Influence of Information-Hearsay on Wide-Area Evacuation at a Large Earthquake

Takuya Tsuchiya
Tokyo Institute of Technology
tsuchiya.t.ag@m.titech.ac.jp

Toshihiro Osaragi
Tokyo Institute of Technology
CREST, Japan Science and Technology Agency
osaragi@os.mei.titech.ac.jp

Takuya Oki
Tokyo Institute of Technology
CREST, Japan Science and Technology Agency
oki@os.mei.titech.ac.jp

ABSTRACT

In order to evacuate smoothly and safely at a large earthquake, it is important to obtain the information on property damages (such as street-blockage and fire) and on evacuation areas by hearsay, guidance and bulletin boards. In this paper, we construct a model, which describes wide-area evacuation, information-hearsay among evacuees and guidance behavior. Using this model, we evaluate the influence of information-hearsay on wide-area evacuation in terms of the evacuation time and the risk on evacuation routes. Simulation results demonstrate that the locational information of evacuation areas and damages is the most helpful for people who are unfamiliar with an area. In addition, we discuss the effective and efficient methods of evacuation guidance. The results show that the guides contribute to reducing the evacuation time and the risk on evacuation routes of evacuees, and sharing information among guides enables more efficient and safer evacuation / guidance.

Keywords

virtual city, wide-area evacuation, information-hearsay, evacuation behavior, simulation.

INTRODUCTION

It is important to obtain disaster information such as fire, street-blockage and information on the location of evacuation areas for smooth and safe evacuation after a major earthquake. Particularly, under the situation of difficulty in using information network and in getting information from the media, the bulletin boards, hearsay among evacuees and guidance might play important roles.

There are some studies that focus on the information hearsay in a disaster evacuation. Muraki and Kanoh, (2004) built a multi-agent simulation model which describes evacuation including communication, and executed the simulation in Kobe City (Hyogo Prefecture, Japan) and Tsukuba City (Ibaraki Prefecture Japan). The simulation was focused on a communication rate indicating the probability that information hearsay is performed, and an information possession rate of the guides. However, the physical damage was not considered in the report. Aoki et al. (1992) proposed the models of information hearsay and deterioration of geographical image based on a questionnaire survey. Using this model, they executed simulation in a grid city, and, it is not detailed model of information hearsay and evacuation behavior. Nuria and Norman (2006) considered the evacuation in crowds inside buildings. They modeled evacuees who exchange evacuation route with each other and take different roles such as trained personnel, leaders, and followers. It showed that only a small percentage of trained leaders contributes to increasing the evacuation rate. Smyrnakis and Galla (2012) and Henein and White (2010) also indicated that communication in evacuation affects evacuees' behavior and contributes to more efficient and safer evacuation by using simulation based on cellular automata and floor field model. However, these studies are not focused on the evacuation in city areas.

In this paper, we model the information hearsay and the evacuation behavior of evacuees in the wide area evacuation at a large earthquake. Furthermore, we quantitatively evaluate effects of the information hearsay on evacuation time and safety of evacuation routes.

CONSTRUCTING A SIMULATION MODEL

Virtual City Model

$$\text{Node-Link ratio} = \frac{\text{Total number of streets connected to an intersection}}{\text{Number of intersections}}$$

Virtual city	Value
Average evacuation distance	707m
Size of an evacuation area	153,664m^2
Block size	40m x 40m
Street width	4m
Node-link ratio	2.63
Node-link ratio considering street-blockage	2.57

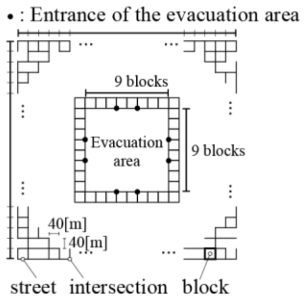

Figure 1. Overview of virtual city

We construct a city model and a model of evacuees' behavior. We build a virtual city to simplify spatial characteristics in the real city as much as possible and evaluate influence of the information hearsay in the wide area evacuation. Figure 1 shows the overview of the virtual city. The characteristics of the virtual city such as block size, road width and size of evacuation areas are based on the GIS data on the land use in Setagaya Ward, Tokyo, conducted in 2011. The average of evacuation distance is calculated from the distance of all intersections in Setagaya to the closest evacuation area.

Property Damage Model

We model street-blockage, fire-outbreak and fire-spreading as property damage at a large earthquake. Streets in the virtual city are randomly blocked. The number of street-blockages is determined by node-link ratio estimated based on the simulation of street-blockage in Setagaya Ward. A fire is assumed to break out on lots selected at random in the virtual city as shown in Figure 2.

