JOINT CHANGE DETECTION AND IMAGE REGISTRATION METHOD FOR MULTITEMPORAL SAR IMAGES

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ABSTRACT

This paper presents a novel method for jointly change detection and image registration over multitemporal Synthetic Aperture Radar (SAR) images. Image registration is performed based on histogram of unregistered images. Detecting the changes occur between the multitemporal images is performed based on the evolution of local statistics of the images. The local statistics are estimated using radon transform which removes the speckle noise occurs in the SAR images. Histogram curve fitting is used to approximate the radon probability distribution function (pdf) into Gaussian distribution which is on the assumption that radon pdf should obeys the central limit theorem. In order to measure the variation between the two pairs of projection pdf, the algorithm uses a local statistic similarity measure called Jeffrey divergence. Experiments results demonstrate that the proposed method can perform change detection rapidly and automatically over unregistered remote sensing images.

KEYWORDS— *Synthetic Aperture Radar (SAR) images, Change detection, Image registration, Radon transform, Jeffrey divergence.*

I. INTRODUCTION

Detecting temporal changes in the state of remotely sensed natural surfaces by observing them at different times is one of the most important applications of Earth orbiting satellite sensors, because they can provide multidate digital imagery with consistent image quality, at short intervals, on a global scale, and during complete seasonal cycles. A lot of experience has already been accumulated in exploring change detection techniques for visible and near infrared data collected by Satellites. The changes that occurred in earth surface are identified by analyzing the multitemporal images acquired at different time.

Automatic change detection [1] [2] [3] in images of a given scene acquired at different times is one of the most interesting topics in image processing. Since the Synthetic Aperture Radar (SAR) sensors are capable of acquiring data in all weather conditions and are not affected by cloud cover or different sunlight conditions, registered SAR images [4] are mainly used for change detection. In recent years, SAR change detection applications have been widely extended to environmental Earth observation, national security, and other fields.

The great prospect of change detection has led to a rapid development of techniques, such as image differencing/ratioing [5], vegetation index differencing, principal component analysis [6], and change vector analysis [7]. However, less attention has been paid to change detection with SAR images. But the change detection procedure using SAR images become difficult due to the presence of speckle noise [8][9], which is a type of multiplicative noise that often severely degrades the visibility in an image. Thus, the simple pixel-by-pixel comparison used in optical remote sensing images is ineffective; instead, alternative approaches have been proposed, based on local-statistic similarity measure.

Change detection can be performed by various methods like pixel intensity comparison, feature point matching, probability density function (pdf) comparison etc. Unlike the classical detector which is based on ratio of local means, more information can be extracted from the comparison of the local probability density functions (pdfs).

Higher order statistics include more information about the probability density function (pdf). For example, the third central moment indicates the lopsidedness, and the fourth central moment is a measure of whether the distribution is tall or short. Since the higher order statistical information has proven to be helpful, here willing to compare the local pdf. Once the pdfs are estimated, their comparison can also be performed using different criteria.

The paper is organized as follows. The overview of the proposed method is briefly presented in section II-A. Section II-B presents the image registration process. Radon transform is discussed in Section II-C. Histogram curve fitting method is described in section II-D and Jeffrey divergence is analyzed in section II-E and then experimental results are presented and analyzed in section III. Finally, conclusions and future works are drawn.

II. METHODOLOGY

A. Overview of the Proposed Method

Consider two coregistered SAR images *Ix* and *IY* acquired over the same geographical area at two different dates. Our goal is to generate a "change/no change" map identifying the changes that occurred during the two dates. The problem can be decomposed into two steps: the generation of a change indicator and the thresholding of the change image. In this paper, only focus on the first step of the procedure. The process is applied for each possible pixel position within the image area. Then, at each pair of SAR images, the following processing stages are performed.

1) *Pre-processing stage*: Image registration procedure is performed if unregistered images are selected from dataset.

2) *Radon transform stage*: Radon transform is applied to the co-registered SAR images respectively, to generate a pair of projections namely horizontal projection and vertical projection.

