SAR Image Change Detection Using SURF Algorithm

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Abstract: With the advent of high-resolution Synthetic Aperture Radar (SAR), applications of satellite SAR have a growing interest in this field and change detection is of high interest in both military and civil applications. Change detection techniques have attracted increased attentions and become a topic of major research. In change detection procedure, geometrical correction of image is essential for effective remote sensing applications. Unlike optical sensor, the geometrical correction of SAR images is highly complicated due to the signal interaction within the complex geometrical properties of the target structures and the inherent speckle noise. In this paper, we present an advanced yet efficient geometrical correction method that may be applied to multi-resolution satellite SAR images. For this purpose, SURF(Speeded-Up Robust Feature) is adopted and modified so as to make it fully applicable to SAR images. KI thresholding technique is constructed and applied to multi-SAR images to verify the performance.

1 INTRODUCTION

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Lu et al., 2004). The goal of change detection is to detect "significant" changes while rejecting "unimportant" ones (Radke et al., 2005). Generally, important changes reflect natural phenomenon or human activities in the Earth. In recent years, with the development of high-resolution imaging satellites, the remote sensing has rapidly advanced that the minute details of the Earth surface could be investigated. Naturally, techniques for change detection have attracted increased attentions and become a topic of major research. Unlike optical image, geometrical distortions commonly occur during image acquisition of SAR images due to the geometrical characteristics of the targets. Therefore, geometrical correction of images plays an important role in this area. Geometric correction of the SAR images could be performed by utilizing satellite's orbit and attitude information. However, due to the inevitable errors in measuring SAR sensor's orbit and attitude information, and the acquisition errors of Earth's geographical parameters, the reflected radar signals are contaminated with considerable geometric errors. In order to acquire more accurate geometrical corrections, error correction needs to be performed with respect to the ground control points. Regardless of the methodology adopted, int is prerequisite to carry out accurate geometrical correction for the change detection to be properly applied, especially when the image resolution improves below sub-meter levels.

In general, geometric correction techniques can be classified into three categories, which are based on intensity, transform domain and feature characteristic respectively. Feature-based technique is simple and steady and hence has been widely used for this purpose in the past. A number of detectors are known to be applicable for this purpose, which include Harris corner detector, Forstner detector, Moravec detector, Harris-Laplacian detector, Gaussian-determinant detector, Hessian detector and Fast-Hessian detector.

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Among others, SIFT(Scale Invariant Feature Transform) is one of the most widely used method for point feature detection. SIFT algorithm is known to be steady and resistant to geometric deformations and illumination changes for partial target matching and recognition. When the feature points have good lamination changes for partial target matching and recognition, then feature points has stability in terms of geometrical variation. However SIFT algorithm suffers from a drawback of consuming a significant amount of time for searching and calculating the matching points. Hence SURF algorithm has been proposed as a means to replace the SIFT by simplifying complicated SIFT algorithm while the general feature of high accuracy and stability are well preserved. It is asserted that SURF is several times faster than SIFT and claimed by its authors to be more robust against different image transformations than SIFT. In this paper, we adopt the previous SURF algorithm for SAR change detection. Parameter estimation and optimization are carried out to obtain the best matching results.

1.1 SURF Algorithm

SURF is a useful tool for matching points between different images. After SURF is performed, RANSAC is applied to obtain optimal coordinate conversion functions using the extracted matching points. After ground point selection is completed and conversion function is obtained, projective transformation and second order polynomial transformation is used to rearrange the remaining pixels into the new coordinates. Projective transformation needs four or more ground points and second order polynomial needs minimum 4 ground points. Higher multinomial matrix might be required for the optimal geometrical correction depending on the level of distortion in the images and the number of extracted ground points.

SURF algorithm has been mainly applied to optical image cases due to its inherent nature of requiring high contrast of pixel values. Y.Murali has developed a MOSAIC image stitching method based on SURF algorithm. In other case, an input query imaging technique is proposed that SURF feature points detector algorithm is incorporated with the color edge matching method.(Ryo Mitsumori, 2009) A modified SURF algorithm is developed by adopting the color and relative location information of interest points.(KyungSeung Lee, 2012) However the majority of the previous researches have dealt with optical images are SAR images have rarely a topic of research. This is mainly attributed to the low level of contrast in radar image pixels and inherent speckle noises around feature points. For this reason, it has been considered a difficult task to apply SURF for SAR change detection purpose. In this paper, we have adopted higher multinomial matrix equation in the process of applying SURF to the SAR images. By doing this, the probability of erroneous feature point detection is reduced and the point matching can be better performed against target movement, rotation and scale. After desired ground points are selected, the remaining pixels are rearranged on the new coordinate plane using a cubic convolution. We show that the modified SURF algorithm can be easily applied to the conventional SAR images. The performance of the proposed algorithm is verified throughout medium-to-low level resolution satellite SAR images.

