Local Disaster Mitigation Technology with Travel Support Application

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ABSTRACT

Efficient and rapid rescue activities are vital in the immediate aftermath of a large-scale disaster. However, the locations of the tasks requested (e.g. rescues, relief, special care, and assistance) and those who support, assist, or respond are often spatially separated. In this paper, we developed a Web application (travel support application) to support the efficient travel of responders by integrating a method of optimizing travel and navigation for rescue activities and a system of real-time disaster information collection and sharing. We then demonstrated the efficiency of the travel support application through some field experiments. Also, we conducted a demonstration experiment assuming a flood disaster at the crisis management office of a local government. Finally, the possibility of using the developed system at non-emergencies was examined to address the common problem of disaster prevention systems.

Keywords

travel support application, rescue activity, multiple traveling salesman problem, field experiment.

INTRODUCTION

We are faced with the foundational task of saving lives and ensuring the safety and security of our society in the event of a disaster. Because of the many intervening uncertainties in disasters, and because disaster situations change from moment to moment, pre-agreed-upon response methods may not be effective or sometimes impossible. Therefore, there is a need for new tools for First Responders (FRs) that take advantage of the latest technologies. Such tools must be certain, efficient, and effective in saving lives and assisting vulnerable populations.

In order to reduce human casualties and property damage caused by a major earthquake, rescue and firefighting activities must be carried out promptly. However, in past major earthquakes, information on where and what kind of disaster was occurring (early disaster information) was not available, leading to delays in the initial response and the spread of damage. If the location of fires and trapped people could be quickly and accurately identified, firefighting and rescue operations could be carried out with the maximum use of the limited resources of firefighters and rescue workers. In addition, if road blockages caused by collapsed buildings can be identified immediately after a disaster, it is possible to find a travel route that avoids these blockages and to arrive at the site efficiently. In other words, real-time and accurate collection, sharing, and utilization of disaster information immediately after a major earthquake may contribute greatly to reducing human suffering and property damage. Osaragi and Niwa (2018) proposed a practical, real-time system constructed in a cloud server for collecting, sharing, and using disaster information. This system could contribute significantly to reducing human and physical losses by collecting, sharing, and using disaster information immediately after a major earthquake in a quick and precise manner.

At the time of occurrence of a disaster, prompt responses to rescues, relief, and requests for assistance are required. However, it is difficult to foresee when and where such demand will be required. Moreover, there may be instances where it is not possible to respond to this demand because the person in charge of the disaster response is also adversely affected or resides in a distant location (Hisada et al., 2019). In other words, if we call the person

requesting rescue, relief, rescue, etc. a "demander" and the person in charge of responding a "responder," then immediately after the occurrence of a disaster, we face the problem of which responder to assign to which demander. In many cases, responders must respond to multiple requesters in sequence, and responders are required to travel multiple demanders efficiently. Previous disasters have seen imbalances and delays in the assignment of responders to demanders, and this is regarded as an issue to be addressed (Tanaka, 2018). For example, elderly people, young children, people with disabilities and other people requiring special care, and people whose safety needs to be confirmed are assumed to be demanders. Evacuees seeking relief supplies, injured or trapped people, and people requesting firefighting activities can also be considered as demanders. Furthermore, from a long-term perspective, residents requesting assistance in debris disposal and cleanup can also be regarded as demanders. In addition to the personnel of public organizations such as the Self-Defense Forces, police, and fire brigade, the responders can be assumed to be members of the community welfare committee, community association, and fire brigade members, and student volunteers can also be considered as responders. In past disasters, bias and delay have occurred in the assignment of responders to the demanders, and this is considered to be one of the challenges in disaster management. Osaragi et al. (2019) formulated the problem of a limited number of responders traveling efficiently to a large number of tasks in the aftermath of a disaster for rescue/relief as a regional travel problem. They then proposed a solution to the regional travel problem with reference to past research on the multiple Traveling Salesman Problem (mTSP) (Ni, 1997; Imada et al., 2016; Ogawa and Inoue, 2014). Specifically, they constructed a method of determining the assignment of responders to tasks and the travel routes of responders using fuzzy c-means clustering (Ono et al., 2004) and a genetic algorithm (GA) (Nakamura et al, 2004).

The objective of this research is to "efficiently utilize the limited time, human resources and goods and to minimize damage" at the occurrence of a disaster. For this purpose, we integrate the methods and systems, which were proposed in the previous research, and propose and demonstrate the "travel support application", which can efficaciously assign responders to various tasks (the events that require responses) that are spatially distributed at the occurrence of a disaster, navigate by identifying optimal routes for patrol and monitor progress. Examples of functions of the travel support application are shown in Fig. 1. Specifically, we attempt to verify the travel support application using simulations and field experiments, and perform a demonstration experiment at the crisis management office of a local government to demonstrate that the travel support application is useful as local disaster mitigation technology. Finally, after reviewing the limitation of the existing disaster response and mitigation support technology, we discuss a strategy for social implementation by using the travel support application for the application in non-emergencies.

