Unsupervised Change Detection in SAR Image based on Contour let Fusion and Guided Filter

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Abstract

A novel approach to unsupervised change detection method in synthetic aperture radar (SAR) images based on image fusion and compressed projection. Different types of terrain changes can be identified by using SAR images. First, proposed approach to generate a difference image by using Gauss-log ratio. The Gauss-log ratio operator is proposed to obtain a stable and clear difference map. In order to make better use of the Gauss-log ratio operator and log-ratio operator, this paper introduces a fusion strategy to generate a fused difference image based on Contour let Transform and Guided filter. Second non subsampled contour let transform (NSCT) to reduce the noise in the fused difference image and compressed projection is employed to extract feature for each pixel, improve the performance of the subsequent clustering or classification, NSCT model is used to suppress noise of the image and keep shape of the changed portion. The final change detection map is obtained by partitioning the feature vectors into "changed" and "unchanged" classes using simple k-means clustering. At last the experiment shows the performance evaluation of the different fusion strategy, using the PSNR value.

Keywords: Discrete Wavelet Transform (DWT), Ratio Operators, Non subsampled contour let transform (NSCT), Guided Filter, K-mean clustering

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I. INTRODUCTION

In a geographical area at different times to identify the changes because of earthquake, crop growth condition, deforestation, etc. Synthetic aperture radar (SAR) is an active microwave coherent imaging radar, so it can acquire remote sensing data under all weather and all days which can make up for the shortage of optic and infrared remote sensing. SAR images suffer from the presence of speckle noise, so the images are not being clear. The SAR images cannot be clear so about the form of fusion in order to remove the noise in different images. Image fusion via DWT (Discrete Wavelet Transform) [1] and denoising via NSCT [2] in SAR image based on gauss log ratio operator. The ratio operators are two log ratio operator and gauss log ratio operator [3]. The denoised image gives to compressed projection [4] for each pixel because of reducing the dimensionality. In order to base on Gauss-Log ratio operator is proposed to obtain a stable and clear difference map. The difference map is obtained by the fusion strategy based on Contourlet transform and Guided Filter. Nonsubsampled contourlet transform (NSCT) is used to suppress noise of the image and keep shape of the changed portion [5]. Radar is an object-detection system. So it uses radio waves to determine the range of the object, altitude, direction of the object, or speed of objects. It can be used to detect aircraft, ships, pacecraft, guided missiles, motor vehicles, weather formations, and terrain. The ratio operator is robust to calibration and radiometric errors. The multiplicative nature of speckle in SAR images, the log-ratio operator is often used to generate a difference image, which can reduce the influence of speckle noise theoretically. The Contourlet Transform (CT) [6] is a new two dimensional representation for images that can capture the intrinsic geometrical structure of pictorial information.

The Guided Filter [7] generates a filtering output by considering the content of a guidance image, which can be the input image itself or another different image. The another method of image fusion is the DWT shows four sub-bands LL, LH, HL, HH [8]. LL and LH are the low frequency subbands HL and HH are the High frequency subbands. Low frequency subband represent the profile feature of the source image. The three high frequency subbands denotes horizontal, vertical, and direction portion show the information about the salient features of the source image such as edges and lines. Fusion rule represent the different feature information of source image. Algorithm of image fusion based on wavelet transform [9]. The wavelet fusion can be identified by the change detection of SAR images [10]. The (PCA) Principle Component Analysis [11] is based on the ratio operators to be identified. But use the compressed projection is better than the PCA. The denoised image is to be compressed means reducing the dimensionality. The multitemporal satellite image is to be identified is in the form of SAR images.

The fused image have some noise are present, so reducing the noise using NSCT, it can sufficiently capture the geometrical details of the image and the object information and the edge well. The subband image have high and low frequency. The coefficient in low frequency subband remains unchanged and once the high frequency directional subband at different scales are suppressed with a threshold value. To give a threshold value that threshold value remins unchanged otherwise the coefficient are set it as zero. The ratio operator is robust to calibration and radiometric errors. In geographical area at different times to identify the changes because of earthquake, crop growth condition, deforestation, etc. Synthetic aperture radar (SAR) is active microwave coherent imaging radar, so it can acquire remote sensing data under all weather and all days which can make up for the shortage of optics and infrared remote sensing.

