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OPTIMAL APPROACH FOR CT IMAGE SEGMENTATION USING IMPROVED ENERGY BASED METHOD

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Abstract: Accurate segmentation with de-noising is the vital subject of research in the field of medical imaging and computer vision. This paper presents an enhanced energy based active contour model with a level set detailing. Local energy fitting term impacts neighborhood to pull the shape and restrict it to remain in limits. Thus, the global intensity fitting term drives the movement of contour at the object boundaries. The global energy term depends on worldwide division calculation, which can better catch energy data of image than Chan-Vese (CV) model. An improved energy based method for medical image segmentation based on energy minimization principle using level set functions is proposed in this paper. The segmentation is achieved using minimization of energy derived by using level set method and Heaviside function. Energy minimization is achieved by changing the level set with changing local and global image intensities at all the pixels of image. Experiments performed on some sample gray scale images showed that our method has decreased the segmentation time considerably in comparison to earlier segmentation methods. The Weiner filter used in pre processing stage contributed in removing noise and blur effect in source images. The method gives good results on images of varying sizes as shown experimentally.

Key Words: ***Active Contour Models, Energy Based Method, Hybrid Region Based Method, Intensity Inhomogeneity, Level Set Method, Local Binary Fitting, Local Image Fitting, Mumford Shah Model***

1. INTRODUCTION

Image processing provides the useful form of the original image; it converts the original image into a form that can give useful results for analysis. Medical Image segmentation is very crucial step in digital image processing. Image processing consists of a number of steps like pre-processing, segmentation, interpretation, etc. Segmentation is most essential step as it extracts the different objects out of the image and help in getting the useful information from images. There are a number of methods available for carrying out the segmentation of medical images. Some methods can segment both real world images as well as medical images. As medical imaging is quite big in size like MRI images so generally they take more segmentation time than other images. There are number of segmentation methods that give good results based on one parameter or other. Methods can be categorized in many ways like: edge based and region based, local region based and global region based, Clustering based, energy minimization based, fuzzy logic based, level set methods and hybrid methods.

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Now a day's combination of one or more methods is used to give better segmentation results. Like Liu et. al [1] used level set method as well as energy minimization for segmentation. The method is using the traditional Chan Vese model to gather global information and local energy is formulated using the framework in [2] energy obtained in [3]. So basically for accurate segmentation results one or more methods are combined. Most popular categorization of segmentation algorithms is edge based and region based. Edge based methods use the gradient approach to evolve the contour while region based methods use the contour's inside and outside intensities as contour evolution criteria [4]. Region based techniques tend useful in case of images with weak boundary objects as edge based tend to fail in that case. The traditional Mumford Shah functional [5] that is used to find out optimal criteria for segmenting a region into smaller regions used piecewise smooth function to represent an image. The minimum value of function calculated can be used to find out the accurate segmentation solution. Chan Vese model is also a simplified Mumford and Shah function that uses intensities of internal and external regions of contour to give good segmentations for images with weak boundaries but it fails in case of intensity inhomogeneity and mostly medical images have an intensity in homogeneity problem so Chan Vese methods fail to give a good result there. To get the best rate have an Intensity inhomogeneity problem many modifications were proposed like piecewise smooth formulation for Mumford and Shah Model. Various methods were proposed to segment the images with heterogeneous objects proposed a method to calculate the region based energy in a local way [2] proposed a new method for segmenting images based on geodesic flow rather than Piecewise Smooth (PS) methods. This method combined the local geodesic active contour method and global region based active contour method. Geodesic energy was calculated from local regions around a curve and resulting flow was more robust to curve initialization and noise similar to the region based flows, but still this method was dependent on curve initialization to some extent as it is necessary that initial contour should be placed somewhat near to object boundaries to get better results [6] proposed a better method than Chan Vese and Lankton in terms of efficiency and robustness as it incorporated geodesic and region based global information and then extended this method with local intensity fitting energy for segmenting images with intensity inhomogeneity. This method was called geodesic intensity fitting model based on this Li et al. proposed a hybrid region based active contour method. It uses the global information from CV model and local information is attained using local region based active contour (LRBAC) method and a regularization term is added further to evolve the curve. Motivated from [1] the proposed an enhanced hybrid region based active contour method that will formulate the energy minimization equation based on level set methods. The Energy minimization equation is derived using intensities inside and outside the objects. The Proposed method works well on medical images, but it is not giving good results with real world images. It takes both local and global information on image to segment the image. Using the zero level set method and Heaviside function, it calculates the energy function and segment the image. Both internal and external intensities of the curve are used to finally segment the image and stop the curve evolution. It gives better results as it is not sensitive to curve initialization and not mask dependent.

