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Disaster Prevention and Response Support Solutions

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OVERVIEW: With national and regional agencies updating their plans for dealing with large, wide-area disasters based on the lessons from the Great East Japan Earthquake, there is also growing demand for the systems that support disaster prevention and response to incorporate countermeasures against such major disasters. In the case of large, wide-area disasters, realtime and ongoing decision making is a particular challenge because circumstances are continually changing. Hitachi is developing disaster prevention and response support solutions that incorporate operational concepts for emergency situations. To overcome the problem of delayed decision making during a large, wide-area disaster due to gaps in available information, Hitachi is also proposing a rapid situation assessment system that utilizes information from SNSs and other sources to help quickly collect information and determine what is happening.

INTRODUCTION

TAKING note of the lessons from the severe damage that resulted from disasters such as the Great Hanshin Awaji Earthquake in 1995 and the Niigata-ken-Chuetsu Earthquake in 2004, ongoing work is being done to establish organizations and schemes and provide facilities and systems for damage limitation in Japan. Following the Great East Japan Earthquake in March 2011, it is anticipated that further nationwide measures for mitigating disasters will be undertaken in parallel with ongoing recovery and reconstruction in the affected regions. In particular, there is an urgent need to adopt measures for dealing with events such as a Nankai Trough Earthquake or an earthquake directly under Tokyo, both of which have been predicted, and revisions are being made to plans for dealing with large, wide-area disasters under the leadership of the Central Disaster Prevention Council(1) of the Japanese Government. As a consequence, there is growing demand for incorporating countermeasures against large, wide-area disasters into the disaster prevention systems that support the response to a disaster.

This article describes the disaster prevention and response support solutions being developed by Hitachi, and also a rapid situation assessment system that utilizes information from social networking services (SNSs) and other sources immediately after the disaster strikes to help quickly collect information and determine what is happening. This proposed system is intended as a way of overcoming the problem of ensuring realtime and ongoing decision making during a large, wide-area disaster in which circumstances are continually changing.

