Implementation of a Disaster Response Support System Based on Accumulated Past Disaster Response Information

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Abstract

In this study, we implemented a disaster response support system based on accumulated past disaster response information for use by emergency response headquarters during times of natural disaster. The proposed system supports disaster response operation and decision making using a database of information accumulated from past disaster cases and response efforts. The proposed system comprises a disaster response information storage system for accumulating disaster response information and a disaster information visualization system for visualizing stored data and supporting emergency response efforts. The system also displays real-time social media information transmitted by ordinary citizens.

Keywords: Natural Disaster Reduction, Disaster Support, Decision Support, SNS API, Data Visualization

1 Introduction

Because it is formed from four continental plates, earthquakes and volcanic activity are common in the Japanese archipelago. Furthermore, the presence of many rapid rivers flowing from mountainous areas results in a topography of flatlands interposed between rivers and coastal areas, resulting in many flood-prone areas. Geographic features such as these cause the country to have a rate of natural disasters that is among the highest in the world; according to the World Risk Report 2016 [21], Japan ranks fourth in terms of annual disaster occurrence. Indeed, large-scale natural disasters have struck the archipelago nearly annually over the past decade or so, starting with the Great Eastern Japan Earthquake and tsunami of 2011 and continuing with the Ontake volcanic eruption of 2014, the Kumamoto earthquake of 2016, and the heavy rain disaster occurring in western Japan in 2018.

To address such situations, the Japanese government has drafted a number of disaster policies, including the “Disaster Countermeasure Basic Act” [8, 9] and the “White Paper on Disaster Management” [12, 11, 10]. The government is also organizing disaster countermeasures and promoting the development of comprehensive and systematic disaster management methodologies. In this context, there has been a push to improve disaster prevention and disaster reduction capabilities using innovations based on the latest science and technology, leading to the research and development of “resilient” disaster prevention/reduction tools for disaster prediction, prevention, and response.

In natural disasters, “emergency response headquarters” play a central role in implementing disaster countermeasures. The Disaster Countermeasures Headquarters, which was established with the goal of facilitating the aggregation and transmission of information and making decisions with respect to

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response activity, has the following roles:
1) collection, processing, and transmission of various types of information;
2) discussing and determining which disaster countermeasures should be implemented;
3) conducting first-aid activities in response to disasters.

However, as Numada et al. [14] point out, an individual emergency response headquarters will be required to carry out various disaster response activities at the time of a natural disaster (e.g., managing evacuation centers, transporting and providing relief supplies, damage investigation, correspondence regarding injured personnel, public relations activities, etc.). Social media such as Twitter and Facebook are now considered valid channels for collecting and transmitting information at the time of a disaster. During the Great East Japan Earthquake, communication control was significantly restricted by compromised communication lines, while packet communication and Internet lines were less restricted. In certain cases, relief efforts have been triggered by social media information.

The remainder of this article is organized as follows. Previous research and related works are discussed in Sections 2 and 3, respectively. The content and results of an interview survey on local government disaster response activities are described in Section 4. The research objective is described in Section 5. The system configuration and disaster response supporting system are described in Sections 6 and 7, respectively, and, finally, we conclude with our findings in Section 8.

2 Previous Research

In previous research, Takahagi et al. [18, 19] constructed a disaster management system comprising a disaster information registration system and a disaster information sharing system. The former organized real-time information reported by citizens and disaster prevention-related organizations via information terminals into a database, while the latter disseminated this stored information. However, as the system was designed to optimize emergency response headquarters operations, its functions were complicated and difficult to customize.

To solve these issues, Hirohara et al. [4, 6, 5, 7] designed a disaster response decision support Cloud system centered on the use of an interactive large-scale ultra-high definition display. This system enabled the transmission of disaster information to citizens via an interactive information sharing functionality and could also be functionally customized by the emergency response headquarters. However, the system had difficulties in linking data with other disaster prevention systems and, because of its multifunctionality, an overly complicated operability.

3 Related Works

The disaster information system developed by Sanada et al. [1] is based on an analysis of the current state of disaster response operations and an assessment of disaster response issues highlighted by the results of interview surveys of local governments. Their system uses information on factors such as inspection progress, facility damage, emergency restoration, support requests, traffic regulation, etc., as shared data that are linked using an electronic map developed by the Geographical Survey Institute. Although the system was found to be quite convenient to use, it is relatively uncooperative with other systems and has a high information input burden.

Suzuki et al. [17] implemented a fixed-phrase registration function for use by disaster response management systems to support information sharing in the disaster response activities undertaken by local governments. This system is practical in that it is cooperatively hosted on a shared database and can extract requirements from local government staff familiar with disaster response operations through the use of an information transmission function based on the use of fixed-form sentences. However, the system only collects and shares information and does not provide for the analysis of accumulated data.

Nonaka et al. [13] implemented a decision support system for emergency operations to support rapid and reliable execution of disaster countermeasures. The system actively presents disaster information by applying an IF-THEN rule to a pre-prepared database of local disaster prevention plans. However, it is implemented as a standalone desktop application that must be installed in advance on separate terminals, each of which must be manually re-registered when the regional disaster prevention plan is updated.

4 Interview Survey

To gain a better understanding of the current disaster response situation and the related use of social media by local governments, we conducted an interview survey of three local governments within the Ibaraki Prefecture. The findings are shown schematically in Figure 1. The survey results clarified the steps taken by an emergency response headquarters during and after a natural disaster. First, the headquarters collects information from both stored records and other disaster prevention organizations. The headquarters then organizes and analyzes the collected information and confirms its internal consistency; if it is necessary to transmit this information to the outside, it does so through channels including L-ALERT[3], social media, and municipality websites.

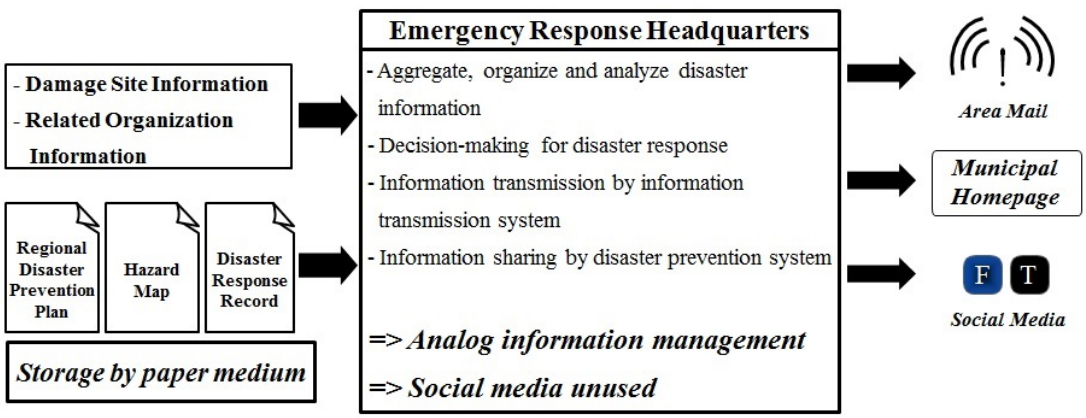

Figure 1: Findings on flow of emergency response headquarters activities based on interview survey