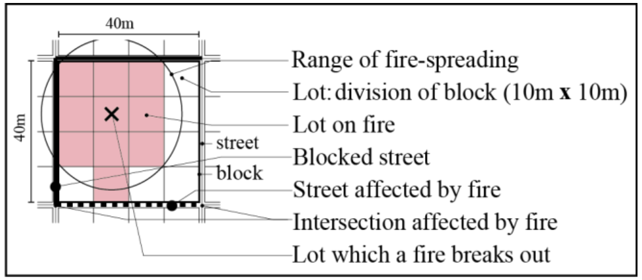

Figure 2. Circumstances of fire spread

The number of fire-outbreaks is fixed to three based on the damage estimation predicted in Setagaya Ward by Tokyo Metropolitan Government (2012). In addition, the range of fire-spreading is assumed to spread out from the center of a lot which a fire breaks out and the velocity is defined with the fire-spread-speed model of Tokyo Fire Dept. (2001). A lot on fire is determined according to whose center is included in the range of fire-spreading. Furthermore, the fire is considered to affect the evacuation behavior of evacuees. Evacuees are assumed to be disable to pass the street affected by fire (inside the range of fire-spreading). Also, the information of intersections affected by fire can be obtained within 150m from the fire.

After getting the knowledge on the location of fire, evacuees are considered to avoid the fire. We make a model describing the resistance which the evacuees receive and the distance from a fire (Figure3). We use this function for estimating the route of the evacuees and calculating the risk on evacuation routes.

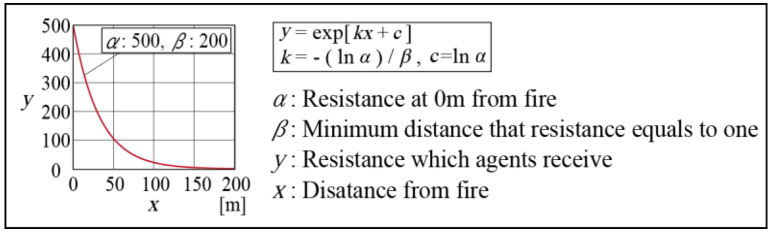

Figure 3. Resistance from fire

Modeling of Evacuees' Behavior

We consider that the evacuation behavior is depending on the degree of the familiarity with an area, and the evacuees are categorized into three types as follows: (1) Unfamiliar evacuee does not know the direction to the evacuation area and street network at all. The direction which the evacuee move to is decided at random; (2) Normal evacuee, who does not know the street network but know the location of evacuation areas, goes to the direction to the evacuation area; (3) Familiar evacuee, who understands the location of evacuation area and street network, evacuates to evacuation areas through the shortest route.

The guides take a role to instruct evacuees. According to the method of collecting information, three behavior types of the guide (Individual guide, Cooperative guide and Universal guide) are defined. We assume that the use of information network is limited immediately after a large earthquake, and evacuees and Individual guides cannot use it. In contrast, Cooperative and Universal guides are assumed to be able to share the information by using the information network. Also, methods of collecting information by guides are defined as follows: (1) Individual guide who collects the information by himself / herself; (2) Cooperative guide who can share the information collected among the guides; (3) Universal guide who constantly grasps all the damages. These three guides are assumed to walk randomly during a certain time immediately after the event and evacuate to the evacuation areas through the shortest route after guidance. In addition, the guides are more familiar with an area than all evacuees.

INFORMATION HEARSAY MODEL

Modeling of Information-Hearsay and Judging Information

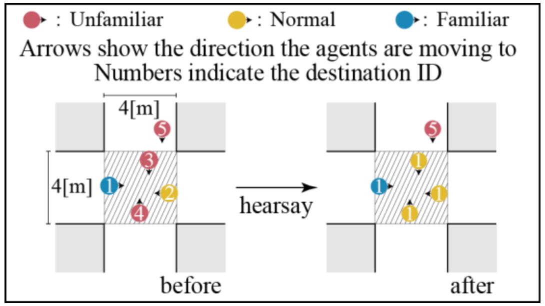

Figure 4. Hearsay model

We consider the information hearsay occurs at intersections (4m x 4m) where evacuees need the information to decide the route to evacuation areas. Exchanging the information by hearsay, the evacuees can share the information on the direction to an evacuation area and disaster information such as fire and street-blockage. Evacuees decide the direction to an evacuation area based on the priority according to the evacuee type. Also, we assume all evacuees and guides can know the evacuee type and the guide type by hearsay in an intersection where the meet. As shown in Figure 4, evacuees follow to the one who are most familiar with an area.

