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A Combined Approach Using Fuzzy Clustering and Local Image Fitting Level Set Method for Global Image Segmentation

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Abstract -- *Image segmentation is an important part in image recognition systems and it has been successfully used in various fields such as medical imaging, finger ridge, retina, and face recognition, etc. In this paper, we are proposing a novel hybrid method for image segmentation to segment all constituent objects of the image under consideration using combination of fuzzy c-means (FCM) and boundary tracking mathematical modeling technique named level set method (LSM). In the proposed method, a contour is obtained by FCM method which serves as initial contour for improved LSM Method. Finally, experimental results validate the effectiveness of the proposed combined method for image segmentation.*

Keywords- Fuzzy C-Means, Level Set Method, Local Image Fitting, Image Segmentation.

I. INTRODUCTION

The segmentation of an image is the first step in identifying and recognition of the constituent objects. The segmentation technique is used in various walks of the life like medical, military, and geography etc. The main goal of segmentation is to identify the relevant regions of interest or objects. However, manual segmentation is time consuming and tedious process and it is inaccurate as well. Therefore, it is preferable to use algorithmic approach in comparison to manual processing to find accurate and desirable segmentation of an image.

Osher and Sethian [1] introduced a geometrical active contour model and termed it as the level set model. It is used for capturing the front of a moving curve. Caselles [2] used active contour model in image segmentation process effectively. For correct implementation of traditional level set, it is necessary to keep the level set function close to sign distance function as much as possible [3]. To avoid the problem related with sign distance, an improvement is purposed over level set method by Li et al.[3].

Dunn [4] introduced the concept of fuzzy c-means (FCM) and later on it was modified by Bezdek [5]. Fuzzy c-means has been used for various image segmentation based devices like finger print identification, retina identification, etc. Several other modifications have also been proposed to FCM [5][6][7][8][9][10] as traditional FCM is not suitable to use for all types of images.

Neither LSM nor FCM is able to produce suitable result that can be used for medical analysis purpose. Therefore, we are proposing a combined approach using fuzzy c-means and modified level set method based on local image fitting. We use FCM to generate clusters and one of these clusters will be automatically selected to serve as initial level set curve for modified level set method.

The remaining of the paper is organized as follow: Section 2 of the paper describes fuzzy c-means clustering algorithm for image segmentation. Section 3 discusses level set method in general and its modification for local image fitting energy formulation in particular. Section 4 discusses about the proposed combined approach for fuzzy c-means and modified level set method. In section 5, results of MATLAB implementation of combined approach, discussed in section 4, are discussed. In section 6, conclusion and future scopes of the paper have been discussed.

II. Fuzzy Clustering

FCM clustering is an unsupervised technique which has been widely used in various applications of image processing such image segmentation, image enhancement, etc. [11,12]. The FCM algorithm classifies pixels of an image data set into clusters based on Euclidean distance of a pixel from the center of the least distant cluster. For a given image data set X = (x_1, x_2, x_3, .., x_n) with n pixels to be partitioned into c clusters based on pixels characteristics, the FCM cost function [6,7] is defined as follow:

$$J=\sum_{j=1}^{n}\sum_{i=1}^{c}u_{ij}^{m}\left\|x_j-v_i\right\|^2, \qquad \text{..........(1)}$$

where u_{ij} represents the membership of an image pixel x_j in the *i*th cluster, v_i is the *i*th cluster center. ||.|| is a norm metric, and m is a constant usually equal to 2 and controls the fuzziness of the partitioned clusters. The value of cost function J is minimum, i.e. the high membership values, when image pixels are close to the centroid of their clusters and the value of function J is maximum, i.e. the low membership values, when image pixels are far from the centroid of their clusters. The membership function provides the probability of a pixel belong to a specific cluster. The membership value of a pixel is dependent on the distance between the pixel and centroid of its cluster. Equation (2) and equation (3) provide the updated values for membership function and cluster centers.

$$u_{ij}=\frac{1}{\sum_{k=1}^{c}\left(\frac{\left\|x_j-v_i\right\|}{\left\|x_j-v_k\right\|}\right)^{\frac{2}{(m-1)}}}, \qquad \text{..........(2)}$$

$$v_i=\frac{\sum_{j=1}^{n}u_{ij}^{m}x_j}{\sum_{k=1}^{n}u_{ij}^{m}}, \qquad \text{.........(3)}$$

Each cluster center is guessed initially to start the algorithm, and then U and V are updated through iterations. When there is no change in either membership function or the cluster centers at two successive iterations, the procedure stops.

