AUTOMATIC SHADOW DETECTION FOR PRECISE MATCHING POINTS EXTRACTION

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KEY WORDS: shadow detection, building edge buffer, co-registration, matching points, high resolution satellite image

ABSTRACT: Using multi-sensor or multi-temporal high resolution satellite images is essential for efficient city analysis and modeling. Yet even when acquired from the same location, these multi-modal images have a geometric inconsistency because of their motion instability, orbital change, and geometrically corrected level. Matching points between images, therefore, must be extracted to co-register the images. With images of an urban area, however, it is difficult to extract matching points because buildings, trees, bridges, and other artificial objects cause shadows, which have different intensities and directions in multi-temporal images. In this study, we propose a shadow detection method to increase the correct-match rate of matching points. The shadow segments are extracted using spatial and spectral attributes derived from the image segmentation. Also, we consider information of shadow adjacency with the building edge buffer. Finally, matching points are extracted through the SIFT method, the representative matching points extraction method, and the points extracted from shadow segments are eliminated from matching point pairs. The results of our study show that we can raise the correct-match rate by about 11% using the proposed shadow detection method.

INTRODUCTION

Multi-temporal satellite images are effective sources for change detection in a wide area. Urban growth, changes in vegetation and natural disasters can be analyzed through the change detection step. In particular, high-resolution satellite images can be used to monitor the changes in an urban area periodically, eliminating the need for time-consuming and labor-intensive field work.

To make the best use of multi-temporal images, image registration is an essential pre-processing step because there is the need for a geomatic standard. Yet even when acquired from the same location, these multi-modal images have a geometric inconsistency because of their motion instability, orbital change, and geometrically corrected level. Image registration is the process of geometrically overlaying two or more images of the same scene (Zitová and Flusser, 2003). The process of image registration is fulfilled by extracting tie-points (or matching points). Scale-Invariant Feature Transform (SIFT), which was introduced by Lowe, is one of the typical feature-based matching-point extraction methods (Lowe, 2004). Since, there have been multiple attempts to use or update the SIFT method to achieve more reliable registration results (El Rube, 2009; Han, 2012).

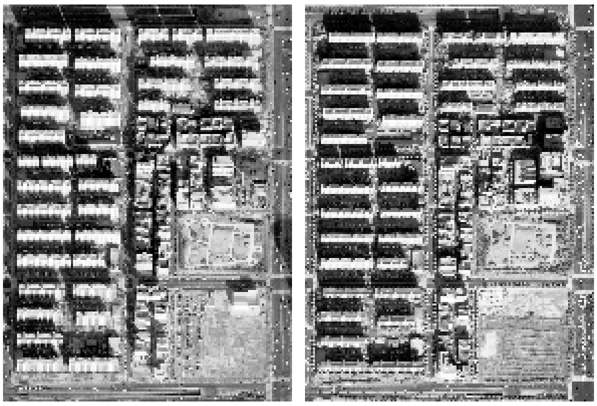
Unfortunately, multi-temporal images that are collected at different seasons and times have an inconsistency of shadow characteristics, such as direction and intensity. Consequently, the shadows cast by urban features may cause false color tone, loss of feature information, shape distortion of objects, and failure of conjugate image matching within the shadow area (2006, Tsai). Corresponding edges for the image matching may break into more than one segment due to shadows, and some weak edges may appear only in the one image and not in the multi-temporal images (Zhang and Gruen, 2006). Similarly, the conjugate matching points are mismatched or fail to extract because multi-temporal images have a different shadow characteristics.

In this paper, an automatic shadow detection approach is proposed to improve the quality of the extraction of matching points. Multi-temporal Quickbird-2 images were acquired at different times and processed using rule-based shadow detection, which is derived from the image segmentation and building edge buffer analysis. The matching points were extracted using the SIFT method, accuracy tests were carried out by calculating the correct-match rates applied to the original images, and the proposed results considered the shadow area.

METHODS

The proposed method is applied to Quickbird-2 high-resolution satellite images, 0.61m spatial resolution in panchromatic image, acquired on December 31, 2002 and October 28, 2006 (Figure 1). The study site is located in

Daejeon, Korea, and includes high apartment complexes and commercial buildings causing wide shaded areas. The shadows in the 2002 and 2006 images have different directions and intensities. The target image collected in 2002 is registered to the reference image in 2006 to evaluate the matching point accuracy because the influences of shadow should be compared in the same geometric condition.



