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Enhanced change detection index for disaster response, recovery assessment and monitoring of accessibility and open spaces (camp sites)

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ABSTRACT

The availability of Very High Resolution (VHR) optical sensors and a growing image archive that is frequently updated, allows the use of change detection in post-disaster recovery and monitoring for robust and rapid results. The proposed semi-automated GIS object-based method uses readily available pre-disaster GIS data and adds existing knowledge into the processing to enhance change detection. It also allows targeting specific types of changes pertaining to similar man-made objects. This change detection method is based on pre/post normalized index, gradient of intensity, texture and edge similarity filters within the object and a set of training data. Once the change is quantified, based on training data, the method can be used automatically to detect change in order to observe recovery over time in large areas. Analysis over time can also contribute to obtaining a full picture of the recovery and development after disaster, thereby giving managers a better understanding of productive management practices.

1. Introduction

Rapid and robust impact assessment of poorly-accessible affected areas is essential for initiating effective emergency response actions following disasters (Dell'Acqua et al., 2009), especially in highly populated urban areas (Vu and Ban, 2010). Information pertaining to accessibility is critical in order to organize medical help and evacuation as well as aiding in both early- and long-term recovery evaluation (Joyce et al., 2009). In addition, identifying the location and sizes of open spaces is important in the early phases of emergency response. This information allows emergency managers to select the best plots for camps. These campsites also require monitoring and evaluation during the early recovery phase to assist disaster managers with the decision making regarding the provision of shelter.

Information on damage caused by an event can be derived quickly from suitable very high-resolution (VHR) satellite imagery (Walter, 2004) by comparing data from a chosen reference before the event (pre-event) to imagery acquired shortly after the event (post-event). The availability of pre- and post-event data opens the possibility for gathering impact assessment data using change detection in complex environments such as urban areas. Change detection from high spatial-resolution images such as IKONOS and QuickBird is even more challenging, especially in complex environments characterised by small objects such as houses, individual trees and roads, and by shadows (Pagot et al., 2008).

In general, change detection techniques can be grouped into two types: pixel-based and object-based (Blaschke, 2010; Chen et al., 2012). Pixel-based change detection analysis refers to using a change detection algorithm to compare the multi-temporal images pixel-by-pixel while object-based change detection analysis refers to using a change detection algorithm to compare multi-temporal images object-by-object. However, the definition of pixel-based and object-based change detection is not absolute. The most basic feature of object-based approaches is to segment the image and regard the objects as the basic unit of operation, rather than the pixel-based approach, which regards a single pixel as the basic unit (Dai and Khorram, 1998).

Object-based methods have the potential to provide more accurate results than traditional pixel-based methods (Al-Khudhairy et al., 2005), but choosing the object feature is not straightforward because the high information content of VHR images requires an accurate definition of the object. Thus the object detection step causes most of the error (Michaelsen et al., 2006).

Most object-based algorithms concentrate on detecting objects such as rectangular buildings (Lin et al., 1998) or parallel lines for detecting roads. This search is complex and rarely accurate, especially after disasters. As noted in the related literature, road

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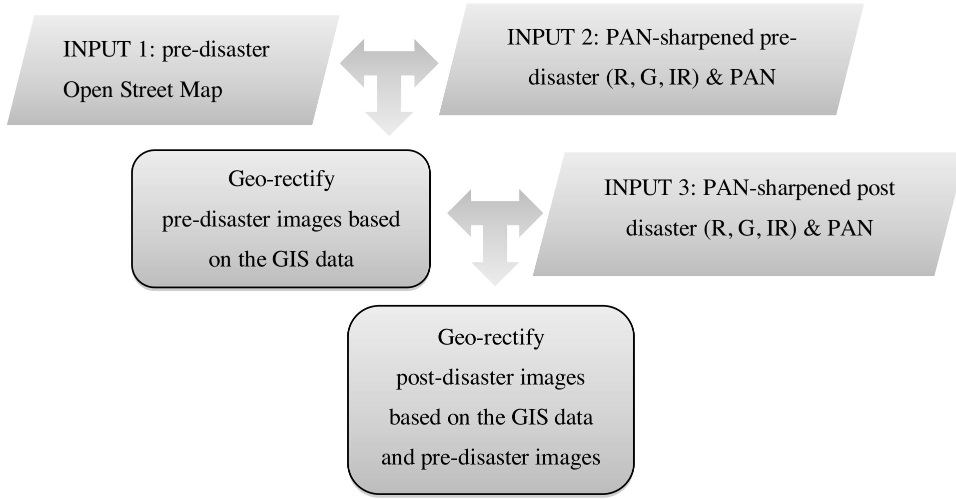