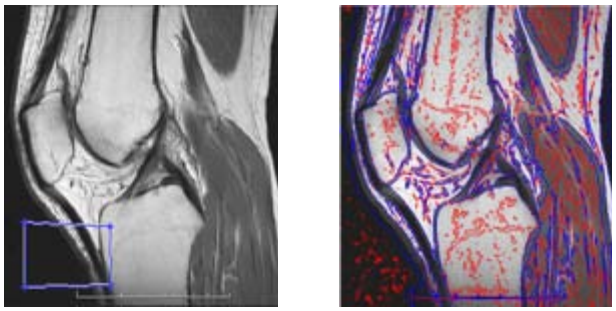
The rest of the paper is organized as follows. Background in section II. The proposed method is presented in section III. Experiments and results in section IV and Concluding remarks are given in section V.

2. BACKGROUND

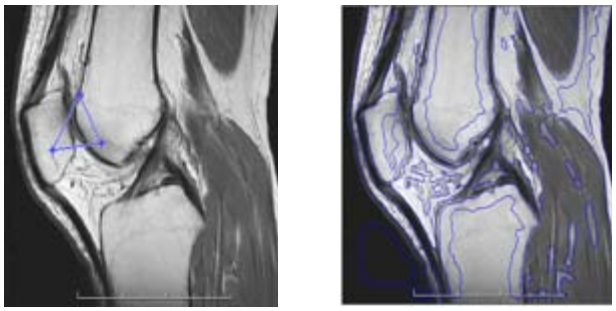
The active contour model is very popular these days to segment the images, the main idea behind this model is to minimize energy functional or in other words a curve is evolved to

minimize energy functional to get the final segmented image. Active contours can be edge based method using a gradient approach to segment the image or can be region based methods that segment image taking in account global information also. Region based methods are better as they are initialization independent and also less sensitive to noise, but the images with heterogeneous objects in the region based methods fail to give good results, in contrast edge based give good results for same. So a new technique is required that uses the benefits of both local and global region based techniques or both edge and region based techniques. Till now many methods have been proposed in literature based on this approach like in [7] Paragios et al. proposed a new method combining both edge based and region based techniques to create new energy functional that is to be minimized. Further Brox et. al [8] shown that segmenting an image with local statistics is a first order approximation of Mumford Shah piecewise smooth model and that was further detailed in the method local binary fitting energy, but there was no proper defined scale or parameter on which the image should be localized. So Piovino et. al proposes convolution study to compute the local statistics more efficiently. Then comes the Geodesic curves in space of localized regions than a piecewise smooth model, but all these models focus on the local energy that was proposed by Chan and Vese piecewise constant model.

Localised region based approach [1] Lankton and Tanenbaum suggested a new method that provide a way to localise any region based energy in a fully variational way. They proposed three localized energy terms and showed segmentation results in case where global energies failed. They showed the way how any energy can be localized. They extended the work of Brex et al, but by doing localisation of various global energies the method become more sensitive to initialization of curve and also the method taking more time than already proposed methods [9]. In order to dispense with the re-introduction system for antiquated level set model and expels the computationally exorbitant re-instatement. A thought about utilizing an old model, this energy based model is more sturdy against images utilizing powerless edge and force anomaly [10]. Liu et. al[1] Proposed a hybrid method which uses both local and global methods to give the correct results quickly. This method again uses Chan Vese method to collect global information and LRBAC to get local information, but again this method while giving better results in terms of noise and accuracy as compared to Chan Vese and LRBAC still takes much time and large number of iterations required and it is sensitive to initialization and fails on big images, mostly medical images are big in size. The local fitting intensity(LFI) energy functional is computational simpler than the local binary fitting (LBF) energy functional prevents from being trapped into local minimum, but also capable of keeping the level set function regular [11], the LBF model is much more efficient. The curiosity inside is to help you locally register enhanced signed pressure function (SPF), which utilizes neighbourhood mean qualities which empowers it to identify limits inside the homogenous spots. An active contour model, energy based model determines profitable points of interest not stuck simply utilizing snappy process, robotization and right microarray [12] and CT image segmentation.



