

Edge-based Suppression of Pectoral Muscle in Digital Mammogram

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ABSTRACT

The pectoral muscle, a non-breast region in mammograms, acts like an additional complexity in automated analysis using computer-aided diagnosis systems. The suppression of pectoral muscle is necessary because the muscle has a similar opacity as tumor. This paper proposed an algorithm for pectoral muscle isolation.

Key words: CAD, ROI, Asymmetry analysis, Pectoral muscle

INTRODUCTION

Computer-aided diagnosis (CAD) is an interdisciplinary technology combining elements of digital image processing with medical image processing. CAD techniques in X-ray, mammogram, magnetic resonance imaging, and ultrasound diagnostics yield a great deal of information, which the radiologist has to analyze and evaluate comprehensively in a short time. The interpretation of medical images, however, is still almost exclusively the work of humans, but in the next decades, this is expected to change.^[1-3]

Breast cancer affecting the women is known to cause high mortality unless detected in time. Detection requires a simple procedure of mammography followed by biopsy of the tumors or lesions presents in the breast tissue. CAD systems require medical image processing, a multidisciplinary science that involves the development of computational algorithms on medical images. In CAD-based breast cancer detection, the digital mammogram image pair is initially preprocessed. The right oriented mammogram is flipped for removal of any unwanted artifacts and noise. Next image registration and homogeneity enhancement are performed. Pectoral muscle holds the breasts to the body and needs to be suppressed as it mimics the intensities exhibited by tumors. The pectoral region is masked out leaving behind the breast region of interest (ROI). Edge detection and contour detection are performed to separate the ROI from the background. The anatomical segmentation

of the breast image is performed to isolate all closed objects within the breast ROI. Asymmetry analysis is performed both morphologically and anatomically for separation of both breast regions. Density estimation of both breasts is performed to suppress low-intensity regions. The presence resulting high-intensity region is measured to establish risk factor.

Digital microscopy is used in field of blood specimen analysis worldwide, but its use in surgical biopsy slide analysis is rudimentary. Using mammogram and other screening techniques can only detect the abnormalities; however, conclusion cannot be drawn from that observation. Hence, the CAD may be a detection tool but not a diagnosis tool without incorporating the histopathological part.

In any CAD-based diagnosis of breast cancer, the schematic diagram of modules is shown in Figure 1.

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. It is important to extract the breast region by eliminating the pectoral muscle region.

LITERATURE REVIEW

The presence of mammary gland is one of the key characteristic features of female mammals. This paired organ

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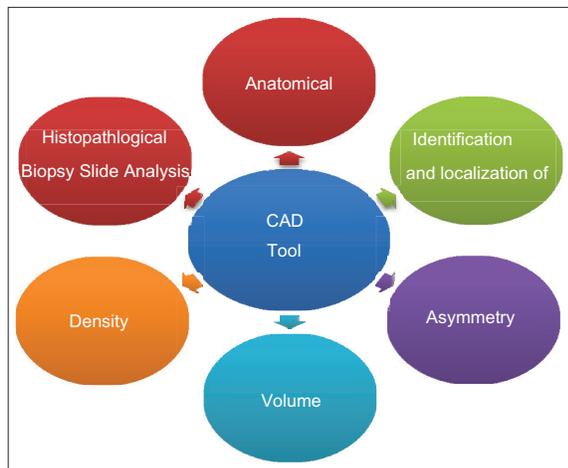


Figure 1: The diagram of computer-aided diagnosis tools for the detection of breast cancer

which looks like a hemisphere is located at the level of the third-sixth ribs.^[2] The breast is one of the most dynamic organs in human. The breast can be divided into three regions skin, nipple, subareolar tissues; subcutaneous region contains fat and lymphatic's; parenchyma region, a triangular shape between the subcutaneous and retromammary regions, with the apex toward the nipple; and finally, retromammary region consists of retromammary fat, the pectoral muscle, ribs, intercostal muscles, and the pleural reflection.^[4] The breast is prone to various benign and malignant conditions. The most common benign conditions are puerperal mastitis, fibrocystic breast changes, and mastalgia. The latter part is very serious in nature that is breast cancer. Breast cancer, a malignant tumor developed from breast cells, is considered to be one of the major causes for the increase in mortality among women, especially in developed and developing countries.^[5-8]

Some researchers proposed improved the seeded region growing algorithm by making it independent of the pixel order of processing and making it more parallel. This algorithm retains the advantages of seeded region growing such as fast execution, robust segmentation, and no parameters to tune. The algorithm is also pixel order independent. All pixels are processed in parallel if more than one pixel in the neighborhood has same minimum similarity measure value. If a pixel cannot be labeled, because it is equally likely to belong to two or more adjacent regions, then it is labeled as "tied" and takes no part in the region growing process. This algorithm produces consistent segmentation because it is not dependent on the order of pixel processing. Parallel processing ensures that the pixels with the same priority are processed in the same manner simultaneously.^[9-10] Other researchers proposed a hierarchical stepwise optimization algorithm for region merging, which is based on stepwise optimization and produces a hierarchical partition of the image. The sequences of partitions reflect the hierarchical structure of the image.^[11]

PROPOSED METHOD

In the pectoral muscle, suppression process consists of two distinct separate processes - initially define rectangle to isolate pectoral muscle from ROI and followed by suppression of pectoral muscle.

