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RESEARCH STUDY ON APPROPRIATE INTERPRETATION TECHNIQUES OF SATELLITE IMAGES FOR NATURAL DISASTER MANAGEMENT

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Abstract: One of the main objectives of image processing is to optimize visualization of particular thematic dataset. The processing methodology and strategy are very different from broadband images in many aspects. For natural disasters such as earthquakes and tsunamis, the data obtained from satellite images can be used for disaster management in order to manage rescue plan during disaster and planning for preparedness for future disasters. This paper reviews the methods of satellite image processing and also the disaster management requirements. Based on these two issues the advantages and limitations of image processing methods have been discussed considering important issues in natural disasters management.

Keywords: Satellite Image, Natural Disaster, Management, Interpretation Techniques

1. INTRODUCTION

Image processing is almost always the first step of any remote sensing application project but it is often given greater significance than it deserves. Visual interpretation is therefore essential. Thematic maps are the most important products of remotely sensed imagery, and they are derived by either visual interpretation or image segmentation (computerized classification). Thus far, broadband multi-spectral and Synthetic Aperture Radar (SAR) images are the most commonly used datasets. The image processing strategy proposed in this section is most relevant to these types of data, and its goal is the effective discrimination of different spectral and spatial targets. We use the word "discrimination" advisedly in this context; in general, it is only possible to differentiate between rocks, soils and mineral groups using broadband data, rather than identify them.

In contrast, the processing of hyper spectral image data is to achieve spectral target identification, to species level in the case of rock-forming minerals, and thus has a different strategy. Many people make the mistake either of thinking that hyper-resolution is the answer to all problems, or of being put off investing in such technology at all because they do not understand its role or are suspicious of its acclaimed capability. A hyper spectral dataset is acquired using an imaging spectrometer or hyperspectral sensor, which is a remote sensing instrument that combines the spatial presentation of an imaging sensor with the analytical capabilities of a spectrometer. Such a sensor system may have up to several hundred narrow bands, with a spectral resolution of the order of 10 nm or narrower. Imaging spectrometers produce a near- complete spectrum for every pixel of the image, thus allowing the specific identification of material rather than merely the discrimination between them.

A hyper spectral dataset truly provides a data volume or cube. Here it is more important to analyze the spectral signature of each pixel than to perform general image enhancement. Considering that hyperspectral remote sensing is a broad and important topic on its own, covering data processing and application development, in this paper we have decided to discuss it only briefly and to focus instead on broad band multi-spectral remote sensing.

When we are involved in a project, we should think along the following lines and, broadly speaking, in the following order:
1-What kind of thematic information do we need to extract from remotely sensed images?
2-At what scale do we need to work? In other words, what is the geographic extent and what level of spatial or spectral detail is required within that area?
3-What types of image data are required and available?
4-What is our approach and methodology for image/GIS processing and analysis?
5-How do we present our results (interpretation and map composition)?
6-Who will need to use and understand the results (technical, managerial or layperson)? [1)]

2. SATELLITE IMAGE INTERPRETATION TECHNIQUES

We should begin by considering the location of the area being mapped. The most obvious consideration in this case is its regional geological setting and its climate. The former will help us to anticipate the tectonics and lithological characteristics. The latter will point to the nature of the terrain surface, whether it is vegetated, weathered to any great depth, subject to persistent cloud and so on. In some case, the area is classified into semi-desert. As a consequence, what is recorded in remotely sensed imagery represents an almost complete record of surface geological exposure across the region, which makes geological interpretation relatively straightforward.
The arid climate makes vegetation a very useful indicator of the presence of ground water and surface water, and the appearance of localized patches of healthy vegetation usually reveals small rural settlements supported by springs, which are themselves controlled by lithology and structure. Even large-scale agriculture may reveal similar geological control of regional water supplies since this is always more cost effective than piping in water from elsewhere. The aspect of mountain areas will also affect the distribution of areas (north-facing slopes) that can support natural vegetation and woodland; their presence will need to be considered in interpreting the spectral properties of ground targets.

