SEGMENTATION OF OIL SPILL IMAGES USING IMPROVED FCM AND LEVEL SET METHODS.

V.RADHIKA,

, Prof & Head ,Department of Computer Science,
,Sri Krishna Arts And Science College,
Coimbatore-641008,India.
radhikavin73@yahoo.com.

DR. G. PADMAVATHI,

, Prof & Head ,Department of Computer Science,
Avinashilingam University for Women,
Coimbatore-641043,India.

Abstract

The main part of image processing and computer vision is Image segmentation. Image segmentation is the task of splitting a digital image into one or more regions of interest. In this paper a robust method for oil spill SAR image segmentation is explored which is already used for medical images by Bing Nan li et al. The unique FCM algorithm yields better results for segmenting noise free images, but it fails to segment images degraded by noise, outliers and other imaging defects. The optimization property of FCM is improved when it is combined with spatial information (SFCM). Level set methods uses dynamic variational boundaries for an image segmentation which embeds the time dependant PDE function. In this paper, an integrated method of spatial based FCM and level set method for oil spill segmentation is discussed.

Keywords: SFCM; PDE; Level Set; SAR; Oil Spill; Segmentation;

1. Introduction

The main cause of marine pollution is oil spills which has dangerous effects to the eco system. Ecological disasters are due to accidents of big oil tankers and ship transportation. SAR images are widely used for monitoring the marine pollution. SAR images are not affected by the sun light, clouds occlusion and enough resolution. Still, they present some drawbacks which complicate the development of a fully automatic oil spills detection system. Marine oil pollution dampens capillary waves, which means that a polluted area will appear in the SAR image as a zone darker than its surrounding. Therefore, we have to process the image to segment the dark spots. However, this procedure will only be possible if there is enough contrast between the dark spots and their background. At low wind, there are no capillary waves, which results in same dark spot.

This method is applied to segmenting images to improve oil spill detection in marine environment. In the recent years, marine pollution has become a major issue due to the increasing number of illicit discharges and accidents of big oil tankers. Spillage of oil in coastal waters can be a catastrophic event. The potential damage to the environment and economy of the area at stake requires that agencies be prepared to rapidly detect, monitor, and clean up any large spill. The complications involved in detecting oil spills are due to varying wind and sea surface conditions. In the last decade, imaging systems have been widely used in remote sensing to improve methods of oil spills detection. We use our approach to detect oil spills in real images obtained with these imaging systems.

There are different types of marine pollution [10], oil is a major threat to the sea ecosystems. The source of the oil pollution can be located on the mainland or directly at sea Discharges are coming from sea-based sources like ships or offshore platforms. Marine pollution from sea-based oil sources can be accidental or intentional. Nowadays, the number of marine accidents and the volume of oil released are reducing to a greater extent. On the other side, regular tanker handling activities results in release of oily ballast water and tank washing residues. In addition to that, fuel oil sludge, engine room wastes and foul bilge water produced by ships, also settles in the sea. Due to the increase in marine transportation, also increase the oil discharges. All kinds of ships and oil tankers discharge the oil and other waste materials in the sea.

The different types of vessels, airplanes, and satellites are the tools to detect and monitor oil spills. Vessels, can cover a very limited area to detect oil at sea when equipped with specialized radars. Mainly vessels are necessary for oil sampling. The airplanes and satellites equipped with Synthetic Aperture Radar (SAR) are mainly used to monitor sea-based oil pollution. SAR is an active microwave sensor, which captures two dimensional images. The brightness of the captured image is a reflection of the properties of the target-surface. The oil spill detection using a SAR image relies on the fact that the oil on the sea decreases the backscattering of the sea surface resulting in a dark formation that contrasts with the brightness of the surrounding spill-free sea. Space borne SAR sensors are extensively used for the detecting the oil spills in the marine environment, as they are independent from sun light, they are not affected by cloudiness, they cover large areas and are more cost-effective than air patrolling. Radar backscatter values from oil spills are very similar to backscatter values from very calm sea areas and other ocean phenomena named "look-alikes" (e.g. currents, eddies).

