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Detection and construction of chest wall on breast magnetic resonance images

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ABSTRACT

Purpose: The purpose of this study is to propose a method for detection and construction of chest wall for breast magnetic resonance images.
Methods: A volume of breast MR slices are firstly acquired and utilized to detect initial points of chest wall. To calibrate the chest wall curve, the points along the curve is set with reference to its neighboring points. Through the calibration method, a curve of chest wall can be detected from a volume of breast magnetic resonance (MR) slices. Such a curve can be applied for segmentation of breast region in a volume of MR images.
Results: The experimental results reveal that the minimal RMSE was measured from the setting two polynomial functions and the points from the vertical position ≤320. If all edge points are used to simulate the curve, two circle functions can reach the minimal RMSE.
Conclusion: The experimental results verify that chest wall for breast density estimation can be better simulated by two circle functions, which simulate right and left chest walls respectively. Furthermore, such a simulation curve is suggested to utilize partial edge points under the given vertical position.

1. Introduction

Breast density, defined as the proportion of fibroglandular tissues in a breast, could help identify women at increased risk of suffering from breast cancer [1–4]. Breast density is categorized using the BI-RADS (American College of Radiology Breast Imaging Reporting and Data System) classification [5]. This classification describes four different degrees of breast density, including BI-RADS I (entirely fat), BI-RADS II, (scattered fibroglandular densities), BI-RADS III (heterogeneously dense), and BI-RADS IV (extremely dense). Although several studies [6–11] have focused on breast density estimation, x-ray mammograms they used cannot truly reflect the composition of fibroglandular and adipose tissues due to compression and distortion during mammographic screening [12]. For this reason, breast magnetic resonance (MR) images have been proposed to use for estimation of breast density instead of X-ray mammograms. Estimation of breast density is required to identify the region of breasts in each MR slice. In the prior studies [13,14], the region of breast for each MR slice was identified by manual delineation. As a breast MR volume normally contains hundreds of slices, manual delineation of breast boundary for each slice is a time-consuming and infeasible task. Automatic delineation of breast boundary is prerequisite for estimation of breast density. The challenging problem is how to automatically separate between the breast region and the chest region. Automatic delineation on breast boundary is considered a research issue of detection of chest wall for a volume of MR slices.

A related study in [15] proposed a scheme for extracting breast regions from computed tomography (CT) images of chest and breast region. The scheme is firstly to create a knowledge base that stores voxel location information of pre-recognized anatomical structures from a number of different CT scans. Then, the knowledge base is utilized to estimate the probability of each voxel belonging to the breast region based on the location of the glandular tissue. The probability of each voxel serves as the reference of the segmentation, thereby deciding the glandular region based on CT number. However, the knowledge base is unreliable for estimation of probability and this method is inapplicable to the breast MRI due to different anatomical regions. The better way is to recognize useful patterns or features to identify the boundary of the breast. It is observed that the chest wall is a transition band which exists between the chest and the breast in an MR slice. The chest wall

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can be regarded as the reference to separate the breast region from the chest region. The main contribution of this study is to propose a method for automatic detection of chest wall for a volume of breast magnetic resonance images.

2. Materials and methods

2.1. Magnetic resonance breast images

These breast MR images were acquired on a 1.5 T dedicated spiral breast MRI system using the T1-weighted, 3D gradient-echo MR sequences [16]. The imaging parameters were TR/TE = 28/4.8 ms, flip angle = 45 degrees, field of view = 36 × 44 cm, slice thickness = 1.1 mm, and matrix = 512 × 512. The total imaging time for this sequence is approximately three minutes. These 160 magnetic resonance breast images were taken before the patient was injected any contrast agent for DCE screening.