Next, the disaster information about the intersection affected by fire and street-blockage is assumed to have different properties between the according to looking or hearsay. The information obtained by looking is assumed not to be updated by hearsay because it is more reliable than the information obtained by hearsay. Also, evacuees who exchange disaster information at an intersection follow to the information which is majority among them.

Change of Evacuee Type after Getting Information

Evacuees are assumed to become more familiar with an area by getting information by hearsay or bulletin boards. Figure 5 shows the change of evacuee types after getting information. Unfamiliar evacuee is assumed to change to Normal evacuee by hearsay information because it is difficult to completely understand the street network correctly. Also, Unfamiliar and Normal evacuees are assumed to become Familiar evacuee with the probability of 50% when they look at bulletin boards and grasp the detailed information on the location of evacuation areas and the street network.

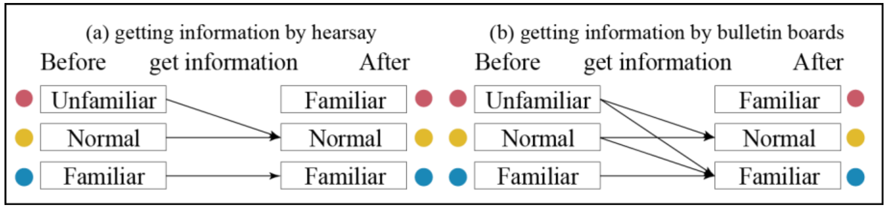

Figure 5. Change of evacuee type

Range of Collecting Information

The spatial range of collecting information varies according to evacuee types shown in Figure 6. Unfamiliar and Normal evacuees are assumed to obtain the information in the range of less than 100 meters from the segment between the current location and the temporal destination. Also, Familiar evacuees obtain the information in the range of less than 100 meters along the evacuation route. Guides obtain the information in the whole range in the virtual city.

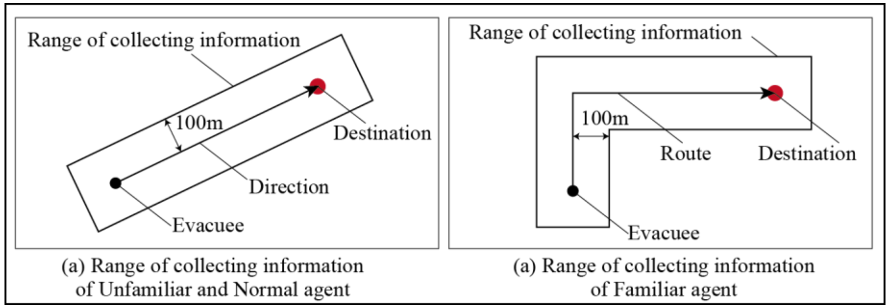

Figure 6. Range of collecting information

SIMULATION CONDITION AND EVALUATION METHOD

Simulation Condition

We determine the simulation condition and the evaluation indicators of the evacuation behavior of evacuees. We set the number of evacuees in the virtual city as 50,000 persons referred to the population density in nighttime in Setagaya Ward (15,102 persons/km^2). Following to the previous research (Osaragi and Oki, 2013), the evacuation start time is distributed by Poisson distribution (λ=3.35). Under the condition, we execute the simulation 10 times using the different pattern of fire-outbreak and street-blockage.

Evaluation Method

We regard a street within 200 m from fire as the street with fire risk, based on the resistance which the agents receive (Figure 3). The risk of evacuation route is evaluated by the number of streets with fire risk and the efficiency of evacuation behavior is evaluated by the evacuation time.

EFFECTS OF INFORMATION-HEARSAY IN EACH VIRTUAL CITY

Effects of Information Hearsay

We demonstrate the influence of information hearsay on the wide-area evacuation and the effects of guides on evacuee agents. The ratio of evacuee types is set to extreme values in four types of virtual city shown in Table 1.