Oil spills are also caused when there is a damage in oil pipes occurs across its cross section. Surveys [11] show that annually, 48% of the oil pollutants in the oceans are fuels, 29% are crude oils and tanker accidents contribute only 5% to this pollution. The major challenging task is to detect the presence of oil spills across the globe. Nowadays, many technical and research bodies serve this purpose. People face a number of challenges due to this problem and hence an attempt is made to have some segmentation measures in this paper.

Image segmentation is a process of partitioning an image into homogeneous regions that share some common properties. There are two main approaches in image segmentation: edge and region-based. Edge-based segmentation based on for discontinuities in the intensity of an image. Region-based segmentation deals with uniformity within a sub-region, based on a desired property, e.g. color, pattern and intensity. Automatic interpretation of images is a very difficult problem in computer vision. Several different methods are developed in the last two decades to improve the segmentation performance in computer vision. Promising mathematical frameworks, based on variational models and Partial Differential Equations (PDE), have been investigated to solve the image segmentation problem. This approach benefits from well-established mathematical theories that make the people to analyze, understand and extend segmentation methods. In this paper, approach is considered to the segmentation using active contours models. Active contours models are used to detect objects in a given image using the techniques of curve evolution.

Fuzzy (FCM) clustering means is an unsupervised technique that has been successfully applied to feature analysis, segmentation, clustering, and classifier designs in many fields. An image can be represented in various feature spaces, and the FCM algorithm classifies the image by grouping similar data points in the feature space into clusters. This clustering is achieved by iteratively minimizing a cost function that is dependent on the distance of the pixels to the cluster centers in the feature domain. There are number of variations in the FCM methods which improve the technique to great extend. Here FCM is embedded with spatial information and the level set methods.

The paper is organized as follows: Section 2 discusses the S-FCM and Section 3 discusses Level set method for image segmentation. Section 4 presents the new integrated S- Fuzzy clustering algorithm with Level Set for segmenting SAR oil spill images. The experimental results with different non–linear parameter evaluation are presented in section 5. Finally, in section 6 conclusions are given.

2. Spatial Based FCM

2.1. Fuzzy C- Means (FCM)

In fuzzy clustering methods, fuzzy c means clustering (FCM) is an universal method that suits to any type of application in uncertainty area. The characteristic of FCM is that every sample point attributes to the clustering center according to fuzzy membership. However, there are two shortcomings in FCM ie, the initial classification number and local minimum problem in calculating the clustering center. Fuzzy clustering is a process of assigning these membership levels, and then using them to assign data elements to one or more clusters. One of the most widely used fuzzy clustering algorithms is the Fuzzy C-Means (FCM) Algorithm (Bezdek 1981). The FCM algorithm partitions[3] an image $X = \{x_1,...,x_N\}$ into a collection of c fuzzy clusters based on pixel values. The cost function (CF) of the algorithm is given as follows

$$CF = \sum_{j=1}^{N} \sum_{i=1}^{c} u_{ij}^{m} \left\| x_j - v_i \right\|^2 \quad \ldots\ldots\ldots\ldots..(1)$$

where uij represents the membership of pixel x_j in the ith cluster, v_i is the ith cluster center, ||. || is a norm metric, and m[1] is a constant is usually equals to 2 . The cost function is minimized when pixels close to the centroid of their clusters are assigned high membership values, and low membership values are assigned to pixels with data far from the centroid. The membership function represents the probability that a pixel belongs to a specific cluster. In the FCM algorithm, the probability is dependent solely on the distance between the individual cluster center and each pixel in the feature domain. The membership functions and cluster centers are updated by the following:

$$u_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{\|x_j - v_i\|}{\|x_j - v_k\|}\right)^{2/(m-1)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

and

$$v_i = \frac{\sum_{j=1}^{N} u_{ij}^{m}\, x_j}{\sum_{j=1}^{N} u_{ij}^{m}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Starting with an initial guess for each cluster center, the FCM converges to a solution for v_i representing the local minimum or a saddle point of the cost function. Convergence can be detected by comparing the changes in the membership function or the cluster center at two successive iteration steps.

