# ARE ESTIMATION ALGORITHMS APPLICABLE FOR DISASTER MANAGEMENT? EXPERIMENTAL DEMONSTRATION OF DISASTER-INFORMATION-INTEGRATION PLATFORM NAMED ‘G-SPACE PLATFORM’

Hideki Hayashi[1], Akinori Asahara[1], Hitoshi Tomita[1], Yuichi Ogawa[1],
Natsuko Sugaya[1], Yoshihide Sekimoto[2], Akihito Sudo[2], Takehiro Kashiyama[2], Toshikazu Seto[2], Hiroki Ishizuka[3], and Satoshi Nishiyama[3]

[1]Hitachi Ltd., {hideki.hayashi.xu, akinori.asahara.bq, hitoshi.tomita.jg, yuichi.ogawa.nf, natsuko.sugaya.tr}@hitachi.com

[2]University of Tokyo, {sekimoto, sudoa, kashiyama}@iis.u-tokyo.ac.jp, tosseto@csis.u-tokyo.ac.jp

[3]KDDI Corporation, hk-ishizuka@kddilabs.jp, sa-nishiyama@kddi.com

## Abstract

Estimation algorithms are needed to estimate the damage situation in large-scale natural disasters from observed information that is often insufficient. *Are the estimation algorithms applicable for disaster management?* This is a serious question for those of us involved in a national Japanese research project known as “research and development of techniques about use and application of real-time information in the G-space platform.” In this paper, we present an experimental demonstration as our final evaluation of this project. We developed an integrated demonstration system implementing people number estimation using cell-phone connection logs and simulation data search using small amounts of real-time data to confirm usability. The virtual disastrous scenario set for the demonstration was a huge M7.3 earthquake that hits Tokyo. The demonstration system was presented to 39 participants (including 26 government officers and 13 university/industry experts) from 13 organizations on Jan. 27–28, 2016 for review. We sent a questionnaire to all participants afterward and nine organizations responded. In total, seven organizations responded with “Yes” to the question about whether our techniques were applicable for disaster management, thus confirming the effectiveness of the developed techniques.

**Keywords:** Disaster management, disaster estimation, spatio-temporal data, people flow data

## 1. INTRODUCTION

Japan is in the so-called Circum-Pacific Mobile Belt, where seismic and volcanic activities occur constantly (Cabinet Office, Government of Japan, 2015). Although the country covers only 0.25% of the land area on the planet, it experiences a high number of earthquakes and has many active volcanoes. Moreover, owing to the geographical, topographical, and meteorological conditions in Japan, the country is subject to frequent natural hazards such as typhoons, torrential rains, and heavy snow. These natural disasters cause great loss of life and significant damage to property in Japan. The probability of an M7-class earthquake occurring in the South Kanto (around Tokyo) area within 30 years is estimated to be 70%. If an earthquake directly hits the Tokyo metropolitan area, the human and material damages caused by collapsing buildings and the spread of fires will be serious. Accordingly, it is a national priority to protect citizens' lives, livelihoods, and property from large-scale natural disasters.

When a large-scale natural disaster occurs, damage information is collected in the first action period. After that, disaster-relief operations and support over a wide area (depending on the scale of the disaster) are requested. At present, to collect damage information, municipalities, cities, districts, towns, and villages report damage information to prefectural governments that then report to the national government by e-mail or fax. Disaster-related organizations need a few days to grasp the damage situation concerning a large-scale natural disaster because they collect the damage information by hand. Naturally, it is important to reduce the time taken to grasp damage situations concerning large-scale natural disasters. Some kinds of researches to quickly and accurately grasp the damage information by using information and communication technology (ICT) techniques including sensor and crowdsourcing techniques have been conducted (Kobayashi, 2014) (NGA, 2016) (To et al., 2015) (Yang et al., 2014). At the time of a disaster, disaster-related organizations usually receive insufficient information, so estimation algorithms are needed to estimate the damage situation concerning a large-scale natural disaster.

Here, the key question is “*Are the estimation algorithms applicable for disaster management?*” This is a serious question for those of us involved in a national Japanese research project known as “research and development of techniques about use and application of real-time information in the G-space platform.” Objectives of the G-space platform project are geared to the development of an innovative disaster management system for the Japanese government. This paper presents the experimental demonstration for our final evaluation of this project. Most governmental stakeholders (fire fighters, police officers, city government officers, and so on) want to start their rescue and support actions immediately when a serious disaster like a huge earthquake occurs. However, it is difficult to do so due to a lack of sufficient information to understand the disastrous situation. The proposed innovative disaster management system consolidates various real-time data to share such information among multiple stakeholders. Moreover, the system provides estimation data using techniques developed by this R&D project to provide more information.

