SEGMENTATION IN LIVER CT IMAGES IS INVOLVED WITH WIDE RANGE OF TECHNIQUES

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ABSTRACT:

Medical Image Processing is undergoing with lots of modifications and various image modalities due to the existence of minute artefacts. Due to such reason image segmentation of images become more cumbersome and critical task when discussed in terms of tumour pathology. The process of image segmentation became more tedious job towards collecting the images of various organs and identifying the problems within them. The major role of the current research is to segment and extract the liver Computed Tomography (CT) image. This process will help to detect various tissues and various artefacts details from the complex part of a human body. There are many types of segmentation methods using thresholding, watersheds, region grownging, deformable models and also by using fuzzy set of CT Images. It is observed that a deformable model includes parametric and geometric active contours. There are many limitations while using traditional snakes, GVF snakes, balloon forces with respect to Gaussian function and Indentation.

 DOI : 10.36893.DRSR.2022.V09I01N01.152-164

1. Introduction

This paper explore the role of segmentation along with it applications at different study areas. In section – 1.2 a brief summary of segmentation is given with various types available in the market. All the four segmentation methods are discussed with appropriate summaries from theories with the help of suitable examples. In the correction method for the errors in segmentations is discussed in details with mathematical approach. In deformable models are discussed which are used while segmenting the digital images. In types of deformable models are discussed along with their behaviour in different conditions. In the segmentation techniques are discussed. In GVF snake model and the vector fields are studied carefully. In section – 3.8 the fundamentals of thresholding with mathematical approach are discussed in detail with examples. In clustering and FCM fundamentals are discussed in detail along with SFCM as well. In level set method was discussed with two scenarios includes with and without re-initialization.

2. Segmentation and Segmentation types

There are many methods for Liver segmentation and different types of algorithms are applied for contrasting and enhancing CT Data [40]. Few approaches developed for analyzing the images of Livers from MRI Data. There will be different organs and structures with same densities and gray values in the liver; that are independent of image modalities applied or used from manifold error sources and challenges [1]. However, liver shapes will be varying largely and the tissue from the organ appears inhomogeneous in most of the images. This kind of images will be seen when the liver diseases like cirrhosis are observed in a patient. Other factors that influence segmentation are intrahepatic structures and pathologies with intensity varying values. Image Segmentation is considered to be as a major process of digital image processing [2]. Wide range of segmentation procedures are in use to deal with different kind of images and applications. No segmentation method can deal with all kinds of images effectively. The common parameters in different pixels are considered as the base for segmentation. Here common parameters refer to the intensity values, color values and etc. these techniques are mostly used to identify the convex objects, edges of different complex objects and closed contours [2]. The segmentation techniques are not used widely for all purposes due to their time consuming methods. Most of the techniques based on intensity levels are more sensible to other objects which are having equal intensities. These results to a wrong classification of pixels when the objects from human eye are not belong to same classes. Generally the segmentation process is done in three simple ways and they are manual methods, automatically and semi-automatically.

Manual segmentation

The pixels in this method will be pointed out manually and it consumes a lot of time if the image is very large. Marking the contours of objects in such scenarios will be better and it can be done by using the keyboard. It gives high accuracy with low speed as a drawback and vice versa in both the cases. This techniques needs to be at the sake of time for tracking the objects, human resources and costlier too.

 DOI : 10.36893.DRSR.2022.V09I01N01.152-164

These methods are still used in traditional methods of medical purposes and many are not good for appropriate results with good accuracy [3].

Automatic segmentation

Total segmentation is difficult by using automatic methods due to the nature of complexity of images and variations in the images. The algorithms used in segmentation process needs to have priori information for defining few parameters in advance using a computer [1]. This priori information will contain the noise levels and probability of various objects with different distribution levels [2]. This method needs a lot of additional research ahead of segmentation for judging the correct information defining the needful parameters.