2.2 Spatial Information

Neighboring pixels of an image are highly interrelated. In other words, these neighboring pixels possess similar feature values, and they may belong to the same cluster. This property is utilized in the classical FCM. A spatial function [3] is defined as follows

$$h_{ij} = \sum_{k \in NB(x_j)} u_{ik} \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where NB(xj) represents a square window centered on pixel xj in the spatial domain. A 5X5 window was used throughout this work. Just like the membership function, the spatial function hij represents the probability that pixel xj belongs to ith cluster. The spatial function of a pixel for a cluster is large if the majority of its neighborhood belongs to the same clusters. The spatial function is incorporated into membership function as follows:

$$u_{ij} = \frac{u_{ij}^{p}\, h_{ij}^{q}}{\sum_{k=1}^{c} u_{kj}^{p} h_{kj}^{q}} \quad \ldots\ldots\ldots\ldots\ldots(5)$$

where p and q are parameters to control the relative importance of both functions. In a homogenous region, the spatial functions simply strengthen the original membership, and the clustering result remains unchanged. However, for a noisy pixel, this formula reduces the weighting of a noisy cluster by the labels of its neighboring pixels. As a result, misclassified pixels from noisy regions or spurious blobs can easily be corrected. The spatial FCM with parameter p and q is denoted sFCMp,q. Note that sFCM1,0 is identical to the conventional FCM. The clustering is a two-pass process at each iteration. The first pass is the same as that in standard FCM to calculate the membership function in the spectral domain. In the second pass, the membership information of each pixel is mapped to the spatial domain, and the spatial function is computed from that. The FCM iteration proceeds with the new membership that is incorporated with the spatial function. The iteration is stopped when the maximum difference between two cluster centers at two successive iterations is less than a threshold. After the convergence, defuzzification is applied to assign each pixel to a specific cluster for which the membership is maximal

3. Level Set Method

This approach is based on the active [5-8] contour model with the integration of adaptive region information to obtain a robust segmentation model. The level set method was first introduced by Osher and Sethian [7]. The level set method is a numerical and theoretical tool for propagating interfaces. The basic idea is to start with a closed curve in 2D or a surface in 3D and allow the curve to move perpendicular to itself at a prescribed speed. In image processing the level set method is most frequently used as a segmentation tool through propagation of a contour by using the properties of the image. One of the first applications was to detect edges in an image [8], but in more recent applications textures, shapes, colors etc can be detected. In the level set method, an interface C is represented implicitly as a level set of a function φ , called level set function, of higher dimension. The geometric characteristics and the motion of the front are computed with this level set function. The interface is now represented implicitly as the zero-th level set (or contour) of this scalar function. Over the rest of the image space, this level set function is defined as the signed distance function from the zero-th level set. Specifically, given a closed curve C, the function is zero if the pixel lies on the curve itself, otherwise, it is the signed minimum distance from the pixel to the curve. By convention, the distance is regarded as negative for pixels outside C and positive for pixels inside C. The level set function φ of the closed front C is defined as follows, [7]

$$\varphi(x,y) = \pm d\big((x,y), C\big) \qquad \text{..........(6)}$$

Where $d((x, y),C)$ is the distance from point (x, y) to the contour C, and the sign plus or minus are chosen if the point (x, y) is inside or outside of interface C. The interface is now represented implicitly as the zero-th level set (or contour) of this scalar function:

$$C = \{(x,y) / \varphi(x,y) = 0\} \qquad \text{..............(7)}$$

Such an implicit representation has numerous advantages over a parametrical appr, oach. The most striking example is topological changes occurring during the propagation, typically when two flames burn together the evolving interfaces merge into one single propagating front.

The level set evolution equation is given by

$$\frac{\partial\varphi(x,y)}{\partial t} = \delta_\varepsilon\big(\varphi(x,y)\big)\left[\frac{vk(\varphi(x,y))}{\{(I(x,y)-\mu_1)^2-(I(x,y)-\mu_0)^2\}}\right] \qquad \text{.......(8)}$$

Where μ_0 and μ_1 are the mean of the image intensity within two subsets ie inside or outside the contours respectively. The final segmented image can be represented as a set of piece-wise constants.

