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Evacuation Guidance Systems and Initial Response to Disaster

Kayo Iizuka[1] and Yasuki Iizuka[2]

[1]School of Network and Information, Senshu University
[2]Department of Mathematical Science, Tokai University

Abstract: *In times of disaster, or other emergency situations, it is critical for people to be evacuated in a smooth manner. However, people often tend to panic when faced with disaster, crowding the evacuation passageways of buildings in the event of fire and congesting roads with cars containing people fleeing from predicted hurricanes. In such situations, an evacuation guidance system might be useful. Making people follow guidance may be one of the most important issues of the evacuation system, because it will affect the effectiveness of the evacuation. To understand more precisely how well people will obey the evacuation guidance, conducting an experiment with a huge number of experimental evacuees would be desirable. However, this is not realistic especially for the requirement analysis phase. Therefore, the authors conducted an attitude survey of initial responses to disasters. The results and findings are presented in this paper, for the purpose of making the evacuation guidance system to be more effective.*

Keywords: *evacuation guidance system, initial response, earthquake early warning (EEW)*

1. Introduction

Much effort has been put into improving disaster prevention countermeasures. Many people survive in times of disaster based on self-help (countermeasures implemented by individuals) and mutual help (countermeasures implemented based on mutual help), although most of the countermeasures that have been implemented are classified as public help, and are implemented by the public sector. Therefore, mutual help and self-help are attracting much attention [1]. Addressing these prevention issues, the authors had proposed a system that facilitates disaster situation information transmission by users [2] (Fig.1). PlaceEngine is implemented for this system to allow users to estimate the current location easily by utilizing Wi-Fi devices. After discovering "which evacuation route is safe" (by using this system), the next issue is "how to evacuate safely and effectively." However, smooth and effective evacuation is not always easy. People tend to rush forward to passageways which are perceived to be safe, which results in congestion. The more people rush, the greater the congestion. On the other hand, some people do nothing special in an emergency situation, if normalcy bias [3] occurs. Corresponding to this issue, the authors have proposed a system that provides optimal evacuation guidance autonomously at the time of a disaster [4,5] (Fig.2). The system uses the mobile devices of evacuees, performs distributed calculation using the framework of the Distributed Constraint Optimization Problem (DCOP), and does not need a central server. In an experiment that the authors conducted, the evacuation completion time decreased by about 10% when evacuation guidance was provided by DCOP. However, the research into human behavior or crowd behavior in emergency or crisis situations is further behind, compared to the hardware progress [6]. In this paper, the authors discuss the human behavioral factors affecting effective evacuation modeling and simulation. Especially considering the behavior of people when they hear an emergency bell, or early earthquake warning (EEW), because these are intended to act as triggers for using evacuation guidance.

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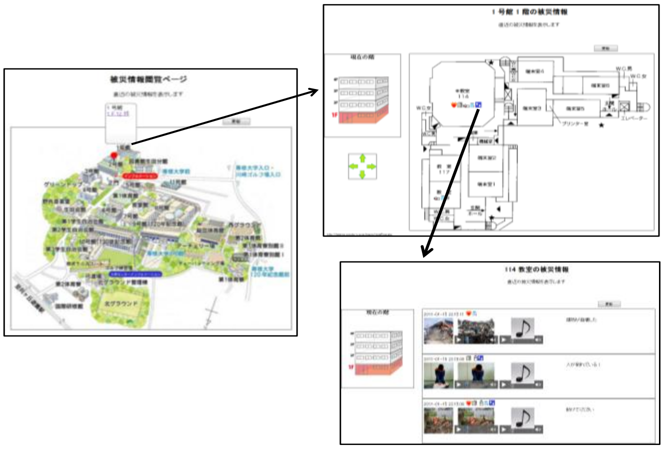

Fig. 1. Situation mapping subsystem of Real-time Disaster Situation Mapping (RDSM) system [2]

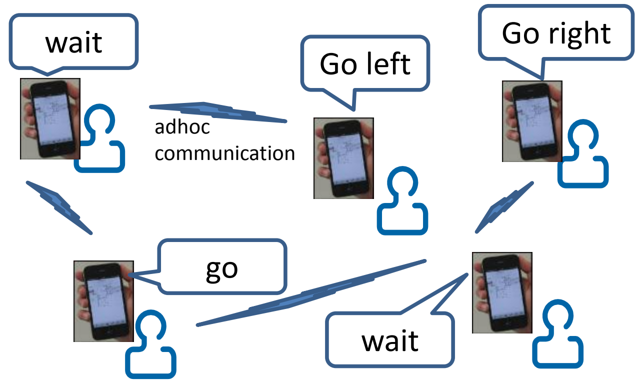

Fig. 2. Disaster Evacuation Assist System [5]

2. Literature Review

For the purpose of seeking human behavioral factors of effective evacuation, the authors reviewed literature in various categories; evacuation guidance methods, evacuation simulation, evacuation simulation incorporating psychological or other human factors, and conflict management.

