COMPARATIVE ANALYSIS OF EDGE BASED AND REGION BASED ACTIVE CONTOUR USING LEVEL SETS AND ITS APPLICATION ON CT IMAGES

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Abstract

Detection of Liver cancer from CT images is an exigent task due to the reason that cancer impression in CT images are of very low in contrast and have indistinguishable edges. Indistinguishable edges are edges in which foreground and background are almost same. Image segmentation is used to extract desired anatomical structure from image. Image segmentation is the process of dividing the image into multiple regions. These regions are sometimes called region of interest (ROI). These ROI's are used as informative inputs to further image processing e.g. feature extraction, selection and ultimately the classification of a disease. Thus an effective image segmentation is utmost important in medical images. In case of indistinguishable edges most segmentation techniques fails to detect edges. Edge based and region based active contour methods are most prevalent for image segmentation. Edge based technique works using gradient function and ultimately stopping function to detect edges , while region based uses average information inside and outside regions to control evolution and termination at edges. In this paper comparative analysis of edge based and region based active contour using level sets is done. When applying these methods on the CT images with an impression of liver cancer, it has been found that the edge based contour able to locate the desired edges more accurately. The quantitative and qualitative results comparison between two techniques has also been done. Results shows that edge based methods performs comparatively better than region based active contour using level set if number of iterations are controlled properly.

Index Terms: *Level Sets, Gradient, Stopping function, Active contours and Liver cancer.*

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1. INTRODUCTION

Cancer diseases accounts for approximately one sixth of death worldwide but as per WHO report liver cancer contributes heavily to overall deaths caused by all types of cancer [1]. Recently it was concluded that fifty percent of cancer diseases are curable if detected early and accurately. Also in the prognosis and diagnosis of a cancer it is necessary to know beforehand the size and area of spread of cancer. In this the studies related to medical imaging plays an important role in the early diagnosis of cancer. The medical imaging has now emerging as a non invasive tool for disease diagnosis [2]. Many medical modalities related to imaging are being used like X-rays, Ultrasound, CT scan, MRI etc. The CT and MRI are the latest and best of all due to their better resolution and contrast. Now with respect to CT scan the MRI scan is more expensive in nature; it is difficult for patient to hold breath for couple of seconds and is not congenial for patients having claustrophobia. In comparison to this the CT scans are less expensive, patient friendly, takes less time to scan as compared to MRI [3]. CT scan is perhaps the oldest and first technology developed by Hounsfield in 1970, which makes possible to take tomography images [4]. Thus, in general the CT images are now becoming more and more popular in disease diagnosis and prognosis. Now days as volume of data increases manifolds and it is not possible for a radiologist or an oncologist to diagnose the disease manually and sometimes this may leads to misdiagnosis of a disease. Thus, computer aided diagnosis system attracts a great amount of interest [4] for detection of diseases to improve accuracy and efficiency. According to the recent statistics , liver cancer is one of the dangerous cancerous disease and in this work our main stress is on detection of cancer in the CT images of a liver. Therefore, designing and developing CAD system for liver cancer is of great interest. The most important part of computer aided diagnosis system is automatic image segmentation.

Image segmentation is the process of dividing the image into multiple regions. These regions are sometimes called Region of Interest (ROI). These ROI's are used as informative inputs to further image processing e.g. for feature extraction, selection and ultimately the classification of a disease. Thus an effective image segmentation is utmost important not only in detecting the location of cancer in liver but also equally imperative to observe the extent to which cancer spread across liver. In addition, it also gives information that how much damage has been done to nearby organs or to liver itself. This information becomes very critical in deciding the line of treatment to be followed by the oncologist/surgeon i.e. chemotherapy or surgery etc. If image segmentation is not proper and gives incorrect information regarding the location and extent of spread of cancer by not detecting desired boundaries of ROIs i.e. either the ROI is over segmented or under segmented, then CAD system may gives false diagnostic report. Thus segmentation method needs to be sensitive enough to detect correct location and area of cancer tissues so that faithful diagnosis can be done.

