BUILDING DAMAGE DETECTION OF THE 2003 BAM, IRAN EARTHQUAKE USING QUICKBIRD IMAGES BASED ON OBJECT-BASED CLASSIFICATION

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KEY WORDS: QuickBird, the 2003 Bam earthquake, building, damage detection, object-based classification

ABSTRACT: In resent years, remote sensing technologies are utilized in disaster management as a means of information gathering in a large scale disaster. QuickBird captured a clear image of Bam City, eight days after the 2003 Bam, Iran, earthquake. The city was also observed by QuickBird about three months before the event. In this paper, we perform building damage detection based on land cover classification. Two supervised classification methods are employed; one is pixel-based classification and another object-based classification. First, these two methods are applied to building detection using the pre-event image. A reasonable result is obtained for the object-based classification while salt-and-pepper noises are observed for pixel-based classification. The object-based approach is further applied to the post-event QuickBird image to detect debris areas. Comparing the result by object-based classification with that from visual inspection, a reasonable level of accuracy is obtained for debris locations although further improvements are suggested.

1. INTRODUCTION

Recently, the research on the use of remotely sensed data is advanced to capture damage distribution in large-scale natural disasters, e.g. earthquakes, tsunamis, typhoons. When a large disaster occurs, damage information on affected areas soon after the disaster is very important. Remote sensing technology can be effectively used as a source of important spatial information, such as damages to buildings and roads.

QuickBird, a high-resolution commercial satellite with the maximum spatial resolution of 0.6 m, launched on October 18, 2001 and it has been acquiring optical images of urban areas, which can be used to detect damages of individual buildings after a natural disaster. The first such image pairs (both pre-event and post-event) were taken for the 21 May 2003 Algeria earthquake and they were used in building damage detection (Yamazaki et al. 2004).

For the 2003 Bam, Iran, earthquake, QuickBird has captured clear images of Bam area both before and after the event. Using the images, visual damage detection of individual buildings has been conducted and its accuracy was investigated comparing with field survey data (Yamazaki et al. 2005). Since detailed visual inspection is time-consuming, image processing techniques are introduced in this paper to detect damages to buildings automatically from high-resolution satellite images. This paper compares the result of pixel-based classification and object-based classification in identifying debris for a sample area of Bam.

2. QUICKBIRD IMAGES OF THE 2003 BAM, IRAN EARTHQUAKE

A strong earthquake struck the city of Bam in the southeast Iran on December 26, 2003. The earthquake brought massive destruction to the city and its surrounding rural areas. QuickBird captured a clear image of Bam on January 3, 2004, eight days after the event. The city was also observed by QuickBird on September 30, 2003, about three months before the event.

In order to observe target areas in a short time interval, QuickBird can change the view angle of its sensors. Thus the two images of Bam have different off-nadir view angles: 10 degrees (pre-event) and 24 degrees (post-event). Hence it is not so easy to superpose these images exactly and to perform automated change detection. The difference in building shadow and vegetation in the different acquisition date images gives additional difficulty.

Figure 1 shows a pre-event QuickBird image and a study area in this paper, located in the southeast of the Bam city. This area was selected because the buildings of various damage levels exist in the small area.

3. BUILDING DETECTION USING THE PRE-EVENT IMAGE

To detect buildings which exist before the earthquake, land cover classification is carried out. We compared pixel-based classification and object-based classification. First, we selected the training data for supervised classification. In this study, five classification classes: building, vegetation, road, soil and shadow, were assigned. Commonly, in supervised classification of an urban area, some classification classes for buildings are needed because of the variation in color and material of the roofs of buildings. However, the buildings in the selected part of Bam city have roughly the same type of roofs. Thus, we used only one building class.

The original image with training data and the results of pixel-based classification and object-based classification are shown in Figure 2. In pixel-based classification, as salt-and-pepper noises are observed in the whole study area, classification of individual buildings seem to be difficult. Some small areas (noises) exist because the QuickBird image has very high resolution: 0.6 m.

