The Fourteenth International Symposium on Artificial Life and Robotics 2009 (AROB 14th '09),
B-Con Plaza, Beppu, Oita, Japan, February 5 - 7, 2009

A Study on Effect of Morphological Filters on Computer-aided Medical Image Diagnosis

N. Homma, Cyberscience Center, Tohoku University, Sendai, Japan, 980-8579

S. Shimoyama*, Y. Kawai*, T. Ishibashi*, *Graduate School of Medicine, Tohoku University, *Sendai, Japan, 980-8575

M. Yoshizawa, Cyberscience Center, Tohoku University, Sendai, Japan, 980-8579

Abstract

We develop several morphological image filters that can be useful for computer-aided medical image diagnosis. Some computer-aided diagnosis (CAD) systems for lung cancer and breast cancer have been developed to assist radiologist's diagnosis work. The CAD systems for lung cancer can automatically detect pathological changes (pulmonary nodules) with a high true positive rate (TP) even under low false positive rate (FP) conditions. On the other hand, the conventional CAD systems for breast cancer can automatically detect some pathological changes (calcifications and masses), but TP for other changes such as architectural distortion is still very low.

Motivated by the radiologist's cognitive process to increase TP for breast cancer, we propose new methods to extract novel morphological features from X-ray mammography. Simulation results demonstrate the effectiveness of the morphological methods for detecting tumor shadows.

1 Introduction

There may be a great potential demand for using computer-aided diagnosis (CAD) systems in clinics. Lung cancer diagnosis is an example. With the increasing mortality rate for lung cancer, X-ray computed tomography (CT) has been used for detection of lung cancer at early stages [1]. The early stage detection of lung cancer is extremely important for survival rate and this is true for any pathological cells of lung cancer. Using the X-ray CT, pulmonary nodules that are typical shadows of pathological changes of lung cancer can be detected more clearly compared to the chest X-ray examination even if they are at early stages. This is an advantage of the X-ray CT diagnosis. In fact, it has been reported that the survival rate of the later ten years can reach 90% after the detection at early stages using X-ray CT images [2].

On the other hand, using the X-ray CT may exhaust radiologists because the CT generates a large number of images (at least over 30 images per patient) and they must diagnose all of them. The radiologists' exhaustion and physical tiredness might cause a wrong diagnosis especially for a group medical examination where most of CT images are healthy and only very few images involve the pathological changes.

Therefore, some CAD systems for nodule diagnosis have been developed to help their diagnosis work [3, 4]. These CAD systems can automatically detect pulmonary nodules with a high true positive rate (TP), but the false positive rate (FP) is also high. To reduce the FP, several advanced methods such as neural network approaches have been proposed [5, 6]. However, there are still some fundamental problems such as a low discrimination rate for variations of size and positional shift of nodule images. This is because they are still so-called low level or simple image recognition methods with pixel based features compared to the radiologist's complex diagnosis process. For this high FP problem in lung cancer diagnosis, we have demonstrated that a new morphological feature extraction method by using gabor filters can be useful to further reduce [7]. This promising results may imply the effectiveness of morphological filter approaches on the lung cancer CAD systems.

Another example is X-ray mammography screening [8]. The disease rate of the breast cancer is the worst among cancers for women and early detection is also very important for the breast cancer [9]. Although the number of images per patient is less than the X-ray CT screening, diagnosis of the breast cancer using X-ray mammography is more difficult than that of lung nodules and thus it makes more tiredness to diagnose.

For some pathological changes such as calcifications and masses, CAD systems have been developed and they can automatically detect such changes with a high TP [10]. However, TP for other changes of the breast cancer, such as an architectural distortion, is still very low even under a high FP condition [11]. This fact implies the difficulty of the mammography diagnosis.

In this paper, we propose new methods to extract novel morphological features from X-ray mammography images to increase TP for breast cancer diagnosis. The extraction of new features are motivated by the radiologist's higher level cognitive process in which several features are combined and integrated to conduct precise diagnosis. Simulation results demonstrate the effectiveness of the new morphological features for enhancing detection rate of architectural distortions of breast cancer.

