameter are mentioned below.

Table 1. Parameter settings of evacuee agents

Starting time of evacuation	25 minutes later
Walking speed	8 km/h
States of agents	Now on evacuation, safety or death

2.3.1. Starting time of evacuation
The agents start to evacuate 25 minutes after the origin time of an earthquake in this system. Furthermore, tsunami waves will arrive the area at sea level in 30 minutes later.

2.3.2. Walking speed
The agents' walking speed is set to 8 km/h by reference to adult average walking speed in this system.

2.3.3. States of agents
States of agent are three kinds of situation, such as, 1) now on evacuation, 2) arrival to evacuated center safely, or 3) death when the agent is engulfed by tsunami.

2.4. Evacuation procedure

In this system, the agents basically move to the evacuation center. However, at first, the agents move toward the first destination, that is different with each case study mentioned below, before moving on to the center. Therefore, the agents move on to the center after they reach the first destination. In addition, the parameter settings on starting time of the evacuation and walking speed of the agents are assumed to be same in all case studies. In this paper, following six evacuation procedures are assumed.

2.4.1. Evacuation in confusion (Case1)
In this case, the agents are assumed to be unaware of the position of the evacuation center. Therefore, the first destination is set to the point: x-coordinate is determined randomly from 0 to 400-meter mark, and y-coordinate is determined randomly from 300 to 400-meter mark, where is higher than the evacuation center. In this case, agents are assumed to find the location of the evacuation center after they reach the first destination point. Consequently, the agents move toward the first destination at first and, secondly, they move to the evacuation center. Figure 2 shows an outline of evacuation procedure in Case1.

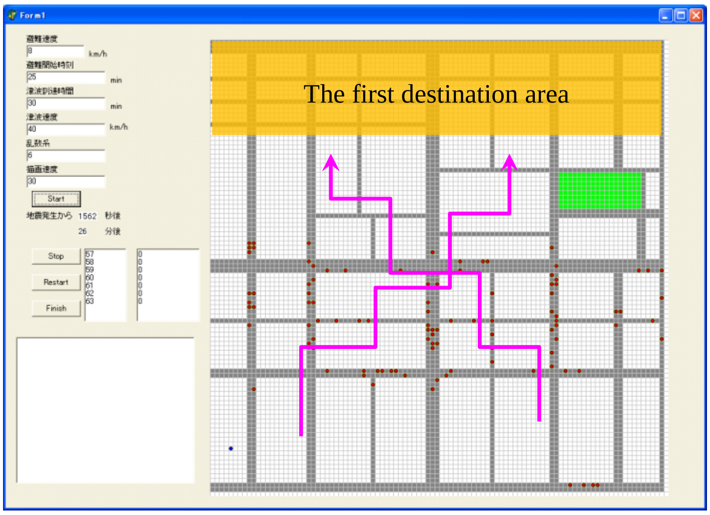


Figure 2. Evacuation procedure in case of evacuation in confusion (Case 1)

2.4.2. Evacuate to high altitude (Case2)

In this case, the agents move to high altitude. Therefore, the first destination is set to the point: x-coordinate is the same coordinate of the agent's current location, and y-coordinate is 600-meter mark. In this case, the agents move toward the first destination at first and, secondly, they move to the evacuation center as in the Case1. This evacuation procedure is adopted by reference to a slogan "if an earthquake occurred, evacuate to high altitude" in Kushimoto town, Wakayama prefecture (2008). Figure 3 shows an outline of evacuation procedure in Case2.