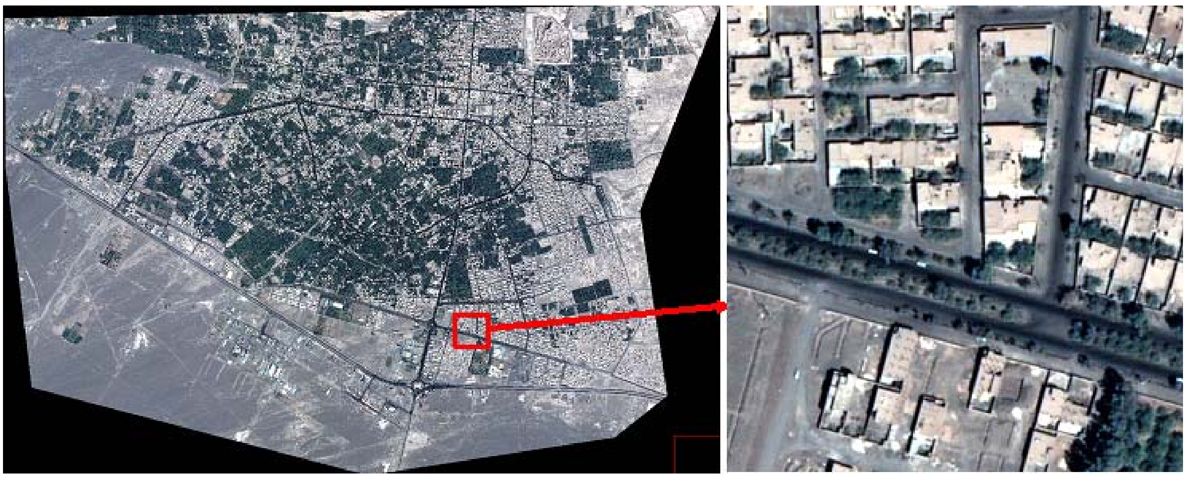

Figure 1. Pan-sharpened natural color QuickBird image of Bam captured on September 30, 2003 and a study area in this paper, located in the southeast of the city

In object-based classification, e-Cognition software (Definiens Imaging, 2004) was used. In the first step of the object-based classification, segmentation of the image is carried out. This software has some segmentation parameters, and this study used three segmentation parameters (layer weight, scale parameter, shape factor, Baatz and Schape 2000). The layer weight (w_{layer}) assigns the weight of each spectral band. In this study, four bands (Blue: 0.45-0.52 µm, Green: 0.52-0.60 µm, Red: 0.63-0.69 µm, NIR: 0.76-0.90 µm) were used and all the w_{layer} values were set as 1.0. The scale parameter (*SP*) corresponds to the number of pixels for an object. Thus changing the *SP* value influences the average object size: a larger value leads to a bigger object and vice versa (Figure 3). The shape factor (*SF*) controls the shape of an object. By changing the range of the *SF* value between 0 to 0.9, the shape of each object changes: a larger value leads to a smoother shape of the object edge (Figure 4).

In the stage of segmentation, the size and shape of an object changes by adjusting these parameters. We tested several sets of parameter values, and the most suitable set of parameters for building detection were selected (*SP* =30). In object-based classification, salt-and-pepper noise is removed because similar adjacent pixels are merged in the segmentation process,

Figure 5 shows the result of object-based classification of buildings, that by visual inspection (correct result), and the comparison between the two. Red areas show ones where the result by object-based classification coincides with that by visual inspection. Blue areas correspond to commission error (28%), and yellow areas correspond to omission error (9%). Commission error appeared where the color of ground looks like that of building roofs. But as a whole, acceptable result has been obtained.

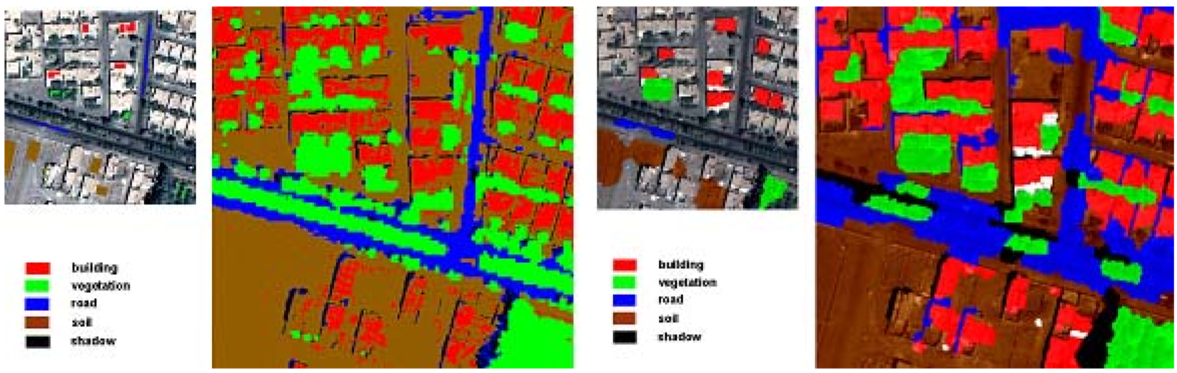

Figure 2. The original image with training data and the result of pixel-based classification (left) and object-based classification (right, w_{layer}=1.0, *SP*=30, *SF*=0.7)