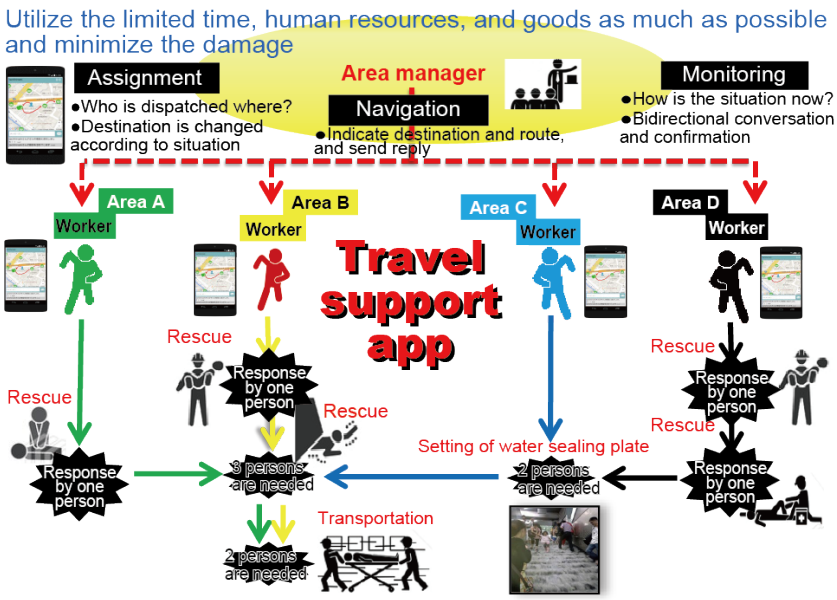

Figure 1. Concept of travel support application

Based on the field experiments with the travel support application and its evaluation from a quantitative perspective, we present a technology that can be leveraged by various FRs (fire departments, emergency medical services, police agencies, and civil protection organizations). More specifically, we demonstrate that the travel support application allows for the following.

- Enables a large number of responders to help protect the safety and security of the requestor efficiently and without disruption.

- Enables optimal use of available human resources while automatically and flexibly responding to a variety of situations.
- Enables responders to be deployed when and where they are needed, and allows for real-time sharing of information and communications among teams and with the affected population, by taking into account responders' areas of expertise and capabilities.
- Enables use of the system during normal times to maintain the system and update the database, thereby increasing the cost performance of the system implementation.

This paper presents a way to upgrade the capacity of FRs to use new ICT technologies that facilitate efficient, coordinated responses and ultimately effective decision-making and that work in complex, dynamic, and stressful environments.

SYSTEM AND METHOD DEVELOPED IN PREVIOUS RESEARCH

Real-time web system for collecting, sharing, and using disaster information

Numerous studies have been conducted addressing methods for early gathering of disaster information. There has been a significant increase in the use of social media, including extant research on visual analysis and visualization toolkits for social media for disaster management (Ngamassi et al., 2017; Petersen et al., 2017; Ngamassi et al., 2016; Denis et al., 2014; Hiltz et al., 2014; Yates and Paquette, 2011). In addition, attempts are being made to utilize the capabilities of mobile devices such as smartphones and tablets as "data sensors" for disaster information collection (Kubota et al., 2013; Hiruta et al., 2012; Stuart et al., 2014; Matthew et al., 2010). Kubota et al. (2013) propose a system that automatically places disaster information on a map using location information associated with EXIF (Exchangeable Image File Format) information by sending disaster images and text captured with smartphones via email. Hiruta et al. (2012) proposed an exclusively smartphone-based system for sharing disaster information that requires no communications infrastructure or dedicated servers and is highly robust against disasters. Both concepts are seen as advances over the current systems, but it is difficult to update information in real-time during a disaster because the situation changes from moment to moment, and because the information in the system is likely to degrade with time. Therefore, research has been conducted to collect information posted on social networking services (SNS) to quickly gather disaster information from a wide area. For example, Stuart et al. (2014) proposed a system that extracts keywords related to disaster information from Twitter tweets in real-time, links them with geographic information, and shares disaster information on a map. Experiments using ICT (information and communication technology) have shown that such an approach has while there is potential, but there are also issues to be addressed, such as how to improve accuracy by eliminating lies, mistakes, and outdated information contained in SNS postings. Osaragi and Niwa (2018) have developed a system that enables the real-time collection, sharing, and utilization of information acquired by system users on a disaster-resistant cloud server during a disaster. Among the various users and situations that the system is expected to be used for, they conducted a field experiment assuming that disaster prevention volunteers use the system to collect disaster information. Furthermore, simulation experiments were conducted under the assumption that network bandwidth is limited during a disaster, and it was shown that even if about 3,000 users use the system at the same time, information can be collected without loss of real-time performance when the general communication environment is preserved and bandwidth is limited. For the details of this system, please refer to Osaragi and Niwa (2018).

Method for efficient regional travel for rescue and relief activities in a disaster

First, we proposed a solution method for the intra-regional travel problem, referring to previous research on the multiple traveling salesman problem (mTSP) (Ni, 1997; Imada et al., 2016; Ogawa and Inoue, 2014). Specifically, we developed a method for assigning correspondents to requesters and determining their travel routes based on the location information of demanders and correspondents using the fuzzy c-means clustering method (Ono et al., 2004) and a genetic algorithm (GA) (Nakamura et al, 2004). The problem of multiple responders traveling to multiple demanders is very similar to mTSP. Strictly speaking, however, the mTSP differs in that it is a problem of minimizing the time it takes for a responder to complete travel and return to the starting point, whereas the intra-regional traveling problem here is a problem of minimizing the time it takes for a responder to complete responding to all demanders. When the number of demanders and responders increases, it is known that mTSP is a class of problems called NP-hard, where it becomes difficult to find an exact solution in a finite time.

Based on the aforementioned idea, we proposed a method to support travel activities in the region to minimize damage by maximizing the use of limited time, manpower, and supplies in chaotic situations immediately after a disaster strikes (Osaragi et al., 2019). Specifically, we have developed a method for deriving an efficient travel route from the viewpoint of which responders should travel and respond to which demanders in which order to

minimize the time required to complete responding to all demanders (travel completion time). More specifically, this method enables us to efficaciously assign responders to various tasks spatially distributed at the occurrence of a disaster, navigate by identifying optimal routes for travel, and monitor progress. For the details of this method, please refer to Osaragi et al. (2019).

