Ultrasound Image Segmentation

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1 Introduction

Ultrasound imaging or ultrasonography is an important diagnosis method in medical analysis. It is important to segment out cavities, different types of tissues and organs in the ultrasound image for effective and correct diagnosis. Human experts are very good in segmenting out the required region. But humans lack efficiency when size of dataset increases. The need of high reproducibility and need of increasing efficiency motivates the development of computer-assisted and automated segmentation[1]. These automated procedures segment out different regions in medical images by applying different types of image segmentation methods. The main disadvantage of ultrasound images is the poor quality of images, which are also affected by speckle noise. Therefore, in general, many of the image segmentation methods may not be suitable in case of ultrasound images[2]. Watershed segmentation is one of the most effective methods in complex segmentation problems[3, 4, 1]. The algorithm uses watershed transform applied to images to obtain the segmented regions. However, segmentation of noisy ultrasound image using watershed transform always leads to over-segmentation. In this study some techniques have been studied in order to remove the over-segmentation.

2 Method

Fig 1 shows different steps of the segmentation followed in this study.

2.1 Pre-processing

Poor quality of the ultrasound images and presence of speckle noise leads to oversegmentation when watershed segmentation is applied. So in order to get better and meaningful segmentation we have to improve the quality of the images. In this study this is done by applying Histogram equalization followed by median filtering.

Histogram equalization is well established method to increase the global contrast of image by increasing the range of grey levels in the image[5]. Median filtering is very

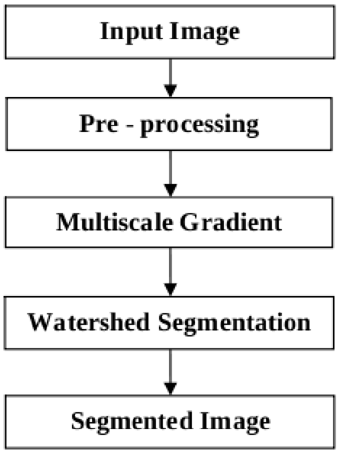


Figure 1: Block diagram of different steps

effective method in removing speckle noise and salt-and-pepper noise[6]. The edge preserving nature of median filtering makes it suitable for this segmentation problem. The ultrasound images are processed using a window of dimension 7x7.

2.2 Multiscale morphological gradient

Gradients maps give better and meaningful segmentation with watershed segmentation. Most of conventional gradient algorithms exhibit a serious weakness for watershed-based image segmentation. These conventional gradient operator, produces too many local minima because of noise and quantization error within homogeneous regions. Each local minimum of the gradient introduces a catchment basin with the watershed transformation and result in over segmentation. Conventional gradient operators also produce low gradient values at blurred edges, even though the intensity change between the two sides of an edge may be high. These two limitations can be overcome by using Multiscale morphological gradient operator and result in better segmentation after removing local minima using morphological methods[7, 4, 8, 9, 10].

Multiscale morphological gradient is given by

$$MG(f) = \frac{1}{n}\sum_{i=1}^{n}\left[\left(\left(f \bigoplus B_i\right) - (f \Theta B_i)\right) \Theta B_{i-1}\right] \qquad (1)$$

where $\bigoplus$ and Θ represent morphological dilation and erosion, respectively. f is the input image and B_i is the structuring element of size $(2i+1)x(2i+1)$. This method exploits the advantage of both small and large structuring elements. Small structuring elements give higher spatial resolution but are insensitive to ramp or blurred edges. Large structuring elements give larger gradient value for ramp edges. Thus the mean of all the structuring elements give better results with both ramp edges and step edges.

Even the multiscale morphological gradient operator gives a lot of small local minima. Small local minima are defined as local minima consisting of a small number of pixels or having a low contrast with their neighbors. This kind of local minima in gradient images is generally caused by noise or quantization error, and therefore should be eliminated. These kind of local minima are effectively removed by reconstruction by erosion of $MG(f)$ from $(MG(f) \bigoplus B_s) + h$[4, 8]. This is also given by

$$\Phi^{(rec)} \left[\left(MG(f) \bigoplus B_s \right) + h, MG(f) \right] \tag{2}$$

where $\Phi^{(rec)}$ denotes reconstruction by erosion, h denote the height threshold and B_s is a square structuring element of dimension s.

