OBJECT CHANGE DETECTION USING SAR IMAGES, AN EXPERIMENT OF QUANGNINH PROVINCE

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ABSTRACT:
Sentinel-1 is a two satellite constellation with the prime objectives of Land and Ocean monitoring. The goal of the mission is to provide C-Band SAR data continuity following the retirement of ERS-2 and the end of the Envisat mission. These data from Sentinel-1 are available free for downloading. Thus, my research focuses on the change detection of the objects on the land surface by using Sentinel-1 SAR image. With the supporting of the NEST free and Open source software, the images of Quangninh province Vietnam were processed in the times before and after flooding in July 2015. Some traffics lines and residential areas were changed. The results proved that the utilization of free radar image were effectively for determining the object change.

1. INTRODUCTION

The earth surface changes every day. It is widely believed that global phenomena such as the earth's increasing of temperature, deforestation and desertification, drought, flooding, and so on, are triggered by or at least accelerated by human activity. Human lives and well-being are strongly affected by the occurrence of such types of phenomena. Thus it is the main reason for land use change. Natural phenomena and man-made conditions are in fact dynamic processes that interact with and affect each other in many different ways (Jensen, 2005). Measuring and documenting these dynamic processes can facilitate a deep understanding of the global changes occurring and consequently, contribute to the development of better strategies for maintaining and sustaining the planet. As it known that, change detection can be carried out using either passive optical images or active radar images. But in the Asian countries, the cloud is the big issue in acquiring optical data. Radar images are independent of solar illumination and atmospheric conditions. Radar can penetrate haze, smoke, conditions normally encountered in the urban environments. Change detection using multi temporal SAR images has been increasingly used in various areas of application, including the studies of flooding (e.g., Martinis et al., 2011; Giustarini et al., 2013) and deforestation (e.g., Phua et al., 2008; Servello et al., 2010), as well as damage assessment (e.g., Bovolo and Bruzzone, 2007a; Brunner et al., 2010). In addition, SAR images have also been used in the field of urban change detection (e.g., Grey et al., 2003; Gamba et al., 2006; Liu and Yamazaki, 2011; Du et al., 2012;Qin et al., 2013). In this paper we would like to use the free Sentinel -1 data for change detection of Quang Ninh province where there big flood happened in 29th July 2015 and caused many change in the objects like roads or house…

2. METHODOLOGY

This paper gives an overview of SAR change detection methods and experiment of Sentinel imagery for Quang ninh province in 2015. Generally there are two basic methods: post-classification and pre-classification methods. Post-classification change detection takes place after classification into land cover or land use. Pre classification techniques operate on the images divided into some different techniques, such as: CFAR detection, adaptive filtering, multi-channel segmentation and hybrid methods. The research focus on non-coherent change detection techniques with pre classification techniques. In pre-classification change detection, changes are detected before classification. Our experiment used the method named CFAR detection with Adaptive filtering. The method are based on the ratio image, which is obtained by dividing the after event image by the before event image. Dividing images is preferred above differencing, in which the images are subtracted (Rignot and van Zyl 1993). In this research we applied the CFAR detection integration with adaptive filter.

2.1 Constant False Alarm Rate CFAR and adaptive filter

2.1.1 Constant False Alarm Rate (CFAR) Detector

The detector used in pre-screening operation is the two-parameter constant false alarm rate (CFAR) detector. The basic idea is to search pixels which are unusually bright when compared to pixels in surrounding area.

Let *xt* be the pixel under test and *T* be a given threshold, then the detection criterion can be expressed as

$$Xt > T \iff TARGET \qquad (1)$$

Let *f(x)* be the land clutter probability density function and *x* range through the possible pixel values, then the probability of false alarm (PFA) is given by

$$PFA = \int_T^{\infty} f(x)dx \qquad (2)$$

and the above detection criterion is equivalent to the criterion below

$$PFA - \int_{xt}^{\infty} f(x)dx < PFA \iff TARGET \qquad (3)$$

If Gaussian distribution is assumed for the land clutter, the above detection criterion can be further expressed as

$$x_t > \mu_b + \sigma_b t \iff TARGET \qquad (4)$$

where μ_b is the background mean, σ_b is the background standard deviation and t is a detector design parameter which is computed from PFA by the following equation

$$PFA = \frac{1}{2} - \frac{1}{2} erf\left(\frac{t}{\sqrt{2}}\right) \qquad (5)$$

The valid PFA value is in range [0, 1].

In real implementation of the two-parameter CFAR detector, a setup shown in Figure 1 is employed. The target window contains the pixel under test, the background "ring" contains pixels for estimating the underlying background statistics while the guard "ring" separates the target window from the background ring so that no pixels of an extended target are included in the background ring. The background mean μ_b and the standard deviation σ_b used in the criterion are estimated from the pixles in the background ring.