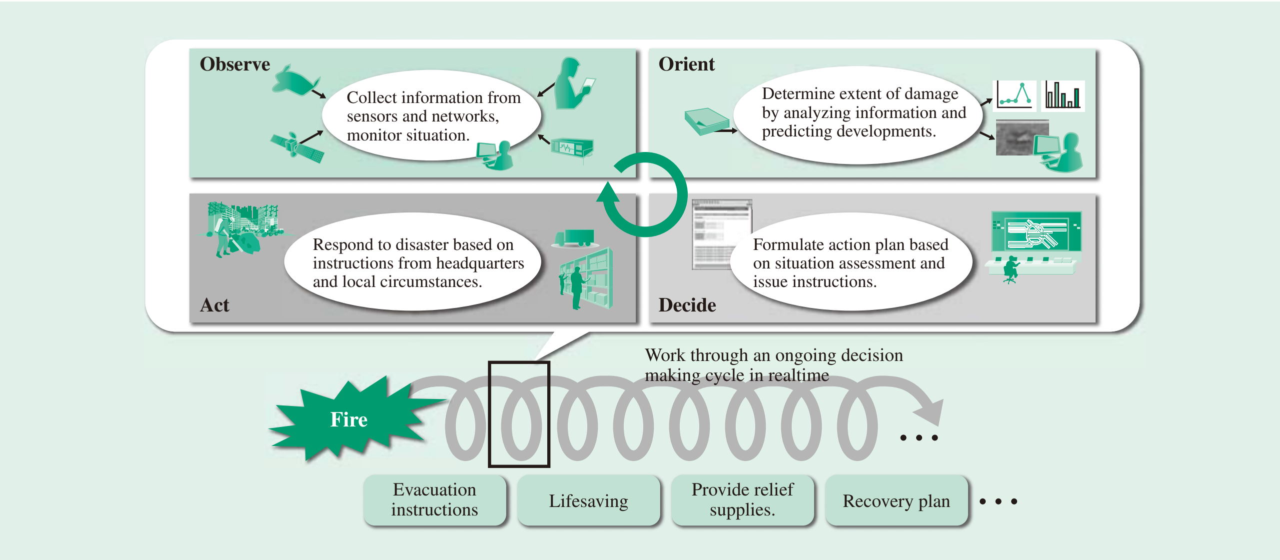
DISASTER PREVENTION AND RESPONSE SUPPORT SOLUTIONS

Concept

During a disaster, response activities must operate in a constantly changing environment. In particular, mounting a rapid and accurate response is difficult if the disaster has caused large amounts of damage over a wide area with numerous unforeseen events.

For this reason, the disaster prevention and response support solutions are based on the concept of implementing the observe, orient, decide, and act (OODA) loop, a decision making methodology from the defense sector that was devised by U.S. Air Force Colonel John Boyd based on insights from aerial combat. It achieves fast and accurate decision making by performing a repeated cycle of observation, orientation, decision, and action. It differs from the conventional plan, do, check, and act (PDCA) cycle in that monitoring and situation assessment are ongoing at all steps in the cycle to allow a flexible response to a continually changing situation.

The disaster prevention and response support solutions aim to provide services that implement a continuous OODA loop from the time the disaster strikes until recovery is achieved (see Fig. 1).



