Hybrid Image Segmentation Method for Oil Spill Detection Using SAR Images

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Abstract: Oil pollution has become a major issue among the different types of marine pollution. This paper presents an efficient hybrid image segmentation method using wavelet transform with K means integrated with Fuzzy C means algorithms (KIFCM) to improve the segmentation accuracy using Synthetic Aperture Radar (SAR) images. The proposed method utilizes the advantage of noise-robust nature of wavelet and provides more information in segmentation process. Moreover KIFCM algorithm is employed to overcome the limitation and to get the benefits of K means and fuzzy C means (FCM) algorithm. The benefit of the k- means clustering for image segmentation in the sense of low computation time and the advantages of FCM in the sense of accuracy are considered. The challenging task of proposed wavelet KIFCM algorithm for image segmentation performance are analysed and evaluated based on their parameter like MSE, PSNR and Accuracy.

Keywords: *Oil spill, image segmentation, wavelet transforms, KIFCM algorithm, SAR images, accuracy.*

1. INTRODUCTION

Marine pollution is against for nature and the community found on ocean. The main reason of marine pollution is oil spills which has series impact on ocean environments. The oil spill may be accidental or pre-decided one. The accidental are often caused by tankers, barges, pipelines, drilling rigs, refineries and storage facilities. Some oil discharge may be illegal one in ocean. To detect the oil spills the tools like vessels, airplanes and satellite sensors are used. The beneficial effect of synthetic aperture radar (SAR) in oil spill detection system is very essential, as it is suitable for all weather condition in ocean. The main source of satellite borne images are from RADARSAT-1, RADARSAT-2, ENVISAT, ERS-2, ALOS, TERRASAR-X AND COSMOSSKYMED-1/2 for oil spill monitoring [1].

The SAR images are having wide application in image processing however it is affected by some noise called speckle noise. The frequency domain filtering techniques are suitable for speckle noise reduction [2]. The oil polluted area address as darker region than its surrounding in SAR images because the oil in sea water dampens capillary waves. On the other hand, some cases like low wind area, natural film, organic film, rain cells, clouds shadow will also appears as dark region in SAR images. Therefore, the identification of oil spill is very important. In oil spill detection system the segmentation process plays a vital role in partitioning the pixels belonging to oil spill and look alike region, so as to make classification process easier. The standard image segmentation techniques are threshold method, region based clustering, edge detection, partial differential equation, watershed method and ANN based technique etc. Each technique suffer from their own pro and cons [2] [3]. In recent years so many segmentation method are developed for oil spill detection but still it is necessary to improve the segmentation accuracy which makes the classifier to classify the oil spill from look-alike accurately.

In this paper we proposed wavelet KIFCM algorithm to improve the segmentation accuracy in oil spill detection system using SAR images. The proposed method makes uses of discrete wavelet transform (DWT) as it is useful in description of edge and line, as well as time - space localization. The approach of KIFCM algorithm is to get the advantages of K means and FCM algorithm. The experimental results of proposed wavelet KIFCM algorithm are evaluated and compared with the exiting methods based on the parameters like MSE, PSNR, and accuracy. The next section deals with the clustering algorithm, proposed method and experimental results.

2. CLUSTERING ALGORITHM

Clustering deals with finding a structure in a collection of unlabelled data. There are four clustering algorithms called K Means, Fuzzy c means, and Hierarchical clustering mixture of Gaussians. K means is an exclusive clustering algorithm; FCM is an overlapping clustering algorithm. In image segmentation K means algorithm work faster than Fuzzy C means. However, FCM predicted oil spill that are not predicted by K means. K means algorithm work in noisy images but FCM fails to segments the noisy images, it works only in noise free images. In this paper we used KIFCM algorithm called K means integrated with fuzzy C means to overcome the limitation and to get the benefits of these two algorithms.

This paper presents wavelet transform with KIFCM algorithm to improve the image segmentation accuracy in oil spill detection using SAR images.