II. METHODOLOGY

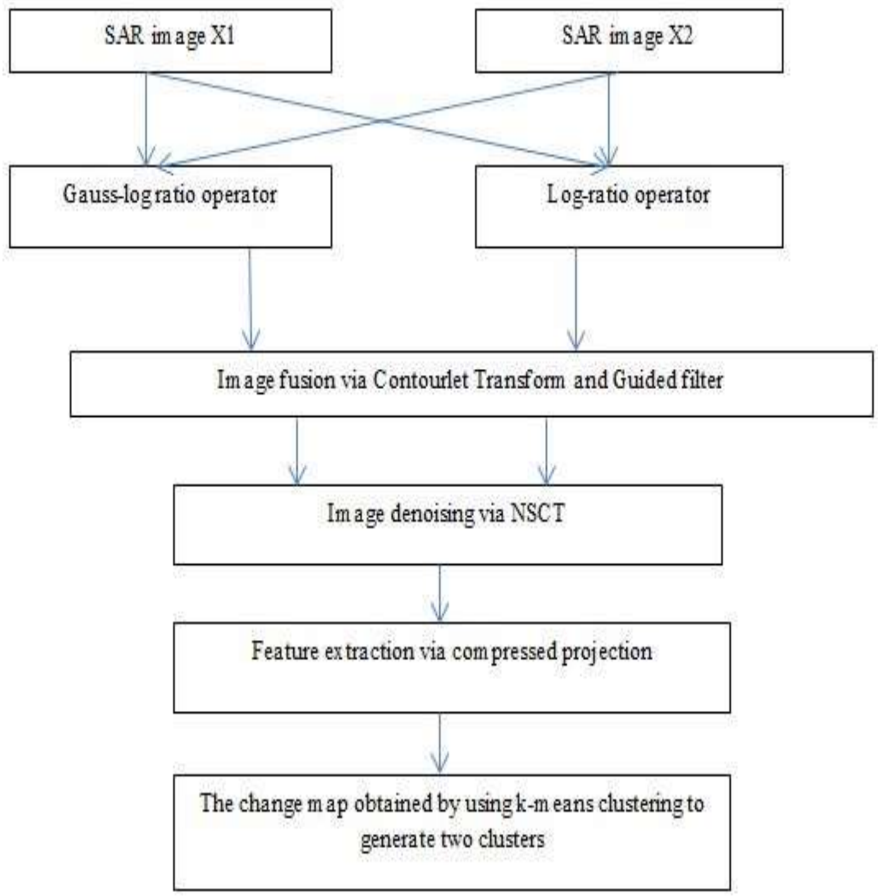


Fig. 1: Block Diagram

SAR (Synthetic aperture radar) is a form of radar, which is used to create image of an object such as landscape these images can be a 2D or 3D representation of the object. Radar is an object detection system it can acquire the uses of radio waves to determine the range, altitude, direction, or speed of the objects. It can be used to detect aircraft, spacecraft, guided missiles, motor vehicles, weather formations, and terrain to detect as changes. The detailed explanation of Fig. 1 given below.

A. Read Input Images

In this module first take two input images of SAR, this means in geographical area at different time to take image at same time.

B. Apply Ratio Operators

After reading the input images the ratio operator is to apply in both images. Ratio operator means widely used technique to obtain a stable and clear difference image. Two ratio operators are Gauss-log ratio operator and Log ratio operator. Log ratio operator means it converts the liner scale of SAR data to a logarithmic scale before the differencing operation. The logarithmic scale to enhance low intensity pixels, by log ratio image cannot completely reflect the real change trends because of those areas of high intensity pixels. Gauss log ratio operator means Gaussian law pass filter is used in order to make changed portion more homogeneous and it is stable and clear image is obtained. The Gauss-log ratio operator can obtain the expected difference image, the unchanged portion in SAR images is also enhanced, which leads to the error detection. In order to suppress the influence of the enhancement of unchanged portion in SAR image on changed one, the absolute valued log-ratio operator is used to generate the second difference image.

$$X_d = |\log \frac{X2}{X1}| = |\log X_2 - \log X_1| \qquad (1)$$

Where Equation (1) is the logarithmic scale, log stands for natural logarithm. The pixel values of the difference image **X**d are normalized into [0, 1]. The unchanged portion in the difference image obtained by absolute valued log-ratio operator is relatively more uniform, whereas the changed one behaves like inhomogeneity. For the two difference images, we use image fusion strategy based on contourlet, guided filter and the local contrast to generate a better difference image.

