17th World Conference on Earthquake Engineering, 17WCEE
Sendai, Japan - September 13th to 18th 2020

EFFECTIVENESS OF SHARING INFORMATION UNDER THE EMERGENCY SITUATION WITH ON-FOOT EVACUATION DRILL

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Abstract

Since nobody has grasped the damage situation when a large-scale disaster occurs, providing appropriate information such as road blocked caused by the disaster to evacuees encourage effective evacuation.

This research developed a smart phone application as part of an EMSS (Evacuation Mutual Support System) for sharing information on the geographic location of evacuees, target evacuation site and road blocked by obstacles such as collapse of a building. We verified the effectiveness of sharing the information with an emergency drill in the Kanazawa-Nomachi area, Ishikawa Prefecture. Participants are provided one of three types of smartphones with restrictions on the information that can be shared and displayed.

We analyze the evacuation trajectory log of evacuees recorded the location every 5 minutes by the application and verified the effectiveness of location information sharing. The trajectory log show that evacuees could choose detours routes in advance using the location information of road blocked from the application. However, some evacuees could not avoid a route blocked by an obstacle despite having acquired this information. It is presumed that the evacuees did not use the application effectively because of following the leading evacuees who were unclear whether could acquire the information. The results imply that it is important to get to know the effectiveness of the application and use it on evacuation.

We conducted a questionnaire survey on effectiveness of the sharing information application for participants.

The results show that effective the information of road blocked and object of evacuation, but evacuees position not effective. It became clear that it was necessary to devise how to show the location information of evacuees.

Keywords: Evacuation assistance, Information sharing, Evacuation behavior, Evacuation drill, Application

1. Introduction

Japan is an earthquake -prone zone- the Tohoku Earthquake that struck the Pacific coast on March 11, 2011 and the Kumamoto Earthquake on April 14–16, 2016 are recent examples. There are future concerns of large-scale earthquakes, such as those that may happen in Tokai and Tonankai. In the event of such a disaster, injury or loss of life is likely to increase due to delayed escape or panic. To reduce the extent of damage, it is important that appropriate information be transmitted to those who can be affected, and evacuation be carried out swiftly. Currently, evacuation shelters are set up in each district of Japan to provide evacuation to people in case of an earthquake or other disaster. However, there are several issues in gathering evacuees at these shelters. First, as seen in evacuation behavior patterns in Japan, people mostly live in non-residential areas that lack sufficient information about the district. In fact, a study by Yamaguchi et al. [1], which analyzed the change in travel behavior between cities by using mobile terminal location information, found that 2–5% of the people in Japan typically stay outside their home prefecture; during the New Year holiday and Bon Festival, this number goes up to around 10%. For example, Kanazawa, a city facing the Sea of Japan, has old townscapes, such as the Higashi Chaya District and the Teramachi Temples, which are popular sightseeing spots. Furthermore, the opening of the Hokuriku Shinkansen has increased the number of tourists. When a disaster occurs in such a tourist spot, those who need evacuation may not be aware of which road to take to reach the evacuation shelter. In such cases, a mechanism is required for providing information on the evacuation destination and route. Second, there is the possibility of the road leading to the evacuation shelter being damaged, or the pre-planned evacuation route being inaccessible due to the collapse of a building or a fire. Thus, it is almost impossible for the victims to obtain the required information to determine the evacuation route immediately after a disaster. Consequently, they might gather on dangerous roads, which could lead to more casualties.

These issues can be addressed by introducing an application utilizing the portable terminal's two-way communication system. First, non-residents can be guided to an appropriate evacuation route and shelter by providing them evacuation behavior information of people familiar with the area's roads and shelters. Second, by informing evacuees about the roads they should avoid, real-time information on road damage can be transmitted to the subsequent evacuees. Thus, concentration of people on dangerous roads and locations can be avoided, autonomously and smoothly.

