Analysis of Margin Sharpness for Breast Nodule Classification on Ultrasound Images

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***Abstract*— Breast cancer has the highest prevalence, incidence and mortality for females in worldwide and no exception in Indonesia. Ultrasound is a recommended modality for diagnosing breast cancer through ultrasound images. However, misdiagnosis might still occurs which is caused by human factors. Margin of breast nodule is one of the malignancy characteristics based on BIRADS. This research proposes a computer aided diagnosis (CADx)-based method for classifying breast nodules in ultrasound images based on margin characteristics. In practice, CADx is used as a second opinion in interpreting ultrasound images in order to obtain more accurate diagnosis results. The proposed approach consists of adaptive median filter for marker removal, pre-processing with normalisation and speckle reduction anisotropic diffusion (SRAD) filter followed by neutrosophic and watershed methods for segmentation process, features extraction and feature selection. A total of ten selected features including of texture, geometry and margin sharpness features are then classified by using multi-layer perceptron (MLP). This study uses 102 breast ultrasound nodule images with 57 non-circumscribed and 45 circumscribed margins. The performance of proposed approach achieves the accuracy of 95.10%, sensitivity of 93.33%, specificity of 96.49%, PPV of 95.45%, NPV of 94.83%, Kappa of 0.9004 and area under curve (AUC) of 0.989. These promising results indicate that the proposed approach successfully classifies breast nodule based on margin characteristics has a potential for assisting the radiologists in interpreting breast ultrasound images.**

Keywords—ultrasound; margin sharpness; breast nodule; neutrosophic; watershed

I. INTRODUCTION

According to IARC GLOBOCAN report in 2012, the highest rate of prevalence, new cases and mortality in women worldwide was coming from breast cancer which was estimated around 36.32% of prevalence, 25.10% of new cases and 14.71% of mortality rates [1]. Breast cancer occurs in 140 of 184 countries in the world [2]. The largest population is found in the Asian continent with the prevalence of 37% [1]. Ultrasound modality has been commonly used for detecting breast cancer since it has a high sensitivity and specificity, more comfortable and radiation-free [3]. However, interpretation of ultrasound images conducted by the radiologists still has false diagnosis probability [4].

Breast nodule is an abnormal area of breast tissue that gradually changes into a mass or a lump. Malignancy of breast nodule in ultrasound images is interpreted by the radiologists based on Breast Imaging, Reporting and Data System (BIRADS) characteristics [5]. There are five characteristics consisting of shape, margin, echogenicity, orientation and posterior acoustic features [6].

Computer aided diagnosis (CADx) is a computerised system developed by learning from knowledge of radiologists in interpreting and analysing ultrasound images in order to increase the accuracy of diagnosis. For diagnosis of breast cancer, CADx has been widely developed based on the echogenicity and shape characteristics. However, related research works about breast ultrasound classification based on margin characteristics are still rarely found.

Some research works about margin nodule were conducted on circumscribed margin with manual segmentation and feature extraction. The experimental result which was conducted by Rahbar *et al.* [7] showed that 91% of breast nodules with circumscribed margin classified as benign nodules. Sehgal *et al.* [8] classified breast nodule into malignant or benign classes by measuring the differences area of nodules margin. The segmentation and determination of posterior shadow features were manually performed by the radiologists. The areas of nodule margin were divided based on radial sector which consists of inner and outer margins. Then, some features such as margin sharpness, margin echogenicity, angular variation in margin (AVM) and age of patients were extracted followed by classification process.

Similar study was conducted by Rangayyan *et al.* [9] which identified relevant features to obtain more accurate result in classifying benign or malignant nodules on mammographic image. These relevant features were acutance, compactness, Fourier descriptor and moment features. However, segmentation process was manually done. Sellami *et al.* [10] extracted morphological and textural features from breast nodule ultrasound images. Then, analysis of margin characteristics was accomplished by measuring the differences in intensity.

To complete the aforementioned studies, this paper proposes an approach to classify breast ultrasound nodules based on margin characteristics by segmenting nodule automatically and analysing some extracted features. The rest of this paper is organised as follows. Explanation of the proposed approach is provided in Section II. Section III discusses about the experimental results followed by conclusion in Section IV.

