Towards an Application of Remote Sensing Technology for Decision Making During Natural Disaster

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Abstract. A large number of remote sensing technologies for disaster management have been made, they still need a time to be accepted in disaster management framework of local governments. Before considering the application, it is necessary to discuss the practicality of remote sensing techniques in the existing disaster management frameworks. Towards the application of remote sensing technologies for decision making during natural disasters, this study addresses the following research questions; Which decision making of local governments can the remote sensing technology assist during natural disasters? And, what kind of remote sensing technologies can be applied? To solve these research questions, this study analyzed the regional disaster response plans of local governments in Japan, and discussed the practicality of the remote sensing technologies to the decision makings of disaster management operations.

Keywords: Remote sensing · Emergency response · Decision making

1 Introduction

In recent years, natural disasters have occurred frequently in Japan, such as the 2011 Tohoku earthquake and tsunami, the 2016 Kumamoto earthquake, the 2018 Japan floods. These disasters caused severe damages to extensive parts of Japan and breakdown of information network and road networks that resulted in the isolated situation of affected areas. This situation has led to difficulties of damage assessment of extensive affected areas, which resulted in the delay of decision making in disaster response. Therefore, there was a strong demand on establishing a scheme to figure out extensive damage within a short time without visiting affected areas. Remote sensing technology is promising for solving this problem. Remote sensing technology with satellite, airborne, and unmanned aerial vehicle (UAV) made it possible to observe affected areas without visiting within a short time.

The recent development of sensors and spread of machine learning applications have accelerated the development of remote sensing technique that can be applied for disaster management. Until now, various kinds of techniques have been developed in assessing damages on buildings, infrastructures, vegetation and in detecting hazards from tsunami, floods and landslides. In satellite/airborne remote sensing research fields,

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methods to apply synthetic aperture radar (SAR) have been studied for detecting areas inundated by tsunami and flood disaster, estimating the number of damaged buildings due to earthquake and tsunami, detecting landslide areas and identifying bridge damages (e.g. [1–3]). Regarding the UAV application researches, a number of human detection techniques have been developed (e.g. [4]). In onsite remote sensing, methods to classify building damage level with a handy photo of each building have been developed based on deep learning technique (e.g. [5, 6]).

Even though a large number of efforts have been made, they still need a time to be accepted in disaster management framework of local governments. Before considering the application, we need to identify "When", "Where" and "How" we can apply the remote sensing techniques in the existing disaster management frameworks. Towards the application of remote sensing technologies for decision making during natural disasters, this study addresses the following research questions; Which decision making of local governments can the remote sensing technology assist during natural disasters? And, what kind of remote sensing technologies can be applied? To solve these research questions, this study analyzed the disaster response activities of local governments in Japan and discussed the practicality of the remote sensing technologies to the decision makings of disaster management operations.

2 Method

We analyzed disaster response operations of Nomi City located in Ishikawa Prefecture, Japan. For the investigation, we sort out disaster response activities from the disaster prevention plan and extracted the decision makings that remote sensing technologies can assist soon after the disaster.

2.1 Topographic Conditions and Historical Disaster of Nomi City

Nomi City faces the Japan sea in the western part, has the Tedori river alluvial fan in the central part, and the eastern part has the verdant hills connected to the Hakusan mountainous areas. Nomi City is 84.14 km^2, consisting 42% of forest, 22% of agricultural lands and 14% of residential lands. The 1934 Tedori River flood disaster is most famous disaster in Nomi City. At this time, a large amount of snowmelt and heavy rain exceeding 400 mm caused collapse of sediment, which flowed down to downstream of rivers as debris. As a result, almost the entire basin from the upstream to the estuary was flooded. As for the damage at this time, 172 houses were washed away, 586 houses were flooded, 97 were died, and 15 were missing.

