Segmentation of liver in CT images

CS6240 MULTIMEDIA ANALYSIS

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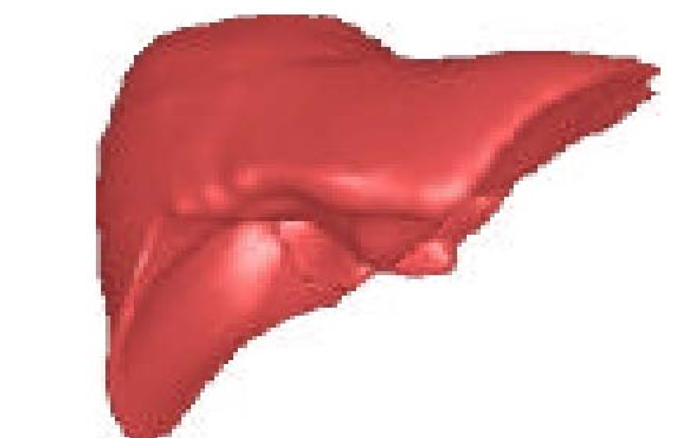
Introduction

➢ **Problem analysis**

◆Objective: The objective of this project is to segmentation of 3D liver in CT images.

◆ Input data: the input data of this project is 512×512×105 abdominal CT volume images stored in DICOM format. The CT value range is -2000-2000Hu. The intra-plane resolution is 0.703125×0.703125 mm. the inter-plane distance is 1.25 mm.

◆ Desired output: the desired output of our algorithm is a 3D surface represent the liver volume.



Introduction

- **Problem analysis**
- Requirements:

1. Contrast stretching: form the original image, we can see that intensity range of the original CT image is very large. And the liver region is not obvious. In order to enhance the part of intensity which we are interest in, we have to first do a contrast stretching.

2. Isotropiclize: the inter-plane and the intra-plane resolution of the original volume image is not the same. For the purpose of conducting some volume operation, we should make the volume image isotropic.

3. Denoising: the original CT image is quite noisy. So some denoising method must be used.

4. Contour extraction: using some contour extraction method to get the surface of the liver.

Introduction

➢ **Problem analysis**

◆ difficulties:

1. the main difficulties of this project is that the intensity of the liver may be quite similar to the intensity of other organ surround it, such as the stomach and spleen. And sometimes, it is almost impossible to distinguish even with visual perception.
2. And the edge information in the abdominal image is also very complicated.

