MRI image tissue separation using meshing method

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Received: March 12, 2012 Revised: March 27, 2012 Accepted: April 2, 2012

ABSTRACT:
Nowadays image meshing has a large number of usages in multitude research and medical areas. In this article two gradient bases and one element comparison base meshing methods have been introduced that, separate image texture from background in addition to provision the ability of individual surveying the tissues components surrounded in each mesh element. These meshes can be used to find particular textures or compare the tissue variations in various medical images.

KEYWORDS: mesh, triangulation, Delaunay, intensity gradient

1. INTRODUCTION

In the recent years image mesh modeling have been founded very useful in image processing usages such as, image compression, motion tracing, medical image processing [2], estimating objects depth in images [3], face recognition [6], segmentation [4] & [5], image enhancement [1]. One of the most important usages of image processing is providing an accurate estimation of human tissues existed in MRI images.

Meshing means to discrete a geometric space of R^d into non-overlapped small shapes or samples (polygons ordinarily) which have been named mesh elements. Mesh modeling provides a compact and effective model of image and also it is an operative tool to execute different processes on the parts with various features in images. To achieve the mentioned targets, a mesh has to obtain the following qualifications;

- It has to follow component borders which might has more than one connected areas
- It has to be accurate enough to provide an acceptable approximation of source image
- The number of elements has to be as few as possible (enhanced) to reduce future processes complexity

In this essay, two gradients based and one element comparative based methods have been used in order to meshing MRI image textures which will be discussed in the following sessions.

2. TISSUE MESHING

According to mentioned points, a segmentation method with following steps suggested;

- Image pre-processing
- Finding tissues edges in image
- Elementary Delaunay triangulation[5]
- Enhance the triangulation
- Separation

In above steps, canny [7] and intensity gradient methods have been used to find edges and corners. From these methods, the first one is a known algorithm which has been used widely and the second one is an enhanced algorithm that reduces the computation costs in addition to acceptable accuracy. After that, in order to separate human tissues from background, an addition mesh element based method have been supposed that prove the ability of surveying and comparing each individual mesh element whilst separates tissues. The figure 2-1 shows a MRI image of human head which will be surveyed as a sample in this article.

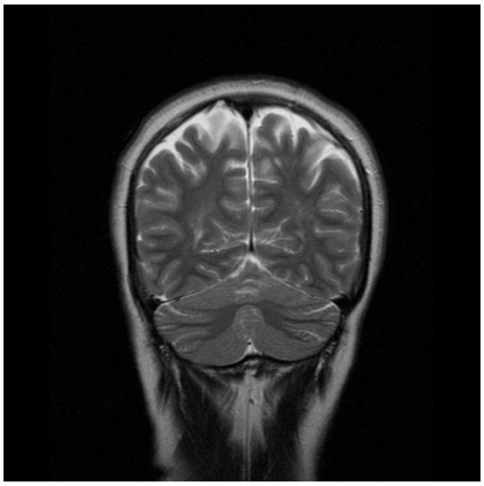


Figure 2-1: Human brain sample image

2-1 Image pre-processing

An important part of mesh segmentation is the adaptation between mesh and image structure that can be achieved from image edges. The adaptation process strongly effects from edge detection quality (canny and intensity gradient methods), so I suppose to filter input data in order to strengthen the weak edges as has been shown in figure 2-2. It is noticeable that, this image will be only used to improve edge finding process accuracy.

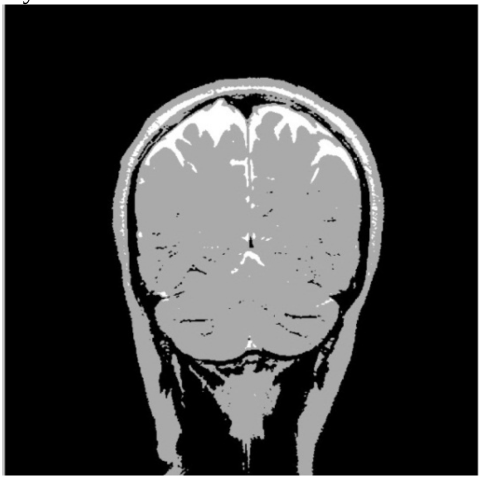


Figure 2-2: Edge enhanced image

2-2 Edge detection

Triangulation process starts from a group of candidate vertexes which have been extended through the tissue edges of image and they can be found from various edge detection algorithms. There are many different methods to find region borders in images which two of them have been introduced in this section.

