Automatic Template-based Breast Segmentation on MRI Using Nonrigid Registration Algorithms

Muqing Lin[1], Jeon-Hor Chen[1,2], Orhan Nalcioglu[1], and Min-Ying Lydia Su[1]

[1]Tu & Yuen Center for Functional Onco Imaging, University of California, Irvine, California, United States, [2]Department of Radiology, China Medical University Hospital, Taichung, Taiwan

Background and purpose:

Breast segmentation in MRI is the preliminary step for the detection of various tissues inside the breast, including lesion and fibroglandular tissue (or, breast density). Manual/semi-automatic segmentation methods are usually used but they are time-consuming and often the results are inconsistent. An automatic breast segmentation method would help developing computer-aided-diagnosis method for detection of breast cancer, as well as the quantitative method for analyzing breast density for risk management. In general, the strategies to segment the breast from the MR slice are either to find the breast region directly, or to exclude the chest body region. Since breast can have a variety of shapes and density patterns, it is difficult to find generalized features suitable for breast segmentation. On the other hand, in most breast MR scans the chest region including the lung and the heart can be detected at similar locations with similar shape and intensity features. A chest body model can be registered to match the subject's specific chest body region, and this deformed chest body model can be used for segmentation in this subject. In this study we used this approach to develop an automatic template-based breast MRI segmentation method using nonrigid registration.

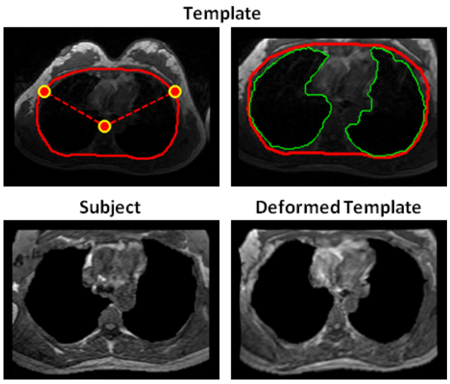

Fig. 1: Template generation and the deformation of the template to match the subject's chest region.

Methods:

Five T1-weighted MR scans were selected from a cohort of breast cancer patients receiving neoadjuvant chemotherapy for testing purposes. The breasts are different in size, shape and their fibroglandular tissue patterns. One of the scans was selected to generate the chest region template. As shown in Fig-1, the chest region template was manually outlined along the posterior chest wall mussel and the outer boundary of the lung. In order to make the registration focus within the chest region, a cropped bounding box covering the thoracic region was used as the input for registration. Three body landmarks, the thoracic spine and the lateral margin of the bilateral pectoralis muscles (the highlighted points in Fig-1) are manually identified on the template. When the template is deformed to match the subject, the deformed location of these three landmarks are used to perform the v-shape cut, which is a necessary step to determine the posterior boundary of the bilateral breasts [1].

The procedures of this automatic segmentation for one breast MR slice are given as follows. Firstly, our previously developed bias field correction algorithm, N3+FCM [2], is applied to remove the intensity inhomogeneity. Secondly, a fuzzy c-means (FCM) clustering algorithm [3] is applied to detect the lung region based on its low intensity and central location. The subject's chest region image is also obtained by using the bounding box as previously described (Fig-1). Thirdly, the subject's chest region image is smoothed using a Gaussian kernel followed by the FCM clustering algorithm to ensure the robustness of nonrigid registration. Fourthly, demons algorithm [4] is applied to register the template chest region image with the subject's chest region image. The v-shape cut is performed based on the deformed body landmarks, and then the deformed chest template (the green contour in Fig-2a) is excluded to obtain the initial segmented breast (Fig-2b). Fifthly, the chest-wall mussel (the green points in Fig-2b) is extracted based on the intensity gradients and the constrains of location and shape. Sixthly, Bezier curve fitting is used to determine a continuous mussel curve (the red line in Fig-2b) and further to obtain the mussel area (the yellow contour in Fig-2b). Lastly, the final breast segmentation (Fig-2c) is obtained by subtracting out the mussel area.