Methods

- **Flowchart**

Preprocessing

↓

AD filtering

↓

Reference slice segmentation

↓

Segment the rest slices using 3d continuity

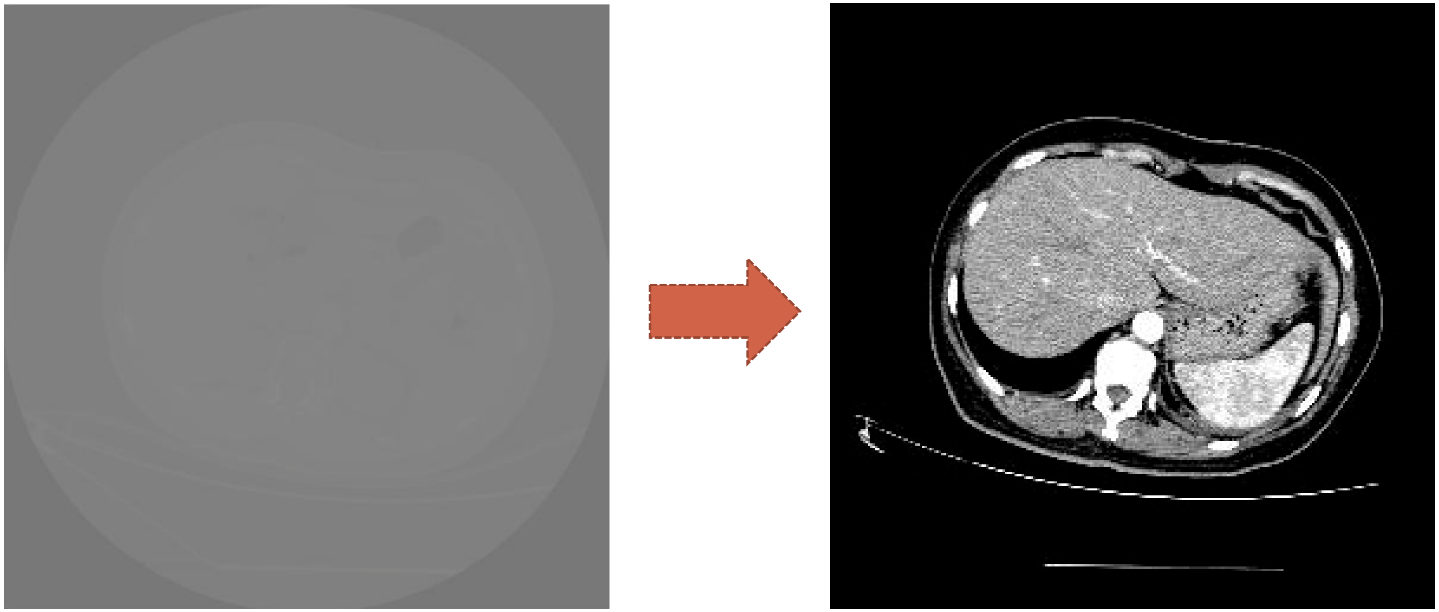
Methods

➢ **Preprocessing**

◆ Contrast enhancement

set a window to the original CT image to enhance the liver region.

here, we set the window based on prior knowledge. The center of the window is 40, and the width of the window is 250. And we map the result intensity range into 0~255.



Methods

➢ **Preprocessing**

◆ Isotropiclize

before we do any volume operation to the image, we should first make the resolution of the image in different direction as the same, or make the image isotropic.

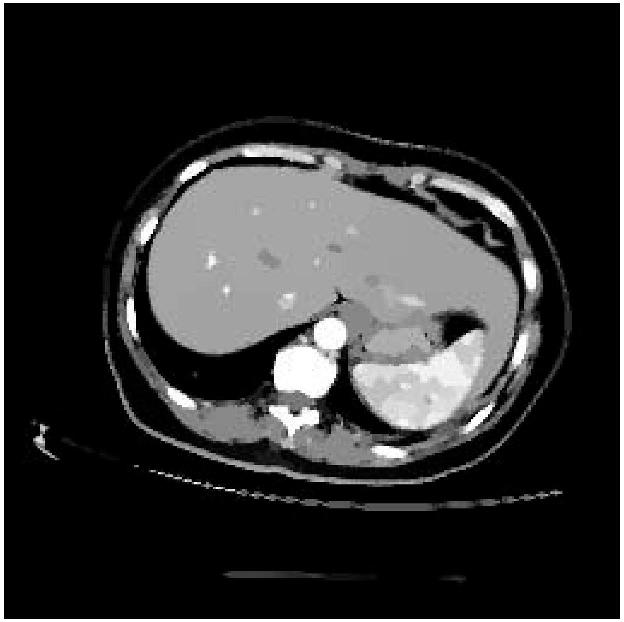
here in order to reduce the computation time. We down size the original image form 512×512×105 into 256×256×93. And the resolution is made the same as 1.406mm.

