The Role of Computerized-Aid Diagnosis in Mass Classification Using Ultrasound

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Abstract- Computerized analysis of sonograms is to increase the accuracy of mass classification. This paper presents a novel enhancement algorithm of breast ultrasound images based on fuzzy logic, fuzzy entropy principle. and textural information. We fuzzified the original breast images, extracted the edge and textural information, and enhanced the images, then assessed and evaluate the diagnostic results of ultrasologists using original and enhanced images by the areas (Az) under ROC curves. The diagnostic accuracy and specificity were evaluated by the induces of sensitivity and specificity. We analyzed 49 cases of 86 ultrasound images including 14 benign lesions and 35 malignant lesions. After the images were enhanced, the results demonstrated that it had improved the rate of discrimination of breast masses. The result suggests that if false-positive rate is 35.7%, the sensitivity had largely raised from 88.6% to 94.3%. The area (Az) under ROC curve of qualitative diagnosis also had increased from 0.87 to 0.90. The algorithm can raise the classification accuracy and decrease the rate of missing and misdiagnosis. It has demonstrate the value in clinical practice.

Keywords: Breast lesions, Breast ultrasound image, Enhancement, Fuzzy logic.

1. INTRODUCTION

Recently, the morbidity of breast cancer has increased year by year, which is the main cause of the death for women. To find, diagnose and treat masses in the early stage are the essential step to prevent and cure and control breast cancer, which can prolong patients' life and increase clinical curative rate. Sonography is a principal method to diagnose breast cancer, especially after the invention of high frequency ultrasound devices. It has incomparable superiorities since it can distinguish the characteristics of masses and discover the tumors with no side effects. Bassett et al.[1] manifested that sonography showed the same effectiveness as mammography for women younger than 35. Kolb et al. [2] reported that ultrasound can depict small, early-stage malignancies of dense breasts, indicating.

Sonography can examine dense tissue of breasts. In addition, sonographic equipment is portable and relatively cheap, and does not involve ionizing radiation. However, sonographic images are not distinct because it has a series of artifacts. Moreover, when the range of scale was narrow, the edge of breasts' texture and masses were obscure, and contrast was low, masses usually cannot be discovered. Furthermore, there is a limitation in detecting microcalcifications [3,4]. Therefore, many researchers devote themselves to improve images' quality. At present, computerized analysis of sonograms for the detection of breast cancer is one of the major goals of a multi-center American College of Radiology Imaging Network[5,6].

We would solve the above problems by proposing a novel enhcement algorithm and use clinical experiments to demonstrate its effectiveness.

2. MATERIAL AND METHODS

2.1. Images acquirement

The cases were acquired from the patients in the period from 2003 to 2004 of the second affiliated hospital of Harbin medical university. All patients were examined by the high frequency ultrasound and confirmed by surgery and pathological examinations or biopsy. At present, 86 patients with 137 images had been collected. The ultrasonic imaging system is Vivid 7 color Doppler equipment (GE, USA) with 5-14MHz high frequency line transducer. The images were stored in hard disk through the ultrasonic equipment. For every patient, 1-10 images (2-5 images on average) were obtained The occipitofrontal diameter of most masses is 3-4 cm, and transverse diameter is 5-6 cm. The maximum depth of the masses is 2.0 cm, and the

minimum depth is 7.0 cm. The average number of pixels of the images is 720×576. From the database, we selected 49 cases with 86 images including 14 benign lesions and 35 malignant lesions.

2.2. Enhancement algorithm based on fuzzy logic

We deal with the original images of 49 cases in the database. We propose a novel contrast enhancement algorithm based on fuzzy logic. First, the maximum fuzzy entropy principle was used to map an original image from the spatial domain to the fuzzy domain by a membership function, then edge information and textural information are extraction in order to evaluate the lesions' feature, and local information is used to define the enhancement criterion and contrast ratio. Finally, we enhanced the images by modifying the contrast ratio using local fuzzy information[7].