Interpretation of different themes in multiple layers:

(1) Structure of the map project file – the data will likely be organized slightly differently from case to case, because of difference in the specific GIS software used. Essentially, though, it is sensible to keep solid and drift geological feature in separate layers. At this simple level of data capture, it is desirable to capture lithological areas as polygons. This makes for a rather more rapidly constructed map than the more correct method of capturing arcs and later building topology to construct polygons. This choice of strategy rather depends on the time available to complete the task and the software tools available to us. Doing this "quick", non- topologically correct way means that they have certain limitation on the complexity of information that is captured and conveyed: silver and gaps, and island polygons are to be avoided. This method is perfectly acceptable if the final product is required only as a single map product for reference and if no further spatial analysis will be required of the geological polygons.

(2) Other features such as quarries are also easily stored as simple polygons. Faults on the other hand, by the inherent nature, are stored as linear features in a poly line file. Other cultural data can also be captured/imported and stored but should be stored separately from the interpreted features, but could be grouped together for convenience. Such features could include towns (points), roads (poly line) and drainage (poly line). In addition to the images which are the source data for the interpreted features, there are other raster images in the database, namely the Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) and the regional geological map. Again these raster data layers are, by their nature, stored differently and separately from the vector features, but could usefully be grouped together as reference layers or in two groups, for example satellite images and regional data.

(3) Use of an interpretation guidance table – This forms an important step in understanding the way in which the displayed spectral bands determine the color of features in each image. The connection is made between relative reflectivity in particular wave bands (Landsat bands 1, 2, 3, 4 and 5 in this instance) and image brightness in particular color bands (red, green and blue).

(4) Map composition – The final product will include the interpreted geological information plus sufficient cultural information to make the map navigable, and items normally found on any map, such as a coordinate grid, scale bar, north arrow, annotation, title and map legend to explain colors and symbols used on the map. Given the database contains height data, in the form of the SRTM DEM, both the images and the final map can then be visualized in pseudo three dimensions [1)].

3. NATURAL DISASTER MANAGEMENT REQUIREMENTS

The aim of the disaster management plan is to ensure that the following components are addressed to facilitate planning, preparedness, operation, coordination and community participation:

- Promoting a culture of prevention and preparedness by ensuring that Disaster Management (DM) receives the highest priority at all levels.
- Ensuring that community is the most important stakeholder in the DM process.
- Encouraging mitigation measures based on state-of-the-art technology and environmental sustainability.
- Mainstreaming DM concerns into the developmental planning process.
- Putting in place a streamlined and institutional techno-legal framework for the creation of an enabling regulatory environment and a compliance regime.
- Developing contemporary forecasting and early warning systems backed by responsive and fail-safe communications and Information Technology support.
- Promoting a productive partnership with the media to create awareness and contributing towards capacity development.

- Ensuring efficient response and relief with a caring approach towards the needs of the vulnerable sections of the society.
- Undertaking reconstruction as an opportunity to build disaster resilient structures and habitat.
- Undertaking recovery to bring back the community to a better and safer level than the pre-disaster stage.

The above mentioned objectives normally require a complete information system which can be utilized by using satellite image processing. The main approaches to follow for using these data are:

- Immediate information for rescue and relief plan during disaster
- Information database and detail processing for disaster preparedness for future disasters

Besides the above approaches the type of disaster may also dictate the type of processing and interpretation technique of images. Based on the two discussions in section 2 and section 3 of the paper, the appropriate methods can be described in the next section [2].

4. PROCEDURE

(1) Disaster change detection by remote sensing

A method is described here to utilize remotely sensed pre- and post-disaster imagery data in order to detect the change specifically associated with structural and major regional damage caused by natural disasters such as a strong earthquake. Figure 1 shows the flow of disaster change detection. The input is a pair of co registered remotely sensed images of the same scene acquired at different times and the output is a binary image in which 'changed' pixels are separated from 'not-changed' ones. A method of principal component analysis (PCA) is employed. The approach produced promising results on the model images and currently under further study to be extended for near real-time damage assessment purposes. This method advances structural change detection by enhancing and uniquely tailoring some of the existing methods for seismic hazard mitigation purposes.

