A Multi-agent based simulation Model for evacuees escaping from Tsunami disaster.

- To evaluate the evacuees escaping program in Fujisawa city, Japan. -

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ABSTRACT

In this research, we are trying to develop a framework to evaluate the prevention program for Tsunami disaster based on the Multi-agent simulation model. Tsunami has arisen by the earthquake. It happened after few minutes or few hours when it occurred. It is clear that Tsunami will come after earthquake and from seashore. If we prevent the damage by Tsunami, we should make people who is in the seashore and lived near the seaside escape from there. Moreover we must forecast the escape activity from Tsunami. Former research of this field, some researches try to forecast the escape activity as macro level. However, people who escape from Tsunami is differ from their physical ability and ability of information processing. It needs a more accuracy model to forecast the escape activity of them. Furthermore they make a decision step by step using the various information. Therefore escape activity from Tsunami will describe using an agent based model which can only treat the information processing of human being. In this paper, we develop the evacuation model from Tsunami disaster using the Multi agent based model. The purpose of this study is to analyze the human action pattern when Tsunami occurred, and to make an accurately assessment for damages by Tsunami. The Fujisawa city government is planning and operating the various prevention program for Tsunami. However nobody assess it, because they do not have any simulation models for Tsunami disaster. If they want to set an effective prevention program for Tsunami, they should have any kinds of simulation model. The results of this study are 1) To develop the Multi agent based evacuees escape activity model. 2) Assess the damage of Tsunami in Fujisawa-City.

1 INTRODUCTION

Fujisawa city, located on the southwest fringe of the Tokyo metropolitan area about 60 km from the central business district, is one of the satellite cities of the megacity Tokyo. In addition to serving residential functions by housing approximately 370,000 people[10], it serves as a favorite recreational area for all of the inhabitants of the megacity. On an average summer day, 30,000 tourists[1] visit its coast, and during its summer festival as many as 150,000 people[3] gather in the area.

Due to this area's popularity to tourists, it is necessary to consider the safety of the tourists as well as the inhabitants in the event of a natural disaster. With this factor in mind, we, the disaster management research group of Keio University's Shonan Fujisawa Campus, conducted a research project regarding the protection of sightseeing visitors along the Shonan Fujisawa coast in the event of a disaster caused by Tsunami.

In order to propose adequate management systems corresponding to the varying conditions during Tsunami disasters and to the different types of information given to the affected people, we needed to develop a simulation model for the behaviors of evacuees with various attributes.

2 PHYSICAL CONDITIONS OF TSUNAMI

From the standpoint of disaster management planners, it is essential to know the Time Allowance from an earthquake occurrence to the arrival of a Tsunami, as well as the Affected Distance from the coastline. With the recent advances in technology, we are able to predict the former index (Time Allowance) using the average depth to the ocean floor. On the other hand, the latter index (Affected Distance) is rather difficult to predict. It depends on the intensity or height of the Tsunami when it arrives at the coastline. In principle, it would be a function of not only the magnitude of the earthquake, the depth of the sea and geographical conditions of the ocean floor at the arrival point, but also the seismic ground movement. The last one is very difficult to identify during an actual event.

3 JAPANESE EXPERIENCES OF TSUNAMI DISASTER AND STANDARD FOR WARNING

We have had frequent Tsunami disasters in our history. The most severe Tsunami disaster occurred in the Sanriku area in northeast Japan in 1896, with its height of 24.4 meters, causing 27,122 deaths. The time allowance was around 20 minutes, but we had no early warning system at that point in history.

When the same area suffered from a wave as high as 25 meters in 1933,3008 people died in the first 30 minutes after the earthquake. After this destructive event, the Japan Meteorology Agency(JMA) decided on a warning standard of broadcasting a predicted result within 20 minutes. When the Chili earthquake Tsunami hit the same area in 1960, the number of casualties was reduced to 139 persons due to the long, 22- hour Time Allowance. [4]

In the case of Nihonkai Chubu earthquake in 1983, the Allowance Time was less than ten minutes, and therefore the JMA revised its warning standard from 20 minutes to five minutes on the basis of advanced computer technology. Ten years later, however, when the Hokkaido Southwest Offshore earthquake occurred, a tsnami with waves 10 to 30 meters high hit the Okusiri island in Hokkaido, as indicated in Fig.1. The Time Allowance was as short as five minutes and so the issued warning could not prevent the deaths of 199 individuals. (Sono,[11]) Then the JMA developed the new warning system which predicate result within 2 or 3 minutes at 1999.