Semi – automatic Segmentation

It combines the advantages of both the above discussed methods. One can proceed with automatic segmentation by having the basic or initial information about the structures to be studied. This method includes many types of segmentation techniques. They are thresholding, boundary tracking, clustering methods, neighboring methods, binary mathematical morphology and level set method. The *threshold based* segmentation depends on the distribution of intensities. Based on this distribution thresholding divides an image into two regions; manually they are represented as follows [3]:

If $B(i,j) \geq a$, $B(i,j) = 1$ *(object);*

else $B(i,j) = 0$ *(Background)*

For each region this will be repeated at different threshold values that results in four regions. For successful segmentation at least few properties are to be known ahead of segmentation. This process of segmentation is having a drawback, which includes separated regions that are correctly existed within specified limits. However, they do not belong to selected regions regionally. The better way of selecting a threshold value by choosing a fixed value and most of the times it is taken from the mean value of the image. Generally used method of calculating the threshold value is to calculate the mean values of image at different segmented regions and based on these values the threshold will be identified as a mean value.

$$Threshold_{new} = mean\ (mean_{region\ 1} + mean_{region\ 2})$$

In the case of *boundary tracking* the edges are found by using the values of gradients at boundaries manually and in the version of automatic segmentation this gradient values will follow until they return to same point. Sometime it might find difficult for returning to same point but the probability of including entire holes in the region in a wrong way is high. This in turn creates a problem of gradient that specifies a varying boundary when the region is very small. To overcome this problem the gradient is calculated before applying for segmentation [4].

 DOI : 10.36893.DRSR.2022.V09I01N01.152-164

Region Based Segmentation

This method focus on the important aspect of segmentation process that is not covered by point based technique. A pixel will be divided as pixel objects based on their gray values independently. The isolated points or small areas will be differentiated as object pixels by not considering the connectivity as an important characteristic [1]. An original image in this method will be divided into pixels with neighboring small pixels. The pixel size is generally based on the mask size used by the operators. The features of the object are computed at the edges of the object and the masks consider the pixels from even background images as well. Generally used method to compute the features of an image is by limiting mask size at edges to point of objects or backgrounds [1]. Generally the goal of this method is to satisfy the predefined homogeneous criteria of a research area [5]. Most of the computer assisted liver segmentations are generally based on gray value analysis. The input image will be tessellated first into a set of homogeneous primitive regions. Model based segmentation

Segmentation methods discussed earlier use only local information. However, the human eye can identify the incomplete information from an input. Sometimes the information observed from the neighborhood operators may not be sufficient for performing the given task. However, the geometric shape of the object can be compared by the specific knowledge of an object is done with local information [6].