2-2-1 *Canny edge detection method*

In this section, popular canny edge detection method [7] which consist of following steps, have been used to find the places with least distance to image tissue edges;

- Applying Gaussian filter to smoothen the image and reduce the noise
- Computing local gradient and edge direction at each point of image. (Edge point is the point with maximum local power in the gradient direction)
- Strengthen edge points and remove the points with the intensity values out of thresholds range

Applying this algorithm to figure 2-1 will make mesh nodes on border areas, which can be seen at figure 3-2. It can be find that, there are many nodes that have been occurred on areas borders while, there is no node in the tissues range. The sensitivity of node placing to the intensity of edges can be controlled via adjusting the thresholds values.

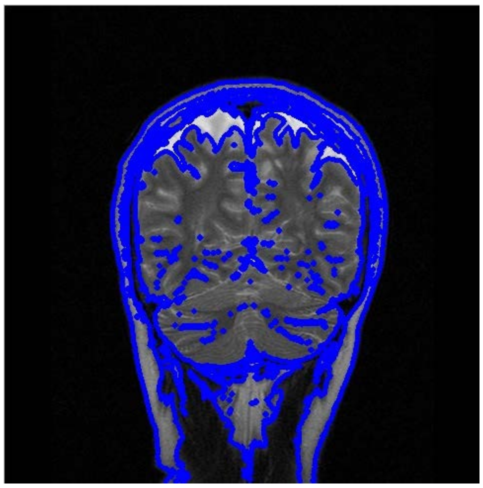


Figure 2-3: Canny mesh nodes

2-2-2 *Image intensity gradient method*

Image intensity gradient method for meshing is a texture separating method that has not been concerned widely in the articles. This algorithm is based on the fact that the complexity of each tissue in an image has a direct relation with its intensity changes in that area which means that, the intensity of images changes more rapidly in the areas with complicated texture than the smooth parts.

This typicality can be helpful in designing a method that indicates image edges accurately while producing nodes with image density related image texture complexity. It means that, the distances between nodes will decrease by reducing texture complexity in any area of the image. This goal can be achieved using an algorithm with following steps;

- Placing a uniform array of nodes on image

- Moving each node toward the intensity gradient of beneath pixel

2-2-2-1 Forming a uniform array of nodes

In this step, a uniform array of nodes that will be the vertexes matrix of mesh elements, has to be placed on the image. The distance between each two neighbor nodes in horizontal or vertical directions is constant through array and its dimension is equal to images one as has been shown in figure 4-2. Note that, the number of these initial nodes will determine the number of mesh elements and their sensitivity to pixels intensity variations in the following steps.

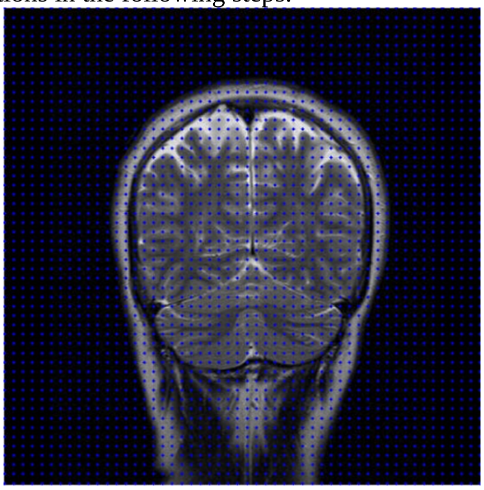


Figure 2-4: Uniform array of nodes

2-2-2-2 Moving array nodes

In digital images, the intensity of each individual pixel can be assessed by a numerical value, so if two neighbor pixels have same intensity values, it means that they are located in same area, therefor appropriate locating of mesh nodes means to arrange them as their locations follow border areas and also their density have a relation with beneath texture specifications.

To place mesh nodes properly, first of all the nodes that have the neighbor pixels with more than a threshold value intensity difference, have to be founded by computing the intensity gradient of each pixel located under mesh nodes in different directions.

$$G_x(x,y) = \frac{\partial I(x,y)}{\partial x} \quad \text{Eq1}$$

$$G_y(x,y) = \frac{\partial I(x,y)}{\partial y} \quad \text{Eq2}$$

In equation 1, Gx(x, y) describes the directional intensity gradient of a pixel located at (x, y) in x direction, and in equation 2, Gy(x, y) describes the directional intensity gradient of a pixel located at (x, y) in y direction. I(x, y) shows the intensity value of a pixel located at (x, y).