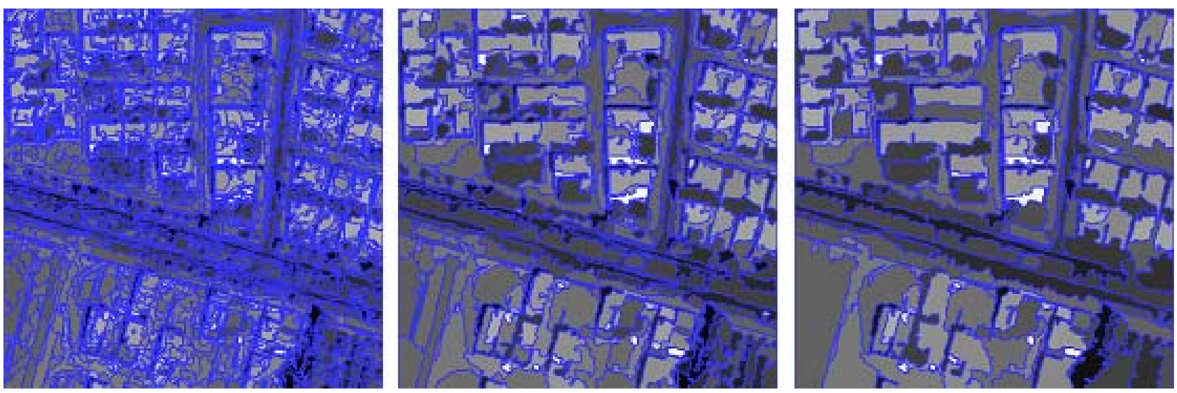

Figure 3. Difference of image segmentation by changing the scale parameter value (left: *SP*=10, center: *SP*=30, right: *SP*=50)

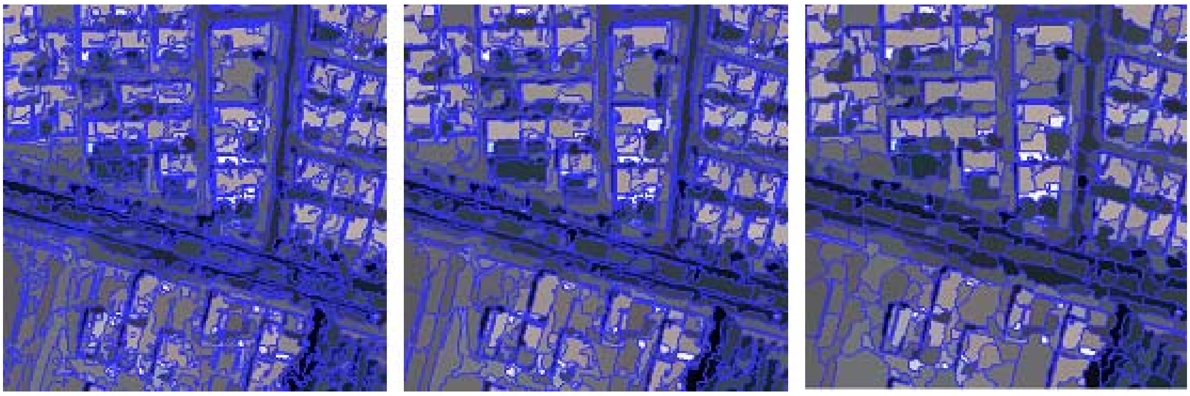

Figure 4. Difference of image segmentation by changing the shape factor value (left: *SF*=0, center: *SF*=0.2, right: *SF*=0.5)

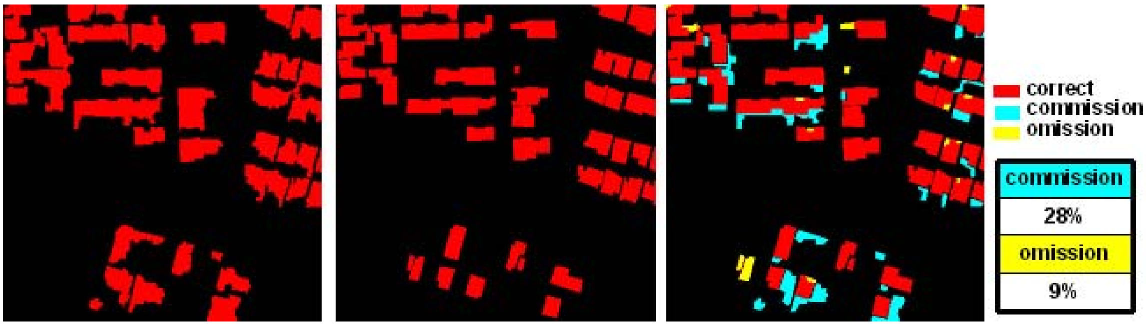

Figure 5. Results of object-based classification of buildings (left) and visual inspection (center) and comparison between these images (right).