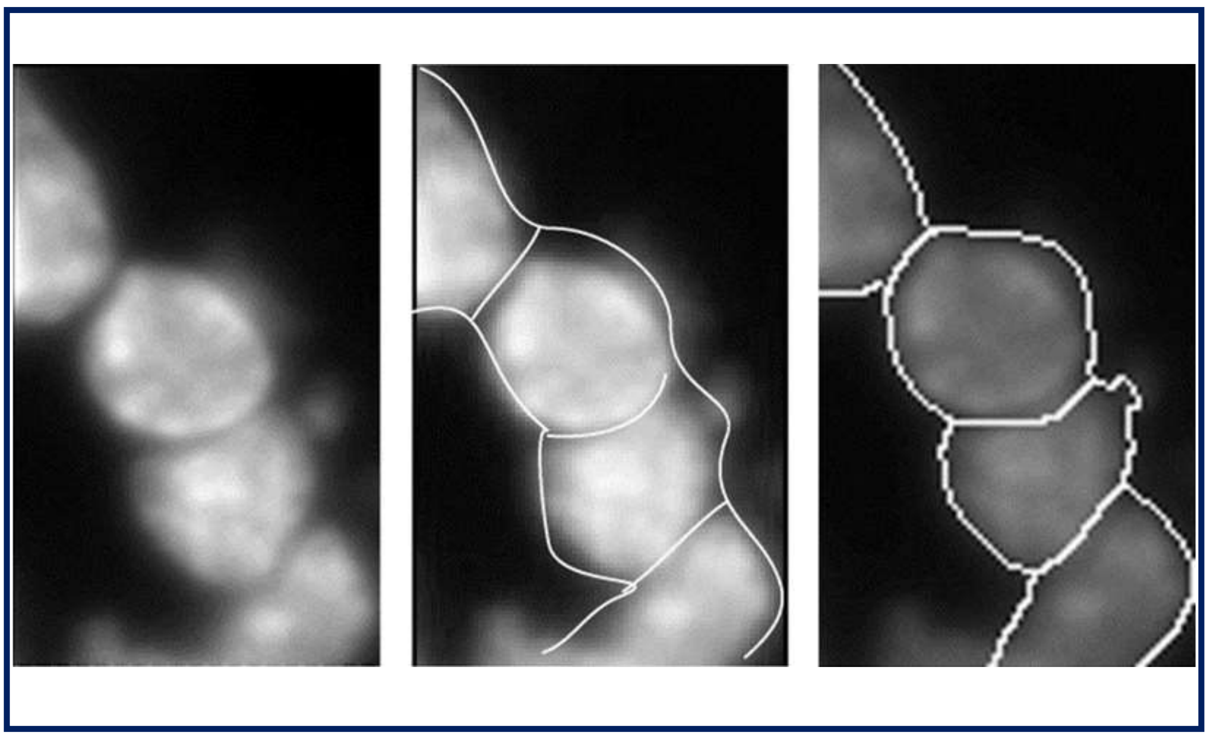

Figure – 1: Shows the comparision of data with speicific knowledge in a model based segmentation process

 DOI : 10.36893.DRSR.2022.V09I01N01.152-164

In this method a set of training data sets are defined with existing object segmentation to create the model. To do so various shapes, gray – values information from different object surfaces, probability of all voxel related with object will be considered. Sufficient numbers of landmarks from the images or masks are defined for aligning all training data sets. In the shape models liver surfaces of training data is aligned to set of landmarks that are defined by users. For computing the actual shape variations of the organ component analysis will be applied. Average liver model will be placed in the new data set in automated method and landmark positions will be optimized in main shape various during the segmentation process. Gray value profiles that are learned from different training data at different landmarks or surface normal will be applied [6].

Combined segmentation

As discussed in model based approach the neighbor organs and their structures in the liver will impose wide range of problems towards automatic methods of focusing gray values. Hence the best liver segmentation methods use combinations of different segmentation paradigms. These kind of combined segmentation methods achieved best results and most successful approach was based on combination of intensity based algorithms and shape based models.

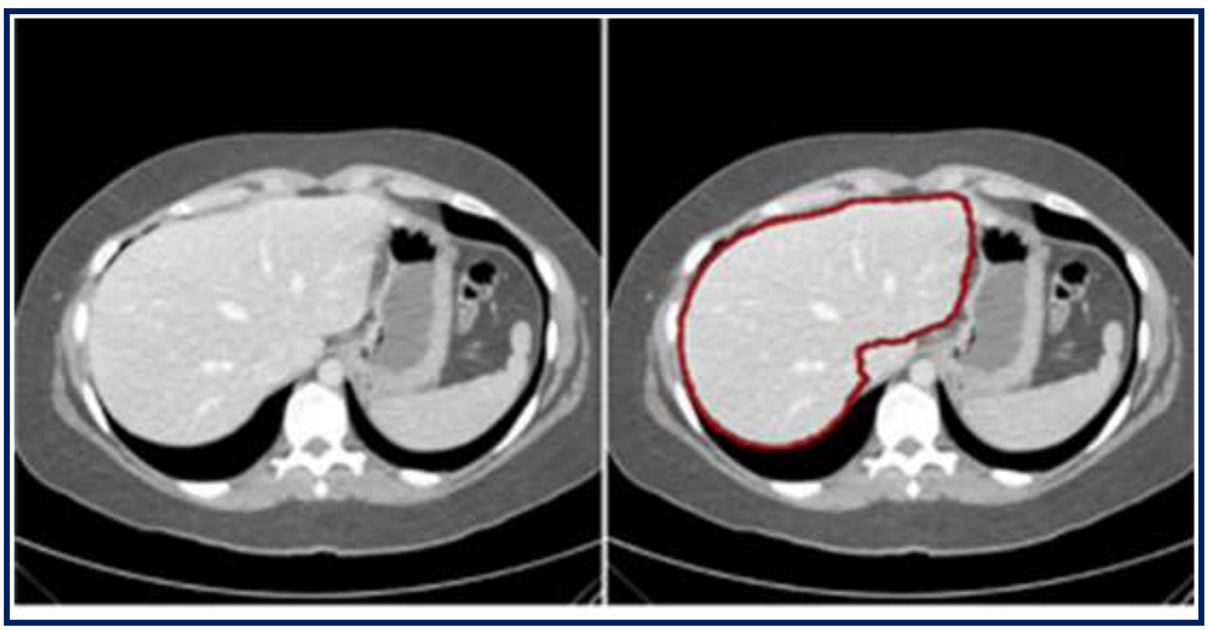

Figure – 2: Shows the example for a Combined Segmentation

However, the biggest drawback of this method is that they include liver tissue and different parts of external vessels also (see figure – 2). Sometimes the model based approach does not reach the requirements of clinical requirements.