After mentioned steps, both x and y directional gradients have to be compared to each other for each individual node and then the node have to progress toward larger gradient while, the nodes with gradient value of zero have to be deleted. The resulted node array can be seen in figure 5-2.

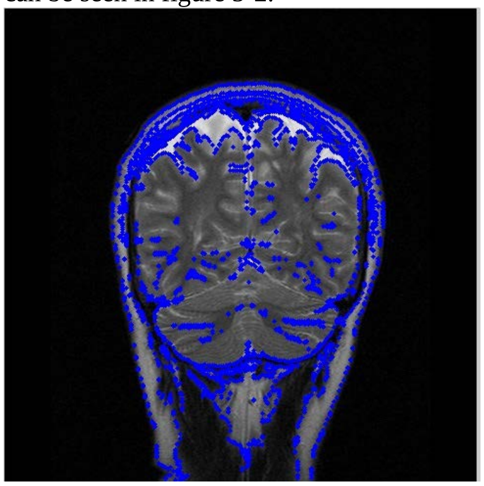
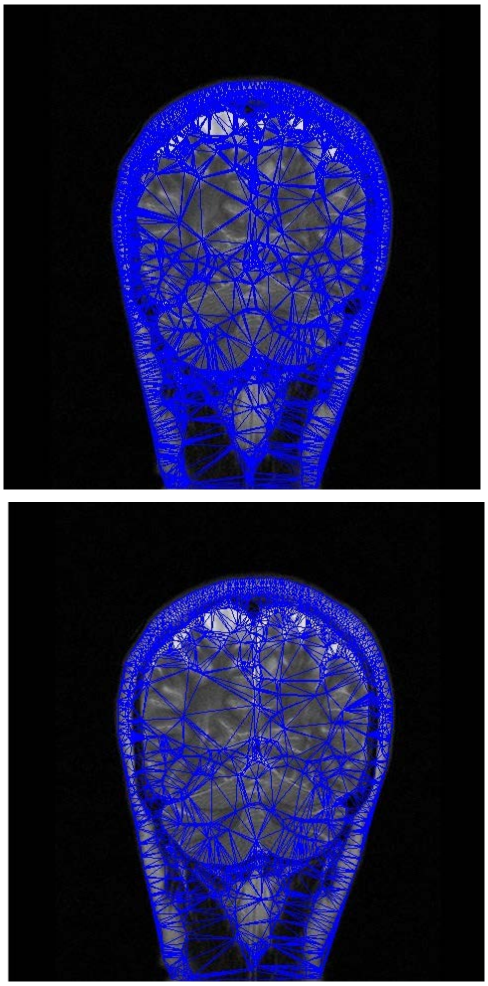


Figure 2-5: Gradient intensity nodes

2-3 Initial triangulation

To form a mesh on the image, the resulted nodes from pervious steps have to be connected via Delaunay triangulation algorithm [5] to obtain the image 6-2.



