Masses Characterization Using Active Contour

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Abstract: This paper presents the application of active contour or snake for the segmentation of masses on breast ultrasound images and the characterization of the segmented masses as malignant or benign. Initially, the balloon snake is chosen to segment the masses. Comparison on the masses areas segmented by the balloon snake is done against the areas traced by radiologist. Experimental result shows that from 42 masses tested, the balloon snake successfully segment the masses with accuracy of 96.74%. Then, a segmented mass by the balloon snake is characterized as benign or malignant based on the criteria of “taller than wide” shape. The mass is considered as malignant if the shape is taller than wide. This implies that the shape has a maximum vertical distance greater than maximum horizontal distance. The characterization reading of a mass by the balloon snake based on the criteria is compared with a reading of a mass by an expert radiologist. The comparison is made in terms of sensitivity and specificity values. Based on the values, the ROC (receiver operating characteristics) curve is plotted. It is found that the area under curve is 0.75. The value implies that the balloon snake is good in characterizing benign from malignant mass.

Key words: Image segmentation, active contour, masses, characterization.

1. Introduction

Ultrasound is one of the modalities that can be used to detect breast masses at the earliest stage. As a modality that uses no ionizing radiation, it becomes the most suitable modality to be used by the pregnant women [1].

In order to characterize a mass as benign or malignant, radiologists will examine the output images produced by the screening modalities. For a radiologist, an image produced is an information carrier. However, the image may be corrupted by noise or may be tied up with irrelevant information, resulting in difficulties for them to interpret the important information from the image using the conventional method (human eye only) [2]. In such cases, a new area called image processing has been developed by combining the computer technology with some mathematical conceptions. Image processing techniques are used to extract information from the image. The first and the most important step in image processing is to segment the image. It is done in order to delineate the foreground (masses region) and the background [3].

Active contours or snakes are computer-generated curves that move within an image to find the object boundary. Snake is computationally formulated based on controlled continuous splines and adopts the mathematical concept of energy minimization. Snake was originally introduced by Kass et al. [4] in 1986.
and the notion of snake for active contours was inspired by the way snakes move, slithering while minimizing their energy.

Although the original snake has been found in many applications, it intrinsically has a small capture range and the convergence of the algorithm is mostly dependent on the initial position. Moreover, it also has difficulties in progressing into boundary concavities [5]. Therefore, the balloon snake was established in 1991 by Cohen in order to overcome the limitations of the original snake. Balloon snake is extensively used for segmentation applications such as segmentation of left ventricle of a human heart from MRI image [6], brain [7], middle ear image from MRM (magnetic resonance microscopy) image [3], and teeth images [8]. In this paper, the balloon snake is used to segment the masses in breast ultrasound images. In order to identify the accuracy of the segmentation by the balloon snake, masses areas of the segmented masses by the method are computed and compared with the actual masses area segmented by the expert radiologist.

Then, a segmented mass by the balloon snake is characterized as benign or malignant based on the criteria of “taller than wide” shape. The mass is considered as malignant if the shape is taller than wide, otherwise it is benign. This implies that the shape is taller than wide if it has a maximum vertical distance greater than maximum horizontal distance. The characterization reading of a mass by the balloon snake based on the criteria is compared with a reading of a mass by an expert radiologist. The comparison is made in terms of sensitivity and specificity values. Based on the values, the ROC (receiver operating characteristics) curve is plotted.

This paper is organized as follows: Section 2 discusses the approaches and methods; Section 3 discusses the implementation; Section 4 presents the result; Section 5 gives the conclusion.

2. Approaches and Methods

This section will discuss the approaches and methods to segment and to characterize a mass as malignant or benign.

The balloon snake is used to segment the masses. Balloon snake is a vector valued function in the spatial domain of an image and parametrically expressed as 

\[ \mathbf{v}(s) = (x(s), y(s)) \] where \(0 \leq s \leq 1\). A curve consists of \(n\) vertices \(v\) connected by straight lines. The parameter \(x\) and \(y\) are the coordinate of the vertices, \(v\) and are functions of the normalized arc length \(s\). The snake has a dynamic behavior that deforms from an initial position and converges to the boundary of the object in the image. It moves through the domain of the image by minimizing its energy function, \(E_{\text{snake}}\), which is defined as

\[
E_{\text{snake}} = \int_0^1 \left[ E_{\text{int}}(\mathbf{v}(s)) + E_{\text{ext}}(\mathbf{v}(s)) \right] ds
\] (1)

The internal energy function is

\[
E_{\text{int}}(\mathbf{v}(s)) = \frac{1}{2} \{ \alpha |\mathbf{v}'(s)|^2 + \beta |\mathbf{v}^\prime(s)|^2 \} \] (2)

The internal energy function, \(E_{\text{int}}(\mathbf{v}(s))\) is computed based on the local shape of the curve \(\mathbf{v}(s)\), and is responsible in determining the continuity and the smoothness of the curve. The parameter \(\alpha\) and \(\beta\) are the coefficient of the internal energy function. The parameter \(\alpha\) is the elasticity parameter. For a large value of \(\alpha\), the curve becomes very straight between two points. The parameter \(\beta\) is the rigidity parameter and for a large value of \(\beta\) the curve becomes smooth. On the other hand, the external energy function \(E_{\text{ext}}(\mathbf{v}(s))\) is derived based on the image information and it drives the curve to the boundary of the object.