PROPOSED SYSTEM COMPOSITION OF TRAVEL SUPPORT APPLICATION

Given the above background, we have integrated a real-time web system for collecting, sharing, and utilizing disaster information, with a method that can efficiently travel the area in response to various requests that arise during a disaster, and have added new functions to the existing system to create a new practical system. This integrated web system is called the "travel support application."

The system composition of the travel support application is shown in Fig. 2. The system is constructed based on a cloud server (Amazon Web Services EC2) (Amazon.com 2017), considering disaster-resistance, stable operability and the real-time operation of the system required at the occurrence of a disaster. The basic structure of this system allows users to post information to the cloud server via mobile devices such as smartphones and that is shared. It can also function as a system for collecting and sharing disaster-related information at an early stage, which is an essential precursor to the initial response immediately after the occurrence of a disaster. The aforementioned objective can be achieved by incorporating computing servers to assign tasks to responders and identify the optimal route into the basic structure of the system. It is possible to flexibly respond to various requests by incorporating different kinds of functions into the computing server.

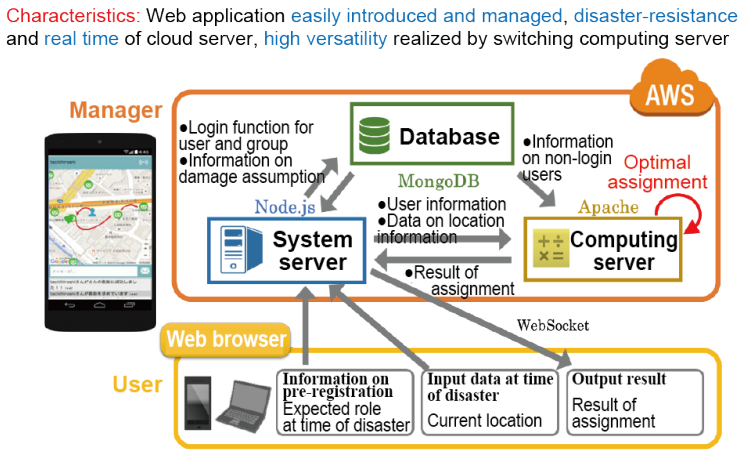

Figure 2. System composition of travel support application

One of the greatest advantages of this system is the "real-time" reporting achieved by employing Node.js (Japan Node.js Association, 2015) and WebSockets (McKelvey, 2015), thereby allowing data synchronization with very short delays. "Real-time" in this study refers to the property of being able to respond and complete the required processing within a certain amount of time. Designing the system servers to be "event-driven" greatly increases the number of connections that can be processed simultaneously, allowing for quicker responses to each user. "Event-driven" means that other software executes the program. That is, the processing is either initiated by the user or by the operation of another program. This is in contrast to the concept of "flow-driven" processing (where the system is controlled by the execution flow of a program). Furthermore, when information in the database is updated, it is pushed out by the server to all users currently on the system, synchronizing data in real-time. Users do not need to issue requests to send data, thus reducing the load on the server. Users do not need to issue requests to send data, thus reducing the load on the server. This ensures that data is kept up-to-date and stable synchronization can be expected even when communication networks are weakened in the event of a disaster. MongoDB (MongoDB Inc., 2017) was chosen as the database foundation because it can process large amounts of data faster than previous databases and is significantly more robust against loss of data currency. In short, MongoDB, a NoSQL database that employs parallel processing compatible with Node.js, is a distributed storage-related input/output process. A number of packages have been developed to manipulate this database format and are designed to facilitate system server data searches, retrieval, and insertion.

The new functions made possible by integrating the existing system and method of regional travel are as follows;

- Real-time sharing of location information between demanders and responders.

- Real-time and dynamic assignment/correspondence of demanders and responders.
- Real-time navigation routes for responders to travel to the demanders.

The administrator of the system can give detailed instructions while monitoring the activities of the demanders and the responders in real time.

METHOD OF EVALUATION EXPERIMENT FOR TRAVEL SUPPORT APPLICATION

Method of experiment 1

In order to evaluate the basic performance of the travel support application, experiments should be conducted and evaluated in the actual field, not in a virtual space. For this purpose, the following field experiment was conducted. The houses of 25 demanders that require special assistance were set within the range of 1.6 km×1.2 km (Fig. 3) and four responders patrolled these houses for safety confirmation. At this time, a comparative experiment was also conducted in which information was exchanged using one of the existing social networking service (SNS), LINE (application software developed by LINE Corporation), and the arrangement was made based on the capability of one individual to verify the safety of another. The experiment was deemed to have finished when all of the tasks had been responded to. The initial locations of responders and the locations of tasks were identical in the both experiments, but the initial locations of individual responders were swapped to eliminate the learning effect.

Method of experiment 2

Not all demanders' requests are uniform and do not require the same amount of time for assistance. In other words, it is necessary to verify whether the travel support application is applicable normally even under a situation in which the support time differs greatly depending on the demanders. To further evaluate this function, another field experiment with more complicated workloads was conducted. Namely, fifty tasks with different working times were set within the range of 0.5 km×0.5 km (Fig. 4) and 10 responders were engaged in patrolling to respond to these tasks. In this field experiment, after adding the option for considering the different workloads to the computing server, (1) the comparative experiment using LINE, (2) based on the travel support application.