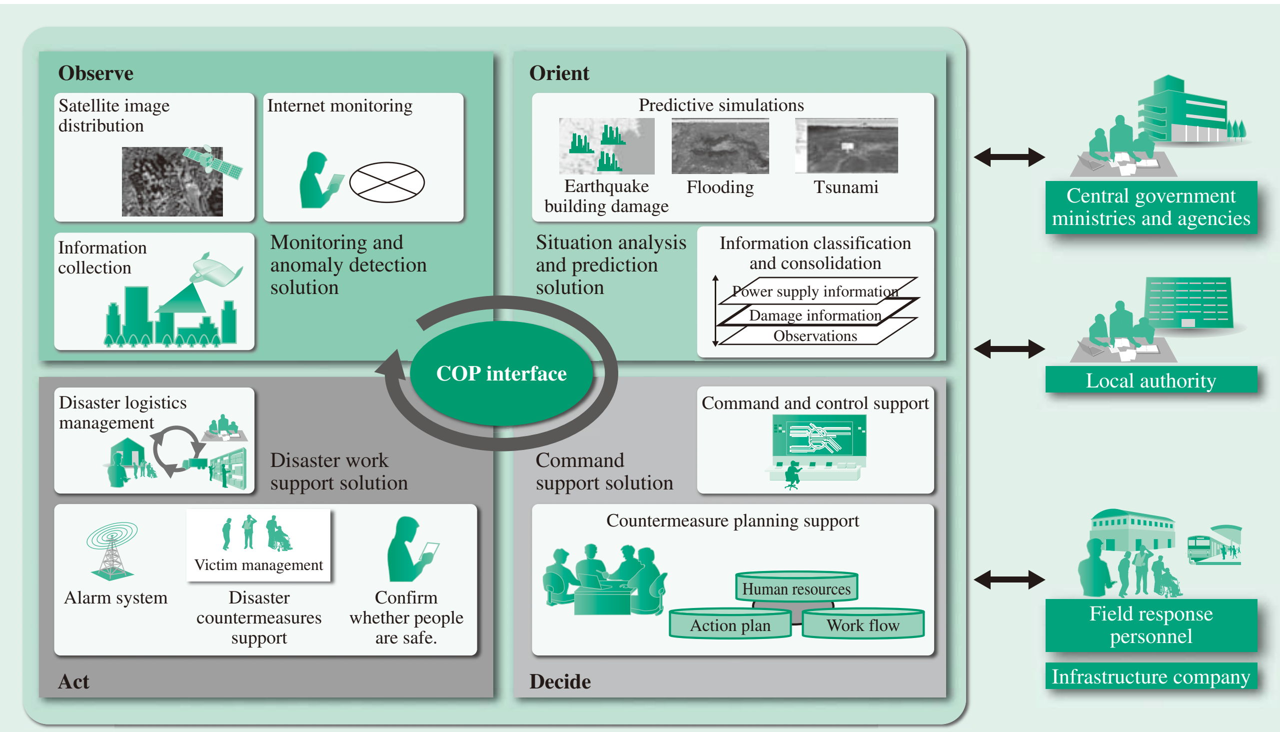
OODA: observe, orient, decide, and act

Fig. 1—OODA Loop for Disaster Response.
The OODA loop achieves fast and accurate decision making by performing a repeated cycle of observation, orientation, decision, and action.

Overview of Disaster Prevention and Response Support Solutions

Fig. 2 shows an overview of the disaster prevention and response support solutions.

Based on the OODA loop described above, Hitachi provides the following solutions that assist with working through the OODA cycle quickly and accurately during a large, widearea disaster.



COP: common operational picture

Fig. 2—Disaster Prevention and Response Support Solution.
The monitoring and anomaly detection, situation analysis and prediction, command support, and disaster work support solutions help implement the OODA loop to support fast and accurate decision making during a disaster.

(1) Monitoring and anomaly detection solution

This solution collects information from sources such as seismometers, river level gauges, surveillance cameras, unmanned aerial vehicles, satellites, and Internet SNSs, and integrates it on a geographic information system (GIS) to detect anomalies by assessing the situation and identifying what has changed.

(2) Situation analysis and prediction solution

This solution provides functions for collating and classifying the information collected by the monitoring and anomaly detection solution and other systems, thereby enhancing its value as intelligence for use in situation analysis and prediction (see Fig. 3). The solution also uses simulation techniques for earthquake building damage, flooding, tsunamis, or the movement of people to conduct risk simulations and provide information to help determine the current situation and assess changing circumstances and possible future developments.

The solution classifies and collates information from sensors such as river level gauges to calculate the rise in river levels, and incorporates information about upcoming weather conditions to perform flooding simulations. This can be used to generate intelligence, such as warning that a particular district is at risk of a levee breach in an hour's time, for example. Intelligence like this facilitates fast and accurate decision making on evacuation alerts.

(3) Command support solution

This solution supports effective and efficient command and control for relief and recovery. For example, it provides the disaster response headquarters with a map of the disaster situation that they can refer to as they assign people, organizations, goods, and other resources in accordance with the evolving situation on the ground. This solution builds a database from which the data required for the tasks associated with the event and their execution can be accessed quickly based on an event model of the time when the disaster strikes, a disaster response model (work flow), a data model that specifies the relationships between data, and a disaster management model that links these other models together. This allows the "push" delivery of information based on users' circumstances and responsibilities (see Fig. 4). For the people or organizations assigned the task of distributing relief supplies, for example, the solution supplies the information needed to complete this task, namely the information associated with the distribution of relief supplies (road damage status, where to distribute supplies, recommended routes, and so on).

(4) Disaster work support solution

This solution provides functions for managing the activities of local authorities (confirming the safety of staff, evacuation site management, issuing victim certificates, and so on) as well as requests for relief