III. Level Set Method Implementation with Local Image Fitting Energy Formulation

The most widely used tracking propagating boundary technique, known as level set method, was introduced by Osher and Sethian [1]. The core idea of implementing level set method is to begin with a closed curve or surface and move this curve perpendicular to itself at a specific speed. At all times, the interface is given by $\phi(x,y,t)=0$. The basic evolution equation for the level set method is given by

$$\phi_t + F\,|\nabla\phi| = 0, \qquad \text{.........(4)}$$

where F is normal speed function.

To implement level set method in image segmentation, we initialize a contour and move it by using information lying in the given image. Let Ω be a bounded open subset of R^2 and $I:[0,a]\times[0,b]\rightarrow R^{+}$ be a given image. Let $C(q):[0,1]\rightarrow R^2$ be a parameterized planar curve in Ω. K. Zhang et al. [13] proposed a local image fitting energy functional by minimizing the difference between the fitted image and the original image. Zhang proposed a local fitted image (LFI) formulation as follows:

$$I^{LIF}=m_1H_\varepsilon(\phi)+m_2(1-H_\varepsilon(\phi)), \qquad \text{.........(5)}$$

where Heaviside function H [14], m_1, and m_2 are defined as follows:

$$\begin{cases} H_\varepsilon(z)=\frac{1}{2}[1+\frac{2}{\pi}\arctan(\frac{z}{\varepsilon})] \\ m_1=mean(I\in(\{x\in\Omega|\phi(x)<0\}W_k(x))) \\ m_2=mean(I\in(\{x\in\Omega|\phi(x)>0\}W_k(x))) \end{cases} \qquad \text{.........(6)}$$

where $W_k(x)$ is a rectangular window function. Using LFI of above eq. () proposed formulation is as follows:

$$E^{LIF}(\phi)=\frac{1}{2}\int\left|I(x)-I^{LIF}(x)\right|^2dx,\quad x\in\Omega$$

.........(7)

Finally, applying the calculus of variation and the steepest descent method, the formulation can be given as follows:

$$\frac{\partial\phi}{\partial t}=(I(x)-I^{LIF}(x))(m_1-m_2)\,\delta_\varepsilon(\phi),$$

.........(8)

where Dirac function $\delta_\varepsilon(\phi)$ [14] is the regularized as follows:

$$\delta_\varepsilon(z)=H'_\varepsilon(z)=\frac{1}{\pi}\cdot\frac{\varepsilon}{\varepsilon^2+z^2},\qquad z\in R$$

.........(9)

IV. Proposed Combined Approach for Global Image Segmentation

In this section, we are proposing a combined approach using fuzzy c-means and level set method based on local image fitting. The introduction of Fuzzy level set automates the initial requirements i.e. generating the initial contour for implementation of level set method based on local image fitting. Main steps for proposed algorithm are described as below:

Step 1: Read the input image.

Step 2: Define the number of clusters in which image pixels need to be divided.

Step 3: Use eqs. 1, 2, and 3 to implement fuzzy c-means clustering to create different clusters.

Step 4: Choose any one cluster from the result obtained in step 3 to define initial contour.

Step 5: Use the contour, defined in step 4, in level set formulation defined in eq. 8 to obtain final image with global segmentation for all the objects constituents in original image.

Step 6: Display the globally segmented image.

V. Experimental Results

The proposed globally image segmentation algorithm, as discussed in section 4, was implemented using MATLAB and was tested on MRI medical images downloaded from http://www.mr-tip.com.

Fig. .1 Original Image - Lumbar Spine-T1-SE.