We make three contributions in this paper.

1. We clarify the research challenge by arranging the actions of the national and local governments at the time when a large-scale disaster occurs. We set a challenge to see if the proposed disaster management system can estimate the number of victims on the basis of insufficient observed information more quickly and accurately than the current disaster management operation.

2. We developed an integrated demonstration system implementing people number estimation using cell-phone connection logs and simulation search using small amounts of real-time data to confirm usability. The virtual disastrous scenario set for the demonstration was a huge M7.3 earthquake that hits Tokyo. The city government can obtain a bit of information about the situation, so their first task is to collect information. The information collection takes over 30 minutes, which means officers cannot take any action for at least 30 minutes. We assume that estimated data is useful for decision making in a poor-information situation of this nature. The demonstration system estimates the location of the evacuating people and identifies the most suitable “spread of fire” simulation scenario for the current situation from a huge spatio-temporal database.

3. Our demonstration system was presented to 39 governmental officers from 13 organizations on Jan. 27–28, 2016 for review. The authors classified their comments into six categories (applications, rules, techniques, usability, data, and promotion). The category with the most comments (five) was “data”, with the majority of comments pertaining to variations of data. Our system should be able to handle extremely varied data, which highlights the importance of having functions in place to import various data. We sent a questionnaire to all participants after the demonstration and nine organizations responded. In total, seven organizations responded with “Yes” to the question about whether our techniques were applicable for disaster management.

The rest of this paper is organized as follows. Section 2 of this paper gives an overview of this R&D project. Section 3 clarifies the research challenge. Section 4 explains the proposed disaster management system. Section 5 discusses the results of our experimental demonstration. We conclude in Section 6 with a brief summary and discussion of future work.

## 2. R&D PROJECT ON TECHNIQUES ABOUT USE AND APPLICATION OF REAL-TIME INFORMATION IN THE G-SPACE PLATFORM

**Large quantities of data (dynamic geospatial information) collected by smartphones and sensor networks make a society resilient to disasters and help create new services. The technology infrastructure to utilize such massive quantities of dynamic geospatial information in real time has yet to be developed. We developed practical implementations of a technology infrastructure to enable the utilization of large-scale dynamic geospatial information in real time. Figure 1 gives an overview of our research and development project on the G-space platform. We established techniques as shown in**

Table **1**. Additionally, we implemented a demonstration system by means of integrated verification tests and assessed the effectiveness and issues of the techniques.