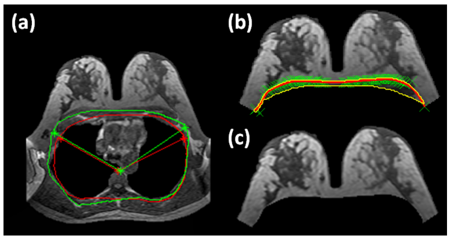

Fig. 2: Template-based breast segmentation. (a) The template chest (red) is registered to the subject's chest (green). The v-shape cut is performed using the three deformed body landmarks. (b) The chest wall muscle is extracted using model fitting. (c) Final segmented breast.

The scheme for segmentation of all MR slices based on the central slice is shown in Fig-3. The breast in the center slice (the mth slice) is first segmented using the method described above. Since there are often a high similarity and correlation between two adjacent MR slices, the deformed chest model for the nth slice is then served as the chest template for the m-1th slice and the m+1th slice. The process continues superiorly and inferiorly until all slices are segmented.

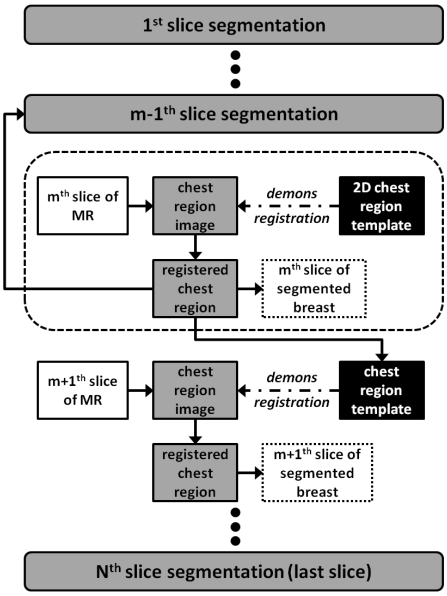

Fig. 3: The scheme of the automatic template-based breast segmentation based on the result of the center slice.

Results:

Figure 4 shows the segmentation results of 4 different cases**.** Fig-4a is the case with low breast density. Fig-4b is the case with moderate breast density on both sides of the breasts. Fig-4c is the case with a large tumor in the right breast and a low breast density in the left breast. Fig-4d is the case with large tumor in the right breast and high breast density in the left breast. In Fig-4a, the fibroglandular tissues are distant from the chest wall mussel. In Fig-4b, c, d, the fibroglandular tissues are closely connected to the chest wall mussel. As shown in the first row of Fig-4, the deformed chest region template can cover most of the chest wall mussel. Also, the v-shape cut can be successfully performed to preserve the entire fibroglandular tissues. For the second row of Fig-4, our mussel detection method using curve fitting is able to produce a smooth contour of breast, to completely exclude all chest wall muscle while preserve the fibroglandular tissues.

Discussion:

We have developed and implemented an automatic template-based breast segmentation method for MRI using nonrigid registration. The initial segmentation results show that our method is able to locate and outline the boundary of breast consistently. Comparison of the performance with manual segmentation in terms of accuracy and processing time is planned as future work.

Ref: [1] Nie et al. Med Phys 2008;35:5253-62. [2] Lin et al. Med Phys 2011;38:5-14. [3] Chen W et al. ISBI 2004:1307-10. [4] Thirion Med Imag Anal 1998;2:243-60.

Acknowledgement: This work was supported in part by CBCRP 16GB-0056.

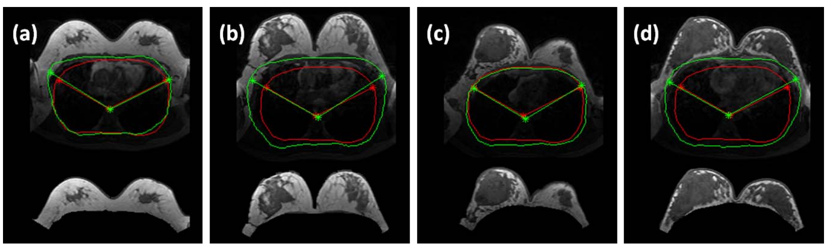

Fig. 4: Example of breast segmentation using the developed method in four cases.