Extensive studies have done is past on image segmentation and many methods have been proposed for the same. Sezgin and Sankur [4] perform a quantitative comparison of various thresholding techniques for image segmentation. Weszka, Nagel and Rosenfeld [5] proposed a technique for the selection of a threshold value for image segmentation. Yenwan and Higgins [6] proposed symmetric region growing method, in which extraction of region is based on some predefined criteria and concentrates on selection of seed point. Coleman and Andrew proposed clustering for image segmentation and is an unsupervised method of segmentation [7], Dunn [8] proposed fuzzy c-means clustering, Bezdex [9] improves fuzzy clustering algorithm and Sewchand [10] proposed expectation maximum algorithm for image segmentation. Dzung, Jerryprince and Chenyang Xu [11] reviewed various methods of image segmentation like thresholding, region growing clustering and deformable contours. Kass [12] proposed deformable contours named as snakes. Caselles [13] introduced geometric curves for representing the deformable or active contours for image processing. Level set is to represent and embed interface to higher dimension function known as level set function ϕ and devise the movement of contour as the evolution of level set function. Based on the stopping criteria the contours were divided into two categories: Region based and Edge based .The edge based active contours used a stopping function, computed using the gradient of an image for stopping the curve at edges. In images where the edges are vague, the contour is unable to terminate. This problem of spreading of contour out of desired region is commonly named as leakage. In order to overcome this problem of leakage region based contour has been proposed by Chan and Vese

In CT images, with an impression of cancer in liver, the intensity of infected region of liver is almost same as that of non infected regions as shown in Fig. (1). It has been found that most of the methods which were used in past for image segmentation of such images do not perform well. This may give the radiologist wrong information about the extent of spread of cancer across the liver.

So two active contour methods i.e edge based and region based active contour models using level sets are compared to find out which one segments tumor better.

In this paper, to determine which segmentation method would provide the best results in locating the cancer region in liver in CT images comparative performance evaluation of these methods has been statistically evaluated using (i) Correlation, (ii) Variation of Information (VOI), (iii) Global Consistency Error (GCE), (iv) Rand Index (RI). Tests are performed on 10 CT images.

The outline of this paper is as follows: Section 2 consists of edge based model Section 3 consists of region based model. Section 4 consists of review of level sets. Section 5 includes results and comparison. Last section concludes this paper.

2. EDGE BASED ACTIVE CONTOURS

In medical imaging Edge based active contours [18] uses an edge detector based stopping function for terminating the contours at edges. This stopping function can be defined by a positive and decreasing function g, depending on the gradient of the image $I(x, y)$, such that

$$g\,|\nabla I(x,y)|) = \frac{1}{1+|\nabla G(x,y)\otimes I(x,y)|^2} \qquad (1)$$

Where g is the stopping function, $G(x,y)\otimes I(x,y)$ is the smoother version of image $I(x,y)$.

In general the gradient is defined as a measure of change in intensity and in context of medical imaging an edge is also defined by the same i.e. change in intensity. So the location in the image where value of gradient is high there is a possibility of an edge.

In edge based active contours when curve evolves and comes closer to an edge, the gradient value approaches maximum and in turn the stopping function approaches close to zero and finally at edge the curve which is evolving attains a zero speed and stops at desired edge.

This method works well for only distinct edges but does not provide satisfactory results when it comes to indistinguishable edges.

This was due to the reason that at indistinguishable edges the gradient value is not high enough to make stopping function close to zero for the curve to terminate at edges and is shown in fig. 1

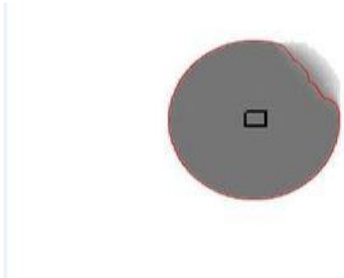


Fig-1: Level Sets applied on Indistinguishable Edges

3. REGION BASED ACTIVE CONTOURS

As edge based active contours suffers from the drawback of not terminating at indistinguishable edges. The region based active contours are proposed [21]; using global information of an image for evolution and termination of curve at edges. In this method the contour divides the image into two regions i.e. inside and outside or foreground and background regions, and calculates the energy based on the mean value of intensity. This method is based on the principal of energy minimization and utilizes the statistical information inside and outside the contour to control the evolution. For a given image I in domain Ω, the energy function is formulated by minimizing equation (3)

$$E^{CV} = \lambda_1 \int_{INSIDE} \left|\mathrm{I}(x) - c_1\right|^2 + \lambda_2 \int_{OUTSIDE} \left|\mathrm{I}(x) - c_2\right|^2 dx, x \in \Omega$$

(2)

Where C1 and C2 are mean intensities inside and outside the contour.

4. LEVEL SETS

The level set method has now become well known and has far-reaching impact in various applications, such as computational geometry, fluid dynamics, and image processing and computer vision . In image segmentation, the level sets along with active contours are being used for detecting indistinguishable edges and shapes.