**Figure 1: Overview of R&D Project on G-space Platform**

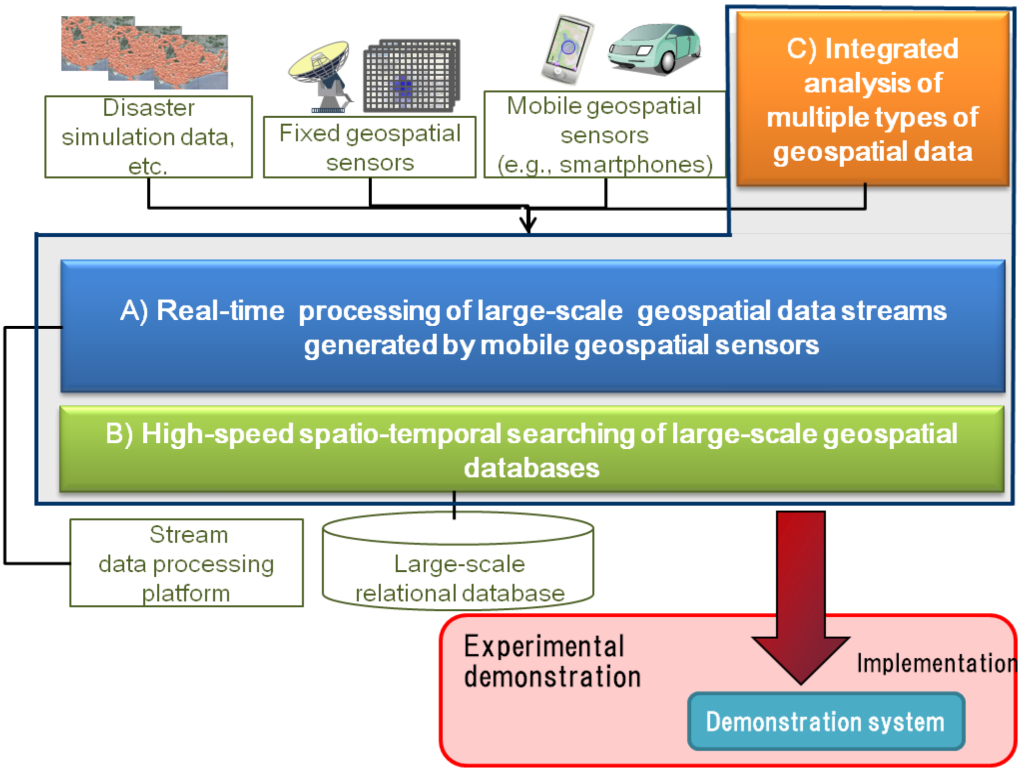


**Table 1: Techniques Developed by R&D Project on G-space Platform**

| Techniques | Goals | Solutions |
|---|---|---|
| A) Real-time processing of large-scale geospatial data streams generated by mobile geospatial sensors | Real-time processing of streamed geospatial data from around one million sensor observations | A technique that eliminates wasteful processing by managing data spaces in grid-shaped divisions |
| B) High-speed spatio-temporal searching of large-scale geospatial databases | High-speed searching of data from hundreds of billions of disaster simulation points corresponding to real-time observation data | A technique that enables high-speed searches of targeted geospatial data without the need to repeat searches through the creation of spatio-temporal indices |
| C) Integrated analysis of multiple types of geospatial data | Estimation of people movement distribution at useful precision even if more than 50% of geospatial data is lacking | A technique for estimating people movement distribution in the event of disasters by combing multiple geospatial data sources at the time of disaster with a normal-time people movement model |

## 3. RESEARCH CHALLENGE

This section clarifies the research challenge by arranging the actions of national and local governments at the time a large-scale disaster occurs.

When a large-scale disaster such as a Tokyo Inland Earthquake occurs, it is difficult to grasp information on the number of disaster victims in the disaster areas. For example, Miyagi prefecture, which is a prefecture in the Tohoku region of Japan on Honshu Island, did not grasp the information about the number of disaster victims (e.g., the numbers of deaths, missing persons, and injured persons) until several days after the Great East Japan Earthquake occurred. In fact, the damage reports published by Miyagi prefecture at this time showed these numbers as “unknown.”

One solution to quickly and accurately grasp the damage information is the application of ICT technologies to the collection of sensing data in real-time. However, even if an ICT infrastructure is developed, it fails to function due to collapse and blackout of the network base station and network communication congestion when a large-scale disaster occurs. In fact, there was blocking and delay of the mobile communication networks in Tohoku and the capital regions when the Great East Japan Earthquake occurred. Therefore, in a large-scale disaster, the disaster information collected by reports (observations) is insufficient and governors must determine whether or not to request support from other local governments. If the disaster information is insufficient, it is assumed that governors take one of the following three actions.

1. The governors delay the decision-making because they cannot grasp the information on the number of victims.
2. The governors decide to request support from other local governments because they have insufficient reports.
3. The governors decide to request support from other local governments by estimating the number of victims on the basis of the insufficient reports.

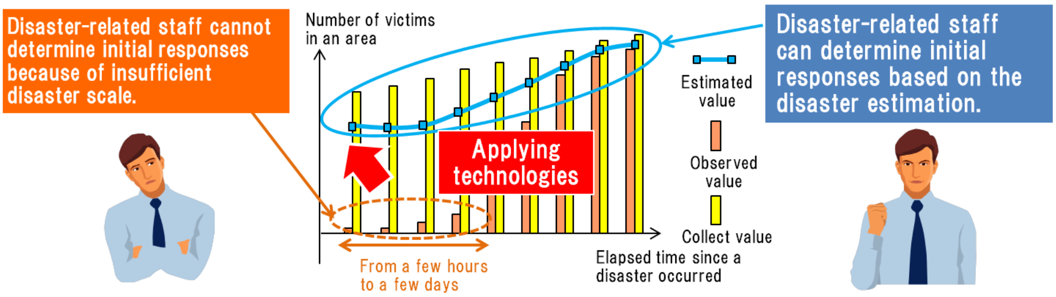
The first action is undesirable because the arrival of resources for the rescue activity is delayed and the support on site arrives too late. The second action is better than the first because it ensures faster arrival of resources for rescue activity. However, it is undesirable in that governors might make a misjudgement and under-estimate the number of victims given the enormous difference between the number of observed victims and that of the actual victims.