1.2 KI Thresholding

For a simple change detection purpose, image thresholding is the most straightforward technique. There are a number of known image thresholding techniques suitable for different applications. Sezgin et al, has shown that the clustering-based method by Kittler and Illingworth (1986) provides the most reliable thresholding result in their experiments. This technique has been called KI thresholding and is performed as: Step 1. Choose an arbitrary initial threshold T. Step 2. Compute priori probability, mean value, variance value. Step 3. Compute the updated threshold. Step 4. Compare old threshold with updated threshold. KI thresholding technique has been widely applied in the past since thanks to its robust performance. In this paper, we adopted KI technique variation for the purpose of change detection between two different SAR images.

2 EXPERIMENT RESULTS

In Fig. 1 and Fig.2 are shown Radarsat-1,2 images taken over Vancouver respectively and their characteristics are described in Table 1 and 2. SAR images can be seen totally different depending upon the sensor position and viewing angle over the same scene. In this case, we have attempted to detect changes for Radarsat-1 and Radarsat-2, which are distinguished by different resolutions and their performances are compared later. Since the scene coverage is different from each other, regions of interest are extracted first. Then SURF algorithms are applied to both images to find out the common feature points that matched with each other.

Table 1: RADARSAT-1 IMAGERY

Name	**Characteristics of products**		
	Acquisition date	***Orbit***	***description***
SSG	1999.07.25.	Descending 19427	Map image
SGF	1998.07.09	Ascending 13975	Path image

Table 2: RADARSAT-2 IMAGERY

Characteristics	**Description**
Name of Satellite	Radarsat-2
Beam mode	FineQuad15
Product type	SLC

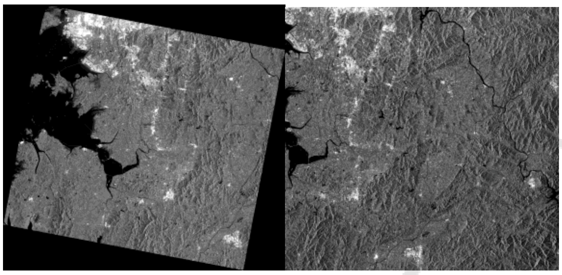

Figure 1: RadarSAT-1 Vancouver area, (a)SSG (b)SGFT

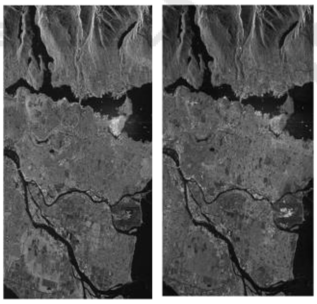

Figure 2: RadarSAT-2 Vancouver area, HH, HV data

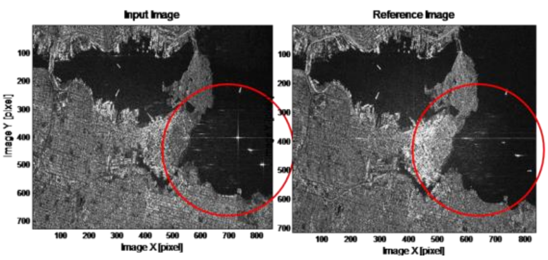

Figure 3: ROI(Region Of Interest) images in Fig.2

Figure 4 presents the number of interest points extracted from each SAR images according to the Hessian threshold. As the Hessian threshold value is increased, the number of extracted interest points is reduced. Figure 5 shows the number of matched points with respect to the varying SURF matching threshold values. SURF matching points are selected by calculating the Euclidean distance around extracted interest points. The number of the selected matching pixels increases as the SURF matching threshold value is increased from 0.4 to 0.9. Processing times to extract interest points and matched points are shown in Figure 6. As Hessian threshold is increased, processing time is reduced, but the number of matched point is decreased. Therefore, there should be an appropriate trade-off between time consumption and accuracy to guarantee the optimization of the image matching.