Yoshida et al. worked on the construction of an Evacuation Mutual Support System (EMSS) to provide necessary information to victims during evacuation. It was based on the ERESS (Emergency Rescue Evacuation Support System) [2~6], which aims to reduce casualties during a disaster. ERESS analyzes and shares information on acceleration and angular velocity of multiple terminals. It can detect a disaster from abnormal behaviors, such as stop and fall for a certain period at multiple terminals, from the aggregated information by using ERESS, thus making quick evacuation behavior possible. On the contrary, EMSS focuses on evacuation assistance to the shelters during a disaster. The novelty lies in supporting appropriate evacuation behavior by sharing information, such as the location of nearby shelters and possible evacuation routes. To build the EMSS, only small-scale evacuation experiments using mobile terminals have been carried out; large-scale experiments with a larger number of participants are yet to be done. Furthermore, evacuation behavior that assumes adequate information sharing among evacuees has not been elucidated. In Yoshida et al.'s experiment [7], it was believed that sharing each other's location information using applications and knowing about impassable places would be effective for a quick evacuation. However, the evacuation distance was short and the actual shelter was not considered among the assumptions. In the present study, we conducted a large-scale experiment involving several participants to test EMSS's practical application. We investigated how information sharing by applications affects evacuation in the case that the amount of information to be shared increased and the evacuation routes became longer.

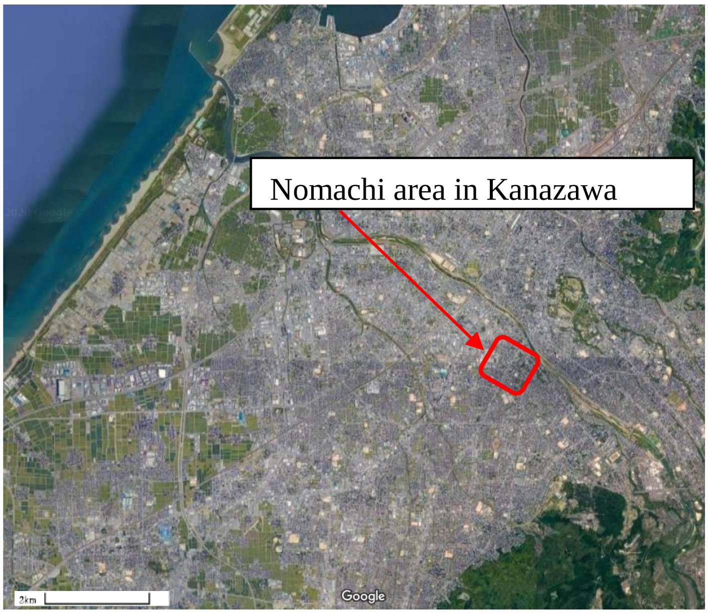

Fig. 1 – Location of target area

2. Overview of evacuation experiment using location information sharing application

2.1 About Nomachi area in Kanazawa

The Nomachi district, which was the subject of this study, is in the center of Kanazawa City in Ishikawa Prefecture (Fig. 1). It comprises 1–4, Nomachi and 5, Teramachi, and has a total population of 3,293 and number of households at 1,724 (as of January 1, 2018) [8]. The area is home to sightseeing spots such as the Nishi Chaya District and Teramachi Temples—the former attracts a huge number of domestic as well as international tourists, with cafes and shops lined up on the 250m street where the traditional cityscape is preserved; the latter is the largest of the three temples areas in Kanazawa with about 70 temples and shrines. The shrines that narrate the history through popular stories include "Myoryuji," a famous ninja temple, while "Shogetsuji," home to a large cherry blossom, is a nationally designated natural monument. Several tourists visit these shrines. In addition, because the Nomachi district (Traditional Buildings Preservation District, Agency for Cultural Affairs) preserves the traditional cityscape, its roads are narrow and labyrinthine, like a maze.

Therefore, it is assumed that the damage will be enormous in case of an earthquake or a fire in this area, as many tourists are not aware of the location of the evacuation shelters. In other words, it is suitable for confirming the effects of the EMSS.

