International Congress Series 1281 (2005) 1036–1040

www.ics-elsevier.com

Detection method for architectural distortion based on analysis of structure of mammary gland on mammograms

T. Matsubara[a,*], D. Fukuoka[b], N. Yagi[c], T. Hara[c], H. Fujita[c], Y. Inenaga[d], S. Kasai[d], A. Kano[d], T. Endo[e], T. Iwase[f]

[a]*Nagoya Bunri University, Aichi, Japan*
[b]*Gifu National College of Technology, Gifu, Japan*
[c]*Gifu University, Gifu, Japan*
[d]*Konica Minolta Medical and Graphic, Inc., Tokyo, Japan*
[e]*National Hospital Organization of Nagoya, Aichi, Japan*
[f]*Cancer Institule Hospital, Tokyo, Japan*

Abstract. Architectural distortions, as well as clustered microcalcifications and masses, are important findings in interpreting breast cancer on mammogram. We have developed an automated detection algorithm for distorted areas based on the concentration of mammary glands in order to aid physicians with diagnosis. The purpose of this study is to suggest an improvement to our previous method to achieve higher sensitivity. The extraction method of the mammary gland was changed to employ both a shape index and curvedness so as not to be influenced by the background density from the breast thickness. The directionality of a normal of mammary gland is toward the nipple whereas that in an abnormal gland is toward another, distorted area. Normal mammary glands were eliminated by virtue of their conformation with the normal directionality. Our image database consisted of 117 cases with architectural distortions. The first-stage detection rate and the number of correct detections of ROIs were improved with our method. It was concluded that our detection method would be effective. © 2005 Published by Elsevier B.V.

Keywords: Mammogram; Architectural distortion; Computer-aided diagnosis; Automated detection; Image analysis

* Corresponding author.
E-mail address: tomoko@nagoya-bunri.ac.jp (T. Matsubara).

0531-5131/ © 2005 Published by Elsevier B.V.
doi:10.1016/j.ics.2005.03.324

1. Introduction

Architectural distortion is the third most common mammographic manifestation of nonpalpable breast cancer, after masses and clustered microcalcifications. In addition, it is associated with a high likelihood of malignancy.

Over the past two decades, there has been an explosion research activity on tools for computer-aided diagnosis (CAD) to assist physicians in the interpretation of mammograms. CAD techniques for detecting mammographic mass and clustered microcalcifications are well-documented and their performance continually improves. By contrast, a few CAD schemes have been specifically designed for detecting architectural distortion [1,2]. In addition, Baker et al. reported that fewer than one half of the cases of architectural distortion were detected by the two commercially available CAD systems [3].

We have developed a detection algorithm based on the concentration of the mammary gland [4]. The purpose of the present study is to suggest an improvement method for extracting the mammary gland in order to achieve higher sensitivity in such examinations.

2. Methods

2.1. Previous method

The distribution of the mammary gland is approximated to linear structures. In a normal breast, the direction of the distribution trends toward the nipple. In an abnormal breast, it trends toward suspect areas (see Fig. 1a and b).

Fig. 2 shows flowcharts for architectural distortion from our previous and new extraction methods. Our previous method is briefly explained as follows.

First, the linear structures of the mammary gland are extracted by a mean curvature sign, which shows either a downward or upward curved surface at any particular point. The mean curvature of the mammary gland is positive. Secondly, suspect areas are determined by the concentration index. The concentration index of a distorted area is a high because the distribution of the mammary gland in such cases trends toward a distorted area. Finally, false positives are reduced by discriminant analysis using nine features.