2.2 Analysis of Regional Disaster Prevention Plan

In Japan, based on the lessons learned from the Isewan typhoon, also known as the Typhoon Vera, in 1959, the basic act on disaster management was enacted in order not to repeat the same damage. In the Isewan typhoon, insufficient information transmission, inadequate awareness of danger zones, and inadequate disaster prevention systems were understood as issues. To overcome these issues, the basic act on disaster management clarified responsibilities of disaster management on local governments. Based on this, local governments have prepared regional disaster prevention plans for disaster prevention phase, emergency response phase, disaster recovery phase and reconstruction phase. Disaster response operations are clarified using a regional disaster prevention plans issued by the Nomi City. The regional disaster prevention plans currently used in the city was created in fiscal 2006 and has been revised several times since the 2011 Tohoku earthquake and tsunami. Nomi City's regional disaster prevention plan consists of 5 parts, "Part 1 General Disaster Countermeasures", "Part 2 Earthquake Disaster Countermeasures", "Part 3 Tsunami Disaster Countermeasures", "Part 4 Accident Disaster Countermeasures", and "Additional documents". Section 3 of each volume describes emergency response operations. Remote sensing is very effective in damage assessment of emergency response operations, therefore we analyzed mainly the work of the emergency response plan in Sect. 3. As an example, the sections of the emergency plan of "Part 1 General Disaster Countermeasures".

Among this plan of emergency response activities, representative tasks and decision makings that are related to wide area decision makings and remote sensing technologies can contribute, were selected and summarized as follow. All might not be covered, and further discussion is needed in terms of the relation with extensive decision makings; (1) Early warning, (2) Request supports from other stakeholder, such as SDF and other cities, (3) Identification of danger zone, (4) Explore isolated people, (5) Decide areas for emergent rescue, (6) Secure emergent road network, (7) Deploying snow removal team, (8) Identification of isolated areas, (9) Decide the quantities of supplies, (10) Individual building damage inspection, (11) Estimating debris, (12) First aid of infrastructures.

Next, I summarized representative hazards that can be observed by remote sensing technology, and typical surface objects that Nomi City will try to assess the damage soon after the disaster occurrence. (1) Hazards that can be observed by remote sensing technology; (a) Flood, (b) Tsunami, (c) Volcano, (d) Snow, (e) Fire, (f) Land slide, (2) Typical surface objects that Nomi City will assess the damage during disaster, (a) People, (b) Building, (c) Road, (d) Embankment, (e) Railway, (f) Park, (g) River, (h) Coast.

2.3 Discussing the Relationship with Remote Sensing Technologies

Finally, we discussed which remote sensing technologies can be applied for the damage assessment of typical surface objects and expected hazards in Nomi City.

3 Results and Discussions

Here, we examined which remote sensing technology can be used for which decision making, based on the hazards and damage situation that can be grasped by remote sensing, and the connection between them.

3.1 Early Warnings

Early warnings are often used in storm surges, tsunamis, and flood disasters, but these are issued by sensors such as seismometers and water gauges, and it is not possible to predict these hazards with remote sensing data. On the other hand, before the eruption of the volcano, there might be some changes in the ground, which may be observed by interferometry of synthetic aperture radar images taken from satellites and aircraft. It is expected that this observation result may be used for early warnings (e.g. [7–9]).

3.2 Request Supports from Other Stakeholder

When requesting support from other stakeholders, information such as locations and affected areas are needed. To identify this information, areas affected by hazards should be observed. Regarding the methods to detect hazards directly, studies to detect flooded areas and tsunami inundation areas, volcano, snow, fire, and landslide, have been accumulated using optical or SAR satellite data (e.g. [10, 11]).

3.3 Identification of Danger Zones

Areas once attacked by hazards should be treated as a danger zones. Methods to detect hazards directly might be able to apply (e.g. [10, 11]).