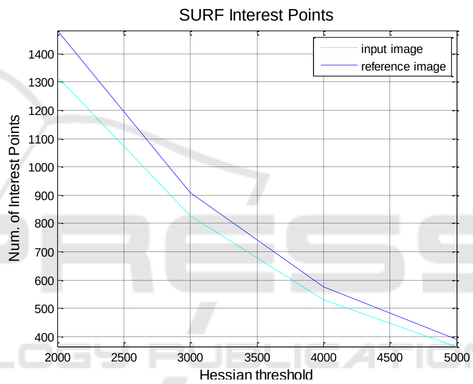

Figure 4: The number of interest point according to Hessian Threshold (Radarsat-2)

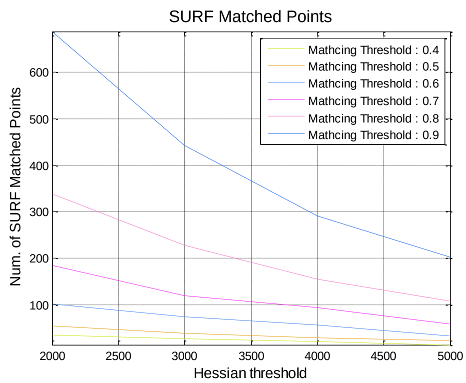

Figure 5: The number of matched points by Euclidean distance calculation (Radarsat-2)

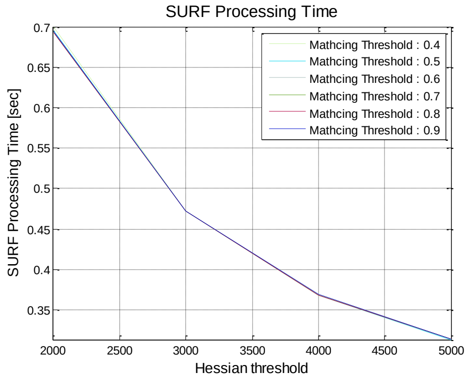

Figure 6: SURF Processing Time according to Hessian threshold (Radarsat-2)

Extracted interest points and matched points are shown in Figure 7 and Figure 8 for Radarsat-1. Similar procedure is performed against Radarsat-2 and shown in Figure 9 and Figure 10 respectively. As mentioned earlier, the performance of the matching algorithm depends upon the parameters in the SURF, particularly the threshold value. In our experiment for Radarsat-2 images, the Hessian threshold value of 2000 and matching threshold value of 0.5 have provided relatively good performance while the calculation burden is minimized. After the matching sequence is completed, geo-correction procedure is followed using the projective transform for image matching of two satellite images. The performance of image matching is measured as the distance of the dislocation of common pixels, calculated as residual sigma. The matching accuracy and error levels are calculated and compared with each other for Radarsat-1 and Radarsat-2 and summarized in Table 3. The result shows that matching accuracy in Radarsat-1 is 42.5% and matching accuracy in Radarsat-2 is 94.6%. Matching accuracy in low resolution images is smaller than high resolution image, which are as expected. It can be inferred that the Hessian threshold in low-resolution case has to be increased than that of the high-resolution image case.

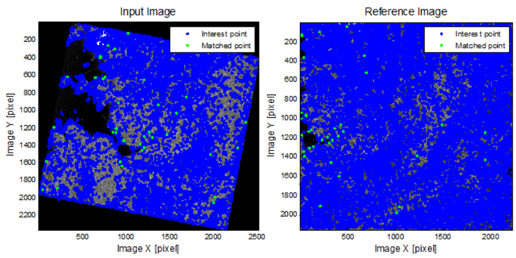

Figure 7: Extracted interest points and matched points (Radarsat-1)

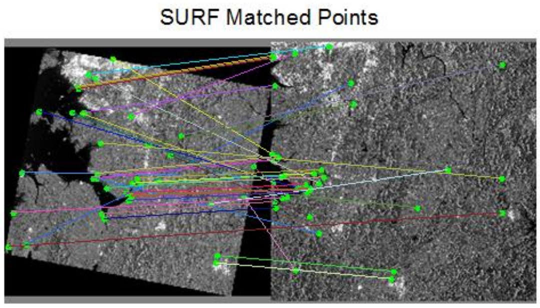

Figure 8: Result of SURF matching (Radarsat-1)