The basic idea of level set method is to represent a contour as the zero level set function of higher dimension called level set function and thus formulate the motion of contour as evolution of this level set function

The movement of contour as the evolution of level set function under the influence of Force $'F'$ is defined using level set equation (5)

$$\phi_t + F\left|\nabla\right| = 0 \qquad (3)$$

Where $'F'$ is force and is a function of various arguments like curvature, normal direction and gradient

During evolution of level set function it is expected that this function behaves like signed distance function but in practice the level set function is not been able to maintain its signed distance profile and this may leads to numerical errors and eventually destroys the evolution of level sets.

C Li et al. [18] proposed Distance Regularized Level Set Evolution (DRLSE), using an edge based active contour method for eliminating the need of re-initialization.

Advantages of level sets are that they inherited with the property of topology change like region merging and splitting naturally. Secondly the numeric calculation can be done on Cartesian grid which leads to the simplification in calculations and making algorithm less complex.

In this work by looking into the merits of active contours level set models, firstly for segmenting the cancerous region in liver using CT images edge based Distance Regularized Level Set Evolution (DRLSE) method and region based active contour level set methods has been used.

5. EXPERIMENTAL RESULTS

In order to evaluate the performance of two methods pictorial and quantitative comparison is done with closely related algorithms DRLSE [18] and Region based active contour [21] models. MATLAB 2010 was used in implementation of methods.

To verify the accuracy of proposed method quantitative comparison is carried using four parameters. The comparison is done to show the effectiveness of edge based method over other technique.

5.1 Rand Index:- Rand Index is the measure of similarity of data partitions. Consider two sets R and R' having N points i.e X={x1,x2……..xN) [27].

Rand Index measures the similarity in these two data sets by taking ratio of number of pairs of points having the similar relationship by using (4).

$$R(S, S') = 1 - \frac{\left[\frac{1}{2}\left(\sum_u n_{u.}{}^2 + \sum_v n_{v.}^2\right) - \sum_{u,v} n_{uv}^2\right]}{N(N-1)/2} \qquad (4)$$

Rand Index measures the similarity ranging from 0 to1. Where 0 means no similarity and 1 means maximum similarity. Higher the value better segmentation.

5.2 Variation of information (VoI): Meila [28] gives another metric called Variation of information which is the measure of information gain or loss changing from one cluster to another. Clusters can be viewed as ROI in this case. VOI is calculated on the basis of entropy and mutual information using (5) [28]

$$VoI(X,Y) = H(X) - 2I(X;Y) \quad (5)$$

5.3 Correlation: Correlation is the comparison of a template of an image with an actual image .The template image is superimposed on the actual image of an object to generate the correlation image to display match or disparity. Mathematically correlation is calculated using (6)

$$F * I(x,y) = \sum_{j=-N}^{N} \sum_{i=-N}^{N} F(i,j) I(x-i, y-i) \quad (6)$$

Where F is original Template and I is segmented template. Correlation value ranges from 0 means no match or maximum disparity to 1 perfect match or no disparity.

5.4 Global Consistency Error (GCE): Global consistency Error is measure of the extent to which one segmented region is refinement of other. Lower the value of GCE better is segmentation.

Experiments were performed on 10 images, but seven cases are used for comparative analysis.

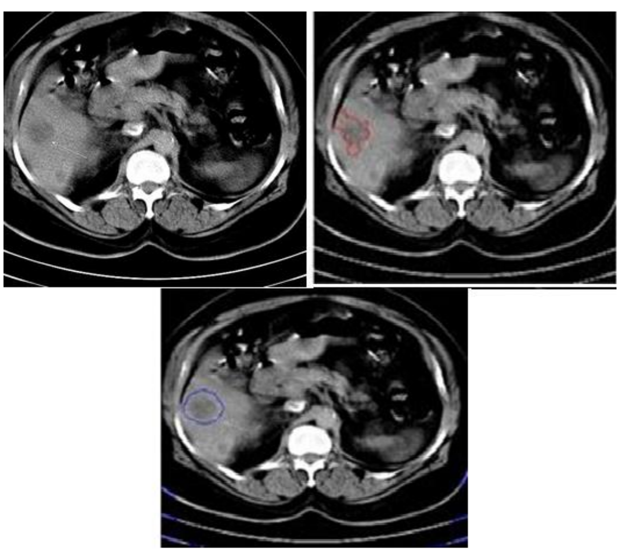


Fig-2: From Top Left to bottom right a) Original CT image cancer marked as ROI b) Segmented output by edge based c) Segmented output by Region based