The third action is more desirable than the second if the accuracy of the estimated number of victims is above a certain level. This is because the difference between the actual number and the estimated number is smaller than that between the actual number and the observed number. Moreover, the third action is more desirable that the first if a system quickly executes the estimate process. Thus, the third action contributes to the quickest decision-making.

Based on the above consideration, we set a challenge to see if the proposed disaster management system could estimate the number of victims from insufficient observed information more quickly and accurately than the current disaster management operation, as shown in

Figure 2. We then applied the techniques developed by this R&D project for disaster estimation.

Figure 2: Estimated, Observed, and Correct Numbers of victims in a Disaster



## 4. DISASTER MANAGEMENT SYSTEM

In this section, we examine the disaster scenario and the effectiveness of the proposed disaster management system by simulating a case of actual use. We then discuss the requirements of the proposed disaster management system.

### 4.1. Disaster Scenario

Before designing the disaster management system, we need to clarify a target disaster, i.e., a disaster scenario. We set a Tokyo Inland Earthquake as the disaster scenario, which is expected to cause extensive damage by fire spreading and building collapse. In this R&D project, we address disaster estimation by the fire spreading, since fire spreading has time-varying characteristics; specifically, the longer the time that elapses since the earthquake occurs, the larger the damage becomes.

Table 2 shows a disaster scenario based on disaster estimation reports about a Tokyo Inland Earthquake published by the Cabinet Office, Government of Japan, that we consider.

Table 2: Disaster Scenario

| Items | Contents | Remarks |
|---|---|---|
| Disaster | Fire spreading caused by M7.3 Tokyo Inland Earthquake | |
| Season and hours of disaster occurrence | Winter<br>Day Time (13:00)<br>Evening (18:00) | Scenario in which damage caused by fire spreading fire is based on a damage estimation report published by the Cabinet Office, Government of Japan |

| | | |
|---|---|---|
| Damage scale<br>(Number of fire locations) | Tokyo prefecture<br>Large-scale: 900 locations<br>Small-scale: 150 locations | The setting of many fire locations to areas where wooden houses are congested is based on a damage estimation report published by the Cabinet Office, Government of Japan |
| Damaged area | 100 km from east to west, 50 km from south to north | Area covers Tokyo prefecture (excluding remote islands) |
| Period | Six hours after the disaster occurs | |
| Situation of mobile communication networks | 10% of base stations do not work due to network damage and base stations going off-air. Additionally, the number of non-functional base stations gradually increases due to their batteries dying several hours after the disaster occurs. | |

### 4.2. Utilization Scenario of Proposed Disaster Management System

The results of hearings from various disaster management organizations have demonstrated that national and local governments typically establish emergency response headquarters within 30 minutes of the occurrence of a large-scale earthquake. After that, the national government requests local governments to examine resource allocations of rescue materials and teams. The local governments need to ensure the safety of the people and request rescue support from their neighbouring local governments. The local governments grasp the damage information from TV and radio broadcasts and physically look around the district to collect damage information first-hand. Therefore, it is difficult to collect sufficient damage information just after a large-scale earthquake occurs.

Here, we assume operations of the proposed management system using developed techniques. However, from the viewpoint of laws and infrastructures, the information created from call detail records (CDRs) cannot be provided now even if a large-scale earthquake occurs.

- The system collects CDRs and disaster information from smartphones just after it detects the large-scale earthquake. The disaster information includes location information.
- The system displays people locations and fire spreading locations including the disaster information sent from smartphones on a map.
- The system estimates fire spread coverage, population distribution, and survivor distribution and displays them on a map. Every 30 minutes, it updates the displays on the basis of disaster information sent from smartphones.

Table 3 shows the disaster scenario, the system operations, and the operations of the national and local governments as a time sequence when the Tokyo Inland Earthquake occurs at 18:00. We assume that the system displays people locations and fire spreading points within five minutes of the earthquake occurring. Additionally, it displays fire spreading coverage, population distribution, and survivor distribution within 30 minutes. In doing so, local governments can initiate evacuation guidance given the disaster information after 15 minutes and start supporting aid requests based on the estimated survivor distribution. The national government can also start allocating rescue parties and relief supplies based on estimated survivor distribution after 30 minutes.