Table 1. Ratio of each evacuee type

Virtual city type	Unfamiliar	Normal	Familiar
Tourist city	100%	0%	0%
Office city	0%	100%	0%
Residential city	0%	0%	100%
Mixed city	34%	33%	33%

In Figure 7 and Figure 8, ○ and × show the results of the simulation with and without the information hearsay respectively. Evacuation time and the number of streets with fire risk which the evacuees passed in the situation without information hearsay are higher in the tourist city than in other cities (Figure 7). This is because there are not any evacuees who have the correct information on the location of the evacuation area. However, considering the information hearsay, evacuees become to avoid fires and decrease their risk, because they can obtain the information on fires in advance. Besides, the reason why the evacuation time increases is that the wrong information on the location of evacuation area is spread among Unfamiliar evacuees. In the office city and the residential city, the evacuees can evacuate efficiently because they have the correct locational information of evacuation areas. The effects of information hearsay is small, since these evacuees seldom encounter other evacuees. On the other hand, because Unfamiliar evacuees get the information on the location of evacuation area from Normal and Familiar evacuees, they can largely reduce the evacuation time and the risk (Figure 8).

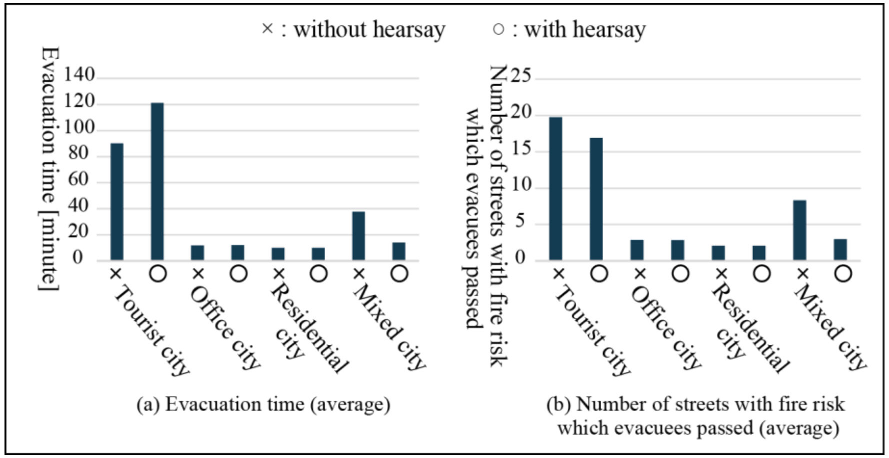

Figure 7. Effects of information hearsay in each virtual city

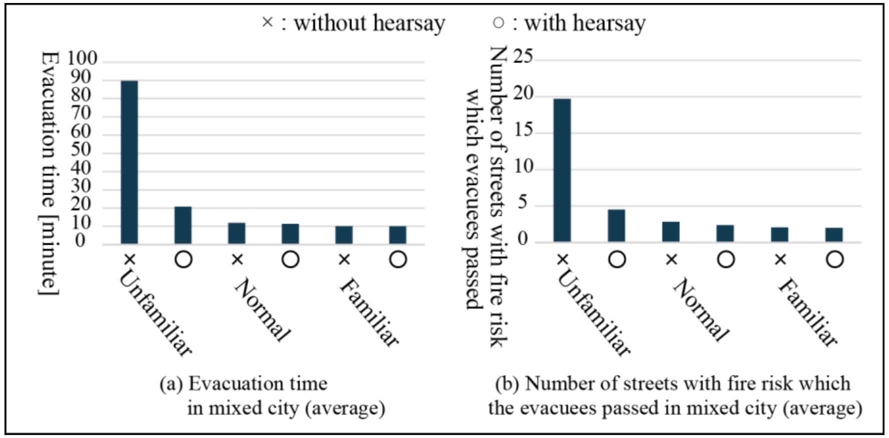

Figure 8. Effect of information hearsay for each evacuee type in mixed city

Effects of Guidance

We analyze the effects of guidance in tourist city where the influence on the evacuees is the most critical. The number of the guides is assumed to be 1% of all evacuees in the virtual city, and they begin to instruct evacuees immediately after an earthquake occurs. Figure 9 shows the difference of the evacuation time and the number of streets with fire risk which Unfamiliar evacuees experienced. These results suggest both the efficiency and the safety of evacuation are significantly improved by guidance in the early stage. However, the effects on reducing the risk by the guidance after four hours since an earthquake occurs are few. It is because the number of evacuees increases three hours or four hours later after earthquake occurrence.

