Detection of Land-Use Change by the Combination of Remote Sensing and Geographic Information Systems

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Abstract

How to achieve rapid and efficient post-disaster survey is a major concern of providing informative suggestions and comprehensive viewpoints, which will be the essential elements of emergency relief and post-disaster recovery. Traditionally, the on-site investigation is the convincing methodology to collect the necessary and required data for decision makers. But for most of practical cases, the interrupted traffic and distorted terrain after major disasters usually doubled even tripled the time, resources and human power before completing reports. Even though, it could take several weeks to reach some remote areas, where some are the most hard-hit areas. In Taiwan, over 70% of island is hillside or slope land. An efficient, effective and reliable methodology in assistance to providing post-disaster survey is a highly-demanded mission to be developed. For accomplishing the designed goals, the National Science & Technology Center for Disaster Reduction (NCDR)in Taiwan has been continuing its devotion to improving the techniques of combining remote sensing products like FORMOSAT-II satellite images with Geographic Information Systems for enhancing higher resolution to identify the affected areas. In the paper, an introduction of operation procedures and analysis benchmarks is firstly described, then some practical case studies are illustrated to test the performance of the proposed procedure and analysis works.

Keyword: Remote Sensing, Geographic Information Systems, Object-Oriented Technology, Hazard Analysis, Hazard Investigation,

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1. Foreword

Since remote sensing (RS) technology was developed, land use change surveillance and disaster investigation have been a major application of satellite images. The near real-time image acquisition and extensive coverage make satellite images a convenient instrument for land use change detection and disaster investigation, and the digital, periodic and multi-spectral features make it easier for computers to interpret and analyze such these images automatically. Plus the advancement in image-processing techniques for aerial and remote sensing photography, computers are capable of automatic identification of extensive, multi-period landslides or land change. How to apply remote sensing, image processing and geographic information systems (GIS) to conduct rapid and effective surveillance and control of land use change and disaster investigation has become an important link in disaster prevention and relief works. Using the images of the northern Sichuan region between May 14 and June 12 of 2008 and the Taiwan region taken in 2006 and 2008 with Formosat II, this study intends to make initial evaluations of how to apply satellite image fusion technology and classified object-oriented image processing on potential disaster locations and land use change areas within the photographic range.

2. Related Remote Sensing Imagery Techniques

A. Summary

Damage assessment after a hazard can provide important information for determining subsequent responses and relief works. Early acquisition of such information will allow the commander of the relief operations to formulate corresponding relief tactics and actions sooner, while in normal times, by performing continuous surveillance on land use change, we will be able to detect abnormal changes possible of leading to disasters and make modifications to prevent disasters with certain effectiveness. Conventional surveys usually apply on site investigations. They may have the advantage of providing more accurate information, but restrictions of transportation or danger of landslides can sometimes make it difficult for surveyors to reach the location. In addition, topographical obstacles could also result in insufficiency of onsite investigation data. In comparison, the aerial view technique and the characteristic of rapid sampling without direct contact allow remote sensing to cover a vast area and provide information on locations that are impossible to reach for surveyors. Taiwan’s Formosa satellite-II is equipped with the capacity of regular remote sensing satellites to survey the surface of the Earth, and its unique function of visiting the same area each day makes it an ideal instrument for surveillance of disaster-prone areas.

B. Formosat II

Formosat II, Taiwan's first own satellite for remote sensing and other scientific purposes, was launched on May 21 2004. A sun-synchronous satellite traveling in a fixed orbit at 891KM above ground, it circles the Earth 14 times each day. When passing over the Taiwan Strait the first time at 10 a.m., it can tilt to the maximum of 45 ° to the left and the right to take pictures for eight minutes and download image data simultaneously. Coming around again at 10 p.m., it doesn't take pictures but can download images taken over other locations. An image taken by Formosa Satellite-II has the swath width of 24 km, at the resolution of PAN (black/white) 2 meters and MS (color) 8 meters. The technical specifications of Formosat II is listed in Table 1.

Table 1. Formosat II Specifications (source: National Space Organization website)

Orbit	Passing over the Taiwan Strait twice daily in a sun-synchronous orbit at 891KM above ground	
Spectral Resolution	Panchromatic (Pan)	0.52～0.82μm
	Multi-spectral (MS)	Blue: 0.45～0.52μm Green: 0.52～0.60μm Green: 0.63～0.69μm Near infrared: 0.76～0.90μm
Spatial Resolution (perigee)	Pan (black and white): 2 meters MS (color): 8 meters	
Swath Width	24 kilometers	
Mission Lifespan	Five years	
Launch Date	May 21 2004	

3. Image Fusion

Images taken with Formosat II have the resolution of Pan (black and white) 2 meters and MS (color) 8 meters. Since there is only a single waveband in Pan (black and white) 2m images, topographical color variations that the relief operation commander needs for reference for decision-making are not available. At the same time, classification using spectral data as the foundation for analysis is also unlikely. Therefore, we first fuse an 8m MS image with a 2m Pan image for further analysis and examination. The image fusion, however, is purely inter-complementation of two images of different spectral and spatial resolutions; it does not generate new data or information. The following are outlined descriptions of the panchromatic image and the multi-spectral image from Formosat II and the fused image:

(1) Panchromatic image: Commonly called the gray-value image, at the wavelength of 0.45～0.90μm and the ground resolution of 2 meters (see figure 1a), in application, features such

the shape, edges, color contrast and texture can be used to identify objects on the surface of the Earth.