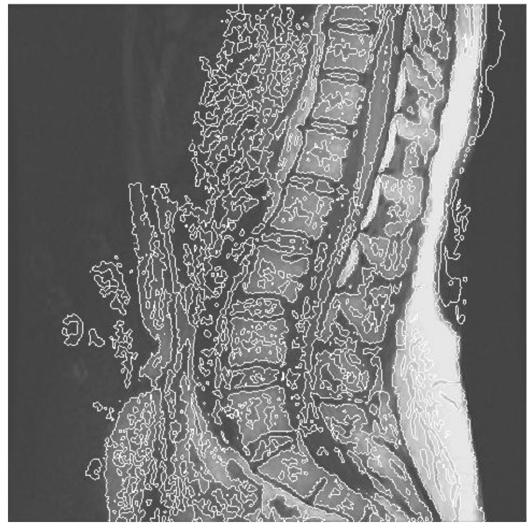

Fig. 2. Segmented Image of Fig. 1.

Fig. 1 is an original image of Lumbar-Spine-T1-SE and Fig. 2 shows the globally segmented image of Fig. 1.

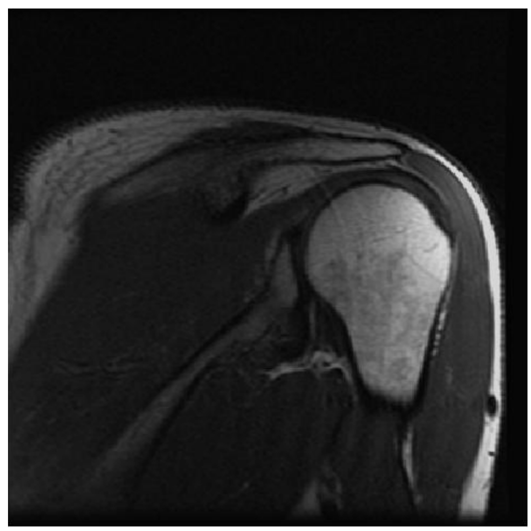

Fig. 3. Original Image - Shoulder-Coronal-T1-SE.

Similarly, Fig. 3 is an original image of Shoulder-Coronal-T1-SE and Fig. 4 shows the global segmented image of Fig. 3.

Both the results contain global segmentation of various parts of objects constituents in MRI medical images.

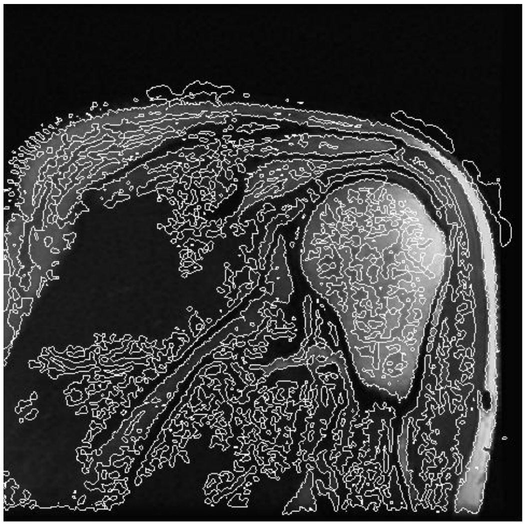

Fig. 4. Global Segmented Image of Fig. 3.

VI. Conclusion and Future Scopes

Experimental results shown in this paper confirm the utility of the proposed model. We demonstrated how the combined approach simultaneously segments the various parts of objects in the image. As the experimental results suggest, combining fuzzy c-means with modified level set method based on local image fitting can segment all the object constituents of the image under consideration and detects the segments of the image with a high degree of accuracy. The combined approach can highlight parts of even low resolution objects. The proposed model can be very useful to segment the image in medical, military and other fields. In future, we plan to use other modified versions of the level set methods based on local image fitting along with modified fuzzy logic for improvement in image segmentation.

Finally, the ability of this type of approach makes it ideal for use in diagnosis of fractures etc. in medical imaging problems.

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BIOGRAPHIES

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