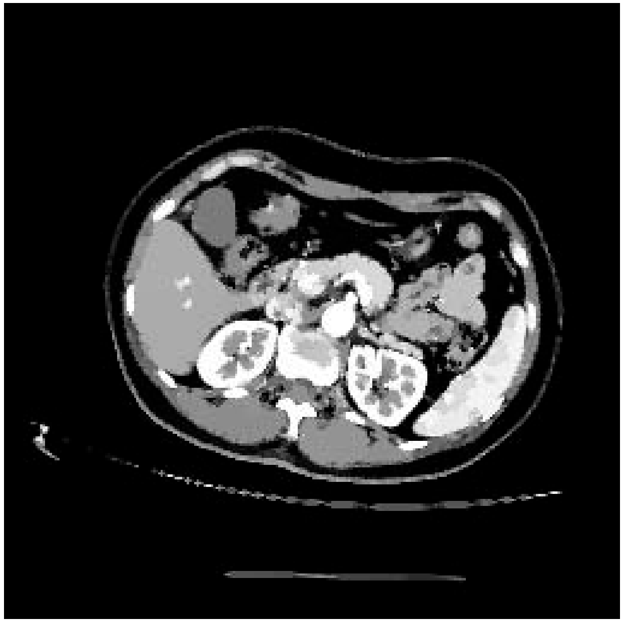
Methods

➢ **Anisotropic Diffusion (AD filtering)**

To reduce the noise and inhomogeneities in the image, we used the AD filter. This filter can reduce the noise as well as enhance the edges of the image. Here we used the multi-edgeness enhancement method in [1]. this method uses a dynamic conduction parameter to enhance different edge range.

