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Mammogram image visual enhancement, mass segmentation and classification

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ABSTRACT

Mammography is the most effective technique for breast cancer screening and detection of abnormalities. However, early detection of breast cancer is dependent on both the radiologist's ability to read mammograms and the quality of mammogram images. In this paper, the researchers have investigated combining several image enhancement algorithms to enhance the performance of breast-region segmentation. The masses that appear in mammogram images are further analyzed and classified into four categories that include: benign, probable benign and possible malignant, probable malignant and possible benign, and malignant. The main contribution of this work is to reveal the optimal combination of various enhancement methods and to segment breast region in order to obtain better visual interpretation, analysis, and classification of mammogram masses to assist radiologists in making more accurate decisions. The experimental dataset consists of a total of more than 1300 mammogram images from both the King Hussein Cancer Center and Jordan Hospital. Results achieved tumor classification accuracy values of 90.7%. Moreover, the results showed a sensitivity of 96.2% and a specificity of 94.4% for the mass classifying algorithm. Radiologists from both institutes have acknowledged the results and confirmed that this work has lead to better visual quality images and that the segmentation and classification of tumors has aided the radiologists in making their diagnoses.

1. Introduction

Breast cancer originates from breast tissues, most commonly from the inner lining of milk ducts or the lobules that supply the ducts with milk, breast cancer occurs in humans and other mammals. The overwhelming majority of human cases occur in women. Mammograms are effective for breast cancer screening and early detection of masses or abnormalities. Masses and calcifications are the most common abnormalities that indicate breast cancer [30]. According to radiologists, a mass screened on a mammogram can be either benign or malignant depending on its shape. Benign tumors usually have round or oval shapes, whilst malignant tumors have a partially rounded shape with a spiked or irregular outline. Non-cancerous or benign tumors include cysts, fibro adenomas, and breast hematomas. A cancerous or malignant tumor in the breast is a mass of breast tissue that grows in an abnormal and uncontrolled way. Normally, malignant masses appear brighter than any tissue surrounding it [30]. Successful diagnosis in mammography depends on detecting cancer in its earliest and most treatable stage. However, as mammogram images are subject to noise and distortion, computer aided detection (CAD) techniques are used to assist radiologists in the early detection of cancer, by enhancing those images and providing in-depth analysis of visual details in mammogram images.

Mammogram image segmentation mutually partition homogeneous regions into meaningful regions of interest. The segmentation algorithms can be categorized into two distinct categories according to the regions to be segmented, i.e., breast region segmentation and region of interest (ROI) segmentation. The former is the process of splitting the mammogram image into a breast region and a background, in order to limit the search for abnormalities on the breast region without the effect of the background on the results. The latter is the process of segmenting the suspicious regions to be analyzed for abnormalities. Furthermore, ROI segmentation can be classified into other groups, such as: segmentation using a single view and segmentation using multiple views.

Many mammogram image enhancement and segmentation techniques were proposed in literature. However, the majority of the proposed techniques share the common steps of image

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enhancement, segmentation, quantification, registration, and visualization. Those techniques can be differentiated by the varying algorithms employed at each step. One of the challenges faced by current mammogram image detection techniques lies in the difficulty of analyzing dense tissues. This difficulty can be attributed to the breast region which appears white in the mammogram images making masses and specifically micro-calcification highly invisible intermixed with the background tissue. Moreover, literature reveals that those approaches are designed for single view mammograms, and propose either an enhancement or a segmentation method. In this work, the proposed mammogram enhancement and segmentation algorithms are designed for mammograms taken from different views, which include: medio-lateral oblique (MLO) view and cranio-caudal view (CC).

In order to support radiologists in the detection of abnormalities, image enhancement is applied on mammogram images to increase their contrast and decrease the noise present. For this reason, this research investigates the use of different combination of conventional and feature-based contrast enhancement and noise reduction algorithms in order to enhance the visual details for radiologists and facilitate the masses segmentation process.

Moreover, in this research, a semi-automated mammogram analysis research tool is built to aid radiologists in analyzing breast regions and in detecting cancerous masses. With the help of this research, the radiologist can effectively segment the breast region and enhance its visual quality appropriately in order to clarify any abnormalities. Following the enhancement step, suspicious regions are segmented and sent to a mass classifying method to classify masses into all possible benign or malignant cases.

