APPLICATION OF GEO-INFORMATION DATA AND REMOTE SENSING IMAGERY FOR DISASTER SURVEILLANCE IN TAIWAN

Tzu-Yin CHANG*, Chia-Cheng YEH**, Wen-Ray SU***

*Sensor Assistant Research Fellow, National Science and Technology Center for Disaster Reduction,

9F., No 200, Sec. 3.Beixin Road., Xindian District, New Taipei City 231, Taiwan;
Tel: +886(0)-2-8195-8668; Fax. +886 (0)-2-8195-7766
E-mail: geoct@ncdr.nat.gov.tw

**Assistant Research Fellow, National Science and Technology Center for Disaster Reduction,

9F., No 200, Sec. 3.Beixin Road., Xindian District, New Taipei City 231, Taiwan;
Tel: +886(0)-2-8195-8665; Fax. +886 (0)-2-8195-7766
E-mail: andrew@ncdr.nat.gov.tw

***Associate Research Fellow, National Science and Technology Center for Disaster Reduction,

9F., No 200, Sec. 3.Beixin Road., Xindian District, New Taipei City 231, Taiwan;
Tel: +886(0)-2-8195-8672; Fax. +886 (0)-2-8195-7766
E-mail: wrsu@ncdr.nat.gov.tw

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Abstract: Taiwan is a narrow island and over 70% area covers by mountains. Due to the location, average 3.6 typhoons hit Taiwan per year. Natural disasters including flood, landslides, debris flow triggered by typhoons often caused huge losses of properties and casualty in the past five decades. Disaster surveillance is important intelligence for disaster management and response. Meanwhile mountainous roads and bridges damage limit authorities to gather disaster information, remote sensing technology become a powerful tool for disaster surveillance. However, cloud still a big issue by using optical satellite remote sensing especially in floods. Therefore, unmanned aerial vehicles (UAV) and synthetic aperture radar (SAR) imagery are respective able to take disaster images under cloud cover and uninfluenced of weather condition would be regarded as the other solution of gathering disaster information. In order to speed up the data processing in emergency, the results of historical disaster analyses such as terrain analysis, potential damage analysis, and spatial autocorrelation are useful auxiliaries with remote sensing imagery. Besides historical data, electronic maps and monitoring data such as land cover map and spatial accumulated precipitation are also helpful in the processing. The more geo-information we have, the faster disaster analysis our model can afford. In addition, the method of combining geo-information and remote sensing images can also have large scale vision to evaluate disaster scale which is significant information for central government to estimate the impact on social economy.

INTRODUCTION

Over two thirds of the land surface of Taiwan is hills and mountains. The average annual rainfall in the mountainous areas can reach between 3,000 and 5,000mm. As the slopes around the catchment areas in the mountains are often extremely steep, plus the weakened geological structure after the 921 Earthquake and overly developed hillsides, the torrential rain brought by one single typhoon could easily trigger compound disasters such as floods, mudslides and formation of barrier lakes and lead to landslides, broken bridges, damaged dams and levees, traffic disruption, agricultural damages and serious human life and property losses. Statistics for the past four decades show that the average damages from typhoons each year stood at NTD17.4 billion, approximately 0.33% of the GNP of Taiwan.

In August 2009, Typhoon Morakot brought over 2,000mm of rainfall to Taiwan. The 24-hour and 48-hour rainfall achieved respectively 89% and 96% of the world-record rainfall in the same durations. As a result, the worst typhoon catastrophes in the past five decades happened in central and southern Taiwan. Among the affected areas, Siao-lin Village in Kaohsiung County was buried under an enormous amount of mud and debris. Many villagers were either dead or missing. What followed immediately after Typhoon Morakot was rescue work and investigation. Disrupted traffic and collapsed roads and bridges made it impossible to assess the scales of disaster; meanwhile landslides have caused the formation of several barrier lakes. Disaster surveillance becomes even more urgent for the protection of the lives and properties of downstream residents. To achieve this, the Emergency Remotely Sensed Group has to be organized and used to collect the near real time disaster intelligence (Chang et al., 2011). Moreover, massive flash floods, barrier lakes and large scale landslides triggered by heavy rain are usually needed to respond and face for Taiwan's government every year. Establishing a standard operating procedure (SOP) of disaster surveillance can give all levels of government ample time to manage and evacuate.