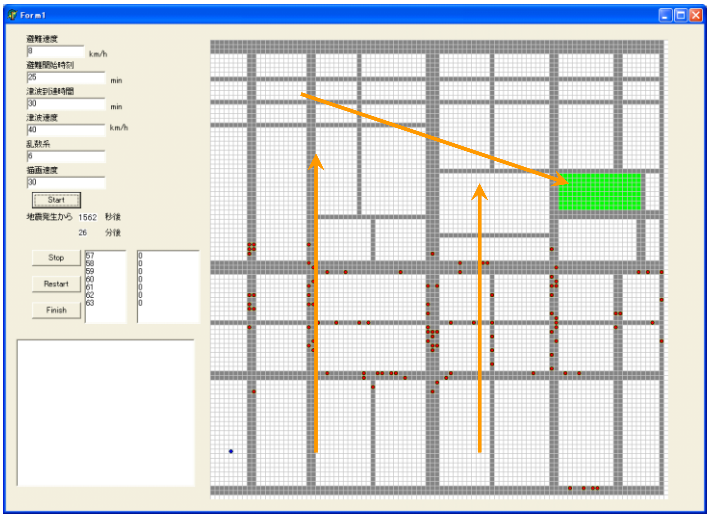


Figure 3. Evacuation procedure in case of evacuate to high altitude (Case 2)

2.4.3. Evacuate along main streets (Case3)

In this case, the agents move on along main streets. Therefore, the first destination is set to the nearest point of the main street from the agent's current location. In this case, if the agents reach the main street, they are assumed to find the location of the evacuation center and move on to the center through shortest path. As shown in Figure 1, two main streets with 12m road width intersecting one another are allocated in the evacuated area. Figure 4 shows an outline of evacuation procedure in Case 3.

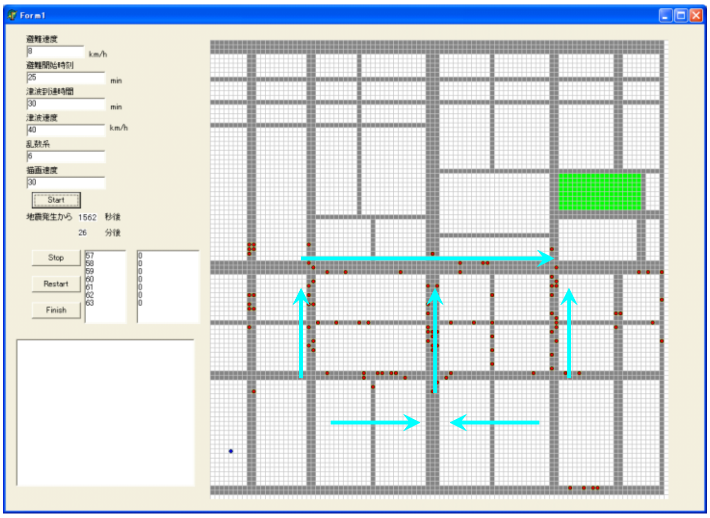


Figure 4. Evacuation procedure in case of evacuate along main streets (Case 3)

2.4.4. Evacuation with directional sign (Case4)

In this case, there are directional signs regarding the location of the evacuation center at every intersection in the evacuated area. Therefore, the agents can move to the center along shortest path. For this reason, the first destination is not applied in this case. Figure 5 shows an outline of evacuation procedure in Case 4.