(a) (b)



(c) (d)

(a) Initial Contour (b) Segmentation Result (c) Initial contour in Different Location (d) Segmentation Result

Figure 1 shows the initial contour and segmented result, but the major problem with existing methods is when the initial contour location changes the result changes and it varies each time that is not the symptoms of good method. The energy based model [9] is an established model for image de-noising and it uses a standard of image slope greatness to supplant standard of image inclination size as the smooth term of image. This model can secure the limit of an image while diminishing the clamor [13]. The vital capacity is set up with the primary term and the smooth term of image. Energy based segmentation method uses internal and external energy with the smoothing term by proper evolving the level sets using Dirac and Heaviside function the speed of segmentation can be increased.

The proposed method is based on energy that will give more accurate segmentation results in lesser time and independent of curve initialisation. It will not use any mask to initialise contour. Contour can be placed anywhere, results will be same. Also the method will be a combination of edge based and region based techniques and take both local and global information to evolve the contour. A new level set function will control the contour evolution and will stop evolving when energy is minimized. The method will pre process the image to remove any kind of noise to give accurate segmented image. In rest of the paper we describe the generalised energy minimisation formulation and describe the energy formula used in proposed method. Also the energy described in [1] based on which new method is proposed is discussed..

3. PROPOSED METHOD

The basic Chan Vese model was able to handle the images with weak object boundaries but not the images with intensity inhomogeneity. Chan Vese model is special case of Mumford Shah problem. The energy functional derived in this model is formed by taking internal as well as external energies of the contour. The minimization problem is solved by using the level set method. The energy function is reformulated using level set method which is solved with help of gradient descent method.

This method is less sensitive to initialisation of contour but fails if intensity inhomogeneity is there, but in hybrid region based active contour model, energy function is formed by both Local and global energy as well as a regularization term is added to to regularize the contour. The energy functional is solved by taking level set function $\boldsymbol{\phi}(x,y)$. $\boldsymbol{\phi}$ is positive if x,y lies inside curve and negative if point is outside the curve.

$$E^{Hybrid} = \alpha E^{Global} + \beta E^{Local} + \omega L(\Phi) \quad (1)$$

Earlier some methods used only local energy based method or only global energy based method, but as global energy based methods were not suitable for images with the problem of intensity inhomogeneity and local energy based methods are not suitable for images with weak

boundaries. Like local region based active contour method. In the hybrid method energy function consists of three terms global energy, local energy and regularisation term. The global energy term can be expressed as:

$$E^{Global}=\int_{inside(C)} |I(y)-m|^2 \, dy + \int_{outside(C)} |I(y)-n|^2 dy \quad (2)$$

and further Heaviside function is used to rewrite the global energy term.

$$E^{Global}=\int_{\Omega y} (H\Phi(y)(H\phi\,(y)\,(I\,(y)-m)^2+ (1-H\phi\,(y))\,(I\,(y)-n)^2)\,dy \quad (3)$$

Heaviside function is generally written in smoothed version as

$$H_\varepsilon(z)=\frac{1}{2}\left[1+\frac{2}{\pi}(\arctan\left[\frac{z}{\varepsilon}\right]\right] \quad (4)$$

Dirac function that is the derivative of Heaviside function is used.

$$\delta_\varepsilon(Z)=H'_\varepsilon(z)=\frac{1}{\pi}\left[\frac{\varepsilon^2}{\varepsilon^2+z^2}\right] \quad (5)$$

where ε is a positive constant and the local energy is formulated as

$$E^{local}=\int_{\Omega x}\int_{\Omega y} B(x,y)\, F^{Local}\, dx\, dy \quad (6)$$

$$B(x,y)=\begin{cases}1, & |x-y|<r\\ 0, & \text{otherwise,}\end{cases} \quad (7)$$

Where B(x,y) is a Ball function from [7].