The result of image after AD filtering

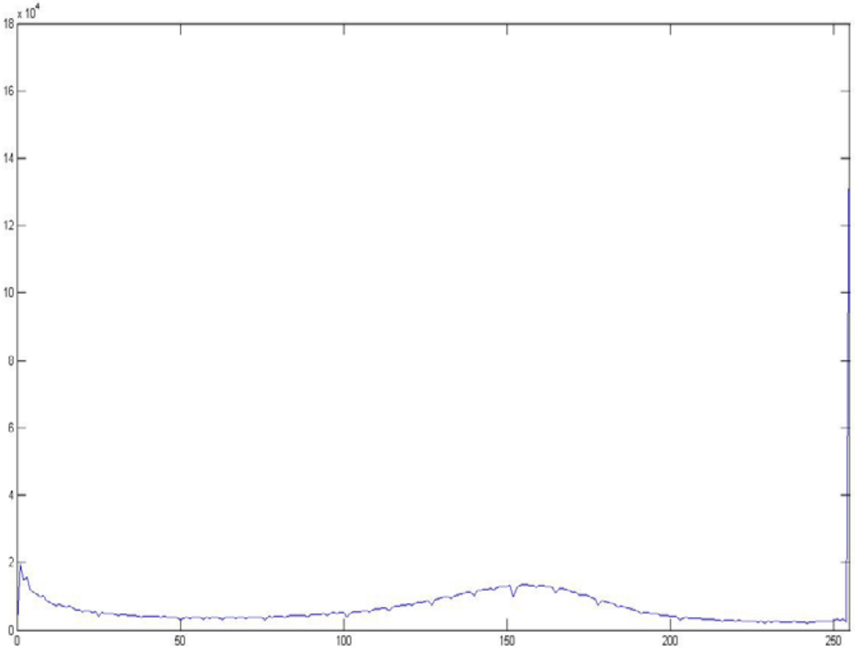


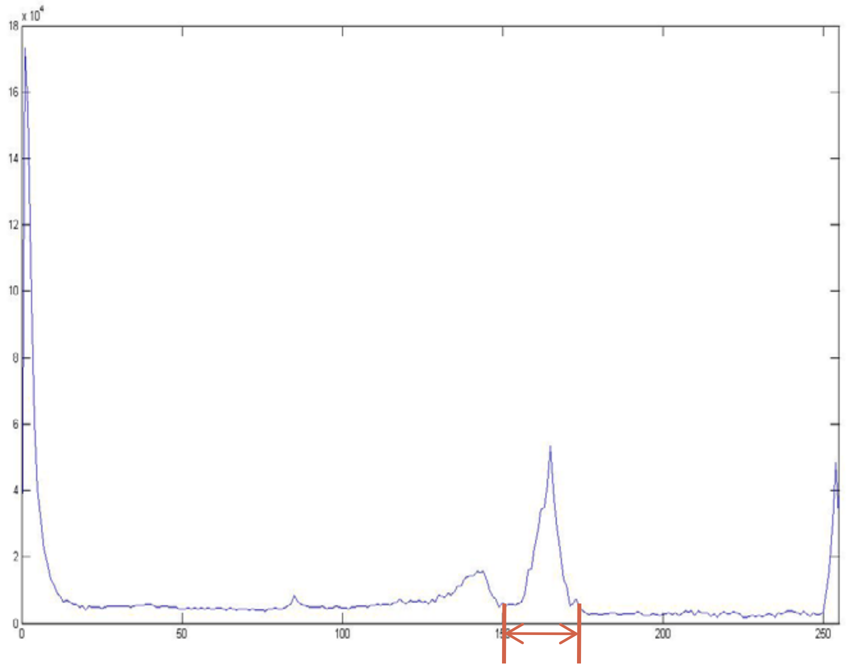


Methods

➢ **Anisotropic Diffusion (AD filtering)**

The AD filter will also make the liver region more homogenous. Which can be seen form the histogram of the volume image.



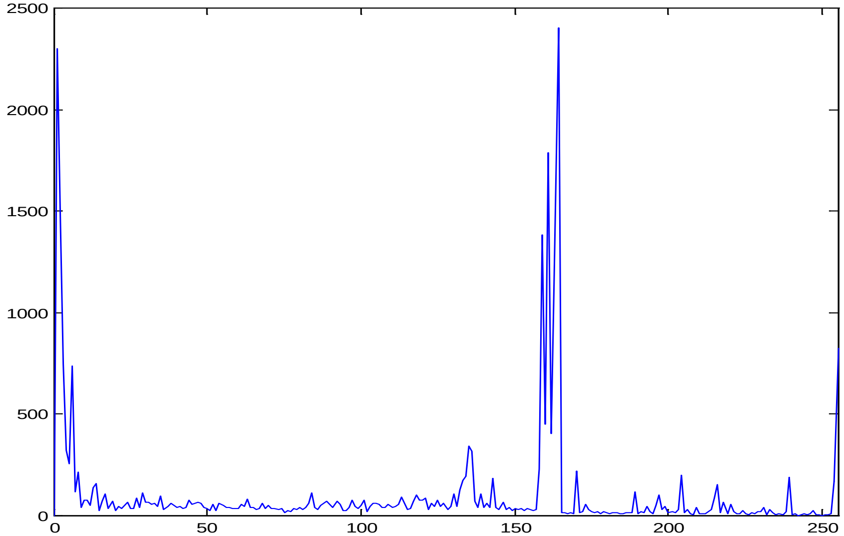


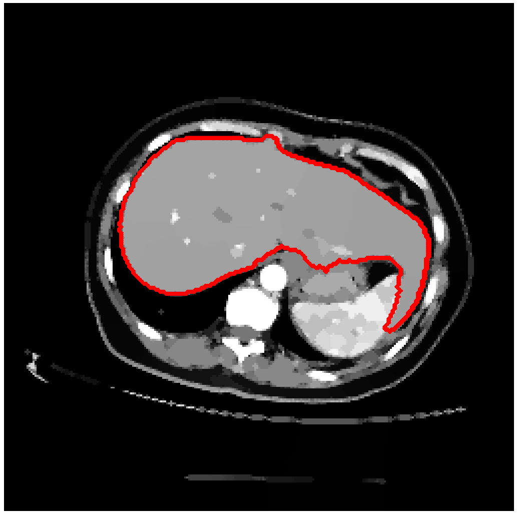
Methods

➢ **Segmentation of a single slice**

◆Initial contour----using thresholding and morphological operation

the starting slice or the reference slice can be select as a middle slice of the liver volume. Here, we select the 70th slice of the 93 slices. The image and the histogram of that slice is showing below. After analysis the histogram, we set the threshold to 155-170 to roughly segment the image. After that we use some morphological operation like connect component labeling, opening and closing to get the initial contour.





