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Research Article

A Noise Reduced FCM-Thresholding Method for Change Detection

Neenu Susan Mathew†* and Abraham Thomas†

†Department of Electronics and Communication Engineering, St. Joseph's College of Engineering and Technology, Palai, India

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Abstract

Change detection is a major application in remote sensing. In this paper, we put forward a novel approach for change detection in synthetic aperture radar images. The approach classifies changed and unchanged regions by fuzzy c-means(FCM) clustering with thresholding. Here we compare the proposed method with MRFFCM which is a modified version of FCM with a novel Markov Random Field (MRF) energy function. Images with speckle noise will results in reducing the contrast of image and is difficult to perform image processing operations like edge detection, segmentation etc.… First, in order to reduce the effect of speckle noise, we introduce a noise reduction technique. A Lee filter is used to remove speckle noise as adaptive filters are more likely to preserve details such as edges or high texture areas. Second, the proposed approach modifies the result of FCM clustering by applying a threshold. In fuzzy c-means clustering the segmented part of the SAR image is not clearly visible. We use global thresholding method and the entire image is segmented using Otsu's thresholding method. We also compare the results of clustering.

Keywords: *Change detection, segmentation, FCM, Otsu's thresholding, Lee filter.*

1. Introduction

In remote sensing applications, change detection is the process intended at identifying differences in the state of a land cover by analyzing a pair of images acquired on the same geographical area at different times. Such a problem plays an important role in many application. Some such applications are described below:

- **Updating Map**: "On demand and timely updating" has become a general pattern of geographic information updating. The change information across the country is a need to be acquired in a short time before updating plans being developed. Change information detection and extraction is a key point to "on demand and timely updating", especially for decision-making department of fundamental geographic data. Change detection with remote sensing images provides a suitable way to access these change information. The latest image and the image at the same time as geographic data that need to be updated are used to detect change information about geographic features. The fundamental geographic data such as various scales topographic maps of the regions which have changed dramatically should be selected to be updated. In this way regions which need to be updated can be quickly located. If the updating cycle time of geographic data is accelerated, the up-to-date state of geographical data is improved.
- **Flood Monitoring**: Floods are among the most severe risks on human lives and properties. Proper monitoring of floods can be used for planning and operation of civil protection measures (e.g. dams, reservoirs) and for early flood warning (evacuation management).
- **Sea Ice Navigation**: Radar extracted sea-ice information can satisfy operational needs for navigation, offshore operations and weather forecasting.
- **Change Detection in Forest Ecosystems:** Monitoring techniques based on satellite-acquired data have demonstrated potential as a means to detect, identify, and map changes in forest.

Several supervised and unsupervised techniques are used for detecting changes in remote sensing images. Supervised methods require the availability of 'ground truth' which is used to derive a training set containing information about changes that occurred in the considered area between the considered dates. Unsupervised method performs the change detection without any additional information besides the raw images (L. Bruzzone *et al*, 2002)

Change detection in unsupervised technique is usually divided into three main steps:

- Preprocessing: Change detection algorithms usually take two digitized images as input and perform preprocessing steps like geometric corrections or co-registration.

*Corresponding author: **Neenu Susan Mathew**

- Image comparison: The two co-registered and corrected images are compared pixel by pixel to generate the difference image (DI). The difference image is computed in such a way that the pixels associated with land-cover changes present graylevel values significantly different from those of pixels associated with unchanged areas.
- Analysis of DI: Land-cover changes can be detected by applying a decision threshold to the histogram of the difference image. The selection of the decision threshold is of major importance as the accuracy of the final change detection map depends on this choice.

Rest of the paper is organized as follows: Section 2 summarizes the system model. Section 3 describes the methodology and design in detail. Results and discussion in section 4 and paper is concluded in section 5.

2. System Model

The block diagram of system model is given in Fig: 1. The two input images are preprocessed, DI is generated and analysis is carried out.