Additional issues relevant to the current disaster response process were also isolated in the survey. Notably, it was found that disaster information is generally arranged and analyzed using analog methods because most materials used in disaster response are stored in paper media. Analog information management can hinder prompt and accurate disaster response. It was also found that the municipalities used a number of different systems, including a proprietary system, for information dissemination and separate disaster prevention systems for information collaboration within the prefecture and with the country as a whole. The use of multiple systems can lead to increased operation time owing to duplicated input that could be avoided through data linkage between systems. Finally, it was found that social media information was not used to its full potential during disaster episodes. With the rapid spread of social media, citizen-transmitted information has become an important source for communicating damage situations. Although each of the three local governments used social media as a means of information dissemination, they did not use it as a means of information gathering. This lack of information gathering was attributable to the following:
1) during natural disasters, enormous volumes of information are transmitted via social media;

2) a lack of personnel made it difficult to gather and arrange this information, and;
3) the social media channels inevitably carried hoax and other low-credibility information.

The survey results suggest several requirements for improving the disaster response process.
A)The ability to quickly reference information from digitized past disaster response materials:

An emergency response headquarters will base its disaster response on past disaster information as well as information reported by response officers and related organizations from the disaster site. However, many disaster response materials archived in government building are preserved on paper and other analog media, making it difficult to immediately source them following a disaster. It is therefore necessary to digitize archived materials for quick reference.

B)Information linkage between systems:

To reduce the operational burden on local government officials, currently existing systems for sharing and disseminating information need to be supplemented by new systems that implement data linkages among different levels of government.

C)Flexible filtering of social media information:

Although the local governments did not utilize social media in gathering disaster information, they understood the need to include useful information in social media content. Accordingly, it is important to develop filters to exclude hoax and other low-reliability information from the social media feeds provided to emergency response headquarters.

5 Research Objective

Based on the results of the survey and the identified areas for improvement discussed in the previous section, we developed a new disaster response support system for extracting and visualizing disaster response information and filtering social media content. In this context, disaster response information refers to disaster response records regarding previously implemented disaster countermeasures and past disaster case information. The proposed system uses a database of such disaster response information to quickly access past data and effectively support the decision making and operations of an emergency response headquarters. The proposed system also enables the acquisition and visualization of real-time social media information, extracting only information with a high degree of reliability through the use of a filtering function that can be dynamically updated during fluid situations. The system is not limited to use in a specific type of disaster but can respond in an equally effective manner to a variety of cases, including earthquakes, tsunamis, and typhoons.

In the emergency response headquarters, various types of disaster response information are organized using a text application. The proposed system can import text files for storage and analysis, reducing the high system operation and data input costs that were problematic in previous systems.

Twitter, a popular social media service in Japan, is used to manage social media data collection. Specifically, the system uses the Twitter application program interface (API) [20] to acquire social media information in the form of real-time and past tweets. A filtering function is used to reduce noise (erroneous and hoax information) from the Twitter feed.

The proposed system is implemented as a Cloud system with the data processing component implemented as an API. Cloud implementation enables the system to be used from anywhere there is a network environment, while designing for multi-device compatibility makes it independent of dedicated terminals. The ability to handle multi-processing via the API enables data linkage with other disaster prevention and management systems.

6 System Configuration

The configuration of the proposed system is shown in Figure 2. The system comprises a database for managing data resources, a Twitter API for acquiring tweets, a disaster information API for linking input/output data with external APIs, and a user interface that acquires data as needed via asynchronous communication with the disaster information API. Data acquisition is reflected in real-time on the user interface. The system achieves real-time data processing and visualization capability by separating the disaster information API from the user interface to improve system speed and flexibility. The disaster information API also enables easier linkage between the proposed and other disaster management systems.