2.2 Overview of the emergency drill in the Kanazawa-Nomachi area

We conducted an experiment as part of the Kanazawa City Disaster Prevention Drill, on August 26, 2018, with 551 participants and Nomachi Elementary School as the evacuation shelter. When a disaster occurs in Kanazawa City, the residents are first evacuated to the temporary shelters of each town council, and then taken to the local evacuation shelter for each group that is smaller than that of the town council. Similarly, in the Nomachi area, people were evacuated to the temporary shelter of each town council, and then divided into groups and taken to the school. The experiment area comprised 140 groups of 26 town councils. We considered each group as a single evacuee to understand the evacuation behavior.

For the experiment, some of the Nomachi residents, the evacuees, used an application to share location information, following which, the evacuation behavior was recorded. Each group had one iPhone to run the application. Some groups were allowed to use the application with limited display information to diversify the evacuation behaviors and study the different ones. The restriction pattern of the display information is described later in this article. Furthermore, it was assumed that the road is damaged, and some evacuation behavioral characteristics were understood by setting impassable routes. During a disaster, routes such as narrow passages facing a block fence or places where roof tiles may fall on the sidewalk are determined as dangerous locations. We decided on these factors by discussing with disaster prevention experts. For this experiment, when an evacuee reached an impassable point, its information was shared with other mobile terminals. Therefore, when the evacuation began and somebody had reached that point, the location information was displayed on the application.

Fig. 2 – Application screen

2.3 Application features

For this research, we used an independently developed application displaying ① to ④ on a map:

① Current location of user, ② Current location of other users, ③ Impassable points, and ④ Evacuation shelter

In addition, a function was installed to record the location coordinates of the mobile terminal every five seconds for analyzing the evacuees' behavior. The application's condition setting was divided randomly into three groups—1, 2, and 3—according to the display condition's restrictions. When "Group 1" was selected, the above-mentioned ① and ④ were displayed; when "Group 2" was selected, ①, ②, and ④ were displayed; and when "Group 3" was selected, all four were displayed.

Fig. 2 shows an example of the application screen when Group 3 is selected—current location of user, current location of other users, and impassable points are displayed (evacuation shelter is not within the display range). As can be seen, various pieces of location information of other persons running the application are displayed on the map simultaneously.