Methods

➢ **geodesic active contour without re-initialization**

To get the final contour of the reference slice, we used the method in [2]. This is a method combined the classic geodesic active contour and a penalizing term. The penalizing term with give a constrain on the level set function, and make it follow the distance function. With this method, the re-initialization step of the level set method is not necessary.

The level set evolution equation is:

$$\frac{\partial \phi}{\partial t} = \mu[\Delta \phi - \mathrm{div}(\frac{\nabla \phi}{|\nabla \phi|})] + \lambda \delta(\phi)\mathrm{div}(g\frac{\nabla \phi}{|\nabla \phi|}) + \nu g \delta(\phi)$$

Where, ϕ is the level set function.

We use a edge detector as:

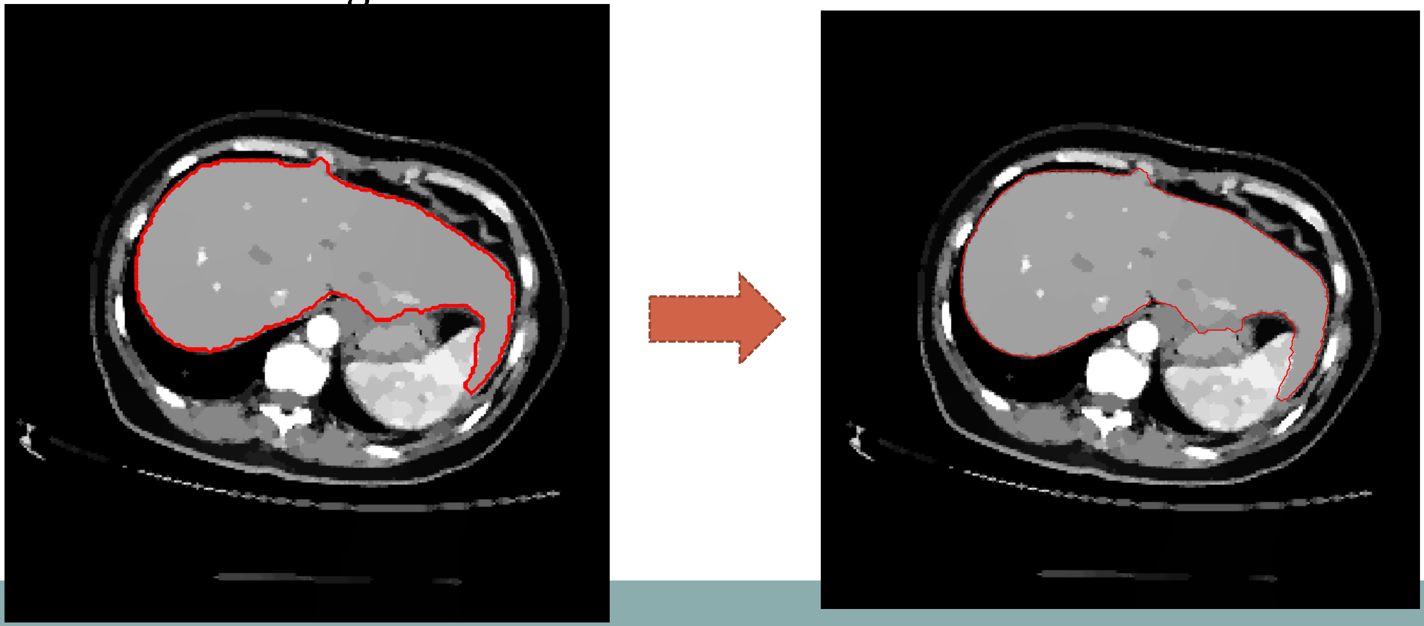
$$g(|\nabla \mu_0(x,y)|) = \frac{1}{1 + |\nabla G_\delta(x,y) * \mu_0(x,y)|^2}$$