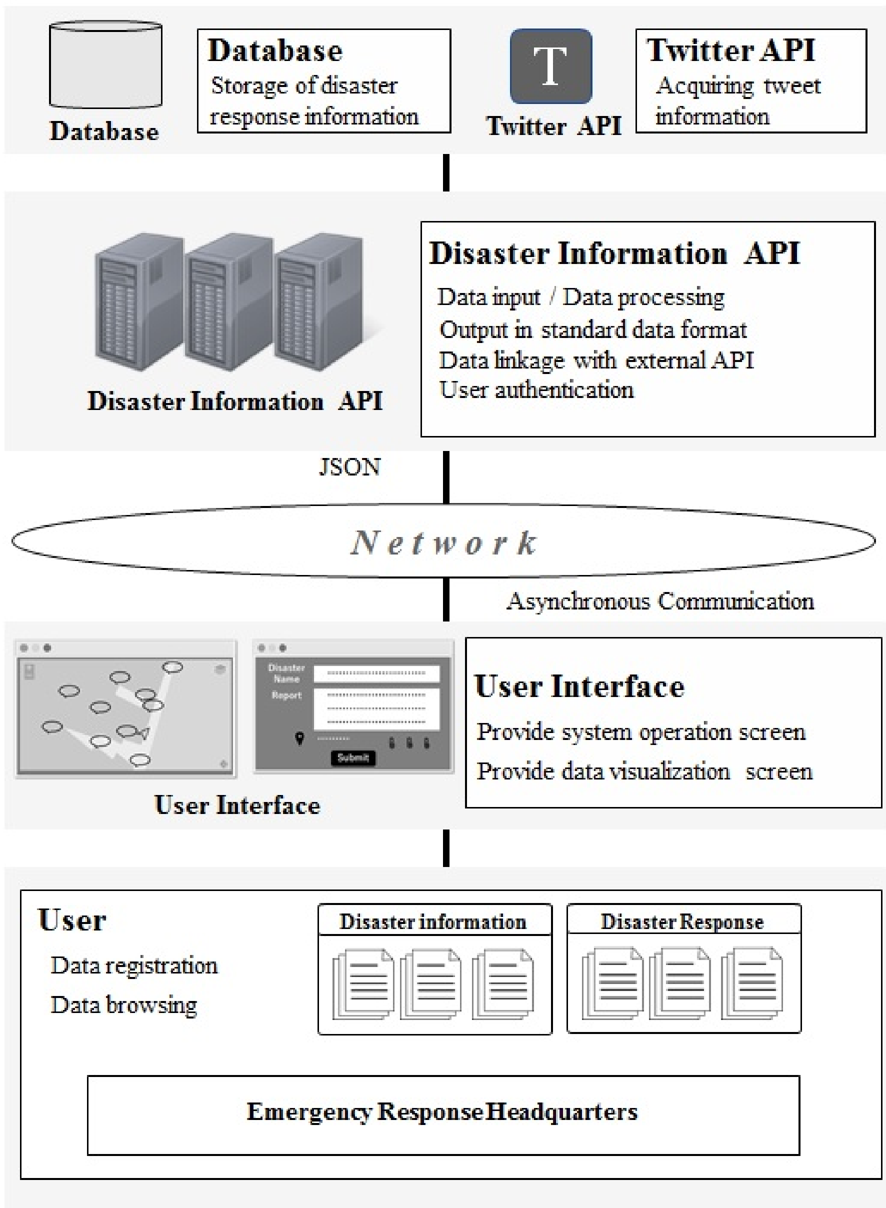

Figure 2: Configuration of proposed disaster management system

6.1 Registering Disaster Response Information

Continuous system operation requires the constant accumulation of disaster response information. Because many emergency response headquarters use text applications to summarize disaster response information, the proposed system is designed to analyze text applications at its data registration interface. The text analysis function (Figure 3), compresses input text files into zip format, decompresses them into xml files with associated png image files, and then stores the results in a media folder. Text extracted from the xml files is embedded into input forms and decomposed into nouns, verbs, and adjectives using morphological analysis. The resulting element group is used as an index for full-text search by the disaster information visualization system. The text data registration process is shown in Figure 4.

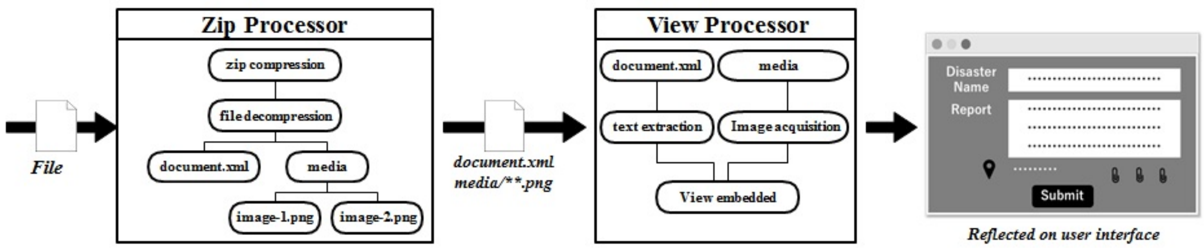

Figure 3: Architecture of text analysis function

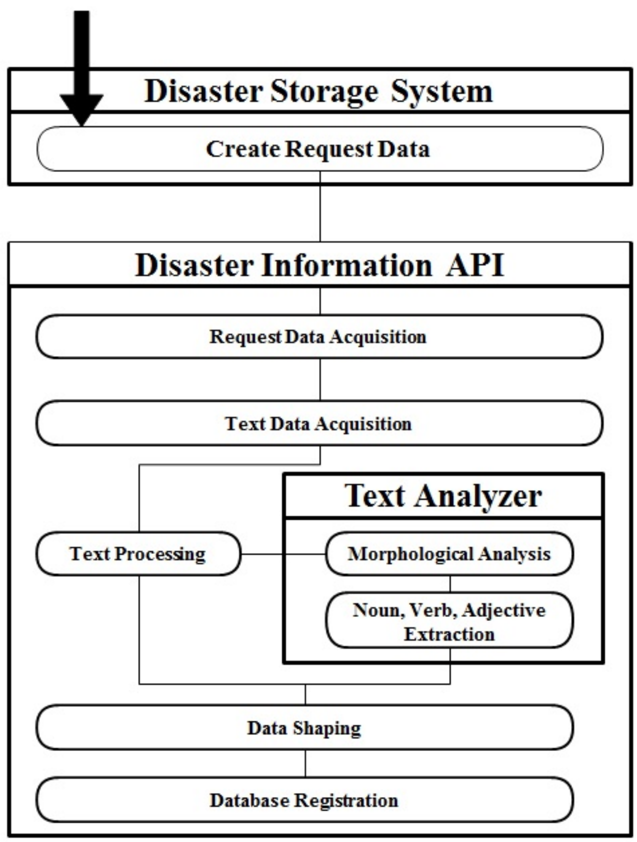

Figure 4: Text data registration Process

In the disaster response information storage system (Figure 5), a web application verifies the input value of user input information; if an input is valid, the data are passed to the state management manager, which also requests data from the disaster information API using asynchronous communication. Following user authentication, the disaster information API performs data registration processing and the state management manager requests that the view manager generate a new interface.

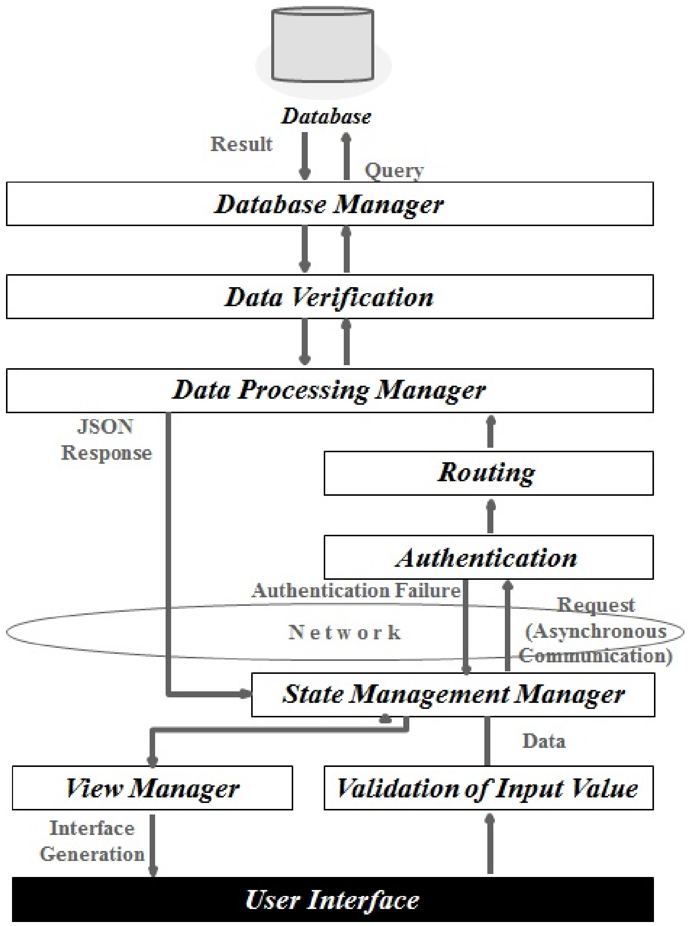

Figure 5: Architecture of disaster response information storage system

6.2 Visualization of Disaster Response Information and Social Media Information

The process of visualizing the disaster response information on the user interface is shown in Figure 6. Upon system startup, the system extracts disaster response data from a cache containing disaster classification, date and time, and location information. In addition to this automatically extracted data, a user can extract more specific information tied to keywords. Following morphological analysis of an input keyword, a full-text search in which the similarities between the keyword and all document contents is carried out to produce a set of scored processing results. The filtered processing results are then given as response data on the user interface.

