Identify Damaged Buildings from High-Resolution Satellite Imagery in Hazardous Areas using Morphological Operators

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Abstract- This paper presents a methodology and results of evaluating damaged buildings detection algorithms using an object recognition task based on Differential Morphological Profile (DMP) for Very High Resolution (VHR) remotely sensed images. The proposed approach involves several advanced morphological operators among which an adaptive hit-or-miss transform with varying size, shape and gray level of the structuring elements. IKONOS satellite panchromatic images consisting of a pre and post earthquake site of the Sichuan area in China were used. Morphological operation of opening and closing with constructions are applied for segmented images. The Unsupervised classification ISODATA algorithm is used for the feature extraction and the results comparison with ground truth data, complex urban area before the earthquake gives 76% and same area wracked after the earthquake gives 88% buildings detection on object based accuracy. This work is being extended to extract shadows and non building objects for better classifications of building roof footprints.

Keywords- Differential Morphological Profile, IKONOS, Building Extraction, Unsupervised ISODATA Classification

1. INTRODUCTION

With the increase of natural hazards on urban areas in resent years, satellite remote sensing has been an important tool used for recognizing, rescuing, management and recovery tasks in the event of a disaster. In this paper, we focus on automatic damaged building detection method using high-resolution satellite images, morphological operators and ISO Data classification. The very high spatial resolution satellite images offer the opportunity to recognize features such as road, vegetation, buildings and other kind of infrastructures. The high-resolution imagery that we used from IKONOS Satellite capturing a 3.2m multispectral, Near-Infrared (NIR)/0.82m panchromatic resolution at nadir. Its applications include both urban and rural mapping of natural resources and of natural disasters, agriculture and forestry analysis, mining, engineering, construction, and change detection. Automatic extraction of damaged an undamaged man-made structures are a fundamental task in image processing. In the past decade, many kinds of methods have developed especially for geometric classification and feature extraction using high-resolution imagery. According to different manners, these methods can be summarized in to different kinds: automatic and semi-automatic according to the iteration extent of human; single view and multi views, according to different principles, region-based and edge-based according to the principle elements acquired manners. Among these methods, region base segmentation, edge detection and mathematical morphology have already proved to be effective for many applications in remote sensing [1] - [13]. Classification and Feature Extraction for Remote Sensing Images From urban Area Based on Morphological Transformations and Classification of Hyper spectral Data From Urban Areas Based on Extended Morphological Profiles were presented by Benediktsson et al [14,15]. Similarly, Aaron K. Shackelford et al were investigated a method for Automated 2-D Building Footprint Extraction from High-Resolution Satellite Multispectral Imagery [16]. This research also focused on region based classifications.