Methods

- **geodesic active contour without re-initialization**

$$\frac{\partial \phi}{\partial t} = \mu[\Delta \phi - \mathrm{div}(\frac{\nabla \phi}{|\nabla \phi|})] + \lambda \delta(\phi)\mathrm{div}(g\frac{\nabla \phi}{|\nabla \phi|}) + \nu g \delta(\phi)$$

The first part of the equation is the penalizing term, the second and third term is the classic geodesic active contour as in [3].
The result is as following:



Methods

- **Segmentation of other slice using 3D continuity**

Since the difference between neighborhood slice is small, the final contour of one slice can be a good approximation to its neighborhood slices. Using the final contour of the reference slice as the initial contour of its neighborhood slices, we can start segment the whole volume.

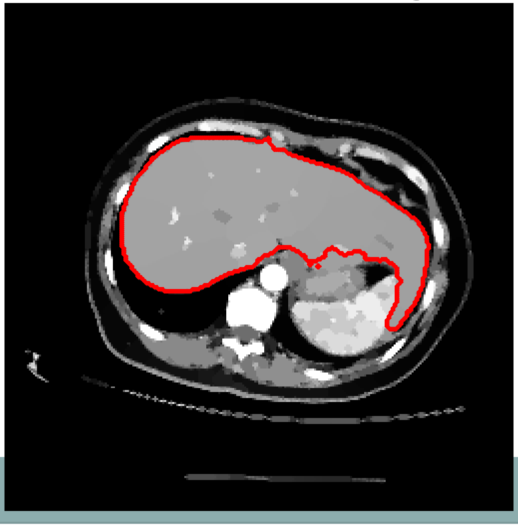
Methods

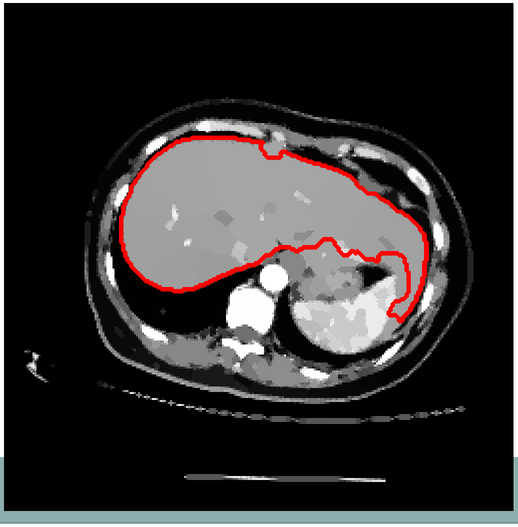
➢ **Problem encountered**

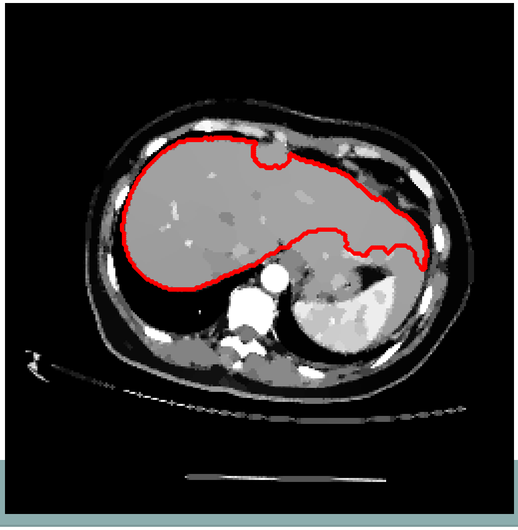
However, when implementing this method, we encounter some problem.