2.1. Evacuation Guidance Method

Sugiman categorized manual (non-computer) evacuation guidance methods as “the finger-pointing guidance method (Yubisashi Yudoho, in Japanese)” and “the bring-around guidance method (Kyuchaku Yudoho, in Japanese)”. With the finger-pointing guidance method the inducers shout and point at the evacuation exit. This method is popularly used at the time of evacuation drills [6]. Sugiman developed the bring-around evacuation method, with which the inducers bring one or two nearby persons to the exit. In this method, inducers do not shout or point out the evacuation exit. According to the experiment results, the bring-around guidance method was effective for evacuation because an instantaneous small group was formed which followed the persons that the inducers had gathered together, and this led to the rapid evacuation of many people [6].

2.2. Evacuation Simulation

Evacuation simulation has started to gain recognition as one of the important factors in planning; not only disaster prevention planning, but also building or city planning. The Building Standards Act in Japan [7] stipulates the verification of "evacuation safety performance". A Mark of Excellence is given, for free, by the Tokyo Fire Department to any building certified as "well prepared". To obtain this mark, the person responsible for a building is required to apply to the fire station in his area and have his building assessed for its fire safety. Upon the fire station chief's decision, the mark is issued as a fire safety certification. The Mark of Excellence can be placed and shown at the entrance, exit or reception of a building. Certified buildings are announced on the Tokyo Fire Department's website [8]. The Tokyo Fire Department permits evacuation simulation as one of the verification methods of ensuring safety of the entire building. This means the importance of evacuation simulation is increasing.

As for modeling methods, the "potential model", "cellular automaton" and "discrete element model" used to be the major methods of evacuation simulation [9]. However, the usage of multi-agent simulation is increasing nowadays because with traditional models it is difficult to predict non-linear phenomena [10, 11]. Formalizing crowd behavior is required to refine the result of multi-agent simulation, and some works focus on this theme [12].

2.3. Evacuation Simulation Incorporating Psychological or Other Human Factors

Traditional crowd simulators ignore the difference between individuals and treat everyone as exhibiting the same simple behavior [13]. However, it is human beings, not machines or robots who behave in accordance with the information provided by the evacuation guidance systems. Pelechano et al. developed a tool for psychological representation in order to make multi-agent simulation more realistic. The modules of their tools are “decision”, “emotion”, “perception” and “stress” [13]. Shimizu and Nakanishi mentioned that most of the works on interactive agents focus on making the agent behave like a real human being, but most of them deal with superficial matters such as actions triggering interactions, and utterance content. To address this situation, they developed a model that construes persuasiveness from non-verbal behavior [14].

2.4. Conflict Management

The definition of the word “conflict” is “a state of disagreement or argument between people, groups, countries etc.” [15], and conflict management is often discussed in regard to the field of organization or community management. In the case of disaster evacuation, conflict may occur between evacuees who have or have not been instructed to wait for a while. There may be conflicts between the inducer and evacuees, though in the evacuation guidance system that the authors are proposing, the inducer is not a human being, but a system working with an evacuation optimizing algorithm. The types of conflict management solution are: remission (or suppression), backing down (or withdrawal), compromise, enforcement, and problem-solving [16].

3. Survey Result on Awareness of Evacuation Guidance

Making people follow guidance may be one of the most important issues affecting the use of evacuation systems, because it will affect the effectiveness of the evacuation. To understand the extent to which people will obey evacuation guidance exactly, conducting an experiment with a huge number of experimental evacuees would be desirable. However, this would not be realistic. Therefore, the authors conducted an attitude survey focusing on emergency bells or EEW, as triggers for using an evacuation guidance system.

3.1. Survey Results

Data collection took place as an internet survey in November, 2015. In total, 110 samples were collected. Profiles of the survey data are shown in TABLE I to TABLE III.