3) *Jeffrey divergence stage*: The Jeffrey divergence is calculated as the distance measure between the two pairs of pdf. The probability distribution functions (pdfs) used in Jeffrey divergence is approximated to Gaussian pdf by Histogram curve fitting method.

B. Image registration

The backbone of any SAR image processing task requires initial image matching and registration procedure. Intuitively, registration correctly aligns all or parts of two or more images containing the same scene. The two matched images are used to extract temporal changes in a scene, to relate differences in the appearance of a scene under differing imaging conditions, to detect parallaxes, to mosaic the images, or to create a multidimensional data set or automated analysis. The many important tasks that depend on precision registration make this a very significant problem of image processing and the analysis of multiple SLR (Single Look Radar) images. An approach has been described in the registration process of two images incorporating the difference in translation and rotation.

The most common image matching method is dimension correlation, where image windows are found that resemble one another in the two images to be matched. If the images are not matched then the image registration is performed.

C. Radon Transform

The Radon transform is the projection of the image intensity along a radial line oriented at a specific angle [10]. The resulting projection is the line integral of the pixel intensities in each direction. It is a mapping from the Cartesian rectangular coordinates (x, y) to a distance and an angle (ρ, θ) also known as polar coordinates.

For a given pixel, a new random variable is generated by averaging along a line oriented at an angle θ with respect to the x axis, and it is named as "projection variable" which is denoted by ρ. For any ρ and θ, the value of $R(\rho, \theta)$ is the amount of density that falls along the θ-line that passes within a distance ρ of the origin. For image processing, the 0° and 90° cases are chosen and these projections are called *v*-projection or vertical projection and *h*-projection or horizontal projection respectively.

Projection variable of an image f(x, y) oriented at an angle θ can be written mathematically as,

$$\rho = x\cos\theta + y\sin\theta \qquad \dots (1)$$

Radon transform of that image can be written as

$$R(\rho,\theta) = \iint_{-\infty}^{\infty} f(x,y)\delta(\rho - x\cos\theta - y\sin\theta)dxdy \quad \dots (2)$$

where $\delta(.)$ is the Dirac delta function.

Fig.1 shows the geometry of Radon transform of the image f(x,y). x' and y' is obtained by rotating image axis around the centre of the image at an angle θ degrees. R_θ (x') is the amount of distribution that falls along the θ angle that passes within a distance x' of the origin.

Fig.2 shows a single projection at a specified rotation angle. It is a parallel beam projection at rotation angle θ. For the radon transform computation,source and sensor is rotated about the center of the image having coodinates x and y. For each angle θ the distribution of the image is obtained by when the rays from the source passes through the image and it is acccumulated at the sensor. This is repeated for a given set of angles usually from θ € [0:180]. The angle 180 is not included since the result would be identical to the angle 0.

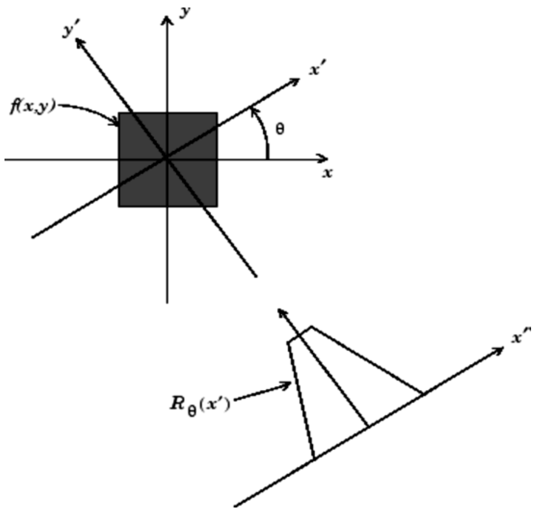


Fig. 1 Geometry of Radon transform.

In a way, by averaging the pixels, the Radon transform makes the speckle noise weak and shortens the tail. The shape of horizontal radon pdf and vertical radon pdf is much closer to the Gaussian distribution and the histogram curve fitting approximation method fits them better.

