Optik 130 (2017) 114–122

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

Gabor filter based change detection in SAR images by KI thresholding

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ARTICLE INFO

Article history:
Received 1 April 2016
Received in revised form 7 October 2016
Accepted 7 November 2016

Keywords:
Synthetic aperture radar
Change detection
Difference image
Gabor filter
Kittler-Illingworth thresholding

ABSTRACT

In this paper, automatic change detection (CD) method using Gabor filter is proposed for Synthetic Aperture Radar (SAR) images. Fixed sized Gabor filter is designed using its parameters. CD involves two SAR images; hence a difference image is generated by logarithmic ratio of two images. Dot product is performed between Gabor filter in row vector format and local window of the difference image in column vector format to localize boundaries of the changed area accurately. Kittler- Illingworth thresholding algorithm is exploited to produce a binary change map to discriminate changed and unchanged pixels. Experiments are carried out to validate the effectiveness of the algorithm with and without preprocessing speckle removal filters. Experimental results obtained on SAR images acquired by the ESA Envisat, ERS-2 and ERS-1 satellites show the achievement in terms of quality metrics such as low false alarm rate, high CD accuracy and less computational time. It shows the efficacy of the proposed algorithm when speedy detection is required during natural calamities.

1. Introduction

Monitoring and detecting the changes occurred on the remote places of the earth during specified time intervals is becoming active research area. To alleviate the detection process, active remote sensor is used. Particularly, Synthetic Aperture Radar (SAR) got the attention due to its inherent capacity of acquiring data at all weather conditions and at all times [1]. The process of detecting changes occurred over specified time interval on the same area in two SAR images is called change detection [2]. CD can be carried out either in spatial or in transform domain.

In spatial domain, numerous CD techniques have been implemented with different strategies. Final binary CD map is generated by using either thresholding or clustering technique. In [3], Bazi et al. presented an unsupervised CD approach using modified Kittler-Illingworth (KI) threshold under the assumption of Generalized Gaussian model. It has the following steps: preprocessing for noise removal, log ratio difference image generation and thresholding for discriminating changed and unchanged classes. This threshold based method does not exploit spatial contextual information for the correct estimation of changed and unchanged statistics [3]. In [4], Wang F. et al. proposed CD method based on the Triplet Markov Field (TMF) model. TMF method can achieve better detection result with a high detection rate and a low false alarm rate but takes more computing time. In [5], O. Yousif et al. considered a Non Local Means (NLM) denoising algorithm to ease the CD process in urban areas. Principle Component Analysis (PCA) was then used to reduce the dimensionality of its neighborhood feature vectors. The performance of the PCA-NLM algorithm was slow due to its high computational complexity.

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http://dx.doi.org/10.1016/j.ijleo.2016.11.040
0030-4026/

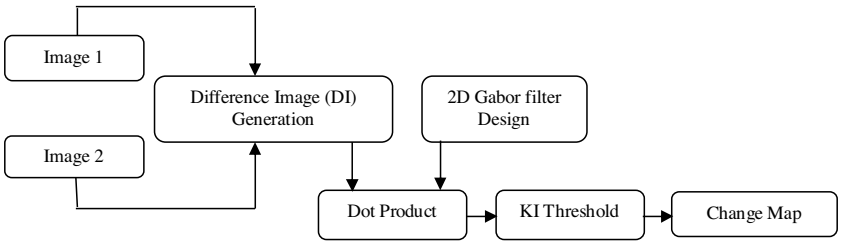

Fig. 1. Flowchart of proposed change detection work.

Under clustering framework, in [6], unsupervised CD algorithm was proposed using Principal Component Analysis (PCA) and K-means clustering. Equal sizes of non overlapping blocks were formed in an image. Eigen vectors were extracted for those blocks. Then the feature vectors were extracted by projecting Eigen vector into non overlapping block. K- means algorithm was employed to discriminate the feature vectors in to changed and unchanged groups. Recently, in [7], unsupervised CD approach using Gabor wavelet representation was proposed. Gabor wavelets were employed to log ratio difference image (DI) at multiple scales and orientations. Feature vectors were formed by concatenating maximum magnitude over all orientations in each scale. Features were discriminated in to changed and unchanged classes by using two level clustering algorithms. This cascading algorithm combines fuzzy c-means clustering with the second level nearest neighbor rule. Tuning of Gabor filter parameters was required to achieve satisfactory results for different datasets. Even all the methods yield effective results yet there is a need for developing novel techniques.

Computationally simple yet effective CD algorithm is needed with good detection efficiency to monitor changes occurred during disaster time. This work focuses on the effectiveness of Gabor filters in CD applications using thresholding technique. Gabor function is exploited for finding precise edge direction. Dot product of filter response and local window of the DI make it suitable for linear structure extraction. It has good localization and edge direction finding techniques and to produce low false alarms. Then Gaussian based KI automatic thresholding technique discriminates pixels into two classes namely changed and unchanged. KI threshold simplifies the computational burden by employing Gaussian instead of Generalized Gaussian (GG) model. This approach differs from previous approaches mainly in the way the filter response is computed and exploiting thresholding instead of clustering technique.

The paper is organized as follows: Section 2 describes the proposed change detection approach and briefly explains the theoretical background describing generation of Difference Image, Gabor filter design, Kittler-Illingworth Thresholding. The experimental results are discussed in Section 3. Finally, conclusion is drawn in Section 4.

2. Proposed change detection approach

This section explains the proposed algorithm used for detecting changes in SAR images and deals with the DI generation, Lee filter, Gabor filter design and KI thresholding technique used for developing the proposed methodology. In the proposed method, change detection in SAR images is carried out in the spatial domain. If both SAR images have the same edge information, then that edge information is nullified in DI and contains only change information and speckles. Consider DI of size MxN, consider a Gabor filter of size nxn, dot product of the vectors 'a' and 'b' is calculated. Vector 'a' is a row vector equivalent of filter mask and 'b' is a column vector equivalent of the local window of the DI. Repeat the process by sliding the window sequentially from top left corner of the image to bottom right corner of the image by a pixel. It gives the leading change direction if the center of the filter is placed on changed pixel. Then binary discrimination of changed and unchanged pixels is done by using minimum error KI thresholding method. The detail flowchart depicting the proposed system is shown in Fig. 1.

2.1. Difference image (DI)

Two co registered SAR images I1 and I2 with a size of MxN, acquired at different time instants on the same geographical area are considered. DI is generated by taking absolute valued logarithm ratio using I1 and I2 images. Logarithmic operator is used to compress the dynamic range of variation of the ratio image and to balance the values of the pixel lesser or greater than one.

$$DI = |log\frac{I_2}{I_1}| = |logI_2 - logI_1| \quad (1)$$

where log denotes natural logarithm.

2.2. Gabor filter design

Lee filter is used for preprocessing step to remove noise [8]. It is carried out on DI and the performance of the proposed method is tested with and without Lee filter. Gabor filter function closely resembles to the processes in the human visual