3. Errors in Segmentation and Correction Methods

General errors identified while segmenting was having more than 20% errors due to insufficient results. And the best methods shown in a research by MICCAI (2007) found that mean volume overlap errors

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from ten data sets are between 6.0 – 8.5 % [1]. The results also shown that a lot of user interaction and user control of all results are needed based on wide range of image pieces need more than an automated approach. However, if the errors are to be corrected afterwards, it needs a correction tool for getting required additional user effort. Very few groups across the world are focusing on correction method for segmenting in medical data. Manual corrections on 2D images are generally applied like cutting, adding part of segmentation mask by drawing and intersection line or curves at boundaries. The same can be applied to 3D images as well with user defined radius. But these 3D tools are not intuitive and results from these are bound to give strange modification [7]. Segmentation based on the deformable models
In this approach the segmentation will be based on deformable models that allow detecting automatic outlines of a liver in CT image. This method of deformable model is generally used to give better results that are needs manual initialization which is close to real contour. Generally the initialization is done automatically. Automatic initialization will be based on the study of histogram and low processing levels of salaries. Gaussian and Rayleigh curve will be used for modelling the image by the histogram. The noisy background of an image will be shown by the Rayleigh curve and Gaussian defines the image classes of gray scale. To obtain the contour of liver images various filtering methods and thresholding are applied successively. Based on the internal and external forces of gradient vector flow (GVF) and power ball the detection of attracted boundaries are done [8]. GVF deformable contour is having advantage of having insensitivity to initialization and it is having the ability to move into boundary concavities when compared with traditional deformable contour. Generally the initialization of GVF will be either inside or outside or across the boundary of the object. However like in ballon model, GVF deformable contour does not require advanced knowledge about to shrink or for expanding towards the boundary.

GVF deformable contours will be having large range of capture that bar interference of other objects which is also is able to initialize for far away boundary. Due to the increase in the capture range, which is achieved by diffusion process will not allow the edges to be blurred on their own so that multi resolutions methods are avoided.

4 Types of Deformable models

Generally SNAKES and Active Contours are the curves that are defined within an image domain which moves under the influence of different internal forces that comes from within the curve itself. The external forces are used for computing the image data. Internal and external forces will be defined in such a way to confirm an object boundary or to define the desired properties of the image to be analysed. In general the snakes are mostly used with wide range of applications that includes edge detection, modelling the shapes and motion tracking [33]. The contours are generally classified broadly in two categories as: parametric active contours and geometric active contours. Parametric active contour are again classified into three types: Traditional snake, GVF snake and Ballon forces. Similarly the Geometric active contours examples are given by Level set.

 DOI : 10.36893.DRSR.2022.V09I01N01.152-164

Parametric Active Contours

Parametric curves are synthesized by parametric active contours in an image domain and they allow them for moving for the required features generally edges. By using potential forces the curves are drawn at the edges defined as negative gradient of potential functions. However, the external forces are comprised with all pressure forces along with potential forces within the curves together. Internal forces will hold the curves together and keeps it away from bending too much. These models represent curves and surfaces explicitly in parametric form [9]. They also synthesize the parametric curves and surfaces of an image domain and allow them for moving towards required features. Generally they are moved towards edges drawn by potential forces. These forces are generally having negative gradient of potential functions. Apart from these there are additional forces included with potential forces and external forces. Geometric models are based on the *Curve evolution* theory and geometric flows that represent curves and surfaces as scalar functions. The internal (elasticity) forces keep the model together and this force keeps them from bending too much due to bending forces [9].