2.3. Assess the breast lesion using original and enhanced images

We marked the interested regions of 86 original images manually, then process them using the proposed enhancement algorithm. Then, the original images and enhanced images were randomly displayed to an experience ultrasologist who didn't know initially, and were diagnosed according to the following criteria [8]. (1) The shape is irregular, with spiculated and angular margins, (2)The membrane isn't integrated or disappears, (3)The mass is hyperechoic or anechoic, and its internal echo isn't well-distributed, (4)Presence of microcalcifications in the mass, (5)The posterior wall of the mass is indistinct, weak, even disappearing, (6)Posterior acoustic attenuation, (7)Lateral hyperechoic bands of mass are wider than anterior one, (8)The margin of the mass growing aggressively is unclear, (9)There are more blood flow signals, especially, arteries are growing penetrately. The cases that conform to 4-5 criteria above are diagnosed as malignant; those that conform to 2-3 criteria are diagnosed as probably malignant; those that conform to 1-2 criteria are considered as possibly benign/ malignant, otherwise, it is considered as benign or probably benign. According to these ultrasound characteristics, the lesion was located, and the margin feature was analyzed, and the ultrasound characteristics of lesions were extracted. Then benign or malignant was determined. Finally, the results were divided into 5 categories: (1) definitely or almost definitely benign, (2)probably benign, (3)possibly benign/ malignant, (4)probably malignant, (5)definitely or almost definitely malignant.

2.4. Statistical methods

The diagnostic results of ultrasologist on the original breast images and enhanced breast images were analyzed and assessed by ROC curve with SPSS 11.5 software. Then the results before and after enhancement were tested by Chi-square test in 2×2 table. The accuracy and specificity of the diagnosis were evaluated in two aspects of sensitivity□Se□ and specificity(Sp). The accuracy of the two methods was explained by the area "Az" under the ROC curve. $Az = \int_0^1 Se \cdot d(1-sp)$ □ $0 \le A_z \le 1$ □ □when Az >0.5, the more Az was close to 1□the better the diagnosis was. When Az =0.5, it acted no effect. When Az <0.5, it didn't accord with the reality.

3. RESULTS

3.1. Ultrasound images before and after enhancement

It shown that the grand of breast and tissue got mixed up in the original image, but they were well distinguished after it was enhanced, and the lesions became more prominent (figure 1-a, b). By the dispose of enhancement algorithm, not only the edge of lesions was shown distinctly, but also the small calcium in the lesions became more distinct (figure 1-c, d).

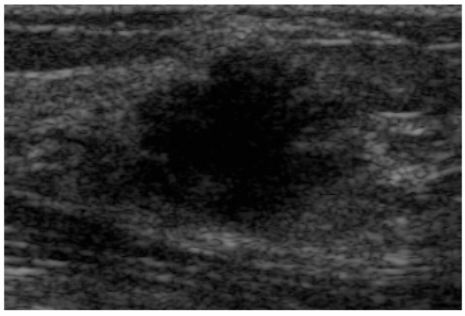

Figure 1 -a The original image

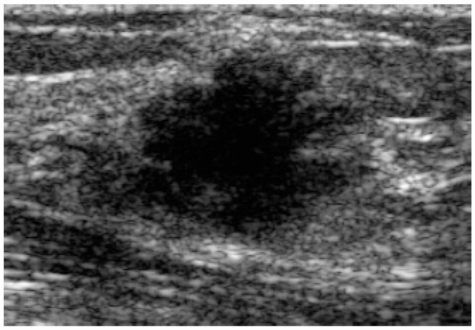

Figure 1-b The enhanced image

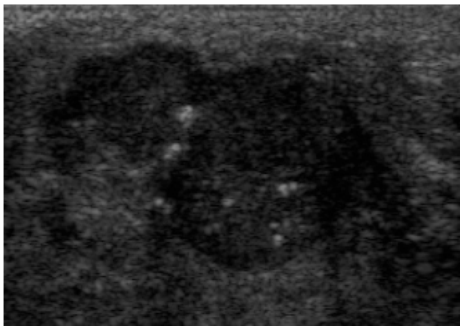

Figure 1 -c The microcalcifications of lesions in the original image

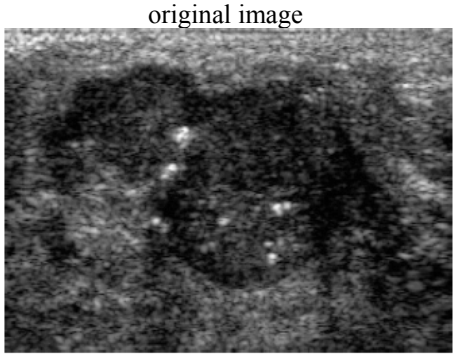

Figure 1 -d The microcalcifications of lesions in the enhanced image

3.2.Diagnostic results by ultrasologist

The diagnostic results by ultrasologist using the original images and enhanced images and the pathological results were shown in Tables 1 and 2, respectively.