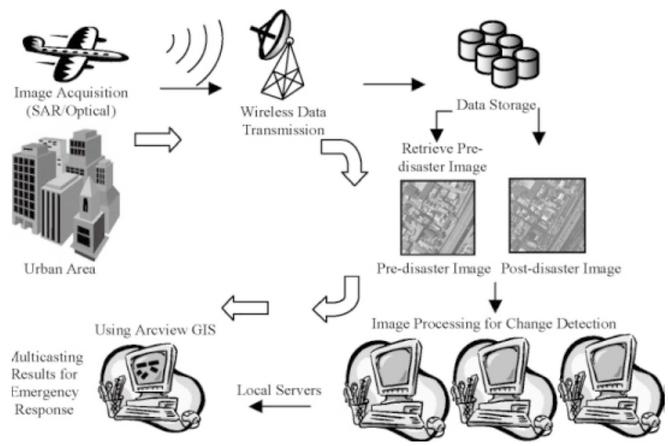

Figure 1 Employing Remote Sensing Imagery Data for Disaster Management [3]

In order to focus on the image processing techniques and provide a practical framework for the present methodology, it is required to make a few assumptions. The most important assumption is that the input images are co-registered, namely certain key points that represent the pattern are at the same location (same pixel) in both pre- and post-disaster image pairs, without any relative displacement.

The approach includes three major steps; 1) Depending on the local variance of each neighborhood in the image and the intensity value of the pixels in that neighborhood, intensity values are weighted. 2) This value can be used to compute conditional probability for appropriateness of a class (“change” or “not-changed”) to explain the classification of a pixel. 3) Using Bayesian statistics and initiating the values of conditional probability, the posteria probability of “change” or “not change” is computed for pixel to belong to a certain class in an iterative fashion. Figure 2 shows the pre-disaster image, post- disaster image and the result of their correlation.

In order to interpret the output, it can be virtually overlaid on a set of spatio-temporal database such as GIS. The detection procedure becomes semi-automatic but reliable algorithms can be developed so that human assistance is optimally minimized and eventually it can be improved towards a fully automatic procedure that is the ultimate goal of this study [3].

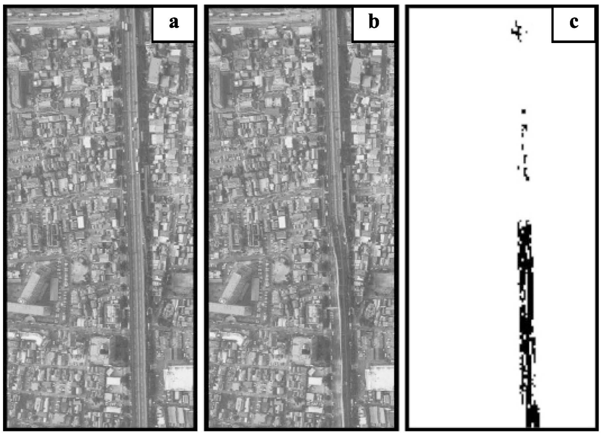

Figure 2 a) Pre-disaster image created from the original image, b) Post-disaster image; courtesy of Asia Kosoku Co., c) Result of correlation analysis [3)]

(2) Collaboration with GIS

It is possible to use advanced GIS for loss estimation and rapid post-earthquake assessment of building damage by the following objectives of the research:

1) Develop regressions between building damage and various seismic parameters to improve loss estimation
2) Identify the most reliable seismic parameter for estimating building losses
3) Develop GIS-based pattern recognition algorithms for the identification of locations with the most intense post-earthquake building damage.