a

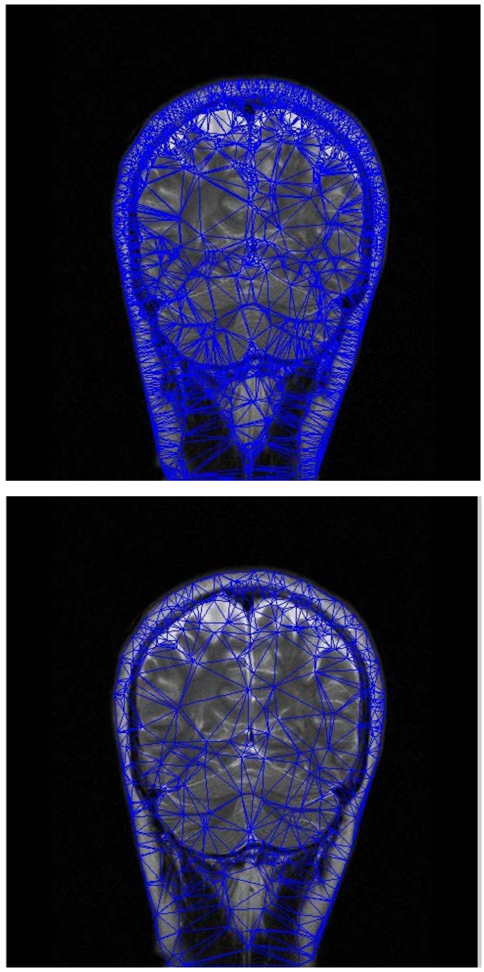
b

Figure 2-6: Resulted mesh; a) Canny, b) Gradient intensity

It can be seen that the intensity of triangles in an area follows texture complexity of that area.

2-4 Enhancing triangulation

Surveying the resulted mesh elements in 2-3 shows that, there are many elements with spiky vertexes which will cause calculation complexity in future steps. To solve this problem, a number of nodes which are located oppose to spiky vertexes have to be deleted in order to reduce the number of elements without losing the adaption between remained cells and image texture, as shown in figure 2-7.



a

b

Figure 2-7: Enhanced mesh; a) Canny, b) Gradient intensity

2-4-1 Mesh separation

In this step, each element will be grouped into segregate parts of image that seems to be related to tissues of same type. On the other hand, each mesh triangle describes by its feature vector that can be classified by an automatic clustering method so, according to desired usage, the triangles with similar specifications such as; color, intensity, histogram, … can be grouped in same area. Because in this essay the aim is to separate whole of human tissue from the background of the image, and also the triangle elements are only located in tissue parts, all of the mesh elements can be concerned as a single area. Before separating tissue from background, a new element based algorithm will be discussed in the following section which does not need to find edges and only use mesh element features comparison to separate the tissue parts from the background.

2-4-2 Element feature based segmentation

In this section, a texture separation algorithm have been supposed that only use mesh element features to extract tissue areas from the image that consists of following steps;

- Forming a uniform array of nodes
- Making structured Delaunay triangulation
- Grouping mesh cells according to needed features

2-4-2-1 Making structured Delaunay triangulation

This step is similar to 2.2.2.1 which a uniform array of nodes organized on source image and resulted to figure 2-4.

2-4-2-2 Triangulation

Applying Delaunay triangulation to constructed nodes from 2.4.2.1, a uniform structured mesh will be crated which divide whole picture to distinctive triangle shaped elements as has been shown in figure 2-8.