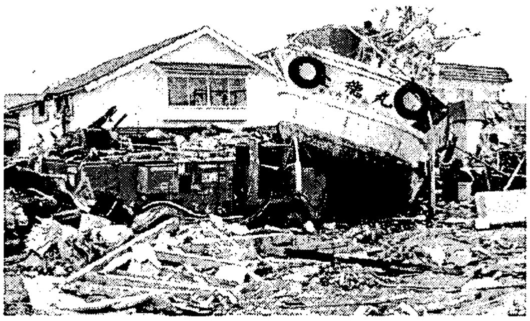


Fig.1 The damage of Tsunami on Okushiri Island on 1993

4 ACTUAL MANAGEMENT PLAN TO COPE WITH TSUNAMI BY FUJISAWA CITY GOVERNMENT

As mentioned above, the Shonan Coast in Fujisawa city is a popular tourist destination, where on an average day somewhere between 31,500 and 146,750 people are enjoying their summer vacation. At the time of the Great Kanto earthquake in 1923, this area was not as popular of a recreational place as it is currently, and there were very few residents living in the area. Consequently, even though the Tsunami reached 6 meters high, it did not cause many casualties. An historical record indicates 57 people died in this coastal area. At present, the conditions of this area have changed significantly, with densely populated residential areas and high numbers of visitors.

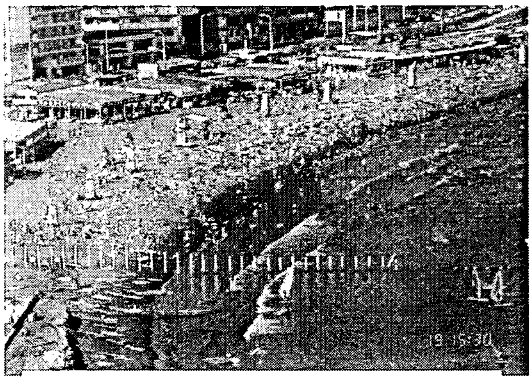


Fig.2 The beach aroud the Enoshima

To help cope with Tsunami disasters, Fujisawa city has designated some existing buildings along the beach as tentative shelters to protect tourists and inhabitants in the event of a Tsunami. According to city office estimates, total capacity of these designated buildings is 77,217 persons. Our recent survey, however, found that the total capacity would be 51,099 persons (Sanemasa,[8]). Moreover, in the event that an earthquake stronger than the Great Kanto earthquake strikes this area with associated Tsunami, there is insufficient shelter capacity to protect all of the affected people, including both tourists and residents. As we mentioned, there are 30,000 visitors to Enoshima beach on an average day in the summer, most of whom do not know the local roads and buildings. Therefore, before the Tsunami arrives at the beach, these visitors must head to the shelters or get away from the beach. When they decide to escape from Tsunami, people attempt to gather information about Tsunami, such as when the Tsunami will arrive, which building is safe, and the shortest path to the safe building. If they are all to be safe from Tsunami, they must be able to gather valuable information from their surroundings (e.g., signs, landmarks) and from other people. We presume that all of them are processing the information related to a safe place alone and their results affect their evacuation activities. When we consider these conditions, our model must deal with the information processing of evacuees during the evacuation activities.

When tsunami occurred, Fujisawa City assign to evacuee to go higher place by wireless warning system. It is unknown in whether people hear an alarm. Moreover It does not know whether people evacuate from the seashore. Unless tsunami occurs, it does not know what action people perform. Anyway local government such as Fujisawa city will make a disaster prevention plan for

Tsunami, they should make an effective plan. For that purpose, it needs an exact predictions such as arriving time to seashore, number of victims height of waves by Tsunami using a various simulation models are required. But there are no simulation models for evacuees by Tsunami which focused on individual behavior. It means that it is difficult to forecast the human behavior when Tsunami occurred. If Tsunami will come in 30 minutes later, people in seashore will be in panic. Nobody knows that what they act. It is clear that it is necessary to simulate the evacuees behavior to improve the evacuees planning.