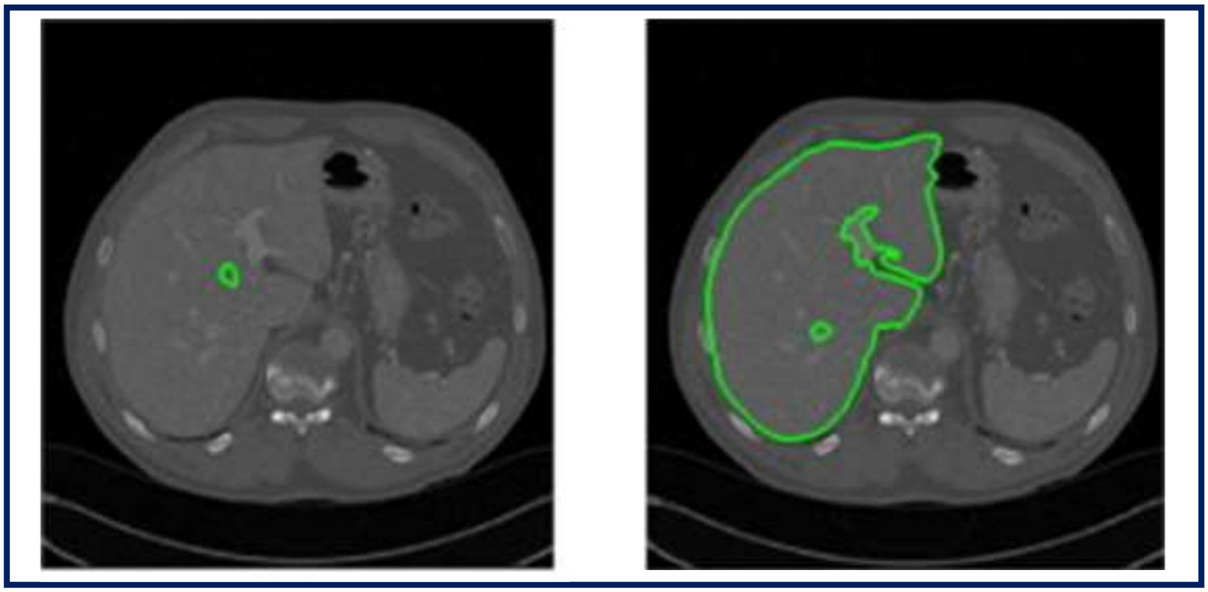

Figure – 3: Shows the example for a Parametric Active Counter

Two difficulties are observed using parametric models in the real time applications. In the first case, the initial model must be closer to the actual boundary otherwise it is likely to converge with wrong results. Thought several methods tried to solve this problem area includes multi resolution method, distance potentials and pressure forces [9]. The basic idea in this method is to get the desired boundary by increasing the capture range of external force fields.

In the second problem, deformable models are having problems to progress into boundary concavities. Many proposed solutions in this case include control points, pressure forces, domain adaptivity, directional attraction and applying solenoidal fields. In both the problems the solutions are creating a new problem while solving another [9].

In the present research the resultant outputs of a liver image using these models are also presented. Most of the areas observed in this model are having denser vector fields and they are derived from the images by reducing energy functions in a varying frame work. The reduction of energy function is possible by

 DOI : 10.36893.DRSR.2022.V09I01N01.152-164

solving pair of decoupled PDE equations in which they diffuse the gradient vectors of gray value levels or for the given image the binary edge maps will be computed [9]. The active contour, which is using GVF filed, is considered to be as its external force of a GVF Snake. These are insensitive to initialization and are capable of moving into concave boundary regions when compared to traditional snake models.

Behaviour of Traditional Deformable Contours

A traditional deformable contour had shown in figure – 4 (a) shows 64×64pixel line drawn in U shape object with boundary concavity on the top. It also shows the sequence of curves that are depicting the iterative progression of traditional contour (α= 0:6, β= 0.0) initialized beyond the object in capture range of potential force field. The potential force field $F_{ext}^{(p)} = -\nabla E_{ext}^{(4)}$ Where σ= 1.0 pixel is shown in Fig – 4(b). Final solution in Fig 4(a) below solves Euler equations of the deformable contour formulation, but remains split across the concave region.