(2) Multi-spectral image: Commonly called color image, at the wavelength of 0.45~0.52μm (blue), 0.52~0.60μm (green), 0.63~0.69μm (red) and 0.76~0.90μm (near infrared), and the ground resolution of 8 meters (see Figure 1b), in application each object's unique reflection properties when exposed to different wavelengths can be used to identify the possible features of objects on the surface of the Earth to increase the accuracy and efficiency of readings.

(3) Fused image: By combining an orthographic, low-resolution multi-spectral satellite image with a high-resolution panchromatic satellite image, we can create a multi-spectral image with a high spatial resolution. There are many fusion approaches, such as fusion through color space conversion, HIS conversion, fusion through principal component analysis (PCA), or fusion through wavelet transform, etc. No further elaboration on those other fusion approaches will be made since this study adopts the Pansharp image fusion function in PCI software to fuse images. The result is shown in Figure 2(b). Compared to the image in Figure 2(a), it is apparently superior to the 8m multi-spectral image whether in visual quality or actual analysis.

(a) Panchromatic image (b) Multiple spectral image

Figure 1. Comparison between a panchromatic image and a multiple spectral image

(a) Color image (b) Fused image

Figure 2. Comparison between a color image and a fused image

4. Image Classification

When humans interpret satellite images with their eyes, a series of complex nervous activities are executed. We normally call this “image comprehension.” When these activities are converted into computer programs, we will be able to use the calculating capacity of the computer to perform automatic interpretation. In conventional pixel-based classification, we can only rely on the spectral variation of a single pixel in an image to classify by the statistic approach. Unfortunately, due to noises and other elements, pixel-based classification often results in classification fragmentation. Some scholars have therefore proposed the object-oriented concept: to gather up objects of the same category first to prevent fragmented classification when sorting out the images. Object-oriented classification provides a variety of guidelines for object detection, such as object color statistics, form/shape, area/size, texture, context, etc. Together they are called object features. Before performing classification in accordance with spectral data, use of these guidelines to establish object features (see Figure 3) can prevent object fragmentation. This study uses the object-oriented classification in the Definiens software to classify images from Formosa II. Possible areas of land use change are marked out after classification for later use (see Figure 5.)

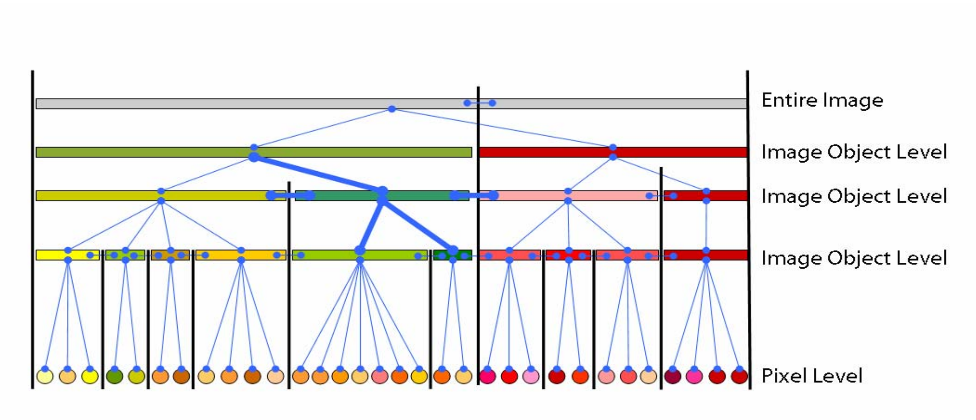

Figure 3. Building a level network between objects through depiction of the features of different objects