(a) (b)

Figure 1: 2002 (a) and 2006 (b) Quickbird-2 panchromatic images

First, image segmentation is performed using the feature extraction module of ENVI 4.5 software, and building edge buffer is derived from each panchromatic image. The segmentation results of the feature extraction module are determined by scale and merge parameters. The higher the scale factor, the larger the segments become. From the first segmentation result, spectrally similar segments are merged using the merge parameter. In building edge buffer process, the building edges are extracted by the Canny edge operator, and then a dilation filer is applied to make buffer areas of buildings which are the shadow candidate regions. The size of the dilation filter was set as 40 pixels because we can assume that a shadow exists in a 25m building neighborhood. The parameters of segmentation and buffer creation are as shown in Table 1.

Table 1: Parameters of segmentation and building edge buffer

Type	Parameter	Value
Segmentation	Scale	20
	Merge	80
Building edge buffer	Canny threshold 1	0.2
	Canny threshold 2	0.4
	Gaussian standard deviation	2
	Dilation filter size	40

The shadow segments are determined from the overlay analysis with building edge buffer and rule-based extraction using shape and spectral features (Table 2). Generally, shadow segments have a big size and a low brightness relative to other segments because the shadow area is homogeneous, with a dark color. For this reason, we detect the shadow segments first using the Z-statistics of size and brightness. Final shadow segments are selected according to the buffer ratio, which is the ratio of a segment's size to the size of its intersecting buffer.

SIFT method is used to evaluate the effectiveness of shadow detection for the matching point extraction. It calculates the location, scale, and orientation of each feature by using its neighboring pixels, and creates a description of each feature for matching. For a more detailed explanation of the SIFT method, interested readers are referred to the paper written by Lowe (2004). SIFT-based feature matching is carried out for the original images, and the matching points extracted from the shadow segments, in the 2002 or 2006 images, are removed from the matching-point set. The accuracy of the matching points extracted from the pair of original images and the proposed method is compared by visual inspection. Figure 2 shows the flow chart of this study.

Table 2: Criteria of rule-based shadow extraction

Feature	Criteria
Size	$Z_S > 1$
Brightness	$Z_B < -1$
Buffer ratio	$B < 3.5$

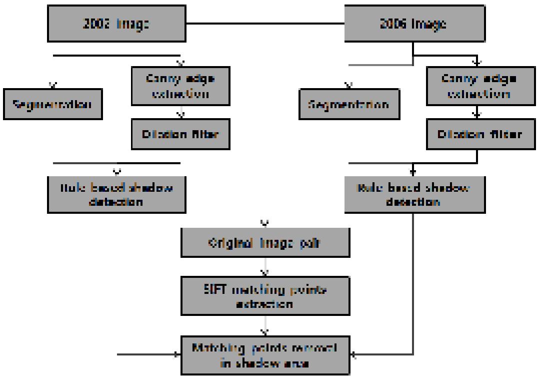
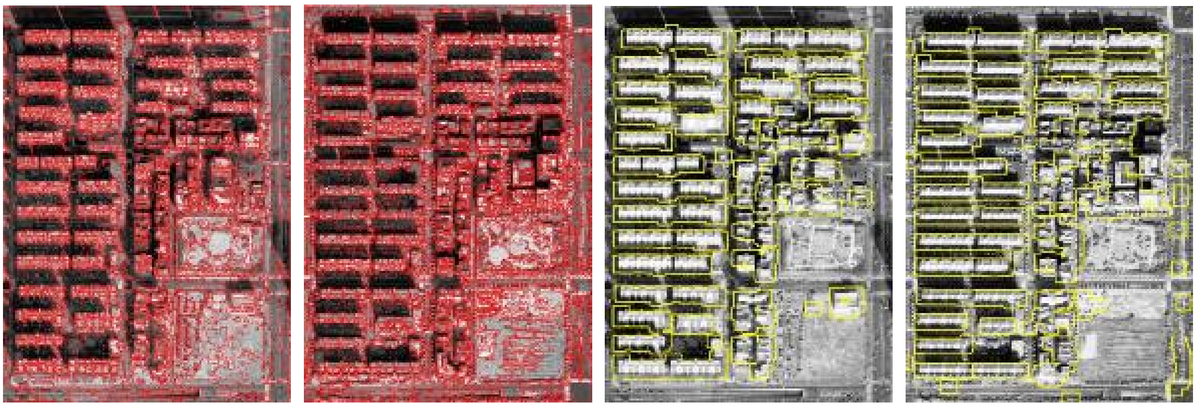