The imaging system of SAR is based on coherence radiation, SAR images are inherently degraded by multiplicative speckle. Hence, the unchanged portions in multi temporal SAR images acquired at the same geographical area also have a little difference, which usually results in many fractional regions not belonging to the real change portions in the detection result, whereas the changed portions usually lack the integrity during the subsequent clustering or classification because of the speckle. So, use the rotationally symmetric Gaussian low-pass filter G to reduce the above mentioned fractional regions and make the changed portions more homogeneous. On the other hand, we hope the contrast between the changed and unchanged portions (the background) in the difference map should be enhanced. Compared with, $| X_{1r} (i, j) - X_{2r} (i, j) |$if the pixels in the map belong to the unchanged portions, $X_r (i, j)$ is increased by a small margin after performing double summation operation in, whereas $X_r (i, j)$ is increased by a large margin if they belong to the changed portions. Hence, the edge features of the changed portions in the difference image are enhanced.

C. Image Fusion

In this module shows an image fusion of the two SAR images, after applying the ratio operators of both images. This fusion strategy is applied by using contourlet transform and guided filter these are the proposed method. Contourlet transform is a two dimensional representation for images that can capture the intrinsic geometrical structure of pictorial information. The guided filter generates the filtering output by considering the content of a guidance image, which can be the input image itself or another different image. The existing method is the image fusion via DWT, this much not get changed area.

D. Contour let Transform

Wavelets can pick up discontinuities of one dimensional piecewise smooth functions very efficiently and represent them as point discontinuities. When it dealing with the images characterized by a one-dimensional discontinuities, and classical two-dimensional wavelets transform, which are separable products of one-dimensional wavelets, can no longer claim to be sparse representation. Contourlets are based on an efficient two-dimensional non separable filter bank that can deal effectively with images having smooth contours are availabe. Contourlets not only possess the main features of wavelets (namely, multiresolution and time-frequency localization,) but also show a high degree of directionality. Contourlet-based fusion method performs better than the conventional wavelet-based fusion methods in terms of both spatial and spectral analyses. Third, conducted an analysis on the effects of the image decomposition level and observed that the decomposition level of 3 produced better fusion results than both smaller and greater number of levels.

The contourlet transform consists of two major stages: the subband decomposition and the directional transform. The first stage is the Laplacian pyramid that decomposes into a number of radial subbands for each images, and for the second one we used directional filter banks (DFB) for each LP detail subband is fed to this stage to be decomposed into a number of directional subbands. The LP decomposition at each step generates a sampled low frequency of the original and the difference between the original and the prediction of the frequency, resulting in a bandpass image. Those bandpass images into a DFB that directional information to be well captured. The scheme can be iterated repeatedly on the coarse image. The end result is decomposition into directional subbands at multiple scales. The scheme is flexible since it allows for a different number of directions at each scale. Fig 3. Is the pyramidal directional filter bank (PDFB).

E. Guided Filter

Fig. 2 shows the process of guided filter, the source images are first decomposed into two-scale representations by average filtering. The base layer of each source image is obtained as follows:

$$B_n = I_n * Z \qquad (2)$$

Equation (2) is, where I_n is the nth source image, Z is the average filter, and the size of the average filter is conventionally set to 31×31. Once the base layer is obtained, the detail layer can be easily obtained by subtracting the base layer from the source image.

$$D_n = I_n - B_n \qquad (3)$$

The two-scale decomposition step aims at separating each source image into a base layer containing the large-scale variations in intensity and a detail layer containing the small scale details. Equation (3) is the Weight Map Construction with Guided Filtering is Laplacian filtering is applied to each source image to obtain the high-pass image H_n.

$$H_n = I_n * L \qquad (4)$$

Equation (4) is, where L is a 3×3 Laplacian filter. Then, the local average of the absolute value of H_n is used to construct the saliency maps S_n.

$$S_n = |H_n| * gr_{g,}\, g_{\sigma g} \qquad (5)$$

where g is a Gaussian low-pass filter of size (2rg+1)(2rg+1), and the parameters r_g and σ_g are set to 5. Equation (5) is the measured saliency maps provide good characterization of the saliency level of detail information.