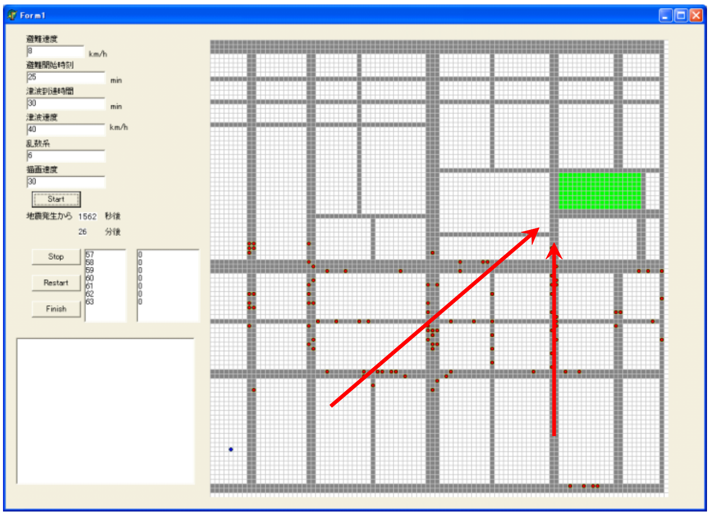
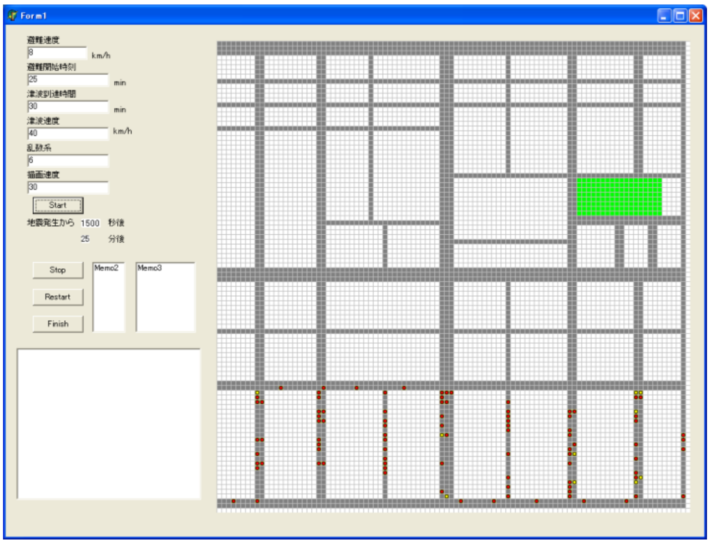


Figure 5. Evacuation procedure in case of evacuation with directional sign (Case 4)

2.4.5. Evacuation with guide (Case5)

In this case, 10 guide agents (10% of the residents) know the shortest path to the evacuation center, and 90 follower agents (the other 90%) don't know the shortest path and follow the guides. Figure 6 shows an outline of evacuation procedure in Case 5. In this figure, yellow circles indicate the guide agents, and red circles indicate follower agents.



: guide agent : follower agent

Figure 6. Evacuation procedure in case of evacuation with guide (Case 5)

2.4.6. Evacuate to buildings for evacuation (Case6)

In this case, the agents move to buildings for evacuation. The first destination is set to the nearest building for evacuation. Although the agent who reaches the building can complete an evacuation, the capacity of the building is not enough for the all of agents. Therefore, the agents who can't enter the building for evacuation have to go to the evacuation center. That may cause roundabout route and waste of time. Figure 7 shows an outline of evacuation procedure in Case 5.

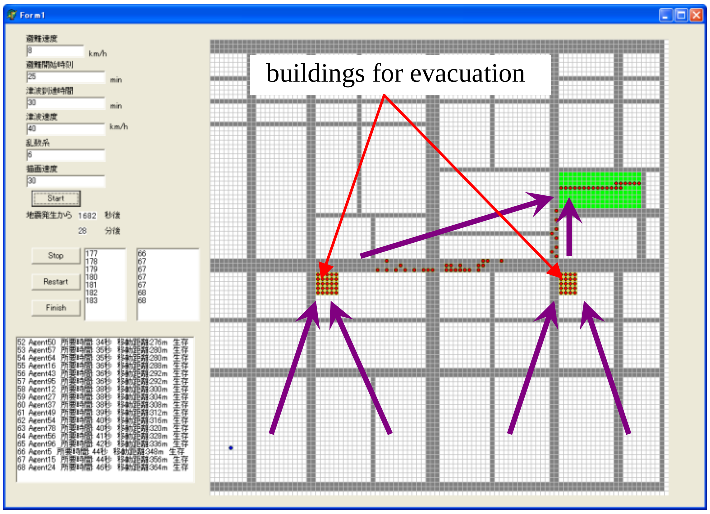


Figure 7. Evacuation procedure in case of evacuate to buildings for evacuation (Case 6)

3. SIMULATION RESULTS AND DISCUSSION

Figure 8 shows a process of the number of agents who completed evacuation. In this figure, the abscissa denotes elapsed-time from starting evacuation, and the ordinate denotes the number of agents who completed evacuation. Additionally, the colored lines correspond to simulation results of Cases 1~ 6 as shown in this figure.