2. OBJECTIVES AND METHODOLOGY

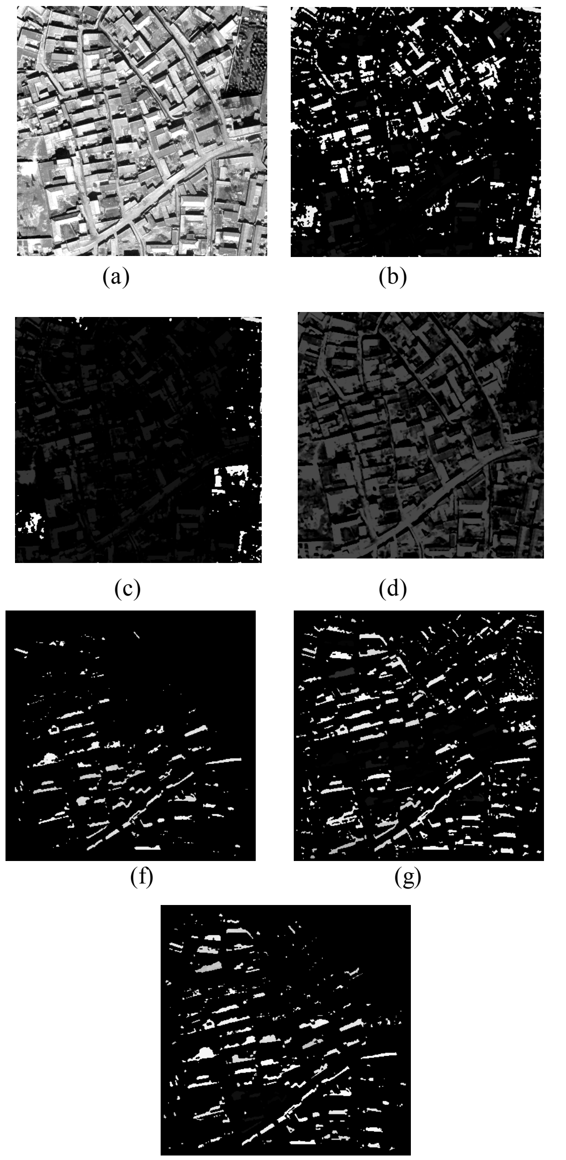
2.1. Differential Morphological Profile

The Here Differential Morphological Profile (DMP) was developed by feature detectors attempts to identify buildings, shadows, roads and so on of the high-resolution panchromatic images and it is constructed using morphological opening and closing by reconstruction operators. Mathematical morphology employs a set of image operators to extract and analyze image components based on shape and size of quasi-homogeneous regions in the image. This concept is used to create a feature vector from a single image, I and it is based on the repeat use of the opening and closing operators, which are commonly used in mathematical morphology [12]. Opening and closing by reconstruction is obtained following by erosion and dilation under the original image [10]. The gray-scale reconstruction of image I could be defined as follows. Opening is defined as the result of erosion followed by the dilation. Opening and closing by reconstruction can be considered as lower-leveling opening and upper-leveling closing operations [13].

The *derivative of the opening profile* $\Delta\gamma(x)$ is defined as the vector

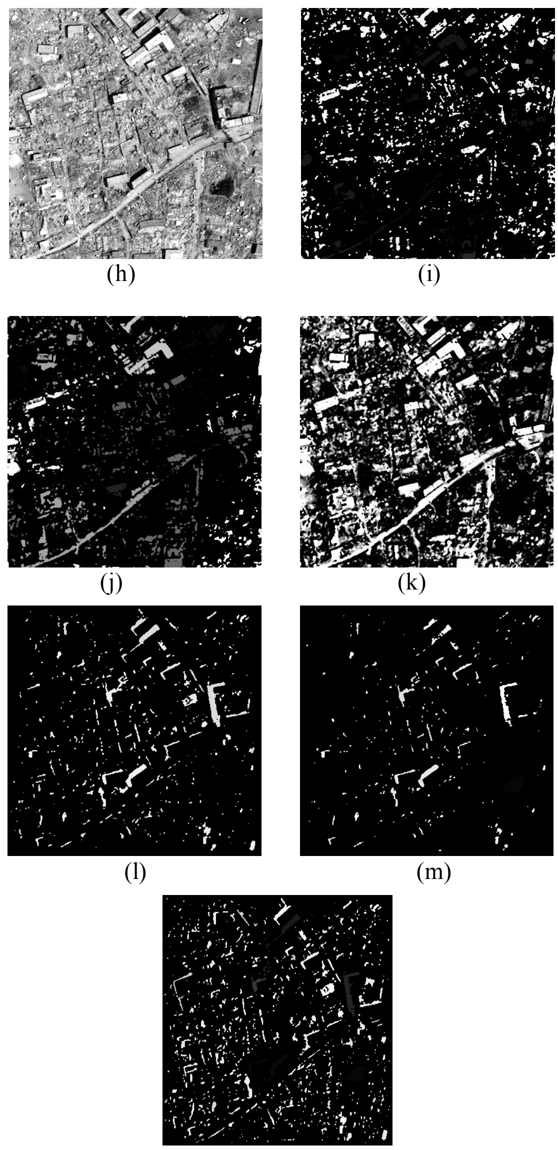
$$\Delta\gamma(x)=\{ \Delta\gamma\lambda : \Delta\gamma\lambda =|\Pi\gamma\lambda - \Pi\gamma\lambda\text{-}1 |, \forall\lambda v [1,n]\} \quad (1)$$