2 Methods

We consider two principal morphological features of architectural distortions shadow although there are a variety of other minor features involved in the pathological changes of architectural distortions [12]. One of the principal features is a radiate spiculation from a point on the shadow. The other is a local distortion of mammary gland.

To detect candidate shadows with such features, shapes of mammary gland can be an important piece of information. Thus, we first extract the shapes of mammary gland from the original mammography images by using a morphological filter that can detect lines structure [11]. The morphological filter conducts the morphological opening by using multiple linear structuring elements and an square element. Line structure of mammary gland can be extracted by subtracting images between the two opening images. The spiculation feature is approximated by a set of the extracted line segments. Takeo et al. [11] have proposed the following feature of spiculations existence, f, given as

$$f = f_c \times H \tag{1}$$

Here f_c is a concentration feature of line segments on a target point given by

$$f_c = \sum_{i=1}^{n} \cos\theta_i \tag{2}$$

where n denotes the number of line segments and θ_i is the angle between the ith line segment and the straight line containing both the target point and the center point of the ith line segment. On the other hand, H is a distribution entropy of angles θ_i of line segments defined by

$$H = -\sum_{j=1}^{S} P_j \log P_j \tag{3}$$

where $S = 8$ is the number of discrete angles considered in this paper and P_j is the possibility function of the jth angle.

Since the spiculations of architectural distortions consist of radiate line segments with uniformly distributed angles to the target point, both f_c and H may be large. Thus, f becomes large for such local spiculated architectural distortions.

2.1 Modified method 1

The feature of existence f becomes small for spiculations near to the edge of mamma. This is because such spiculations near to the edge consist of line segments with angles not uniformly distributed and thus it makes H be very small.

To overcome this drawback, we modify the definition of the feature of existence, f_m, as follows.

$$f_m = f_c + wH \tag{4}$$

where w is a weighting coefficient. The modification is nothing but to change the product of f_c and H into the weighted sum of two. However, it can be expected that we can detect spiculations near to the edge of mamma by choosing the w appropriately due to the adjustment of the effect of small values of H on f.

2.2 Modified method 2

The difficulty of diagnosis of architectural distortions may also be caused by a wide variety of the distortion shadows in size, shape, and distribution of spiculations. Indeed, there are many spiculations not limited to such shapes concentrating on a target point, but on a target line segments or small regions. The conventional feature f in Eq. (1) becomes small for such cases as well. This is another drawback of the previous method.

To improve the detection capability for such cases, we propose another modification of the feature of existence. The basic idea of a new modification is to use a global structural feature observed commonly in a wide range of spiculations. That is, the general and global structure of mammary gland can be radially symmetric or a tree structure from the nipple. Thus, if the gland directions are inconsistent with the global structure, such gland can be a candidate of architectural distortions.

To formalize this feature, we calculate a global concentration feature, f_g, on the nipple as follows.

$$f_g = -\frac{1}{n}\sum_{k=1}^{n} \cos\theta_k \tag{5}$$

where n is the number of line segments in a local region and θ_k implies the angle θ_i in Eq. (2) with the target point of the nipple. Note that if the gland directions are more consistent with the global structure, the feature is negative with the relatively larger absolute value, i.e., the smaller number. On the other hand, the feature is the relatively larger with smaller absolute value for the inconsistent case. Thus, large values of f_g may imply a candidate point of such strange distortion cases.

The Fourteenth International Symposium on Artificial Life and Robotics 2009 (AROB 14th '09),
B-Con Plaza, Beppu, Oita, Japan, February 5 - 7, 2009

3 Results

3.1 Improvement by the method 1

Fig. 1 shows an example of mammography that involves spiculations near to the edge of mamma for evaluating the proposed method 1. Fig. 2 shows detected candidate regions by using the conventional method (f) and the proposed method 1 (f_m). The weight coefficient w was adjusted to $\frac{5}{3}$ by a trial and error.