**Table 3: Assumed Disaster Scenarios, System Operations, and Operations of National Government and Local Governments**

| Time | Disaster scenario | System | National government | Local government |
|---|---|---|---|---|
| 18:00 | •An earthquake directly hits Tokyo<br>•Buildings collapse, roads are disrupted, power outages occur, and trains are derailed | •Collects CDR<br>•Collects disaster information from smartphones | •Establishes emergency response headquarters | |
| 18:05 | •Multiple and simultaneous fires break out<br>•Communication fails | | | •Collects disaster information from TV and radio<br>•Initiates evacuation guidance given the disaster information |

|  |  |  |  |  |
|---|---|---|---|---|
| 18:15 |  | Starts displaying disaster information |  |  |
| 18:30 |  | Starts displaying estimated results of fire spread, population distribution, and survivor distribution | Starts allocating rescue parties and relief supplies on the basis of estimated survivor distribution | •Establishes emergency response headquarters<br>•Starts supporting aid requests on the basis of survivor distribution |

### 4.3. Functional Requirements

Functional requirements of the proposed system are as follows.

1. The system can estimate population distribution on the basis of insufficient CDRs.
2. The system can extract sudden events on the basis of insufficient CDRs.
3. The system can estimate people flow data on the basis of population distribution estimated from insufficient CDRs and estimated fire spread coverage. To implement this function, we use a technique people movement estimation presented in (Sekimoto et al., 2016). This technique combines with a people flow simulation, the CDRs and the estimated fire spread coverage.
4. The system can receive disaster information and people locations sent from smartphones in real time.
5. The system can create population distribution (represented by grid data) from people flow data (represented by point data) in real time.
   The system can estimate fire spread coverage (represented by grid data) on the basis of observed fire spread locations included in the disaster information. To implement this function, we use a technique of spatio-temporal similarity search presented in (Hayashi et al., 2015). This technique searches a database storing many scenarios of fire spread simulation data represented by time-series grid data for scenarios similar to the observed fire spread locations included in the disaster information.
6. The system can estimate the number of victims on the basis of estimated people flow data (represented by point data) and estimated fire spread coverage (represented by grid data). To implement this function, we use a technique of spatio-temporal join presented in (Hayashi et al., 2015). The proposed method efficiently spatio-temporarily joins btween the estimated people flow data and the estimated fire spread coverage by narrowing spatial and temporal attributes simultaneously.

7. The system can display the fire spread locations (represented by point data) on a map.
8. The system can display estimated fire spread coverage (represented by grid data) on a map.
9. The system can display estimated population distribution (represented by grid data) on a map.
10. The system can display estimated survivor distribution (represented by grid data) on a map.

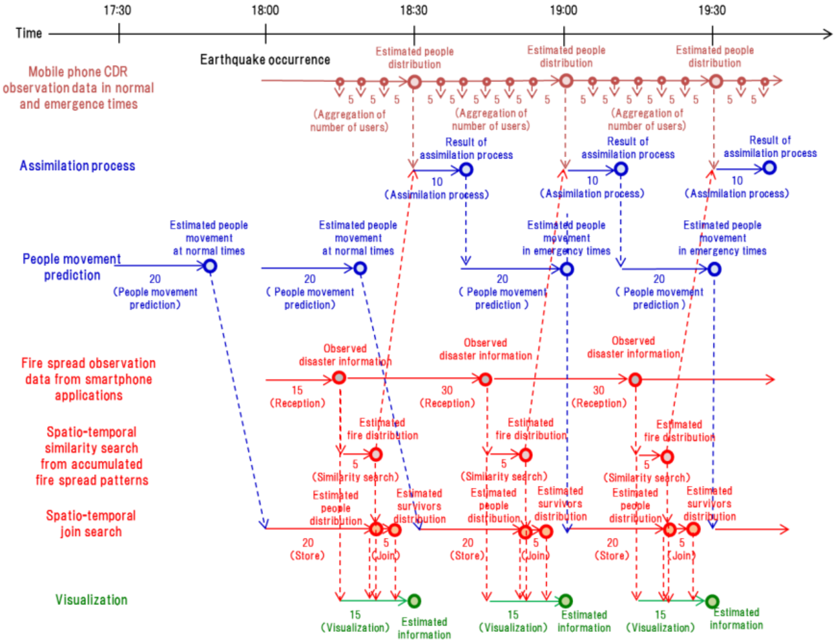
### 4.4. Performance Requirements

We defined performance requirements as follows. Each performance requirement means allowed processing time of each function in the proposed system. These requirements are set in cases where the system display has estimated fire coverage, estimated population distribution, and estimated survivor distribution within 30 minutes of the occurrence of a large-scale earthquake and are updated every 30 minutes.

