Introduction of Computerized Detection Method to Breast Cancer Screening in Mie Prefecture

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Abstract— **A remote image diagnosis via telemedicine network is pervasive in Japan because the number of experienced radiologists for reading mammograms in breast cancer screening is insufficient. However, radiologists in a medical institution where mammograms are sent from the other medical institutions have to read larger number of mammograms, and are overtasked. This would decrease radiologists' performance. On the other hand, it is known that radiologists' detection performance will be improved by taking into account the detected lesions automatically by a computerized method. In order to assist radiologists in detection of clustered microcalcifications, therefore, we attempt to introduce our computerized detection method to a remote image diagnosis in Mie Prefecture. For the remote image diagnosis in breast cancer screening, digital mammograms taken at six medical institutions in Mie Prefecture are transferred to a DICOM (Digital Imaging and COmmunication in Medicine) image server in Mie University Hospital via telemedicine network based on virtual private network. The digital mammograms acquired with five different mammography equipments which are manufactured by GE (General Electric) Corporation, Fujifilm Corporation, and Konica Minolta are treated in this remote image diagnosis. Our computerized detection method detects individual calcifications on mammograms based on an artificial neural network (ANN) with objective features obtained from a multi-resolution analysis. The proposed method identifies automatically which mammography equipment a digital mammogram was acquired with from the DICOM header and uses appropriate ANN which had been trained for not each mammography equipment but each vender. We applied the proposed method to all mammograms transferred to the DICOM image server in Mie University in a year. Sensitivity and the number of false positives per image were 94.3% and 0.79 for GE Corporation, 100% and 0.47 for Fujifilm Corporation, and 100% and 0.19 for Konica Minolta, respectively. These results were comparable with the average detection results of the commercial computerized detection systems manufactured exclusively for each mammography equipment. The proposed method was shown to have the high detection performance for clustered microcalcifications, and to have a possibility of being useful in the remote image diagnosis for breast cancer screening in Mie Prefecture.**

Keywords: **computerized detection method, clustered microcalcifications, mammograms, remote image diagnosis, breast cancer screening**

I. Introduction

Mammography considered the most sensitive method for early detection of breast cancers has been introduced to breast cancer screening in Japan [1]. However, it is difficult to employ a radiologist for reading mammograms in the regional hospital because the number of experienced radiologists for reading mammograms in breast cancer screening is insufficient. Therefore, a remote image diagnosis via telemedicine network is becoming pervasive. However, radiologists in a medical institution where mammograms are transferred from the other medical institutions have to read larger number of mammograms, and are overtasked. Nonpalpable lesions are sometimes missed due to this tiredness. On the other hand, it is known that radiologists' detection performance will be improved by taking into account the detected lesions automatically by a computerized method [2]. Therefore, many investigators have developed the computerized detection methods for lesions on mammograms [3-8]. Some of these computerized detection methods (systems) for mammograms have already been commercialized from vendors. All venders sell the commercial detection system only as an optional function when medical institution newly buys the own digital mammography equipment. Although it is expected to introduce such computerized detection systems to the remote image diagnosis for breast cancer screening via telemedicine network, it is very difficult to introduce the commercial detection system to the remote image diagnosis in which digital mammograms obtained by some different vender's equipments are treated.

In this study, as the world's first activity, we attempt to introduce our computerized detection method for clustered microcalcifications which are one of radiographic indications related to breast cancer to the remote image diagnosis in Mie Prefecture. In the remote image diagnosis for breast cancer screening, digital mammograms acquired with five different mammography equipments which are manufactured by GE (General Electric) Corporation, Fujifilm Corporation, and Konica Minolta at six medical institutions in

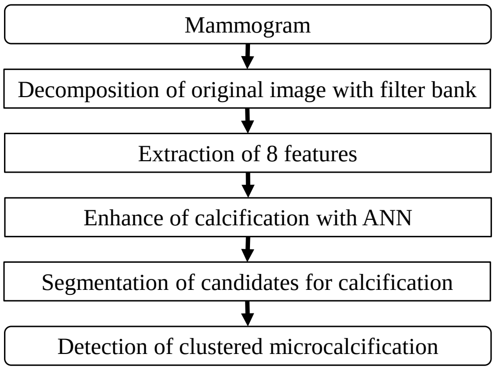


Figure 1. Schematic diagram of our proposed method for detecting clustered microcalcification in mammograms