5 MULTI-AGENT SIMULATION MODEL FOR THE TSUNAMI DISASTER.

5.1 Review of Evacuation model.

At the first, it shows that former research for simulation model about evacuation behavior briefly.
According to Lee's(Lee[7]) research, simulation model for evacuation activity is divided two fields, one is to treat evacuees as a crowd, the other is to tread as an individual. First one is developed various model, which are focused on density and speed of a crowd, length of it and Following model. Shimada[9] forecasts the suffers by Tsunami using the GIS(Geographical Information System). Therefore his model is classified traditional model(e.g. based on the crowd) Furthermore new computer simulation model using the new concept such as Artificial Intelligence, Fuzzy Inference and Artificial Life in the field of computer science. For example, Kagawa[5] developed new evacuation model using Fuzzy Inference and Artificial Life. In his model, it is possible to communicate for each evacuees, then simulate the more complicated behavior than before. In Kagawa's review, objective area is described by small area (like a mesh) or focused on the network topology (e.g. road network and the crossing)

In recent years, human behaviors have been modeled based on an agent-based simulation technique. Kohler and Gumerman[6] at the Santa Fe Institute are producing remarkable research results. Many researchers are inspired by these results and are attempting to develop new behavior models based on their agent model. In our work, we develop an agent-based simulation model for Tsunami evacuation activities.

5.2 What are Multi-agent Simulation Models?

In the Multi-agent simulation model, the agent is a computer-programming module can mimic various human reactions as evacuees escaping. The agent, which is in virtual space, acts autonomously based on its own decision-making processes and environmental information. The agent-based model simulation forecasts movement by each agent, allowing us to simulate the behaviors evacuating people at each stage.

Each agent decides his/her own way and responds like a real human to various situations. By simulating signage planning and refugee control, these simulation results allow pre-disaster planning in order to minimize future total disaster damages.

First, to define the acronyms and technical terms. AGENT is an autonomic program module, which can execute behaviors in a computer simulation environment. PLACE refers to the platform or environment where many agents exist and influence each other. We call this PLACE a Multi-agent environment.

In this system the agent has three basic functions as listed below.

i) Autonomic Action
The agents make their own decisions to act. Those decisions depend on the agent's own physical ability and experience.

ii) Coordination
The agents communicate with each other and coordinate to act. Each agent has transmitter and receptor to exchange information.

iii) Flexibility to Various External Environments
The agent's decisions are flexible. If environmental information changes, the agents reconsider their actions and decide their next action.

5.3 Effectiveness of Multi-agent Simulation for Evacuation Activity

In an actual Tsunami disaster, the people threatened by Tsunami take a variety of actions, including: running away from the beach areas to higher places; saving their family; or doing nothing due to lack of information. Evacuees make decisions by using environmental information and human interaction.

Ordinary simulation methods using System Dynamics do not take account each person's individual actions because it simulates only an aggregate variable. In the Multi-agent simulation environment, the core part of the simulation system depends on autonomic agents' actions and their interactions as if they exist a real world. The realistic simulation results in a more accurate model than the traditional, aggregate technique.

If we could accurately simulate the decision-making system of human beings, we could construct an accurate model and analyze its results by computer. Unfortunately, the cognitive system and decision-making system of human beings are beyond the computer's ability, so we must make some assumptions to create models.

In the case of escape activity from Tsunami, human beings act only in response to the evacuation. Nevertheless, we consider about many possible conditions for the people, such as physical condition, information processing ability and etc.

