Effect of Morphological Enhancement on Mammographic Phantom Images

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Citation

Abstract
The effect of morphological enhancement on detection of nodules, fibrils and micronodules in mammographic phantom images was studied. Ten images each divided into nine partitions in which materials to mimic the nodules, fibrils and micronodules were affixed, were acquired by a mammography system. The images were morphological enhanced to produce second set of images. Receiver operating characteristic analyses were performed to compare the detection performance from the two sets of images. The detection of nodules was higher in the morphological enhanced images, while the detection of fibrils and micronodules was comparable in both original and morphological enhanced images. The study suggests that morphological enhancement of mammography image increases the detection of low frequency signals of the images.

1. Introduction
Breast cancer is the most common form of cancer in the female population and continues to be leading cause of death among woman around the world. Early detection and treatment of breast cancer are the most effective methods to reduce mortality. Breast cancer mortality has declined among woman of all ages over the past decade although breast cancer incidence has increased [1]. Mammography screening had reduced the mortality and improved the treatment of breast cancer [2]. Mammography has proven to be the most effective tool for detecting breast cancer in early stage.

ROC analysis evaluates the plots by calculating the area under the curves. The mammographic images are scored based on subjective interpretation by observers. Usually, the structures of the image were enhanced using morphological techniques and 2D wavelet transform, but in this study we only discuss about the morphological technique. Morphological operation using dilation and morphological closing were used in morphological techniques

2. Materials and Methods
2.1. Image Acquisition
Ten images, each divided into nine partitions in which materials to mimic nodules, fibrils and micronodules were fixed, were acquired using a Hologic Lorad Selenia
mammographic system. A 12 cm by 12 cm perspex slab of 4.7 cm thick was used as the phantom. Figure 1 shows the set up of the image acquisition, while Figure 2 shows the phantom and the mimicked nodules, fibrils and micronodules.

These 10 images were the original set of images. The images were then processed by morphological enhancement described in Section 2.2. Thus we obtained two sets of images for our ROC analysis.

2.2. Morphological Enhancement Technique

The mammographic phantom images were enhanced using morphological techniques, in which the strel was applied in flat structuring elements which support arbitrary shapes [3]. In the enhancement, the images were dilated using a disk shaped structuring element to suppress noise and improve image contrast. In order to reduce elimination of any micronodules, the sizes of the structuring element was chosen experimentally. Morphological closing was applied to the image after dilation [3].

2.3. Receiver Operating Characteristics (ROC) Analysis

ROC analysis was performed to investigate the characteristics and the accuracy of detection of the 2 sets of images relying on subjective interpretation [4, 5]. CORROC2 and ROCFIT software were used to process the clustered data from the ROC scoring and operating point calculation dataset [6, 7, 8].

Positive and negative cases with confidence ratings scale from the ROC data were required as inputs to CORROC2. This CORROC2 calculated the statistical significance of the differences between two estimated ROC curves from the two conditions, original images and enhancement images using morphological techniques. The software produced the true positive fraction (TPF) values for condition X (original images) and condition Y (enhancement images) at selected false positive fraction (FPF) values. The areas under the fitted ROC curves from the two conditions with estimated standard deviations and correlation appeared after running the software [7]. ROCFIT only fits a binormal ROC curve for one diagnostic test to determine the ROC area index, \( A_Z \) and standard deviation [8].

3. Results and Discussions

The morphological enhanced and original images are shown in Figure 3 and Figure 4. Micronodules appeared as bright spots with higher intensity value and more visible compared to nodules and fibrils for all image conditions. Micronodules have a very high contrast and broad frequency distribution compared to nodules and fibrils.

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**Figure 1. Setup of image acquisition.**

**Figure 2. Nodules, fibrils and micronodules on the phantom.**

**Figure 3. Original image acquired at 29 kVp, mAs = 124.6 under 5.8 cm compression using Rh filter.**

**Figure 4. Morphological enhanced image of Figure 3.**
From the observation, morphological enhanced techniques improved the image contrast. The embedded structures from Figure 4 could be seen clearly compared to Figure 3. Nodules with low density have low contrast. Nodules and fibrils are often difficult to detect compared to the micronodules because of its varying size, shape and density.

Figure 5 shows the ROC curves in detection of nodules from original images and morphological enhanced images. Morphological enhanced images have higher area index ($A_z = 0.9764$) compared to original images ($A_z = 0.9555$). Using CORROC2, the difference in area indices of original images and morphological enhanced images was found statistically not significant because $p$-value = 0.19 which is larger than 0.05. Thus the enhancement weakly increased the detection of the nodules.

Variation of position, shape, size, density for nodules is difficult to identify from the background of the phantom [9]. According to [10], variation intensity of the nodules causes difficulty in interpreting the mammographic images. Most nodules have weak contrast because of small difference between the nodule pixel values and the background pixel values. [11], [12] and [13] proved that by applying the structuring element to the original images, morphological techniques could enhance the image contrast.

Figure 6 shows the ROC curves for the detection of fibrils from original and morphological enhanced images. The area indices of the original and the morphological enhanced images were almost the same. Thus the enhancement did not increase the detection of fibrils.

Figure 7 shows the ROC curves for detection of micronodules from original and morphological enhanced images. The area indices were almost the same, showing that the enhancement did not increase the detection of micronodules.

4. Conclusion

The morphological enhancement of mammographic images was studied by ROC analysis. Original and morphological enhanced images were prepared. The results show that the enhancement weakly increased the detection of nodules, but has no effect on detection of fibrils and micronodules. The morphological enhancement technique might be used to increase the detection of low frequency signals in mammographic images.

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