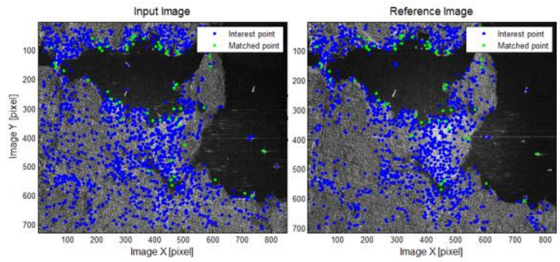

Figure 9: Extracted interest points and matched points (Radarsat-2)

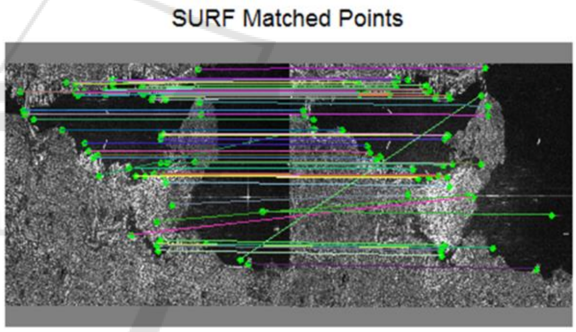

Figure 10: Result of SURF matching (Radarsat-2)

Table 3: Matching results between the satellite SAR images (Hessian threshold = 2000, Matching threshold = 0.5)

	Radarsat-1	Radarsat-2
SURF Interest Points	11865/23164	1319/1483
SURF Matched Points	40	56
Matching Accuracy	42.5%	94.6%
Residuals sigma_x [pixel]	1.303	1.018
Residuals sigma_y [pixel]	1.176	1.009

In SAR imaging mode, comparison between two different images is difficult due to the residing speckle noise and ratio comparison tend to be perferred for the high noise image application.

As in the SURF case, it is important to select a proper threshold value when KI thresholding method is applied. In our experiments, the optimal threshold value was chosen to be 0.057 for Radarsat-1 and 0.026 in Radarsat-2. Pixels with intensity values bigger than the optimal threshold are extracted in Figure 12. These areas are considered to implicate changes over the scenes. Here it is seen that high resolution SAR provide more realistic details of the changes between different images.

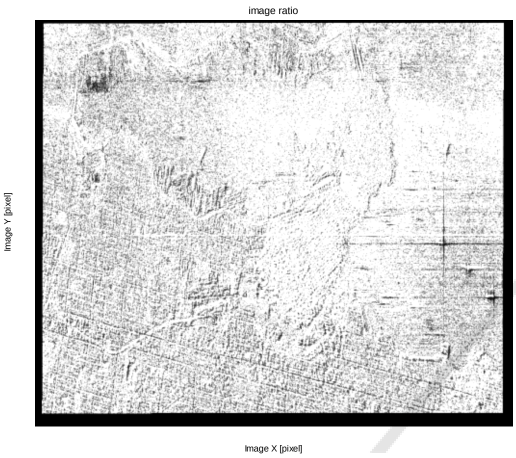

Figure 11: Ratio image (Radarsat-2)

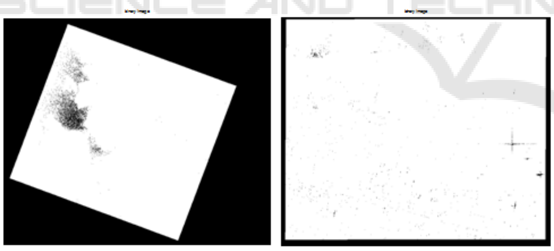

Figure 12: results of applying KI thresholding (a)Radarsat-1 (b)Radarsat-2

3 CONCLUSION

Accurate geometrical correction of radar imagery is essential for effective change detection procedure. The geometrical correction of SAR images is highly complicated due to the complex geometrical properties of the targets, signal interaction within target structures and speckle noise. In this paper, we present a modified SURF algorithm to geo-registration on SAR image. The KI thresholding technique has been applied to detect changes over medium resolution SAR images. It is shown that the parameter selection of SURF algorithm needs to be carefully designed on applying SAR image by adjusting the Hessian threshold value according to resolution of images.

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