By duality, the *derivative of the closing profile* $\Delta f(x)$ is the vector



(a) (b) (c) (d) (f) (g) (e)

Fig 1. The image (a) shows the original image before the earthquake event and (b)-(g) represents structural decomposition of the image using differential morphological profile. The images have been visually enhanced. The derivative has been calculated relative to a series generated by six iterations of the elementary SE with radius from 7-19m. Derivative of the opening profile with r=(b)7, (c)11, (d)15 and closing profile with r=(e)7,(f)11,(g)15 are shows above respectively.



(h) (i) (j) (k) (l) (m) (n)

Fig 2. The image (h) shows the original image after the earthquake event and (h)-(n) represents Structural decomposition of the image using differential morphological profile. The images have been visually enhanced. The derivative has been calculated relative to a series generated by six iterations of the elementary SE with r (radius) from 7-19m. Derivative of the opening profile with r=(i)7, (j)11, (k)15 and closing profile with r=(l)7,(m)11,(n)15 are shows above respectively.

$$\Delta f(x) = \{\Delta f\lambda : \Delta f\lambda = |\Pi f\lambda - \Pi f\lambda\text{-}1|, \forall \lambda \vee [1,n]\} \quad (2)$$

Generally, the *derivative of the morphological profile* $\Delta(x)$or the DMP can be written as the vector

$$\Delta(x) = \begin{cases} \Delta c : \Delta c = \Delta f\ \lambda = n-c+1,\ \forall c \vee\ [1,n] \\ \Delta c : \Delta c = \Delta\gamma\lambda = c-n,\ \forall c \vee\ [n+1,2n] \end{cases} \quad (3)$$

with equal to the total number of iterations, c=1,…..,2n, and , and |n-c|=the size of the morphological transform.

that is brighter or darker than the surrounding region. The maximum DMP response indicates with well a matched SE value that the pixel resides within. There are 8 differential morphological profiles were created using disc shaped morphological elements with radius (r) increasing 7 to 19m (step size is equal to 4m). The SE that are less than 7m are not reliable for use because of they consists of small shadows, trees and wrecks of buildings. Those figures give noise for the classification results, we used SE more than 7m to detect for remain Buildings. Most of the bright building roof is gives the maximum response with opening differential profile and dark color roof, shadows are with closing differential profile.

2.2. Used Data

The morphological filter theory was designed for a series of gray-level images. In this paper, we used pre and past IKONOS panchromatic (PAN) imagery of Sichuan earthquake in China in 2008. The gray color image of high-resolution IKONOS panchromatic images that consists of 1m resolution band (450-900 nm) is used. The images were smoothed using median filter for removal post classification procedures like "salt-and-paper" and other visual enhancement procedures. IDL programming language and ENVI 4.7 commercial software package is used for image processing and classification on this research.

3. BUILDING EXTRACTION

The building shadows are easy to extract using their low reflection value. Mask for shadows is built up using the reflection value between 0 and 60. The structures with similar scale to the SE diameter give high responses when SE in DMP value with bright structures in opening portion and dark structures in closing portion of the profile. For each pixel in the image, the position of the maximum responses within the DMP vector ($\Delta(x)$), indicate both the SE size that best characterize the structure that the pixel resides within and whether the pixel is part a structure that is brighter or darker than the surrounding region. The maximum DMP response indicates with well a matched SE value that the pixel resides within. There are 8 differential morphological profiles were created using disc shaped morphological elements with radius (r) increasing 7 to 19m (step size is equal to 4m). The SE that are less than 7m are not reliable for use because of they consists of small shadows, trees and wrecks of buildings. Those figures give noise for the classification results, we used SE more than 7m to detect for remain Buildings. Most of the bright building roof is gives the maximum response with opening differential profile and dark color roof, shadows are with closing differential profile.