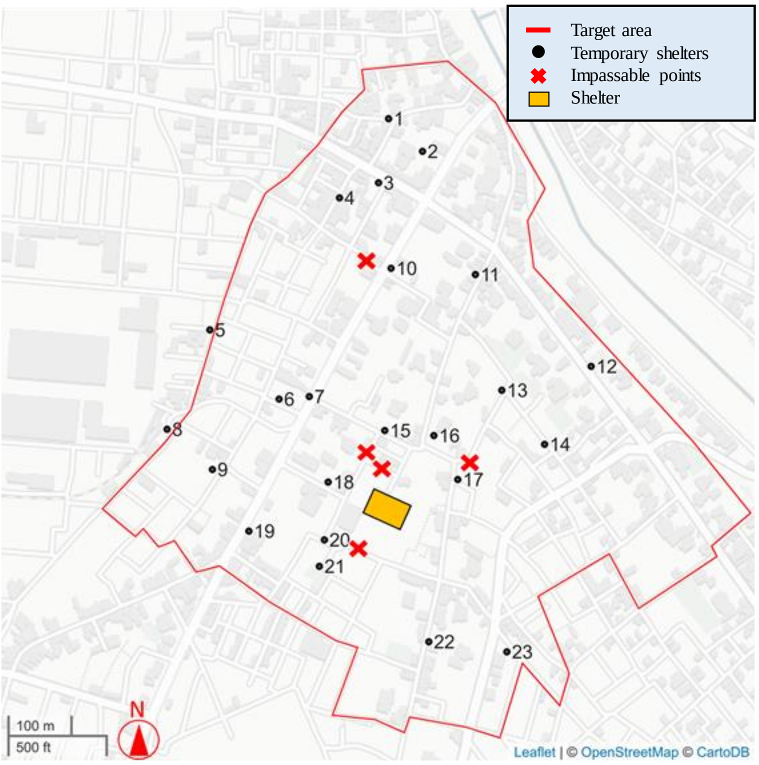

Fig. 3 – Location of the temporary shelter and impassable points

2.4 Experimental method

After the earthquake alert was issued, the residents who were evacuated to the temporary shelter, as shown in Fig. 3, were divided into groups, with each given an iPhone with the application condition settings completed. Then, they were evacuated to the shelter after detouring around the impassable points. At impassable points, the staff shared the information with other terminals by selecting and activating the application type "thing" when the residents reached those places. Then, other staff received the iPhones from the residents evacuated to the shelter and sent the data log of the passage route to the server. Table 1 shows the results of the attributes related to the subjects.

Table 1 – Subject attributes

Group	Number of subjects
1	46
2	45
3	46

Sex	Number of subjects
male	93
female	44

Age	Number of subjects	Age	Number of subjects
10's	3	50's	29
20's	18	60's	31
30's	6	70's	32
40's	16	80's	2

3. Evacuation experiment results and discussion

We distributed 163 iPhone 6s for data collection, but some of them had improper recorded log data due to the recording of location information was terminated during the emergency drill. After the pre-processing for data exclusion, analysis of 137 iPhones was required. Processing included, “if the position information at two consecutive times is more than 20m, split at that point and use the group as correct where many log data are continuous,” and “30m from the set start point data commencing from within the buffer and the analysis target” was executed. The distance was set to a value at which no further movement was considered based on the subject’s moving speed. Fig. 4 shows the behavior logs of the 137 iPhones analyzed—it was found that the evacuation behavior noted was not on narrow streets but the widest possible roads.

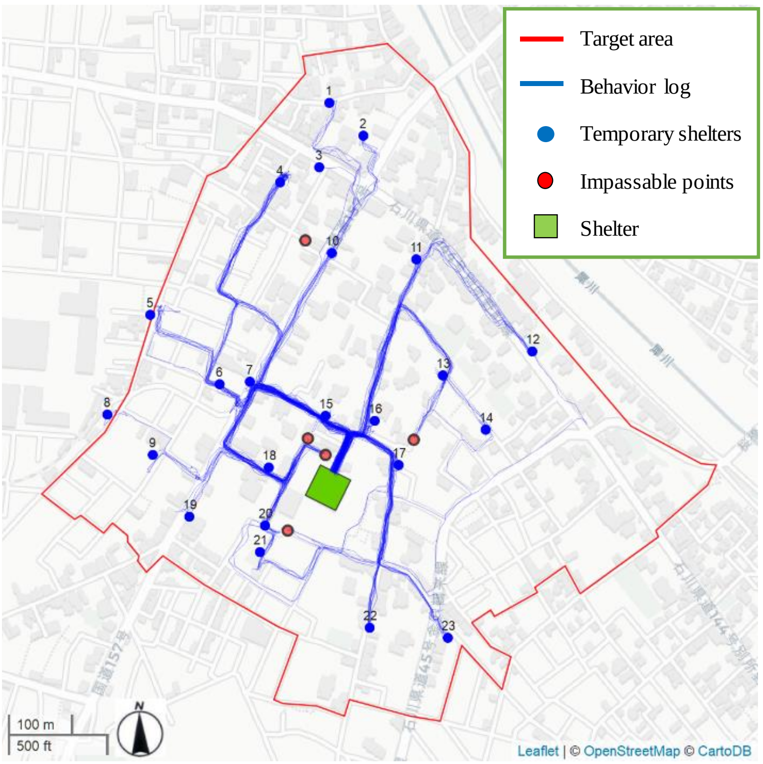

Fig. 4 – All behavior log

Fig. 5 shows the locations where the slow and fast evacuation speeds behavior log was recorded, and the circled location indicates the temporary shelter. It can be confirmed that the places with almost no movement and slow speed (0.01m/sec or slower) were primarily the temporary shelter, intersection facing the main street, and vicinity of the impassable points. In instances where the moving speed near the impassable points was slow, actions such as checking the application and examining a detour were carried out. Contrarily, it can be confirmed that many locations near the evacuation shelter witnessed a fast moving speed (1.8m/sec or faster). We inferred from this that the evacuation speed is often increased by recognizing that the user has arrived at the destination (evacuation shelter). Since there is time to check the application in places with slow evacuation speed and those with almost no movement, it is possible to detect such an action and provide immediate information to promote a more efficient evacuation.