In case that the target window contains more than one pixels, this operator uses the following detection criterion

$$\mu_t > \mu_b + \sigma_b t \iff TARGET \qquad (6)$$

where μ_t is the mean value of pixels in the target window. In this case, t should be replaced by $t\sqrt{n}$ (where n is the number of pixels in the target window) in the PFA calculation.

2.1.2 Adaptive Threshold Algorithm

The object detection is performed in an adaptive manner by the Adaptive Thresholding operator. For each pixel under test, there are three windows, namely target window, guard window and background window, surrounding it (see Figure 1).

Normally the target window size should be about the size of the smallest object to detect, the guard window size should be about the size of the largest object, and the background window size should be large enough to estimate accurately the local statistics.

The operator

- First computes detector design parameter t from user selected PFA using equation above.
- Then computes background mean μ_b and standard deviation σ_b using pixels in the background ring.
- Next computes the mean value μ_t of the target window.
- If $\mu t > \mu_b + \sigma_b * t$, then the center pixel is detected as part of an object, otherwise not an object.
- Move all windows by one pixel to detect the next pixel.

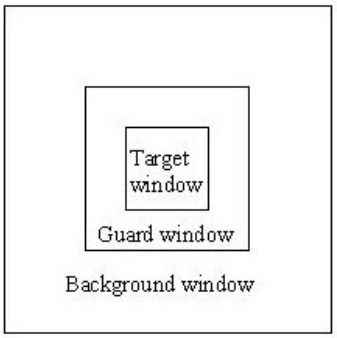


Figure 1. Window setup for adaptive thresholding algorithm.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Image preparation

Quangninh is a large province along the north eastern coast of Vietnam. The province is home to Hạ Long Bay, aWorld Heritage Site. The provincial capital is Hạ Long. Nearly 80% of the province is mountainous with abundant land, forest water and mineral resources.

In 2015 Quangninh had worst rainfall and flood in 40 years. The average rainfall was 1500 mm since July 23rd – July 29th 2015 which was the main reason made worst flood in the life of many local residents. The rainfall and flood had damaged more less 100 million USD, it had destroyed many main road connect throughout Quang Ninh province on number 18 National Road, beside rainfall and flood had have isolated several villages on the high land, even worst flood in the sunken area, destroyed many rice field, vegetables, more than 23 people killed by the landslide or flood and 4000 houses were sunk in flood, water provided main pipe of Dien Vong water work company to Ha Long City and Cam Pha City was broken, 16 coal mines were in flood to result in whole Quang Ninh Coal Industrial have stopped produce to rescue these coal mines.

In our research we used the Sentinel-1 images at two different times, the first image is acquired on 2015 July 12th and the second one is 2015 August 17th

Sentinel-1 is a space mission funded by the European Union and carried out by the ESA within the Copernicus Programme, consisting of a constellation of two satellites. The payload of Sentinel-1 is a Synthetic Aperture Radar in C-band that provides continuous imagery (day, night and all weather). The characteristics of the Sentinel-1 data used in the current study are shown in Table 1.

Table 1: Data source for experiment

No	Characteristics of data Sentinel-1		
	Data Polarization	Acquisition time	Processing Level
1	VV	12/7/2015	Level 1
2	VV	17/8/2015	Level 1

The region of interest for objects detection is illustrated in Figure 2

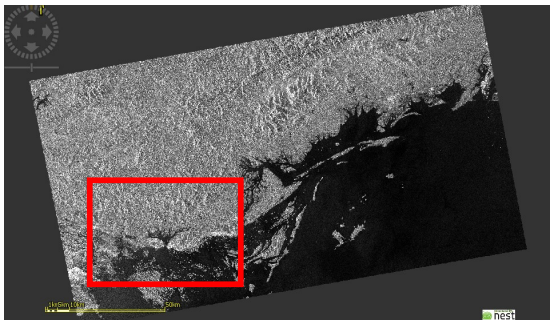


Figure 2: Sentinel image of Quangninh province

3.2 Experimental results and analysis

Processing steps for Sentinel-1 image is shown in Figure 3.

Major Processing using Constant False Alarm Rate CFAR and adaptive filter
The object detection operation consists of the following four major operations and can be illustrated in the Figure 3

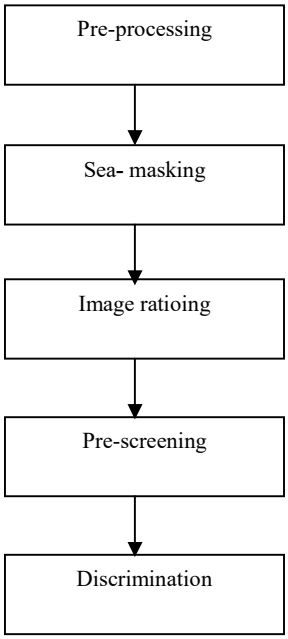


Figure 3: The flowchart of processing for object change detection

a. **Pre-processing:** Calibration is applied to source image to make further pre-screening easier and more accurate.