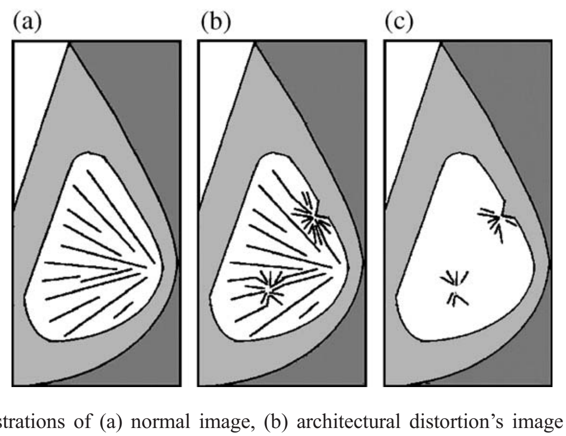

Fig. 1. Simplified illustrations of (a) normal image, (b) architectural distortion's image with retraction (upper right) and spiculation (lower left), and (c) structures of mammary glands within distorted areas.

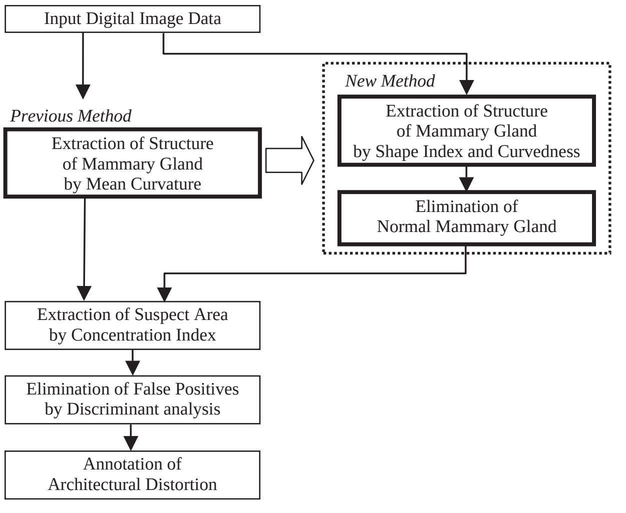

Fig. 2. Flowchart of previous and new extraction methods for architectural distortion.

The high sensitivity of this method indicates the system's potential usefulness. However, some mammary glands have not been successfully extracted by the mean curvature. Therefore, it is necessary to improve the accuracy of the mammary gland extraction. The improved processes in our new method are shown within the dashed rectangle in Fig. 2.

2.2. Extraction of structure of mammary gland by shape index and curvedness

We tested the performance of the extraction of the mammary gland by synthetic images consisting of many lines radiating in all directions with background density patterns. It was found that the lines in the density change areas were not detected by the mean curvature. In clinical cases, it was difficult to extract the mammary glands around the breast border by the mean curvature because of the influence of the background density from the breast thickness. On the other hand, lines in the density change areas were detected by the shape index and curvedness [5]. Hence, the extraction method of the mammary gland changed from mean curvature alone to a shape index and curvedness. The shape index classifies the shape of a curved surface into five classes: cup, rut, saddle, ridge or cap. The curvedness characterizes the flatness, or scale, of the shape indicated by the shape index. The shape index (S) and curvedness (C) are defined respectively by the equations:

$$S = \frac{2}{\pi} \arctan \frac{\kappa_1 + \kappa_2}{\kappa_1 - \kappa_2}, \tag{1}$$

$$C = \sqrt{\frac{\kappa_1^2 + \kappa_2^2}{2}}, \tag{2}$$

where κ_1 and κ_2 are the principal curvatures.

2.3. Elimination of normal mammary glands

The directionality of normal mammary glands trends toward the nipple while that of abnormal glands toward a distorted area. Normal mammary glands were eliminated before calculating the concentration index in order to determine suspect areas (see Fig. 1c).

Firstly, the nipple was determined by curve analysis based on angle estimation of the breast border [6]. Secondly, the breast region was divided into radial areas centered on the nipple. Finally, normal mammary glands were eliminated when the directionality of each area corresponded to the expected trend.

3. Results

Our image database of architectural distortion consists of 117 cases (Database A). Within Database A are forty-four cases that show concentrations of mammary glands, designated Database B. To our knowledge, ours is the largest database of mammographic architectural distortions in the world. An experienced radiologist verified the diagnostic sketches and commented in details of all cases used in our studies.

