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Digital Mammogram Segmentation and Abnormal Masses Detection System

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Abstract:

Digital Mammogram has emerged as the most popular screening technique for early detection of Breast Cancer and other abnormalities. Raw digital mammograms are medical images that are difficult to interpret so we need to develop Computer Aided Diagnosis (CAD) systems that will improve detection of abnormalities in mammogram images. Extraction of the breast region by delineation of the breast contour allows the search for abnormalities to be limited to the region of the breast. We need to perform essential pre-processing steps to suppress artifacts, enhance the breast region and then extract breast region by the process of segmentation. In this paper we present an automated system for detection of abnormal masses by anatomical segmentation of Breast Region of Interest (ROI).

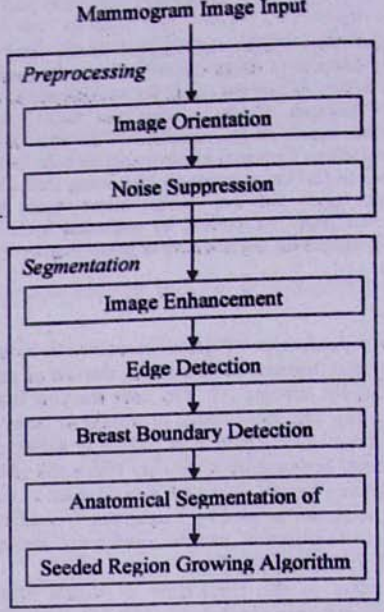
1. Introduction

Breast cancer is the most common type of cancer in women in both developed and developing countries. The National Cancer Institute estimates that one out of eight women develops breast cancer at some point during her lifetime [1]. Year after the year indexes of the morbidity with breast cancer are growing [2]. The same image is viewed in many countries: USA, European Union, Russian Federation and North America, as well as in Armenia. Mammography screening associated with clinical breast examination is the only viable and effective method at present for mass screening to detect breast cancer. A digital mammogram is created when a conventional mammogram is digitized, so, it can be used by a computer, without the loss of information from the original mammogram. Digitization can be performed through the use of a specific mammogram digitizer [3] or a camera [4], [5].

Digital mammography refers to the application of digital system techniques on digital mammograms. Digital systems have the capacity to bring revolutionary advantages to breast cancer detection [6]. Radiologists turn to digital mammography for an alternative diagnostic method due to the problems created by conventional screening programs. An automated system can overcome these problems by reducing the number of false positive and false negative readings from radiologists and increase the chance of detecting abnormalities early. Hence in this research work, image processing software with step-by-step algorithms used for mammogram segmentation is described.

2. Proposed Methods

Digital Mammograms require a preparation phase in order to improve the image. The objective during this process is to improve the quality of the image to make it ready for further processing by removing unwanted parts in the background of the mammogram.
After preparation phase is over segmentation phase starts. Segmentation divides image into its constituent regions or objects. Segmentation plays an important role in image analysis. The goal of segmentation is to isolate the regions of interest (ROI) depending on the problem and its characters. The approach is to partition an image based on abrupt changes in intensity, such as edges in an image and partitioning image into regions that are similar according to a set of predefined criteria.



2.1 Image Orientation

The mammogram image is transformed, so that the chest wall location, i.e., the side of the image containing the pectoral muscle, is on the upper left corner of the image.

2.2 Noise Suppression

There are different types of noises, which appear in mammography images. High intensity noise is characterized by high values of optical densities, such as labels or scanning artifacts. Such noises are filtered using a two-dimensional (2D) Median Filtering approach in a 3-by-3 neighborhood connection. Each output pixel contains the median value in the 3-by-3 neighborhood around the corresponding pixel in the input images. The edges of the images however, are replaced by zeros.

2.3 Enhancement Algorithm (CLAHE)

As enhancement technique was selected a well-known technique of adaptive contrast enhancement - the contrast-limited adaptive histogram equalization (CLAHE) [7].