The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the radar backscatter of the scene. Though uncalibrated SAR imagery is sufficient for qualitative use, calibrated SAR images are essential to quantitative use of SAR data.

Typical SAR data processing, which produces level 1 images, does not include radiometric corrections and significant radiometric bias remains. Therefore, it is necessary to apply the radiometric correction to SAR images so that the pixel values of the SAR images truly represent the radar backscatter of the reflecting surface. The radiometric correction is also necessary for the comparison of SAR images acquired with different sensors, or acquired from the same sensor but at different times, in different modes, or processed by different processors.

This Operator performs different calibrations for many type of imagery deriving the sigma nought images. Optionally gamma nought and beta nought images can also be created.

b. **Sea masking:**

A sea mask is generated to ensure that detection is focused only on the area of interest.

The Create Sea Mask operation will turn any pixels on sea into no data value. The operator will automatically download a course SRTM 5 minute DEM the first time it is used. This DEM is used to very quickly determine if a pixel is on land or in the ocean.

Alternatively, a geometry from the product could also be used. This could be a user create ROI or an imported Shape file.

c. **Image ratioing**

This step can help us separating the objects change by dividing the after event image by the before event image.

d. **Pre-screening**

Objects are detected with a Constant False Alarm Rate(CFAR) detector as mentioned above.

e. **Discrimination**

The discrimination operation is conducted by the Object Discrimination operator. During this operation, false detections are eliminated based on simple target measurements.

- The operator first clusters contiguous detected pixels into a single cluster.
- Then the width and length information of the clusters are extracted.
- Finally based on these measurements and user input discrimination criteria, clusters that are too big or too small are eliminated.

After processing the data between two different times before and after the flood, the composite image were illustrated in the Figure 4

According to the processing shown in Figure 3, with CFAR method the change of some object could be extracted by using threshold for the image.

The object changes are usually located on the roads, bunds or residential areas, compared with composited color image in Figure 4

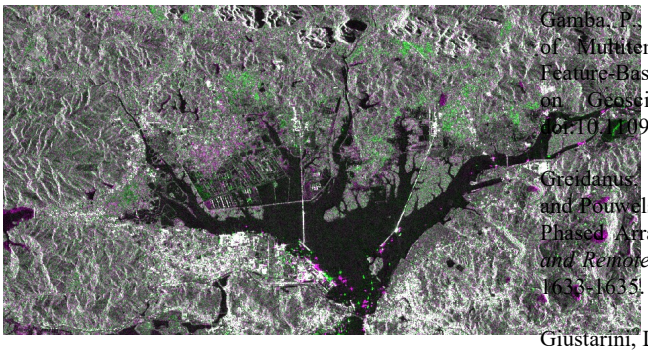
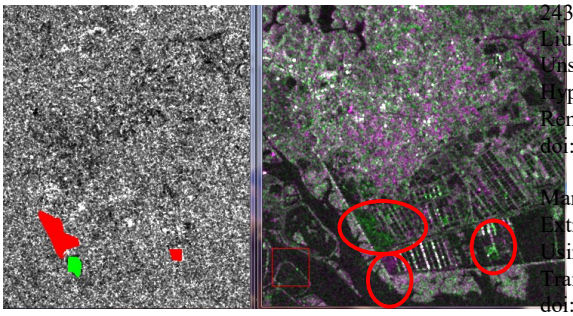


Figure 4: The composited image by before and after flood.



(a) (b)

Figure 5: (a): Ratio image and (b): composite image at the same place with ratio image

Discussion: The result shown that some object changes found in the areas that marked by the red circle. These were the water land that existed after raining, some other were changed on the roads or the boundary of farm lands. However we could not validate the result with the field check because the event happened last year and at that date there were no processing images carried out.

4. CONCLUSION

After processing Sentinel -1 radar data we concluded as follow:
The method of change detection by SAR radar for the areas like Vietnam is very suitable especially with the region effected by rain and flood. Sentinel -1 are free image that is a source of good data for many purpose.
The method is a combination of CFAR detection and adaptive filtering combines the appropriate detection of distributed and small changes, even for noisy SAR images. As a result there were some object changes found in the residential areas, roads or farm land… Although the result could not be validated, it is a good experiment for method understanding.

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