This collaboration has resulted in the development of regressions between building damage and various seismic parameters, as well as the application of GIS-based recognition algorithms with the potential for screening remote sensing data to identify areas of highest post-earthquake damage intensity. With GIS, the spatial distribution of damage can be analyzed by dividing any map into squares, or cells, each of which is n by n in plan. As explained by O'Rourke et al. (1999), the hyperbolic relationship can be used for damage pattern recognition, and for computer "zooming" from the largest to smallest scales to identify zones of concentrated disruption.

The visualization algorithm allows personnel who are not specifically knowledgeable about structures or trained in pattern recognition to identify the locations of most severe damage for allocation of aid and emergency services. The entire process is easy to computerize, and personnel would be able to outline any part of a map with a "mouse" and click on the area so defined. In each instance of defining a smaller area for evaluation, the average damage ratio (DR) is recalculated for the new, smaller-sized map. In this way, the average is calibrated to each new map area.

When the damage pattern recognition algorithms are combined with regional data rapidly acquired by advanced remote sensing technologies, the potential exists for accelerated management of data and quick deployment of life and property saving services [4)].

(3) Area discrimination by remote sensing

Another approach is to define the objectives as:

- Using a combination of remote sensing technologies, discriminate with a high degree of confidence the difference between the built and natural environment.
- With a moderate level of reliability, quantify the important structural and economic parameters associated with large-scale urban and suburban developments (building heights, floor areas, replacement values, material or structural types, and usage).

It is possible using a variety of different sensors (SPOT High-Resolution Visible multi-spectral data, SPOT panchromatic imagery, Landsat-TM, and U.S. Geological Survey aerial photographs) to classify the land cover of an area. Each sensor offers a range of visible and in some cases, infrared bands that characterize the chemical composition of the earth's materials and vegetation.

Figure 3 shows two images. The first image, Figure 3a, is an aerial photograph of a residential area in the city of Santa Monica, California. The second image, Figure 3b, is a map derived from the aerial data using a classification scheme contained within the Environment for Visualizing Images (ENVI) [6)], an imaging processing software, that distinguishes roof types from other objects, e.g., roads, bushes, trees, etc. It is clear from the comparison that large trees are easily recognized, roadways can be distinguished from yards and improved properties, and that the outlines of buildings are reasonably clear. The significant advantage of Figure 3b is that the information used to derive the image can be translated into vector data that are usable in GIS systems. In fact, the percentage of area covered by building footprints can be quantified relatively easily using GIS technology.

The extraction of building footprints can be complicated by a number of factors. For example, nearby trees often obscure the outline of a building by covering part of the roof. Symmetrically shaped areas, such as yards or asphalt areas that often look like the tops of buildings may also complicate the classification of building footprints. Therefore, to outline building footprints using only visual information may not be the most effective approach, particularly if large areas are to be evaluated and checked. However, as a first approximation of footprint area, these data are judged to be adequate [5)].

Figure 3 Aerial photograph of a residential area in the city of Santa Monica, California and its classification by Spectral properties [5)]

The aerial photographs are useful data in classifying the footprints of short buildings. Since aerial photos are collected at a relatively low elevation, tall buildings which are not directly under the flight path appear to lean in these photos. Automatically extracting the footprints of tall buildings using aerial data leads to a horizontal displacement corresponding to the visible portion of the side of the building. Because satellite data collected from a higher elevation, displacement of the building footprint due to perspective is very slight. In the future, this may not be a problem with the high-resolution satellite data that will be available[5)].