1. The system can estimate population distribution on the basis of insufficient CDRs within five minutes.
2. The system can estimate people flow data (represented by point data) on the basis of population distribution estimated from insufficient CDRs and estimated fire spread coverage within 30 minutes.
3. The system can receive disaster information and people locations sent from smartphones in real time.
4. The system can create population distribution (represented by grid data) from people flow data (represented by point data) in real time.
5. The system can estimate fire spread coverage (represented by grid data) on the basis of observed fire spread locations included in disaster information within five minutes.
6. The system overlaps estimated fire spread coverage and population distribution within five minutes.

Figure 3 shows the timeline of data processing for real-time estimation in a case where a large-scale earthquake occurs at 18:00. If each function meets the above corresponding performance requirement, it means that the proposed system meets the performance requirement that the system displays estimated fire coverage, estimated population distribution, and estimated survivor distribution within 30 minutes of the earthquake occurrence and updates them every 30 minutes.

Figure 3: Timeline of Data Processing for Real-Time Estimation



## 5. EXPERIMENTAL DEMONSTRATION

### 5.1. Demonstration

We conducted an experimental demonstration with 39 participants (including 26 government officers and 13 university/industry experts) from 13 organizations on January 27–28, 2016. The purpose was to evaluate the effectiveness of the techniques developed by this R&D project in a disaster use case from the technical and professional viewpoints.

In the experimental demonstration, we first gave an overview of this R&D project and the contents of the demonstration. Two types of demonstration were performed: an offline demonstration in which the system displays observed and estimated data that are stored in a database (as shown in Figure 4 whose background map is Tokyo area) and an online demonstration in which the system receives the disaster information and estimates fire spreading coverage, population distribution, and survivor distribution in actuality and then displays them on a map (also shown in Figure 4). After the demonstration, we discussed with the participants the effectiveness of the developed techniques when applying them to disaster management operations. We sent a questionnaire to each participating organization after the demonstrations had been concluded.

**Figure 4: Display of (a) Observed and (b)(c)(d) Estimated Data**

(c) Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under CC BY SA.

(a) Fire spreading locations sent from smartphones

(b) Estimated fire spreading coverage

(c) Estimated population distribution

(d) Estimated survivor distribution

## 5.2. Discussion Results

In this experimental demonstration, we discussed with the participants the effectiveness of the developed techniques when applying them to disaster management operations. The discussion items are as follows.

1. Do the developed techniques contribute to rapid initial responses of disaster-related organizations?
2. In what kind of disasters are the developed techniques useful?
3. What are the disaster management operations to which the developed techniques contribute?
4. Are there any issues when the developed techniques are applied to the disaster management system? If so, what are they?

We classified participant comments that came up in the discussion into six categories (applications, rules, techniques, usability, data, and promotion), as listed in Table 4. The category with the most comments (five) was “data”, with most the comments pertaining to variations of data. Our system should be able to handle extremely varied data, which highlights the importance of having functions in place to import various data.

**Table 4: Comments from the Participants in the Discussion**

| Category | Comments | No. of comments |
|---|---|---|
| Applications | The developed techniques contribute to thinking of a next action, which is important in the case of complex disasters. | 1 |
| | The developed techniques are considered to contribute effective rescue party assignment by using estimated results. | 2 |
| Rules | The developed techniques contribute to effective rescue party assignment by using estimated results. | 1 |
| Techniques | It is important to obtain reliable information from disaster-related organizations. | 2 |
| | The stable system operation is necessary even if a large amount of observed data is sent in the event of the disaster. | 2 |
| Usability | Stable system operation is necessary even if a large amount of observed data is sent. | 1 |
| Data | A common data format is necessary for smooth information exchange between systems | 1 |
| | It is better if we are able to use various dynamic data from disaster-related organizations. | 4 |
| Promotion | It is important to show that the developed techniques can process dynamic geospatial data in real-time. | 2 |

### 5.3. Questionnaire Results

We sent each of the participating organizations a questionnaire and received responses from nine. We asked the same questions as in the discussion because we did not have enough time to hear comments from each organization during the discussion.