4. Improved FCM And Level Set Method

FCM algorithms and level set methods are general-purpose computational models which can be applied to any type application of any dimension. Here the same is applied to oil spill SAR image segmentation, for the better results. A new fuzzy level set algorithm is there by proposed for an oil spill image segmentation. It begins with spatial fuzzy clustering, whose results are utilized to initiate level set segmentation, estimate controlling parameters and regularize level set evolution.

The new fuzzy level set algorithm automates the initialization and parameter configuration of the level set segmentation, using spatial fuzzy clustering. It employs an FCM with spatial restrictions[2] to determine the approximate contours of interest in an oil spill image. The enhanced level set function can accommodate FCM results directly for evolution. Number of parameters(Dirac, smoothing factor ,time step number of iteration etc)plays vital in controlling the working of the level set methods. The proposed method is utilizes the benefits of SFCM and level set methods.

5. EXPERIMENTAL RESULTS

To test the accuracy of the segmentation algorithms, below mentioned steps are followed.

i) First, an oil spill image is taken as input.
ii) Second segmentation algorithm is applied on the oil spill image.
iii) Third , the performance evaluation is obtained by the statistical method like Mean, Entropy and Evaluation Time.

The reconstruction of an image has the dimensions of 256 pixel intensity. The oil spill [9] images in this contain a wide variety of subject matters and textures. The images used are oil spill images from European Space Agency (ESA) which are resized to 256 X 256 . The Entropy, Evaluation time and Mean must be less value for a better segmentation algorithm.

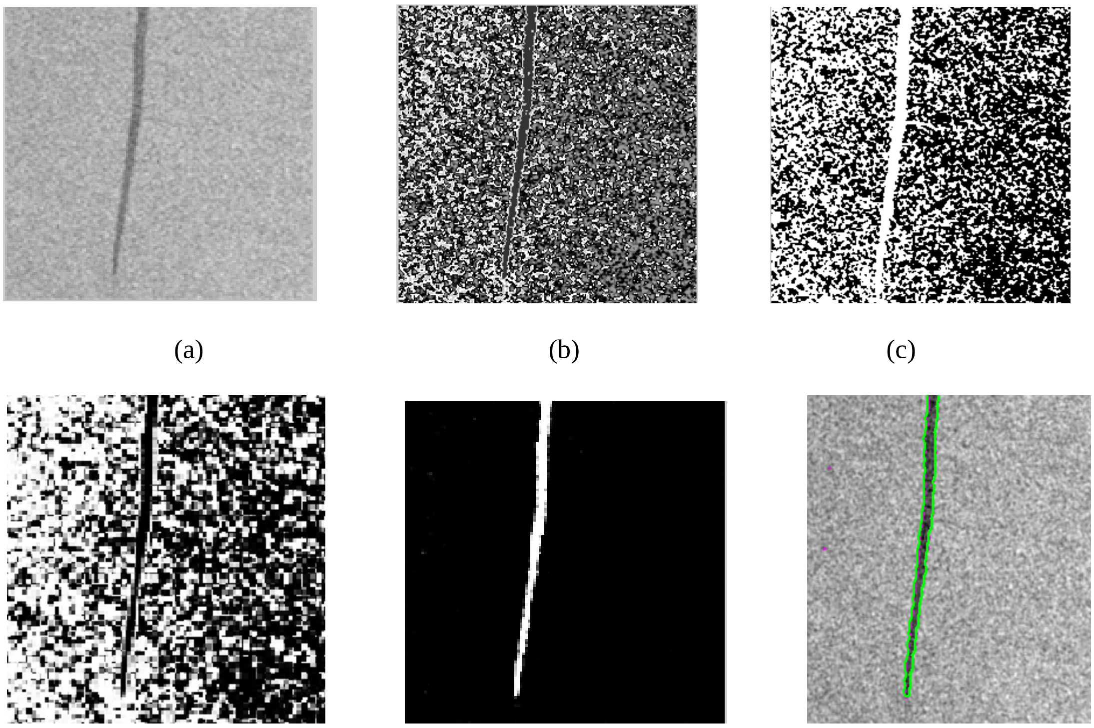
a.) Entropy

Suppose that two discrete probability distributions of the images have the probability functions of p and q, the relative entropy of p with respect to q is then defined as the summation of all possible states of the system, which is formulated as,

$$d = \sum_{i=1}^{k} p(i) \log_2 \frac{p(i)}{q(i)} \quad \ldots\ldots\ldots \qquad (9)$$