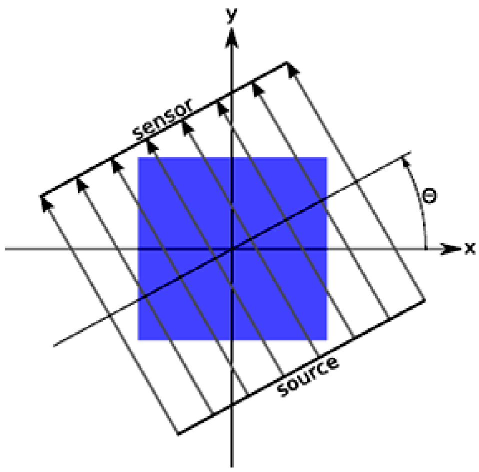


Fig.2 Parallel beam projection at angle θ.

D. Histogram curve fitting

The method called Histogram curve fitting is used to approximate Radon pdf R(ρ, θ). Histogram curve fitting succeeds based on the assumption that the density to be approximated is not too far from a Gaussian pdf, which has been satisfied after Radon transform [12]. A histogram is a way to graphically represent the distribution of data in a data set. Each data point is placed into a bin based on its value. Bin means pixel intensity range.

Histogram curve fitting plots a histogram of the values in the data is plotted using a number of bins equal to the square root of the number of elements in data, which will give a fitted normal distribution. In order to obtain the normal pdf the mean μ and standard deviation $\boldsymbol{\sigma}$ are estimated from the histogram data, and these values are substitute into the equation of the normal pdf.

Reason of using the curve fitting method is that the central limit theorem (CLT) says, the mean of a sufficiently large number of independent random variables, each with finite mean and variance, will be approximately normally distributed. Therefore, the pdf of Radon should not be too far from a normal distribution.

E. Jeffrey Divergence

Let *fx(x)* and *fy(x)* be two probability distribution function of the random variables X and Y. The Jeffrey divergence between the densities $fx(x)$ and $fy(x)$, is given by

$$J(Y/X) = \int (log\frac{fx(x)}{m(x)}fx(x) + log\frac{fy(x)}{m(x)}fy(x)) \qquad \dots (3)$$

where $m(x) = (fx(x) + fy(x))/2$.

It is an information similarity measure that calculates the divergence from one pdf with other [13]. This measure is symmetric and nonnegative; therefore, it can be used as a statistical similarity distance [14]. The Jeffrey divergence is numerically stable and robust with respect to noise and the size of the bins than that of KL divergence. Since it is a modification of the KL divergence [15], it can be written as

$$J(X, Y) = K(Z|X) + K(Z|Y) \qquad \dots (4)$$

In order to estimate the Jeffrey distance, decompose it into two KL divergences.

III. RESULTS AND DISCUSSIONS

A pair of SAR images, acquired by the Space borne imaging radar sensor taken at the Manaus, Brazil in April 1994 and October 1995, respectively is used in the experiment. In order to better understand the behavior of projection based detection, simulations have been performed.

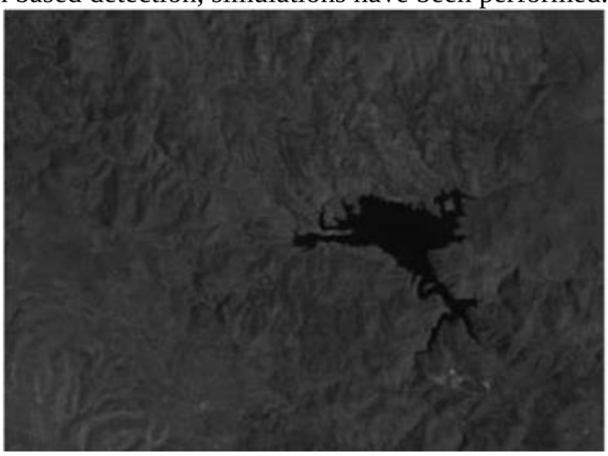
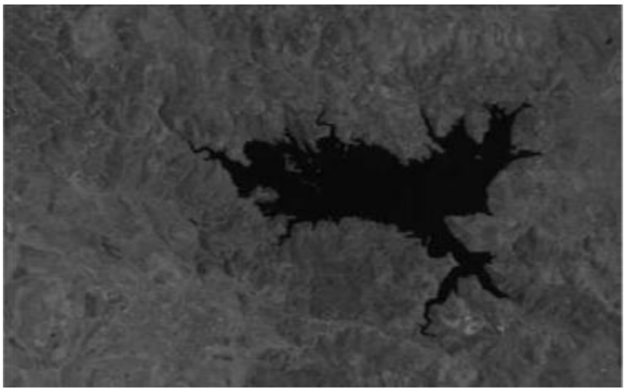