3. PROPOSED IMAGE SEGMENTATIONS METHOD IN OIL SPILL DETECTION

In an image processing, the image is an input and the output is also an image or parameter which is used to solve identification problems. In oil spill detection system image segmentation plays an important role by extracting and representing information from SAR image in order to group pixels together into similar regions and makes classification process easier to classify the oil spill from look alike. There are number of image segmentation methods which are improved to a great extent to detect the oil spill using SAR images, but still the accuracy of image segmentation process needs to be improving to classify the oil spill accurately. In this paper we proposed image segmentation using wavelet based KIFCM algorithm for oil spill detection in SAR images. The objective of wavelet based image segmentation is to extract high level details of similar oil spill feature from SAR images and features are clustered using KIFCM algorithm. The combination of wavelet transform with KIFCM algorithm for image segmentation gives better results in terms of accuracy for accurate classification of oil spill from look alike. Fig.1 shows the block diagram of proposed method.

3.1 Block diagram of proposed method

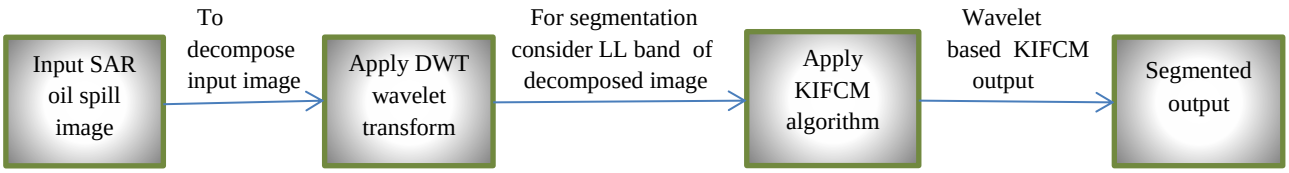

Fig: 1. Block diagram of wavelet KIFCM method

4. BASIC CONCEPT OF PROPOSED WAVELET KIFCM METHOD

4.1 Wavelet Transform for image segmentation

Wavelet transform brings out the algorithm free from noise because wavelets come up with frequency information and also time-space localization. It presents a compact description of images having time limitation and useful in representation of edge and line that are highly important [4]. The problem of resolution is solved by this transform which represents the signal without information loss and reduces the complexity. In this proposed method the discrete wavelet transform is employed to decompose the SAR oil spill input image into four subbands namely LL, LH, HL and HH. Analysing the decomposition properties of DWT the colors, regions and shapes are detected to segments the oil spill area. The wavelet concept [5,6] for image segmentation is applied by considering the approximation band of an image which is small in dimensions and provides important information of original image and hence reduces the computation time.

A 1-level wavelet transform of a discrete image f can be done by using the following two steps [5]

Step1: Perform a level-1, 1D wavelet transform, on each row of f, thereby producing a new image.

Step2: On the new image obtained from Step 1, perform the same 1D wavelet transform on each of its columns.

A 1-level wavelet decomposition of an image f can be defined as follows

$$f \rightarrow \begin{array}{c|c} h_1 & d_1 \\ \hline a_1 & v_1 \end{array} \longrightarrow (1)$$

Where h_1, a_1, d_1 and v_1 are sub images each have $\frac{M}{2}$ rows and $\frac{N}{2}$ columns. Where M and N are the number of rows and columns respectively.