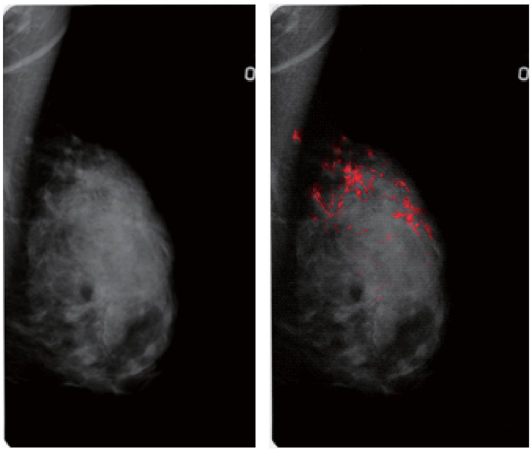

Figure 1: An example of mammography. The original image (left) and diagnosis results by a radiologist (right). The answer sketch is superimposed in red on the original.

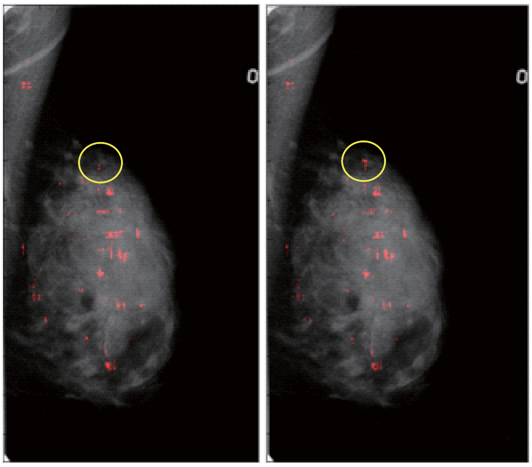

Figure 2: Detected candidate regions by the conventional method (left) and the proposed method 1 (right). Note that TP for spiculations near to the edge of mamma (yellow circle) is improved as expected.

Comparing the results, it can be said that TP for spiculations near to the edge of mamma (yellow circle) is improved by the proposed method 1. Note that this improvement can be achieved without increasing FP. Thus, these results are promising.

3.2 Improvement by the method 2

Another example of mammography that involves a spiculated distortion concentrating on a linear mammary gland is shown in Fig. 3 for evaluating the proposed method 2.

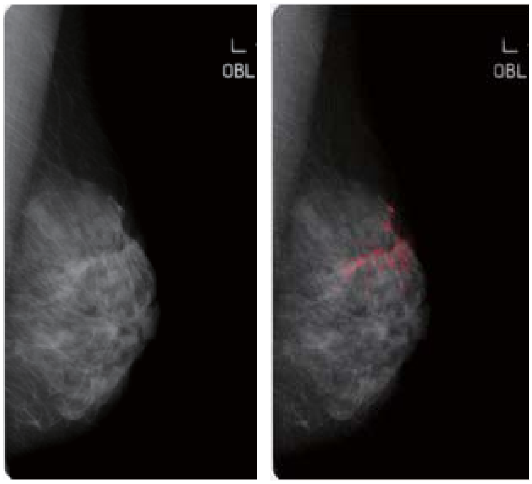

Figure 3: Another example of mammography. The original image (left) and diagnosis results (answer in red) by a radiologist (right).

Figure 4: Detected candidate regions by the conventional method (left) and the proposed method 2 (right). Note that TP for spiculated distortions concentrating on a linear mammary gland (yellow circle) is improved as expected.

Fig. 4 shows detected candidate regions by using the conventional method (f) and the proposed method 2 (f_g).

As new candidate regions have been detected for spiculated distortions concentrating on a linear mammary gland (yellow circle), TP for such distortions can be improved by the proposed method 2. On the other hand, FP increased for other candidates compared to the conventional method. The reduction of FP can be achieved by the other feature incorporated into the proposed one as a future work that is now in progress.

