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A new method of detecting micro-calcification clusters in mammograms using contourlet transform and non-linking simplified PCNN

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ABSTRACT

Background and objectives: Mammography analysis is an effective technology for early detection of breast cancer. Micro-calcification clusters (MCs) are a vital indicator of breast cancer, so detection of MCs plays an important role in computer aided detection (CAD) system, this paper proposes a new hybrid method to improve MCs detection rate in mammograms.
Methods: The proposed method comprises three main steps: firstly, remove label and pectoral muscle adopting the largest connected region marking and region growing method, and enhance MCs using the combination of double top-hat transform and grayscale-adjustment function; secondly, remove noise and other interference information, and retain the significant information by modifying the contourlet coefficients using nonlinear function; thirdly, we use the non-linking simplified pulse-coupled neural network to detect MCs.
Results: In our work, we choose 118 mammograms including 38 mammograms with micro-calcification clusters and 80 mammograms without micro-calcification to demonstrate our algorithm separately from two open and common database including the MIAS and JSMIT; and we achieve the higher specificity of 94.7%, sensitivity of 96.3%, AUC of 97.0%, accuracy of 95.8%, MCC of 90.4%, MCC-PS of 61.3% and CEI of 53.5%, these promising results clearly demonstrate that the proposed approach outperforms the current state-of-the-art algorithms. In addition, this method is verified on the 20 mammograms from the People's Hospital of Gansu Province, the detection results reveal that our method can accurately detect the calcifications in clinical application.
Conclusions: This proposed method is simple and fast, furthermore it can achieve high detection rate, it could be considered used in CAD systems to assist the physicians for breast cancer diagnosis in the future.

1. Introduction

Breast cancer is a public health problem, which has both high incidence and mortality, especially among women. According to the International Agency for Research on Cancer (IARC) 2012, there were estimated nearly 1.7 million people diagnosed with breast cancer on a global scale, which was close to 11.9% of all cancers, and about 0.52 million women died of the disease in the same year. The data from IARC 2012 also reveal

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that new cancer cases will increase to nearly 19.3 million by 2025, and it is worth noting that breast cancer is the fastest growing of all diseases [1].

In order to improve the diagnosis and prognosis of breast cancer, early detection is becoming more and more important [2]. The ways of breast cancer detection and diagnosis can be concluded into breast self-examination (BSE), clinical breast exam (CBE), imaging or mammography and surgery. Among these methods, X-ray mammography as the most efficient and reliable early detection technique is widely used by radiologists; it can detect 85–90% of all breast cancers. Microcalcification clusters (MCs) are a major sign of breast cancer in mammography [3], the size, shape, texture and distribution of the micro-calcifications provide significant information for diagnosis, hence the accurate detection of MCs is a critical step in computer aided detection (CAD) system.

Recent years, there have a great deal of researches engaged in development of computerized methods for automatic detection of MCs, which potentially give assistance to radiologists in diagnosis of breast cancer. Although making research on MCs detection in CAD system has sustained for decades, the research of calcification detection still possess meaningful and challenging topic because of the inhomogeneous background and the high noise level in mammography. Various approaches have been suggested to detect MCs accurately.

According to these studies, these methods can be roughly divided into classic methods and emerging methods. These classic methods can be decomposed into three steps; firstly, reduce the noise and enhance MCs; secondly, detect the MCs applying a specific segmentation technique; thirdly, select true MCs by diverse novel methods. A variety of techniques have been used in different steps. For mammogram enhancement, variety attempts have been done, such as improved histogram equalization [4], image enhancement based on wavelet fusion [5], automated lesion intensity enhance [6], modified multifractal analysis [7], etc.; in the segmentation step, many techniques have been suggested, such as multistable cellular neural networks, geodesic active contours (GAC) technique associated with anisotropic texture filtering [8], case-adaptive decision rule method [9], new scale-specific blob detection technique [10], etc.; in the third step, select true MCs by extracting a group of features of micro-calcifications like moment-based geometrical features [11], wavelet feature and Gabor feature [12] and so on. These aforementioned techniques make great contributions, however because the MCs detection faces different difficulties, the hybrid detection algorithms combining different theories seems more popular.

For years, Oliver et al. [13] presented a knowledge-based approach to detect MCs automatically, which was based on local features extracted by a bank of filters to gain a local descriptor of the micro-calcifications morphology, the approach was demonstrated on the full digitized MIAS database and full-field digital mammograms extracted from a non-public database, and resulted in better than 80% sensitivity at 1 false positive cluster per image. Pal et al. [14] proposed to use multi-layered perceptron network to segment the MCs. In their approach, the position of the MCs was taken into account, so the system could locate the calcified regions quite accurately. They used 7 abnormal and 1 normal mammogram images from MIAS digital mammogram database to design the system. Lifeng [15] introduced a novel multi-scale and multi-position classification (MSPC) method for detecting mammographic MCs, and their experiments tested on the digital database for screening mammography (DDSM) data showed that the detection rate of clustered pleomorphic calcification (CPMC) could reach up to 97.26% with a 36.84% false positive rate. Yu and Huang [16] investigated the performance of MCs by adopting combined model-based and statistical textural features, 20 mammograms containing 25 areas of MCs from the MIAS database were used to test the performance, and a true positive rate of about 94% was achieved at the rate of 1.0 false positive per image, or the false positives per image could be reduced to 0.65 false positive per image at the rate of true positive about 90%. Malar et al. [17] exhibited the effectiveness of wavelet based tissue texture analysis for detecting MCs in mammograms using extreme learning machine (ELM), the sample image were collected from the MIAS database, and achieved relatively better classification accuracy (94%). AbuBaker [18] proposed a novel algorithm to detect and classify the MCs accurately and automatically by employing multi-statistical filters and wavelet transform, the proposed method was found sensitive in detecting MCs in mammogram images by achieving a high true positive percentage of 98.1% and a low false positive rate 0.63 cluster per image for both MIAS and USF database. Zhang and Gao [19] presented an innovative framework for detection of MCs in mammograms employing the twin support vector machine (TWSVM), the proposed scheme is evaluated on the DDSM database. Chen et al. [20] presented a multi-scale topological approach to MCs classification by building a multi-scale graph of the inter-micro-calcification relationships, then various graph metrics were extracted from this graph and were fed into a k-nearest neighbor classifier to produce the final classification results, and evaluated this method on MIAS database. Although these approaches achieved competitive detection results, there was still room for improving MCs detection rate.

In our work, a new MCs detection method is proposed, in the first step, remove label and pectoral muscle adopting the largest connected region marking and region growing method; then enhance MCs using the double top-hat transform and grayscale-adjustment function; in the second step, obtain the suspicious calcification clusters by reconstructing the modified sub bands only with high frequencies contourlet transform coefficients; finally, use the non-linking SPCNN to detect calcification clusters. The results show our method is efficient and accurate. The remainder of paper is structured as follows: Section 2 briefly describes the database used in this work. In Section 3, we extend our approach to the detection of MCs. The assessment indicators are defined in Section 4. We illustrate the algorithm in three aspects, including the subjective evaluation, objective evaluation and method validation in Section 5. At last, the conclusion is presented in Section 6. Our detection algorithm is depicted in Fig. 1

2. The choice of mammogram database

The mammograms tested in this paper are collected from the Mammographic Image Analysis Society (MIAS) database [21] and the Japanese Society of Medical Imaging Technology