OPERATION FRAMEWORK

It is helpful to marshal the data demand analysis following different stages of disaster management. Figure 1 outlines the four phases of disaster management: preparedness, response, recovery, and mitigation (Waugh, 2000). Preparedness phase is a state of readiness and plans out activities prior to disaster. Geo-information, including territory map, digital elevation model (DEM), land use, geological map and disaster historical records, and multi-temporal remote sensing imagery with hydrological model and slope stability analysis are used to circle the vulnerable regions of inundation and slope failure.

Figure 1： Four phases of disaster management

Figure 2 shows the flood hazard map, where the high flood vulnerable area of Taipei City indicated by red color, is simulated the precipitation magnitude of 600mm accumulation per 24 hours. Social welfare institutions and public transportation information near vulnerable area need to keep a close watch on if the water status value of nearby water level station or measuring precipitation of nearby rain gauge station approaches the warning value.

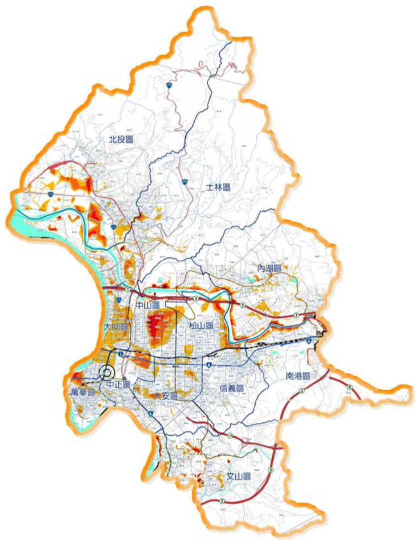
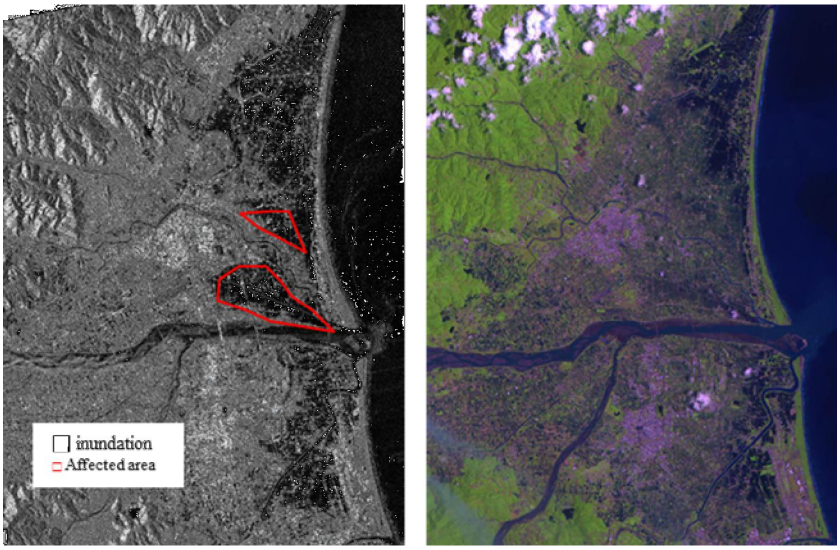


Figure 2： Flood hazard map of Taipei City

Disaster sometimes comes with plenty of warning like typhoon events, and other times disaster will come in an instant like earthquakes, with no warning at all. As response phase, immediate reaction of research and rescue are the important activities during a disaster. We have more experience on responding typhoon events because there are at least 3 days for preparedness. When typhoon warning is issued by Central Weather Bureau, forecast track of typhoon, regional hazard maps, and historical hazard records are used to assess the flood-prone and landslide-prone area of each typhoon event. Emergency planning for satellite synthetic aperture radar (SAR), operating independent of cloud and solar illumination, is scheduled to take an image for disaster magnitude assessment. Figure 3 shows an example of the inundation detection in Yi-lan County following heavy rains caused by Typhoon SAOLA acquired from TerraSAR-X. This SAR imagery, the first post-disaster image, provides the near real time intelligence of affected area for decision maker. Then after the weather conditions turned better, optical satellite images from SPOT4 or FORMOSAT-2 or aerial photos from airborne or unmanned aerial vehicles (UAV) can be acquired in cloudless day. These post-disaster high resolution images are used to carry out details interpretation of collapsed buildings, roads, bridges, and slopes.



