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A dual stage adaptive thresholding (DuSAT) for automatic mass detection in mammograms

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ABSTRACT

Background and Objective: Early detection and diagnosis of breast cancer through mammography screening reduces breast cancer mortality by around 20%. However it is often a complex process to differentiate abnormalities due to the ill-defined margins and subtle appearances.
Method: This paper investigates a new computer aided approach to detect the abnormalities in the digital mammograms using a Dual Stage Adaptive Thresholding (DuSAT). The suspicious mass region is identified using global histogram and local window thresholding method. The global thresholding is done based on the Histogram Peak Analysis (HPA) of the entire image and the threshold is obtained by maximizing the proposed threshold selection criteria. The local thresholding is carried out for each pixel in a defined neighborhood window that provides precise segmentation results.
Results: The algorithm is verified with 300 images in the DDSM database and 170 images in the mini-MIAS database. Experimental results show that the proposed algorithm achieves an average sensitivity of 92.5% with 1.06 FP/image for DDSM database and an average sensitivity of 93.5% with 0.62 FP/image for mini-MIAS database.
Conclusion: The achieved results depict that the proposed approach provides better results compared to other state-of-art methods for mass detection that helps the radiologists in diagnosis of breast cancer at early stage.

1. Introduction

Breast cancer is a significant public health problem for women all over the world. In 2016, there were approximately 246,660 new cases of invasive breast cancer and 40,450 related deaths expected among US women [1]. Early detection is the best way in breast cancer prognosis. Mammography is the most effective screening method for early detection of breast cancer. There is a chance for physicians to miss up to 30% of breast cancers due to high complexity of breast tissues or dense breast tissues [2]. Masses and microcalcifications are the two powerful indicators of cancers in examining mammograms. The mass detection is a more challenging problem than microcalcification, due to its variation in size and shape also it exhibits poor image contrast [3].

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Computer Aided Detection and Diagnosis (CAD) system can be used to assist the physician in analysis and it highlights potential areas of concern. After the CAD analysis is done, a visual check is performed by physicians on those potential areas and decide how serious the concern areas may be, based on their experience and training. Many research in the area of CAD system carried on certain exploitations on detecting the abnormalities in the mammogram during last few decades [4–10]. Mass detection in mammogram is a very challenging process. The extraction of suspicious mass region is difficult due to the ill defined nature of the mass boundaries; also there are some overlapping of normal dense breast tissues present in masses [11]. It may also be affected by the existence of pectoral muscles and the unstable shape and the size of masses. The reader is suggested to refer to recent review articles [12–15], for a survey of the state of the art of CAD systems. In order to overcome the above mentioned issues, this paper proposes a novel automatic mass detection algorithm to identify suspicious mass regions in mammograms.

One of the most common techniques for detecting the suspicious regions is global thresholding. It is based on the image histogram. Generally the masses have greater intensity than the surrounding tissues. So the peak in the histogram used to define the global threshold value. But this simple method is not efficient to detect the region of interest because masses are often superimposed on the surrounding tissues with same intensity. Zhang and Desai [16] developed a multi-resolution histogram based adaptive thresholding method to detect the suspicious region. This method selects a global adaptive threshold value based on the gray level Probability Density Function (PDF) of the low frequency sub image of the wavelet transformed input image. This method is also not effective when the target and background region contain small intensity difference. A local adaptive thresholding method for detecting the masses in the mammogram was proposed by Kom et al. [17]. A threshold is found for every pixel in the image, according to their neighbors in the window. This method is tested on 61 mammograms that obtain the sensitivity of 95.91%. This method works well for mass detection but it did not consider the case where a mass contains the small window. So it fails to detect the center of abnormality and gives an empty area in the segmentation output.

Later, Cao et al. [18] proposed a mass detection algorithm based on robust information clustering by incorporating spatial information in mammograms. This method is tested with 60 mammograms and achieved a sensitivity of 90.7% with an average of 2.57 FP/image. Kai et al. [19] proposed an adaptive thresholding based on multiresolution to detect the suspicious mass lesions. This method utilizes the combination of adaptive global and local thresholding on the multiresolution representation of the original mammogram. This algorithm is verified with 170 mammograms with the sensitivity of 91.3% at 0.71 FP/image. Various other thresholding techniques [3,20] also proposed in the literature to perform mass regions identification in the mammogram.

Qian et al. [21] uses the Ipsilateral Multi-view CAD system where the suspicious region segmentation is carried out using Fuzzy C Means (FCM) algorithm. Then the suspicious regions are classified into True Positive (TP) and False Positive (FP). This method achieves an average of 89.6% sensitivity with 1 FP/image. A detection and segmentation method for identifying the masses using multiple thresholding, wavelet transform and genetic algorithm is developed by Danilo et al. [22]. This method acquired a sensitivity of 95%, with 2.8 FP/image for the first stage and 1.37 FP/image for the second stage. Eltony et al. [23] proposed a morphological technique to detect the mass lesion in mammogram. This technique is implemented on 270 mammograms and achieves 92% sensitivity with 5.4 FP/image.

A mass detection method using statistical and morphological techniques using two concentric masks for detecting the mass region is developed by Ayman [24]. Here the detected region is classified into TP and FP based on the wavelet features and Support Vector Machine (SVM) classifier. This method is tested on 70 mammograms that achieve a sensitivity of 94% at 0.05 FP/image. Verala et al. [25] performed an adaptive threshold to segment the suspicious region. Then the segmented region is enhanced with iris filter. It yields a sensitivity of 88% with 1.02 FP/image. Sampaio et al. [26] demonstrated the potential of cellular neural networks (CNN) in segmenting the suspect regions in mammographic images that includes geostatistical functions as texture signatures for mass detection. These regions are further classified as masses or non-masses by Support vector machines with sensitivity of 80% and FP/image of 0.84.

From the literature, it is understood that the computer aided detection methods developed in this area have limited scope because of the specificity or due to the methodology used for mass detection in mammograms. These methods achieved good detection rates for certain type of lesions but unjustified results for many other types of lesions due to mass characterization. There are three main lesion features such as gray level, texture and shape in mammography. The most common characteristics for any type of lesions are characterized by gray level features, such as brightness and gray value. The gray level feature based detection has been proven to be an effective mammographic mass detection methodology for yielding more comprehensive and competitive results, particularly the adaptive thresholding detection techniques. Grounded on this motivation, this paper proposes a computer aided approach to detect the abnormalities in the digital mammograms using a dual stage adaptive thresholding (DuSAT) that utilizes an optimal global threshold obtained by maximizing between-class standard deviation and window based threshold obtained by image contrast.

The dual stage thresholds such as global and local thresholds are adaptively selected to perform a coarse level and fine level segmentation respectively. The global thresholding is done based on the Histogram Peak Analysis (HPA) of the entire image that provides localization of the suspicious lesions. The local thresholding is done based on the threshold for each pixel in a defined neighborhood window that provides precise segmentation results. Experiments are carried out on the images in mini-MIAS database [27] and DDSM database [28]. The results show that the proposed methodology using DuSAT mechanism outperforms the other methods. The rest of the paper is organized as follows: Section II describes the detailed methodology to perform the proposed DuSAT mass detection algorithm. In Section III, experimental results obtained from the proposed method are discussed and example images of detected mass lesions are visualized. Finally, Section IV concludes the work.