Here ‘r’ is the radius of ball. This function will return 1 if the point y is within the ball and 0 otherwise. The total energy formulation is given as

$$E^{Hybrid}(\phi,m,n,u_x,u_x)=\alpha\int_{\Omega y}(H\phi\,(y)\,(I\,(y)-m)^2+(1-H\phi\,(y))\,(I\,(y)-n)^2)\,dxdy+$$
$$\beta\int_{\Omega x}\int_{\Omega y} B(x,y)\,(u_x-V_x)^2 dx\,dy+\omega\int_{\Omega x}\delta\phi\,(x)\,|\nabla\phi\,(x)|dx \quad (8)$$

Gradient descent used in Chan Vese is also used here to calculate the level set for minimising the energy functional. For both the real images and synthetic images this method gives better results in terms of segmentation time and accurate segmented image. The proposed energy based method for medical image segmentation which is not sensitive to initialization of contour and also works in case of intensity inhomogeneity. It takes both local and global energies into account and use level set method [14] to evolve the contour. This method takes the source image and pre process it using the wiener filter. This filter has been used for digital signal processing [15] so far and it is also giving good results in case of medical images. So this method is using Weiner filter first time in field of medical image processing. After the initial pre processing stage , any kind of noise or blur effect is removed from source image and chances of successful segmentation increases in further steps. Energy function is formulated using level set function, initially zero level set is taken at the boundary of contour. Energy minimization is formulated using level set function, which is further calculated by using smooth Heaviside function [16] where Dirac function that is the derivative of Heaviside function is used. Epsilon and Dirac are taken as positive constants. Dirac δ, is derivative of H_ε (smooth Heaviside function). Internal and external energies are

calculated using smooth Heaviside function and Dirac function for the source image. Then the level set function is calculated using average of inside and outside intensities of the evolving contour.

