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Experiments with 3-D Mammography and their Possible Applications in Telemammography

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Mammography is the leading method for breast imaging today. However, mammography is a projection imaging process, which produces 2-D images of a 3-D object; thus, the spatial arrangement of tissues cannot be preserved, causing loss of morphologic information. Different techniques of 3-D radiographic breast imaging have been considered. This paper describes techniques of stereomammography, linear breast tomosynthesis, and limited view breast tomography. These techniques are compared with respect of the dose needed for imaging and potential use in telemedicine.

KEY WORDS: *Mammography; Breast imaging, Stereo imaging*

INTRODUCTION

The three-dimensional (3-D) breast imaging is an attempt to overcome limitations related to 2-D nature of conventional projection mammography, which is the leading method for the breast imaging today. Conventional mammograms are 2-D projection images of the breast, which is a 3-D body. Thus, the spatial arrangement of tissues cannot be preserved, causing loss of morphologic information [1]. In addition, superimposed projections of breast tissues, which are not spatially adjacent cause loss of the tissue interrelationship. Figure 1 shows two calcified masses, one malignant and one benign, with similar mammographic appearances. Enhancing the difference between these two types of masses can be an important diagnostic achievement.

Methods for 3-D mammography can potentially be used for both early detection and diagnosis of breast cancer. In early detection, they may be suitable replacements for two-view mammography, since they can eliminate the superposition artifacts. However, they might not include as much breast tissue as the two views combined. The 3-D mammography can also be used as an adjuvant diagnostic technique, with a goal of reducing the number of breast biopsies. This paper describes the 3-D mammographic techniques, since the diagnostic quality of the x-ray based images is better than those obtained by other modalities. Other approaches to 3-D breast imaging include breast MRI, ultrasound-mammography, SPECT and PET based imaging, transillumination, elastography, electrical impedance imaging, etc. [2].

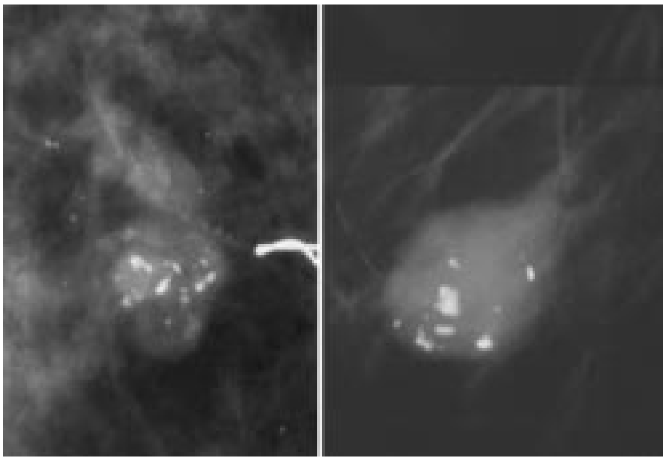

Figure 1. Mammographic appearance of a malignant (left) and a benign (right) calcified mass. Calcifications have uniform 3-D distribution throughout the mass in the left image, and a peripheral 3-D distribution in the right image. These distributions are, however, hard to distinguish in 2-D mammograms

The primary concern in the 3-D mammography is the received dose. Dose for the screening should not exceed the dose currently used in mammography (approx. 2.3 mGy of mean glandular dose, per image) unless the sensitivity is greatly improved. This is why the full computed tomography (CT) reconstruction is not considered to be clinically acceptable, since in order to achieve resolution appropriate for early detection, CT requires large number of slices and high dose. Another concern is duration of the exam, due to the number of screening patients, and the amount of the tissue visualized. Imaging geometry must allow rapid imaging and include all glandular tissue. The 3-D mammography is based upon digital mammography and utilizes its advantages of separate optimization of image acquisition, reconstruction, visualization, and storing. Reconstruction methods include stereoscopy, tomosynthesis, and a modified CT algorithm with small number of views for dose reduction. Limited view reconstruction algorithms use reduced amount of image data, which is more appropriate for

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the applications in telemammography. Images included in this work have been produced on a stereotactic breast imaging table shown in Figure 2 [1]. Multiple images are acquired at different angles of the X-ray tube, with respect to the longitudinal table axis.