2.3 Watershed segmentation

The watershed segmentation is an algorithm that splits an image into areas, based on the topology of the image. The gradient values from the gradient maps are interpreted as elevation information. This segmentation results into sharp 1-pixel wide boundaries[11, 8, 3, 7].

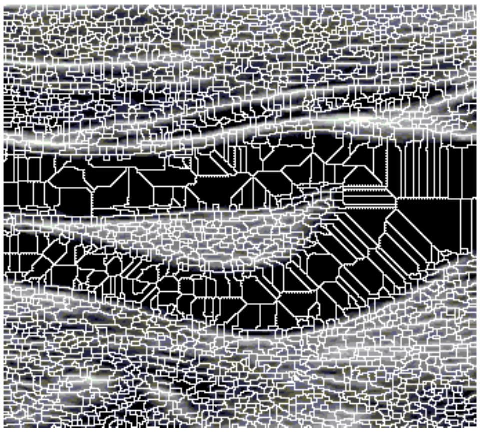
Watershed algorithm can be seen as flooding technique starting from local minima. The pixels are sorted in increasing order of gradient values, which efficiently accelerates the algorithm. Then, progressive flooding of the catchment basins in the gradient image is performed, starting with the lowest catchment basin. Starting from this lowest altitude, the water gradually fills up the first catchment basin. Suppose the flooding reaches a given level h. Every catchment basin whose corresponding minimum is smaller than or equal to h is assigned a unique label. Thus each label corresponds to a unique region. Then we find the catchement basins for level h+1. New catchment regions are given new labels. If two different catchment basins are being merged in level h+1, then 1-pixel wide dam is build to prevent merging of the two regions. Therefore, at each level of the flooding procedure, the labeled catchment basins are extended and new catchment basins are detected. This procedure is repeated until every pixel in the image has been assigned a label. The dams build to prevent merging at each stage are the final boundary of different region.

3 Experimental result

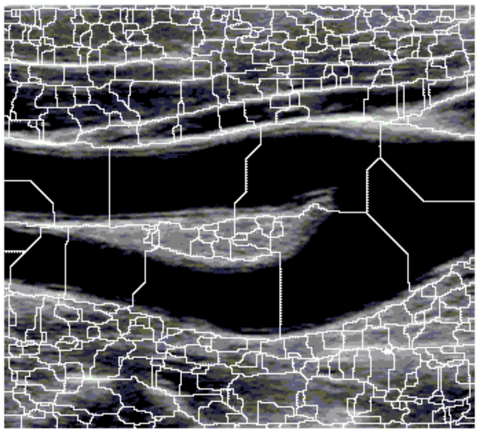
In this study, the images were first contrast enhanced using histogram equalization and then median filtered using 7x7 window. Then the gradient map is generated using multiscale morphological gradient as given by eq. 1. Value of n in eq. 1 is set to 5. Then the small local minima removed by reconstruction by erosion as given by eq. 2. Height threshold h is increased to get better segmentation. Dimension of structuring element B_s was set to 2x2.

Fig 2b to 3b shows the effect of different steps of segmentation on input image in fig 2a. Fig 4a and 4b shows the segmentation result on some different images.

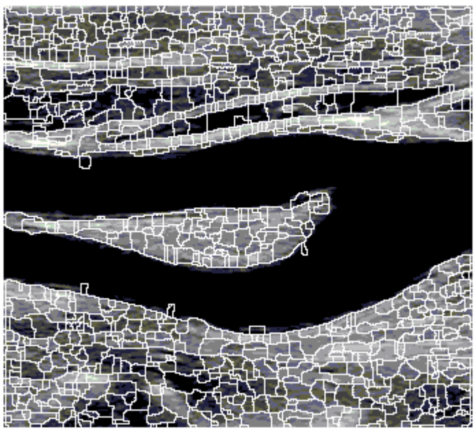
(a) Original image



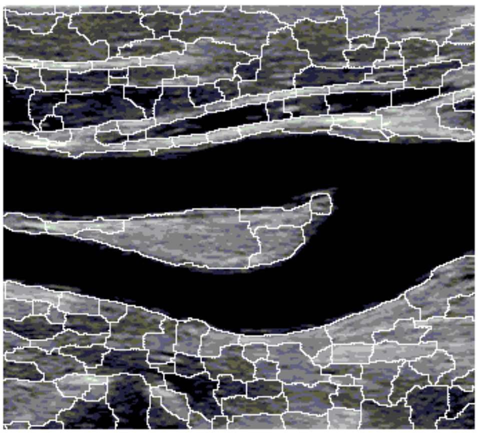
(b) Watershed segmentation on 2a



(c) Watershed segmentation on 2a after preprocessing.