F. Image Denoising
After the fusion strategy is applied that have some noise are present, so removing that noise that is image denoising via NSCT (Nonsubsampled contourlet taransform). NSCT is a flexible multiscale, multidirection image analysis tool. NSCT can sufficiently capture the geometrical details of the image and keep the object information and the edge well. Fig. 2.8.1 displays an overview of the NSCT. The structure consists in a bank of filters that splits the 2-D frequency plane in the sub bands. Transform can thus be divided into two shift-invariant parts:

– A nonsubsampled pyramid structure that ensures the multiscale property
– A nonsubsampled DFB structure that gives directionality.

NSCT has the characteristics of multiresolution, localization, directionality, anisotropy, and shift-invariant. It can sufficiently capture the geometrical details of the image and keep the object information and the edge well. This paper utilizes log-ratio operator to transform multiplicative noise into additive one. In order to make the change map possess more complete edge and contour, it is feasible to use NSCT to reduce the noise of the fused difference image . The main steps are described as follows. First, subband images in the different scales and different directions are obtained after the decomposition of the fused difference image, which have the same size as the fused one.

The subband images consist of low-frequency subbands and highfrequency subbands. Second, the coefficients in low-frequency subbands remain unchanged and ones of high-frequency directional subbands at the different scales are suppressed with Donoho threshold. It is defined as, $\lambda = \sigma\sqrt{2}\log N$ where σ represents noise standard deviation and denotes the sample size. σ is generally unknown, so estimation method is used to determine .It is defined as $\sigma = Y_j/0.6745$, where Y_j denotes the value of coefficient which lies in the intermediate position according to the order of amplitude of high-frequency coefficients of at scale . When the high-frequency coefficients are larger than the threshold, the coefficients remain unchanged. Otherwise, the coefficients are set to zero. Finally, the denoised difference image is obtained by using inverse NSCT transform.