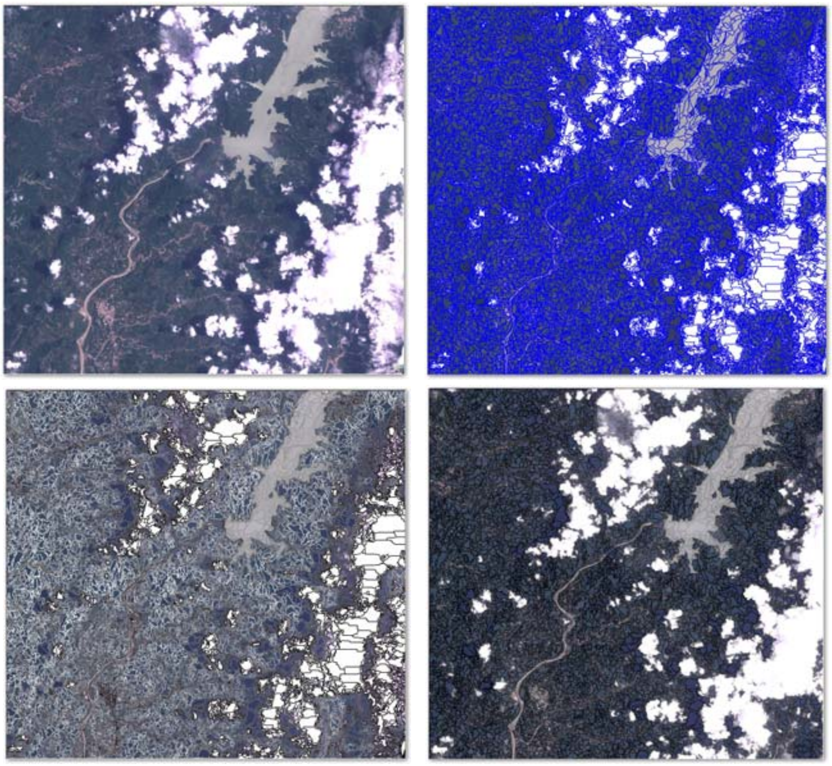

Figure 4. Object classification according to image features

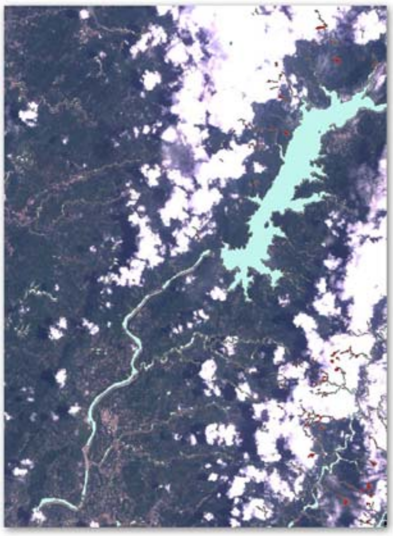

Figure 5. Conversion of the classification result into vector data and overlapping it on the original image

5. Disaster Interpretation

The most urgent concern of a commander of disaster relief operations is normally understanding the scale of damage after a disaster. Remote sensing images can provide such understaning within the shortest time and the relief operations commander can establish a series of responsive measures accordingly. Figure 6 exhibits the operating procedure for damage scale assessment this center currently applies with images from Formasa II. Having established a cooperative relationship with the National Space Organization, we are able to acquire image data from Formosat-II within the shortest time and the information section of NCDR will apply the abovementioned techniques to fuse satellite images and interpret the results. The interpretation process will be participated by our disaster specialists and the results will be handed over to the relief operations commander ot other units to be reference for decision-making.