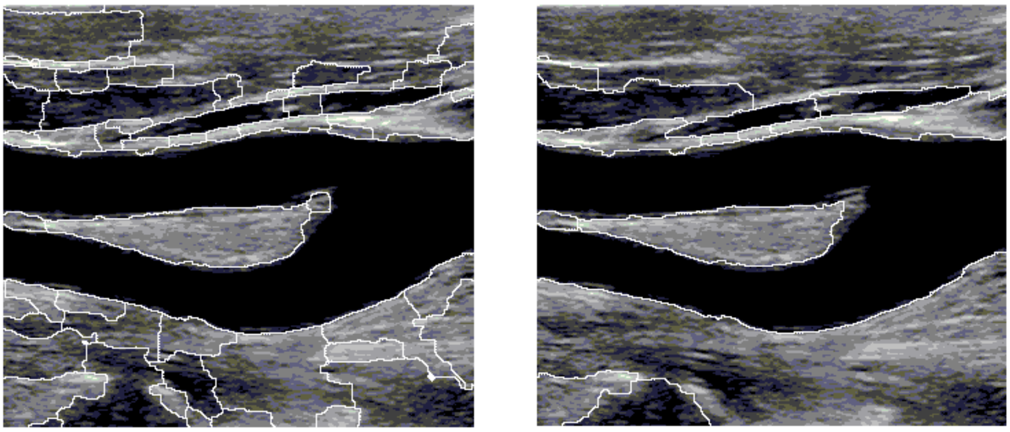


(d) Watershed segmentation on 2a after preprocessing and multiscale morphological gradient operation.



(e) Watershed segmentation on 2a after preprocessing, multiscale morphological gradient operation and removal of small minima with threshold 4.

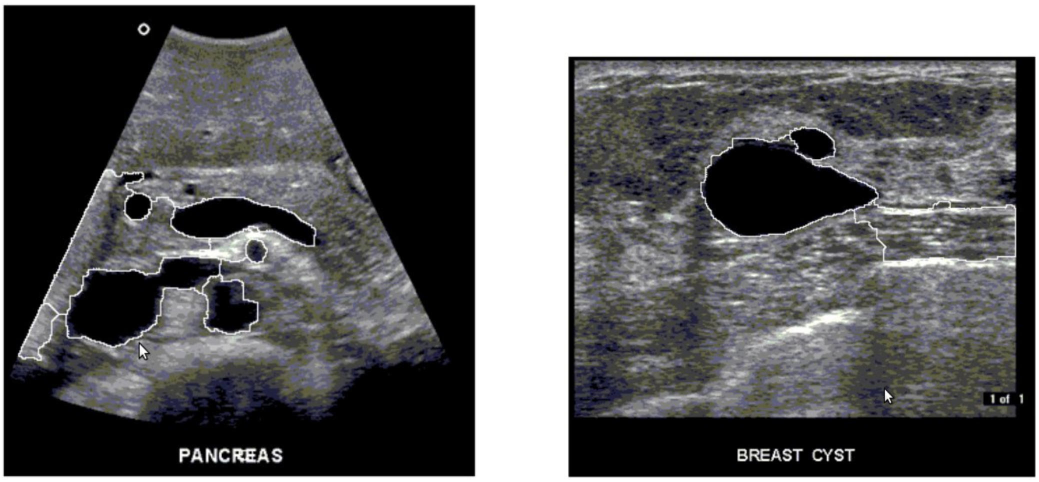
Figure 2



(a) Watershed segmentation on 2a after pre-processing, multiscale morphological gradient operation and removal of small minima with threshold 10.

(b) Watershed segmentation on 2a after pre-processing, multiscale morphological gradient operation and removal of small minima with threshold 22.

Figure 3



(a) Segmentation result on an ultrasound image of pancreas

(b) Segmentation result on an ultrasound image of breast cyst

Figure 4

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