CHANGE DETECTION WITH SPACEBORNE INSAR TECHNIQUE IN HONG KONG

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ABSTRACT

Change detection is an application to which SAR is particularly well suited since SARs can consistently produce high quality fine resolution imagery from multiple repeat pass collections. The aim of this paper is to extract all possible information from SAR-InSAR data and to asses to which extent this information can be exploited for change detection purposes in Hong Kong. We collaborate with Planning Department of Hong Kong and choose two small areas as experimental cases. A time series of high resolution SAR images acquired by the German satellite TerraSAR-X are used. High resolution optical images are used for comparison and comprehension.

***Index Terms*—** Change detection, SAR, InSAR, coherence

1. INTRODUCTION

Change detection based on remote sensing images has been one of the most important applications in recent years. It usually detects the land cover changes by exploiting the difference of two or multiple remote sensing images acquired at different time over the same area [1]. With the rapid development of synthetic aperture radar (SAR) technology, it shows powerful monitoring ability in any weather condition and all year around. SAR Change detection started to play an important role in urban environment change, land use, forest cover change and other applications [2]. This potential is also reinforced by the availability of multichannel SAR data with short revisit time and high resolution which are granted by the new systems like TerraSAR-X and COSMO/SkyMed [3].

2. METHODOLOGY

We use both intensity and phase information of SAR images to exploit the change detection information. Below are some of the technical tools we are going to apply [4].

2.1. Change detection maps

2.1.1 Amplitude Incoherent Mean Map

The amplitude incoherent mean is defined as the temporal average of all images in the dataset. It could reduce noise of single SAR image and clearly show intensity character of the whole scene.

$$m_A = \sum_{i=1}^{n} I_i / n \tag{1}$$

2.1.2 Amplitude Stability Index Map

Amplitude stability index is a measure of amplitude stability. It is computed as

$$D_A = 1 \quad \frac{\sigma_A}{m_A} \tag{2}$$

Where m_A and σ_A are the mean and the standard deviation of the amplitude values. For amplitude stability map, red points are amplitude stable pixels such as buildings or other man-made objects, while blue implies pixels with amplitude changes in time series.

2.1.3 Intensity Change Detection Maps

With this function, difference in the SAR intensity of the two acquisitions calculated as below is used as the indices representing the changes in the scene, where I_i is the amplitude value of the i^{th} SAR image, x, y is range and azimuth index respectively, $f_{win}\{\}$ is filtering of the intensity change map.

$$_{i,j}(x, y) = f_{win}[\frac{I_i \quad I_j}{I_i + I_j}] \tag{3}$$

2.1.4 Phase change detection maps (Coherence maps)

In addition to the intensity information, the complex interferogram contains information about the correlation of the two SAR scenes which is formed as

$$_{i,j} = \frac{E[s_i s_j^*]}{\sqrt{E[|s_i|^2]E[|s_j|^2]}} \tag{4}$$

Where s_i is the complex value of the i^{th} SAR image, $E[]$ denotes expectation of the complex image. When changes happen to a scene, the cross correlation coefficient tends to be low. So the coherence of the image pair could be used to detect such changes.

2.2. Pixel based time series

With this module you can visualize a series of parameters such as amplitude time series and change matrix based on a selected pixel in the image.

2.2.1 Amplitude time series
It can show amplitude values on a single pixel between every repeat-cycle SAR images. This index is suitable for isolated stable targets.
2.2.2 Amplitude changes matrix
As quantitative measures of change, the amplitude changes matrix is defined as

$$ {}_{i,j}(x_{target}, y_{target}) = E_{win}[\frac{I_i \quad I_j}{I_i + I_j}] \qquad (5) $$

It is the amplitude change of a small window area centered by the pixel located at (x_{target}, y_{target}) between the i^{th} and j^{th} SAR images. This index is more suitable for extended targets such as vegetation, land, etc.
2.2.3 Coherence matrix
Coherence matrix focuses on the coherent information between images, it is defined as

