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Spatial fuzzy C-means Clustering based Liver And Liver Tumor Segmentation on Contrast Enhanced CT Images

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Abstract*— Analysis of CT images plays an important role in liver tumour segmentation. Segmentation methods include thresholding, region growing, splitting and merging etc. Segmentation methods are of two types fully automatic and semi-automatic. It is the first and essential step for the diagnosis of liver diseases. Region based segmentation plays an important role in CT liver image analysis. In this paper a hybrid image processing method is presented based on spatial fuzzy C means clustering combined with Mumford Shah model. In image processing Mumford shah model is used for minimizing an energy function involving a piecewise smooth representation of the image. Thus we can detect interior contours automatically enhanced the blurred contours and increase the robustness of an image with less number of iterations. Thus we can improve the segmentation of liver image thereby increasing the detection of tumour effectively.

Index Terms— **Spatial FCM, Mumford Shah model, Image segmentation, CT liver image analysis**

I. Introduction

Liver and liver tumour segmentation on contrast enhanced CT images is a challenging task due to the similarities in intensities of liver tissues with their surrounding organs. Also, the location of liver tumour is not exact in all cases which make the atlas based algorithm meaningless. These challenges must be considered while segmenting liver and liver tumour. Thus, segmentation remains a challenging task in medical imaging field [1]. The most common medical imaging techniques include Ultrasonagraphy (US), Computed Tomography (CT), and Magnetic Resonance Imaging (MRI). CT is often the preferred method for diagnosing many cancers to confirm the presence and size of tumors. By examining the CT image, the radiologist can plan and decide the proper treatment. Fuzzy C-means[2,3,4] clustering is a technique that has been successfully applied to medical imaging field. The FCM algorithm classifies the image into clusters by grouping similar data points in the image. This is achieved by the minimization of cost function through iteration. The immediate neighbourhood pixels possess similar features. Therefore, spatial information should be included that can help in image segmentation. A variety of algorithms have been proposed to solve the image segmentation problems [5,6,7,8]. Among them partial differential equations (PDE) based methods have wider range of uses, due to its high accuracy [9,10,11,12]. For this, the technique of snakes or active contour has grown to the curve evolution theory, edge based models and then to region-based models[13,14,15,16,17].. The idea in active contour model or snakes is to evolve a curve and is subjected to constraints. The curve moves downwards its interior normal and stops at the boundary of the objects. The most widely studied mathematical models in image processing is the Mumford-Shah model, which is about the variational problem of minimizing a functional involving a piecewise smooth representation of an image.

In this paper, a segmentation technique is proposed, which combines the advantages of spatial fuzzy C-means clustering and Mumford-Shah model, so that we can segment out the liver and the liver tumour with increased efficiency and robustness.

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II. Proposed System

The input is the CT image of the abdomen shown in fig.1. Among the various imaging techniques such as MR and X-ray, CT has the unique ability to image a combination of soft tissue, bone and blood vessels, which makes it the preferred method to diagnose liver tumor. After getting the CT image, it has to be clustered by using spatial fuzzy c means algorithm to get better details.

For better boundary detection, we combine the Mumford-Shah model with the FCM. After segmentation, we get the segmented image of liver with tumor and tumor alone.

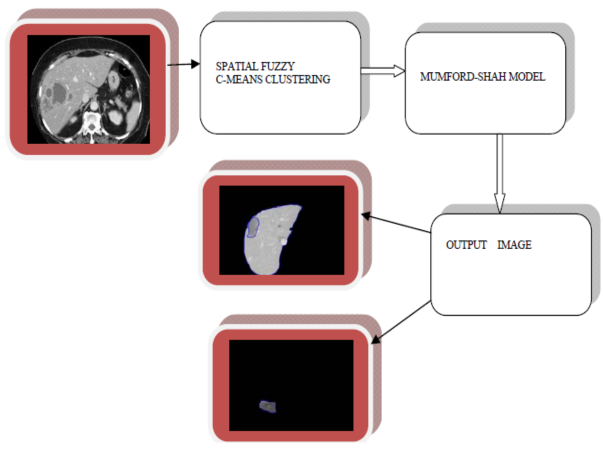

Fig.1.Block diagram

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III Spatial Fuzzy C-means Clustering

Clustering techniques can be categorised into two: Hierarchical and Partitional. Partitional clustering yields a single partitioning of data instead of the clustering tree obtained by hierarchical clustering. It usually involves optimizing an objective function. The frequently used objective function is the Euclidean distance to measure the distance between data points and centroids. A hard or crisp technique allocates each point to a single cluster. But in fuzzy approach, the data points are allocated with membership degrees. The FCM technique has robust behaviour as well as the ability to model the uncertainty. But FCM doesn't contain the spatial information, which makes it sensitive to noise.

