

A New Intensity Inhomogeneity Correction Method for Improved Segmentation of Breast Density on MRI

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Background and purpose:

Breast density has been proven as an independent risk factor associated with the development of breast cancer. This was established using density analyzed on mammography. MRI may provide more information about the dense tissue volume and distribution morphology, but needs a more sophisticated segmentation method. Our group has published a complete processing method for segmentation of breast density on MRI [1]. Fuzzy C-means (FCM) algorithm was applied for bias field correction and dense tissue segmentation. However, in the presence of a strong field inhomogeneity, the FCM algorithm is not sufficient to successfully correct the bias-field. In this work we implemented a new bias field correction method (N3+FCM) by combining the N3 algorithm (nonparametric non-uniformity normalization) [2] and FCM-based algorithms to improve segmentation accuracy. The segmentation results based on the N3+FCM corrected images were compared to the N3 and FCM alone corrected images and another recently published method, coherent local intensity clustering (CLIC) [3], corrected images.

Methods:

Our database consisted of 30 healthy subjects (age 23-61, mean 35), including 25 pre-menopausal (mean 30 years old) and 5 post-menopausal women (mean 58 years old). Two breasts in each subject were analyzed separately, and a total of 60 breasts were studied. Breast MRI was performed using a Siemens 1.5T scanner using a non-fat-sat sequence. The first analysis step is to segment the breast from the body (Fig-1a). The second step is to remove intensity inhomogeneity using the iterative N3+FCM. Specifically, N3 algorithm was applied to the segmented breast to correct the major bias field (Fig-1b). Then FCM correction was applied to the N3-corrected image to further eliminate the residual bias field (Fig-1c). As shown on the image, while removing the bias field, FCM correction also changed contrast between densities and fat, and this was corrected using iterative smoothing procedures. The bias field is estimated by subtracting FCM-corrected image from N3-corrected image in the logarithmic space; then B-spline parametric surface fitting [2] was applied to ensure the bias field is smoothly varying (Fig-1d). The smoothed bias field was applied to FCM-corrected image to obtain the improved image without the erroneous contrast (Fig-1e). This process combining FCM and B-spline fitting was repeated iteratively and terminated when the area of difference between two consecutive images is less than a threshold. Fig-1f shows the final corrected image, obtained after 10 iterations. Fig-1g outlines skin and nipple excluded breast. The last step is to perform segmentation using FCM. A total of 6 clusters were used, 3 as fat and the other 3 as fibroglandular tissues. The segmented fibroglandular tissue is outlined in Fig-1h.

Since there is no ground truth, the segmentation quality was evaluated based on visual inspection of an experienced radiologist. The segmented densities using N3+FCM, N3, FCM and CLIC were presented blindly in a random order noted by (A, B, C and D), and the segmentation accuracy among these sets was ranked (e.g., N3+FCM>CLIC>N3=FCM). To assess the consistency of radiologist's evaluation, the rating was done twice with one-month interval in between. The pairwise Wilcoxon signed-rank test was applied to statistically compare two different methods (X and Y). If X ranked better than Y, then X=1 and Y=0; if X and Y were ranked equally, then X=1 and Y=1. A p-value less than 0.05 was considered significant.

Results:

Figure 2 shows the comparison of segmented density on one image slice using different methods. The proposed N3+FCM and CLIC both show a clean separation between these two histogram peaks, thus allow a clean differentiation between fibroglandular tissues and fatty tissues to achieve an accurate segmentation result, close to the gold-standard outlined by a radiologist. In the radiologist's first visual evaluation, the performance of N3+FCM is better than using N3 in 24/60 cases, with equal performance in 34/60 cases, and worse than N3 in only 2/60 case(s). N3+FCM is better than using FCM in 58/60 cases and with equal performance in 2/60 cases. N3+FCM is better than using CLIC in 4/60 cases, with equal performance in 54/60 cases, and worse than CLIC in 2/60 cases. The result of radiologist's second reading is similar. The comparison indicates that N3+FCM is better than N3 or FCM alone, with $p<0.001$. The performance of N3 and CLIC is comparable without a significant difference. An example of N3+FCM=CLIC > N3> FCM is shown in Figure 3.

