Automatic Initialization of Multiple Active Contours Applied to Ultrasound Images of Breast Cancer

Khwunta Kirimasthong†* Stanislav S. Makhanov† Annupan Rodtook‡
†School of Information, Computer and Communication Technology, Sirindhorn International Institute of Technology, Thammasart University, Thailand
‡Department of Computer Science, Ramkhamhaeng University, Thailand
khwunta.kir@mfu.ac.th

Abstract
The multiple active contours (snakes) are widely used in image processing to extract objects of interest. However, initialization of the active contours is still an open problem. This paper proposes a new completely automatic initialization of snakes based on a combination of Phrase Portrait Analysis (PPA) image intensity clustering and multi-stage evolution of the active contours. The proposed method has been tested with the ultrasound images of breast. The experiments show that the proposed automatic initialization is applicable to noisy ultrasound images.

Keywords: Automatic initialization, Active contours, Snakes, Phrase portrait analysis, Generalized gradient vector flow

1 Introduction
The accuracy of the computer based diagnostics of ultrasound (US) images is still not sufficient. It is often difficult to separate the tumor region from the background even when the existence of the tumor is evident.

Among the most promising techniques for extraction of complex objects from digital images are active contours or snakes, originally introduced by Kass et al. [1], [2]. However, the success of the snake based segmentation depends strongly on initialization [3-4] that is on the position where the snake is initially placed.

Up to now several solutions of the problem have been proposed and implemented. A quasi-automatic initialization that relies on the divergence of gradient vector flow field is proposed in [5]. The mean shape algorithm for automatic initialization is used in [6]. The Poisson inverse gradient for automatic active contour initialization is introduced in [7]. Finally, a problem dependent solution based on self-organizing maps [8] has been proposed for extraction roads in satellite images.

However, the proposed methods do not show display proper results when applied to US images of the breast cancer. Therefore, the main contribution of this paper is a completely automatic initialization model based on the combination of PPA, image intensity clustering and active contours applied using a multi-stage evolution algorithm.

2 Methodology
Our proposed algorithm consists of five steps. First, the PPA [3] is combined with edge-based detection in the preprocessing sequence that includes a speckle noise reduction, median filtering, contrast enhancing and region growing. Next the general gradient vector flow (GGVF) [3] is applied to the resulting image (Figure 1). Furthermore, we evaluate the PPA map which is clustered and classified as the background, boundary and the noise. Next, we perform a geometric analysis of the pixels with a strong PPA score and set up seeds for and multiple quadratic active contours [4]. Finally, we run the active contours using a special multi-stage evolution algorithm.

Consider now the geometric analysis illustrated in Figure 1. The PPA map clustered into the boundary points, noise points and background points. Next, we using the assumption that the tumor is in general round we construct a convex hull based on the candidate boundary points. Note that it is possible that some candidate boundary points belong to the false boundaries represented by speckle noise and shadows. However, our simple procedure makes it possible to confine the tumor within the convex hull.
Next, we select the noise points inside the convex hull positioned far from the boundary. These points are the seeds for the quadratic multiple snakes. In other words the snakes have been initialized at the points of convergence and noise inside the tumor (Figure 3 (a)). This approach makes it possible to avoid false boundaries inside the tumor since the false boundaries are already inside the initial snakes (Figure 3(b)). We run the snakes until convergence using the anti-gradient. This is because the convergence and noise points are represented by attracting (not repelling) stars. At this stage the snakes converge and stop at the false boundaries between the attracting stars and the background. Therefore, we offset the snakes and use the original gradient vector field to evolve the snake to the true boundary. The algorithm is illustrated in Table 1.

3 Experiments and Results

The algorithm has been tested by two synthetic tumors and three real tumors. The automatic initialization works well and the desired boundary was successfully extracted in every case. The PPA score corresponding to the boundary was 0.9.

4 Conclusion

The proposed initialization model based on a combination of the PPA and the image intensity classification works well to extract the boundary of breast cancer tumor in both synthetic and real ultrasound images. The results make it possible to conjecture that the proposed techniques will further succeed in segmentation of a variety of tumors displayed in ultrasound images of the breast.

(a) GGVF of the original image  (b) PPA of the actual and false boundaries
(c) PPA of noise points  (d) Final GGVF

Figure 1. The GGVF fields and the PPA analysis
Figure 2. PPA classification based on the image intensities

Figure 3. The automatic initialization based on PPA
Table 1. Extraction results

<table>
<thead>
<tr>
<th>Image</th>
<th>Point in Polygon Checking</th>
<th>The 1st initial snake</th>
<th>The 1st round snake extraction</th>
<th>The 2nd round snake extraction</th>
<th>The result on input image</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td><img src="image9.png" alt="Image" /></td>
<td><img src="image10.png" alt="Image" /></td>
<td><img src="image11.png" alt="Image" /></td>
<td><img src="image12.png" alt="Image" /></td>
</tr>
</tbody>
</table>

References