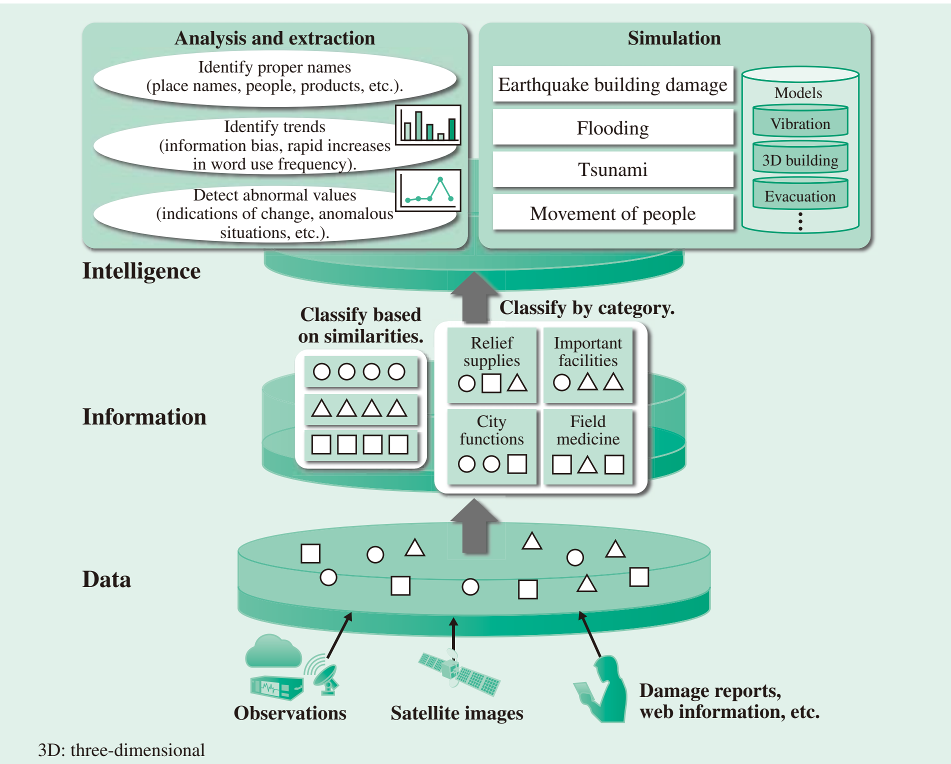


Fig. 3—Situation Analysis and Prediction Solution.
The solution categorizes and collates data and uses trend analysis, simulation, and other techniques to supply information that is useful for fast and accurate decision making.