The process for filtering social media information is shown in Figure 7. The system acquires real-time tweet information using the Twitter streaming API. Words related to disasters are extracted from a database and used as keywords in running the streaming API to ensure that only tweets satisfying prescribed conditions are selected. In selecting keywords, the streaming API performs partial match-

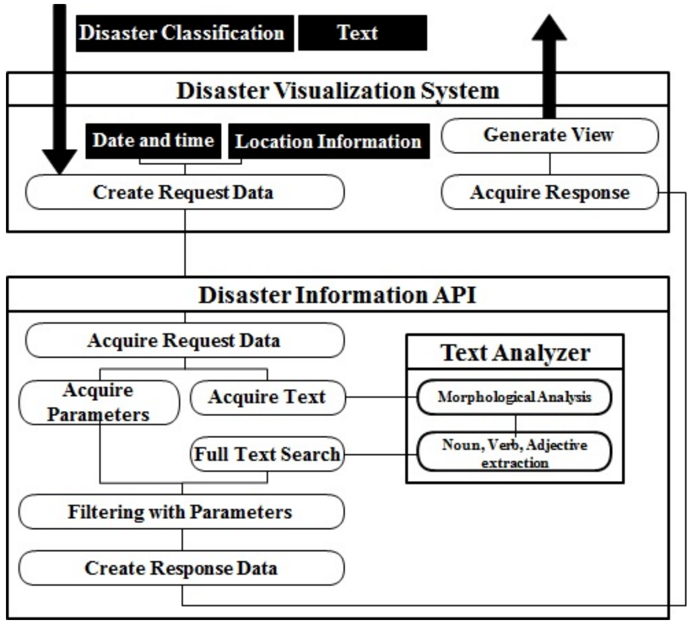

Figure 6: Extraction and visualization of disaster response information

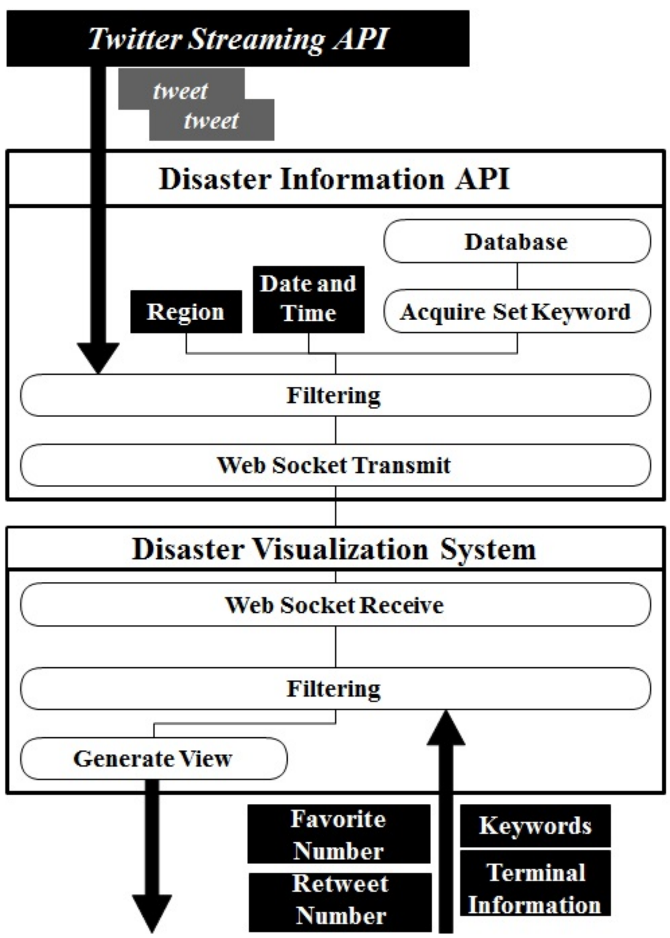

Figure 7: Social media information filtering

ing searches on real-time tweets. However, in addition to disaster-related tweets a number of regular bot tweets and tweets not related to disasters are acquired; therefore, the system implements a dynamic filtering function on the received tweet stream. Specifically, the system filters the tweet information transmitted to the disaster information visualization system by selecting for keywords, number of favorites, number of retweets, etc. This filtering enables the emergency response headquarters to acquire the targeted social media information that is most useful in monitoring a changing disaster situation.

The disaster information visualization system (Figure 8) uses a state management manager to asynchronously send search query requests to the disaster information API, which then acquires related data from the database and Twitter API and converts them to standard data format (JSON). The system employs a mapping function (OpenStreetMap API [16]; OpenStreetMap) to generate a map on the visualization screen while directly providing a stream of real-time tweets using the WebSocket communication protocol.

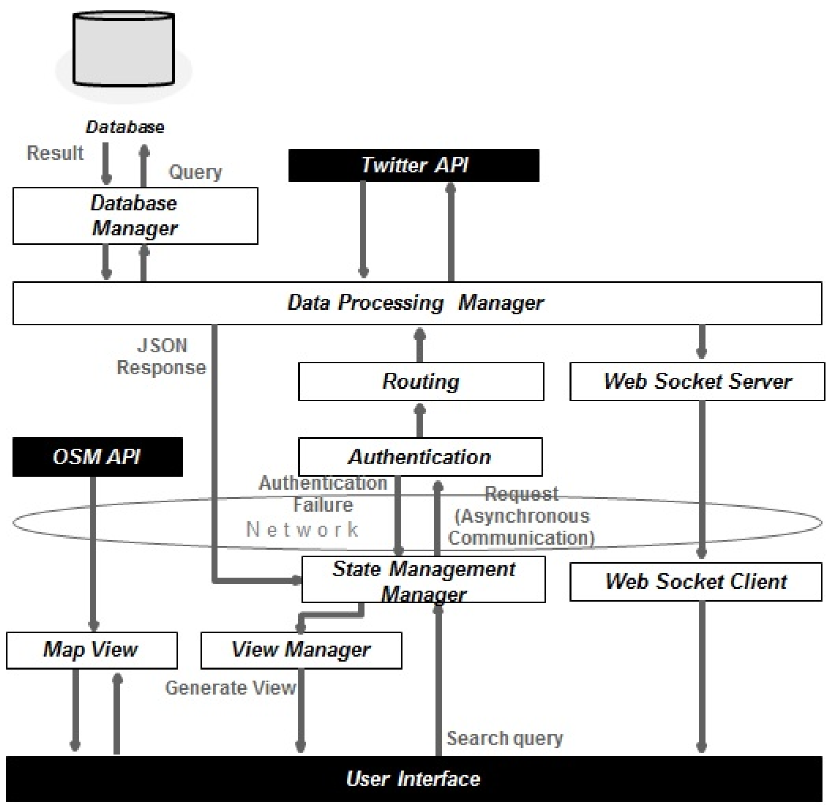

Figure 8: Architecture of the disaster information visualization system

6.3 Data Linkage using API

The survey revealed that the local governments had already introduced systems for reporting to the national and prefecture governments and for disseminating information to local citizens. To take advantage of this interconnectivity, the proposed system provides an interface (the disaster information API) to allow other systems to use its accumulated data. The disaster information API is implemented in the form of a web API that can acquire data by accessing specified URLs. The API responds to data acquisition requests with information in JSON format. The data acquisition sequence is shown in Figure 9.