Mie Prefecture are transferred to a DICOM (Digital Imaging and COmmunication in Medicine) image server in Mie University Hospital via telemedicine network based on virtual private network. Although the difference in the image properties between mammograms acquired with different equipments which are manufactured by the same vendor is small relatively, that between different vendors is large. We trained our computerized detection method every vendor. We applied the proposed method to all mammograms transferred to the DICOM image server in Mie University in a year.

II. Materials and methods

A. Materials

In the remote image diagnosis for breast cancer screening in Mie Prefecture, digital mammograms were acquired with five different mammography equipments which are manufactured by GE Corporation, Fujifilm Corporation, and Konica Minolta. The pixel size and the gray scale were 0.10 mm and 12-bit for GE Corporation and 0.05 mm and 12-bit for Fujifilm Corporation and Konica Minolta, respectively. In this study, we used all mammograms transferred to the DICOM image server in Mie University in a year. The locations of clustered microcalcification were determined by more than two experienced radiologists.

B. Methods

Figure 1 shows a schematic diagram of our proposed method for detecting clustered microcalcification in mammograms. Image header in a digital mammogram transferred to a DICOM image server in Mie University Hospital is analyzed automatically to identify which vender's equipment the digital mammogram was acquired with. The computerized detection method trained for each vendor is selected appropriately and is applied to the digital mammogram.

B.1 Extraction of eight objective features

Mammogram image is first decomposed into several subimages at different scales from 1 to 4 by a filter bank [8]. These subimages are the horizontal subimages for the second difference in the vertical direction, the vertical subimage for the second difference in the horizontal direction, and the diagonal subimage for the first difference in horizontal direction followed by the first difference in vertical direction. The subimages for the nodular structure (NS) and the subimages for the nodular and linear structure (NLS) are then defined by the small eigenvalue and the large eigenvalue of the Hessian matrix composed of the pixel values of those subimages for the second difference, respectively (Fig.2). Hessian matrix H is defined as

$$H = \begin{pmatrix} \dfrac{\partial^2 f}{\partial x^2} & \dfrac{\partial^2 f}{\partial x \partial y} \\ \dfrac{\partial^2 f}{\partial x \partial y} & \dfrac{\partial^2 f}{\partial y^2} \end{pmatrix} \approx \begin{bmatrix} W_j^V f(x,y) & W_j^D f(x,y) \\ W_j^D f(x,y) & W_j^H f(x,y) \end{bmatrix}. \qquad (1)$$

Here, $W_j^V f(x,y)$, $W_j^H f(x,y)$,and $W_j^D f(x,y)$ represents the vertical subimage, the horizontal subimages, and the diagonal subimages at scale j, respectively. Objective features for evaluating whether a pixel belong to calcification or not were given by values of the corresponding pixels in the subimages for the NS at scale from 1 to 4 and the subimages for the NLS at scale from 1 to 4.

B.2 Detection of clustered microcalcifications

The ANN [9] which is a three-layered, feed-forward network is employed to evaluate the likelihood that each pixel belongs to calcification on mammogram. The input layer, the hidden layer, and the output layer in the ANN are composed of eight neurons, six neurons, and one neuron, respectively. For the input of the ANN, we use eight objective features (NSs and NLSs at scales from 1 to 4) obtained from the filter bank at each pixel. The ANN for each vender is trained by using abnormal pixels of interest (POIs) on calcifications and normal POIs on normal breast tissues. Here, the numbers of abnormal POIs and normal POIs is 150 and 150 for GE Coporation, 114 and 105 for Fuji film Coporation, and 165 and 235 for Konica Minolta, respectively. These POIs are randomly chosen from 3 mammograms which are not used for the evaluation of the proposed method every vender. Each of eight objective features obtained from these POIs are normalized at each vender and are used for training the ANN based on the backpropagation technique. The enhanced image for calci-