Table:1 Statistical values of various segmentation algorithms

Sno	Statistical parameter	FCM	KFCM	SFCM WITH LEVEL SET
1	Mean	4.05	4.09	**2.69**
2	Entropy	1.93	.73	**.73**
3	Time	7.62	**2.9**	28.1



(a) (b) (c)

(d) (e) (f)

Fig 1. (a) Original Oil Spill SAR image (b) Segmentation FCM (c) Segmentation by KFCM
(d)-(f) Various stages of Segmentation by spatial FCM with level set

This Spatial FCM integrated with level set method which was used by B.N.Li et al[2] for medical images the same is applied to Oil Spill images in this paper which results in better segmentation than other methods.

6. Conclusion

The quality of oil spill SAR images are directly affected by back scattering, wind , noise , and other environmental factors. The RADAR back scatter values are very much similar to low wind areas and other phenomena named look-alikes. This emphasizes the necessity of image segmentation, which divides an image into parts that have strong correlations with objects to reflect the actual information collected from the real world to discriminate the oil spills. Image segmentation are most practical approaches among virtually all automated image recognition systems. Clustering of numerical data forms the basis of many classification and system modeling algorithms. The purpose of clustering is to identify natural groupings of data from a large data set to produce a concise representation of a system's behavior. In this paper the proposed fuzzy c means is combined with level set method to get better results. The results of different FCM based methods are compared and Spatial FCM with level set method gives better segmentation even in the noisy image. The future work can be taken in the direction of reducing time consumption using the genetic algorithms.

References

[1]. Pal N R, Bezdek J C. On Cluster Validity for the Fuzzy c-Means Model. IEEE Trans Fuzzy Systems. Vol. 3, No. 3, pp. 370-379, 1995.

[2]. Bing NanLi , CheeKongChui , StephenChang , S.H.Ong Integrated spacitial Fuzzy clustering with level set methods for automated medical image segmentation , , Computers in Biology and Medicine. Feb 2011.

[3]. K.S.Chuang, H.L.Hzeng, S.Chen, J.Wu, T.J.Chen, Fuzzy c-means clustering with spatial information for image segmentation, Computerized Medical Imaging and Graphics (2006)9–15.

[4]. Chen Wei, Lu Tingjin, Wu Jizheng, Zhao Yanqing, An Improved Genetic FCM Clustering Algorithm, 2nd International Conference on Future Computer and Communication, 2010, V1-46.

[5]. M. Airouche, L. Bentabet and M. Zelmat,Image Segmentation Using Active Contour Model and Level Set Method Applied to Detect Oil Spills, Proceedings of the World Congress on Engineering 2009 Vol I WCE 2009, July 1 - 3, 2009, London, U.K.

[6]. T.F.Chan, L.Vese - Active Contours Without Edges, IEEE Trans. Image. Proc.,vol10(2) : 266- 277, 2001

[7]. J. A. Sethian, level set Methods and Fast Marching Methods, second ed.,Cambridge University Press, 1999.

[8]. M. S. Allili, D. Ziou nad L. bentabet. A robust Level Set approach for image segmentation and statistical modeling, Proceedings of Advanced Concepts for Intelligent Vision Systems, ACIVS 2004, Brussels,Belgium, *Aug. 31-Sept. 3, 2004*.

[9]. http://cearac.poi.dvo.ru/en/db (oil spill SAR images from ERS-1,ERS-2& Envisat-1 belonging to European Space Agency (ESA)).

[10]. Konstantinos N. Topouzelis ,“Oil Spill Detection by SAR Images: Dark Formation Detection,Feature Extraction and Classification Algorithms” ,Sensors 2008.

[11]. HANG Le Minh, DUONG Nguyen Dinh, Vietnam “ Oil Spill Detection and Classification by ALOS PALSAR at Vietnam East Sea” 7th FIG Regional Conference Spatial Data Serving People: Land Governance and the Environment – Building the Capacity Hanoi, Vietnam, 19-22 October 2009