5.4 The Simple Structure and Simple Action Pattern of Agent

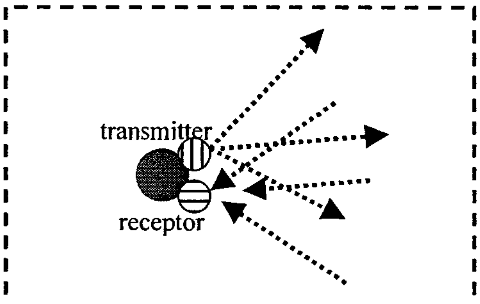


Fig.3 The function of communications

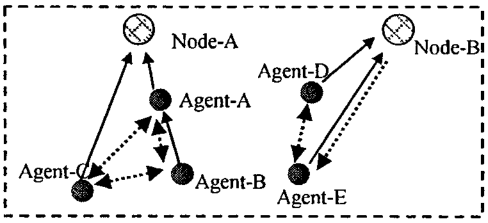
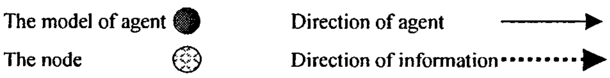


Fig.4 The interaction between agents



Each agent has transmitter and receptor. (Fig-3) The receptor is the part of the agent that can receive information from other agents and the environmental information. The transmitter is the part of the agent that can send information. Fig-4 shows the interaction between the agents. Each agent receives information that is transmitted by nearby agents and the nearby node. Additionally, all agents are planning their next action.

6 THE SPECIFICATION OF SIMULATOR.

6.1 The Attribute of Agent

We define the agents' attributes as shown in Table 2.

Table 2 The attribute of agent.

classification	attribute	discription	range of value
ability	walk speed	n (m/ sec) *	0.5 - 2.8
?	experience	a sense of locality	
?	?	general evacuees escape knowledge	
?	information	transmit information level *	1 - 5
?	?	recept information level *	1 - 5
?	decision	ability to decide next action *	1 - 5
		a sense of direction	
	independence	decide oneself *	1 - 5
?	coordination	coordination ability *	
?	flexibility	flexibility for decision making	
property	age	n (year)	
?	height	n (cm)	
?	weight	n (kg)	

* Activate variables in the simulator

6.2 Simulation Cases

Fujioka et.al. [2] was developed Multi-agent simulation model for evacuation behavior when Tsunami occurred. In their model, they simulate the number of shelters and capacity of the shelter. According to their results, increasing the number of shelters and capacity of shelters will improve safety rates. Anyway their model was only numerical example in virtual space. In their model, they showed the subject in future research as follows. To execute an accurate simulation using simulate the number of the actual data (such as location of shelters, road network, the crossing)

In this research, we aim to simulate more actual situation in Fujisawa city. Firstly, we construct the digital map for simulation based on the digital survey map which made by Fujisawa city government. Specifically, we pick up road network and the crossings, mapping the shelters our map. Moreover we relate the data base which include the capacity of each shelter. We already know the relation between the number of shelters and capacity of it(Fujioka et.al [2]). Considering actual case when Tsunami occurred. Evacuees will go to the shelter which located near seashore. As the result, a lot of evacuees will be gathering only shelters near seashore. Therefore the capacity of them are limited. If young people run into shelters at the first, less of them such as handy-capped people or aged people will not be able to run far away from seashore. As the result, They are attacked by Tsunami.

In this research, we aim to less victims by Tsunami. We set following assumption. When Tsunami will occurred about 30 minuets later after the earthquake, Fujisawa city government will control to enter the shelter only 5 minuets after the earthquake occurred. We established the two simulation cases as shown in Table 3.

Table3 The simulation cases

CASE	TITLE	Delay to open the gate
A	Non Control shelter gate	0
B	Control shelter gate	300(sec)

The CASE-A shows the autonomic evacuees behavior without shelter gate control. The CASE-B shows the autonomic evacuees behavior with 5 minutes delay control about shelter gate open. Both simulation cases, the distribution of node sets (shelters and crossings) are actual data of Fujisawa city. The number of agents set to 10,000 and locate along the coast at random. Attribute value set at random as range of shown in table2. Research area by coordinates assuming one pixel equals one square meter. The step time was also defined using computer cycle time assuming that one time step equals a second.