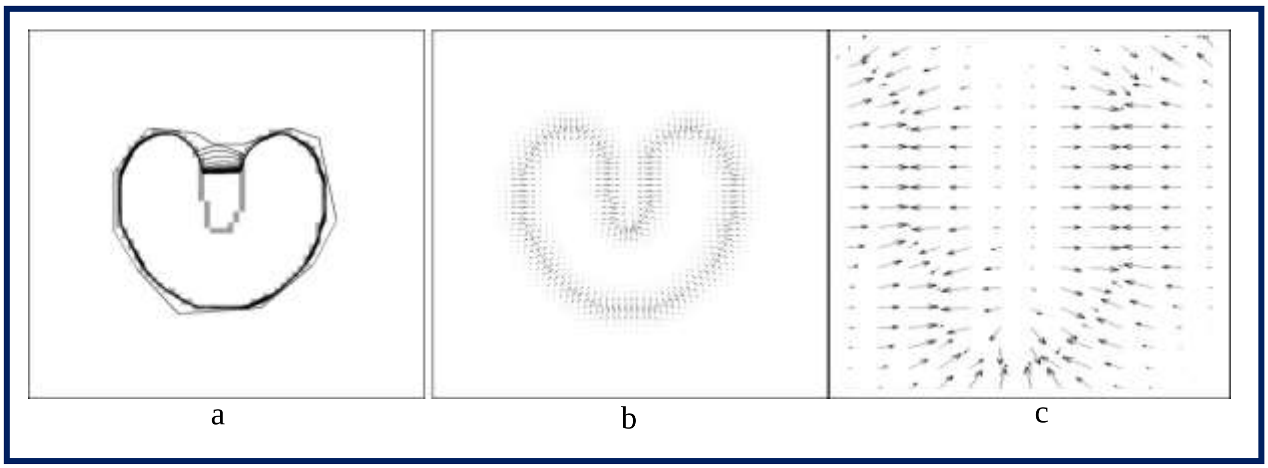

Figure – 4: Convergence of deformable contour using (a) traditional potential forces (b) Close-up within the boundary concavity (c) poor convergence from deformable contour

In figure – 4(c) the reasons for poor convergence from deformable contour is explained where the external force field in close – up within boundary concavity is shown. Though, the external forces are pointing correctly towards object boundary concavity, the forces pointing horizontally in opposite direction. Hence deformable contour pulls apart towards the fingers of U shape and no progress is made downward in the concavity and cannot expect α and β to be correct in this problem. Limited capture range is another major problem of traditional deformable contour formulations. This problem can be seen in figure – 4 (b) in which magnitude of external forces dies out rapidly far from the boundary of object. The range value will be increased with the raise in the value of σ; however boundary localization will become less accurate and distinct at the sake of concavity when the σ value in increased largely. Generally the external forces will be having negative gradient of potential function which is computed by using Euclidean distance map. These forces are referred to as distance potential forces that distinguish traditional potential forces as shown in figure – 5.

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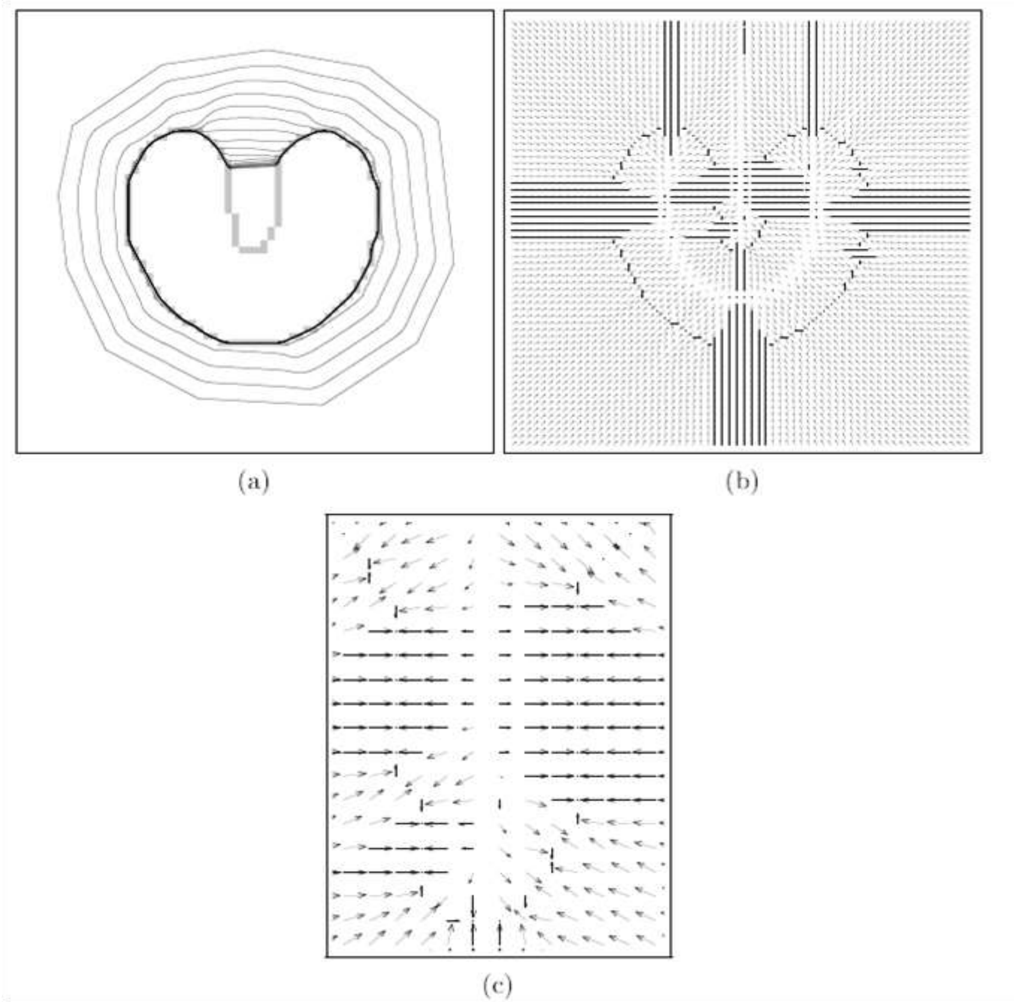

