Efforts for Disaster Prevention/Mitigation to Protect Society from Major Natural Disasters

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Natural disasters on devastating scales are happening more often. As these are becoming a major issue in many countries, there is a growing need for effective countermeasures using information and communications technology (ICT). Fujitsu Laboratories develops technologies for disaster prevention and mitigation, drawing on expert knowledge of specialists in this field. Effective ways to reduce the impact of natural disasters include their early detection, and forecasting of the vulnerable areas and scale of potential damage. In this paper, we first describe an enhanced estimation technique involving social networking services (SNS), in order to quickly identify the locus of a disaster. Reliable information on disaster-stricken areas can be obtained by combining data from SNS with other sources. We then describe a method to optimize the parameters of a flood-forecasting simulator that helps to identify high-risk areas in large river basins. This makes it possible to automate parameter configurations, which had been difficult to do before.

1. Introduction

Today, as humans expand their activities to every corner of the world, they are exposed to the forces of the natural environment. Natural disasters are occurring on a larger scale and having an increasing impact on our lives, and this is considered to be partly due to global warming. There is a need for more sophisticated systems of disaster prevention and mitigation to protect human lives. To maximize the coverage of disaster response efforts, it is also necessary to enhance the efficiency and effectiveness with which resources are used for anti-disaster efforts. This has prompted the development of the software aspect (here, software refers to systems and technologies) of disaster prevention as well as the hardware aspect (constructing strong physical structures). One typical example is weather forecasting, which also requires disaster prevention/mitigation measures to be improved in the future.

Information and communications technology (ICT) alone cannot resolve natural disasters of global proportions. Therefore, we have been collaborating with expert institutions and research bodies specializing in disaster prevention and mitigation. With their expert knowledge and our technological expertise, we try to achieve practical measures with sure results.

This paper introduces some example of such efforts, describing the latest achievements of the technology for promptly identifying disaster-stricken areas, and showcasing flood forecasting simulation technology in the context of torrential rain.

2. Technology development directly impacting disaster mitigation

In order to avoid damage, it is important to prepare some kind of preventive measures against all possible natural disasters. In contrast, disaster mitigation is the idea of minimizing the damage caused by natural disasters. We have seen natural disasters of unforeseen magnitude in recent years, and we are thus faced with an urgent need for practical disaster mitigation measures as well as strengthening of preventive measures. We are conducting research on this disaster mitigation, in a search for ways to facilitate responses to disasters at early stages (**Figure 1**).

Disaster detection is an important early response. We are developing a technology that leverages the information on SNSs, where real people in actual situations provide information. This technology allows us

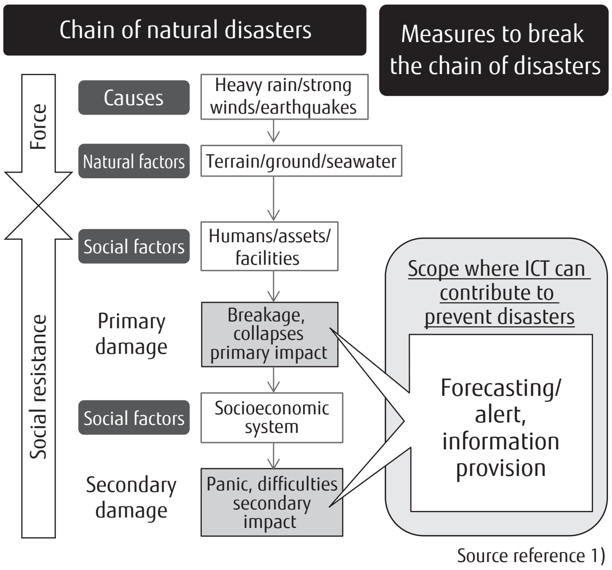

Figure 1
Disaster prevention/mitigation to sever the chain of natural disasters.

to promptly detect any irregularities occurring in inhabited areas, and send an initial response team at earlier opportunities.