4.2 KIFCM Algorithm for image segmentation

KIFCM algorithm integrates the K means clustering algorithm with the Fuzzy C-means algorithm to make an efficient image segmentation method in term of accuracy, minimum computation time and iterations. This algorithm is already used in medical image for brain tumour segmentation done by Eman Abdel-Maksoud et al (2015) [7]. There are many clustering algorithm that can be used in oil spill detection such as for a large dataset K

means clustering is fast and simple and to retain more information from original image FCM is useful. The main objective of integrating these two clustering algorithm to reduce number of iterations, done by initializing the right cluster centres to Fuzzy C-means clustering which minimizes the execution time and give good qualitative results in term of accuracy. In clustering stage the cluster centers are calculated by:

$$\mathcal{M}_U = \frac{(1: k)*m}{(k+1)} \rightarrow (2)$$

Where $\mathcal{M}_U$ is the initial means that can be calculate due to k. k is the number of clusters and m is defined as:

$$m = \max(\text{SAR image}) + 1 \rightarrow (3)$$

Assign every point to the nearest cluster center by calculating the minimum distance between the point and cluster centers. Then re-compute the new cluster centers and this process will continue until the criterion is met. However, there are some points scattered far away from any cluster center. Hence, the resulting new cluster centers, the clustered points and the scatted points are entered at same time to the looping step to calculate the new distances and the points were re-clustered due to fuzzy membership value. Determining the condition of closing, the membership and means values are updated. The output of this method is segmented clustering image. This algorithm provides better results when compared with conventional K means and FCM algorithm. To improve the segmentation accuracy here we applied KIFCM algorithm with wavelet transform.

4.3 Proposed wavelet KIFCM algorithm

Step 1: Read an input (*I)* SAR oil spill image.

Step 2: Resize the input image in to 256 x 256 pixel sizes.

Step 3: Apply wavelet transform on SAR oil spill (*I)* images to decompose the input image using DWT into four subbands LL, LH, HL and HH respectively where LL represents approximation coefficients, LH represents horizontal coefficients, HL represents vertical coefficients and HH represents diagonal coefficients. After decomposition the LL subband contains the low frequency of an image holding highest pixel information and the other three subband contains high frequency of an image.

Step 4: Apply the integrated KIFCM clustering algorithm into the approximation band (LL) of decomposed output image to partition the image pixels into *c* clusters by initializing the cluster center and fuzzy membership matrix value for image segmentation.

Step 5: Update cluster means and membership value.

Step 6: After integrating dark regions are segmented.

Step 7: Calculate the MSE, PSNR, Time period and Accuracy.

Step 8: Finally, the segmented regions are displayed with results.

Discrete Wavelet Transform (DWT) is applied to SAR oil spill images because it provides frequency information as well as time – space localization. For image segmentation the colors, regions and the shapes of an image are extracted by decomposing the original input image by applying DWT and it also makes segmentation fast by considering the approximation band (LL) of DWT where LL band is small in size and has significant information of the original image, hence reduces the computation time. The decomposition level should be considered to avoid over decomposition which reduce important information in an input image. An integrated KIFCM clustering algorithm is applied to the approximation band LL of decomposed output image to segments the clustered oil spill region. KIFCM algorithm integrates the K means clustering algorithm with the Fuzzy C-means algorithm to make the efficiency of image segmentation process more accurately to detect the oil spill in SAR images in minimum execution time with improved segmentation accuracy. The oil spill image is fed to KIFCM method by initializing the cluster center and fuzzy membership matrix value for image segmentation. K means gives each point to belong only closest cluster and FCM gives each point a degree of membership, rather than belonging wholly to just one cluster. An image segmentation technique to partition and detect the oil spill areas in the images has been proposed as shown in Fig.1.

5. EXPERIMENTAL RESULTS

The efficiency of the proposed wavelet KIFCM method for image segmentation to detect oil spill in SAR images is observed and the results are analysed and showed with various evaluation measures such as segmentation accuracy and the execution time with less iteration. To assess the quality of images, the parameters like MSE and PSNR are evaluated. For a better segmentation algorithm the MSE value, execution time must be less and PSNR

value must be high [8]. We showed our experimental results in Table.1 and Table.2 for different Image set in Fig.2 and compared our results with existing method with less MSE value, less execution time, less iteration, higher PSNR value and improved segmentation accuracy. Moreover the proposed method decides the initial cluster k value with decreased execution time of 4.6s for image 1with Iteration count 38, 4.7s for image 2 with iteration count 13 and 3.4s for image 3 with iteration count 36.