Fig 3 SAR images (a) Before change (SAR image 1)



(b) After change (SAR image 2)

Fig 3(a) and (b) are the registered SAR images. After the pre-processing radon transform is applied to both images. The resulting projection is the sum of the intensities of the pixel in each direction. The Radon pdf obtained is in random manner. It is approximated into the Gaussian pdf for statistical analysis by histogram curve fitting method. Fig 4(a) and Fig 4(b) shows the projection pdfs of SAR image 1.

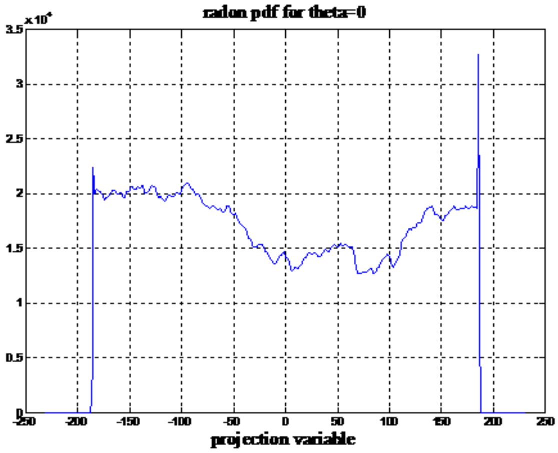


Fig 4(a) Vertical projection pdf of SAR image 1

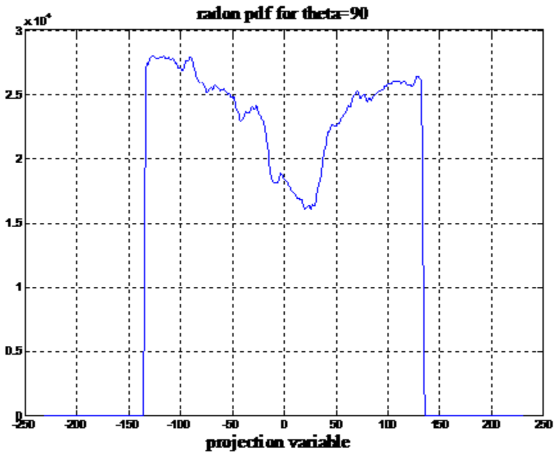


Fig 4(b) Horizontal projection pdf of SAR image 1

Fig 5(a) and Fig 5(b) shows the Vertical and Horizontal projection pdf of SAR image 2. Gaussian pdfs are obtained by the approximation of projection pdfs by using the method called Histogram curve fitting. In order to detect the changes between the SAR images, comparison of the local probability density functions (pdfs) of the homologous pixels of the pair of images are performed. Fig 6(a) and (b) shows the variation between vertical Gaussian pdfs and horizontal Gaussian pdfs of SAR images.