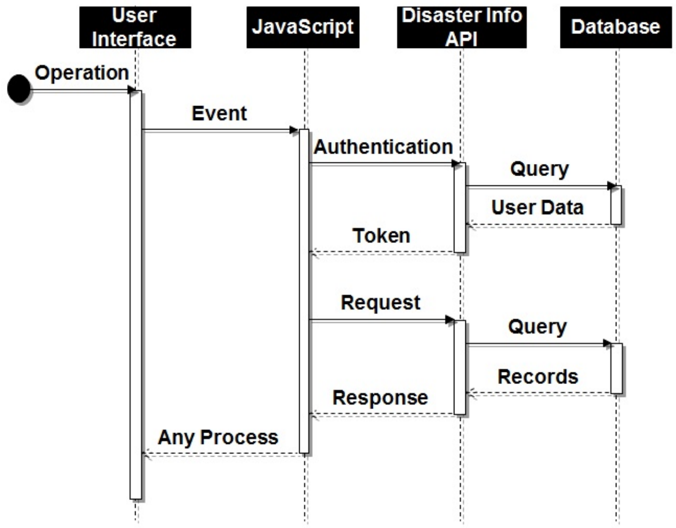

Figure 9: Disaster information API data acquisition sequence

6.4 System Utilization under Communication Disruption

Because power and communication facilities can be damaged when disasters occur, we implemented a caching function to allow the system to work effectively in cases of communication interruption. The sequence of the cache function is shown in Figure 10. When normal system requests for data from the server result in an error upon communication interruption, the proposed system refers to the information cache accumulated by the application. Any available cache information is returned to the user; if the cache is empty, the application stores the information request. When communication is recovered, the system automatically relays its accumulated information requests to the server to acquire the latest data and update the cache. These data can accessed by a user up to the moment that a communication interruption occurs.

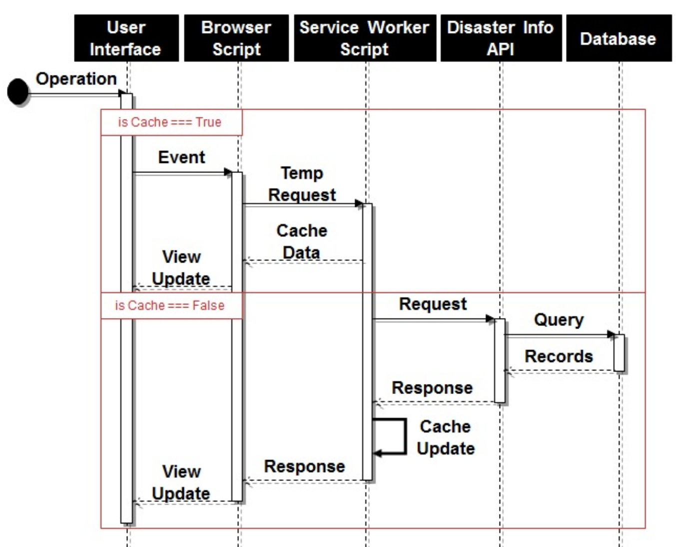

Figure 10: Cache function sequence

7 Disaster Response Support System Implementation

We implemented the disaster response support system in the Cloud. After the user selects a disaster type from the selection screen shown in Figure 11, disaster names, seasons, etc., are pulled up from the disaster type registration screen shown in Figure 12. The stored disaster types reflect the natural disasters defined in the Basic Disaster Prevention Plan [2], i.e., earthquake, tsunami, wind and flood, volcanic, and snow disasters.