Segmentation Accuracy

Segmentation Accuracy is defined as the ratio between the total numbers of pixels in the segmented area to the total number of pixels in the original image [9].

$$Segmentation\ Accuracy = \frac{Total\ number\ of\ pixels\ in\ Segmented\ SAR\ oil\ spill\ image}{Total\ number\ of\ pixels\ in\ Original\ SAR\ oil\ spill\ image}$$

Fig.2 shows the input SAR images and the segmented output image of K means, FCM, KIFCM and proposed wavelet KIFCM algorithms. The graphical representation of Mean square error (MSE), Peak signal to noise ratio (PSNR) and Accuracy are shown in Fig.3, 4 and Fig.5.

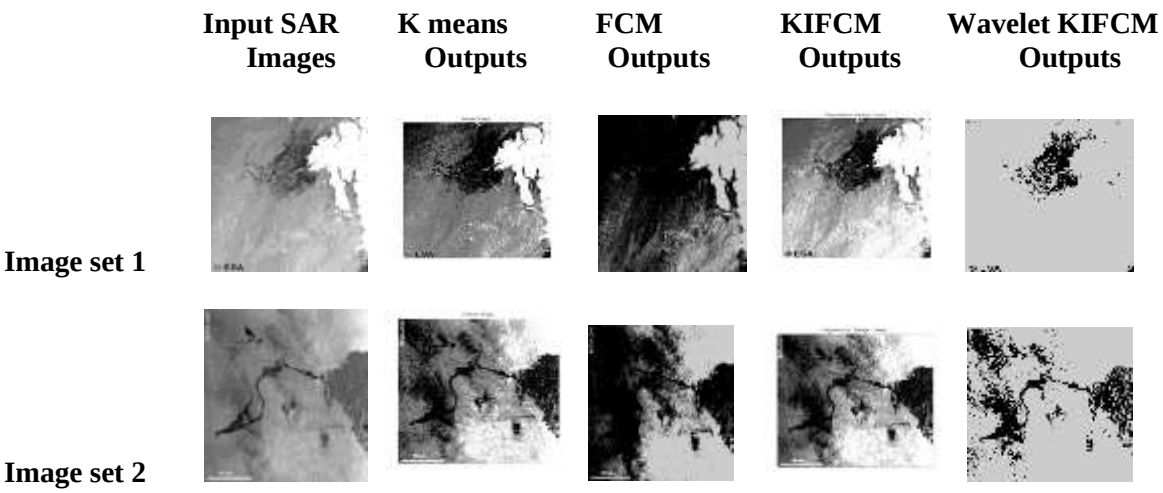

Image set 3

Fig: 2. Image sets of oil spill using SAR images

Table.1 The parameters measures of MSE and PSNR value

Parameters	Algorithm	Image set 1	Image set2	Image set 3
MSE	K – means	1.27	1.70	1.65
	FCM	3.00	2.80	2.65
	KIFCM	1.56	1.72	1.44
	Wavelet KIFCM (proposed)	1.08	1.21	1.26
PSNR	K – means	47.14	45.87	46.00
	FCM	43.39	43.69	43.93
	KIFCM	46.23	45.82	46.57
	Wavelet KIFCM (proposed)	47.84	47.35	47.16

Table.2 The parameters measures of segmentation accuracy value

Parameters	Algorithm	Image set 1	Image set2	Image set 3
Accuracy	K – means	25.25	28.65	26.29
	FCM	51.00	56.00	49.00
	KIFCM	75.02	65.26	68.32
	Wavelet KIFCM (proposed)	93.38	92.26	93.60