II. Approach

Schematic representation of the proposed approach is shown in Fig. 1. First, region of interest (RoI) of breast nodules is manually selected by the radiologists. Then normalisation and speckle reduction anisotropic diffusion (SRAD) filter are conducted to the RoI image. It is used for image enhancement and speckle noise reduction [11]. Then neutrosophic set and watershed segmentation [12] are applied to find the margin of breast nodule. Then, margin area is obtained by employing morphological operation. The characteristics of nodule are extracted based on texture and geometry features and also margin sharpness analysis. The last is the classification process for determining class of nodules based on margin characteristic.

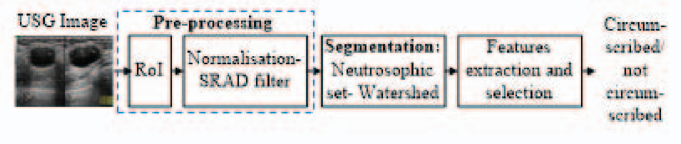


Fig. 1. Block diagram of the proposed approach

A. Morphological Operation

Morphological operation is commonly performed on binary image to change the structure of object form contained in the image. In this research, it is performed to obtain the margin area of breast nodule. The margin area consists of inner edge and outer edge areas. It is obtained by combining dilation and erosion results from the segmented nodule. The purpose of dilation operation is to obtain widening effect on an object. If A and B are members of Z, the dilation between A and B is defined by (1). While erosion operation has the effect for minimising the image structure as formulated in (2) [13].

$$A \oplus B = \{z \mid [(B)_z \cap A] \subseteq A\} \tag{1}$$

$$A \ominus B = \{z \mid (B)z \subseteq A\} \tag{2}$$

B. Texture Analysis

A statistical approach is conducted on the first statistical order based on histogram. Histogram is the simple way for estimating probability density functions (PDF) of an image. In this work, texture features consist of mean, standard deviation, skewness, energy, entropy and smoothness [14, 15].

C. Geometry Analysis

Geometry analysis is constructed by a set of geometrical elements such as points, lines, curves and surfaces. In this research, convexity, solidity and disperse features from binary image of segmentation result are analysed. Convexity is the ratio measurement of convex perimeter and nodule perimeter as defined in (3). Solidity is the ratio between nodule area and convex hull as formulated in (4). Whilst disperse is irregularity of nodule by calculating the ratio between the length of a major chord and nodule area as stated in (5).

$$Convexity = \frac{Convex\ Perimeter}{Nodule\ Perimeter} \tag{3}$$

$$Solidity = \frac{Nodule\ Area}{Convex\ Area} \tag{4}$$

$$Disperse = \frac{Major\ axis\ length}{Nodule\ Area} \tag{5}$$

D. Margin Sharpness Analysis

Sharpness is the average gradient magnitude of the nodule margin. As an illustration, if the intensity of the pixel at position x, y is represented as f (x, y), then the partial derivatives in the x and y directions are respectively expressed in (6) and (7). The magnitude gradient and sharpness feature can be obtained based on (8) and (9).

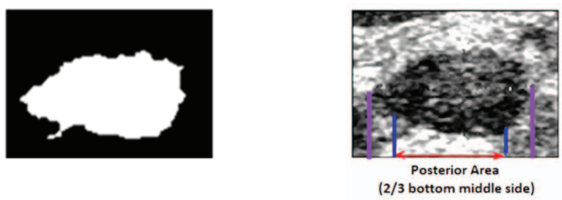
$$G_x = \frac{\delta f(x,y)}{\delta x} = f(x+1,y) - f(x,y) \tag{6}$$

$$G_y = \frac{\delta f(x,y)}{\delta y} = f(x,y+1) - f(x,y) \tag{7}$$

$$G[f(x,y)] = \sqrt{{G_x}^2 + {G_y}^2} \tag{8}$$

$$Sharpness = mean\ (G[f(x,y)]) \tag{9}$$

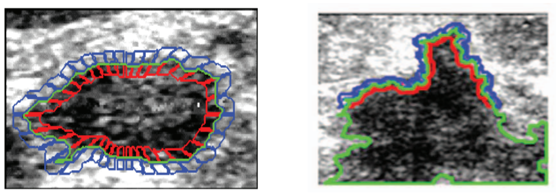
In this research, indicator of posterior shadow is proposed by detecting 2/3 bottom middle side of nodule. While the 1/6 area of the bottom right and bottom left sides of nodule are ignored to avoid of edge shadow (edges leakage) as shown in Fig. 2. If the posterior area is segmented as a nodule more than equal to 50%, then the shadow indicator is 1. And vice versa, if that of less than 50%, then the shadow indicator is 0.