The FCM objective function is given by

$$J_{FCM} = \sum_{j=1}^{n}\sum_{k=1}^{c} \mu_{jk}^{q} \left\| y_j - v_k \right\|^2 \qquad (1)$$

Where $_{jk}$is the membership of data point y_j in cluster k
v_k is the centre of cluster k
n is the number of data points
c is the number of clusters and
q is the fuzziness index.

But it should satisfy the following constraint,

$$\sum_{k=1}^{c} \mu_{jk} = 1 \qquad (2)$$

Using the above equations, the membership, μ_{jk} is computed using

$$\mu_{jk} = \frac{1}{\sum_{m=1}^{c}\left(\frac{\left\| y_j - v_k \right\|^2}{\left\| y_j - v_m \right\|^2}\right)^{\frac{1}{q-1}}} \qquad (3)$$

And the cluster center v_k is given by

$$v_k = \frac{\sum_{j=1}^{n} \mu_{jk}^{q} y_j}{\sum_{j=1}^{n} \mu_{jk}^{q}} \qquad (4)$$

In spatial Fuzzy C-means clustering, a penalty term is added with the Image Euclidean distance.

Euclidean method is commonly used to measure the distance. It is in the form

$$\sqrt{\sum_{i=1}^{d}\left(x(i) - y(i)\right)^2} \qquad (5)$$

Where x and y are two images
d is the number of pixels and
$x(i)$ is the gray level of the i^{th} pixel.

This form of Euclidean distance doesn't provide any spatial information and is sensitive to noise. So a new image Euclidean distance is introduced,

$$\text{IMED}(x,y) = \sqrt{\sum_{i,j=1}^{d} g_{ij}\left(x(i) - y(i)\right)\left(x(j) - y(j)\right)} \qquad (6)$$

$$= \sqrt{(x-y)^T G (x-y)} \qquad (7)$$

where G is a symmetric matrix.

With the matrix G, the objective function of the SFCM becomes,

$$J_{SFCM} = \sum_{j=1}^{n}\sum_{k=1}^{c}\left(\begin{array}{c}\mu_{jk}^{q}\left(y_j - v_k\right)^T G\left(y_j - v_k\right) \\ +\beta \prod_{k=1}^{c}\sum_{l\in N_j}\left(1 - u_{lk}^{q}\right)\end{array}\right) \qquad (8)$$

Solving the above equations, we get,

$$\mu_{jk} = \frac{1}{\sum_{m=1}^{c}\left(\frac{d_{jk}^2 - \beta\sum_{t\in N_j}\frac{1}{\sum_{l\in N_t}\left(1-\mu_{lk}^{q}\right)}}{d_{jm}^2 - \beta\sum_{t\in N_j}\frac{1}{\sum_{l\in Nt}\left(1-\mu_{lm}^{q}\right)}}\right)^{\frac{1}{q-1}}} \qquad (9)$$

IV. MUMFORD-SHAH MODEL

Mumford-Shah variational methods have been widely studied in image processing because of their numerical advantages and flexibility.

Let C be the evolving curve and the boundary in a region Ω, and ω be the open subset of Ω.

i.e. ω⊂Ω and C= ω

Also, inside C denotes region ω and outside C denotes Ω\

If an image u_0 is formed by two regions of approximately piecewise-constant intensities, considering the fitting term,

$$F_1(C) + F_2(C) = \int_{inside(C)} \left|u_0(x,y) - c_1\right|^2 dxdy + \int_{outside(C)} \left|u_0(x,y) - c_2\right|^2 dxdy \qquad (10)$$

where c_1 andc_2 the constants depending on C are the averages of u_0 inside C.

C_0, the boundary of the object is the minimizer of the fitting term

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$$F_1(C_0)+F_2(C_0)\approx 0 \qquad (11)$$

If the curve C is outside the object, then $F_1(C)>0$ and $F_2(C)\approx 0$. If the curve C is inside the object then $F_1(C)\approx 0$ and $F_2(C)>0$. If the curve C is both inside and outside the object then $F_1(C)>0$ and $F_2(C)>0$. And of C=C_0,the energy is minimized and the curve C is now the boundary.Fig.2 indicates the curve fitting pictorial representation of the mathematical expressions.

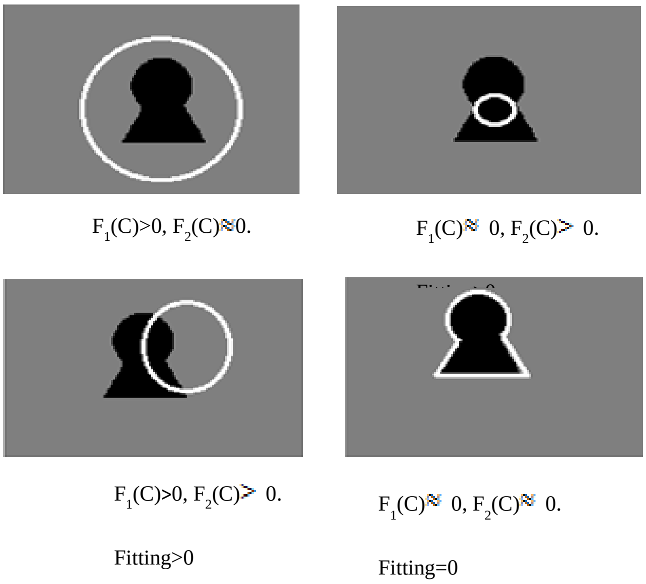


Fig.2.Curve fitting representation

If we add some regularizing terms such as length of the curve, C and the area of the region inside C, then