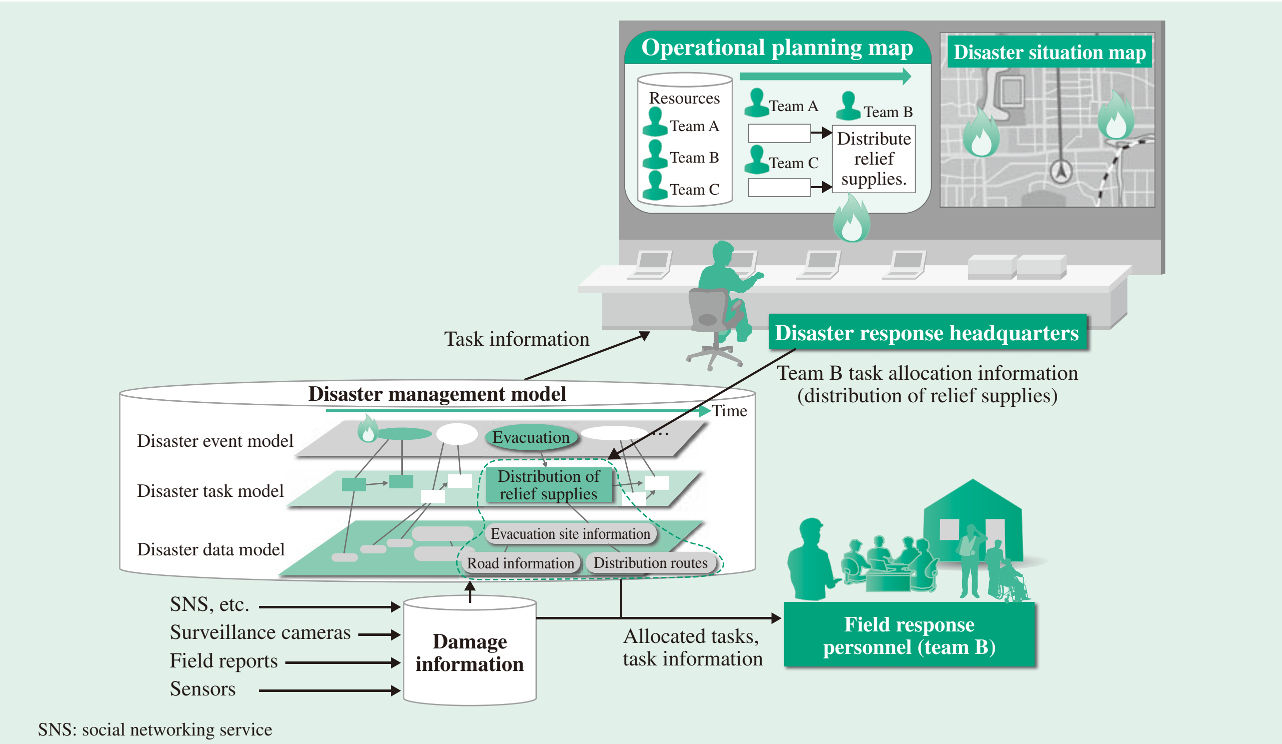


Fig. 4—Command Support Solution.
This solution is used to prepare an activity plan and support the assignment of personnel, organizations, goods, and other resources. When a task is assigned to a person or organization, the information required to complete that task is extracted from the database and supplied to the person or organization using "push" style delivery.

supplies, stock control, dispatch instructions, and other aspects of logistics.

RAPID SITUATION ASSESSMENT SYSTEM

Challenges of Decision Making during Disasters

As noted above, the key to successful disaster response is to work through the OODA loop decision making cycle as quickly as possible based on the actual situation. However, there are numerous obstacles to achieving this during a large, wide-area disaster. Damage at local government, fire department, police, or other local agencies, for example, may result in a lack of information for making decisions. At the Cabinet Office, one of the problems during the Great East Japan Earthquake was that the government needed to mount an emergency response despite a lack of information caused by the impairment of local government functions due to damage to their buildings or injuries to staff(2).

This information vacuum in the immediate aftermath of a disaster can result in fatal delays in decisions for the most urgent lifesaving response activities. As it is recognized that survivability falls off rapidly once 72 hours have elapsed since a disaster, the important factor is how to work through the OODA loop quickly during this 72 hour period.

In response, Hitachi has developed a rapid situation assessment system to enhance the observation and orientation functions of its disaster prevention and response support solutions. The system looks to SNSs such as Twitter*, blogs, and bulletin boards to provide the information that can fill in these temporal and spatial gaps in information during a disaster.

Strategy for Using SNS Data

The characteristics of SNS data mean it provides the following benefits.

(1) SNSs can be used from mobile phones or other devices with hardware and software familiar to large numbers of users, including the general public and public agencies. They are currently used by about 30% of local government disaster prevention and management agencies, with a further group of nearly 20% considering their adoption(3).

(2) The collection of realtime information on communication between the public in the immediate aftermath of a disaster can indicate the status of

* Twitter is a registered trademark of Twitter, Inc.

affected areas (how the situation is developing, including actions by the public). As base station batteries running out after the power fails is the major cause of interruptions to mobile phone and other telecommunications infrastructure[(4)], mobile networks in affected areas can be expected to remain available for about half a day after a disaster strikes.
(3) The system can utilize systems and networks that are already available and widely used.

The disadvantages, meanwhile, are as follows.
(1) Information includes incorrect reports and rumors.
(2) Huge volume of data can bury important information and make it difficult to find.

For these reasons, accepting that incorrect reports and rumors will be present, the new system collects SNS data continuously in realtime and uses it to augment information from more reliable sources.

System Overview

Fig. 5 shows an overview of the rapid situation assessment system.