(a) (b)

Fig. 2. Determination of shadow indicator (a) segmentation result (b) determination of the posterior area

Margin sharpness, margin echogenicity and AVM are the features proposed by Sehgal *et al.* [8]. Margin area is divided into *N* radial sectors through the centroid of nodules. On each sector, the average of pixel intensity is calculated for inner edge and outer edge areas. For nodules that have shadow indicator of 1, only top of nodule is divided into sectors as shown in Fig. 3. A significant test of the two-tailed Welch's *t*-test is performed for each pair. If the *p*-value is less than 0.001, then the sector is defined as sector with distinct margin. Margin sharpness is obtained by using (10). Here, n is the number of sectors with distinct margin and N is total sector.



(a) (b)

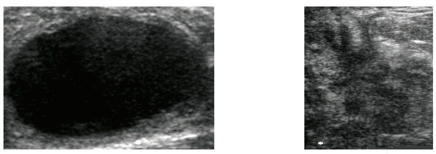
Fig. 3. Radial sectors of margin area (a) nodule with shadow indicator of 0 (b) nodule with shadow indicator of 1

$$Margin\ sharpness = \frac{n}{N}\ x\ 100\% \tag{10}$$

The margin echogenicity (M-Echo) is defined as the brightness difference at the nodule margin. This feature is determined by measuring the mean grey level difference (MGL diff) of inner edge and outer edge areas on sectors with distinct margin. AVM represents inhomogeneity between margin brightness and angle. It is determined by calculating the ratio between standard deviation and mean of MGL difference on the inner edge and the outer edge areas in each sector. S3 feature is sharpness which is generated from combination of sharpness in spectral (S1) and sharpness in spatial (S2) domains [16].

III. Results and Discussion

This study uses breast ultrasound nodule images which are taken from three hospital databases with 57 circumscribed and 45 non-circumscribed margins. Two samples of these margin characteristics is shown in Fig. 4.

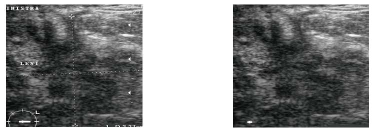


(a) (b)

Fig. 4. Characteristics of nodule margin (a) circumscribed (b) non-circumscribed

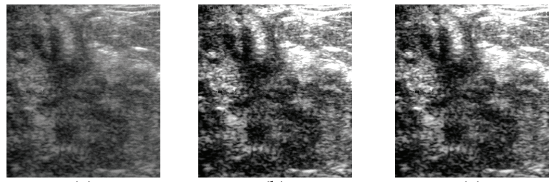
A. Pre-processing

The RoI of breast nodule is determined based on the area marked by the radiologists. Some of ultrasound images have labels and markers, so it is important to get rid of them. Adaptive median filtering is effective to solve this problem without any blur produced. The results of these processes are shown in Fig. 5. In order to enhance contrast and reduce speckle noises without damaging the edge of the object, normalisation and SRAD filter are then applied as presented in Fig. 6.



(a) (b)

Fig. 5. (a) Original image (b) Unmark image



(a) (b) (c)

Fig. 6. (a) Original image (b) normalisation image (c) SRAD image

B. Segmentation

Segmentation based on neutrosophic set and watershed is conducted to obtain the margin of breast nodule. Segmented nodule is then validated by comparing it to the ground truth marked by radiologists. As shown in Fig. 7, segmentation result by involving normalisation-SRAD in pre-processing obtains better performance than that of without normalisation with accuracy achieved of 90.88%. It is proven that normalisation can improve the performance of segmentation.