$$F_1(c_1,c_2,C)=\mu.Length(C)+\nu.Area(inside(C))$$
$$+\lambda_1\int_{inside(C)}|u_0(x,y)-c_1|^2dxdy$$
$$+\lambda_2\int_{outside(C)}|u_0(x,y)-c_2|^2dxdy \qquad (12)$$

Where $\mu \geq, \nu \geq, \lambda_1>0$ *and* $\lambda_2>0$

V. RESULTS AND DISCUSSION

The ultimate aim of this work is to segment the liver, liver with tumor and tumor alone. Four CT images are considered for the analysis of liver tumors. The proposed hybrid image segmentation technique is applied on four CT image data sets and the results are shown in fig(3),(4),(5),(6),In this paper a hybrid image processing technique consisting of spatial fuzzy C means clustering and Mumford Shah model have been presented,

Figure (3) shows the abdominal CT image of a patient with liver tumor.The Region of interest (ROI) is selected from the original CT image. This is shown in figure (3). Figure (4) shows the abdominal CT image of a patient with liver tumor..The Region of interest (ROI) is selected from the original CT image. This is shown in figure (4). Figure (5) shows the abdominal CT image of a patient with liver tumor.The Region of interest (ROI) is selected from the original CT image. This is shown in figure (5). Figure (6) shows the abdominal CT image of a patient with liver tumor..The Region of interest (ROI) is selected from the original CT image. This is shown in figure (6).

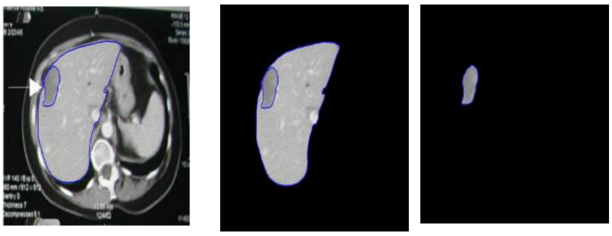


Fig.(3) Liver CT image

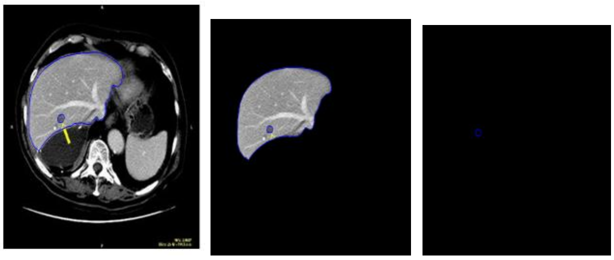


Fig.(4).Liver CT image

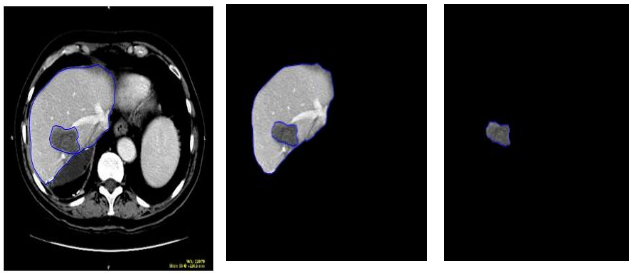
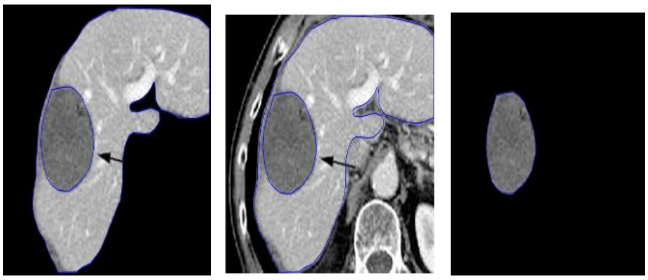


Fig.(5).Liver CT image

Fig. (6).Liver CT image



VI. CONCLUSION

In this work, the segmentation of liver, liver with tumor and tumor alone from CT image is implemented. It has been observed that the segmentation is affected by factors like inherent organ complexities etc. These inherent factors introduce error in segmentation. Improper segmentation leads to errors in segmentation of tumors. To avoid such unfortunate situation the system has provided segmentation by making use of Spatial fuzzy C means clustering and Mumford Shah model. Hence this work presents a system for the segmentation of liver, liver with tumor and tumor alone by making use of optimum human intervention for improving the accuracy of the results.

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