Discussion:

We proposed a new bias field correction method combining N3 and FCM-based algorithms and using the advantage of N3 for a global correction and then by iteration of FCM and B-spline fitting to gradually correct the intensity inhomogeneity without erroneously changing the tissue contrast. The N3+FCM and CLIC methods are both useful for removing a severe regional bias-field, which is commonly presented in the MR images of large size breasts acquired using a flat-bed breast coil. Choosing an appropriate intensity inhomogeneity correction method is a very important preprocessing step to allow an accurate segmentation of fibroglandular tissues based on breast MRI for measurement of breast density.

Ref: [1] Nie et al. Med Phys 2008;35(12):5253-5262. [2] Sled et al. IEEE Trans Med Imaging 1998;17(1):87-97. [3] Li et al. IPMI 2009;299-299.

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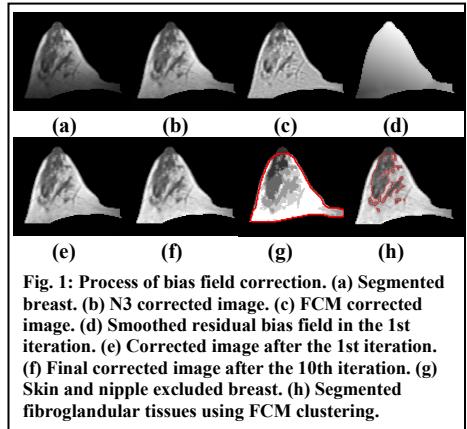


Fig. 1: Process of bias field correction. (a) Segmented breast. (b) N3 corrected image. (c) FCM corrected image. (d) Smoothed residual bias field in the 1st iteration. (e) Corrected image after the 1st iteration. (f) Final corrected image after the 10th iteration. (g) Skin and nipple excluded breast. (h) Segmented fibroglandular tissues using FCM clustering.

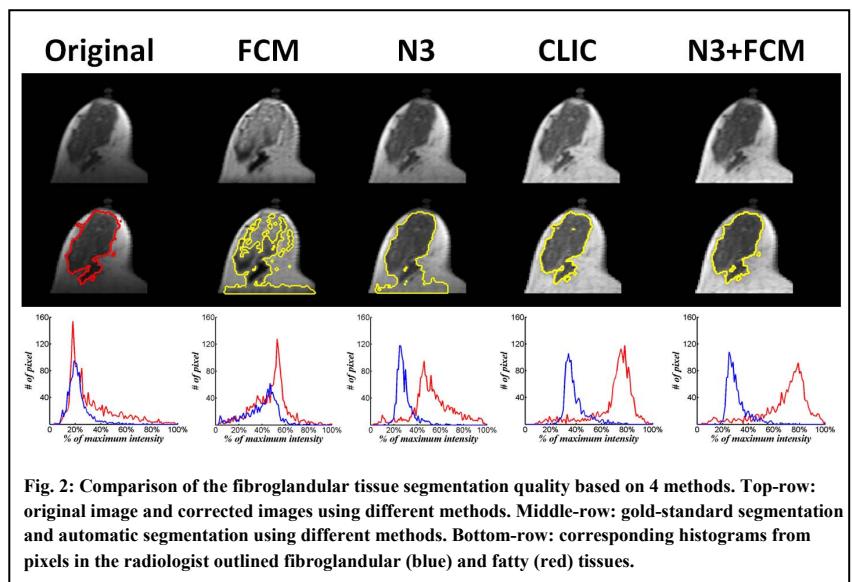


Fig. 2: Comparison of the fibroglandular tissue segmentation quality based on 4 methods. Top-row: original image and corrected images using different methods. Middle-row: gold-standard segmentation and automatic segmentation using different methods. Bottom-row: corresponding histograms from pixels in the radiologist outlined fibroglandular (blue) and fatty (red) tissues.

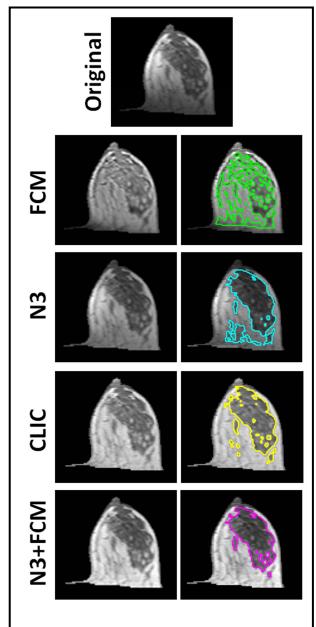


Fig. 3: An example of "N3+FCM = CLIC > N3 > FCM".