3.4 Explore Isolated People

Searching for those who are left in the disaster area is important matter after the disaster, especially when the information and communication networks does not work. It is difficult to extract humans with the spatial resolution of satellite images, but it is possible to capture humans sufficiently with UAV images. Some researches on human detection by UAV have been made assuming emergent response, and these are considered to be effective (e.g. [4]).

3.5 Decide Areas for Search and Rescue

In order to send limited resources to limited disaster-stricken areas, it is necessary to identify areas where human damage is particularly large. Human damage cannot be seen from satellite image, but building damage can be identified. The amount of building damage is related to human damage. Remote sensing data taken by satellites and airplanes is effective for damage assessment of buildings (e.g. [2, 3]).

3.6 Secure Emergent Road Networks

Securing an emergency transportation route during disaster is important for effective emergency response, recovery and reconstruction. Various technologies have been proposed for assessing road damage, such as those using artificial satellites and those using in-vehicle cameras (e.g. [12, 13]).

3.7 Deploying Snow Removal Team

Nomi City has mountainous areas, and should pay attention to the isolation of village areas by snow. In order to prevent the isolation of villages due to snow, it is necessary to dispatch a snow removal corps to an appropriate place. Researches on snow extraction have been carried out, and it is expected that these might be useful for dispatching a snow removal team to appropriate place (e.g. [14, 15]).

3.8 Identification of Isolated Areas

In order to find an isolated village due to the disaster, it is necessary to identify the areas affected by hazard and the location of road interception. By overlaying the existing road map with the distribution of hazards ascertained from satellite images, or detecting road damage, it might be possible to find such kind of isolated areas (e.g. [2, 3, 12, 13]).

3.9 Decide the Quantities of Supplies

Information on how many victims have occurred in the stricken area is important in determining the quantity of supplies. Although the amount of human damage is not known from satellite images, the amount of building damage estimated from satellite images is considered to be useful for predicting human damage (e.g. [2, 3]).

3.10 Individual Building Damage Inspection

After a building is damaged due to a disaster, the damage inspection of the building is carried out officially by local government. This inspection is done on a site by site, but it takes a long time as the number of damaged buildings are too many. A method for classifying image data captured by a handy camera by deep learning has been developed, and it is considered that this result may be very useful in the future for individual building damage inspection (e.g. [5, 6]).

3.11 Estimating Debris

One of the major issues during disaster is waste disposal after a disaster. Estimating the amount of debris caused by disaster is important in planning waste management. Land cover classification using satellite images or 3D data restoration using UAV might be effective for this purpose (e.g. [16]).

3.12 First Aid of Infrastructures

In order to carry out recovery and reconstruction effectively, it is necessary to comprehend the impacts caused by the disaster. Damages on infrastructures owned by the local governments are also important matter. Remote sensing technology using satellites is effective for understanding the damages on infrastructures (e.g. [1, 12, 13]).

3.13 Summary of Discussions

The above examples are part of emergency response works, and off course, it should not cover all activities that remote sensing technology can contribute. However, discussions on how to apply remote sensing technology for decision makings of local governments are needed for promoting practical usage. In particular, in order to adopt a new technology that is not used in the existing framework for disaster countermeasures, it is necessary to design a new framework including new technologies and verify its effectiveness quantitatively. This study is just the brief consideration of application of remote sensing technology on actual disaster management of local government, however, it was found that many works of emergency response have a possibility to be improved with new remote sensing technologies.

4 Conclusion

This study analyzed the disaster response activities of local governments in Japan, and discussed the practicality of the remote sensing technologies to the decision makings of disaster management operations. As the result, it was found there is a large potential in remote sensing technology on the improvements of disaster management of local governments on (1) Early warning, (2) Request supports from other stakeholder, (3) Identification of danger zone, (4) Explore isolated people, (5) Decide areas for emergent rescue, (6) Secure emergent road network, (7) Deploying snow removal team, (8) Identification of isolated areas, (9) Decide the quantities of supplies, (10) Individual building damage inspection, (11) Estimating debris, (12) First aid of infrastructures.

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