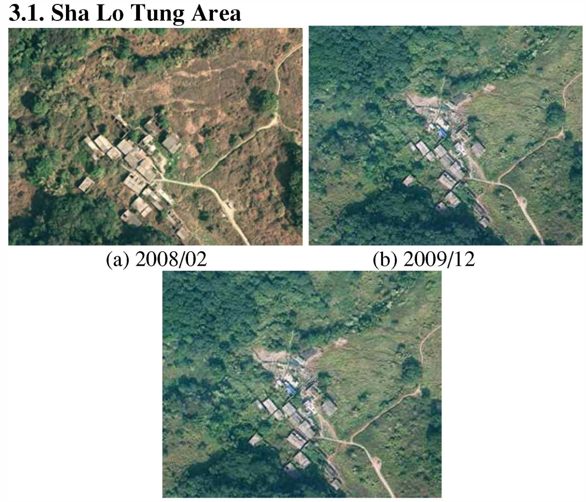
$$ {}_{i,j}(x_{target}, y_{target}) = \frac{E_{win}[s_i s_j^*]}{\sqrt{E_{win}[|s_i|^2] E_{win}[|s_j|^2]}} \qquad (6) $$

It shows the coherent correlation changes between the i^{th} and j^{th} image pairs in the small window area centered by the target pixel. It is a very sensitive index as for phase change.

3. RESERACH AREAS AND EXPERIMENTAL RESULTS

For the study areas, the Planning Department of Hong Kong locates two small rural areas which they have been traced down for the past four years as shown in Figure 1 and Figure 6. We apply all the SAR/InSAR change detection technical tools to the 72 scenes of SAR data including 61 TerraSAR-X and 11 TanDEM-X images acquired between October 2008 and June 2012. The TerraSAR-X and TanDEM-X sensors acquire images over Hong Kong at about 6:25pm every 11 days, along an ascending orbit with an incidence angle of approximately 37 degrees. All the images are acquired in StripMap mode with resolution up to 3m.

3.1. Sha Lo Tung Area

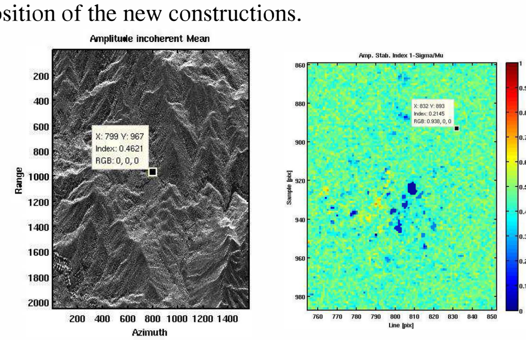


(a) 2008/02 (b) 2009/12

(c) 2011/09

Figure 1 Optical images of Sha Lo Tung

Sha Lo Tung locates on a hill near Pat Sin Leng Country Park in the north-east of Hong Kong. Most areas are densely covered by woods and grass. There are many small villages at the edge of the park like the one shown in Figure 1. Constructions of new village buildings and roads have been carried on now and then. As we can see from the three optical images, two new small buildings and one new walking path appeared in the third image which can only imply the construction started between Dec. 2009 and Sep. 2011 with a wide time range. But with a number of SAR data and technique tools, we can locate the detail time and position of the new constructions.

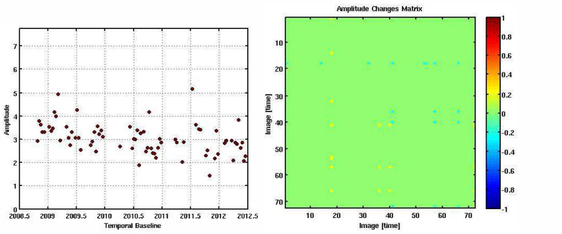


(a) Amplitude incoherent mean map (b) Amplitude stability map

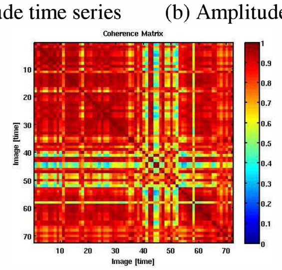
Figure 2 SAR images of Sha Lo Tung

By applying SAR analysis tools, we first show amplitude incoherent mean map and amplitude stability map in Figure 2. In stability map, the red points are amplitude stable pixels such as the old buildings which exist through the time, while blue implies amplitude changes in time series which may be new construction.