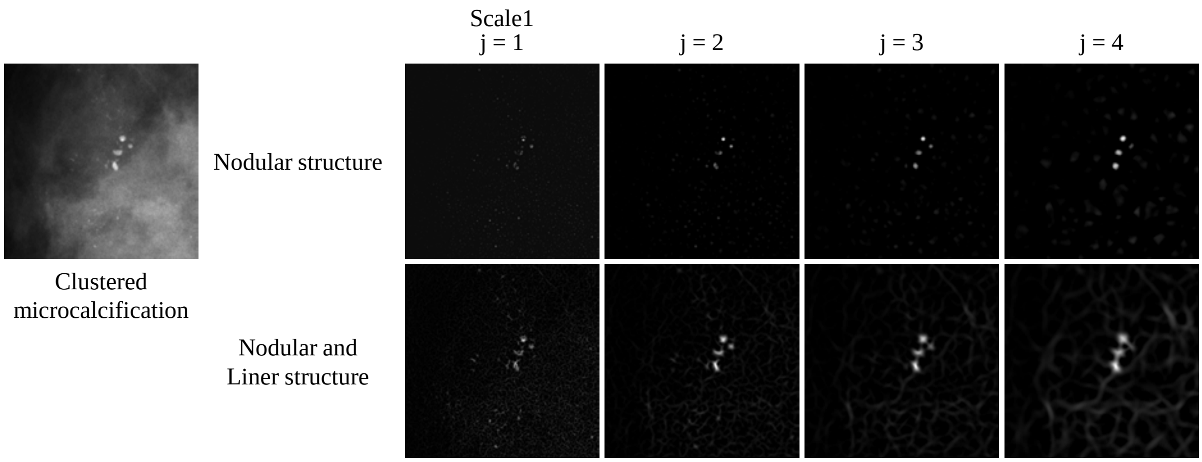


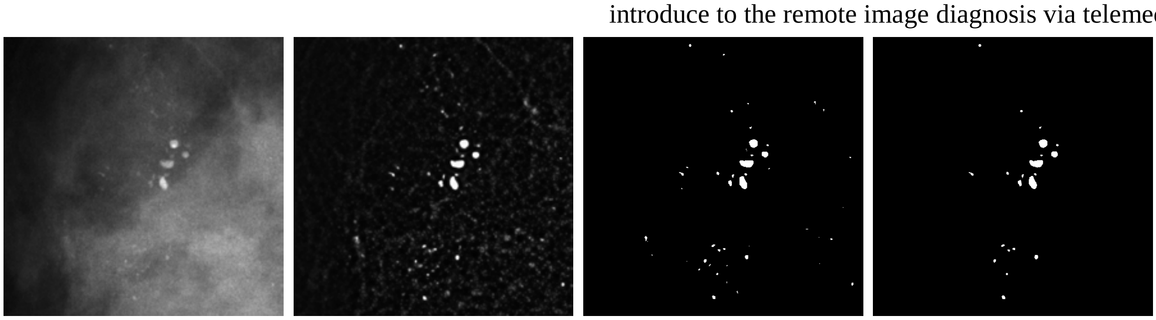
Figure 2. Subimages for NS and for NLS, which were obtained from an abnormal ROI with clustered microcalcifications

fications is then defined by the output value of the ANN at each pixel. Figure 3(b) shows an example of an enhanced image for calcifications. The candidates for calcifications are segmented by applying a gray-level thresholding technique [10] to the enhanced images, as shown in Fig. 3(c). Finally, we assume the segmented candidates with area less than 10 pixels as false positives and remove them from the segmented images, as shown in Fig. 3(d). When more than five segmented calcifications in a region of 1cm x 1cm exist, the region is detected as clustered microcalcifications.

III. Result and discussion

When the center of the detected region as clustered calcifications was within a true clustered microcalcification region, this region was considered to have been “truly” detected. When the center of the segmented region as clustered microcalcification was not within a true clustered microcalcification region, this region was considered a false positive. With our detection method, sensitivity and the number of false positives per image were 94.3% and 0.79 for GE Corporation, 100% and 0.47 for Fujifilm Corporation, and 100% and 0.19 for Konica Minolta, respectively. Figure 4 shows the example of the clustered microcalcifications detected by the proposed method. These results were comparable with the average detection results of the commercial computerized detection systems manufactured exclusively for each mammography equipment.