TABLE I
PROFILES OF THE SURVEY DATA (AGE)

Age	Frequency	Percentage
20~24	6	5.45%
25~29	4	3.64%
30~34	11	10.00%
35~39	10	9.09%
40~44	14	12.73%
45~49	11	10.00%
50~54	17	15.45%
55~59	15	13.64%
60~64	12	10.91%
65~69	5	4.55%
70~	5	4.55%
Total	110	100.00%

TABLE II
PROFILES OF THE SURVEY DATA (SEX)

Sex	Frequency	Percentage
Male	64	58.20%
Female	46	41.80%
Total	110	100.00%

TABLE III
PROFILES OF THE SURVEY DATA (PREFECTURE)

Prefecture	Frequency	Percentage
Tokyo	20	18.20%
Saitama	11	10.00%
Kanagawa	8	7.30%
Aichi	8	7.30%
Hokkaido	6	5.50%
Miyagi	5	4.50%
Chiba	5	4.50%
Oosaka	5	4.50%
Hyogo	5	4.50%
Ibaraki	3	2.70%
Niigata	3	2.70%
Kagawa	3	2.70%
Fukuoka	3	2.70%
Other	25	22.72%
Total	110	100.00%

Regarding the prefecture of the respondents, there were many who lived in the areas around Tokyo, and Nagoya (TABLE III).

When the emergency bell rang, whether or not they were with someone they knew, only 35% of the people went to check the situation straight away, and 13% people answered "I was just waiting while someone sent to check the situation. This means only a half of people tried get the situation information of the emergency, and another half of the people continued their work [Fig. 3 and 4]. This situation may come from normalcy bias. On the other hand, when people were staying somewhere alone, 60% of them went to check the situation straight away. [Fig 5]. This may also be due to normalcy bias.

Fig. 3. The Attitude Survey Result (1)
Q1. What did you do when you heard the emergency bell in the building (when you were with someone they knew)?

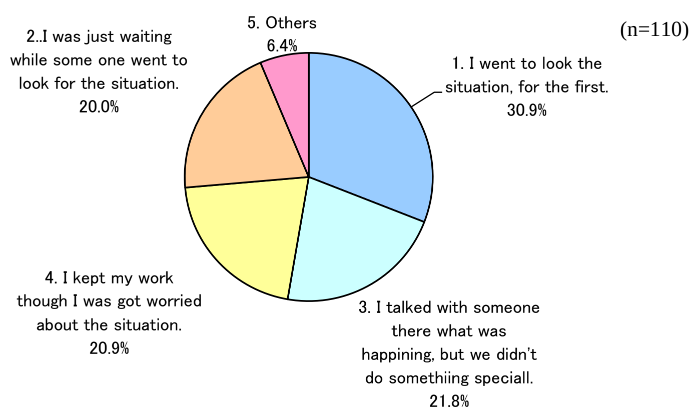

Fig. 4. The Attitude Survey Result (2)
Q1. What did you do when you heard the emergency bell in the building (when you are with someone you did not knew)?

(n=110)

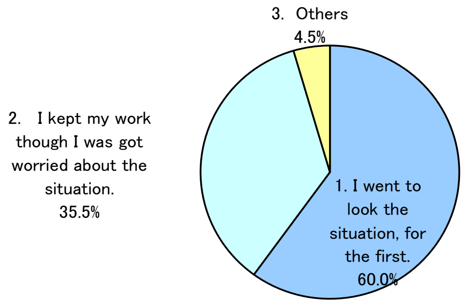

Fig. 5. The Attitude Survey Result (3)
Q3. What did you do when you heard the emergency bell in the building (when you are alone)?

(n=110)

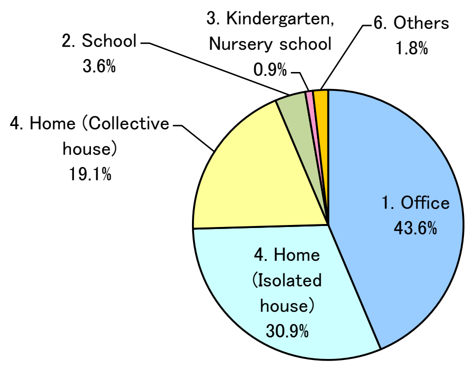

Fig. 6. The Attitude Survey Result (4)
Q4. Where do you stay usually?

The EEW, based on the information from installed seismometers in Japan, quickly conveys information system in the region that is not it still shaking when detecting the shaking of an earthquake. On the other hand, with respect to an earthquake emergency, about 30% of people hide under a desk and about 60% take action, such as to check the evacuation passage (Fig. 7). From this result, people tend to trust EEW rather than emergency bell. Emergency bell sometimes offer misinformation, generated as a result of a sensor error. On the other hand, current EEW such as those provided by mobile phone carriers to inform globally, are believed to have reliable information that “an earthquake is coming.” However, since EEW provide that earthquake will come, and the information about magnitude of the shaking is not provided. Therefore, there is possibility that people think that EEW provides the information that is not always emergent. In addition, Japanese people have a tendency to avoid extreme action, and hiding under a desk may be considered "embarrassing".