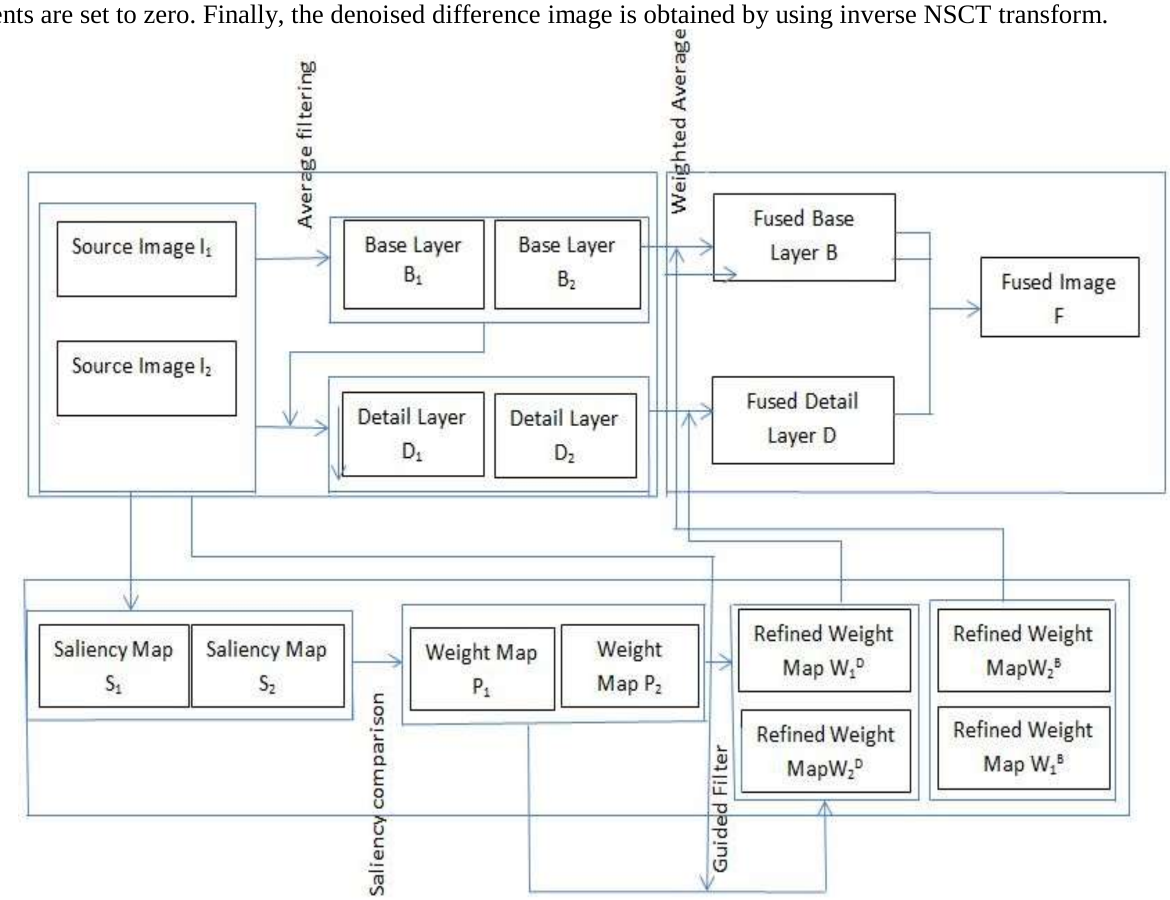


Fig. 2: image fusion method based on guided filtering.

G. Compressed Projection
Compressed projection also known as random projection. The benefit is that compressed projection can provide dimensionality reduction, which can greatly reduce the amount of data to be processed. Compressed projection (also known as random projection) has recently emerged as a surprisingly useful tool in signal processing. Fig. 3 compute fast Fourier transform (FFT) of a vectorized image and then the measuremen is multiplied with double-star shape sampling filter. The compressed projection can preserve the relevant structure in a signal when the signal is projected onto a small number of random basis functions. Although some information may be lost through such a projection, this information tends to be incoherent with the relevant structure in the signal. That is to say, a small number of compressed vectors obtained by compressed projection contain enough

information to preserve the underlying local texture structure. In this sense, compressed projection is a universal measurement tool. Another benefit is that compressed projection can provide dimensionality reduction, which can greatly reduce the amount of data to be processed.

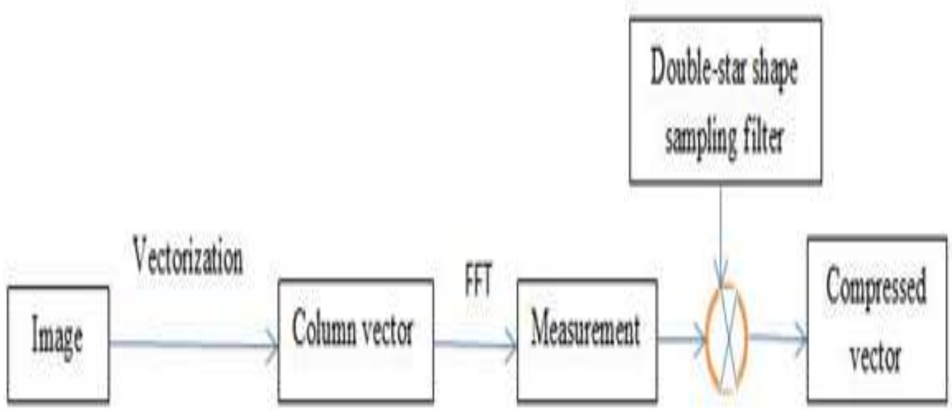


Fig. 3: Block diagram of computing compressed vector

H. K-Mean Clustering

Clustering is the classification of objects into different groups, the partitioning of a dataset into subsets (clusters), so that the information of each subset (ideally) shared some common trait according to some defined distance measure. The k-means algorithm is an algorithm to cluster *n* objects based on attributes into *k* partitions, where $k < n$. The feature vectors into two categories using k-means clustering with k=2. The two cluster centroid positions are chosen at random. The cluster means feature vectors for changed class and unchanged class, respectively. The change map is obtained according to the Euclidean distance, “255”represents the changed pixel and“0”represents the unchanged one.