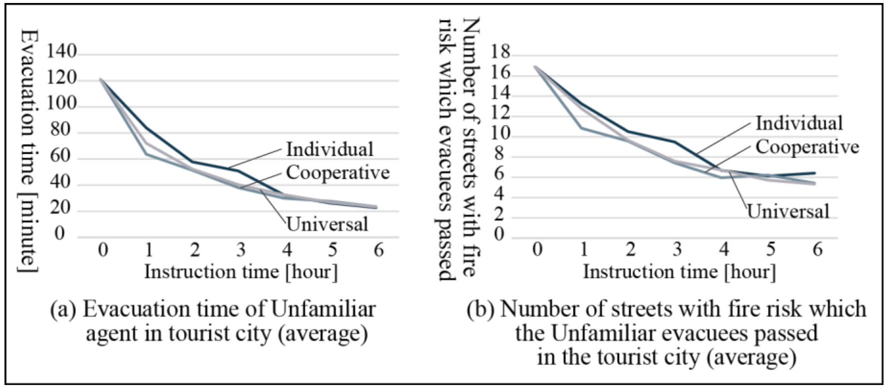

Figure 9. Effects of guide in tourist city

Next, we focus on the effects on improving the evacuation time and risk for the difference of guide types. Cooperative guide can instruct evacuees effectively than Individual guide. In addition, as shown in Figure 10, the risk which guides received monotonously increases according to the instruction time. Particularly, the risk of Individual guide is twice as much as that of Cooperative guide. When the information is collected individually, the amount of collected information is limited and it is likely to become incorrect after a while (Figure 10(b)). 25% of the information which Individual guide collect during the instruction consists of the information by hearsay with other evacuees after six hours (Figure 10(c)). Furthermore, it is hard to get the correct and latest information. However, Cooperative guide can constantly instruct the evacuees using the latest and wide-area information because they have correct information shared among other Cooperative guides. These results suggest that it is important to take cooperation among the guides for more effective and safer instruction.

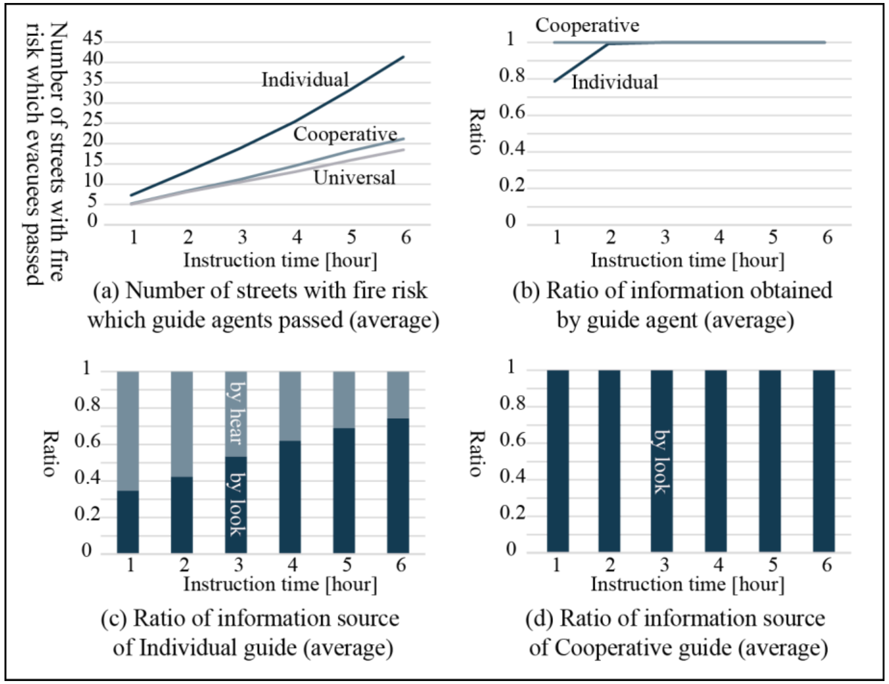

Figure 10. Results of guide agent in the tourist city

SUMMARY AND CONCLUSIONS

We evaluated the influence of information hearsay and guidance on the evacuation time and risk in the wide-area evacuation after a major earthquake. The information hearsay is more effective for the people who are unfamiliar with an area. The instruction by guides is most effective at the time when many evacuees are evacuating. In addition, we demonstrated that cooperating among the guides is important for efficient and safe evacuation.

The information hearsay might sometimes cause inefficient and unsafe evacuation because wrong information might be spread by hearsay. Also, it might be derived from misrecognition. In future research, we will take them into account to improve our simulation model and investigate the influence of information-hearsay on wide-area evacuation at a large earthquake.

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