Figure 2: Flow chart

RESULTS

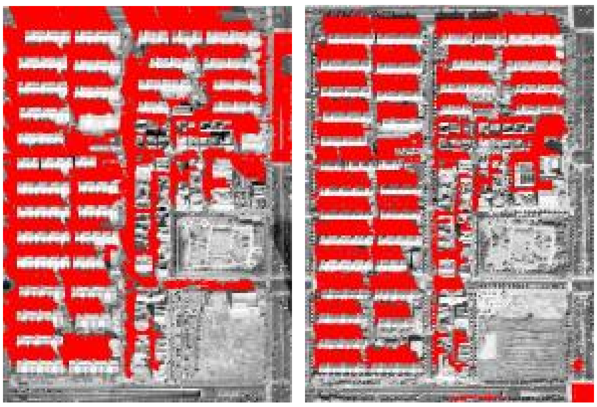
The results with segmentation and building edge buffer analysis use the parameters in Table 1. Homogeneous areas such as road, bare soil, and particularly shadow, are delineated more clearly than any other building objects (Figure 3). This segmentation result is due to the low scale and high merge segmentation factors, because shadows have a high homogeneity. Also, building edge buffers are well designed to cover the building areas adjacent to shadows (Figure 3). Some buffer areas are not coincident with the building in the 2006 image due to the edges of bright vehicles.



(a) (b) (c) (d)

Figure 3: 2002 (a) and 2006 (b) segmentation results and 2002 (c) and 2006 (d) building edge buffer results

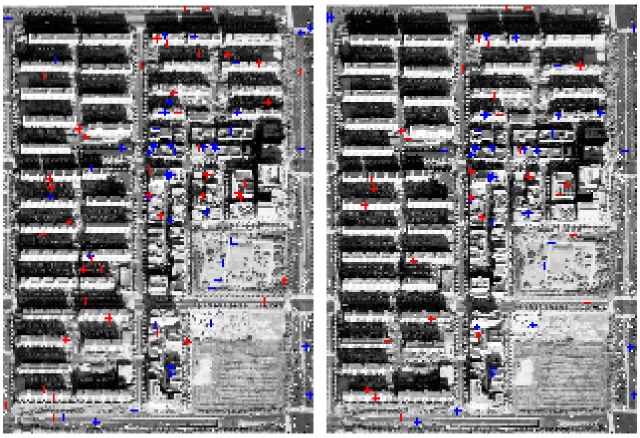
Automatic shadow detection results are shown in Figure 4. The shadows of apartments and commercial buildings in multi-temporal images are well-extracted through the proposed automatic process. Some shadows cast in crossroads or road lines are omitted because of separation between segments. In addition, some detection errors occurred because roads have a dark color that is similar to shadows, and intersect with building edge buffers.



(a) (b)

Figure 4: 2002 (a) and 2006 (b) shadow detection results

The matching points in the shadow area are frequently incorrect because shadows have a low contrast and a spectral distortion, causing errors in the extraction of registration features. It is confirmed that the results of the original image pair have a lot of error points, red crosses, in shadows (Figure 5). On the other hand, there is an improvement of matching point quality from the removal of error points.



(a) (b)

Figure 5: Extracted matching points in 2006 image of the original image pair (a) and proposed method (b) ; red (incorrect), blue (correct)

The accuracy of extracted matching points is assessed through a visual inspection. The proposed method has an 11% higher correct-match rate in comparison with the pair of original images (Table 3). Though correct-match rates are relatively low overall in this study site because there are many high buildings, the proposed method efficiently eliminates outlier points extracted within the shadow area.

Table 3: Comparison of matching results

Type	Original	Proposed
True matches	64	54
False matches	51	27
Total matches	115	81
Correct-match rate (%)	55.65	66.67

DISCUSSION & CONCLUSION

It is important to extract correct matching points in an urban area because a high number of error points in shadows or building objects can distort the result of image co-registration of multi-temporal images. The proposed method automatically extracted shadows in an urban area using image segmentation and building edge buffer analysis. From the image segmentation, intact shadow segments are efficiently delineated. In addition, the adjacency information of buildings and building edge buffer are considered to extract accurate shadow areas. The matching points extracted using the SIFT method are processed with a rule-based shadow detection algorithm. As a result, the accuracy of matching points was increased by about 11%. This means that the quality of image registration in urban area can be improved using our algorithms. Future research should focus on verifying the accuracy of registration products such as RMSE and overlay analysis.

ACKNOWLEDGMENT

This work was supported by the Global Surveillance Research Center (GSRC) program funded by the Defense Acquisition Program Administration (DAPA) and Agency for Defense Development (ADD).

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