The detection performance for GE Corporation was lower than that for Fujifilm Corporation or Konica Minolta. This reason would be because the pixel size on mammograms for GE Corporation was larger than that for Fujifilm Corporation and Konica Minolta. We applied the filter bank with the same filter size to mammograms for all venders. Although the average diameter of calcifications is smaller than approximately 1 mm, the filter sizes at scales 3 and 4 were 13 pixels (1.3 mm) and 17 pixels (1.7 mm) on mammograms for GE Corporation, respectively. Therefore, NS and NLS at especially scale 4 for GE Corporation had hardly information for calcifications. The detection performance for GE Corporation might be improved by magnifying mammogram based on the bi-linear interpolation method. From October, 2010, our proposed method will introduce to the remote image diagnosis via telemedicine



(a) (b) (c) (d)

Figure 3. Segmentation process of calcifications (a) Original image (b) Enhanced calcifications (c) Segmented calcifications (d) Segmented calcifications removed false positives

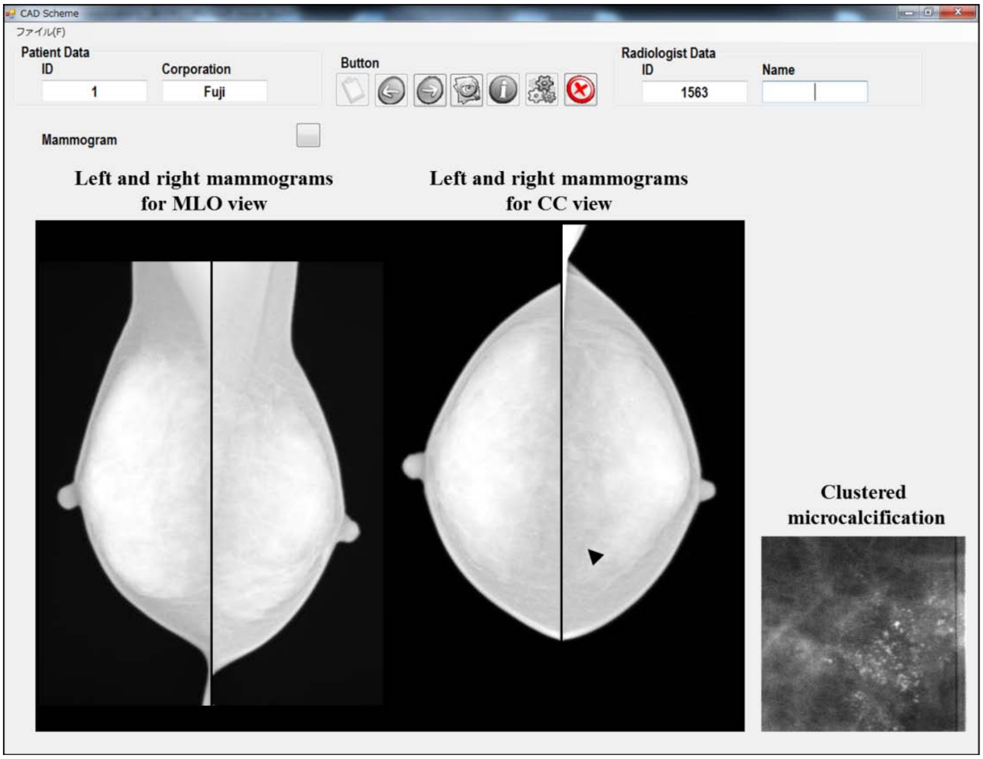


Figure 4. Example of the clustered microcalcifications detected by the proposed method

IV. Conclusions

In this study, we evaluated the possibility of being useful in the remote image diagnosis for breast cancer screening in Mie Prefecture. We applied the proposed method to mammograms acquired with different mammography equipments, and obtained the detection performance of the proposed method which was comparable with the average detection results of the commercial computerized detection systems manufactured exclusively for each mammography equipment. The result implied the proposed method have the possibility of being useful in the remote image diagnosis for breast cancer screening in Mie Prefecture.

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