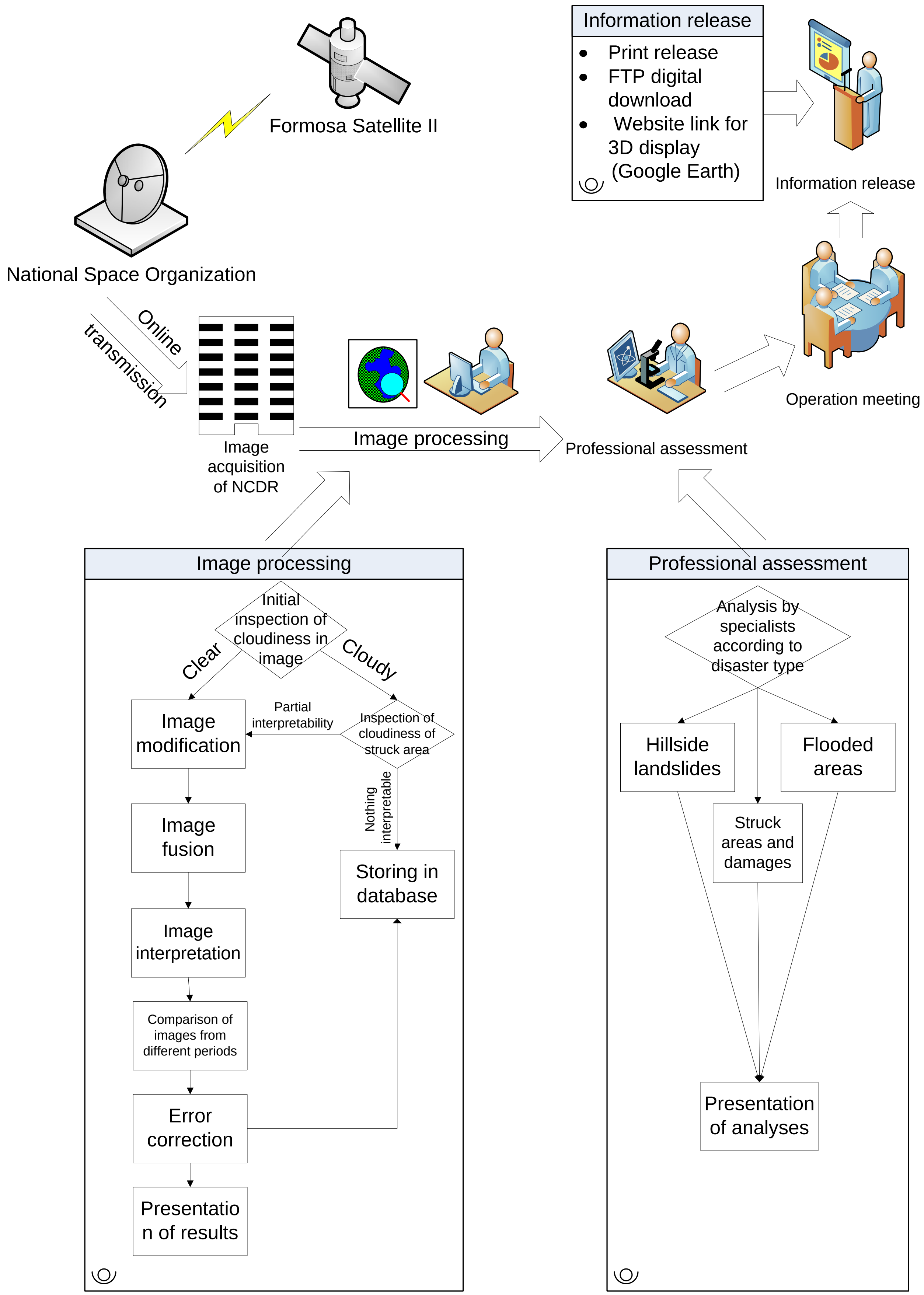

Figure 6. Procedures of interpretation of disaster magnitude using satellite images

6. Surveillance of Land Use Change

We have developed a land use change surveillance system to be used by concerned personnel. In this system, images of the same area from different time periods are available. The user can select any area and enlarge a local section for visual interpretation. Images from Formosat- II taken in 2006 and 2008 have already been imported into the demonstration system this study provides. The user can randomly choose to display images from two different dates on the screen and enlarge, reduce and move the images with the corresponding functions in the GIS tool bar to facilitate visual identification of changed areas. An automatic interpretation system on the server end of this system will regularly interpret surface change at different times and export the GIS layers for users to choose for overlapping. Figure 7 shows the main operating screen of this system.

This system allows overlapping of various GIS layers, such as land use data, road map, building map, and cadastral map, etc., to provide surveillance and law enforcement personnel with reference for further operations. Figure 8 shows results of layer overlapping.

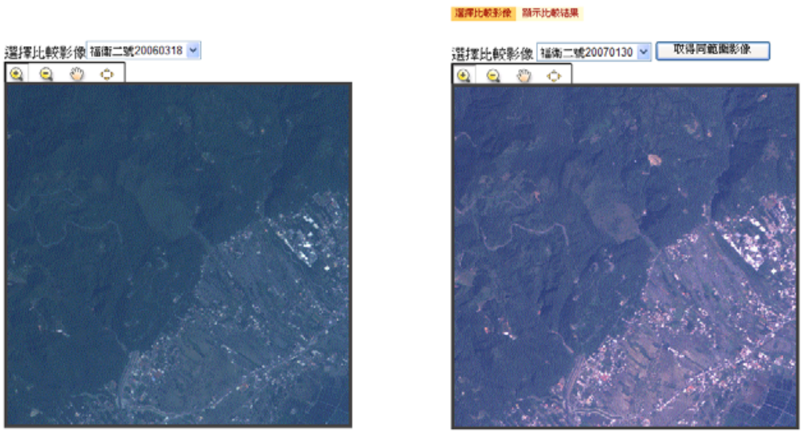

Figure 7. Main screen of the demonstration system for land use change surveillance

Figure 8. GIS layer overlapping in the demonstration system for land use change surveillance

7. Conclusion

Actual applications in disaster investigation after the Wenchuan Earthquake in Sichuan and several typhoons in Taiwan proved that use of remote sensing satellite images to assess and interpret the struck area and planning of disaster survey routes was very helpful. Applying the demonstrative system this study has developed for surveillance of land use change will allow us to detect the possible range of land use change. It will be useful in ensuing onsite surveys and natural disaster early warning.