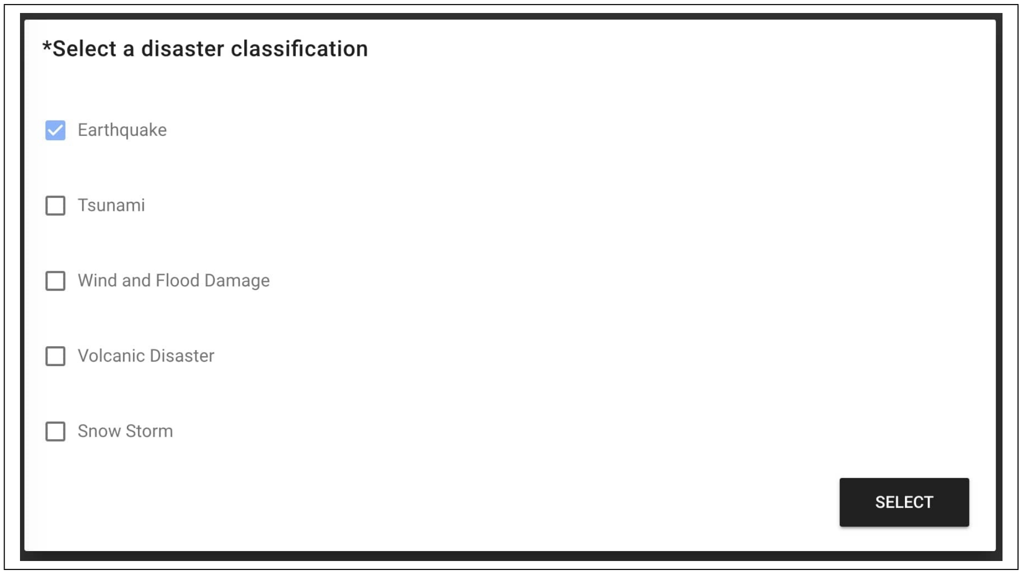

Figure 11: Disaster type selection screen

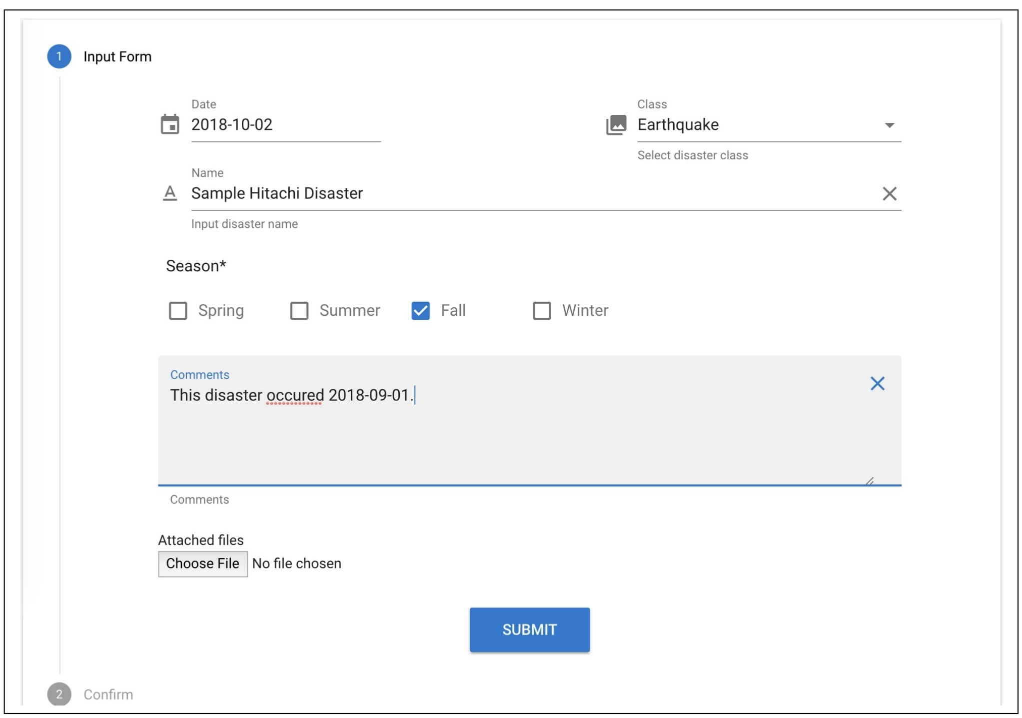

Figure 12: Disaster case registration screen

On the screen for registering disaster response information (Figure 13), the user inputs disaster cases, disaster response phases, importance levels, and disaster response information. The registration screen also allows the user to upload media files in the form of images and videos taken from the disaster site.

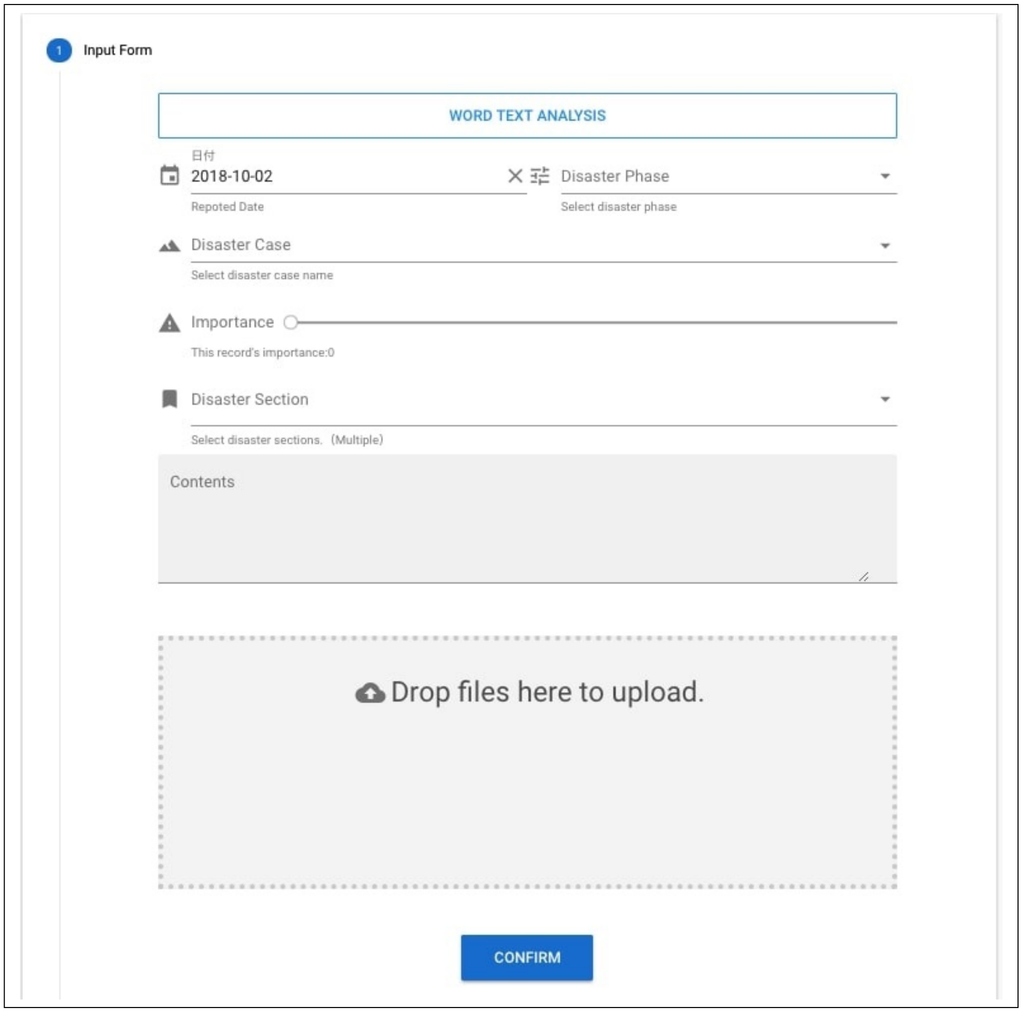

Figure 13: Disaster response information registration screen

The accumulated disaster response information visualization screen is shown in Figure 14. Search results are displayed in the center of the screen, while nouns extracted from the disaster response information to be used as keywords for searching social media are displayed as a list on the left side of the screen.

The social media information acquisition screen is shown in Figure 15. The system uses WebSocket to receive social media information in real-time. Implementation of WebSocket communication requires a separate address from that of the server that must be connected to a browser application. When the "Connect" button on the upper part of the screen is selected, a real-time stream of social media information is displayed at the center of the screen, while information on the results of a partial matching search by disaster-related keyword is displayed on the browser. As information irrelevant to disaster response (noise information) is also provided, the user can perform detailed filtering, as shown in Figure 16.