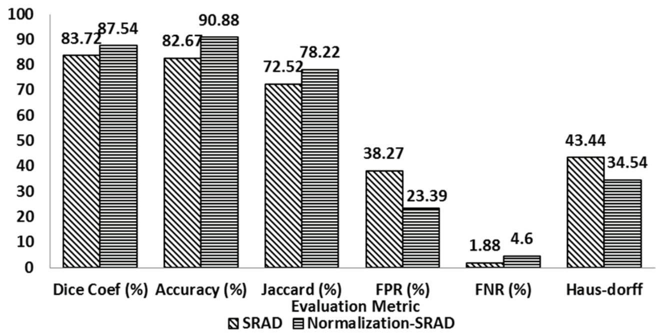


Fig. 7. Performance comparison of segmentation results

C. Feature Extraction

The margin area of nodule is obtained by morphological operation as shown in Fig. 8. The two-tailed Welch's *t*-test of unequal variance is used to determine the statistical significance difference between circumscribed and not circumscribed classes with a significance level of 5%. Table I shows the evaluation result of 15 full features for each class. Based on *t*-test result, there are ten significant features obtained with *p*-value<0.05 on the circumscribed and non-circumscribed classes. Disperse feature has the smallest *p*-value meaning that the average difference of this feature is the most significant. While the convexity has the largest *p*-value showing that this feature has no significant difference. Therefore, ten significant features from 15 extracted features are then selected based on *p*-value with less than 0.05 to improve classification performance.

D. Classification

Multi-layer perceptron (MLP) with 3-fold cross validation is used to classify breast nodule into circumscribed or non-circumscribed margins. Table II shows the comparison of classification performance between extracted full features and selected features. The ten selected features yields better performance than 15 full features with the accuracy of 95.10%, sensitivity of 93.33%, specificity of 96.49%, PPV of 95.45%, NPV of 94.83%, Kappa of 0.9004 and area under curve (AUC) of 0.989.

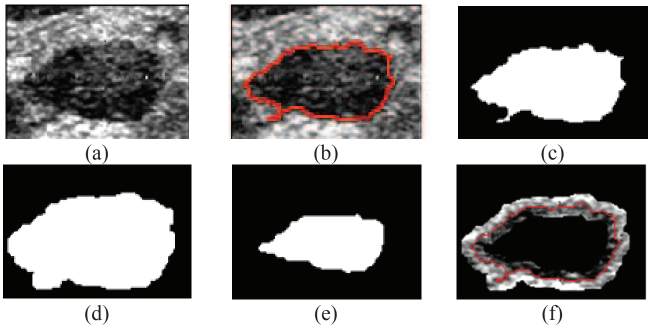


Fig. 8. (a) Pre-processing image (b) Boundary of nodules (c) Binary image of segmentation result (d) Dilation result (e) Erosion result (f) Margin area of breast nodule

TABLE I. THE RESULTS OF FEATURES EVALUATION

No.	Feature	Mean		*p*-value
		Circum scribed	*Non-circumscribed*	
1	Disperse	0.522	0.412	2.90E-14
2	Entropy	4.589	4.334	7.11E-12
3	Skewness	1.454	0.678	3.97E-11
4	Margin sharpness (%)	83.772	61.265	4.52E-09
5	Energy	0.013	0.016	5.17E-09
6	Solidity	0.838	0.761	6.65E-09
7	S3 average 1%	0.930	0.912	1.59E-06
8	Standard deviation	53.857	48.833	6.20E-06
9	Shadow indicator	0.053	0.444	9.34E-06
10	Smoothness	0.043	0.036	1.22E-05
11	Mean	92.554	95.365	5.23E-02
12	Margin echogenicity	60170	52460	1.16E-01
13	AVM	1250	1078	3.23E-01
14	Sharpness	10.037	9.478	3.51E-01
15	Convexity	0.831	0.808	6.19E-01

TABLE II. PERFORMANCE OF CLASSIFICATION

Performance	15 Extracted Features	10 Selected Features
Accuracy (%)	91.18	95.10
Sensitivity (%)	91.11	93.33
Specificity (%)	91.23	96.49
PPV (%)	89.13	95.45
NPV (%)	92.86	94.83
Kappa	0.8215	0.9004
AUC	0.982	0.989