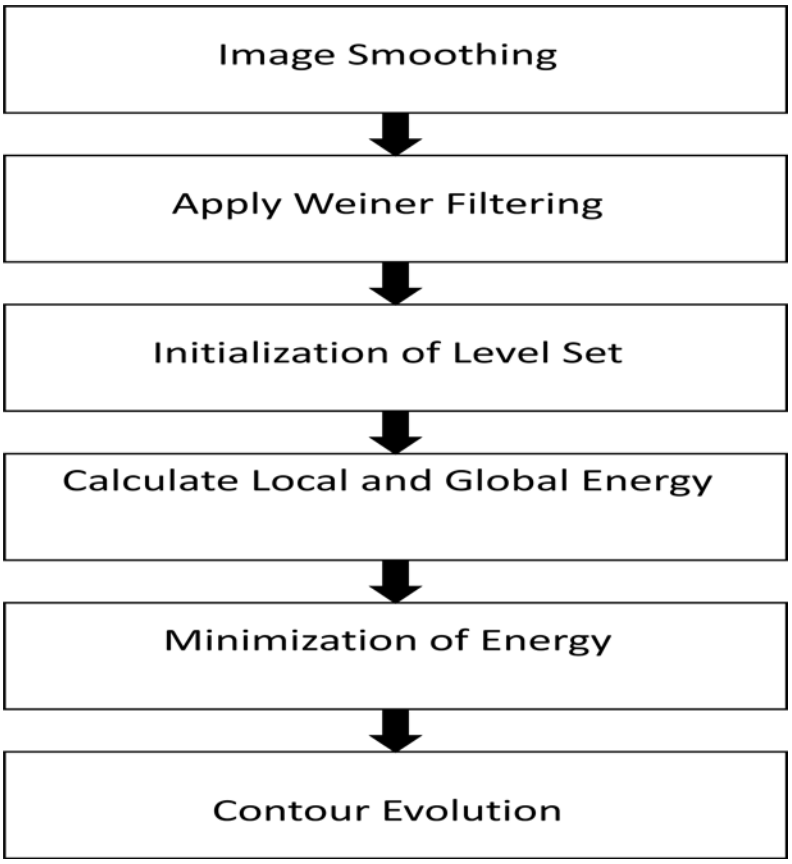


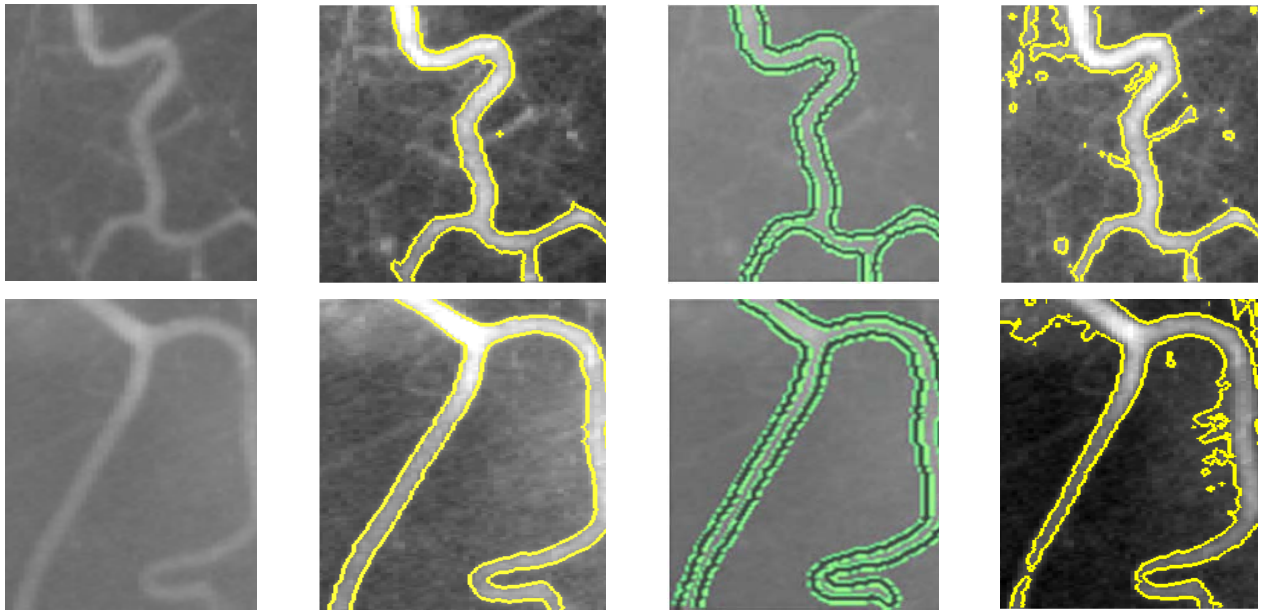
Figure 2. The Proposed Method

$$\phi = \phi + \delta(I-(u_x + v_x)/2) \quad (9)$$

With this equation contour keeps on evolving. The values of level set ϕ keeps on changing until final segmented image is obtained.

4. EXPERIMENT AND RESULT

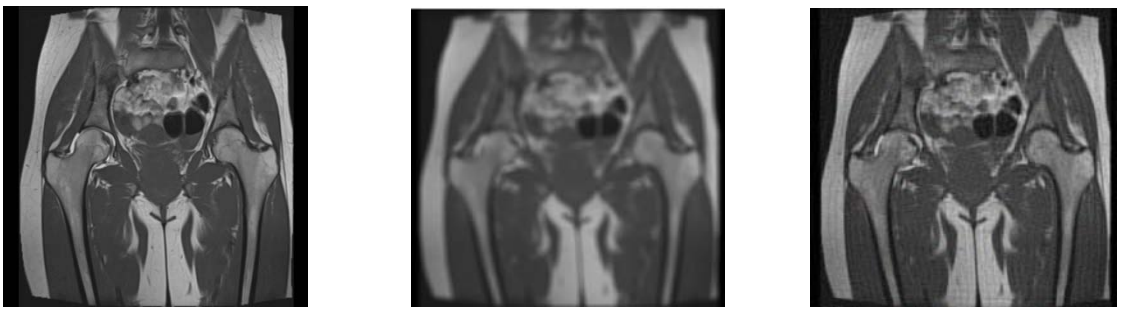
This section demonstrates the accuracy and the effectiveness of the proposed method by comparing it with other energy based image segmentation methods and illustrates the ability of the proposed method in terms of speed and efficiency. In the implementation of proposed method. All the methods have been implemented using Matlab R2014b installed on a PC Pentium(R) Dual-Core CPU E5500 processor with a clock speed of 2.80 GHz and 2 GB of RAM. In order to prove the benefits of this method we applied the method on some images along with hybrid method and also local region based active contour model. Then results are compared for all three methods side by side.The method is not sensitive to placement of initial contour as we are initially taking zero level set and not initializing the contour to any specific position and also like LRBAC method no initial mask is explicitly given and the experiments proved that it takes less time on bigger medical images like CT images as compared to LRBAC.



(a) (b) (c) (d)

Figure 3. Comparison of Proposed Method with LRBAC and Hybrid Method. (a) Original Image.(b) Results of LRBAC Method; (c) Results of Hybrid Method; (d) Results of The Proposed Method.