Method of experiment 3

The travel support application provides the optimal solutions assuming that all responders have equivalent capabilities. In other words, it assumes that all responders can walk at an average walking speed and respond to tasks at an average processing speed, and then the system presents optimal assignments and optimal walking routes. In reality, however, each responder has its own individuality, and there is likely to be variation in walking speed and processing speed. Therefore, to confirm this, we attempted to reproduce the behavior of an average responder based on multi-agent simulation (MAS) and compare it with the actual responder's behavior. Here, the same assumptions as in Method 2 were used, namely, demanders with different workload requirements are assumed (10 seconds workload x 40 tasks and 300 seconds workload x 10 tasks).

RESULTS OF EVALUATION EXPERIMENT FOR TRAVEL SUPPORT APPLICATION

Results of experiment 1

Figure 3 shows the results of experiments corresponding to Method 1. First, looking at the results of the experiment using LINE (Fig. 3 top), we can confirm that students who are familiar with LINE on a regular basis and have a faster walking speed show higher performance than young adults. The movement tracks of young adults are obviously long, some crossings of tracks can be recognized, and their travels are obviously inefficient, while this is true even for students who are familiar with the usage of LINE. On the contrary, in the experiment using the travel support application, the movement tracks are obviously simple and short and it is evident that an efficient patrol is achieved. Furthermore, by examining the relationship between the elapsed time and the number of safety confirmations (Fig. 3 bottom left), it is evident that the slope is smaller and the rate of task completion per unit time is lower when using LINE. In particular, the reduction of the work efficiency immediately prior to the completion of all the safety confirmations is substantial. It appears that the work efficiency was reduced and the work completion time was delayed in the last stage of the experiment. This is because each responder places priority on the neighboring tasks and the completion of tasks at distant locations was postponed. In contrast, using the travel support application, even young adults, who are not familiar with the usage of LINE, can be completed

with almost constant efficiency with high work efficiency. When the travel support application is used, it is evident that all the travels could be completed in less than half the time compared to the case of using LINE.

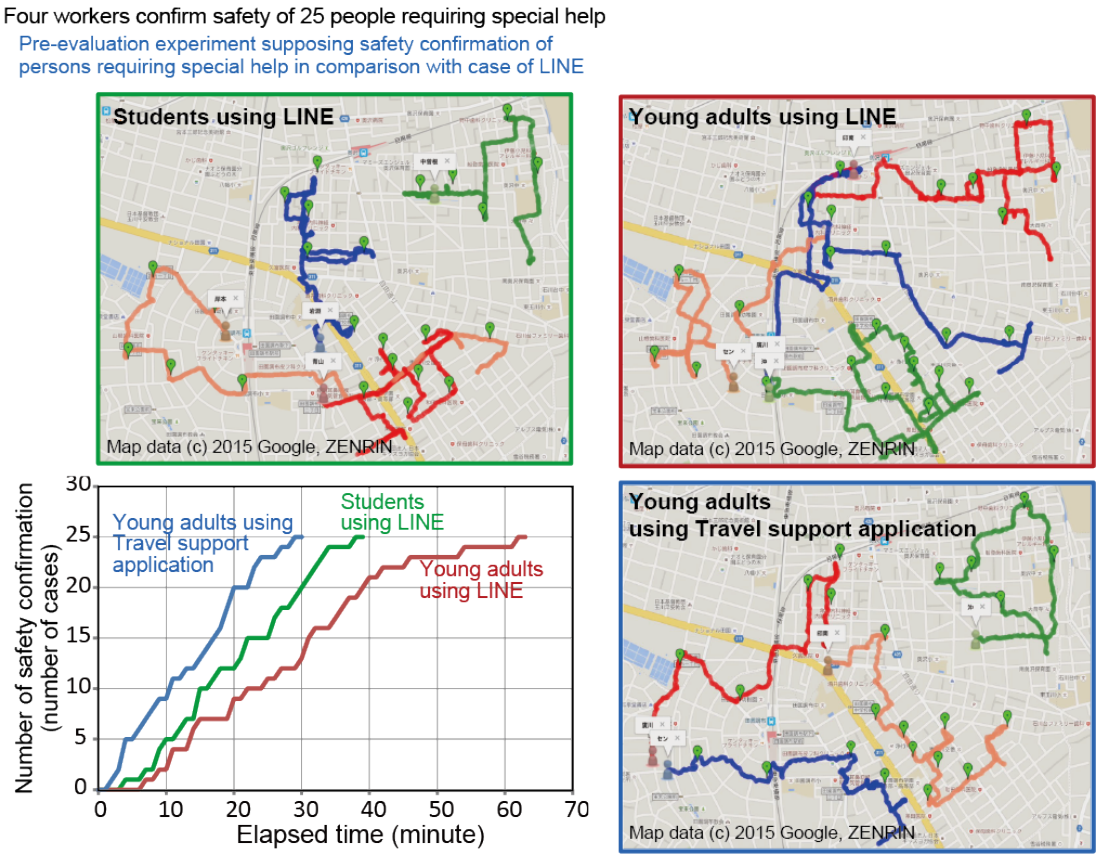

Figure 3. Field experiment of safety confirmation patrol

Results of experiment 2

Figures 4 and 5 show the results of experiments corresponding to Method 2. When LINE was used, there were instances of duplicate patrol where multiple responders patrol the same workplace and other instances of workplaces without patrolling responders. However, was confirmed that such problems can be avoided and patrol can be efficiently implemented using the travel support application.

More specifically, the travel completion time was much shorter in the experiment using the travel support application than using LINE. Note that, when LINE was used, efficiency declined rapidly after approximately half of the travel was completed. In particular, there were two omissions and four duplications of task responses. Similar omissions and duplications are said to have occurred in confirming the safety of people at the Great Hanshin-Awaji Earthquake (1995) and the Great East Japan Earthquake (2011) (Usui et al., 2013; Takamura and Yamada, 2018). In the experiment using the travel support application, the responders could complete their travels without a decline in efficiency and neither omissions nor duplications occurred. Moreover, the results approximate the results of the multi-agent simulation, in which regional travels of responders were optimized.