2.4 Edge Detection Algorithm (EDA)

Edge detection is used for getting edge map of the breast region. In the first step horizontal scanning is performed. If any change of pixel intensity is observed it is marked by a black pixel indicating a horizontal edge point. This process is continued for all rows of pixel data to obtain a horizontal edge map. In the next step, image is scanned vertically. Continuing the process for all the columns a vertical edge map image is obtained. Finally, the horizontal edge map is merged with vertical edge map by performing a logical OR operation on the two image files, to obtain the edge map of mammogram image. The algorithm steps for the horizontal image map are:

1) Scan the image array horizontally from left-most pixel to right-most pixel from the first row to the last row and take the first pixel intensity value as a reference value.
2) Compare intensity of subsequent pixels with the reference value. If the same value go on to next pixel.
3) If the value differs, change the value of reference value to the pixel intensity value and mark the pixel black.
4) If the last row and column pixel are not reached then go to Step2.

Steps for horizontal image map are the same as implemented for rows.

2.5 Breast Boundary Detection Algorithm (BBDA)

The breast region contains the outline edges of various breast constituents bounded by the breast boundary that defines the breast region from the image background. For further processing it is of utmost importance to extract the boundary of the breast. We now proceed with the output image of the edge extraction process and our objective is to identify the outermost edge line that constitutes the edge of the breast. We scan the image from the right side of the image to locate the rightmost point at the first row of the image, which is the starting point of the processing. We then consider all the surrounding pixels in a clockwise priority and consider the pixel with the highest priority. We store the pixel traversed in a Plotting List to be used later for drawing the breast boundary. The pixels that surrounded the starting pixel, but are of lower priority are stored in a Backtrack Stack to be used only if the traversal process reaches a dead end. If a dead end is reached, we pop out from the Backtrack stack a lesser priority pixel and continue with the traversal process. The traversal continues to the next pixel and continues till it reaches the baseline or the bottom of the image, indicating the end of the breast region. The Plotting list contains the breast boundary pixels that are plotted after smoothening for further processing.

Algorithm to Detect Breast Boundary:

1) Scan the image from the Left side of the image to locate the leftmost pixel of the breast region.
2) Draw a vertical line along this pixel from top to bottom representing the Left baseline or boundary.
3) Scan the edge map from the right side to left, from the first row.
4) Obtain a pixel that is black indicating an edge path, traverse the pixel path by considering all the surrounding pixels in a clockwise priority and consider the pixel with the highest priority.
5) The pixels that surrounded the edge pixel, but are of lower priority are stored in a Backtrack Stack to be used only if the traversal process reaches a dead end.
6) If a dead end is reached, pop out from the Backtrack stack a lesser priority pixel and continue with the traversal process
7) Store the pixels traversed in a Plotting List to be used later for drawing the Breast boundary.

8) Traversal continues to the next pixel till it reaches the left baseline or the bottom of the image.
9) If the bottom of the image or the left baseline is not reached the path is discarded, the plot list is erased and the procedure continues from Step4. Else Get pixels from the Plotting List at a discrete interval.
10) Plot the first pixel.
11) Draw a simple curve between two consecutive pixel positions separated by the discrete interval.
12) Continue plotting till the last pixel in the Plotting List is plotted.

2.6 Anatomical Segmentation of Breast ROI (ASB)

After previous steps we get the ROI of the Breast. We now consider the edge map that corresponds only to the ROI of the breast. The edge map indicates various closed structures within the breast region that corresponds to the different anatomical regions of the breast. The objective is to identify these regions on the mammogram image. The algorithm starts by identifying the left baseline of the breast image from the edge map. Then a line is drawn vertically from top to bottom identifying the left boundary of the breast. Then the breast boundary is scanned on the right side to locate the rightmost pixel on the breast contour. After the pixel is located another vertical line is drawn from top to bottom passing through the rightmost pixel thus partitioning the image only to the breast ROI. This process optimizes the algorithm and increases the processing efficiency. At this stage the algorithm tries to locate all edge paths that are circular or terminate either on the left base line or the bottom of the image, forming a closed structure. Locating all the edge paths that originate from the top margin line namely the first row of the image is started. The algorithm travels each individual path and stores them on the plotting list. This list is plotted on another image if the edge path is circular or end on the last row of the image or the vertical line representing the left boundary of the breast. After all pixel paths on the first row are traversed the algorithm repeats similar scanning and traversal of all pixel paths from the row that is indicated by dividing the image vertically into sixteen segments. The first row of each segment is used for locating pixel paths for traversal. All complete paths are then plotted on another image thus providing regions of the breast. The algorithm steps to detect regions are:

1) Scan the image from the left side of the image to locate the leftmost pixel of the breast region and draw a vertical line along this pixel from top to bottom representing the left baseline or boundary.
2) Scan the image from the right side of the image to locate the rightmost pixel of the breast region and draw a vertical line along this pixel from top to bottom.
3) Partition the obtained rectangle horizontally into sixteen segments and start with the first row of the first segment.
4) Scan the enclosed rectangle from the right side to left, from the first row of the segment.
5) Obtain a pixel that is black indicating an edge path, traverse the pixel path by considering all the surrounding pixels in a clockwise priority and consider the pixel with the highest priority.
6) The pixels that surrounded the edge pixel, but are of lower priority are stored in a history stack to be used only if the traversal process reaches a dead end.
7) If a dead end is reached, pop out from the history stack a lesser priority pixel and continue with the traversal process.
8) Store the pixels traversed in a plotting list for plotting.
9) Traversal continues to the next pixel till it reaches the left baseline or the bottom of the image or the start position is reached.

10) If the traversal is terminated, the plotting list is erased and the procedure continues from Step5. Else plot pixels from the plotting list.
11) Continue to Step4 till all black pixels, indicating an edge path, is traversed.
Move to the first row of the next segment and continue from Step4 to Step9.

2.7 Seeded Region Growing Algorithm (SRGA)

The segmentation process performed on the edge map differentiates various regions on the breast depending on their intensity values. Each region has a different intensity value. The fatty tissues, glands, lobules and the ducts display different intensity values and thus can be segregated into different regions. An abnormality such as a mass, tumors or calcifications may be present within the breast has distinctly higher intensity values than the normal tissues of the breast. So in this step we need to categorize all the obtained closed structures to their intensity values. The distribution of pixels intensities also varies within each segmented region but the majority of the pixels have similar intensity values. So for each region we calculate the arithmetic Mode value for the intensities from the original mammogram and replace those pixels in the region with the computed mode values.

To identify, isolate each closed structure and then perform coloring of each structure with its respective Mode values the seeded region growing method for coloring bounded objects is used [8].

Algorithm steps for Seeded Region Growing:

1) Scan the image from the Left side of the breast ROI from first row.
2) If the pixel is not colored and is not a boundary pixel consider it as a seed for coloring.
3) Store Pixel in a Seed Stack.
4) Consider pixels at top, bottom and two sides of the seed pixel.
5) If the pixel is not colored and is not a boundary pixel Push to Seed Stack.
6) Pop from Seed Stack a seed pixel and store the pixel into Color List for coloring.
7) Continue till no white pixels are left in the bounded region and Seed Stack is not empty, and Goto Step2.
8) After getting the complete region on the Color List Scan the Original Mammogram for the Pixel Locations.
9) Calculate the Mode Value of the pixel intensities in the image for the set of Pixel Locations.
10) Color the pixels representing the region with the corresponding Mode intensity value.
11) Clear Color List and continue till the Breast Regions are completely colored, Goto Step1.

3. CAD System

All methods proposed in Section 2 were implemented and included in CAD system, for automated mammogram segmentation and masses detection. The system is written using C#, C++ programming languages and their libraries.

The main window of the system is shown on Fig.1.

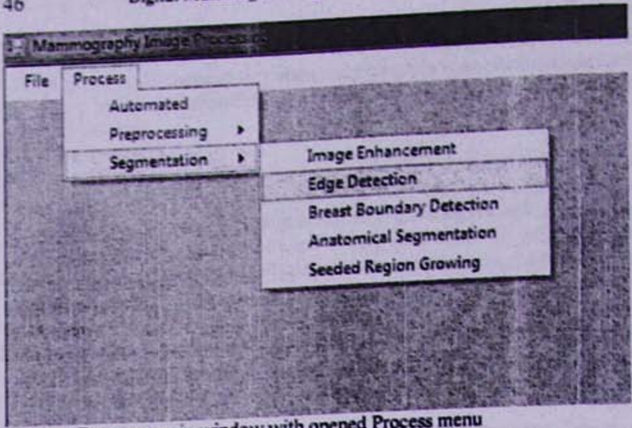


Fig.1 CAD system main window with opened Process menu

It has File and Process menus, which actions are listed below:

Menu Actions	Description
File>>Open	Opens a window for choosing mammography image
File>>Save As	Saves opened image
File>>Exit	Exits from the system
Process>>Automated	Step-by-step applies all methods described in Section 2 on the opened image
Process>>Preprocessing>>Image Orientation	Applies only Image Orientation method described in Section 2.1 on the opened image
Process>>Preprocessing>>Noise Suppression	Applies only Noise Suppression method described in Section 2.2 on the opened image
Process>>Segmentation>>Image Enhancement	Applies only Image Enhancement algorithm described in Section 2.3 on the opened image
Process>> Segmentation >>Edge Detection	Applies only Edge Detection algorithm described in Section 2.4 on the opened image
Process>> Segmentation >>Breast Boundary Detection	Applies only Breast Boundary Detection algorithm described in Section 2.5 on the opened image
Process>> Segmentation>>Anatomical Segmentation	Applies only Anatomical Segmentation method algorithm in Section 2.6 on the opened image
Process>> Segmentation>>Seeded Region Growing	Applies only Seeded Region Growing algorithm described in Section 2.7 on the opened image

On Fig 2 Results obtained after running the system with Automated Process mode are shown.

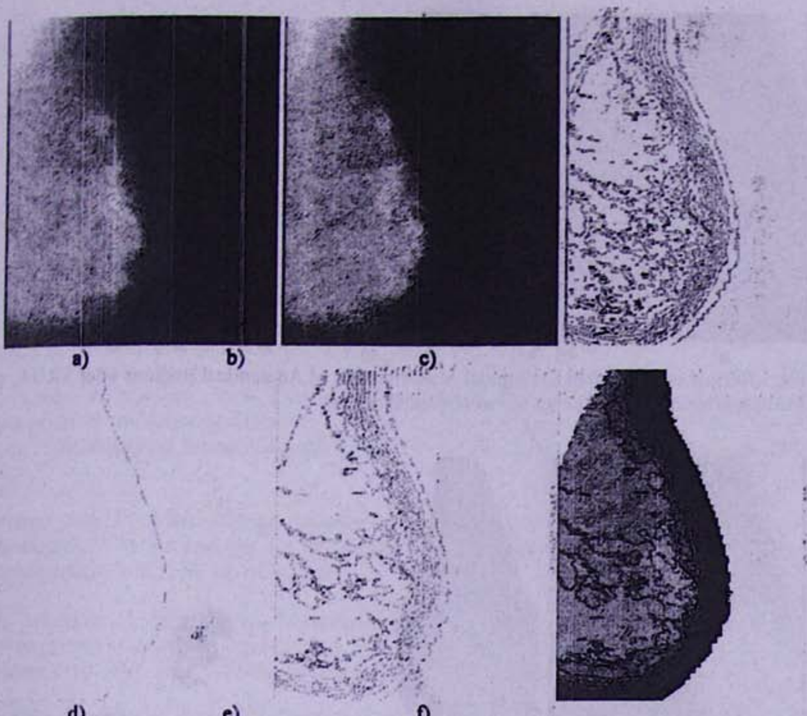
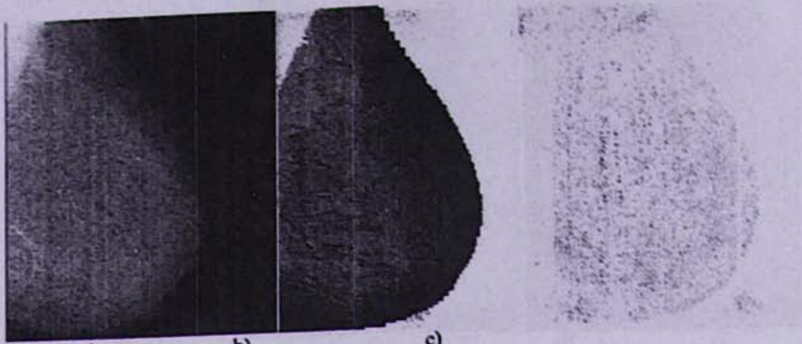


Fig.2 Results after running CAD system Automated mode. a) Original mammogram, b)after CLAHE, c) after EDA, d) after BBDA, e) after ASB, f) after SRGV