IV. CONCLUSION

An approach to classify breast nodules of ultrasound images based margin sharpness analysis has been proposed. The pre-processing stage consists of RoI determination, normalisation and noise reduction. The margin area of breast nodule is obtained using automatic segmentation based on neutrosophic set-watershed and morphological operations. A total of ten significant features of texture, geometry and margin sharpness are then classified based on MLP. The performance of the proposed method achieves promising results with the accuracy of 95.10%, sensitivity of 93.33%, specificity of 96.49%, PPV of 95.45%, NPV of 94.83%, Kappa of 0.9004 and area under curve (AUC) of 0.989. These results indicate that the proposed approach has a potential to be implemented as a part of a computerised aided breast cancer diagnosis for assisting the radiologists in final decision making.

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REFERENCES

[1] International Agency for Research on Cancer. (2012, 08 March 2017). *Cancer Today*. Available: http://gco.iarc.fr

[2] American Cancer Society, "Global Cancer Facts & Figures," Atlanta, 2015.

[3] H.-D. Cheng, J. Shan, W. Ju, Y. Guo, and L. Zhang, "Automated breast cancer detection and classification using ultrasound images: A survey," *Pattern recognition,* vol. 43, pp. 299-317, 2010.

[4] M. B. Mainiero, A. Lourenco, M. C. Mahoney, M. S. Newell, L. Bailey, L. D. Barke*, et al.*, "ACR appropriateness criteria breast cancer screening," *Journal of the American College of Radiology,* vol. 13, pp. R45-R49, 2016.

[5] L. Levy, M. Suissa, J. Chiche, G. Teman, and B. Martin, "BIRADS ultrasonography," *European journal of radiology,* vol. 61, pp. 202-211, 2007.

[6] American College of Radiology (ACR), "ACR BI-RADS Atlas Fifth Edition," 2015.

[7] G. Rahbar, A. C. Sie, G. C. Hansen, J. S. Prince, M. L. Melany, H. E. Reynolds*, et al.*, "Benign versus malignant solid breast masses: US differentiation," *Radiology,* vol. 213, pp. 889-894, 1999.

[8] C. M. Sehgal, T. W. Cary, S. A. Kangas, S. P. Weinstein, S. M. Schultz, P. H. Arger*, et al.*, "Computer□Based Margin Analysis of Breast Sonography for Differentiating Malignant and Benign Masses," *Journal of ultrasound in medicine,* vol. 23, pp. 1201-1209, 2004.

[9] R. M. Rangayyan, N. M. El-Faramawy, J. L. Desautels, and O. A. Alim, "Measures of acutance and shape for classification of breast tumors," *IEEE Transactions on medical imaging,* vol. 16, pp. 799-810, 1997.

[10] L. Sellami, O. B. Sassi, and A. B. Hamida, "Breast Cancer Ultrasound Images' Sequence Exploration Using BI-RADS Features' Extraction: Towards an Advanced Clinical Aided Tool for Precise Lesion Characterization," *IEEE transactions on nanobioscience,* vol. 14, pp. 740-745, 2015.

[11] Y. Yu and S. T. Acton, "Speckle reducing anisotropic diffusion," *IEEE Transactions on image processing,* vol. 11, pp. 1260-1270, 2002.

[12] M. Zhang, L. Zhang, and H. Cheng, "A neutrosophic approach to image segmentation based on watershed method," *Signal Processing,* vol. 90, pp. 1510-1517, 2010.

[13] W. Gonzalez and R. E. Woods, "Eddins, Digital Image Processing Using MATLAB," *Third New Jersey: Prentice Hall,* 2004.

[14] B. Jahne, *Digital image processing* vol. 4: Springer, 2005.

[15] M. Rahmawaty, H. A. Nugroho, Y. Triyani, I. Ardiyanto, and I. Soesanti, "Classification of breast ultrasound images based on texture

nalysis," in *International Conference on Biomedical Engineering (IBIOMED)*, 2016, pp. 1-6.

[16] C. T. Vu, T. D. Phan, and D. M. Chandler, "S_3: A Spectral and Spatial Measure of Local Perceived Sharpness in Natural Images," *IEEE Transactions on Image Processing,* vol. 21, pp. 934-945, 2012.