Different types of snakes use different type of external energy function. By calculus of variation, Eq. (1) is minimized by solving the associate Euler’s equation as follows:

\[
-\alpha \mathbf{v}''(s) + \beta \mathbf{v}^{(4)}(s) + \nabla E_{\text{ext}}(\mathbf{v}(s)) = 0
\] (3)

The numerical solution of the Euler’s equation is approximated with finite difference method since it is
difficult be computed analytically. As proposed in Ref. [9], the balloon snake uses the sum of pressure energy and image energy as the external energy function,

\[ E_{ext}(v(s)) \text{ defines as follows:} \]

\[ E_{ext} = -k \frac{F_{image}}{||F_{image}||} + k_{pressure} n(s) \]  

(4)

The parameter \(k_{pressure}\) is the pressure weight or pressure energy and its positive or negative sign causes the snake to inflate or deflate respectively. The image energy \(F_{image}\) is the gradient of the image edge map. The parameter \(k\) is the image energy weighting. The symbol \(n(s)\) represents the unit normal vector to vertices.

Ultrasound has been used to distinguish malignant from benign masses [10]. There are specific criteria that should be considered in order to differentiate a mass that appears on ultrasound image as malignant or benign. One of the malignant mass criteria is “taller than wide shape” as proposed in Ref. [11]. A mass with no malignant criteria is considered as a benign mass. This characteristic will be used in the research to classify the masses.

The authors proposed a new mechanism in order to determine whether the shape of a mass is taller than wide. There are two main steps. The first step is to segment the boundary of a mass using the balloon snake, and the second step is to measure the maximum vertical and horizontal distance of the segmented mass. The authors define a mass has a taller than wide shape if it has a maximum vertical distance greater than maximum horizontal distance.

The characterization reading of a mass by the balloon snake based on the criteria of taller than wide shape is compared with a reading of a mass by an expert radiologist. The comparison is made in terms of sensitivity and specificity values. Based on the values, the ROC curve is plotted and the AUC (areas under curves) of the ROC curves are computed. The AUC represent the accuracy of the balloon Snake in characterizing malignant from benign masses based on the criteria of taller than wide shape.

3. Implementation

42 breast ultrasound images are obtained from Palace of the Golden Horses Screening Center. The images are cropped in Adobe Photoshop CS2 to the size of 64 pixels by 64 pixels. Cropping is done around the ROI (region of interest) which contains breast masses. The ROI images are first preprocessed using median filter to remove speckle noise, and then histogram stretching method is applied to enhance the contrast of the images. Some parameter values are standardized experimentally for all the images. The image edge map is computed using Canny edge detector with threshold value used is 0.3. This value is suitable for the ROI images because image information will reduce if the value is higher whereas noise will increase if the threshold value is decreased. The number of iterations for snakes deformation is standardized to 500 which are enough for ROI images of size 64 by 64 pixels. The pressure energy for balloon snake is 0.08 whereby positive number indicates inflation of the snake. The Matlab R2008a software is used to implement the median filter, histogram stretching, and the deformation of balloon snake. In order to identify the accuracy of the edge segmentation, the areas of the segmented masses by the balloon snake are compared with the true pixel area value. The true pixel area value is obtained from the average of two pixel area values of a mass traced by expert radiologist in each image. The unit of the area used is in \(\text{pixel}^2\).

In order to distinguish the segmented mass is benign or malignant, the maximum vertical and horizontal distance of the segmented mass are measured. A mass has a taller than wide shape if it has a maximum vertical distance greater than maximum horizontal distance which indicates the mass is malignant, otherwise the mass is considered as a benign.

However, it is difficult to measure the vertical and
horizontal distance directly from the segmented image because the vertices cannot be seen clearly. Therefore, extraction of vertices coordinates from the segmented mass must be done first. This is followed by plotting the coordinates.

In order to evaluate the ability of the balloon snake in characterizing benign from malignant masses based on the criteria of taller than wide shape, the type of mass characterized by the method is compared with the type of mass characterized by expert radiologists.