After checking the overall SAR images, we apply the time series tools on some selected pixels. Figure 3 is an example of a stable pixel. We can see the amplitude keeps in high value at every acquisition time. The amplitude changes matrix are mostly zero between each two acquisitions and the coherence matrix shows high coherence all the time.



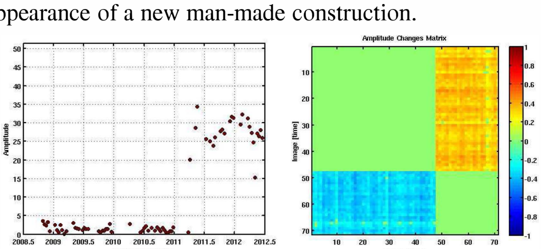
(a) Amplitude time series (b) Amplitude change matrix



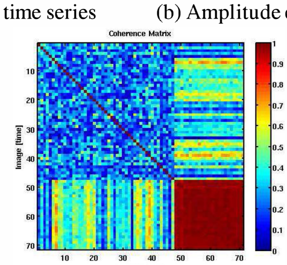
(c) Coherence change matrix

Figure 3 Stable pixel on old building

Figure 4 shows an example which we successfully detected on a new construction. From the amplitude time series, we can clearly see an amplitude jump around April, 2011. Amplitude change matrix also shows the amplitude keeps stable both before and after the amplitude jump. Coherence change matrix further confirms the coherence became and kept high value up to 1 after the jump which implies the appearance of a new man-made construction.



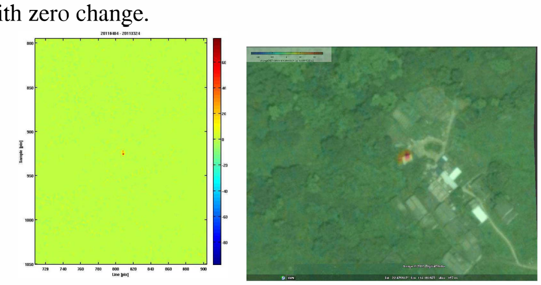
(a) Amplitude time series (b) Amplitude change matrix



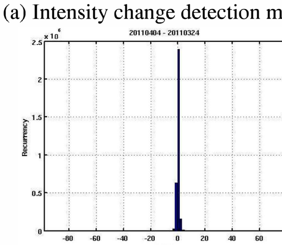
(c) Coherence matrix

Figure 4 Change pixel on new construction

In order to verify the above change around April, 2011, we chose two SAR images which were acquired on 2011/03/24 and 2011/04/04 respectively, and make an amplitude difference map. Figure 5 (a) clearly shows a small red area with big amplitude difference. After geocoding in Google Earth, the red area locates at a new construction which shows good agreement with the optical images. The recurrence image also shows most pixels of the image are with zero change.