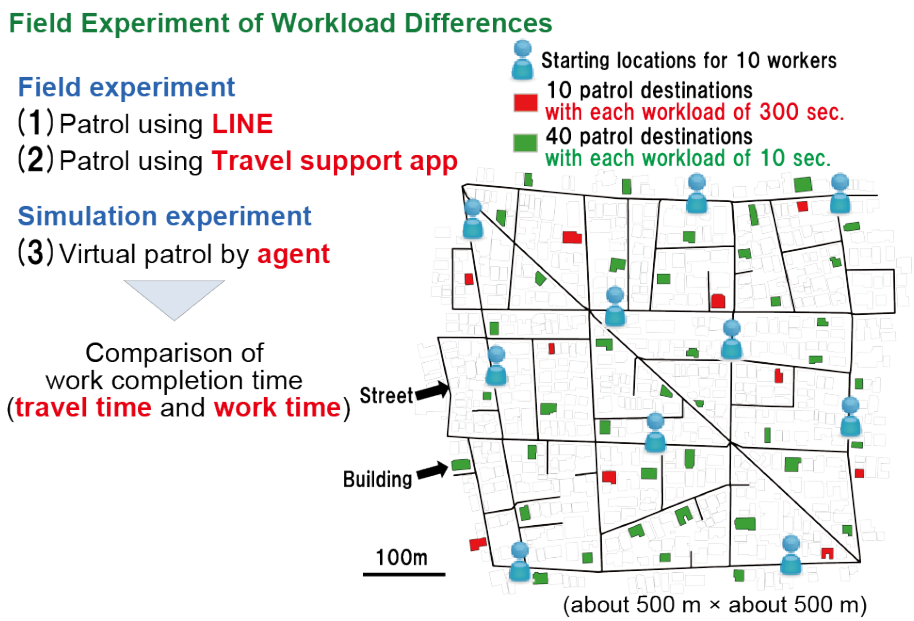

Figure 4. Experiment considering differences in workloads at patrol destination

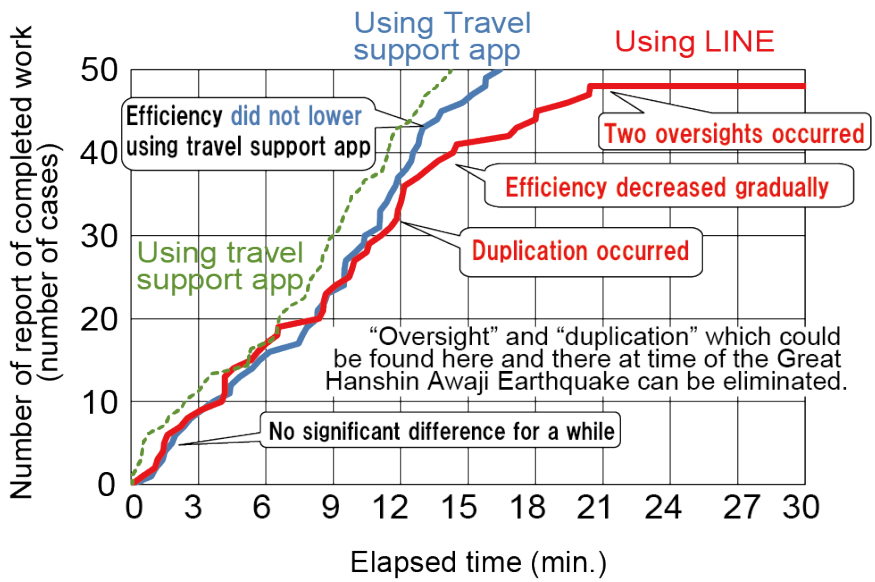

Figure 5. Comparison of regional travel efficiency using travel support application and existing social media (LINE)

Results of experiment 3

Furthermore, Fig. 6 is the results of experiments of corresponding to Method 3. It shows a comparison between the work efficiency of the agent corresponding to responder A and that of the agent corresponding to responder B. Responder A patrols with the efficiency equal to the optimized agent. In contrast, there is a significant difference between the work efficiency of responder B and that of the corresponding agent mainly because responder B travels slower. This indicates that not only is the work efficiency of responder B lower, but that it is also important to optimize the total system, taking the difference in the performance of each responder into consideration. As such, the system should not be built based on the assumption that all the responders have equal performance, but by integrating the different performances and characteristics into the computing server depending on the responder. In this way, the travel support application can easily respond to tasks. Moreover, the results of this system can also be used as the basis for reviewing the working time and the sequence of response, in addition to updating the manual for disaster drills by comparing the work efficiency of each responder for a disaster drill with the optimal solution calculated using the application.