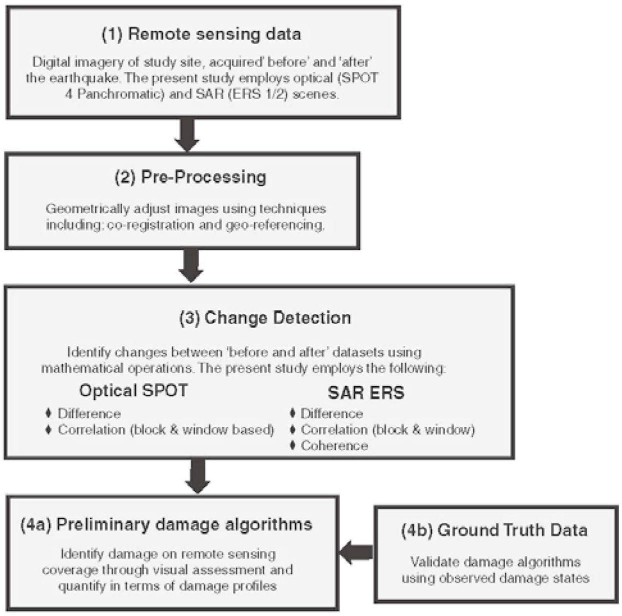

Figure 4 Flowchart Summarizing the Sequence of Methodological Procedure Involved in Damage Detection using Optical SPOT and ERS SAR Imagery[7)]

Figure 4 introduces the methodological approach that forms the basis of this research. The flowchart indicates that damage arising from a disaster is detected in the form of 'changes' between a temporal sequence of images acquired 'before' and 'after' the event. This comparative analysis is facilitated by pre-processing the imagery, which also minimizes the occurrence of false positives.

Following the earthquake event, surface reflectance on the SPOT coverage increases within the urban center, where numerous buildings collapsed. The preliminary SPOT and ERS change detection algorithms successfully distinguish between spatial variations in the extent of catastrophic building damage observed in Golcuk. As shown in figure 5, for the SPOT panchromatic data, simple subtraction and correlation profiles vary with observed damage. While SAR correlation indices also distinguished trends in the density of collapsed buildings, the subtraction profile was instead dominated by a large radiometric offset between the 'before' and 'after' scenes[7].

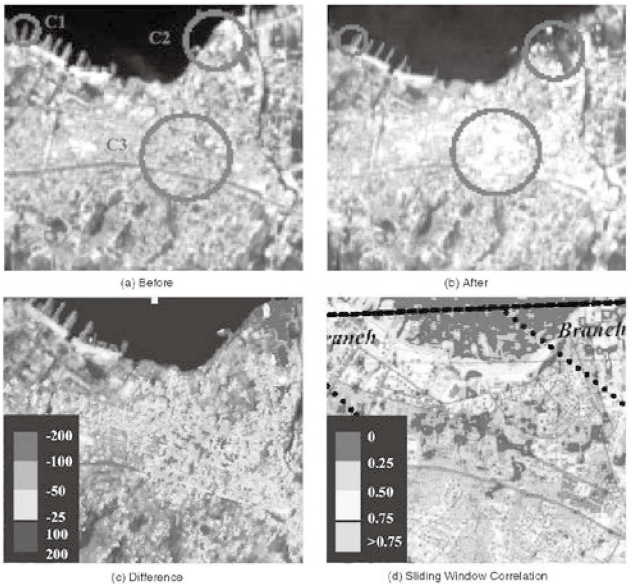

Figure 5 Panchromatic SPOT4 Coverage of Golcuk, Showing (a) ‘Before’ Image; (b) ‘After’ Image (c) Difference Values; (d) Sliding Window Correlation [7]

5. CONCLUSION

This study addressed the problem of change detection for the purpose of natural hazard mitigation in general and demonstrated the feasibility of employing remotely sensed images for this purpose. Due to the limited access to actual registered imagery data, scaled structural models are constructed and their images are used for experiments. Some of the major technical challenges involved in the problem of structural change/damage were also identified and successfully dealt with.

In this paper, the assumption of employing registered images is made which in practice might be difficult to achieve. Employing ground control points (GCP) and an imaging processing software like ENVI with GIS technique should be helpful for improving registration accuracy.

The authors believe that processing time has a lower priority compared to the precision of the results as long as the near real-time nature of the algorithm is maintained. Algorithms developed for pipelines have been modified and validated to choose optimal GIS mesh dimensions and contour intervals for visualizing post-disaster damage patterns. Statistically significant regressions have been developed at any damage state. Such work improves loss estimation significantly and also creates advanced technology to visualize post-disaster damage patterns for rapid decision support and deployment of emergency services.

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