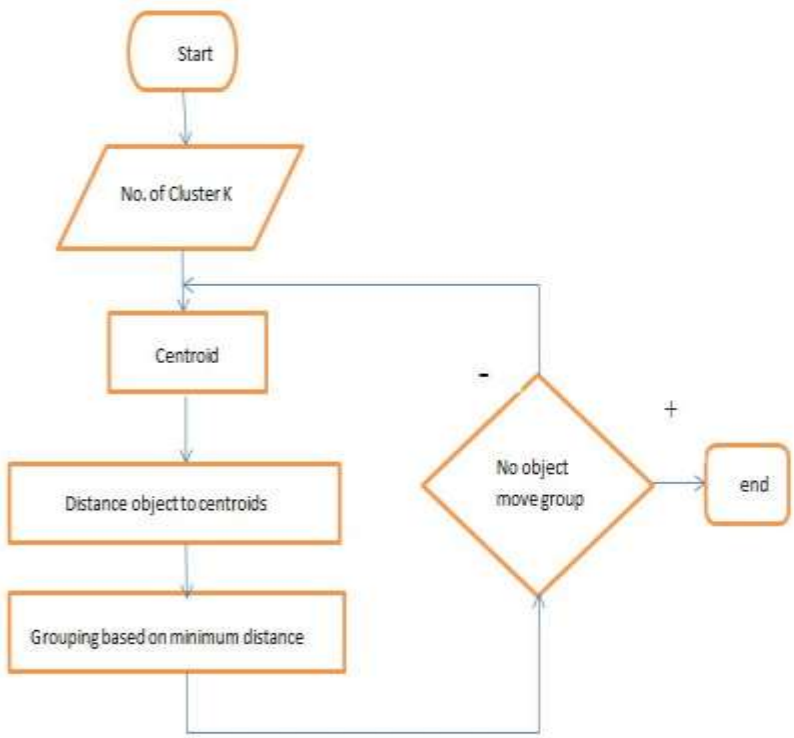


Fig. 4: K-Mean Clustering algorithm works

Fig. 4 is the algorithm works on K-mean Clustering shown step by step process given below:

1) Step 1: Begin with a decision on the value of k = number of clusters.
2) Step 2: Put any initial partition that classifies the data into k clusters.

Assign the training samples randomly, or systematically as the following:

– Take the first k training sample as single-element clusters
– Assign each of the remaining (N-k) training samples to the cluster with the nearest centroid. After each assignment, recompute the centroid of the gaining cluster.

3) Step 3: Take each sample in sequence and compute its distance from the centroid of each of the clusters. If a sample is not currently in the cluster with the closest centroid, switch this sample to that cluster and update the centroid of the cluster gaining the new sample and the cluster losing the sample.
4) Step 4: Repeat step 3 until convergence is achieved, that is until a pass through the training sample causes no new assignments.

III. EXPERIMENT AND RESULT

This section describes the experiments and results about two different SAR image take at same geographical area. In order to validate the effectiveness in SAR image based on ratio operator, image fusion, image denoising, feature extraction and change detection. In this experiment shows the different time to take the SAR image at same geographical area and the result is obtained by using different techniques to fused the image and removing the noise in the image, the feature is extracted then finally the change detected.

The input images are in the grey scale or color image, if it is a color image then it converts to grey scale image. The first data set is a section (pixels) of two SAR images with 10 m resolution acquired by Radarsat SAR sensor in July and August 1997, as shown in Fig 5(a) and (b), respectively. These images were provided by the Defense Research and Development Canada, Ottawa. Roughly, there are two regions in these images, i.e., water and land. The ground truth map shown in Fig. 5 (c) is generated by integrating prior information with photo interpretation based on the input images in Fig. 5 (a) and (b).

The second data set is pair (pixels) of two SAR images with 30 m resolution acquired by the European Remote Sensing 2 (ERS-2) satellite SAR sensor over an area near the city of Bern, in April and May 1999, as shown in Fig. 6 (a) and (b) respectively. The River is flooded entire parts of cities of Thun and Bern and the airport of Bern between the two dates. So, selected the Aare Valley between Bern and Thun as a test site for detecting flooded areas. The ground truth map shown in Fig. 6 (c) is generated by integrating prior information with photo interpretation based on the input images in Fig. 6 (a) and (b).

The third data set is pair (pixels) of two SAR images with 3 m resolution acquired by Radarsat-2 at the region of Yellow River Estuary in China in June 2008 and June 2009, as shown in Fig. 7 (a) and (b), respectively. These two images include vegetation areas (paddy field) and are with different levels of strong noise. The first image is with four looks and the second image is with single look. The ground truth map shown in Fig. 7 (c) is generated by integrating prior information with photo interpretation based on the input images in Fig. 7 (a) and (b).