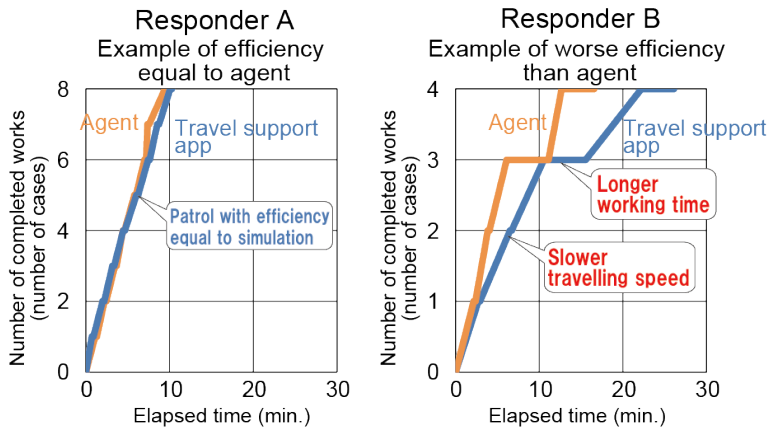

Figure 6. Comparison between the work efficiency of an agent of simulation and a responder in the field

DEMONSTRATION EXPERIMENT FOR SOCIAL IMPLEMENTATION

Demonstration experiment at the crisis management office of the local government

In order for the proposed Web application to be implemented in society, it is necessary to conduct a demonstration experiment in a real department in charge of disaster prevention and collect opinions from related parties. Therefore, at the crisis management office of Kawasaki City, Japan, a demonstration experiment was conducted assuming a flood disaster i.e., flood of the Tama River. Figure 7 shows the outlines of the experiment and Fig. 8 shows the monitoring projected on a screen during the experiment. This demonstration experiment consists of three methods.

The first method is the experiment on the collection and sharing of disaster-related information in the early stage. In this part of the experiment, the officials confirm the condition of the water level of the Tama River and the condition of submerged roads in the process of traveling to work at the local government office.

The second method is an experiment that involves the application of the system during the issuance of the disaster management system from Kawasaki City. Kawasaki City is obligated to send an (alert, warning or emergency) issuance of the disaster management system to approximately 900 facilities via fax. Using the application, not only can the disaster management system be issued, but also it is possible to confirm whether each facility received the information or not, and which kind of system has been arranged.

The third method is the experiment at Kawasaki Azalea, one of the facilities that receive the issuance from the disaster management system. Kawasaki Azalea is a large-scale underground shopping area with the third most shopping visitors in Japan. In 2010, serious flooding occurred because of heavy rains and this underground shopping area suffered from inundation. In this experiment, the travel support application was utilized to confirm the connection parts between the underground and surface in the patrolled area. The responders posted photos of the installation location of the water sealing panel to the management system and the situation was monitored at the Disaster Management Centre in this experiment.

As the results of demonstration experiments based on the above methods, the preceding three demonstration experiments were completed without delay. In addition, the official in charge of Kawasaki City expressed appreciation for this application system because of its effectiveness, which cannot be replicated using telephone or fax.

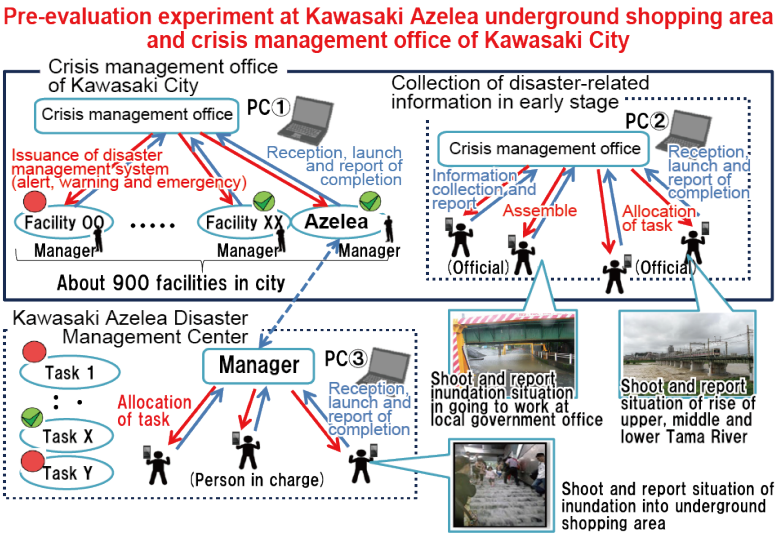

Figure 7. Demonstration experiment at the crisis management office of the local government

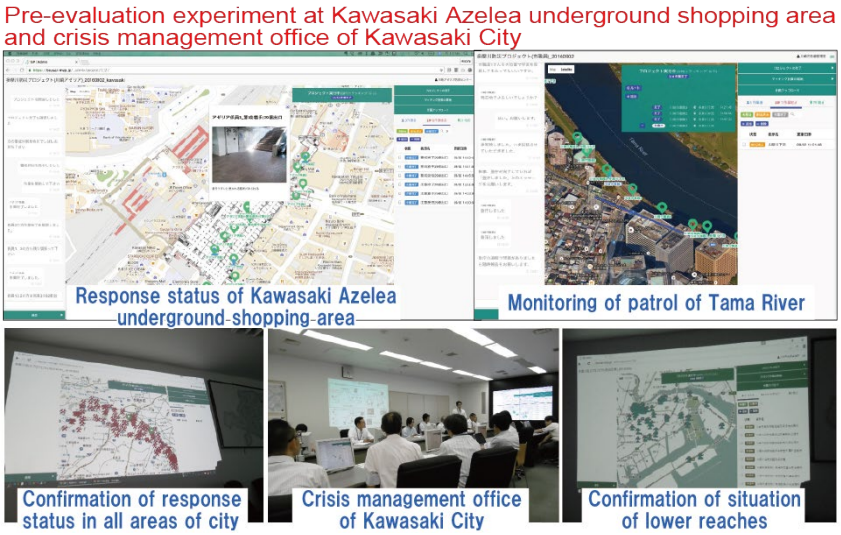

Figure 8. Monitoring projected on a screen during the demonstration experiment

Demonstration experiment based on presumed use at non-emergencies

A common problem of many similar systems developed so far is the challenge associated with implementation at the time of an actual disaster. The following reasons account for this difficulty. (1) There is a feeling of resistance (especially among public companies) towards the cost of introducing a system that is specialized only for disaster management, (2) apart from the initial cost of introduction, the cost of maintenance is a continuous requirement (if maintenance fails, this can lead to deterioration of the system), and (3) relocation of the person in charge could create a situation where there are no qualified operators for appropriate usage of the system.