Of all natural disasters, droughts and floods have caused damage across the world. To prevent flood damage there are water-level observation points installed along rivers, monitoring the rising water levels at times of heavy rain. However, there is a limit to the number of monitoring points. Thus, Fujitsu Laboratories has developed an enhanced simulation technology, which can optimize parameters for simulation models used to predict flood flow in river basins, thereby enhancing the efficiency of flood forecasting. With this technology, we have also succeeded in making fast, high-resolution forecasts of inundation areas ahead of the arrival of a tsunami following an earthquake.[2)]

3. Deployment of SNS for disaster mitigation

In order to counter the natural disasters of today, which are increasingly diverse and complex, it is crucial to identify disaster areas at an early stage. To achieve this, we have been conducting development to obtain accurate data on precipitation and transmit them immediately. Leveraging ICT, such development has enabled river management and disaster prevention agencies to respond quickly to flooding, while the general public are provided with crucial information that lets them make important decisions about what precautionary actions to take.

Meanwhile, a large and wide-ranging amount of big data is being accumulated and distributed outside the area of conventional disaster prevention measures, and such data may serve as a reserve of information that can be useful in disaster mitigation. In particular, the online communication services such as SNSs and highly functional mobile phones like smartphones, both growing rapidly in their utilization and prevalence, have meant that a large amount of data containing locational and photographic information is uploaded onto the internet by people who are witnessing disasters.

Previously, most information derived from residents was obtained through telephone calls. The pieces of information posted on SNSs, by contrast, contain various other data, thus making them potentially a viable option for preparing countermeasures. For example, when highly sophisticated analytical technologies are applied to analyze SNS-derived data, they are expected to produce a new source of information to predict the occurrence of natural disasters or quickly estimate the caused damage, which are things that have not been possible to do with conventional sensors or other methods.

Nevertheless, there are challenges to be overcome from the perspective of disaster prevention/mitigation if the SNS-based information is to be used to derive useful data.

1) Credibility of the information

Disaster-related postings on the internet include information that has less credibility in the sense that the content is secondary, as well as hoax and deliberately misleading posts.

2) Insufficient information

The postings that appear at the time of natural disasters do not necessarily contain all the information that disaster response teams would need, such as the location and time of occurrence as well as the nature of the disaster.

Fujitsu Laboratories worked on these challenges and developed a technology to generate information sourced from SNSs that can help to mitigate the impact of natural disasters.[3), 4)]

Among the major SNSs currently operating in

Japan (Facebook, Twitter, etc.), Twitter, one of the micro-blog services on the internet, caught our attention. The following are the relevant characteristics of Twitter:

1) Real-time

Compared to other SNSs, Twitter users are more likely to post about what they see or hear immediately on the spot.

2) Fast propagation

For the "retweet" feature, which allows users to re-post information posted by others, Twitter encourages proactive propagation of information.

3) Open nature of the data

Unlike other SNS media, data on Twitter is open to the public, and some of them can be downloaded for free.

Of the above characteristics, the real-time aspect has the highest priority in terms of using information for disaster mitigation. We took the above into consideration, and decided that Twitter was the most suitable source of information for the developed technology.

We then developed an algorithm to identify the time and location of disaster occurrences based on postings ("tweets") on Twitter. Specifically, the system recognizes a sudden increase in certain keywords relating to a specific disaster case, based on which the location of occurrence is estimated on the prefectural level. Then, the locations at the municipal level are identified by using tweets (**Figure 2**). This approach is explained as follows:

1) Tweets are filtered to remove the "noise" such as secondary information.
2) Locations are estimated based on where the tweets were sent from, and the data is aggregated by separating them into the prefectures they originated from.
3) Tweets are observed to detect a rapid increase in a single category, based on which a disaster occurrence is estimated on the prefectural level.
4) After the estimated time of disaster occurrence, tweets are collected in order to estimate the location at the municipal level.

We verified this method by applying it to two scenarios of natural disasters.

- Highly frequent disaster that occurred in a densely populated area: a flooding in Uji, Kyoto, on August 14, 2012.
- Infrequent disaster that occurs in mountainous areas: a landslide in Kumamoto Prefecture caused by torrential rain in north Kyushu on July 12, 2012.