(n=110)

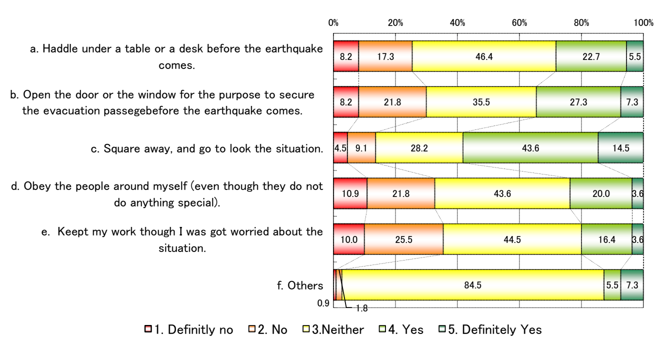

Fig. 7. The Attitude Survey Result (5)
Q5. How do you behave when you hear the EEW at the place answered in Q4?

*EEW: Early Earthquake Warning

As regards the reason people do not take action after the earthquake early warning, about 60% respondents answered “definitely yes” or “yes” for the answer item “to know the situation is important than do something” (Fig. 8). In general, people receive EEW by mobile phone in Japan. There are limitations that the strength of the shaking level of earthquake is not provided. On the other hand, for a fixed terminal in hospitals and power plants EEW can receiver for advanced users of (the installed address was clearly of the terminal) is installed, and shaking level, time to reach is notified.

(n=110)

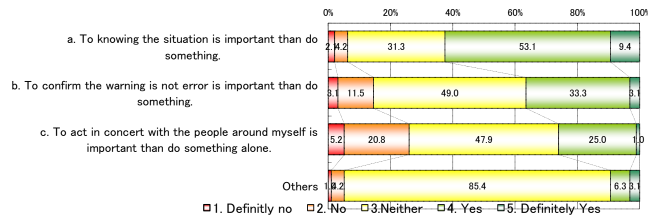

Fig. 8. The Attitude Survey Result (6)

Q5. The reason why you did not take action in response to the EEW *Q5 was asked to respondents who answered “No” or “Definitely no” for the Q5a-c.

(n=110)

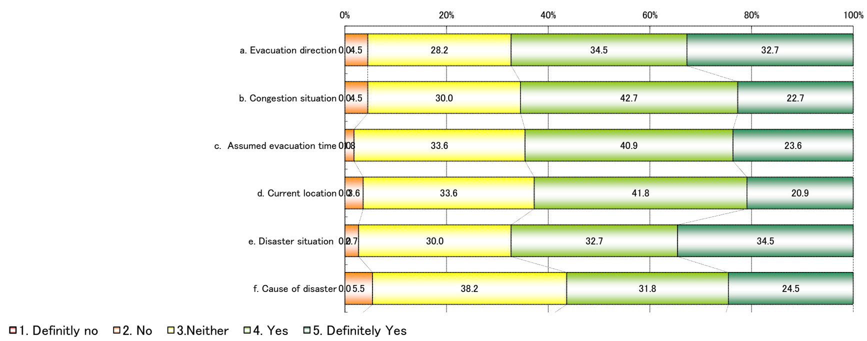

Fig. 9. Required information for evacuation guidance

Fig. 9 shows required information for evacuation guidance. The evacuation direction and the disaster situation seem to be thought more important for the people. The evacuation direction seems to be important because it is crucial for evacuation action, and the disaster situation seems to be important because it might be an inducement for evacuation direction, that means it may prevent normalcy bias.

3.2. Functional and Conditional Requirements for the evacuation guidance system

From the survey results, functional requirements for an evacuation guidance system considering behavioral psychological issues can be described as follows.

- Evacuation guidance starts with the EEW when the disaster is an earthquake.
- The actual situation of the disaster must be shown

This types of information are important because not only are they crucial for evacuation action, but also they help people avoid normalcy bias.

4. Conclusion

In this paper, we reviewed and indicated some important psychological factors to consider in evacuation simulation. It is human beings, not machines or robots, who behave in accordance with the information provided by the simulation. From the attitude survey, the authors found some important factors that should be considered in order to support a smooth evacuation. From the survey result, clarifying the effect of waiting would motivate evacuees to follow the system. However, this result is pre-existing attitude survey asked at normal times, not emergency times. Therefore, research from other mean in addition to the survey we describe in this paper is desirable. In future research, the author will conduct a new survey, enhance the prototype of the evacuation system, and conduct further experiments.

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