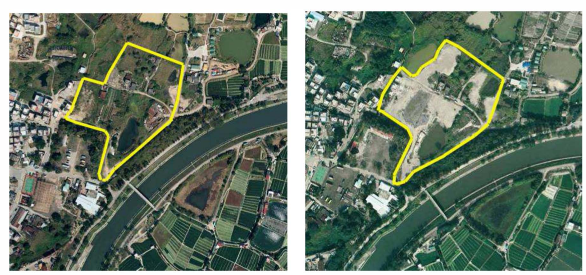
(a) Intensity change detection map



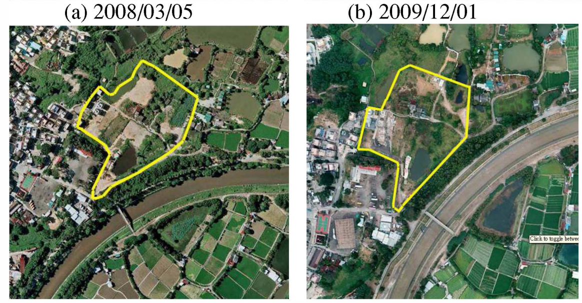
(b) Recurrence image

Figure 5 Sha Lo Tung Area

3.2. Ho Sheung Heung Area



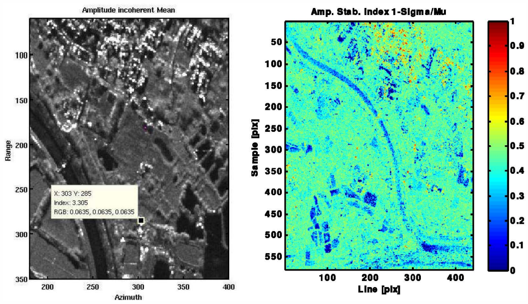
(a) 2008/03/05 (b) 2009/12/01



(c) 2010/08/03 (d) 2012/01/19

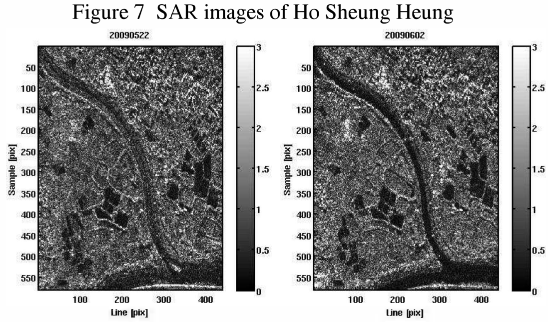
Figure 6 Optical images of Ho Sheung Heung

Ho Sheung Heung area locates between latitude 22°30' 32"~22°30' 49" and longitude 114°6' 31"~114°7' 3" in New Territories of Hong Kong. There is a river to the south-east, low density building in the west, and the rest are mostly rural farmland. From the optical images, we can see the land cover have been changed a lot because of season effect and constructions.

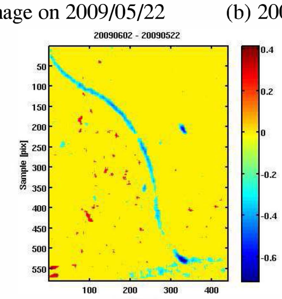


(a) Amplitude incoherent mean map (b) Amplitude stability map

Figure 7 SAR images of Ho Sheung Heung

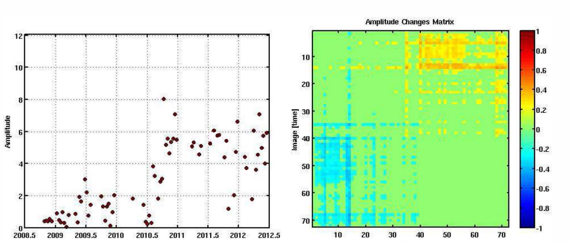


(a) SAR image on 2009/05/22 (b) 2009/06/02

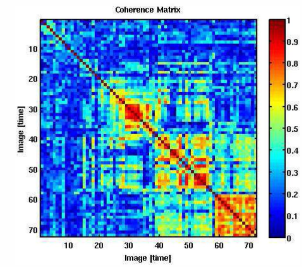


(c) Amplitude difference between two images

Figure 8 Amplitude difference example



(a) Amplitude time series (b) Amplitude change matrix



(c) Coherence change matrix

Figure 9 Ho Sheung Heung Area

Figure 8 is an example of amplitude change. It is hard to tell any difference only in the single SAR image pair because of speckle noise. But with the help of amplitude difference map, we can locate the change places in the big area. Furthermore, specific change pixels could be detected with the time series tools in Figure 9.

These are only the preliminary analysis and results of change detection with SAR data and methodology. It shows the ability of detecting urban land cover changes with more details both in temporal and spatial domain than optical images. The processing has been carried on mostly manually and is time-consuming now. In the near future, we hope to define and standardize an automatic SAR change technique for analyzing wide areas.

4. ACKNOWLEDGEMENT

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5. REFERENCES

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