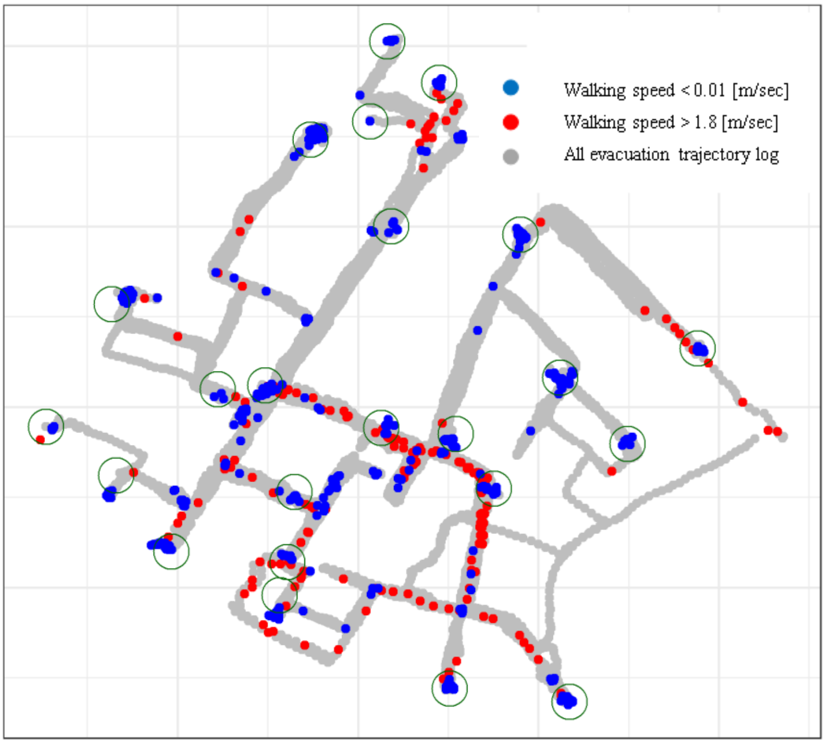

Fig. 5 – Locations where the slow and fast evacuation speeds behavior log

Fig. 6 shows the distribution of time from the point the iPhone was handed over to the subject at the temporary shelter to the point when evacuation started for each group (time when the user moved 3m or more per five seconds). In this study, we defined "to start moving (evacuating) to the evacuation shelter" as "to move 3m or more in five seconds" and proceeded with the analysis. This is because "Fair Competition Regulations Enforcement Regulations on the Labeling of Real Estate" [9] stipulates that "the required time on foot should be a value calculated as taking 1 minute per 80m (1.33m/s) of road distance." Therefore, we defined it based on a 50% walking speed, that is, 0.67m/s. Analysis of variance using the null hypothesis—that the time required for the evacuation to start was the same for each group—showed that the p-value of significance was 0.081, and the null hypothesis could not be rejected. Thus, the evacuation's starting time had almost no effect due to the difference in the information obtained from the application. Moreover, it was confirmed that evacuees take from five seconds to 50 to determine the evacuation behavior policy and confirm the application.