There are four cases of characterization used in presenting the results, namely FP (false positive), TP (true positive), FN (false negative) and TN (true negative). The positive cases show that the method characterized a mass as malignant and negative cases show that the method characterized a mass as benign.

FP is defined as the situation whereby a mass is characterized as malignant by the method but the radiologist characterizes the mass as benign. On the other hand, TP occurs when the method characterizes a mass as malignant and the radiologist also characterizes the mass as malignant. FN is the situation whereby the method characterizes a mass as benign but the radiologist characterizes the mass as malignant. Lastly, TN occurs when the method and the radiologist characterize a mass as benign.

The characterization capability is illustrated by ROC curve by plotting sensitivity or true positive rate against 1-specificity or false positive rate. The value of AUC which represents the accuracy of characterization result by the balloon snake based on the specific criteria used is computed. The area can range from 0 to 1. The perfect result has an area of 1 under the curve [12].

4. Results

Fig. 1 shows the three samples of original ROI of breast ultrasound images that contain breast masses in part (a) and the corresponding segmented images in part (b). The samples are taken from the original ROI numbers 24, 37, and 39. The percentage difference of masses areas of the images in Fig.1 are listed in Table 1.

The authors have tested on 42 ROI images. The experimental result shows that the average percentage area difference for all 42 images used in this experiment is found to be 3.26%.

Fig. 2 shows the example of a mass in image number 39 segmented by the curve produce by the balloon snake. The curve represents the shape and margin of the mass.

The curve is used to measure the maximum vertical distance ($h_{\text{max}}$) and maximum horizontal distance ($w_{\text{max}}$).

However, it is difficult to measure $h_{\text{max}}$ and $w_{\text{max}}$ directly from the output image because the vertices cannot be seen clearly. Therefore the vertices of the segmented mass in the image is extracted and re-plotted as shown in the Fig. 3 by the blue dots.

After that, the values of $h_{\text{max}}$ and $w_{\text{max}}$ are measured in Matlab. The values will appear automatically in pixel unit. The $h_{\text{max}}$ and $w_{\text{max}}$ values give the measurement of height and width of the mass respectively. This implies that the shape of a mass is taller than wide if the value of $h_{\text{max}}$ is greater than $w_{\text{max}}$ and vice versa. The $h_{\text{max}}$ and $w_{\text{max}}$ values obtained for the image 39 are shown in Figs. 4 and 5 respectively.
Fig. 1  (a) Original ROI; (b) balloon snake.

Table 1  Percentage difference of segmented masses.

<table>
<thead>
<tr>
<th>Image</th>
<th>True area (Pixel$^2$)</th>
<th>Balloon snake area (Pixel$^2$)</th>
<th>Percentage difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>171.65</td>
<td>100.04</td>
<td>41.72</td>
</tr>
<tr>
<td>37</td>
<td>74.29</td>
<td>71.45</td>
<td>3.82</td>
</tr>
<tr>
<td>39</td>
<td>244.97</td>
<td>245.77</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Fig. 2  Image number 39 segmented by the curve produced by the balloon snake.

Fig. 3  Vertices of the segmented mass of image number 39.

Fig. 4  $h_{max}$ value of image 39.

Fig. 5  $w_{max}$ value of image 39.

Fig. 6  The ROC Curve of the balloon snake.

Figs. 4 and 5 show that the values of $h_{max}$ (98 pixels) < $w_{max}$ (215.75 pixels). This implies that the shape of the mass is not taller than wide. In other word, the shape is wider than tall. Therefore, the mass is considered as a benign.

In order to evaluate the ability of the balloon snake in characterizing benign from malignant masses based on the criteria of taller than wide shape, the type of mass characterized by the method is compared with the type of mass characterized by expert radiologists.

The comparison is made in terms of sensitivity and specificity values. Based on the values, the ROC (receiver operating characteristics) curves are plotted and the areas under curves of the ROC curves are computed. Fig. 6 shows the ROC curve of the method.

Based on Fig. 6, the value of AUC is 0.75.
5. Conclusions

In this paper, the authors have attempted to segment breast masses on the ultrasound images using balloon snake with the average percentage area difference of balloon snake is 3.26% which mean 96.74% accurate. Besides, a segmented mass by the balloon snake has been characterized as benign or malignant based on the criteria of “taller than wide” shape.

Analysis on the characterization results using ROC curve shows that the values of AUC for ROC curve of the balloon snake in characterizing 42 masses based on the criteria used is 0.75. The value implies that the method gives high accuracy in characterizing a mass as benign or malignant [12].

Besides the criteria of taller than wide shape, it is recommended that the balloon snake is used to characterize a mass based on others additional criteria in order to increase the characterization accuracy.

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