Taking these two incidents as pilot cases, we applied the developed technology to the tweets posted at around the time of their occurrence so as to run a computational test. The Uji case showed that the inundation could be detected at 6 a.m. on August 14. It is considered that the first incident of a house being swept away due to the flooding was recognized at around 5 a.m.[5] Thus, we considered that this method could possibly determine the occurrence of natural

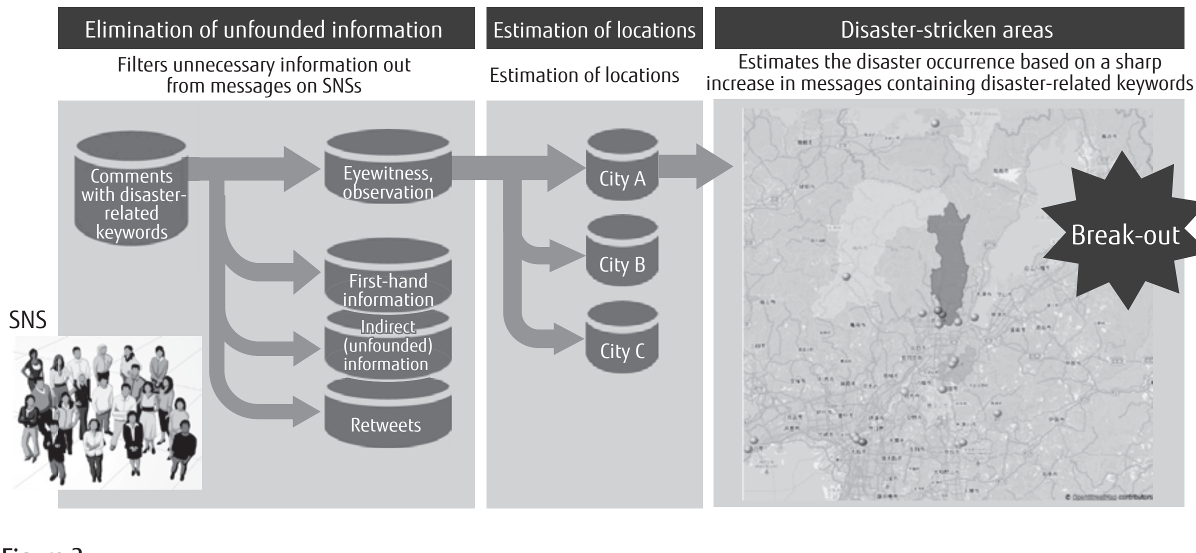

Figure 2
Estimation of disaster occurrence time and location based on posts on SNS.

disasters at an early stage.

The same trial was then run on the Kumamoto case. **Figure 3** depicts the results of analyzing the tweets posted around July 12, 2012. The landslide could be estimated at around 6 a.m. on July 12. Furthermore, in an attempt to locate the areas of disaster, we applied the technology to estimate the location of the 545 tweets sent after 6 a.m. on July 12, 2012. On that day, there were several landslide sites in Kumamoto Prefecture, counting 11 municipalities, and 8 of them could be identified through the tweet analysis.

These trials indicated that the method was useful in promptly identifying disaster occurrences through computation, and thus the method was valuable for making an early initial response and taking other disaster countermeasures. Future challenges include improving the estimation accuracy of disaster occurrence, and incorporating information different from conventional data in the disaster response frontline. We must consider how such new information can be made more acceptable.

4. Projects on simulation system for flood forecasting

Disaster prevention efforts have hitherto focused on preventing such disasters from occurring, and this requires large funds and long-term development of infrastructure. The recent trends, however, are towards disaster mitigation, for more practical measures to minimize the impact of natural disasters.

To this end, it is important to have not only infrastructure, but also plans for aid and support to be given in the evacuation and first-aid efforts. A useful method for providing baseline information for such plans, is to use simulation technology to predict the impact and associated events of natural disasters. As part of research in disaster prevention/mitigation based on ICT-rich simulation technology, Fujitsu Laboratories is working on the development of flood/tsunami simulation technology. We will describe the flood forecasting simulation in this paper.[6), 7)] For details of the tsunami simulation and real-time inundation analysis, see reference.[2)]

River management agencies predict the amounts of river discharge when there is a typhoon or heavy rain, dispatch personnel to affected sites, issue warnings to local residents, and make other efforts to reduce the impact of the events. Recent years have seen intensive torrential rains and other natural disasters increasing their scale and magnitude, necessitating better and more thorough countermeasures against water-related disasters.