Table 1 The diagnostic results using the original breast ultrasound images

Ultrasound / Pathology	(1)	(2)	(3)	(4)	(5)	total
benign	7	2	3	1	1	14
malignant	2	2	3	6	22	35

Table 2 The diagnosis results using the enhanced breast ultrasound images

Ultrasound / Pathology	(1)	(2)	(3)	(4)	(5)	total
benign	9	1	1	1	1	14
malignant	2	2	3	6	26	35

Notice: (1)benign, (2)probably benign, (3)possibly benign/malignant, (4)probably malignant, (5) malignant

The two tables show that the breast lesions which can be diagnosed definitely increased from 29 cases of the original images (malignant 22 cases and benign 7 cases in Table 1) to 35 cases of the enhanced images (malignant 26 cases and benign 9 cases in Table 2). The results of definite diagnosis were significantly better than those before enhancement.

3.3. Sensitivity and specificity of diagnosis on the original and enhanced images

At different cutoff value, the sensitivity and specificity of ultrasologists' diagnosis on the original and enhanced breast images indicate: when the false-positive rate is 14.3%, the sensitivity of the enhanced images is improved from 80.6% to 82.9%, and when the false-positive rate is 35.7%, the sensitivity of the enhanced images is improved significantly from 88.6% to 94.3%.

3.4. The ROC curve analysis of images

The ROC curve[9,10,11] of ultrasologists' diagnosis on the original and enhanced images of breast lesions was showed in Figure 2:

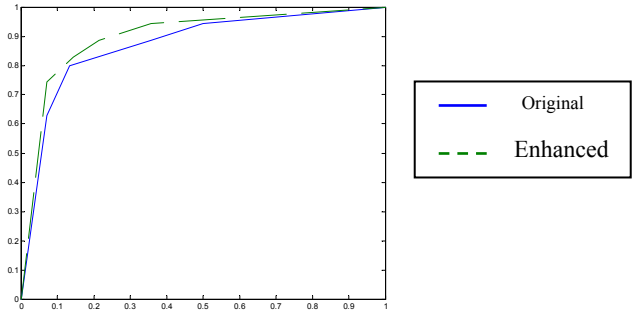

Figure 2 ROC curve of the original and enhanced breast ultrasound images

From the curve we can conclude that the ROC curve of ultrasologists' diagnosis on the enhanced images was more convex than that on the original images. This implies that it has a higher diagnostic value. Through the ROC curve, we calculated the range of A by different methods: the original images A1=0.87, its 95% credible interval was [0.756, 0.985]. While the enhanced images A2=0.90, its 95% credible interval was [0.795, 1.003]. From this we can also conclude that the enhanced images can improved the accuracy of the qualitative diagnosis on the breast lesions. Using Chi-square test to compare if there was difference between the qualitative diagnosis on the original images and the enhanced images. Through the algorithm, we got that the value of χ^2 was 4.167, and the value of P was between 0.05 and 0.025 (r=1).

4. DISCUSSIONS

By the analysis of the proposed image enhancement algorithm based on fuzzy logic, we found this method had a better effect on handling breast ultrasound images: in the enhanced images the margin is more clear; the internal echo can be displayed better; the noise spots can be restrained; and the signals such as microcalcifications, internal echo characters and the margin, including the burying and membrane's appearance. In the original images that can hardly be perceived by naked eyes can be displayed more clearly to the ultrasologist, So the enhancement algorithm can be applied as a reliable proof for the qualitative diagnosis of the breast lesions, improve the diagnostic rate of breast lesions and reduce the misdiagnostic rate in some extent. The method has an obvious significance in the statistical analysis ($0.05>P>0.025$).

At the same time, this article tested the validity of the original and enhanced images of breast lesions using ROC curve, the gained area under ROC curve, in original image A_1=0.87, 95% credible interval [0.756, 0.985], in enhanced image A_2=0.90, 95% credible interval [0.795, 1.003]. We can find that the enhanced images can increase diagnostic rate of breast mass more obviously, and when false positive rate is 35.7%, sensitivity of enhanced images increased more evidently from 88.6 to 94.3. In this group of data, false positive cases were relatively higher, due to the reasons: maybe that the number of the cases was too few, the loss of images' information caused by the limitations of ultrasonic instrument and subjective erroneous diagnosis of ultrasonic experts.

The study has indicated that our algorithm has two advantages: (1) the enhanced algorithm made the details of original configuration clearer, (2) there was no over- enhanced area. These advantages mostly owe to the two features below: (1) it had fuzzified images using a S function based on the maximal information entropy; (2) it depicted the informations of boundary by its grain feature and brought forward a novel dissymmetrical π function, and applied it to fuzzy function of grain feature.

The enhancement technique can remarkably increase diagnostic rate, further study is to decrease false-positive rate through enhanced image in the meantime further increase diagnostic rate of breast masses' quality, increase diagnostic rate of small breast masses' quality and make more effective classification, decrease the subjective error caused by factitious factors, and realize the-detection, identification and classification automatically.

5. References

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