Figure 2. Stereotactic breast imaging system used for acquisition of images for 3-D reconstruction

ALGORITHMS FOR 3-D MAMMOGRAPHY

Experiments with the 3-D mammography have been performed using stereoscopic display, linear thomosynthesis, and limited view CT reconstruction. These methods will be described in more detail in the following subsections.

Stereomammography

Stereoscopic approach uses at least two images, separated by the average angular separation of the eyes (3-8(). Displaying images so that the left and right eye view different images, produces a stereoeffect, where the objects at different distances from the eyes appear farther or closer, therefore separating overlapped breast structure. Acquiring more then one pair of images can be used to rotate the displayed image (maintaining angular separation between the left and the right image).

Figure 3 shows a pair of images used for stereoscopic display. Note two calcification clusters (white dots) in the upper part of the images. The distances between the clusters in the left and right image differ due to different depth of the two clusters and different angle of image acquisition. For the use in telemammography, stereoscopic approach would require transmission of original pairs of source images (with possible compression).

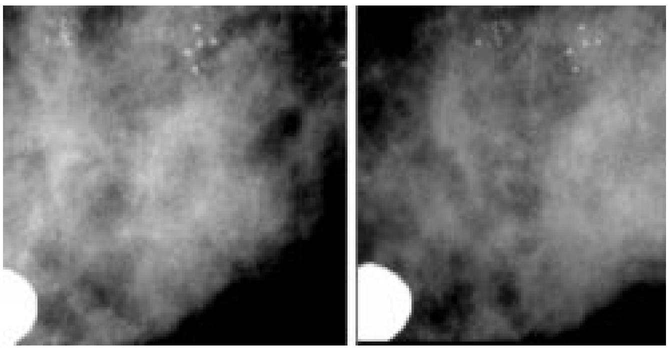

Figure 3. A pair of images used for stereomammography. Images were acquired separated by an average angle between human eyes

Linear breast tomosynthesis

Tomosynthetic approach uses larger number of source images (ten or more) then stereomammography, separated by 3-5(. Computer algorithm is used to project each source image to a plane positioned between the x-ray tube and detector, and compute the reconstruction as an average of all the projections. This algorithm produces a focused image of the structures positioned in the plane of interest only [3].

Tomosynthesis is illustrated using the phantom made of plastic geometric elements and water. The phantom objects were selected to have linear X-ray attenuation similar to the breast tissue. Figure 4 represents a couple of source images of the phantom, differing in the angle of acquisition. Figure 5 represents a couple of reconstructed planes, positioned at different distances from the detector. Tomosynthesis has been shown to be useful for imaging cysts and skin thickening. In telemammographic applications, one can transmit either the reconstructed planes or the source images (with reconstruction at the receiver side). A trade off between the complexity of reconstruction at the acquisition side and transmission degradation should be evaluated.

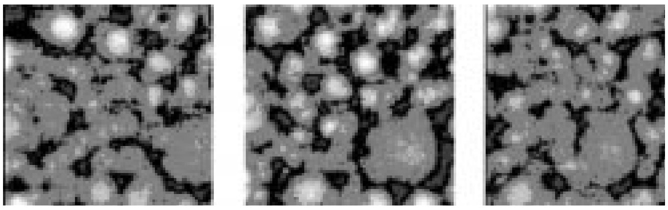

Figure 4. Three source images of a phantom, separated by small angles, used for breast tomosynthesis

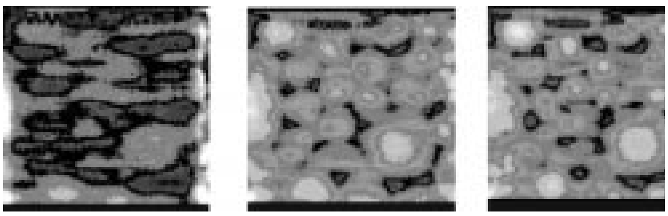

Figure 5. Three tomosynthetically reconstructed planes, positioned at different distances from the detector. (The planes were reconstructed using the source images in Figure 4.)