7 THE RESULTS AND ANALYSIS OF SIMULATION

7.1 Base map of Simulation in Fujisawa City

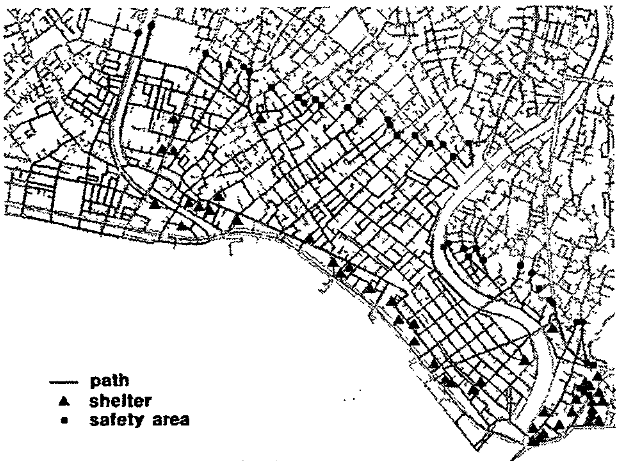


Fig.6

7.2 The Transition of Moving for Each Agent at CASE- A

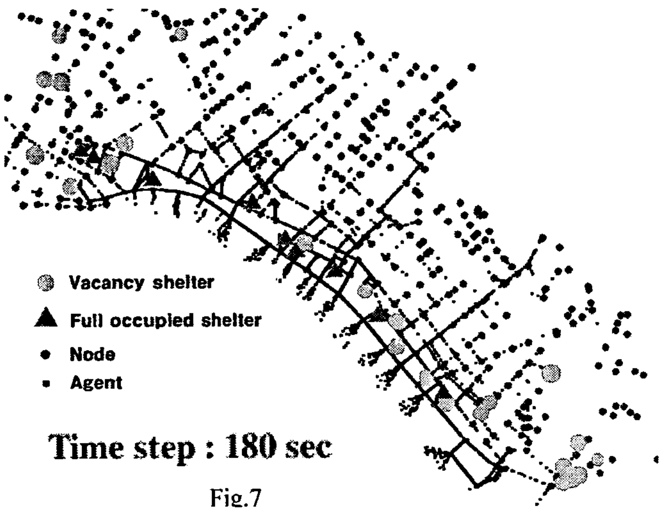


Fig.7

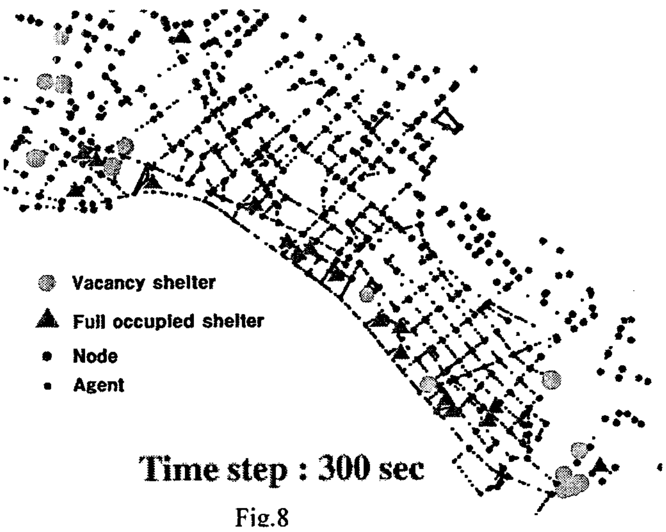


Fig.8

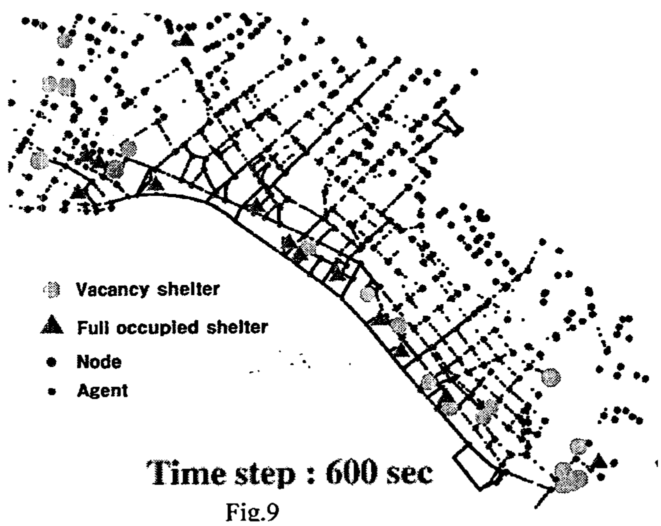


Fig.9

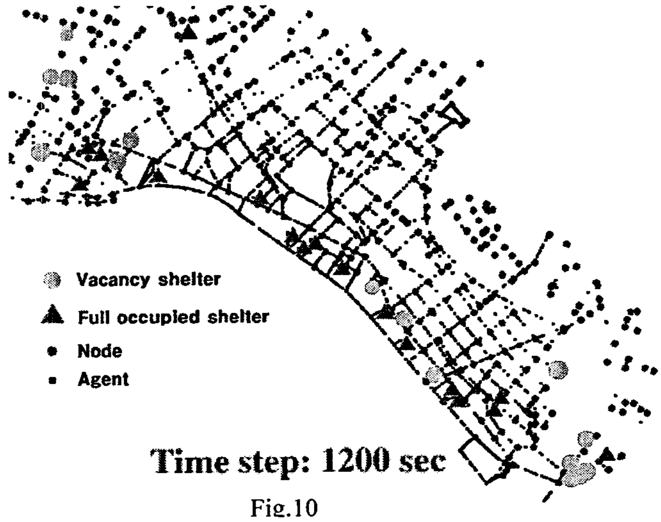


Fig.10

7.3 The Number of Safety Agents.

We established safety areas with virtual space agents and calculated the mean number of agents in a safety zone. Table 4 shows the number of agents in a safety zone by time steps for each simulation case. Fig. 11 shows the transition of safety agent for each simulation case.

Table 4 The number of agents in safety zone by time step for each simulation case

	non control the gate	delay 5 minutes
0	0	0
150	1771	18
300	3905	918
450	4990	3974
600	5699	5306
750	6256	6179
900	6613	6729
1050	6907	7140
1200	7145	7453
1350	7343	7688
1500	7519	7886
1650	7664	8049
1800	7804	8194

safety judgement : in the shelter or safty area
values : The average of simulation on 10 times

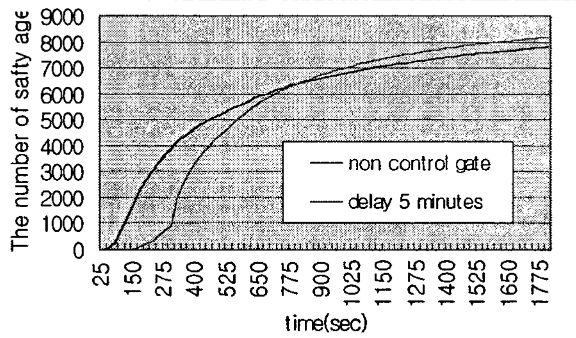


Fig.11 Transition for each simulation cases

7.4 Comparing for Simulation Cases.

We are trying to simulate 10 times for each cases. We can get the data from simulation results. We summarize using the mean value (the number of survivors and time) for this result.

From the results of the simulation, from the beginning of the simulation to about 800 seconds, the number of survivors in Type A is more than Type B. After about 800 seconds, the number of Type B is more than Type A. When 300 seconds passed, the gate of all shelter is open. Evacuees in running into the shelter.

According to this results, shelter gate control is effective to increase the survivors. Because evacuee's has various (such as age, sex, physical condition). When gate is not open, younger people will be able to run away far from seashore. After gate is open, aged people and physically handicapped people can run into shelter where located near seashore.

8 CONCLUSION

In this paper, we attempted to predict the evacuation from Tsunami in Fujisawa city by using a Multi-agent simulation system. From our results, we found the more effective to increase the survivors, when Tsunami occurred.

To develop the model further, we consider the attributes of tourists, and ability of information processing under emergency situation. Specifically, a psychological approach is needed for more accurate simulation. Replacing the verification will lead to improvement of this system and will highlight the problems of measure of Tsunami in urban planning. We hope this system will contribute to construction of safer city environments.

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