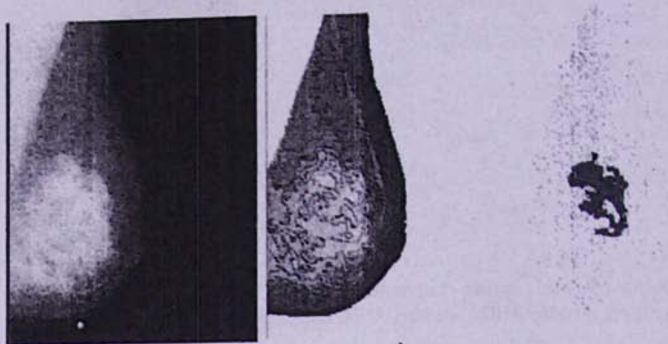
4. Experimental Results

In this section results of images using methods described in Section 2 are shown. For testing images from 'The mini-MIAS database of mammograms.' internet resource were selected [9].
To demonstrate the robustness of the algorithms it has been tested on mammograms with differing breast tissue densities. Overall, for the mammograms evaluated, the accuracy average values for mass detection were 0.99. Results are shown on Fig.3 and Fig.4



a) b) c)

Fig.3 Normal mammogram a) Original Mammogram, b) Anatomical Regions after SRGA, c) Mammogram showing absence of abnormal region



a) b) c)

Fig.4 Mammogram with abnormalities. a) Original Mammogram, b) Anatomical Regions after SRGA, c) Mammogram showing presence of abnormal region

5. Conclusion and Future Works

In our proposed method, we have developed and merged several algorithms and the combination of these methods has provided excellent detection of mass in mammograms having abnormal regions. Results of the proposed methods show a reliable detection rate of abnormal regions if present within the mammogram, furthermore, due to its simple procedure the method executes faster than other complicated methods. The CAD system was tested on most of mammograms from mini-MIAS mammogram database. The system has detected abnormalities in only those mammograms which contain abnormal mass according to the MIAS database. The other mammograms that are normal have shown negative results.

In conclusion, it can be mentioned, our CAD system is acceptably accurate, promising and comparable with any other standard systems.

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Թվային մամոգրամների սեգմենտավորման և աննորմալ զանգվածների հայտնաբերման համակարգ

Ա. Սահակյան

Ամփոփում

Կրծքագեղձի քաղցկեղի և այլ աննորմալ զանգվածների վաղ հայտնաբերման մեթոդներից է թվային մամոգրաֆիան: Թվային մամոգրամները բժշկական պատկերներ են, որոնց վերամշակման և վերլուծության համար անհրաժեշտ է մշակել համակարգչային ախտորոշման դիագնոստիկ (CAD) համակարգ, որը կօգնի աննորմալ զանգվածների հայտնաբերմանը: Կրծքի եզրագծերի շրջագծման օգնությամբ, կրծքային շրջանի առանձնացումը թույլ է տալիս, որ աննորմալ զանգվածների որոնումը սահմանափակվի միայն կրծքի շրջագծով: Անհրաժեշտ է իրականացնել աղմուկների հեռացման նախամշակման քայլեր, բարելավել կրծքագեղձի պատկերը և այնուհետև սեգմենտավորել: Այս հոդվածում ներկայացված է աննորմալ զանգվածների հայտնաբերման ծրագրային համակարգ, որը իրականացնում է պատկերի հետաքրքիր տիրույթների (ROI) սեգմենտավորումը:

Система цифровой сегментации маммограм и обнаружения аномальных масс

А. Саакян

Аннотация

Цифровая маммография является самой популярной техникой скрининга для раннего выявления рака молочной железы и других нарушений. Цифровые маммограмы являются медицинскими изображениями и для их обработки нужно разаработать вспомогательные диагностические компьютерные (CAD) системы, которые будут способствовать выявлению нарушений. Отмечение области груди контуром позволяет поиски аномалии быть органиенным только областью груди. Мы должны выполнить шаги преварительной обработки, чтобы подавить шумы, улутшить изображение области груди и затем отметить область груди процессом сефментации. В этой статье мы представляем автоматизированную системы для обнаружения аномальных масс анатомической сефментацией области интереса (ROI) груди.