2.2. Initial detection of chest wall

Detection of chest wall starts with initial identification of chest wall in breast MR slices. The method of detecting chest wall is firstly to denoise images with median filter, and then find the torso consisting of breast and chest region in the MR slice. The chest region within the torso can be found by the moment preserving method. The moment preserving [17] is a thresholding method to determine an appropriate threshold value for the binary segmentation. Given a gray-scale image I with $X \times Y$ pixels, the gray scale at pixel (x, y) is defined as $I_{x,y}$. The ith moment of the image in the classic moment preserving method is express as [18]

$$m_i = \left\{ \frac{1}{X \times Y} \right\} \sum_{x=1}^{X} \sum_{y=1}^{Y} I_{x,y}^{i} \tag{1}$$

To divide the image I into two classes of p_0 and p_1 pixels with gray scale z_0 and z_1, respectively, an initial threshold T can be found by solving Eq. (2), where m_0, m_1, m_2, and m_3 are the first four moments of the image.

$$\begin{cases} p_0 z_0^0 + p_1 z_1^0 = m_0 \\ p_0 z_0^1 + p_1 z_1^1 = m_1 \\ p_0 z_0^2 + p_1 z_1^2 = m_2 \\ p_0 z_0^3 + p_1 z_1^3 = m_3 \end{cases} \tag{2}$$

Once p_0, and p_1 are solved, setting the threshold T to a value between the gray scales of p_0-th and (p_0+1)-th pixels will yield segmentation result that preserves the first four moments of the image. The image I'can be obtained by Eq. (3)

$$I'(x, y) = \begin{cases} 1 & \text{if} \quad I(x, y) \geq h \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

where the adaptive threshold $h = T - \sigma_I$, and σ_I is the standard deviation of the image I. Next, eight-connected pixel regions are clustered as individual groups in an MR slice. As the maximum number of pixels in the vertical axis must be located in the group of chest wall, a histogram of the binary image is created to present the number of pixels in the vertical axis with the binary values. With the histogram, we can identify the group of chest wall and find the edge points of the chest wall group. Fig. 1 illustrates the process of identifying the chest region.

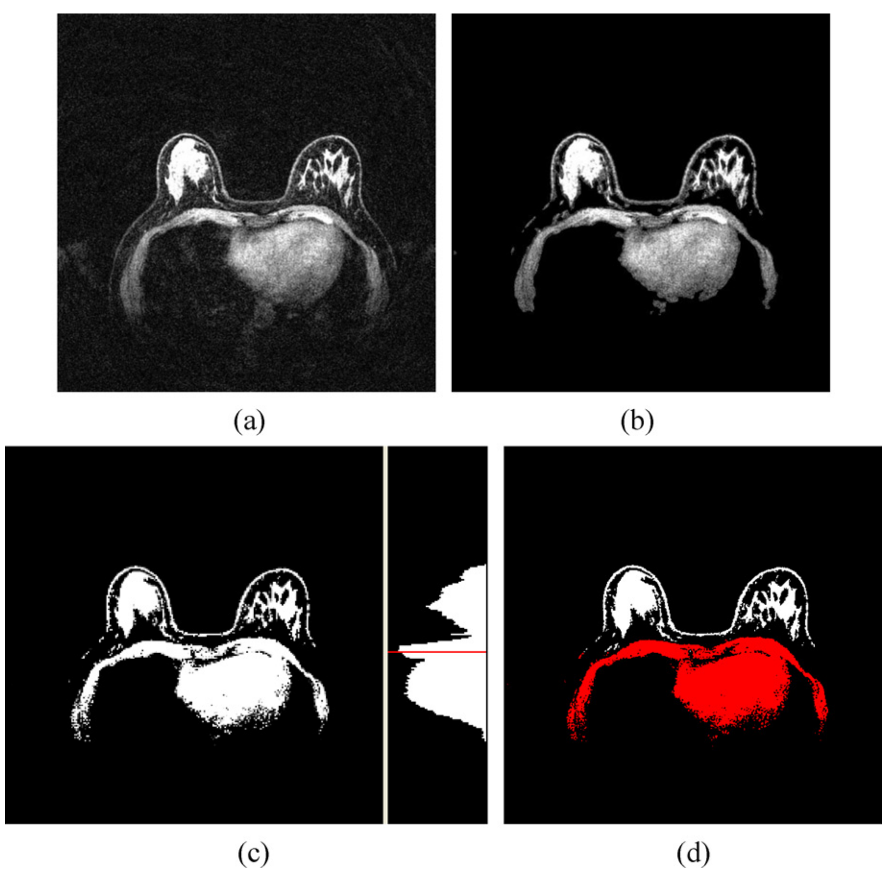

Fig. 1. (a) Original breast MR image; (b) denoised result; (c) binary result and its histogram in the vertical axis; (d) segmented region.