(a) (b)

Figure 3: (a) TerraSAR-X scene acquired on the 2012-08-03 (b) SPOT4 scene acquired on the 2012-08-05 over Yi-lan County (provided by NSPO and CSRSR)

Lots of activities following a disaster, including repair, restoration and disaster loss assessment, are focused on at the recovery stage. Estimate of the disaster loss is helpful to consider whether proposed investments in mitigation actions will provide value for money. Disaster losses can generally refer to losses as direct or indirect (EMA, 2002). Direct losses result from the physical impact of the hazard. They are generally the most visible, and often represent the largest loss component. Damage to buildings, vehicles and infrastructure from floods and wind would be regarded as direct losses. On the other hand, indirect losses arise as a consequence of the impact of the hazard. They reflect disruption to economic which flow from the effects of flooding, quake and so on. For example: disruption of transport when roads are cut by floods and landslides, or agriculture reduction if not due to direct damage. Remote sensing imagery can afford useful information especially roads and bridges damaged by landslides for disaster loss assessment.

FORMOSAT-2, optical satellite of Taiwan’s space agency, mainly applies to provide post-disaster high resolution images of Taiwan. FORMOSAT-2 imagery going through radiometric correction, geometric correction, and orthorectification can be overlaid with existing dynamic map and GIS data for spatial analysis. In addition, the ortho-image through automated segmentation can reveal several quantitative properties of each segment, such as means, standard deviations, lengths, areas, length to width ratios, the relationship with ambient objects, and textures, for further analysis and change interpretation. Change detection is one of the most applied techniques in circling affected area such as inundation, slope failure and landslides (Figure 4). In addition, it is possible to figure out the amounts of landslides and debris accumulation with DEM information. These analytical data can serve as reference for mentioned disaster losses assessment.

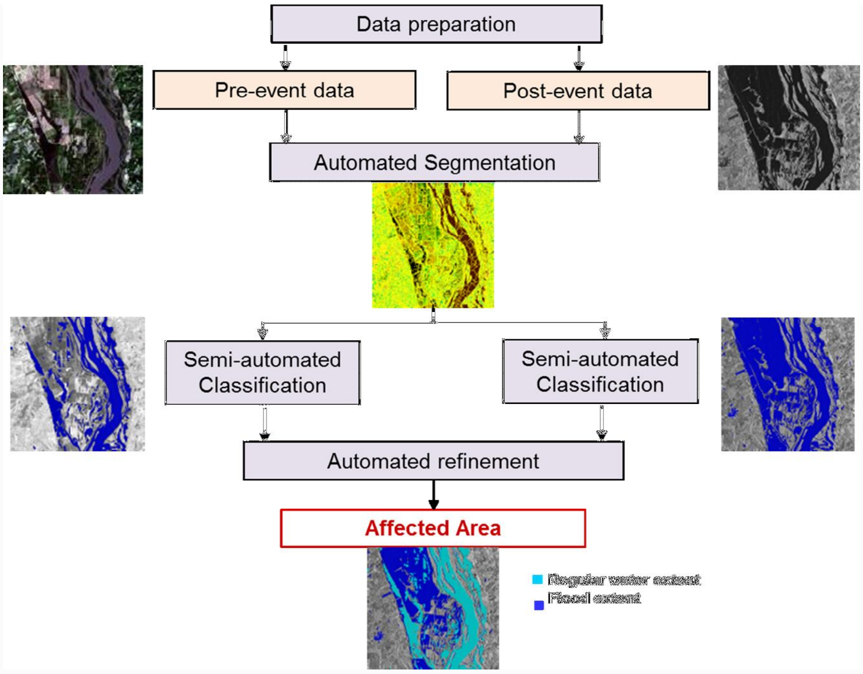


Figure 4: Change detection flowchart

Mitigation phase is an ongoing process with continual reassessments as necessary to ensure proper preparedness. Some experts argue that there is such thing as post-disaster mitigation, and that pre-disaster mitigation ought to be called prevention. All geo-information data and post-event remote sensing imagery will be stored into the spatial database or image database for follow-up relief and planning investigation (Su et al., 2011).

CONCLUSIONS & DISCUSSIONS

Disaster surveillance is a race against time. Data collection is one of the key works for disaster surveillance. Some of the affected areas are devastated so severely that it is dangerous for assembling overall intelligence of affected areas though direct surveying. Remote sensing can help to collect large images without entering into these areas. However, image acquisition, file transfer and image processing are still time-consuming. Therefore, to organize an emergency remote sensing group which invite related institutes join in can effectively accelerate image processing work and allow each institute to interpret based on its own specialties.

Different disaster management phases need different geo-information. For the disaster prevention, there geo-information and remote sensing imagery can be used to detect land overuse and illegal development on hill slopes. It is also helpful to regular environment surveillance in disaster mitigation.

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