$$\frac{\partial \phi}{\partial t} = \mu[\Delta \phi - \mathrm{div}(\frac{\nabla \phi}{|\nabla \phi|})] + \lambda\delta(\phi)\mathrm{div}(g\frac{\nabla \phi}{|\nabla \phi|}) + \nu g\delta(\phi)$$

In the level set method, we have set the parameter υ. This will decide the general propagation of the level set function. Although the geodesic active contour have the ability to move in both direction, this only happens when the initial contour is quite close to the final one. However, since the edge information is quite complicated in the image, there may be some mistake. And this mistake will accumulate due to the continuities based segmentation method.





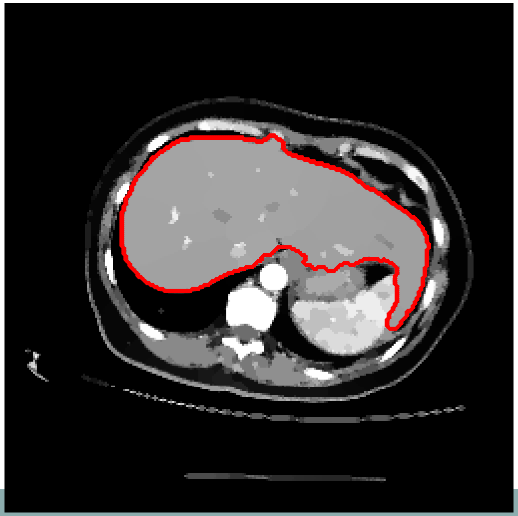
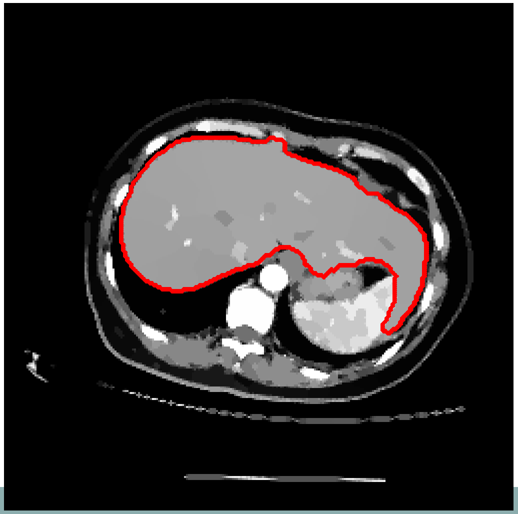
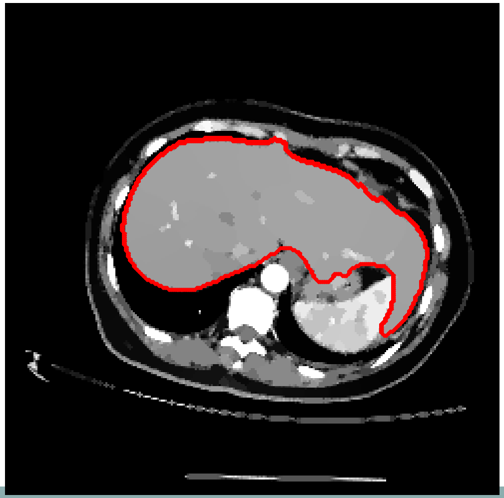