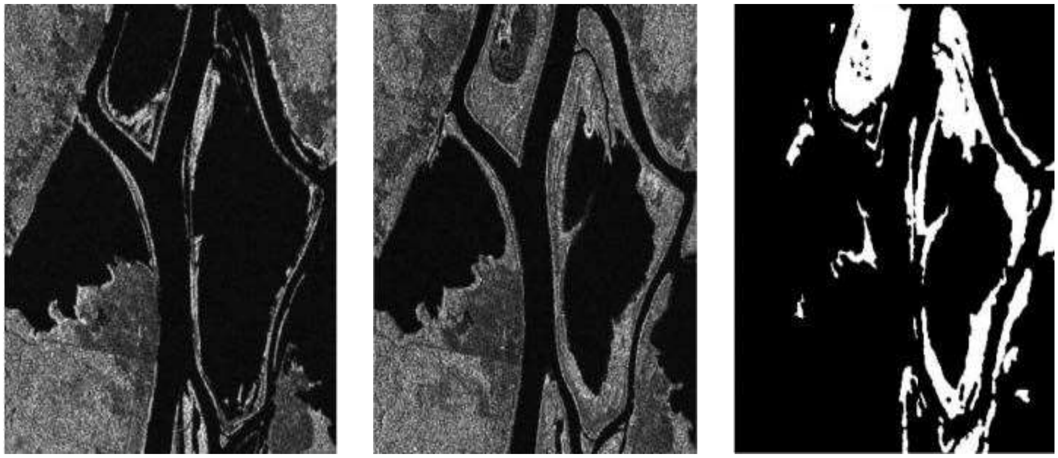
The fourth data set is also pair (pixels) of two SAR images with 3 m resolution acquired by Radarsat-2 at the region of Yellow River Estuary in China in June 2008 and June 2009, but the size of the images is larger, as shown in Fig. 8 (a) and (b) respectively. It can be seen that the changed areas are a newly reclaimed farmland and the borderline of the river. These two SAR images are also with different levels of strong noise, but with complex terrain. The reclaimed farmland on the seaside has irregular shape. The first image is also with four looks and the second image is with single look. The ground truth map shown in Fig. 8 (c) is generated by integrating prior information with photo interpretation based on the input images in Fig. 8 (a) and (b).

Table. 1 shows the PSNR (peak signal-to-noise ratio) value of different methods in SAR image. The proposed methods are contourlet transform and guided filter are the good accuracy methods than the other existing methods, mainly shows the existing method DWT (Discrete Wavelet Transform). The PSNR value is compared with the output (change detecting image) of the SAR image and the ground truth image. This project represents the SAR image of different time to take the image at same geographical area and also the SAR provides the ground truth of the image. The ground truth image and the changed region of the image, which image is better, that shows through the manually experiment for using different methods.

The data set of Ottawa the DWT method for fusion is not be clear for the change detection, because of the subband. Then the proposed methods are two contorlet transform and guided filter, both of two methods the better method is guided filter, which shows through PSNR value in the Table.1.

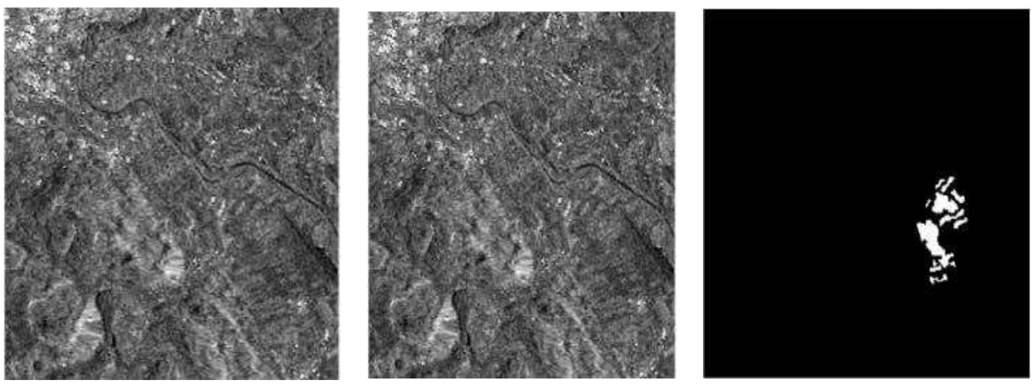
Table – 1
PSNR (peak signal-to-noise ratio) value of different methods in SAR image

SAR image Data set	*Methods*		
	DWT	*Contourlet Transform*	*Guided Filter*
Ottawa	*24.4689*	*28.5363*	*28.9587*
Bern	*24.9422*	*31.573*	*38.3489*
Small Yellow	*24.5026*	*28.0111*	*28.949*
Large Yellow	*24.5729*	*27.9794*	*29.1861*