The system consists of SNS data collection, SNS data analysis, and common operational picture (COP) interface functions. It collects SNS data from sources such as Twitter and provides users with screens that help them assess the situation. The following sections describe these functions in detail.
(1) SNS data collection function

The SNS data collection function crawls the Internet to collect SNS data (raw data) from social media services and other targeted web pages. It also subjects the collected data to metadata and natural language analyses[(5)] to determine the time, location, identity of poster, and classification tag (disaster-related key words such as earthquake, tsunami, fire, or evacuation). The raw SNS data is stored in a database together with this extracted information, which is used for indexing. This classification then provides a basis for presenting the information on a map via the COP interface function, where it can be used to detect events such as fires, determine the extent of damage (such as halted trains or the location of injured people), and determine how the response is progressing (such as the deployment of fire fighters).
(2) SNS data analysis function

The SNS data analysis function consists of reliability analysis and anomaly detection.

The reliability analysis uses the criteria listed in (a) to (e) below to score the reliability of the SNS data so that information deemed to be reliable can be utilized for purposes such as situation assessment.

(a) Analysis of information source (person)

This assigns a reliability score based on the ID or other account information for the person who supplied the information. Information from local government personnel, for example, is given a high score whereas that from the general public is given a lower score. For example, it uses the account name included in Twitter data to determine whether or not a tweet is from an official local government account. If it is, it is given a

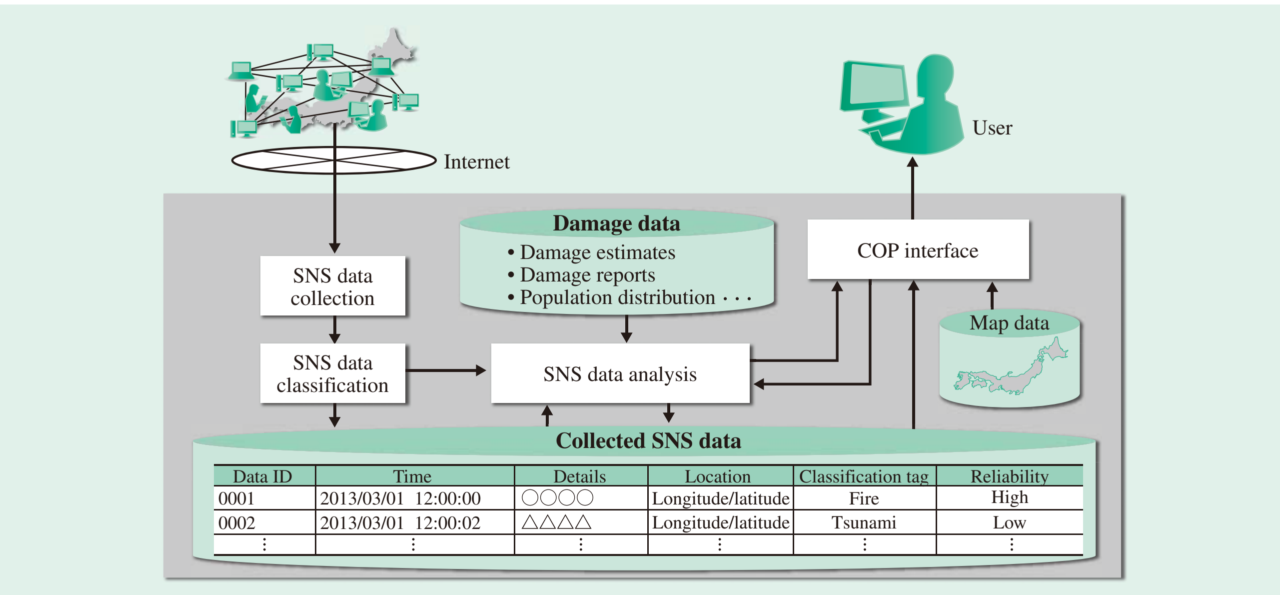


Fig. 5—Rapid Situation Assessment System.
The system collects, classifies, and displays SNS data to fill in gaps in information after a disaster occurs, and to provide a rapid assessment of the overall situation.

high reliability score and saved in the database. The identity of official accounts is available because local governments publish this information.