In Case 1, the agents move in the various directions, therefore, encounters of agents and evacuation procedures with roundabout trip are observed.

In Case 2, agents evacuate to high altitude. In this case, although the number of the agents who completed evacuation become double in comparison with Case 1, it is not enough to select the evacuation procedure to high altitude, because many agents can't evacuate safely to the evacuation center.

In Case 3, although most agents can complete evacuation, there are observed the condition that the narrow road leading to the evacuation center is very crowded. Therefore, it is recommended that the evacuation center is located along the main street.

In Cases 4~6, all the agents can complete evacuation. Especially in Case 6, half of the agents can complete evacuation in about two minutes because of buildings for evacuation.

From the simulation results of Cases 1~6, Case 5 can complete evacuation of all agents in the shortest time. Therefore, it is recommended for evacuees to evacuate to high altitude at first, and to evacuate to evacuation center according to directional sign when they come to a main street.

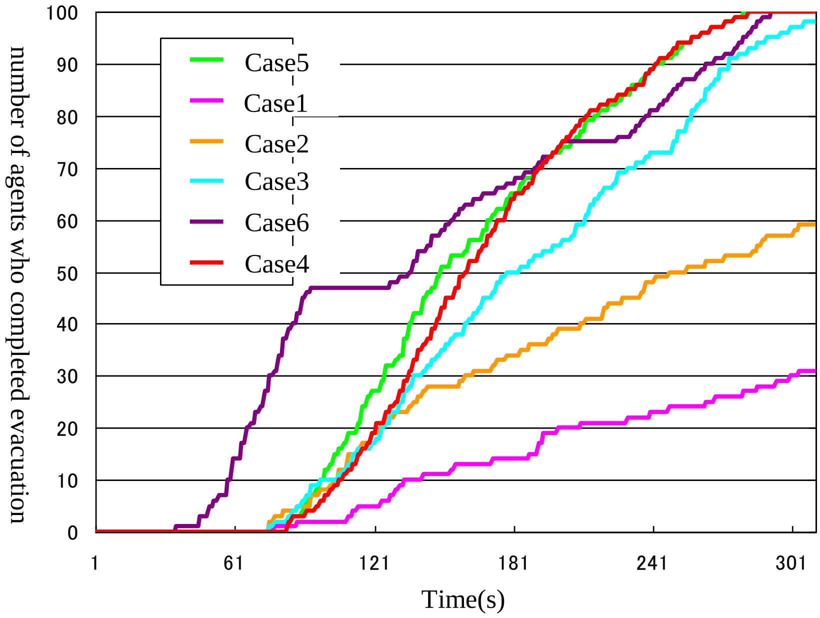


Figure 8. process of the number of agents who completed evacuation

4. CONCLUSIONS

As described in this paper, various patterns of simulations on tsunami evacuation using multi agent systems are performed, and the relationship between evacuation behaviors and tsunami victims are discussed. Although simulations settings are simple and basic, following conclusions can be obtained.

1) For safety and speedy evacuation, settings of an objective area and/or a guide are useful.

2) If the evacuated area is at a low altitude and will be flooded due to tsunami, it is benefit to encourage the residents to evacuate not only to high altitude, but also to a safe nearby place.

3) To complete the evacuation more rapidly, it is useful to build buildings for evacuation. However, it is difficult how to determine the capacity of the building.

As for additional projects of this research, it is necessary to perform more detailed simulations in consideration with individualities of evacuee, such as age, walking speed and state of mind, and to apply this simulation system to actual areas so as to provide useful disaster information.

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