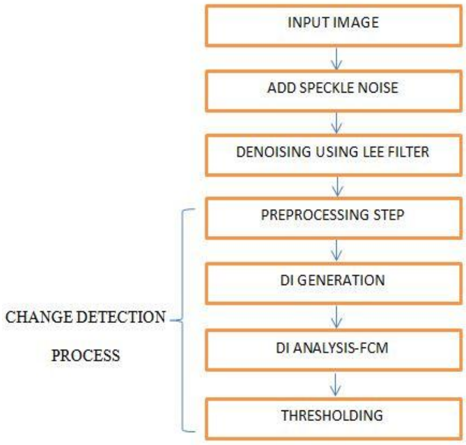

Fig.1: Block diagram of system model

Speckle noise degrades the quality of Synthetic Aperture Radar images and thereby reducing the ability of a human observer to discriminate the fine details of investigative examination. Images with speckle noise will result in reducing the contrast of image and difficult to perform image processing operations like edge detection, segmentation. Speckle noise is dominant in SAR imagery and makes it difficult to discern the two classes. It is important to cope up with speckle noise.

3. Methodology and Design

3.1Image Acquisition

Ottawa Dataset: It is a section of two SAR images over the city of Ottawa acquired in May and August 1997 and presents the area where they were once afflicted with floods.

Mar Chiquita dataset: Mar Chiquita is the largest of the naturally occurring saline lakes in Argentina. The image taken for analysis is taken in1988 and 2011.

Landslide near Oso, Washington: On March 22, 2014, a massive landslide occurred in the Cascade Mountains near Oso, Washington. The images taken for analysis is that taken on January 18, 2014 and March 23, 2014.

3.2 Denoising

Speckle noise is added in the first stage and denoising is performed using Lee filter.

Lee Filter: Speckle suppression uses filtering methods; namely adaptive and non-adaptive filters. Adaptive filters uses weights that are dependent on the degree of speckle in the image. A non-adaptive filter uses the same set of weights over the entire image. Adaptive filters are more likely to preserve details such as edges or high texture area (eg: forest or urban areas) because the degree of smoothing is dependent on local image statistics.

Best non-adaptive filters are those based on the use of the mean or the median. Median is more effective than mean in eliminating speckle noise while retaining sharp edges. In comparison with non-adaptive filters adaptive speckle filters are more successful in preserving subtle image information. The effectiveness of adaptive filters is dependent on the following 3 assumptions:

1) SAR speckle is modeled as a multiplicative noise
2) The noise and signal is statistically independent
3) The sample mean and variance of a pixel is equal to its local mean & variance computed within a window centered on the pixel of interest.

The lee filter is basically used for speckle noise reduction. Gray level value R for the smoothed pixel is given by:

$$R = I_c * W + I_m(1 - W)$$

where W is the weighting function, I_c =central pixel of filter window, I_m =mean intensity with filter window.

3.3 Preprocessing

The initial step of change detection procedure is preprocessing. It involves geometric corrections, co-registration etc.... Image co-registration is the process of geometrically aligning two or more images to integrate or fuse corresponding pixels that represent the same object.

3.4 DI Generation

Difference image is generated using log-ratio method. This part is also known as image comparison in which the two images are compared pixel by pixel. For DI generation step log-ratio operator is often used because of its robustness.

3.5 DI Analysis

The analysis step can be viewed as image segmentation in which the changed area/land cover is segmented. The analysis is carried out using FCM modified with MRF energy function and FCM-Thresholding method which is the proposed method.

3.5.1 Procedure for MRFFCM

MRFFCM improves FCM by modifying the membership of each pixel. An image can be viewed as a field, and each pixel of image is an element.

1. Derive the mean μ_i^1 and the standard deviation σ_i^1 of the two classes through the KI method[3]. The initial membership matrix u_{ij}^1 is generated by utilizing the original FCM algorithm unmodified (i = u, c).

2. Establish the energy matrix E_{ij}^k. This step is the key step to utilize the spatial context.

3. Using Gibbs expression, compute the point wise prior probabilities of the MRF, and get the point wise prior probability matrix π_{ij}^k

$$\pi_{ij}^k = \frac{\exp(-E_{ij}^k)}{\exp(-E_{uj}^k) + \exp(-E_{cj}^k)}$$

4. Compute the conditional probability p_i^k and then, generate the distance matrix d_{ij}^k

5. Compute the objective function J_{ij}^k as given below, where I_X denotes the DI generated by the log-ratio operator. In case of convergence, exit and output u_{ij}^k; otherwise, go to 6.

$$J_{ij}^k = \sum_{i=u,c} \sum_{j \in I_X} (u_{ij}^k)^2 (d_{ij}^k)^2$$

$$\left| J_{ij}^k - J_{ij}^{k-1} \right| \le \delta$$

6. Compute the new membership, generating the new membership matrix u_{ij}^{k+1}, which is to be used in the next iteration process.