Fig. 1. Data preparation workflow: Pre-disaster images are PAN-sharpened and geo-rectified to the Open Street Map and then the PAN-sharpened post-disaster images are geo-rectified to the pre-disaster images.

extraction has been achieved in single or multiple operations such as image segmentation (Yang and Wang, 2007; Singh and Garg, 2014), classification (Mohammadzadeh et al., 2008), using morphological operations (Mena and Malpica 2005; Al-Khudhairy et al., 2005) and merging relevant road segments (Akcay and Aksoy, 2008; Mohammadzadeh et al., 2009). Hough transform and edge detection have also been used to detect linear parallel segments with constant width (Talib and Ramli, 2015), snakes (Butenuth and Heipke, 2010) (contour-based object outlines) and matching road templates to obtain networks (Touya, 2010). Kodge and Hiremath (2011) have used a sequence of filtering followed by segmentation, grouping and optimization on VHR images to identify open spaces in complex urban environments.

Many current change-detection mechanisms do not make effective use of available pre-disaster data and existing knowledge. Hence using pre-disaster GIS objects such as roads, open spaces, bridges etc. as indicators allows targeting the search for specific changes to these areas within the objects of interest. The proposed indicator-specific method uses readily available pre-disaster GIS data and existing knowledge to enhance the detection of change while offering the possibility to target specific types of changes pertaining to similar man-made objects.

The GIS object-based method discussed here is based on a pre/post normalized index, gradient. texture, and edge similarity filters within the object and an existing set of training data. The proposed semi-automated method is evaluated with QuickBird, Geoeye 1, and Worldview 2 datasets for abrupt changes soon after a disaster. The method could also be automated to monitor progressive changes months after a disaster.

2. Method

2.1. Case study sites

2.1.1. Van, Turkey

The Van earthquake was a destructive M7.1 earthquake that struck the city of Van in eastern Turkey on Sunday, 23 October 2011 at 13:41 local time. Based on the reports at least 534 people were killed, 2300 injured and 14,618 buildings and homes destroyed or damaged in the Ercis-Tabanli-Van area. As a part of the SENSUM (European Commission under FP7 (Seventh Framework Programme): SENSUM: Framework to Integrate Space-based and in-situ sENSing for dynamic vUlnerability and recovery Monitoring, 312972) project, the Van earthquake was selected for study because it was one of the most recent destructive, vast earthquakes for which imagery was available and suitable for a data-poor country for which remotely sensed tools were well suited.

2.1.2. Muzzaffarabad, Pakistan

The Kashmir earthquake was a destructive 7.6 Mw earthquake that struck the northwest region of Pakistan, near the city of Muzaffarabad, on 8 October 2005 at 08:52 local time.

The Muzaffarabad area was selected as a study site of the ReBuilDD (Remote sensing for Built environment Disaster and Development) (Brown et al., 2012) project because it was a major earthquake with severe damage. The timing, the extent of the disaster and the fact that very little ground based data existed, made it a well suited as a case study of remotely sensed data.

2.2. Data acquisition and data preparation

The process of initial data preparation for the proposed change detection method is shown in Fig. 1. The following paragraphs explain the data preparation in detail.

2.2.1. OpenStreetMap data

The data pertaining to the road layer was downloaded directly from the OpenStreetMap (OSM) archive (GEOFABRIK (Download.geofabrik.de, 2015)). In the case of Muzzaffarabad, the street layers for the primary and secondary roads were manually digitised from the QuickBird VHR images using QGIS since the OSM data were incomplete.

2.2.2. Satellite images

For the case study of Van, four satellite images were acquired from 2011 to 2013 (Table 1). For the case study of Muzzaffarabad, three satellite images were acquired from 2004 to 2006 (Table 2).

2.2.3. Geo-rectifying the pre-disaster image

All the satellite data were co-registered to the road layers obtained from OSM to ensure the best alignment (accuracy < 1.47 m). The pre-disaster IR R,G bands were first PAN-sharpened (using QGIS OTB (OrfeoToolBox) Processing toolbox) and then co-registered to the reference vector layer such as a road layer (See Fig. 1).