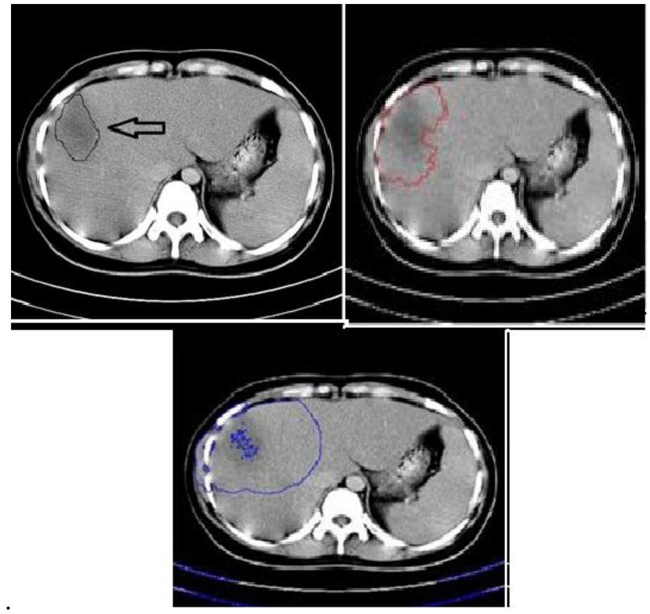


Fig-3: - From Top Left to bottom right a) Original CT image cancer marked as ROI b) Segmented output by edge based c) Segmented output by Region based

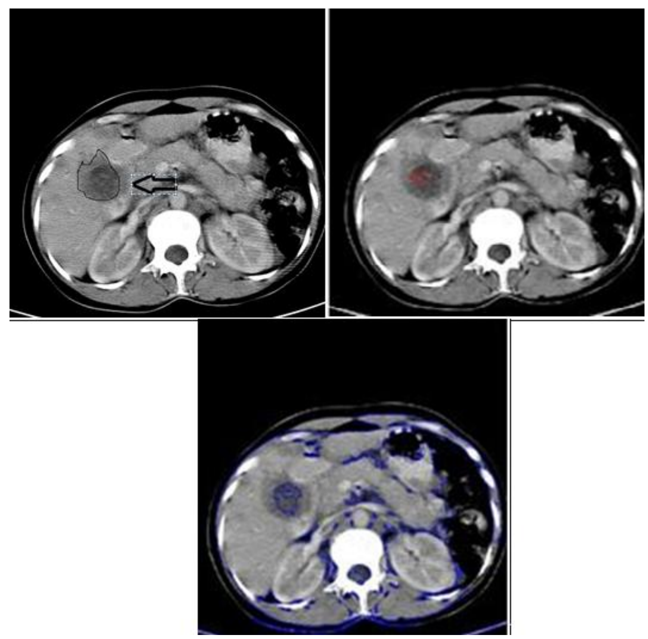


Fig-4: - From Top Left to bottom right a) Original CT image cancer marked as ROI b) Segmented output by edge based c) Segmented output by Region based

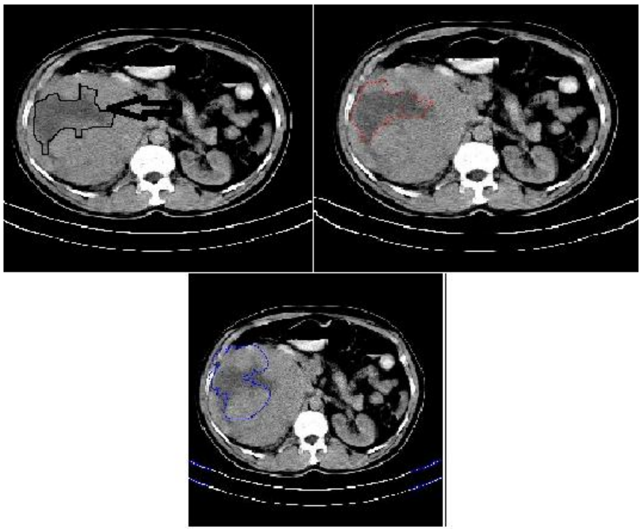
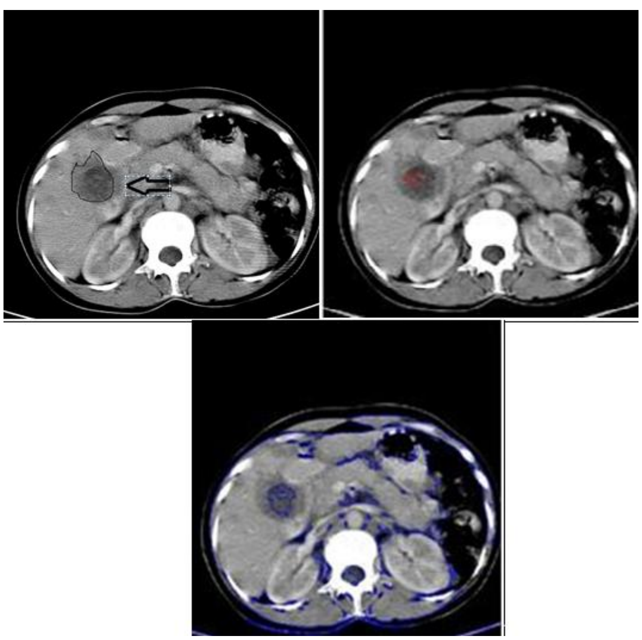