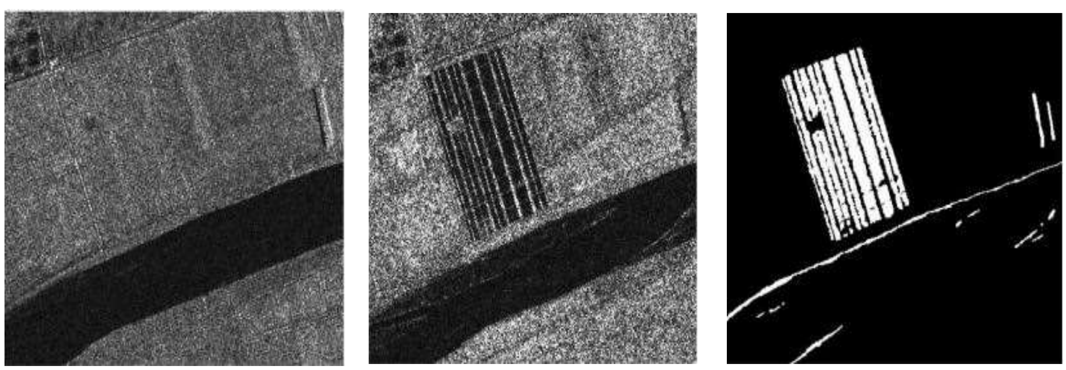
(a) (b) (c)

Fig. 5: Ottawa data set. (a) Image acquired in July 1997. (b) Image acquired in August 1997. (c) Ground truth



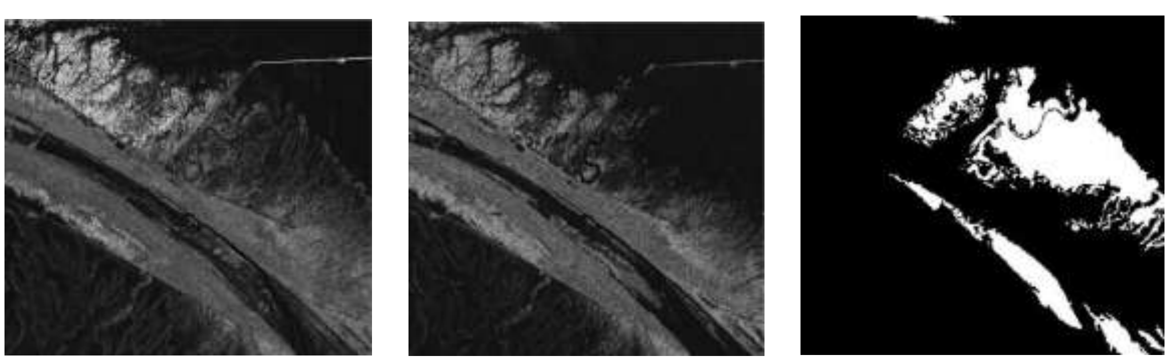
(a) (b) (c)

Fig. 6: Bern data set. (a) Image acquired in April 1999. (b) Image acquired in May 1999. (c) Ground truth



(a) (b) (c)

Fig. 7: Small Yellow data set. (a) Image acquired in June 2008. (b) Image acquired in June 2009. (c) Ground truth



(a) (b) (c)

Fig. 8: Large Yellow data set. (a) Image acquired in June 2008. (b) Image acquired in June 2009. (c) Ground truth

IV. CONCLUSION

The SAR image based on different operators is used log ratio, mean ratio and Gauss-log ratio. The combination of gauss log ratio and the log ratio are the better performance. The SAR image based on Gauss-log ratio image fusion via contourlet transform and guided filter. The Gauss-log ratio operator can enhance the information of the changed portion in the difference image. The Gauss-log ratio image and log-ratio image are fused to produce a new difference image. The fused image of the SAR image have some noise are there, so denoised that image used to NSCT, which is used to reducing the noise of the fused difference image and keep the object information and edge that approach has better performance in shape preservation Then the denoised image the feature is extracted by using compressed projection, which gives to reduce the dimensionality of the image. At last the change detection is identified by using K-means clustering. The changed region is in the white color and the unchanged region is in the black color. These methods are better used for SAR images. The experiment and result is shown by the use of Contourlet transform and Guided filter output is to be clear.

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