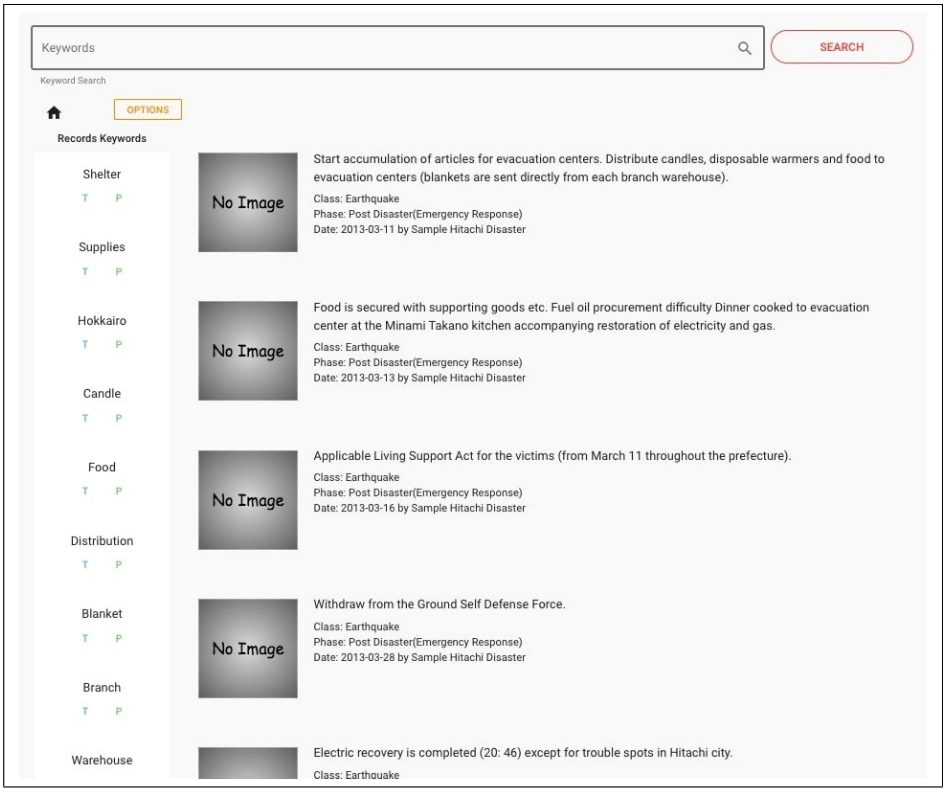

Figure 14: Disaster response information visualization screen

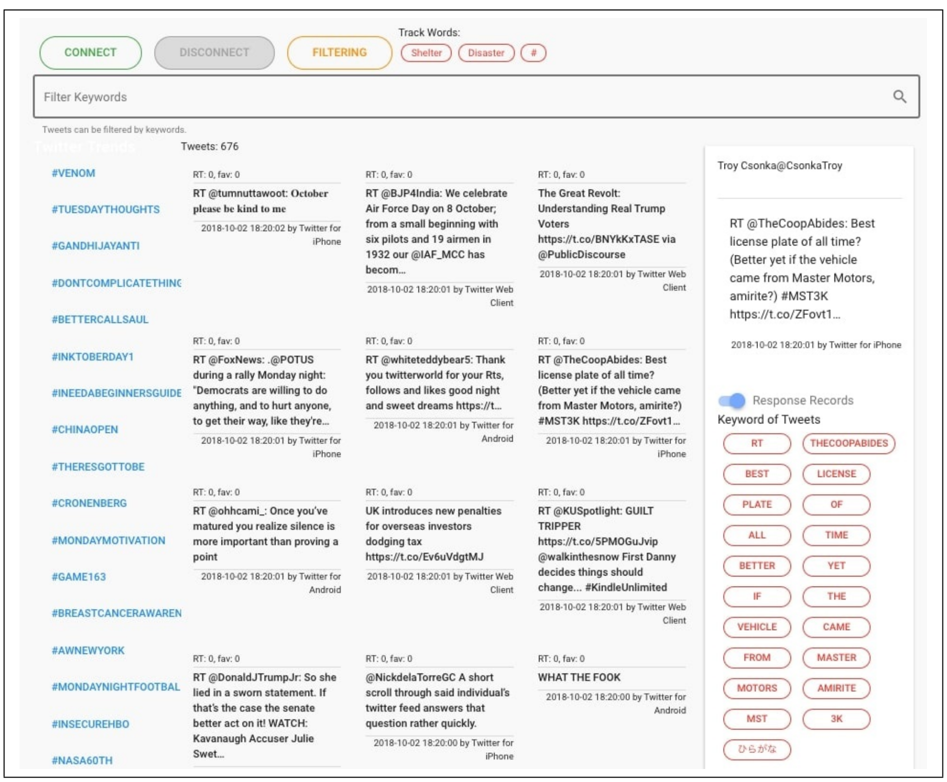

Figure 15: Social media information acquisition screen

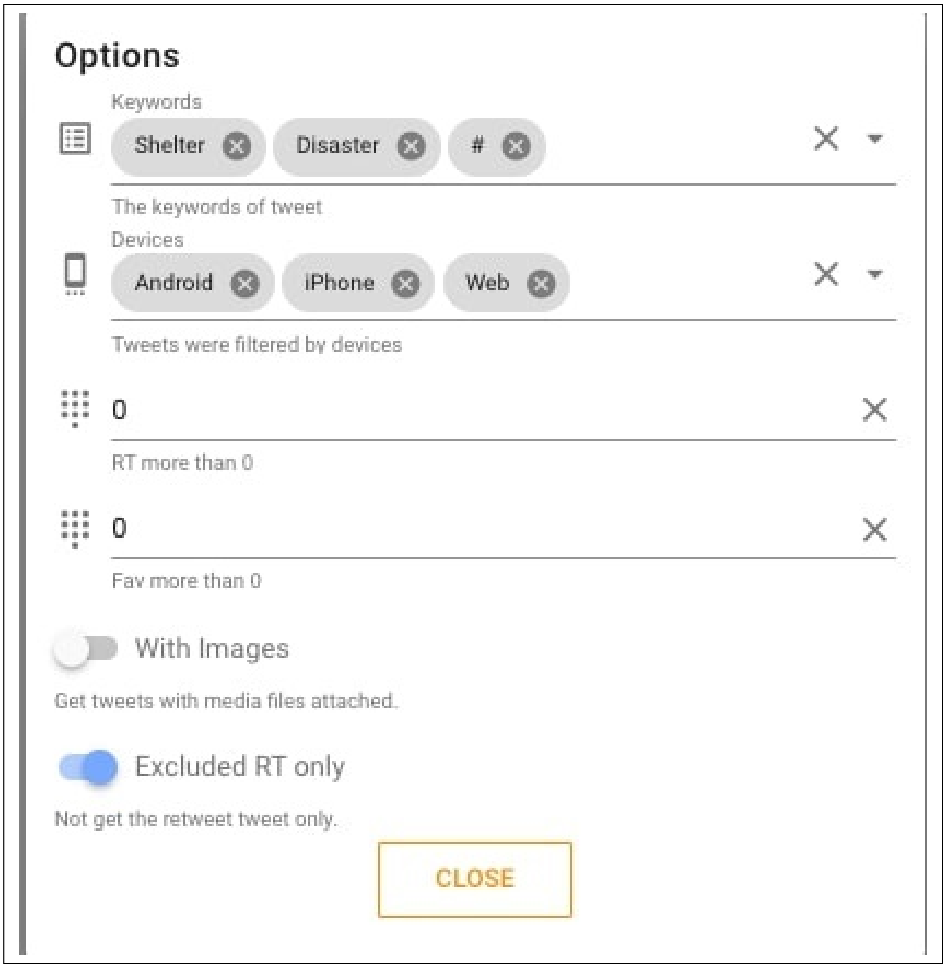

Figure 16: Social media information filtering options

8 Conclusion and Future Work

In this study, we developed a disaster response system that uses accumulated past disaster response information to support rapid decision making at emergency response headquarters. To identify issues that should be addressed in designing a disaster response system, we first conducted an interview survey of three local governments in Ibaraki Prefecture. By separating the user interface and data processing functionalities, the implemented system can provide fast data linkage with other systems to enable them to use the data accumulated in the system. The disaster response system includes an information storage component to extract past disaster response information from text files and an information visualization system for accessing this information. Social media information can also be monitored in real-time using disaster response information keywords. Noise is extracted from the social media stream using a two-stage filtering process on the server and client sides. The dual user interface and information processing architecture of the proposed disaster response support system supports quick decision making at emergency response headquarters, with an additional cache function allowing the system to function even when network communication is interrupted.