Fig-5: - From Top Left to bottom right a) Original CT image cancer marked as ROI b) Segmented output by edge based c) Segmented output by Region based



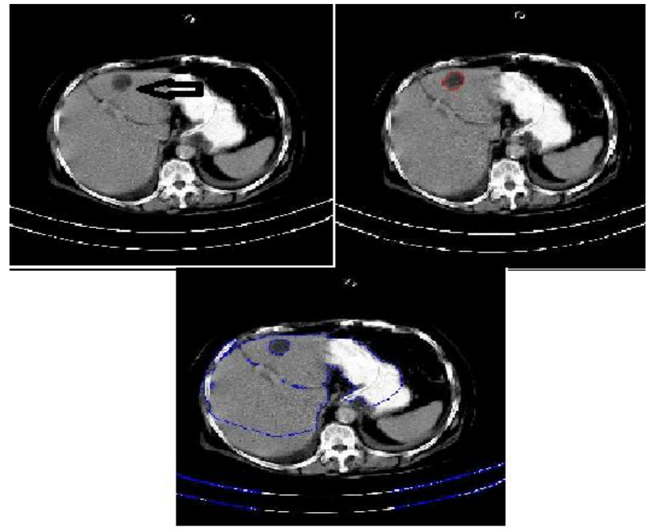


Fig 6: - From Top Left to bottom right a) Original CT image cancer marked as ROI b) Segmented output by edge based c) Segmented output by Region based

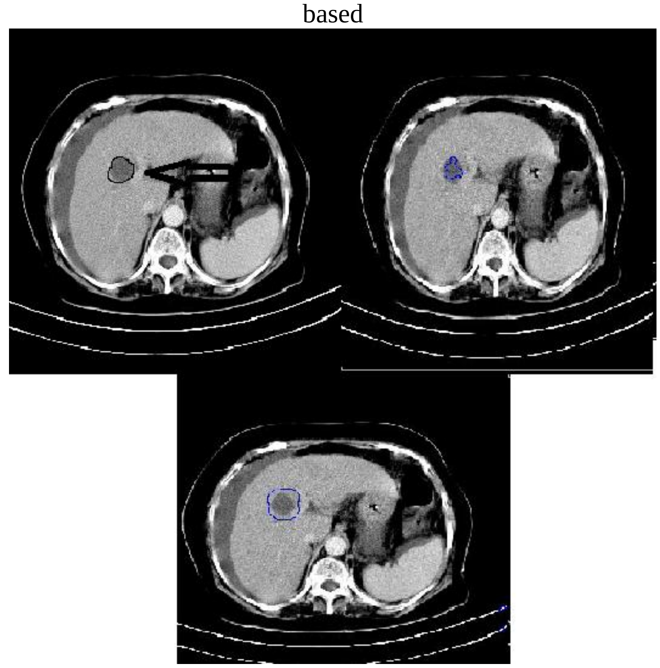


Fig -7: From Top Left to bottom right a) Original CT image cancer marked as ROI b) Segmented output by edge based c) Segmented output by Region based

