Different Types of Errors in Segmentation of Breast Density Using Computer-Aided Algorithms

J-H. Chen[1,2], M. Lin[1], F-J. Lei[2], J-P. Wu[2], S. Chan[3], O. Nalcioglu[1], and M-Y. L. Su[1]
[1]Center for Functional Onco-Imaging and Department of Radiological Science, University of California Irvine, Irvine, California, United States, [2]Department of Radiology, China Medical University Hospital, Taichung, Taiwan, [3]Department of Radiology, Taichung Veterans General Hospital, Taichung, Taiwan

Background and Purpose:

Breast density measured using mammography, termed "mammographic density", has been established as an independent risk factor for development of breast cancer. However, since it is based on a 2D projection image, the quantification suffers from several problems, such as tissue-overlapping, variation in the position of the subject, and the different angle and degree of compression that lead to different projection views. In order to improve the reliability, the 3D MR-based methods have been developed. Although the drawbacks associated with 2D projection image no longer exist, MRI-based method has its own problems. Since a large area is imaged using the surface coil, one major issue is the intensity non-uniformity due to the strong bias field. This presents a difficulty for thresholding-based segmentation approaches. Previously, we used the fuzzy c-means technique (FCM) algorithm [1] for both homogeneity correction and segmentation, but FCM did not work well in cases with a strong bias-field. We have further developed an iterative bias-field correction scheme utilizing the combination of N3 [2] and FCM-based algorithms (noted as N3+FCM). Although in general the segmentation accuracy is improved, yet errors in some regions are still seen. The purpose of this study is to classify the types of errors that are commonly encountered in segmentation of fibroglandular tissue on MRI, as well as the methods that may be implemented to correct these errors.

Materials and Methods:

A non-fat-sat T1W MRI dataset from 30 healthy volunteers without breast diseases were analyzed by two operators. The MRIs were acquired using a 1.5T MR scanner. The breast and fibroglandular tissue segmentation was performed using a comprehensive method we have developed before based on computer algorithms [3]. The breast segmentation procedures consisted of: 1) Perform an initial horizontal line cutting based on the posterior margin of the sternum to exclude thoracic region. 2) Apply FCM clustering and b-spline curve fitting to obtain the breast-chest boundary. After the breast is segmented out, the total breast volume is calculated. 3) Apply dynamic searching to exclude the skin along the breast boundary. 4) A novel method based on N3 and adaptive FCM algorithm was used to remove the strong intensity non-uniformity and correct the bias field for segmentation of fibroglandular tissue and fatty tissue. 5) The standard FCM algorithm is applied to classify all pixels on the image into 6 clusters; 3 as fibroglandular tissues and the other 3 as fatty tissues. Using the original T1W images as the reference, two operators determined the accuracy of fibroglandular tissue segmentation based on visual inspection. The errors were noted and classified into three types. The methods that can be used to correct these different types of errors were recorded.

Results:

Three types of errors were noted, including Type-1: fatty tissue mistakenly segmented as fibroglandular tissue due to incomplete bias field correction; Type-2: inclusion of nipple; and Type-3: incomplete segmentation of fibroglandular tissue due to partial volume effect. The two operators consistently identified Type-1 error as the most frequently encountered segmentation problem (29/30, 97%; and 30/30, 100%). The frequency of Type-2 error noted by the two operators was very different (6/30, 20%; and 17/30, 57%). This is probably due to different definition of the nipple being included in the segmented images by the operators. Type-3 was seen in (8/30, 27%; and 10/30, 33%) cases. These errors, when occurred, only involved one or several slices in the entire set of breast images. The operators can easily go through the images slice by slice and identified the errors visually. Based on the nature of these errors several different strategies were developed for the correction, including: 1) improve bias-field correction; 2) re-segment breast region using a different landmark; 3) redo nipple exclusion using computer algorithms based on its protruding nature; 4) change local contrast; 5) change FCM cluster setting for segmentation. Depending on the type of error, one method or several methods in combination can be used for correction. In most cases, these errors can be corrected, with the final results verified by a senior breast radiologist. The processing time to analyze the whole set of images for two breasts of a subject, including the corrections, can be completed in 45 minutes. **Figure 1** illustrates the three types of errors and the corrected results.

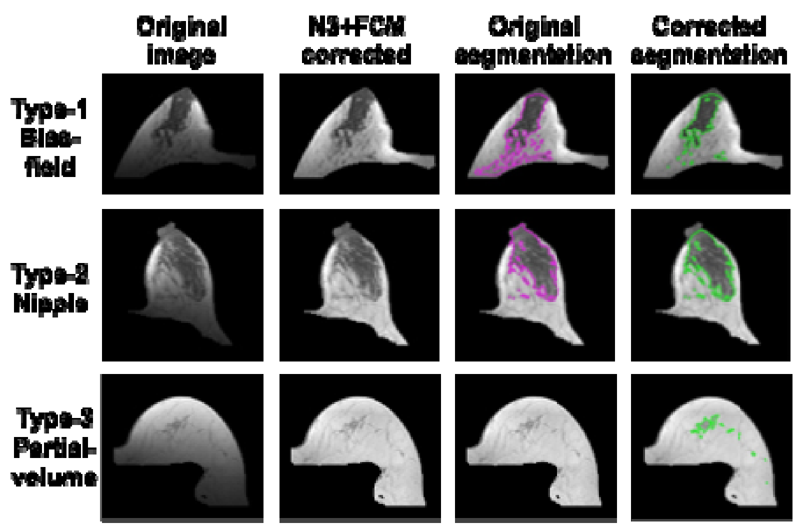

Figure 1. Three types of segmentation errors and the corrected results. First column: original uncorrected images; second column: images after N3+FCM bias field correction; third column: initial segmentation result of fibroglandular tissue that was determined as not accurate; fourth column: segmentation results after applying the correction algorithm. In Type-1 case, note that even after applying the N3+FCM bias-field correction algorithm, some fatty tissues in the lateral side still appear dark and mistakenly segmented as dense tissue. Further bias-field correction can be applied to correct this mistake. In Type-2 case, the nipple is included as part of fibroglandular tissues. An algorithm based on its protruding nature can be used to exclude nipple. In Type-3 case the dense tissues appear bright due to the partial volume effect. Although they can be differentiated visually, the algorithm fails to correctly segment them as fibroglandular tissue. Adjusting the number of FCM clusters can correct this type of error.

Discussion:

Our results showed that although the computer-aided algorithm in general worked well, yet some errors in small regions of breast were noted. The major problems came from the strong intensity inhomogeneity within the large breast region, as well as the low contrast between fibroglandular tissue and fatty tissue. The correction methods that are presented here may be applied to successfully correct these errors. Nevertheless, since the errors were seen in a relatively small region of a large breast, it did not change the measured dense tissue volume or the percent density significantly. These processes to identify potential errors and the correction strategies are important for developing a fully automated procedure for quantitative analysis of MRI-based breast density in the future.

References: [1]. Chen et al. International Symposium on Biomedical Imaging (ISBI), pp. 1307–1310 (2004); [**2**]**.** Sled et al. IEEE Trans. Med. Imaging. 17:87-97 (1998). **[3].** Nie et al. Med. Phys. 35:5253–5262 (2008).