4 Conclusions

In this paper, we have developed new methods for improving detection capability of architectural distortions in mammography. The results suggest the effectiveness of the proposed methods on the architectural distortions detection. Further reduction of FP and improvement of TP for the other types of distortions are future works.

Acknowledgements

This work was partially supported by The Ministry of Education, Culture, Sports, Science and Technology under Grant-in-Aid for Scientific Research #19500413 and Okawa Foundation.

References

[1] T. Iinuma, Y. Tateno, T. Matsumoto et al., "Preliminary specification of X-ray CT for lung cancer screening (LSCT) and its evaluation on risk-cost-effectiveness," *Nippon Acta Radiologica*, Vol. 52, pp.182-190, 1992 (in Japanese).

[2] International Early Lung Cancer Action Program (I-ELCAP): Survival of Patients with Stage I Lung Cancer Detected on CT Screening, *New England J. Medicine*, Vol. 355, No. 17, pp. 1763-1771, 2006.

[3] T. Okumura, T. Miwa, J. Kako, S. Yamamoto, M. Matsumoto, Y. Tateno, T. Iinuma and T. Matsumoto, "Variable-N-Quoit filter applied for automatic detection of lung cancer by X-ray CT," *Proc. of Computer-Assisted Radiology*, pp.242-247, 1998 (in Japanese).

[4] Y. Lee, T. Hara, H. Fujita, S. Itoh and T. Ishigaki, "Nodule detection on chest helical CT scans by using a genetic algorithm," *Proc. of IASTED International Conference on Intelligent Information Systems*, pp.67-70, 1997.

[5] K. Suzuki, S. G. Armato, F. Le, S. Sone and K. Doi, "Massive training artificial neural network (MTANN) for reduction of false-positives in computerized detection of lung nodules in lowdose computed tomography," *Med. Phys*, Vol. 30, No. 7, pp.1602-1617, 2003.

[6] Y. Nakamura, G. Fukano, H. Takizawa, S. Mizuno, S. Yamamoto, T. Matsumoto, S. Sone. F. Takayama. M. Koyama, S. Wada, "Recognition of X-ray CT image using subspace method considering translation and rotation of pulmonary nodules," *TECHNICAL REPORT OF IEICE*, Vol. 104, No. 580, MI2004-102, pp.119-124, 2005 (in Japanese).

[7] N. Homma, K. Saito, T. Ishibashi, M. M. Gupta, Z.-G. Hou, and A. M. G. Solo: "Shape Features Extraction from Pulmonary Nodules in X-ray CT Images," *Proc. of World Congress on Computational Intelligence*, pp. 3396-3400, June, 2008.

[8] T. Endo: "Trend of Breast Cancer Medical Examination by using Mammography," *Health Culture*, October 2000 (in Japanese).

[9] A. Ito: "Mammography," in *Master Text Book for Radiological Technologists, first volume*, ed. I. Yanagama et al.,2008 (in Japanese).

[10] K. Fujita, T. Hara, Y. Matsubara, D. Fukuoka: "Computer-aided Diagnosis (CAD) in the Field of Breast-cancer Image Diagnosis," *J. Medical Imaging and Informatics*, Vol. 23, No. 2, pp. 19-26, 2006 (in Japanese).

[11] Hideya TAKEO, Kazuo SHIMURA, Takashi IMAMURA, Akinobu SHIMIZU, Hidefumi KOBATAKE: "Development of System for Detecting Abnormal Shadows in CR Mammograms and Its Performance Evaluation," *Medical Imaging Technology*, Vol. 22, No. 4, pp. 201-214, 2004 (in Japanese).

[12] *Mammography Guideline, second edition*, ed. Japan Radiological Society and Japanese Society of Radiological Technology, Gawks-Shorn, 2007 (in Japanese).