(b) Analysis of information source (location)

This assigns a reliability score based on the location from which the SNS information was posted, as indicated by global positioning system (GPS) or other location data. For example, information is given a high score if the location matches the content (such as place names contained in the data).

(c) Analysis of information type

This assigns a reliability score based on the type of information. For example, text is given a low score whereas videos or photographs are scored highly.

(d) Analysis of information timing

This assigns a reliability score based on how current the information is. For example, information is given a high score (timeliness) at the time it is posted, but this falls as time passes.

(e) Analysis of correlation with other information

This assigns a reliability score based on correlation with other information. For example, information is given a higher score the more other posts of the same type (such as those indicating a fire, for example) are collected from the same vicinity. Information is also scored more highly if it is highly ranked by other users.

Anomaly detection analyzes the collected SNS data as follows.

(a) Trend analysis, time-domain change analysis

Trend analysis identifies frequently occurring words and collates and condenses SNS data from each region. Time-domain change analysis identifies sudden increases or decreases in the frequency of particular words, and detects changes in data volumes.

(b) Information gap analysis

This performs comparisons on the disaster data in the database (such as damage estimates, damage reports, or population distributions) to generate data on information gaps (such as anomalous areas that are producing less data than would be expected) and similar. A location from which no data is being generated is likely to be so badly damaged that information can no longer be posted.

(3) COP interface function

After being subjected to the analyses described in (1) and (2) above, the SNS data is displayed on a map where it can be used to aid decision making. Fig. 6 and Fig. 7 show examples of screens displayed by the system. This function uses map and population density data published by the Ministry of Land, Infrastructure, Transport and Tourism.

TRIAL OPERATION

The system's classification and data visualization functions were tested using tweets collected via the Streaming Application Programming Interface (API) supplied by Twitter, Inc.

Typhoon 18 on September 16, 2013 caused heavy rain damage in the area around Kyoto in Japan. Information about flooding started coming in about midnight, with posts by the public about specific damage in upstream areas, such as high river levels or surface flooding on roads, appearing at around 3:50 AM (see Fig. 8). According to the damage report from the Fire and Disaster Management Agency[6], the disaster response headquarters under the jurisdiction of Kyoto Prefecture were set up at 5:00 AM. This suggests that the information collated and presented by this system would have been useful for making this decision, and for quickly assessing the situation once the headquarters was established.

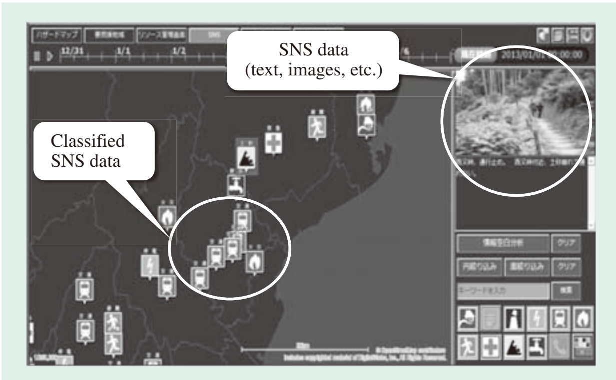


Fig. 6—Rapid Situation Assessment Screen.
The screen displays SNS data classified by the type of event (earthquake, tsunami, fire, etc.).