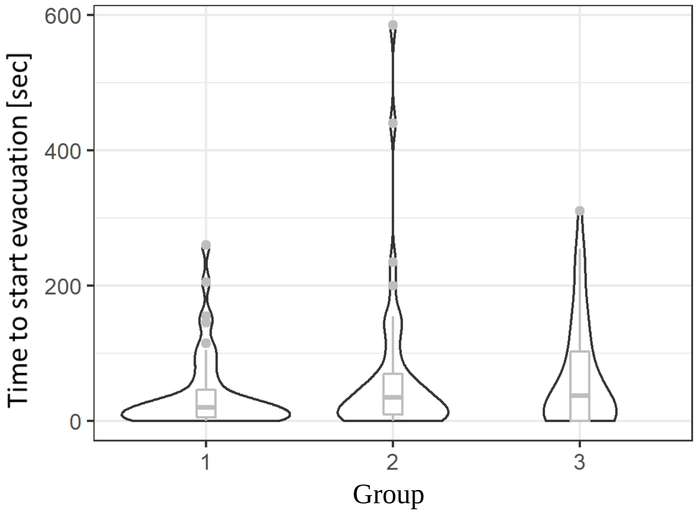

Fig. 6 – Time required for each group to start evacuation

Next, the movement direction was calculated for each subject’s behavior log by taking the difference in the position information at two consecutive times. Furthermore, an angle change from the evacuation direction at the immediately preceding time was calculated for the movement direction from the difference between the two directions. If the turning angle was small, it was presumed that the evacuation behavior is being performed in the same direction as the previous time; if it was large, it meant the evacuation direction had changed. Changes in the turning angle during evacuation are shown in Figs. 7 and 8. Figs. 9 and 10 show the respective behavior logs. Fig. 7 shows a case wherein no impassable point was encountered, and Fig. 8 shows a case where it was—in both, it is assumed that immediately after evacuation from the temporary shelter was started, the application was checked for information on how to evacuate, and it can be seen that the movement directions vary considerably. In Fig. 7, the direction is stable since the start of the evacuation. In Fig. 8, it is generally stable from the start to approaching the impassable point. However, the movement direction greatly fluctuated immediately after the subject noticed that the road ahead was impassable. This is because, as can be seen from the behavior log in Figure 9, when arriving at an impassable point, the evacuees need to return the route and that causes changing moving direction drastically. Even after recognizing from the results of this experiment that an impassable point or road has been reached, it would not lead to a huge time loss to select another evacuation route by using the application. It was found that detecting the change in the movement direction and providing appropriate real-time information is possible; this finding can be used to introduce improvements in the existing system.

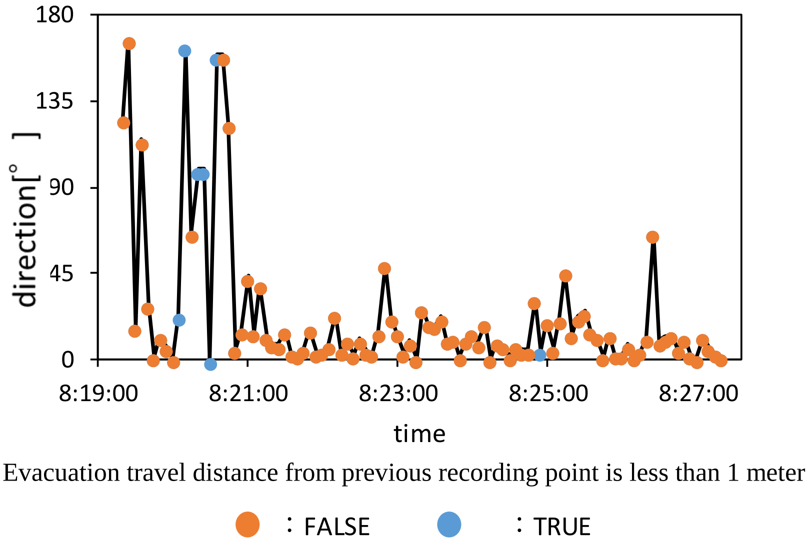

Fig. 7 – Transition of the movement direction (ID:76)