Methods

- **level set methods with dynamic parameters**

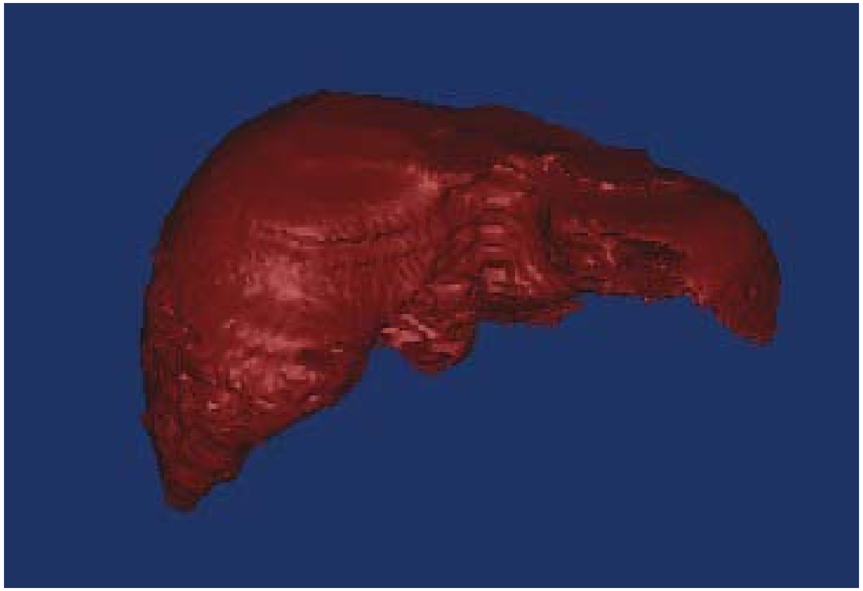
to solve this problem, we use a dynamic parameter method. After analysis of the histogram of the volume image. We find a general threshed for the liver region which is 150-175. when implementing the level set method. We set the parameter with in this range as negative and outside this range positive.

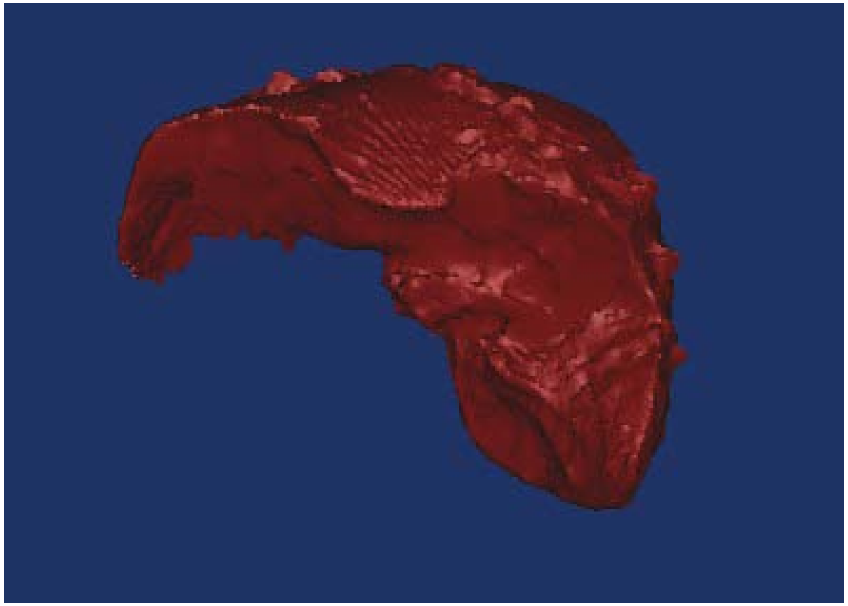
This allowed our level set function to inflate as well as shrink at the same time. The threshold do not need to be very accurate, since the level set method itself also have the ability to adjust its direction.

Results

3D Surface showing using Mimics





Reference

[1] X. Li and T. Chen, “Nonlinear Diffusion with Multiple Edginess Thresholds,” *Pattern Recognition*, vol. 27, no. 8, pp. 1029-1037, 1994.
[2] C. Li, C. Xu, C. Gui and M.D. Fox, "Level set evolution without re-initialization: A new variational formulation," In IEEE Conference on Computer Vision and Pattern Recognition (CVPR)., vol. 1, pp. 430-436, 2005.
[3] V. Caselles, F. Catte, T. Coll and F. Dibos, "A geometric model for active contours in image processing," Numer. Math, vol. 66, pp. 1-31, 1993.