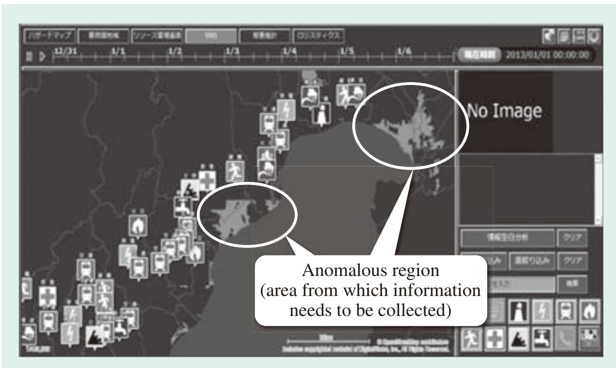


Fig. 7—SNS Data Analysis Screen.
The system performs comparisons on disaster data (such as damage estimates, damage reports, or population distributions) to identify anomalous regions, such as areas that are producing less data than would be expected.

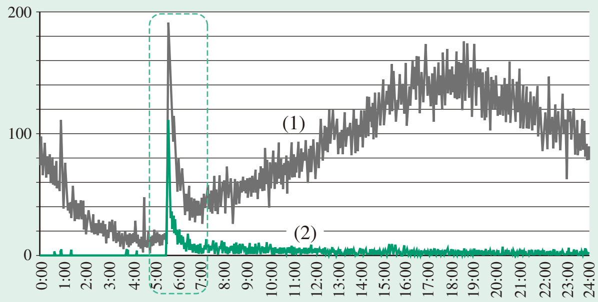
Fig. 8—Screen Displaying SNS Data on Wind or Water Damage.
The screen utilizes SNS data to show specific damage information such as abnormal river levels or surface flooding on roads.

Fig. 9 shows the trend in the number of tweets before and after an earthquake on April 13, 2013 at Awaji Island in Hyogo Prefecture that was measured with an intensity of six lower, and an earthquake on September 20, 2013 in Fukushima Prefecture that was measured with an intensity of five upper. In both cases, a rapid rise occurred in the number of earthquake-related tweets identified by the system after each earthquake, indicating that SNS data provides a valuable source of information to help assess the situation immediately after a disaster, which is the primary objective of this system.

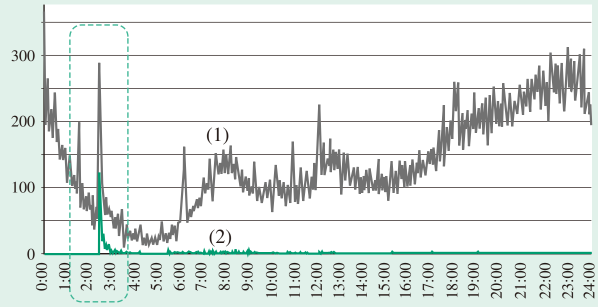
CONCLUSIONS

This article has described the disaster prevention and response support solutions being developed by Hitachi, and also a rapid situation assessment system that utilizes information from SNSs and other sources immediately after the disaster strikes to help quickly collect information and determine what is happening. This proposed system is intended as a way of overcoming the problem of ensuring realtime and ongoing decision making during a large, wide-area disaster in which circumstances are continually changing.

To help create a safe and secure society, Hitachi intends to continue its research and development aimed at combining the different types of information collected when a disaster strikes, and at identifying information that will be of use during the emergency response. By supplying systems that provide effective support for decision making and activities on the ground during a disaster, Hitachi believes it can help reduce the damage that these disasters cause.



Location	Time	Epicenter	Size	Maximum intensity
Awaji Island	2013/04/13 05:33	N:34.251 E:134.497	M6.3	Intensity 6 lower
(1) No. of GPS-tagged posts (in Japan)				120,071
(2) No. of earthquake-related GPS-tagged posts				3,088



Location	Time	Epicenter	Size	Maximum intensity
Fukushima	2013/09/20 02:25	N:37.100 E:140.700	M5.9	Intensity 5 upper
(1) No. of GPS-tagged posts (in Japan)				195,141
(2) No. of earthquake-related GPS-tagged posts				1,271

GPS: global positioning system

Fig. 9—Quantity of Earthquake-related SNS Posts when Earthquake Occurs.
The graphs plot the number of earthquake-related posts on the SNS detected by the system before and after an earthquake.

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