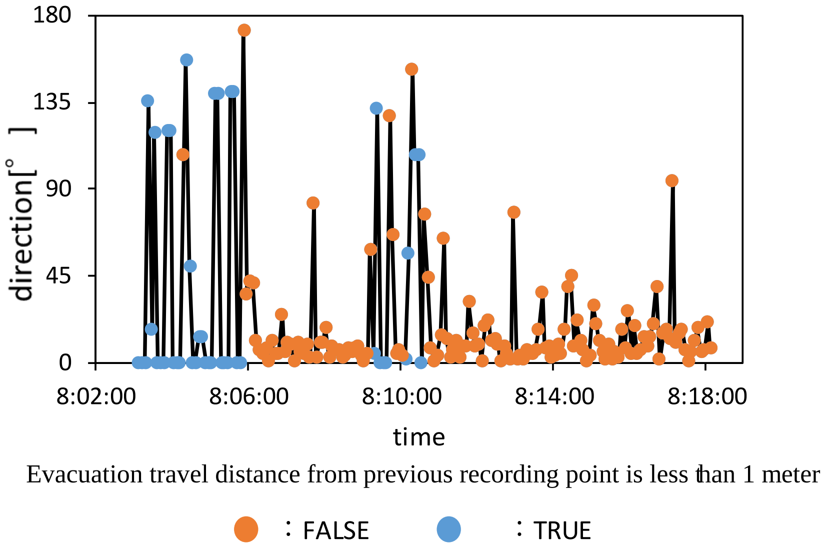

Fig. 8 – Transition of the movement direction (ID:55)

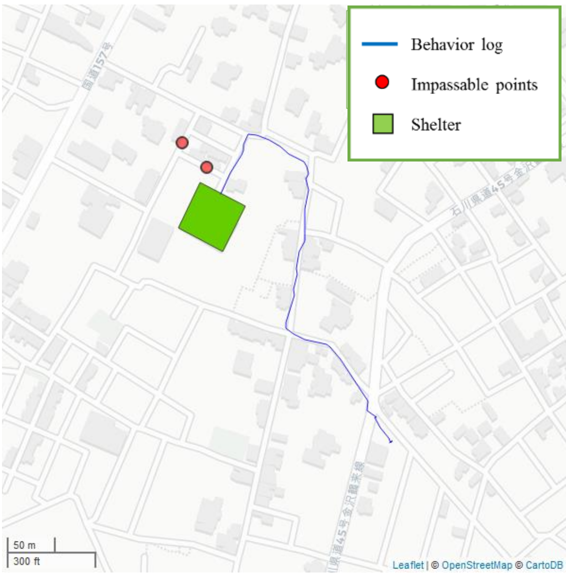

Fig. 9 – Behavior log (ID:76)

Fig. 10 – Behavior log (ID:55)

4. Conclusions and future prospects obtained in this study

After a disaster, a building's collapse may damage the evacuation route. Therefore, it is important to take evacuation actions keeping in mind the dynamic nature of the situation. In this study, we conducted an experiment to investigate evacuation behavior by using an application that introduced a system supporting real-time evacuation through information and communication technology. Consequently, it was found that simply displaying impassable points on the application screen is not enough; it is necessary to create applications that are easier to use. For example, at a point where the moving speed is slow or the direction changes, it is determined that there is time to obtain information from the application, and the real-time evacuation information is displayed by a larger icon on the application screen. In addition, even when information about evacuation, such as where the others or impassable points are, is obtained, the evacuation start time is small irrespective of such information; thus, it is important to actively encourage the use of applications.

In this manner, the experiment clarifies the prospects of EMSS. In the future, the system will be improved and expanded through further experiments to verify its usefulness, thereby achieving safe evacuation. Moreover, calm evacuation behavior can be performed with sufficient mental reserve. An example of the improvement is as follows. An isolated road or a detour is automatically determined based on whether there is any abnormality on the evacuation route or the movement direction, and then, an impassable route is displayed in real time on the application. Furthermore, it is necessary to increase the application's reach by adding daily use functions. However, issues such as what kind of information should be collected and how to provide it to the users are socially important and require urgent attention.

5. Acknowledgments

We would like to thank Editage (www.editage.com) for English language editing,

We would like to thank KAKEN (18H01677-02), Mitani Research and Development Support Foundation (Representative: Yoshihiro Takata) and the Hokuriku Regional Development Association for their cooperation.

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