In addition to the introduction provided in Section 1, Section 2 provides a literature study on mammogram image enhancement and segmentation techniques, in depth information of the provided literature can be found on the authors work in [5]. Section 3 provides the proposed algorithms for enhancement and segmentation processes. Section 4 provides the experimental results and analysis. Finally Section 5 concludes this work with an insight to future work.

2. Related work

Mammogram enhancement methods are used to enhance details and reduce noise and other artifacts in X-ray images, in order to facilitate the radiologist's visual interpretation of the detection of abnormalities. Several methods are used to manipulate mammogram images, and can be categorized into four main groups; conventional enhancement techniques, region-based enhancement techniques, feature-based enhancement techniques, and fuzzy enhancement techniques. Conventional enhancing techniques appear in the works of [8,3,49,43,27,65,29] are fixed neighborhood techniques and are used to modify images based on their global properties. Region-based methods, as in [23,47], are used for enhancing the contrast of mammogram features according to the surrounding pixels. Feature based enhancement methods used in [12,19,46,48,52] are based on wavelet domain enhancement. Finally, the fuzzy enhancement techniques as in the work of [51,38,28,16,56] apply fuzzy operators and properties to enhance mammogram features.

Mammogram image segmentation is the process of partitioning mutually homogeneous regions of a mammogram image into meaningful regions of interest. The algorithms used for segmentation in literature can be categorized into two distinct categories according to the regions to be segmented; breast region segmentation and region of interest (ROI) segmentation. Mammogram acquisition is often taken from two different views, the most common views are: medio-lateral oblique (MLO) view and the cranio-caudal view (CC). Image segmentation techniques using multiple views can be further divided into three categories: left and right mammograms, two mammographic views (CC and MLO) of the same breast, and same view mammograms taken at different times. In the left and right mammograms, the evaluation is done by checking the symmetry of the fibro-glandular tissue in the two breasts. In the two mammographic views (CC and MLO) of the same breast, the evaluation is done by checking the fibro-glandular tissue in CC and MLO images of the same breast. However, in the same view mammograms taken at different times, the evaluation is done by checking the changes of the fibro-glandular tissue of the breast at different times.

Unsupervised segmentation using a single view is categorized into six classes: region-based segmentation, contour-based segmentation, clustering segmentation, pseudo-color segmentation, graph segmentation, and variant-feature transformation. Clustering segmentation methods have been employed in [50,42,59,45,11,61,60,14,64]. Regions of interest segmentation using a single view and the multiple views are used to segment both masses and calcifications, those methods have been used in the work of [49,29,23,51,37,58,66,10,40,53,39,9,15,18]. Graph segmentation methods can also be used to segment masses, and are applied in [4,33,34,20,22,21,67]. Variant feature transformation methods are mostly effective in segmenting micro-calcification along with mammogram masses and have been applied in [8,59,26,54,6,62,36] [57,44,55,1]. Other image segmentation methods that deal with color images include the work of [17,63,13].

Various mammogram image enhancement and segmentation techniques were proposed in literature such as the state-of-the-art approaches that include the work in [2,32,24,31]. However, those approaches are designed for single view mammograms, and propose either an enhancement or a segmentation method.

In this research, mammogram image enhancement and segmentation techniques are proposed based on different combination of conventional and feature-based contrast enhancement and noise reduction algorithms in order to enhance the visual details for radiologists and facilitate the masses segmentation process. Moreover, the proposed algorithms are designed for mammograms taken from different views, which include: medio-lateral oblique view and the cranio-caudal view. With the help of this research, the radiologist suspicious segmented mass regions are classified into four classes: benign, probable benign and possible malignant, probable malignant and possible benign, or malignant, in order to support the radiologists' opinion.

3. Proposed mammogram analysis (enhancement and segmentation) techniques

In this work, the proposed mammogram enhancement and segmentation algorithms are designed for mammograms taken from different views, which include: medio-lateral oblique (MLO) view and the cranio-caudal view (CC). The proposed mammogram analysis algorithm consists of five stages described as follows:

Stage 1: In the first stage of the proposed analysis algorithm (as shown in Fig. 1), breast region segmentation is applied and it consists of three phases: in the first phase, borders, labels, and any additional artifacts are removed from the mammogram images. In the second phase, noise is removed in order to enhance the mammogram images. Finally, in the third phase, the breast region is segmented using contour segmentation.

Stage 2: In order to clarify breast masses, the segmented breast region is enhanced in this stage using two enhancement methods – histogram equalization and un-sharp masking. The former is a contrast enhancement method; it adjusts pixel intensities in order to obtain a new enhanced image with usually increased local