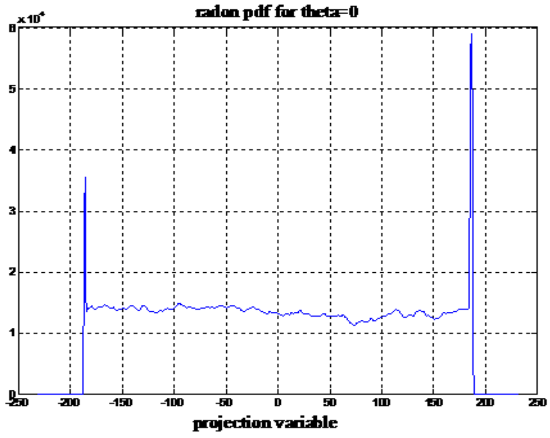


Fig 5 (a) Vertical projection pdf of SAR image 2

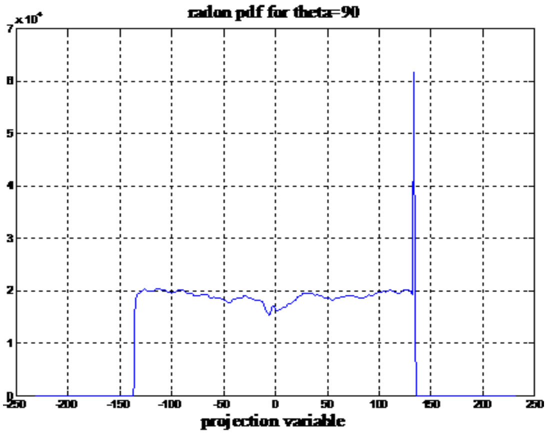


Fig 5 (b) Horizontal projection pdf of SAR image 2

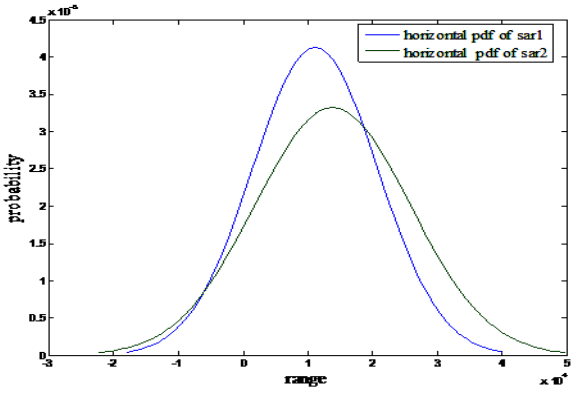
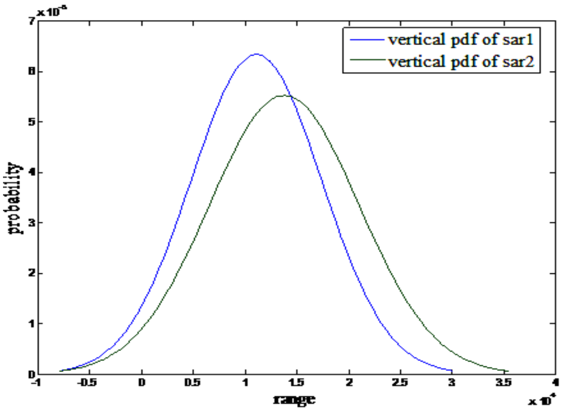


Fig 6 (a) Comparison of horizontal pdfs

As the divergence value is not equal to zero, it shows that changes have occurred. If it is equal to zero, there is no change between the images. The percentage deviation between the vertical pdfs and horizontal pdfs of the images under consideration are 13.68 % and 21.69% respectively. From the results obtained it is clear that as the value of Jeffrey divergence increased, the percentage of change between the images also increased.



(b) Comparison of vertical pdfs.

IV. CONCLUSION AND FUTURE WORKS

In this paper, a new similarity measure between images in the context of multitemporal SAR image change detection is discussed. This measure is based on the Radon transform combined with Jeffrey divergence, which removes the speckle noise generated by random fluctuations in SAR returning signals.

A divergence value between the pdfs is calculated using Jeffrey divergence, which is the similarity measure for change detection. From the results obtained it is clear that as the value of Jeffrey divergence increased, the percentage of change between the images also increased.

Some questions still remain open about the use of projection. As stated in Section II, in theory, it can detect the rotation change of the texture. It would be tested when there were appropriate data.

Some improvements could be done in order for it to be a more reliable approach by using more information rather than only the pdf of the image ie,a change map has to be created from the divergence value to visually analyze the changes between the images. All these aspects will be studied as a future development of this paper.

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