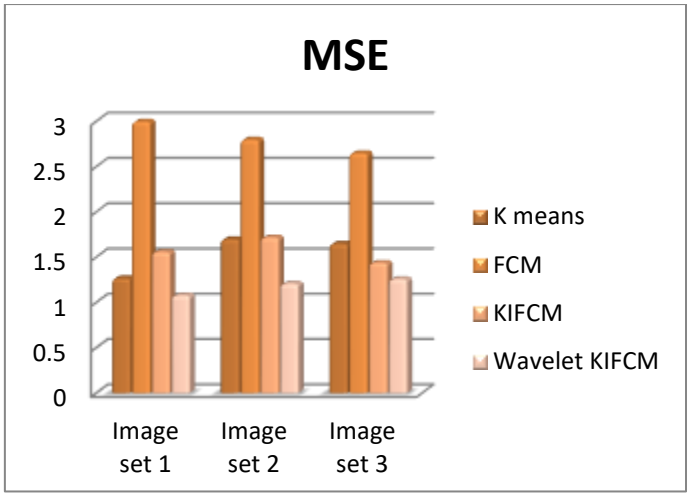

Fig: 3 Graphical representation of MSE value

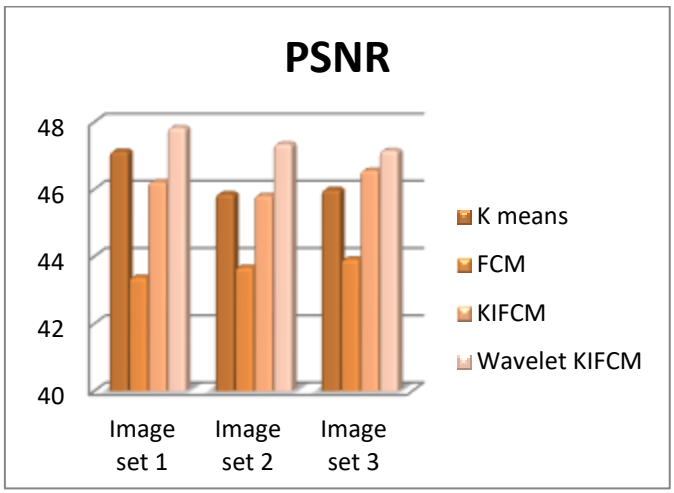

Fig: 4 Graphical representation of PSNR value

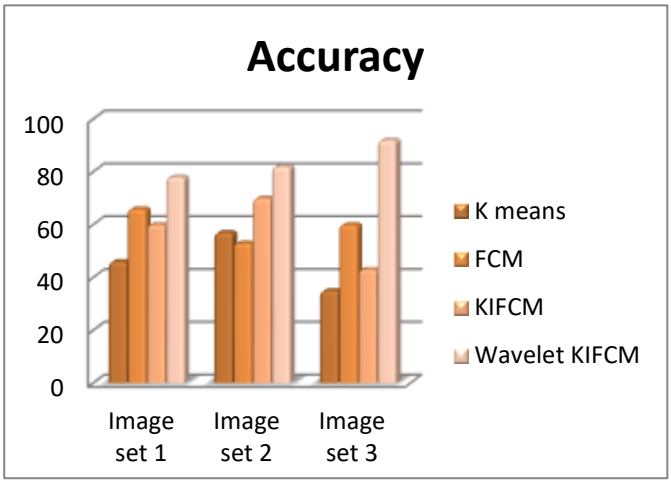

Fig: 5 Graphical representation of Accuracy value

6. CONCLUSION

The performance of the proposed hybrid image segmentation method is compared with convention K means, FCM and KIFCM algorithm based on the parameter measures like segmentation accuracy, execution time, MSE, PSNR value. From the experiments results the proposed wavelet KIFCM has good image quality and proved that the proposed image segmentation algorithm is very effective which results with less MSE, higher PSNR value and improved segmentation accuracy to make classification of oil spill easier. In future we can extend the work for feature extraction using principal component analysis and to classify the oil spill form look-alike the feed forward neural network are considered to be used.

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