Table 5 shows the responses to question 1, which was “Do the developed techniques contribute to the rapid initial responses of disaster-related organizations?” Seven responses were “Yes” (0 were “No”), which demonstrates the effectiveness of the developed techniques.

**Table 5: Responses of Question 1 in the Questionnaire**

| Quesiton | | |
|---|---|---|
| 1. Do the developed techniques contribute to the rapid initial responses of disaster-related organizations? | | |
| **Responses** | | |
| **Yes** | **No** | **Unknown** |

| | | |
|---|---|---|
| 7 | 0 | 2 |

Table 6 shows the responses to question 2, which was “In what kind of disasters are the developed techniques useful?” Many organizations answered that the developed techniques can be applied to the earthquakes, heavy rains, and volcanic eruptions that have recently occurred in Japan—indeed, there is a strong need for these techniques to be applied in these cases. The responses specified that the developed techniques would be effective to deal with the spread of fires, building collapses, and tsunamis caused by earthquakes, floods caused by heavy rains, and ash fall caused by volcanic eruptions. Therefore, the developed techniques are effective for large-scale disasters.

**Table 6: Responses of Question 2 in the Questionnaire**

<table>
<tr><th colspan="3">Quesiton</th></tr>
<tr><td colspan="3">2. In what kind of disasters are the developed techniques useful?</td></tr>
<tr><th colspan="3">Responses</th></tr>
<tr><th>Disaster</th><th># of applicable</th><th>Use case</th></tr>
<tr><td>Earthquake</td><td>7</td><td>Grasp people movement and fire spreading locations</td></tr>
<tr><td>Rain</td><td>6</td><td>Deliver weather warning by using rainfall prediction</td></tr>
<tr><td>Volcanic eruption</td><td>6</td><td>Plan evacuation guidance based on status of lava flow</td></tr>
<tr><td>Wind</td><td>4</td><td>Plan efficient rescue activities for persons suffering from a disaster at sea</td></tr>
<tr><td>Snow</td><td>4</td><td>Plan safe evacuation route considering avalanche areas</td></tr>
<tr><td>Thunder</td><td>3</td><td>Plan efficient air route considering thunderbolts</td></tr>
</table>

Table 7 shows the responses to question 3, which was “What are the disaster management operations to which the developed techniques contribute?” The largest number of "applications" in disaster management operations is those in the initial response, followed in order by those in preparation and those in recovery. Therefore, it is necessary to apply and disseminate the developed techniques in the disaster management field considering the disaster management operations at preparation and initial response times. The number of "applications" in "Estimation and prediction of crowding locations," "Estimation and prediction of damage scale," "Support for initial response," "Estimation and prediction of road closure locations," and "Evacuation support of people requiring assistance during a disaster" is high, which indicates that the developed techniques are applicable to general operations at the time of initial response. The numbers for "Formulation of evacuation training plan," "Formulation of disaster management plan," "Evacuation training," and "Disaster management education" are also high, which shows that the developed techniques are also considered applicable to operations at the time of preparation.

**Table 7: Responses of Question 3 in the Questionnaire**

| **Quesiton** | | | | | |
|---|---|---|---|---|---|
| 3. What are the disaster management operations to which the developed techniques contribute? | | | | | |
| **Responses** | | | | | |
| **Operations** | | **No. of applicable** | **No. of not applicable** | **No. of unknown** | **No. of no answer** |
| Preparation | Formulation of disaster management plan | 5 | 2 | 0 | 2 |
| | Formulation of evacuation training plan | 7 | 1 | 0 | 1 |
| | Evacuation training | 5 | 1 | 2 | 1 |
| | Disaster management education | 5 | 1 | 2 | 1 |
| | Others | 0 | 2 | 2 | 5 |
| Initial response | Estimation and prediction of damage scale | 7 | 0 | 1 | 1 |
| | Estimation and prediction of crowding locations | 8 | 0 | 0 | 1 |
| | Support for initial response, e.g., firefighting and rescue activities | 6 | 0 | 1 | 2 |
| | Estimation and prediction of road closure locations | 6 | 0 | 1 | 2 |
| | Evacuation support of people requiring | 6 | 1 | 0 | 2 |

| | | | | | |
|---|---|---|---|---|---|
| | assistance during a disaster | | | | |
| | Others | 0 | 1 | 1 | 7 |
| Recovery | Relief supplies support | 4 | 1 | 2 | 2 |
| | Formulation of recovery plan | 3 | 1 | 3 | 2 |
| | Others | 0 | 2 | 2 | 5 |

Table 8 shows the responses to question 4, which was “Are there any issues when the developed techniques are applied to disaster management systems? If so, what are they?” There was only one “Yes” in response to "Insufficient performance of data processing", so we conclude that the developed techniques met the performance requirements of the demonstration system. These requirements are important points in this R&D project. However, in terms of technical issues, there were many “Yes” responses to “Improvement of predicted model" and "Reliability of predicted model". These are therefore issues to address in our future research activities. Towards the practical application of the developed techniques, costs and data collection need to be addressed in addition to the technical issues.