In future work, we plan to implement the data import/export functionality of the system as an on-screen mechanism for reducing the user input requirements (Figure 17). This import/export function can also enable data linkage among local governments to support regional responses during natural disasters.

To further evaluate the effectiveness of the system in supporting disaster response, we plan to conduct an evaluation experiment in partnership with municipalities in the Ibaraki Prefecture.

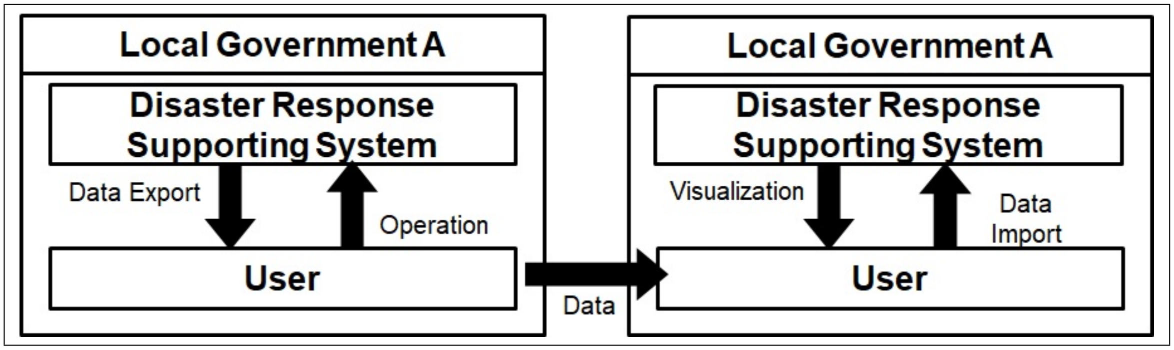

Figure 17: Disaster response information import/export function

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References

[1] S. Akihiro, K. Takaaki, U. Katsumi, Y. Takeshi, and K. Kazushige. Development of a disaster information system based on a present business model analysis. *Journal of applied computing in civil engineering*, 15:39–48, 2006.

[2] C. D. P. Council. Basic disaster prevention plan. `http://www.bousai.go.jp/taisaku/keikaku/pdf/kihon_basic_plan180629.pdf`, [Online; Accessed in May 1, 2018].

[3] F. for Multimedia Communications. L-alert. `https://www.fmmc.or.jp/commons/`, [Online; Accessed in May 1, 2018].

[4] Y. Hirohara, T. Ishida, N. Uchida, and Y. Shibata. Proposal of a disaster information cloud system for disaster prevention and reduction. In *Proc. of the 31th International Conference on Advanced Information Networking and Applications Workshops, Taipei, Taiwan*, pages 664–667. IEEE, March 2017.

[5] T. Ishida, Y. Hirohara, N. Kukimoto, and Y. Shibata. Implementation of a decision support system using an interactive large-scale high-resolution display. *Journal of Artificial Life and Robotics*, 22(3):385–390, 2017.

[6] T. Ishida, Y. Hirohara, N. Kukimoto, and Y. Shibata. Proposal of a decision support system for the local government's disaster control headquarters. In *Proc. of the 22nd International Symposium on Artificial Life and Robotics, Beppu, Japan*, pages 649–652. ISAROB, January 2017.

[7] T. Ishida, Y. Hirohara, N. Uchida, and Y. Shibata. Implementation of an integrated disaster information cloud system for disaster control. *Journal of Internet Services and Information Security (JISIS)*, 7(4):1–20, December 2017.

[8] C. O. Japan. Disaster countermeasure basic act. `http://www.bousai.go.jp/taisaku/kihonhou/index.html`, [Online; Accessed in May 1, 2018].

[9] C. O. Japan. Disaster management in japan. `http://www.bousai.go.jp/1info/pdf/saigaipanf_e.pdf`, [Online; Accessed in May 1, 2018].

[10] C. O. Japan. White paper on disaster management 2015. `http://www.bousai.go.jp/kyoiku/panf/pdf/WP2015_DM_Full_Version.pdf`, [Online; Accessed in May 1, 2018].

[11] C. O. Japan. White paper on disaster management 2016. `http://www.bousai.go.jp/kyoiku/panf/pdf/WP2016_DM_Full_Version.pdf`, [Online; Accessed in May 1, 2018].

[12] C. O. Japan. White paper on disaster management 2017. `http://www.bousai.go.jp/kyoiku/panf/pdf/WP2017_DM_Full_Version.pdf`, [Online; Accessed in May 1, 2018].

[13] H. Nonaka and H. Shoujima. A decision support system for emergency operation. *Journal of Japanese Society for Artificial Intelligence*, 15(3):469–476, 2000.

[14] M. Numada and K. Meguro. Development of disaster process sysetm case for yabuki town in fukushima prefecture. *Seisan-kenkyu*, 67(2):227–231, 2015.

[15] T. Ohyanagi, T. Ishida, N. Uchida, Y. Shibata, and H. Habuchi. Proposal of a disaster support expert system using accumulated empirical data. In *Proc. of the 12th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS'18), Matsue, Japan*, volume 773 of *Advances in Intelligent Systems and Computing*, pages .310–319. Springer, Cham, July 2018.

[16] OpenStreetMap. Openstreetmap api. `https://wiki.openstreetmap.org/wiki/API`, [Online; Accessed in May 1, 2018].

[17] T. Suzuki and T. Tsuda. Development and evaluation of fixed phrase registration function for disaster response management system. *Journal of Japan Society of Civil Engineers, Ser.F6 (Safety Problem)*, 68(2):I82–I87, 2012.

[18] K. Takahagi, T. Ishida, A. Sakuraba, K. Sugita, Noriki, Uchida, and Y. Shibata. Construction of a mega disaster crisis management system. *Journal of Internet Services and Information Security (JISIS)*, 5(4):20–40, December 2015.

[19] K. Takahagi, T. Ishida, A. Sakuraba, K. Sugita, N. Uchida, and Y. Shibata. Proposal of the disaster information transmission common infrastructure system intended to rapid sharing of information in a time of mega disaster. In *Proc. of the 11th International Workshop on Network-based Virtual Reality and Tele-existence (INVITE'15), Taipei, Taiwan*, pages 505–510. IEEE, September 2015.

[20] Twitter. Twitter api. `https://developer.twitter.com/`, [Online; Accessed in May 1, 2018].

[21] U. N. University. World risk report 2016. `http://collections.unu.edu/view/UNU:5763`, [Online; Accessed in May 1, 2018].

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