Unsupervised ISODATA Classification way is used for the classification and identification the structures. ISODATA stands for Iterative Self-Organizing Data Analysis Techniques. This is a more sophisticated algorithm which allows the number of clusters to be automatically adjusted during the iteration by merging similar clusters and splitting clusters with large standard deviations. Combining morphological operations is carried out for remove pixel errors that occurred due to delineation of image objects with DMP before classification.

4. RESULTS

The results have shown the usefulness of the proposed method during detection of various types of building, as illustrated by the portions given this paper. The image patches used to train the Unsupervised ISODATA classifier. The shadows of the building were masked when classification using their low spectral value. The candidate area contained various kinds of roofs with different colors and shapes before the earthquake. There are some building structures that complex and combine together were classified as a one building. Fig. 3 shows the building extraction results. The accuracy assessment of extracted results was calculated simply based on object based and pixel based. Although this result appeared to have high accuracy, the confidence measures produced by the ISODATA training suggested a reliability of post event gives 88.46%.

The error extraction of building structure could be due to over fitting of the decision surface to the data. The totally collapsed building in the applied area is identified as 89 structures according to manually labeled buildings as ground truth and the result of the above algorithm views as 65.

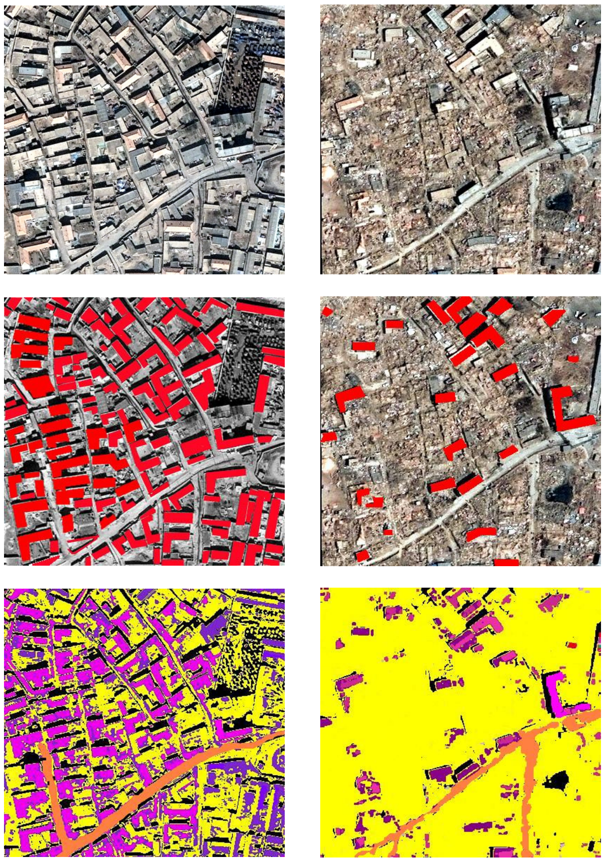


Fig 3. Building extraction results. (up) IKONOS image of the pre and post earthquake area. (middle) Manually labeled buildings as ground truth. (down) Result of the building extraction according to approached method in each areas.

5. CONCLUSIONS

We applied a method for extraction of urban structures and hazard estimation using very high-resolution satellite images. The first step was to segmentation structural information using morphological opening and closing by reconstruction operators. IKONOS satellite panchromatic gray level images of pre and post earthquake event were applied to morphological operators. Then, the building footprint were extracted in candidate region using connected components analysis to the pixels selected according to their morphological profiles, obtained using increasing structural element sizes for 7 to 19m for opening and closing operators. From the analysis of the extraction results, complex urban area before the earthquake gives 76% and same area wracked after the earthquake gives 88% buildings detection on object based accuracy percentage according to the applied method. Further work is required to increase the accuracy of building detection and determine if damage ratio of the structure can be estimated.

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