**Table 8: Responses of question 4 in the Questionnaire**

| **Quesiton** | |
|---|---|
| 4. Are there any issues when the developed techniques are applied to disaster management systems? If so, what are they? | |
| **Responses** | |
| **Issues** | **Yes** |
| Costs of installation, maintenance, operation | 8 |
| Insufficient functions | 5 |
| Insufficient data | 7 |
| Reliability of collected data | 7 |
| Insufficient performance of data process | 1 |
| Reliability of predicted model | 7 |
| Improvement of predicted model | 6 |
| Usability | 8 |
| Improvement of ICT skill of operators | 6 |
| Rules | 4 |

## 6. CONCLUSION

This paper presented the experimental demonstration we performed as the final evaluation of a national Japanese research project known as “research and development of techniques about use and application of real-time information in the G-space platform." We developed an integrated demonstration system implementing people number estimation using cell-phone connection logs and simulation data search using small amounts of real-time data to confirm usability. The authors set a huge M7.3 earthquake that hits Tokyo as the virtual disastrous scenario for the demonstration. The demonstration system was presented to 39 participants (including 26 government officers and 13 university/industry experts) from 13 organizations on Jan. 27–28, 2016 for review. We sent a questionnaire to each organization after the demonstration and received responses from nine. In total, seven organizations responded with "Yes" to the question about whether our techniques were applicable for disaster management, thus confirming the effectiveness of the developed techniques.

Our future work is to make the developed techniques fit for practical use.

## 7. ACKNOWLEDGEMENTS

This work was supported by consignment research and the development of techniques about use and application of real-time information in the G-space platform from the Ministry of Internal Affairs and Communications, Japan.

## 8. REFERENCES

Cabinet Office, Government of Japan (2015). "Disaster management in Japan", http://www.bousai.go.jp/1info/pdf/saigaipamphlet_je.pdf, [accessed 30 June 2016].

Hayashi, H., A. Asahara, N. Sugaya, Y. Ogawa, and H. Tomita (2015). "Spatio-temporal similarity search method for disaster estimation", *Proceedings IEEE Big Data 2015 (2nd Int'l Workshop on Advances in Software and Hardware for Big Data to Knowledge Discovery (ASH)), October 29 2015, Santa Clara, United States*, pp. 2462-2469.

Hayashi, H., A. Asahara, N. Sugaya, Y. Ogawa, and H. Tomita (2015). "Spatio-temporal join technique for disaster estimation in large-scale natural disaster", *Proceedings ACM SIGSPATIAL Int'l Workshop on GeoStreaming (IWGS), November 3, Seattle, United States*, pp. 49-58.

Kobayashi, M (2014). "Experience of infrastructure damage caused by the Great East Japan Earthquake and countermeasures against future disasters", *IEEE Communications Magazine* 52(3): 23-29.

National Geospatial-Intelligence Agency (NGA) (2016) "GeoQ: Geospatial Tasks & Question", https://geo-q.com/geoq/, [accessed 30 June 2016].

Sekimoto, Y., A. Sudo, T. Kashiyama, T. Seto, H. Hayashi, A. Asahara, H. Ishizuka, and S. Nishiyama (2016). "Real-time people movement estimation in the big disaster from several kinds of mobile phone data", *Proceedings 5th Int'l Workshop on Pervasive Urban Applications (PURBA), Heidelberg, Germany*, September 12, to appear.

To, H., S. H. Kim, and C. Shahabi (2015). "Effectively crowdsourcing the acquisition and analysis of visual data for disaster response", *Proceedings IEEE Big Data 2015, October 30 - November 1 2015, Santa Clara, United States*, pp. 697-706.

Yang, D., D. Zhang, K. Frank, P. Robertson, E. Jennings, M. Roddy, and M. Lichtenstern (2014). "Providing real-time assistance in disaster relief by leveraging crowdsourcing power", *Personal and Ubiquitous Computing*, 18(8): 2025-2034.