Limited view 3-D reconstruction

Limited view reconstruction is based upon the CT principles with the small number of required source images [1]. This technique is currently considered in reconstruction of calcification clusters.

Reconstruction of soft tissue with small differential x-ray attenuation require higher dose than conventional mammography. In case of calcification, the reconstruction algorithm consists of the following steps. First, individual calcifications are segmented in each source image. Second, correspondence between calcifications in different images is established. Finally, the location and shape of each calcification are reconstructed, in order to generate 3-D images of clusters.

Reconstructions of position and shape are illustrated in Figure 6. The position can be detected by using two different X-ray tube positions (left image in Figure 6). The shape of the tissue can be reconstructed by using two spatially separated sources producing two different images depending on the density of the observed tissue (right image in Figure 6).

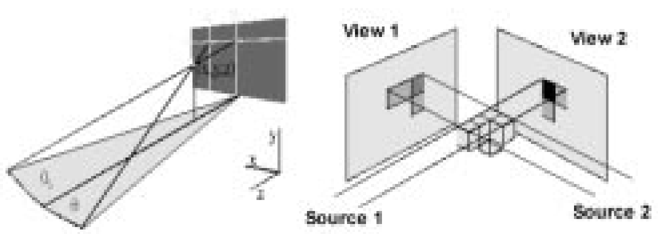

Figure 6. Reconstruction of calcification position (left) and shape (right), using limited view reconstruction technique. Position is reconstructed as intersection of projection lines for different x-ray tube angle. Shape is reconstructed by comparing the intensities in different projection images of the same calcification

An example of reconstructed single calcification is shown in Figure 7. Using this approach, 3-D distributions of homogeneous or linear malignant clusters and of peripheral plate-like benign clusters are more clearly differentiated. This approach offers parametric representation of reconstructed calcifications, which can potentially reduce the amount of data needed for visualization, transmission, and storing, and can be of significance in telemammography.

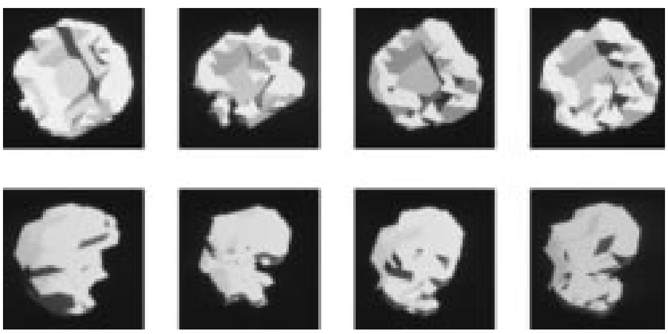

Figure 7. Reconstruction of a single simulated calcification. Shape of the original object is given in the leftmost images. Images on the right show reconstructed shape using 3, 5, or 7 source images, respectively. Two rows correspond to reconstruction of the same calcification, seen from two different angles

CONCLUSION

We have found that the 3-D radiographic breast imaging techniques have potentials for both early cancer detection and diagnosis. The 3-D images of the breast reduce the likelihood of superposition errors and improve separation of overlying tissues. Doses in tomosynthesis and stereoscopy can be similar to those used in film-screen mammography today. Limited view reconstruction has been applied by now to viewing calcifications; however, there are indications that the soft tissue can also be reconstructed, which is a future research topic. Limited view reconstruction also has an advantage of reducing the amount of data needed for transmission in telemedicine. Note that for telemedicine purposes a store-and forward application is adequate. So, the (potentially) large amount of image data should not be the limiting factor and even the low-level telecommunications networks can be used for telemammography applications [4].

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