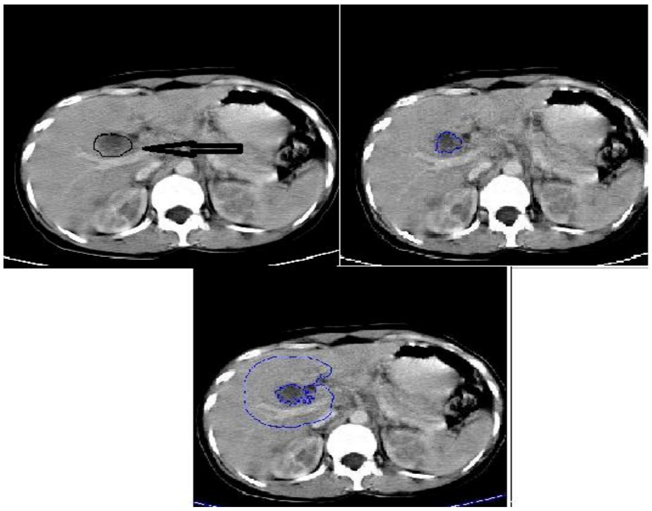


Fig-8: From Top Left to bottom right a) Original CT image cancer marked as ROI b) Segmented output by edge based c) Segmented output by Region based.

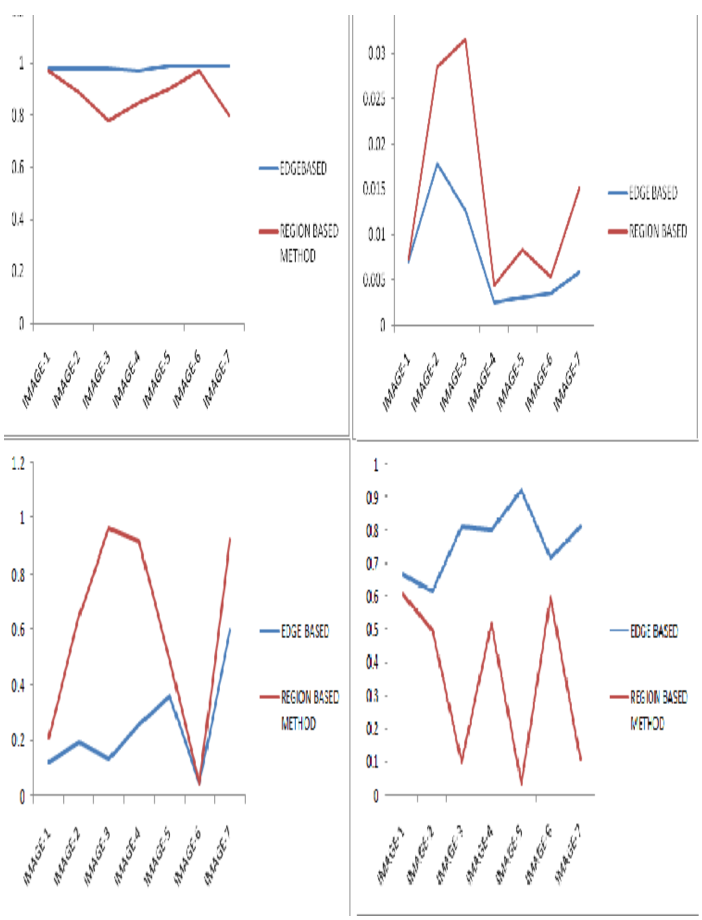


Fig-9: (a) RI (b) GCE (c)VOI (d) Correlation

6. DISCUSSION OF RESULTS

This section demonstrates the results as shown in Fig 2a shows liver cancer in circle. Fig 2b shows the results of edge based active contour model, fig 2c shows result of Region based it is evident that contour reaches far away from desired boundaries in case of region based as compared to edge based. So this gives wrong input to the later stages of computer aided system which in turn gives false result to radiologist for diagnose. This is misleading to the radiologist as he might comprehend wrongly the extent of spreading of cancer in liver. This argument is supported by taking Quantitative parameters and using these parameters for comparison of two techniques. Quantitative Comparison confirms that edge based works better for all types of images taken. Similarly for Figures 3,4,5,6,7 and 8 it is amply clear that while region based methods go beyond the desired region as compared to edge based active contour model, hence giving wrong information about the whereabouts of cancer and also wrong information about the spread of cancer.

CONCLUSIONS

To conclude we compared two methods of image segmentation based on level sets i.e edge based and region based active contours. Results show that if iteration are controlled then edge based can able to locate ROI more accurately as compared to other method. Region based either go far beyond cancer periphery or confined within periphery gives false information regarding the spread of cancer in body. Quantitative comparison is also done which shows that edge based is giving far more accurate idea of location and spread of cancer.

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