4. BUILDING DAMAGE DETECTION USING THE POST-EVENT IMAGE

As a method of automated building damage detection, land cover classification for the post-event QuickBird image was conducted (Gusella et al. 2005, Vu et al. 2005). In doing this, we added debris class as one of the land cover classes. In case of pixel-based classification, a large amount of error is observed for debris class. One of this reasons is the selection of training data. It is very difficult to choose proper training data because the color and shape of debris in high-resolution satellite images are very complex.

In case of object-based classification, several sets of the segmentation parameters were tested and the most suitable set was chosen. Because an area of debris consisting of several pixels with varying color and shape are merged as one object in segmentation stage, it is much easy to select training data for debris class.

Figure 6 compares the result of object-based classification and visually detected debris (Yamazaki et al. 2005) and building damage grade (EMS, 1998). In the detection of debris, the suitable *SP* value was found to be 20. Because the size of debris is smaller than that of buildings in most cases, the suitable *SP* value for debris classification is smaller that that for building classification. It is necessary to set an appropriate value for each parameter depending on the target of classification.

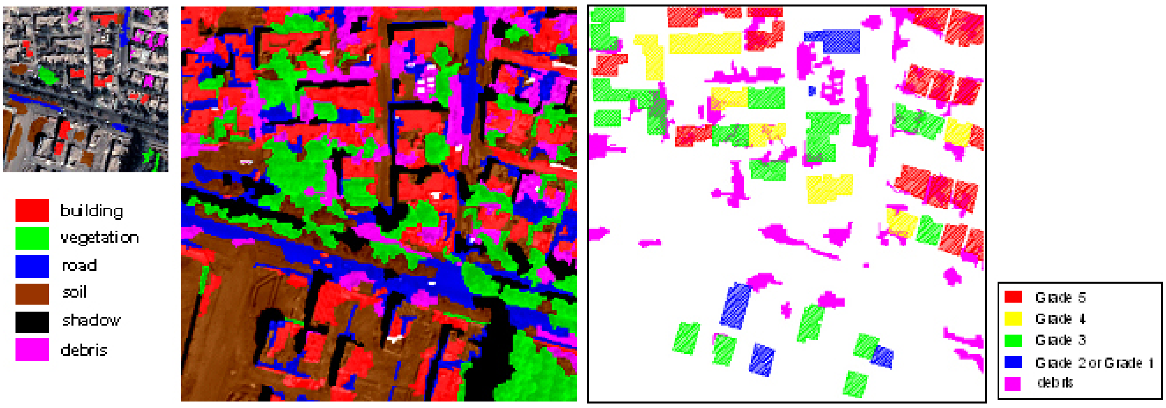

Figure 6. The original image with training data and the result of object-based classification (left, w_{layer}=1.0, SP=20, SF=0.5) and the result of visual debris and building damage detection (right).

Figure 7. The visually detected (correct) area of debris (left), the classified area of debris (center), and the comparison of the two areas (right). (Red color is the true debris area and blue color is the classified area.)

When these results are compared, it is observed that a lot of debris was extracted in the surroundings of high damage-rank buildings by the visual inspection. However, some errors are found for the segments whose color and shape look like debris but actually not.

More detailed comparison is shown in Figure 7 where the correct area of debris (left), the classified area of debris (center), and the comparison of the two areas (right) are plotted. The rate that the classification area corresponds to the correct one (user accuracy) is 44%. In this comparison, overall agreement of debris locations looks an acceptable level. But apparent omission and commission errors are seen. In a future study, spatial relations e.g., “debris is located near buildings”, should be taken into consideration. Change detection between a pre-event image and a post-event image is also a possible alternative approach.

5. CONCLUSIONS

Using the high-resolution satellite images of Bam City acquired by QuickBird before and after the 26 December 2004 Iran earthquake, the methods of building damage detection were investigated based on land cover classification scheme. Two supervised classification methods were employed; one is pixel-based classification and another object-based classification. First, we applied these two methods to building detection using the pre-event image. A reasonable result was obtained for the object-based classification while salt-and-pepper noises were observed for pixel-based classification. The selection of appropriate values of parameters of object-based method was suggested depending on a target object of classification.

The object-based approach was further applied to the post-event QuickBird image to detect debris areas. Comparing the result by object-based classification with that from visual inspection, overall agreement of debris locations looks an acceptable level. But apparent omission and commission errors are seen. To improve building damage detection in a future study, spatial relations e.g., “debris is located near buildings”, should be taken into consideration.

ACKNOWLEDGEMENTS

QuickBird images used in this study were licensed and provided from Earthquake Engineering Research Institute (EERI), Oakland, California, USA and owned by DigitalGlobe, Inc.

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