Figure – 5: (a) shows convergence of deformable contour by using (b) distance potential forces; and (c) shows close up within boundary concavity [33]

In figure – 5 (a) the performance of deformable contour using distance potential forces are shown and both U shaped objects (in gray colour) and contours sequence (is show in black colour). These sequences of contours are depicting the progression of deformable contour from the start point that is very far from the object to be developed as final configuration. The figure showed in 5 (a) represents the deformable contour that is failed from converging to boundary concavity. The same is explained after inspecting the magnified portion of distance potential forces which is shown in figure – 5(c). In the figure – 5 (b) the distance between the potential forces vectors with large magnitudes are shown and they are far from the object. This figure also explains why capture range is large for such external force models. Hence, the observation makes it clear that these forces also indicate in opposite direction horizontally that pulls deformable contour apart. However, it will not pull towards downwards of the boundary concavity. By applying a nonlinear transformation for the distance map the forces does not

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change direction but only changes the magnitudes. Hence, the problems related with convergence to boundary concavities are not yet solved due to distance potential forces.

5. Level set without re-initialization

As seen above discussions the formulation of Level set for a moving front or for an active contour is denoted by C. It is represented by zero Level set C as a function of $\phi(t,x,y)$ as follows:

$$C(t) = \{(x, y) | \phi(t, x, y) = 0\} \quad \text{...... 1}$$

In a general form the evolution equation can be rewritten as

$$\frac{\partial \emptyset}{\partial t} + F|\nabla \emptyset| = 0 \quad \text{........... 2}$$

This is also called as level set equation [1]. F is called as Speed Function and for image segmentation F depends on image data and Level set function ϕ. The standard re-initialization equation for solving the problems is given below equation:

$$\frac{\partial \emptyset}{\partial t} = sign(\emptyset_0)(1 - |\nabla \emptyset|) \quad \text{.......... 3}$$

Where, $\emptyset_0$is the function that has to be re-initialized; and Sign (ϕ) is sign function.