In order to prove the benefits of this method we applied the method on some images along with hybrid method and also local region based active contour model (LRBAC) then results are compared for all three methods side by side. Firstly the source medical image is pre processed to remove the blur effect or noise from image. The filter used here is Weiner filter[17] so far it is used in digital signal processing and for first time we used it in medical image processing. After application it gives better results than other traditional filters like Canny [18], Prewitt and Sobel.



(a) (b) (c)

Figure 4. (a) Original Image (b) Noisy Image (c) Restored Image After Applying Weiner Filter

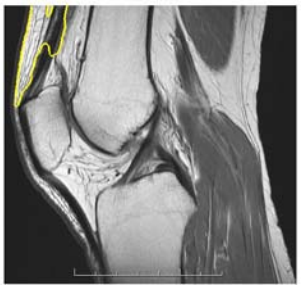
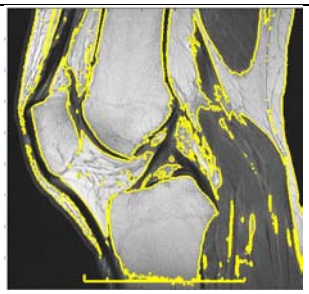
As seen in experimental results Weiner filter removes noise and de blur the source image which in turn saves time for further processing of image. Image obtained from pre processing is then passed to next phases of segmentation process. Improved hybrid method further process the image using level set method and energy minimization technique.

Table -1 Iterations and CPU Time for the LRBAC Method, Hybrid Method and the Proposed Method

	T shaped Object Image		Vessel 1 Image		Vessel 2 Image	
Methods	**Iterations**	**Time (in seconds)**	**Iterations**	**Time (in seconds)**	**Iterations**	**Time (in seconds)**
LRBAC Method	1220	36.678	480	17.156	1500	126.700
Hybrid Method	760	23.648	380	13.516	2500	141.290
Proposed Method	2	1.1214	90	5.3016	80	5.2989

Table 1 show the number iterations and time taken in those iterations of the LRBAC, hybrid and the proposed method for three different type of images in which the proposed method takes less time and performance is better than others. The proposed method gives results in noticeable less segmentation time and also works on images with varying sizes. As shown above it works well on medium sized images. Experiments also proved that it give good results on larger images.

Table -2 Comparison of LRBAC and Improved Method on Basis of Segmentation Time of Medical Images

Method	Segmented Image	Time (in seconds)
LRBAC Method		300
Proposed Method		53

The segmentation time taken by the proposed method is considerably less than previous methods also it gives better segmentation results. There are various measures available to evaluate the quality of final segmented image obtained like peak signal to noise ratio (PSNR), signal to noise ratio (SNR), root mean square error (RMSE) etc. These are mathematically defined measures to measure quality and calculate the amount of distortion in final signal. Below is the comparison of the RMSE values for the proposed method and hybrid method and LRBAC method.

Table-3 Comparison of RMSE values for LRBAC, Hybrid and The Proposed Method

	Vessel 1 Image	**Vessel 2 Image**	**T shape object Image**
RMSE for LRBAC Method	0.60	0.59	0.39
RMSE for Hybrid Method	0.16	0.32	0.34
RMSE for The Proposed Method	0.60	0.46	0.34

RMSE values give the measure of quality of final image obtained after segmentation. lower the value of RMSE better is the quality of image.

5.CONCLUSION

In this paper new energy based active contour method with level set definition is proposed. The proposed energy model consolidates both local and global terms in a more effective way. Local energy fitting term uses neighbourhood data from the image that fragments inhomogeneous objects and global energy fitting term segment homogeneous objects. Improved level set technique utilizes energy to control the inside and outside shape of contour. Accordingly, it can't appropriately fragment complex homogeneous areas which have high power contrasts between the contained pixels. Consequently, it can legitimately section complex homogeneous localized objects. The proposed method presents an improved energy based method for medical image segmentation based on active contour model using level set approach. The proposed method is not sensitive to contour initialization as the previous methods like LRBAC and hybrid region based method. It takes into account both the local and global energies and has reduced the segmentation time considerably as compared with LRBAC and hybrid region based active contour method. The method is tested on gray scale medical images of varying sizes and achieved satisfying results as demonstrated in experimental readings above, but in future there is scope of applying this method on real images as well as coloured images.

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