Considering these issues, the possibility of using the developed system at non-emergencies has also been examined. As a result of this examination, the following is expected in terms of the aforementioned three problems. (1) If the system can improve the efficiency of works at non-emergencies, this may lead to the widespread deployment of the system, (2) use of the system at non-emergencies facilitates continuous maintenance and version upgrade to maintain active status, and (3) use of the system at non-emergencies not only by the person in charge but also by all the employees will lead to improved familiarity with the system and seamless operation during emergencies.

As a method to tackle the aforementioned challenges, the use of the system was examined considering the cleaning work in a hotel in a high-rise building adjacent to the Tokyo Station. In this hotel, there are a series of works for which cleaning workers are assigned depending on the checkout of a hotel guest, which occurs at random. The

floor chief then confirms the condition after cleaning (Fig.9). For this situation, the travel support application is applied as the non-emergency mode. Concerning the emergency mode, an evaluation experiment was conducted, considering the situation where the safety confirmation of hotel guests is supported in the case of the occurrence of a disaster.

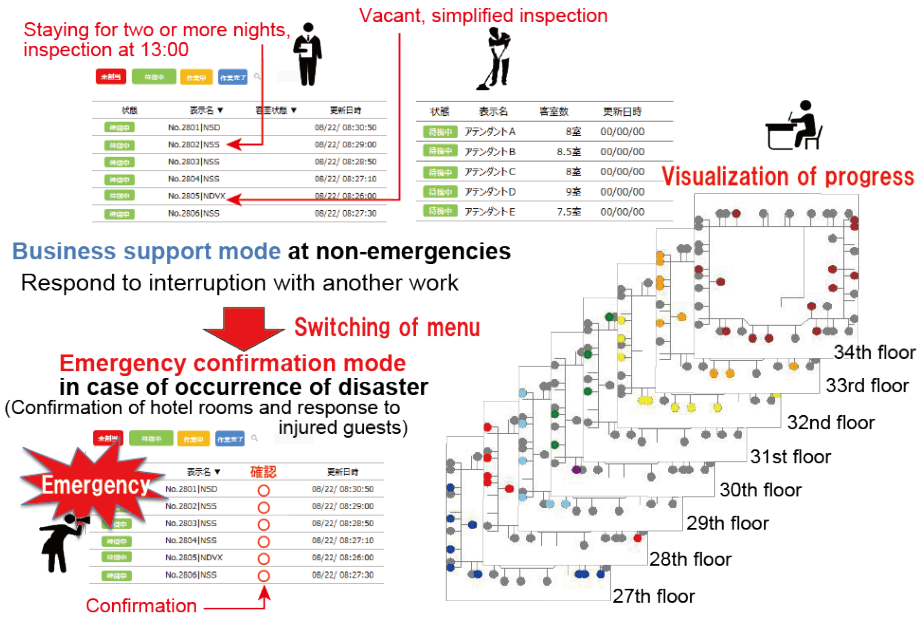

Figure 9. Application to cleaning work in a high-rise hotel

The following results were obtained from demonstration experiments based on presumed use at non-emergencies. Firstly, considering the non-emergency mode for the assignment of cleaning workers and confirmation by the floor chief, it is evident that the efficiency is higher when the application is used compared to the work efficiency under the current situation (Fig. 10). In addition, regarding the emergency mode, safety confirmation of the vacant guest rooms can be omitted by linking occupancy information to the application so that safety confirmation can be completed more efficiently in a shorter time (Fig. 11).

Given that this system can contribute to the improvement of the efficiency of non-emergencies and assist in maintaining the safety of the guests in the case of a disaster, this system has been introduced in the hotel in question in a full scale in 2018.