Predicting the discharge amount in rivers, which is crucial in preparing such countermeasures, employs a flood forecasting simulator that calculates the amount of discharge based on the precipitation data. Such data in recent years are more likely to have a high spatiotemporal resolution, generated by instruments such as a radar rainfall gauges that are used in flood forecasting. Meanwhile, the runoff model (the computational model for flood simulation) may often employ a lumped-parameter system such as a storage function model in many cases. It is difficult to utilize detailed precipitation data effectively with this model, often resulting in precautious actions being taken over the entire basin of a river. By adopting a runoff model that represents the distribution of topographical characteristics and land use of the area along the river, radar precipitation data and other more detailed, mesh-based data can be leveraged better. This will allow for more precise flood forecasting simulations, enabling the relevant parties to take block-level precautious measures in a given basin.

However, the distributed runoff model involves many parameters, which are distributed spatially, and these parameters are inter-dependent. This makes it extremely difficult to correctly select and set up such parameters in order to predict future floods. This is

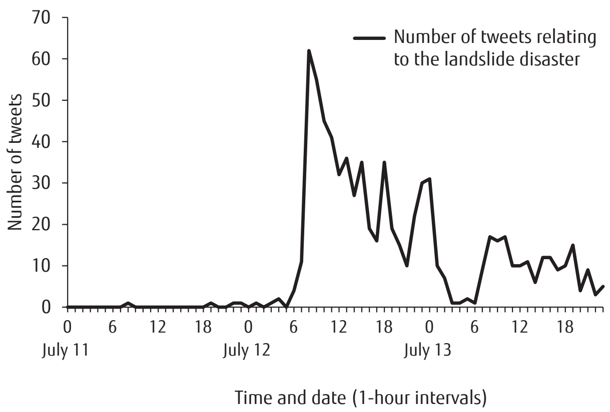

Figure 3
SNS posts in relation to the natural disaster case in Kumamoto (July 2012).

the major difficulty in introducing a distributed runoff model. In order to leverage the flood forecasting simulation based on a distributed runoff model in countermeasures against floods, first of all, the model parameters in relation to past events must be adjusted appropriately. This adjustment requires highly technical skills of experts and specialist knowledge in river engineering and hydrology.

Thus, we commenced joint research with the Public Works Research Institute in 2014, to promote the distributed runoff model. We emphatically pursued research on the mathematical optimization methods for the parameters of flood forecasting models, and thereby developed technology to automatically configure the parameters for the flood-forecasting simulator (**Figure 4**). The details are as follows:

1) Selection of optimal algorithms for the distributed runoff model, and verification against past flood data

In the process of adjusting the parameters, the precipitation data from past floods were input, and the simulation outcomes and the data on actual river discharge were compared. In this test, we executed an automated parameter adjustment using mathematical optimization, a computational method through which better solutions were obtained in fewer attempts of calculation according to a set of rules.

We tested 75 optimization algorithms and shortlisted 13 that were considered suitable for the distributed runoff model. We also developed a mathematical optimization platform to make this selection process automated.

We also processed 15 events of flooding in a certain river in Japan, and ran the flood forecasting simulation. The results verified that the simulation could reproduce the measurements of river discharge. Some examples are shown in **Figure 5**.

2) Analyzing the relationship between characteristic features of floods and parameters

We statistically analyzed the data of characteristic features in flooding such as the maximum discharge and average rainfall against the parameters that are highly repeatable in flood events, and clarified that there was a close relationship between the runoff rate (proportion of the river discharge to the precipitation) and these parameters. This knowledge is valuable since it suggests that parameters need configuring according to the types of floods for forecasting.

These newly developed technologies are supposed to make it possible to run flood-forecasting simulations with optimized parameters at all times, based on the distributed runoff model. River management agencies will be able to make appropriate decisions on measures