 DOI : 10.36893.DRSR.2022.V09I01N01.152-164

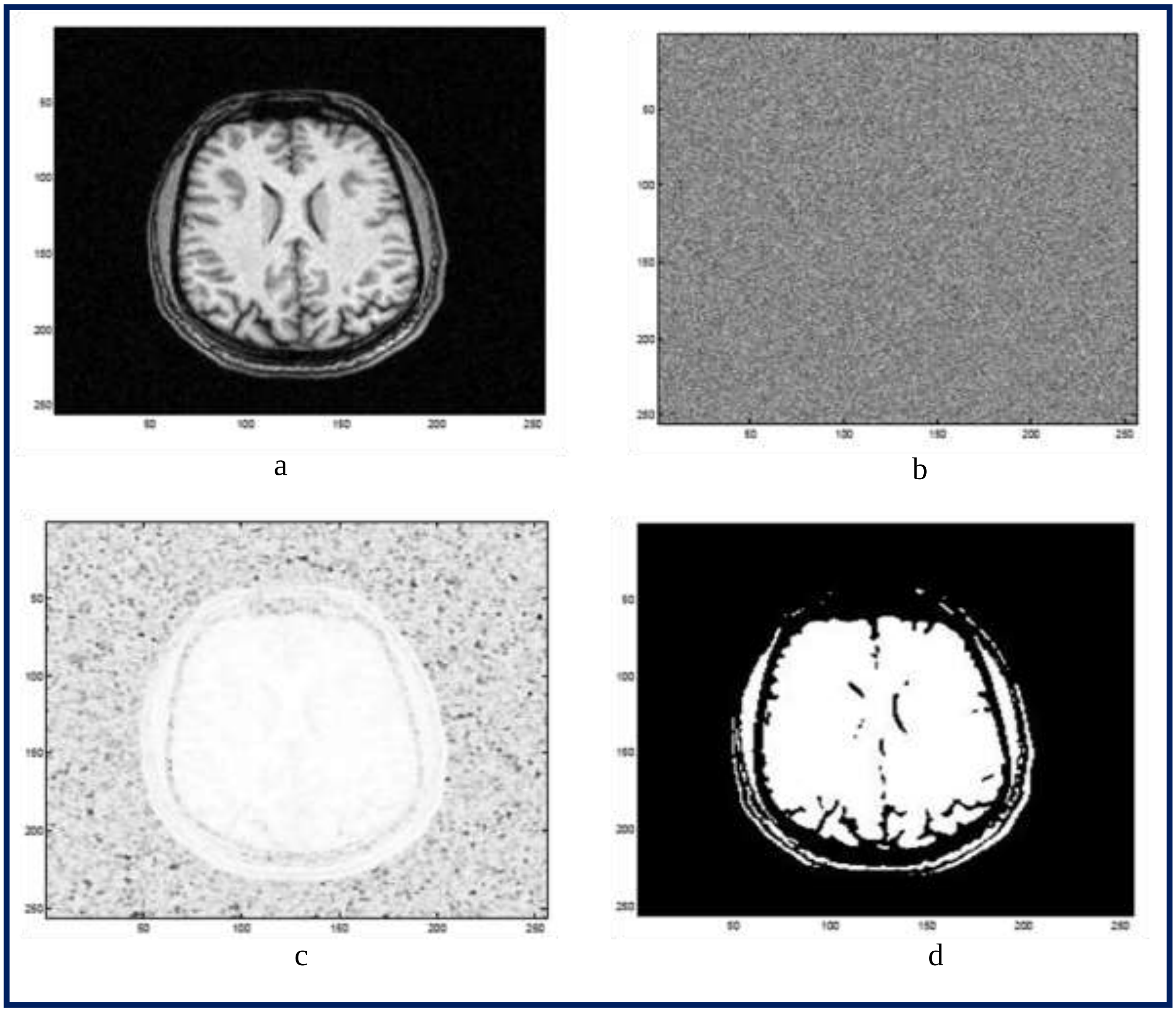

Figure – 6: (a) original image (b) segmented image with randomly selected level set functions ϕ (c) segmented image with level set after 50 iterations and (d) 72 iterations [62]

5.2. Level set with re-initialization

Level set with re-initialization is having drawbacks of varying ϕ value to an incorrect value from the original function. If the Level set function if at distance from signed distant function this function may not be able to re-initialize Level set function to a signed distance function. It can be derived from the values in small number of iteration steps when the time step if not selected small enough. However, the new method proposed for this research Level set without re-initialization will eliminates the need of re-initialization. Easily this method can be implemented by using simple finite difference scheme and it is more efficient computationally when compared with traditional Level set method. Using this method the another great advantage of having larger time step, and it can be implemented for speeding up the curve evolution while keeping the stable evolution of level set function [10][11][12].

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6. Conclusion

Even best automated methods across the world are not able to provide a high quality segmented liver. And hence these automated tools are in need of correction step for getting correct liver shapes. Sometimes the correction takes a lot of time generally when it needs to perform on all slices of images. Using interactive user control approach from initial step of segmentation will be a consequent conclusion. Sometimes this method also reduces the frustration during automated results are differing from the expected and corrected results.

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