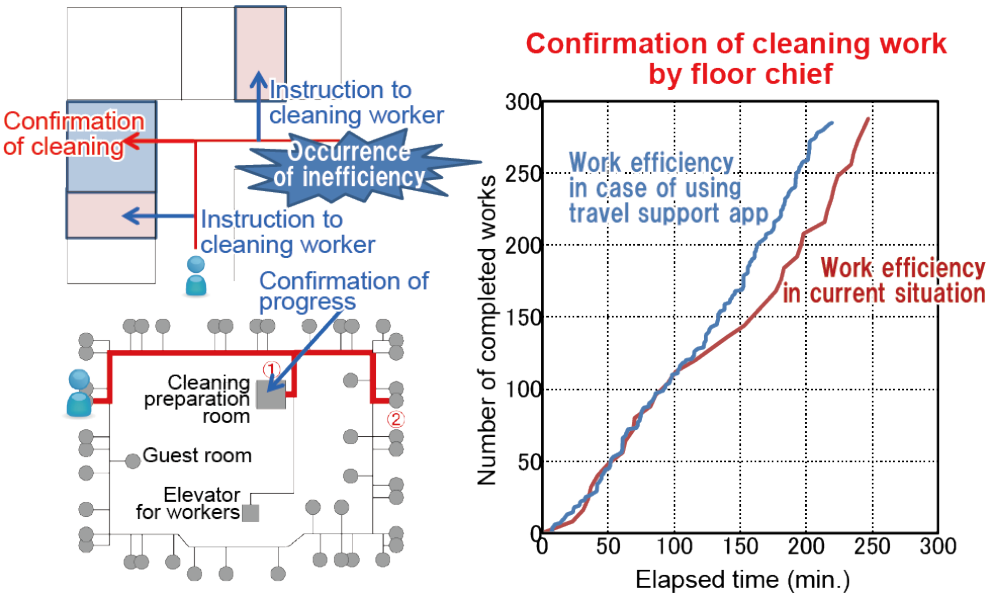

Figure 10. Effect in supporting cleaning business

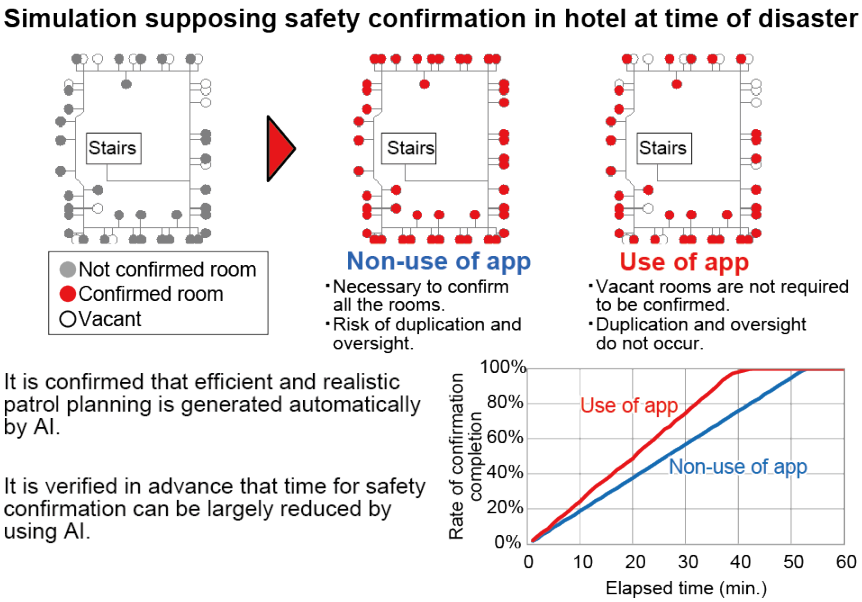

Figure 11. Effect in confirming safety at the time of a disaster

DISCUSSION

In consideration of the possible future development for the social implementation and horizontal development of the proposed system, the following three possibilities with significant potential are assumed (Fig. 12).

Firstly, (1) the application to safety management performed daily (maintenance of elevators, a patrol of guards, firefighting, an inspection of equipment, management of station, etc.) is highlighted. This is because a series of business processes associated with the dispatch of the person in charge of the inspection points are required no matter whether regular use is considered or not and are required for the development concept of the travel support application. As such, the potential to use the application at non-emergencies seems high. Next, (2) the application to facilities and areas where the measures for those weak in disaster are not enough considered (welfare and protective facilities, medical facilities, shelter, etc.) is of great potential. For example, it is expected that emergency requests could be collected promptly, and persons with qualified performance and the appropriate goods could be promptly assigned and dispatched. Furthermore, (3) the application to labor-intensive work (home delivery service, etc.) and business for measuring position, is considered. Although effort has been focused on the efficient delivery of goods to a receiver in fields, such as home delivery services, an approach for delivering the goods more efficiently is required. A method to improve work efficiency based on the intuition and experience of a veteran delivery person has certain limitations and it is difficult to maintain this method in the future. This system can well respond to such labor-intensive work by coordinating the function of the computing server and improving the artificial intelligence (AI) function. In addition, the system has excellent potential for development in this field.

Figure 12. Possible future development

SUMMARY AND CONCLUSIONS

In this paper, we have developed a Web application (travel support application) to support the efficient travel of responders by integrating the method proposed for efficient regional travel and a Web application system for collecting, sharing, and using disaster information. We then conducted some field experiments using the proposed solution (travel support application), which showed that (1) using the application can significantly shorten travel completion time compared to using an existing SNS (LINE), and (2) neither omissions nor duplications occur, thereby indicating that efficient regional travel can be achieved when the application is used.

Also, we performed a demonstration experiment assuming a flood disaster at the crisis management office of a local government, and demonstrated that the Web application system incorporated the proposed methods was of great potential for local disaster mitigation technology.

Effective disaster response and mitigation support technology for complex disasters caused by earthquakes and floods must be stable and continuously available. The previous system that was related to disaster management has been promoted socially using a top-down approach, based on the initiative of administrative agencies. However, in addition to the previous method, a strategy for social implementation based on a bottom-up approach should be actively examined by bundling the function for disaster management to the application for use in non-emergencies. We discussed the possibility to extend our proposed web system for non-emergency situations and demonstrated the effective use by some examples of the assignment of cleaning workers and confirmation by the floor chief.

The limitations of this study include the following points. First, it is necessary to confirm whether the Web application functions properly even when a large number of users access it simultaneously. It is necessary to confirm through demonstration experiments that the system does not malfunction due to the concentration of accesses. Next, it is desirable to store personal information such as the address and medical history of the person in need of care (demanders) in the system in advance, however, this is not allowed under the current personal information protection law. Under the current laws and regulations, it is necessary to consider the most efficient and reliable way to share information about demanders and responders. We need deeper engagement with practitioner spaces and actual attempts at use in the field. For instance, disaster drills should be conducted in local government crisis management offices using this Web application, and the Web application should be improved based on the accumulated quantitative evaluations such as response time and qualitative evaluations such as ease

of use. Finally, in this study, we are conducting a demonstration experiment under the assumption that Internet access is available. However, it is not certain whether or not Internet access will be available in the event of a disaster. This is one of the limitations of this study. However, advanced research on disaster resistance of hardware (Internet connection) is being conducted in other fields. This research is an attempt to anticipate technological developments in other fields.

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