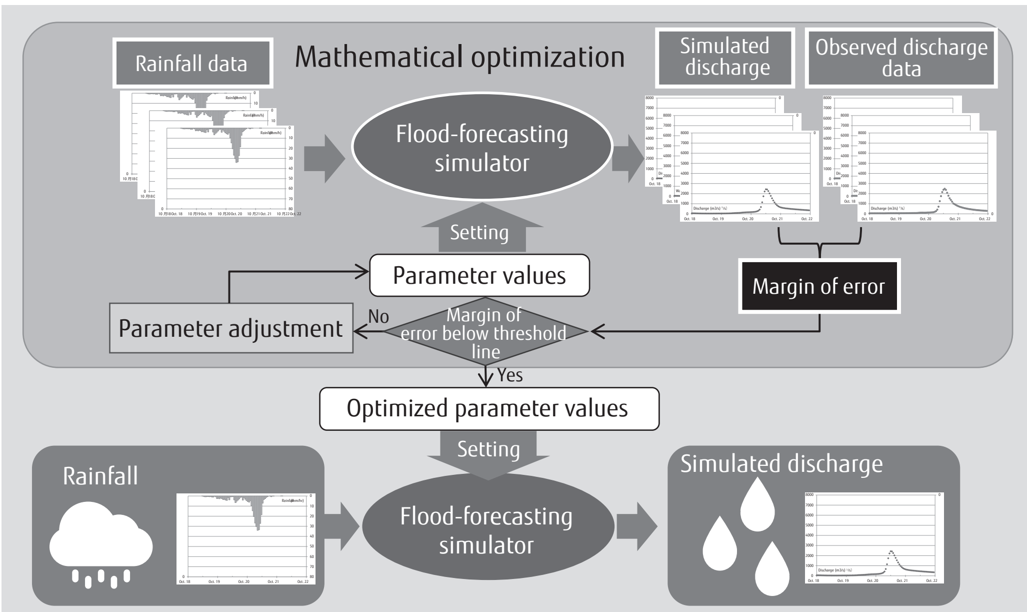

Figure 4
Mathematical optimization and discharge computation.

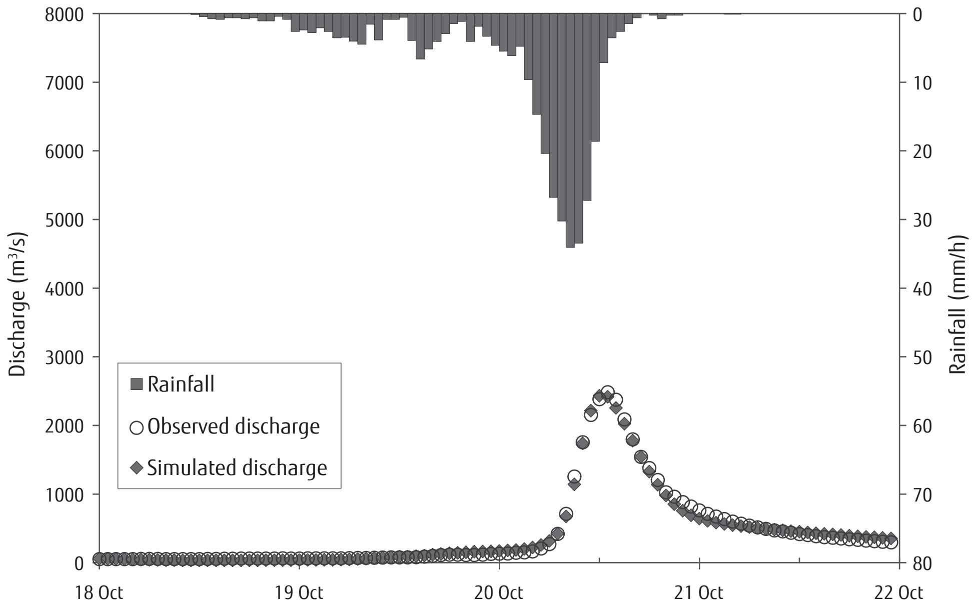

Figure 5
River discharge observation data and simulation results.

for disaster prevention/mitigation based on the river discharge calculated under optimal conditions. Our future tasks will include evaluating the technologies by applying them to various cases of floods and rivers, and practically applying them. We are also planning to develop a system of real-time flood forecasting by data assimilation which amalgamates the simulation results with observational data.

5. Conclusion

This paper described the progress being made on the cutting-edge technologies of Fujitsu Laboratories, aiming to enhance disaster prevention/mitigation systems. Given the increasing impact of natural disasters in recent years, disaster response is expected to become more sophisticated and enhanced.

It is thought ICT will serve more important functions in the future, in terms of the software aspect of disaster prevention/mitigation efforts. Fujitsu Laboratories will continue its diligent efforts to realize the necessary progress in this respect by pursuing research and development activities that are truly valuable to society.

This research has been conducted jointly with the Sediment Disaster Risk Management Division (the National Institute for Land and Infrastructure Management of the Ministry of Land, Infrastructure, Transport and Tourism), and International Centre for Water Hazard and Risk Management (Public Works Research Institute). The authors would like to take this opportunity to thank the members of these institutions for their collaboration.

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