Table 1 shows the results of our detection method using Database B. The first-stage detection rates of the previous and new methods were the same. However, the number of correct detections of ROIs (regions of interest) at the first stage was increased. Table 2 shows the results using the Database A. The detection rate and the number of correct detections of ROIs at the first stage were also increased in this larger sample. The number of false positives per image of the new method was smaller than one of the previous method at the same detection rate. The number of correct detections of ROIs at the first stage was improved by applying both the extraction method of mammary gland and elimination of normal mammary gland more than they were individually employed. Thus, the new methods displayed a high sensitivity. The architectural distortions that were detected only by the new method were located around breast border. It became possible to detect them because the mammary glands around breast border were sufficiently extracted. In addition, the center of the candidate area became more clearly detectable. Nevertheless, many true positives were eliminated, and the number of false positive was increased in the final results. It was thought that the features of the false

Table 1
The results of our detection method by using the database B

	At the first stage			Final results	
	Detection rate per image [%]	No. of correct detections of ROIs	FPs/Image	TP[%]	FPs/Image
Previous Method	84	61	3.0	73	0.9
(1)	82	67	3.2	73	1.1
(2)	82	78	4.5	73	1.2
(1)+(2)	84	83	3.9	68	1.5

Table 2
The results of our detection method by using the database A

	At the first stage			Final sensitivity	
	Detection rate per image [%]	No. of correct detections of ROIs	FPs/Image	TP[%]	FPs/Image
Previous method	65	114	3.3	48	1.2
(1)	72	131	3.0	56	1.1
(2)	68	142	4.2	55	1.3
(1)+(2) #1	65	113	2.8	48	1.0
(1)+(2) #2	72	161	3.8	56	1.5

TP : true positive
FP: false positive
(1) Extraction of mammary gland by shape index and curvedness.
(2) Elimination of normal mammary gland.

positives changed because of the improvement of detection method. It is necessary to improve the method of eliminating false positives.

4. Summary

We suggested the improvement of our previous method for detecting architectural distortion on mammograms. The method of extracting the mammary gland was changed to employ both a shape index and curvedness so as not to be influenced by background density from the breast thickness. In addition, our method was able to eliminate normal mammary glands by trends in directionality. The results showed that our improvement may be effective, since the sensitivity was improved.

In the future, it will be necessary to add new algorithms for the detection of other sorts of distorted areas and to decrease the number of false positives.

Acknowledgements

This work was supported in part by the Ministry of Health, Labour and Welfare under a Grant-In-Aid for Cancer Research and in part by the Ministry of Education, Culture, Sports, Science and Technology under a Grant-In-Aid for Scientific Research, Japanese Government.

References

[1] F.J. Ayres, R.M. Rangayyan, Detection of architectural distortion in mammograms using phase portraits, Medical Imaging 2004: Image Processing, Proc. of SPIE, vol. 5370, 2004, pp. 587–597.
[2] G.D. Tourassi, G.E. Floyd Jr., Performance evaluation of information-theoretic CAD scheme for the detection of mammographic architectural distortion, Medical Imaging 2004: Image Processing, Proc. of SPIE, vol. 5370, 2004, pp. 59–65.
[3] J.A. Baker, et al., Computer-aided detection (CAD) in screening mammography: sensitivity of commercial CAD systems for detecting architectural distortion, AJR 181 (4) (2003) 1083–1088.
[4] T. Matsubara, et al., Novel method for detecting mammographic architectural distortion based on concentration of mammary gland, Proc. of CARS, vol. 1268, Elsevier, 2004, pp. 867–871.
[5] Y. Kawata, N. Niki, Feature extraction algorithms based on 3-D curvatures, Med. Imaging Technol. 19 (3) (2001) 142–153 (in Japanese).
[6] L.U. Miao, et al., Automated detection method for nipple region on digital mammograms, Med. Imag. Inform. Sci. 19 (3) (2002) 141–144 (in Japanese).