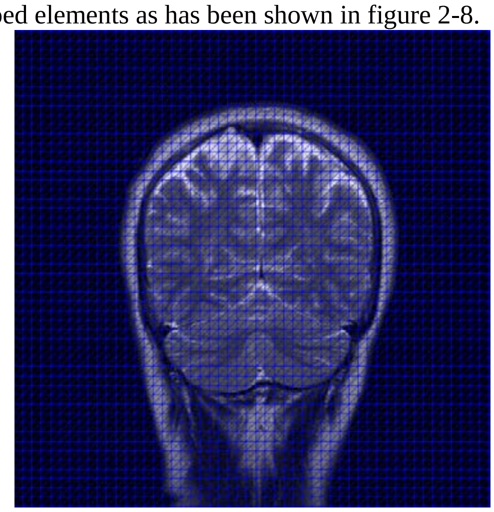


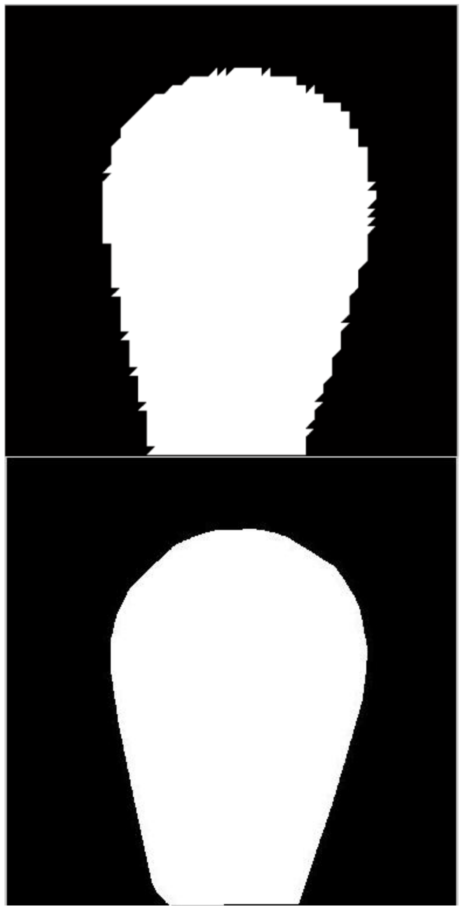
Figure 2-8: Uniform structured mesh

2-5 Elements grouping

To classify resulted elements from 2.4.2.1, individual elements can be placed into distinctive groups according to their internal pixels' specifications which will result to a good approximation of source image and possibility of separating tissues from background.

2-5-1 Separating tissues from background

Tissue separation in images means to generate a picture that in the locations corresponded to its tissue parts has same information as source image and its intensity value in other parts be equal to zero. To achieve this target, a binary mask with the same dimension as source image has to be produced that its value under tissue parts is one and at the other parts is zero, as shown in figure 2-9.

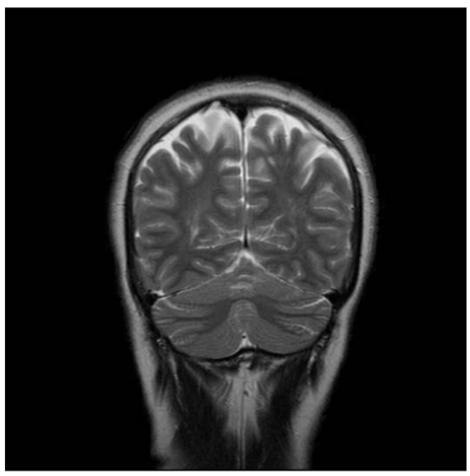


a

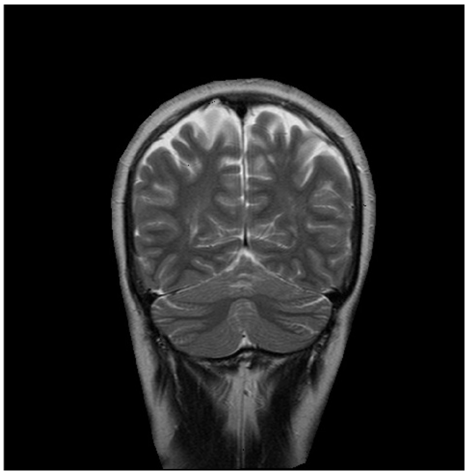
b

Figure 2-9: Tissue mask; a) element feature, b) Intensity gradient

After that, to obtain the final tissue separated picture, corresponding pixels in tissue mask and source image have to multiple to each other which will result to figure 2-10.



a



b

Figure 2-10: Tissue image; a) element feature, b) Intensity gradient

3. SURVEYING THE RESULTS

In this article three different methods with similar threshold values have been used for meshing an image. By comparing the first two of them from the points of the number of mesh nodes, mesh elements and calculation costs in a same computer, the table 1.3 can be obtained.

Table 3-1: Mesh parameters

Enhanced elements number	Initial elements number	Mesh generation time (s)	
۲۳۶	۱۳۹۶	۰,۰۱۲	Intensity gradient algorithm
۱۰۱۵	۶۱۳۳	۰,۰۹۴	Canny algorithm

Comparing table cells shows that the intensity gradient algorithm could complete meshing in a much shorter time than canny algorithm. In the number of mesh nodes and elements, the intensity gradient algorithm have created the mesh with less number of nodes and elements which will reduce the computation costs in the following steps of processes because in the next steps each element specifications has to be surveyed separately to put them in appropriate groups.

By comparing mesh elements on the resulted images in figure 7-2, in can be seen that the intensity gradient method had a better tissue separation while using less mesh elements.

4. CONCLUSION

From all studied processes in this article it can be concluded that the intensity gradient method can provide an enhanced mesh which follows edges and estimates tissues texture, meanwhile the element comparison method is a powerful method to find individual tissues without using old edge detecting algorithms.

All in all, for the targets such as tissue separation or object foundation, a composed algorithm from intensity gradient and element feature can be used to obtain more accurate results. In the other word, intensity gradient can be used to find tissues or textures borders in the image and an by surveying resulted mesh elements via element feature algorithm, different parts and objects in meshed area might be separated.

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