$$u_{ij}^{k+1} = \frac{\pi_{ij}^k \exp(-d_{ij}^k)}{\pi_{uj}^k \exp(-d_{uj}^k) + \pi_{cj}^k \exp(-d_{cj}^k)}$$

7. Update the mean and the standard deviation as μ_i^{k+1} and σ_i^{k+1}, respectively, as is given below. k: =k + 1. Then, return to 2:

$$\mu_i^{k+1} = \frac{\sum_{j \in I_X} (u_{ij}^k y_j)}{\sum_{j \in I_X} u_{ij}^k}$$

$$\sigma_i^{k+1} = \sqrt{\frac{\sum_{j \in I_X} \left[u_{ij}^k \left(y_j - \mu_i^{k+1} \right)^2 \right]}{\sum_{j \in I_X} \left(u_{ij}^k \right)}}$$

3.5.2 FCM-Thresholding

Otsu's Thresholding: The segmented output of FCM is not visible clearly, so we apply Otsu's thresholding to the output of FCM to get a better thresholding.

4. Results and Discussions

Simulation is done using MATLAB. MATLAB stands for matrix laboratory. For technical computing, it is a high-performance language.

This project describes a FCM-Thresholding method for change detection. The results show that the proposed method shows good segmentation. This method also reduces the effect of speckle noise by the use of adaptive filters. The simulation results are tabulated as given below:

Table 1: Comparison of entropy values for FCMMRF & FCM-Thresholding for different datasets.

Dataset	MRFFCM Entropy	FCM-Thresholding Entropy
Ottawa	0.7559	0.5582
Mar Chiquita	0.8747	0.8027
Landslide	0.9329	0.8822

Entropy is a metric that's a measure of the amount of disorder in a vector. Smaller values of entropy indicate less disorder in a clustering, which means a better clustering. The clustering results of MRFFCM and FCM-Thresholding are shown in the following figures.

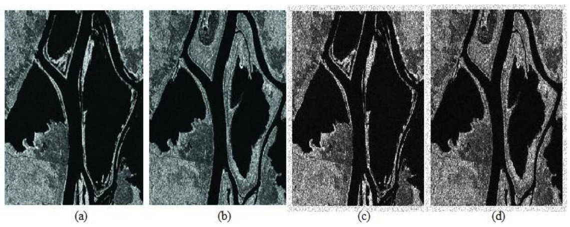

Fig.2: (a) Input image1 (b) Input image2 (c) Noisy image1 (d) Noisy image2

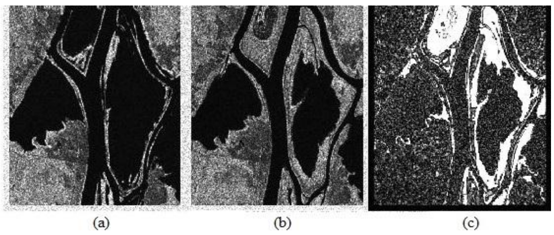

Fig.3: (a) Denoised image1 (b) Denoised image2 (c) Difference image

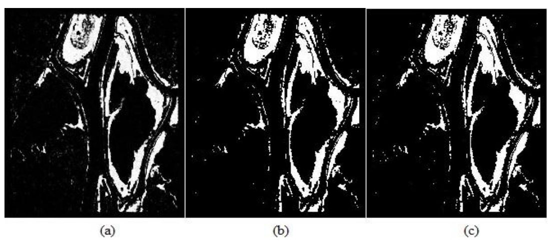

Fig.4: Clustering Results (a) FCM (b) MRFFCM (c) FCM-Thresholding

Conclusions

In this paper, a new approach for change detection on sar images based on noise reduced FCM-Thresholding is proposed. FCM-Thresholding method gives a better segmentation results than that obtained with MRFFCM method. The change map obtained by FCM is not clear and detection cannot be determined. Even if the segmented results are similar visually, the time required to carry out the method is less in the proposed method. We will show that, this method can provide better segmentation than the existing method.
In addition to that a method to reduce the speckle noise present in SAR images is also incorporated. In future, we can increase the efficiency of fuzzy clustering by combining with other algorithms.

Thus we conclude that the proposed system has low noise, better clustering and less computation time.

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