The two common projections of mammogram are mediolateral oblique (MLO) and craniocaudal (CC) view. The advantage of the MLO projection is that almost the whole breast is visible, often including lymph nodes. The main disadvantage is that part of the pectoral muscle is shown in upper left for the left oriented breast image, whereas upper right corner for the right oriented breast mammogram, respectively. In contrast, the CC view is taken from above, resulting in an image that sometimes does not show the area close to the chest wall. In this research work, MLO view is considered for its complete visibility though it introduces a new challenge to detect and isolate pectoral muscle. Edge-based method is proposed for detection, extraction, and isolation of pectoral muscle from the breast region. A smooth pectoral boundary is obtained by taking pixels at a fixed discrete interval and joining them by drawing a simple curve between the pixel positions to obtain a smooth and enhanced pectoral boundary. It is observed that the pectoral muscle lies at the top left corner of the breast region (right pair flipped horizontally during pre-processing) and its boundary line traverses from the top margin downward toward the horizontal reference line, that is, chest wall of the mammogram image forming an inverted triangle. Since it is a muscular structure, so, there are several layers that are present. These layers form several impressions in edge map.

Therefore, more than one inverted triangles are there in edge map. The objective is to identify the largest triangle which is actual border of pectoral muscle and dividing pectoral muscle from the breast region. This is shown in Figure 2.

It is now needed to identify the outermost edge line that constitutes the edge of the pectoral muscle. It is observed that the largest inverted triangle in the edge map starting from the top margin and ending on the vertical baseline, that is, horizontal reference line of the breast region on the left side, is the pectoral region. It is important to identify the rightmost pixel of the breast region on the right side and draw a vertical line from top margin to bottom margin, parallel to the left vertical baseline. Another line is drawn parallel to the top and bottom margin. The said line is originated from the 2/3 position of horizontal reference line to the right vertical line. Figure 3 shows the result.

The pectoral muscle barring a few mammograms lies within the rectangle formed by these straight lines. The search is limited to the obtained rectangle, thus reducing the processing time instead of considering the entire mammogram image.

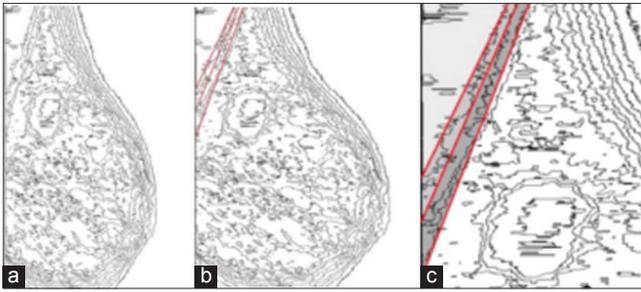


Figure 2: (a) The edge map of mammogram, (b) The layers of pectoral muscle, and (c) inverted triangles marked by different gray shades

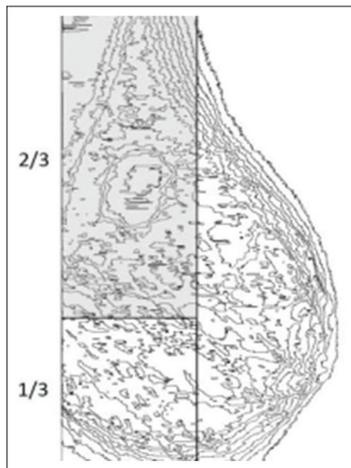


Figure 3: Pectoral muscle lies within gray shaded derived rectangular area

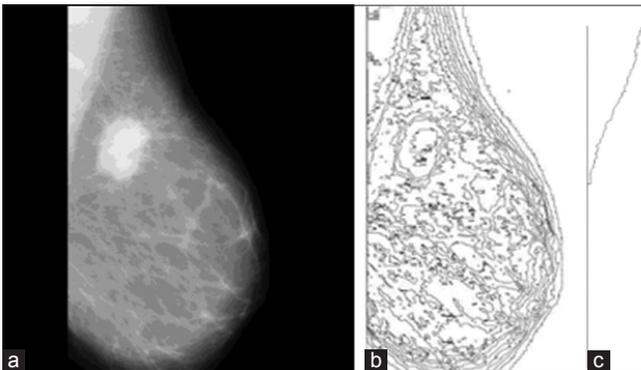


Figure 4: (a-c) Original mammogram, obtained edge map, and isolated pectoral boundary

The scanning will be right to left, starting from the right vertical line at the first row. If a pixel with black intensity is obtained, that is, indicating an edge path. Traverse the pixel path by considering all the surrounding pixels in a clockwise priority and select the pixel with the highest priority for further progress. The pixels that surrounded the edge pixel but are of lower priority are stored in a backtrack stack to priorities value and to be used only if the traversal process reaches a dead end. If a dead end is reached, pop from the backtrack

stack for a lesser priority pixel and continue with the traversal process. The pixels traversed is stored in a plotting list to be used later for drawing the pectoral boundary. It continues up to the left baseline or the bottom of the rectangle. If the bottom of the rectangle is reached, the path is discarded, the plotting list is erased, and the algorithm resumes by searching the next black pixel at the first row from right to left. If the horizontal reference line is reached that specifies the path stored in the plotting list is pectoral boundary and that is drawn in a new image and further processing is terminated. It is shown in Figure 4.

The pectoral boundary obtained is further processed by pectoral boundary smoothing method. The pectoral boundary image obtained so far is not smooth. A smooth pectoral boundary is obtained by taking pixels at a fixed discrete interval and joining them by drawing a simple curve between the pixel positions to obtain a smooth and enhanced pectoral boundary. Figure 5 shows the result.

Algorithm: Pectoral muscle boundary detection

PM-BOUNDARY-DETECTION (Edge Map, HorzRefLine, RightVerLine, Height, Width)

PlottingList ← New Array of coordinates

Loop y ← RightVerLine + 1 to HorzRefLine - 1

Do PlottingList ← NULL

If Edge Map [1, y] = 0

Then PlottingList [1] ← (1, y)

PlottingList ← TRAVEL (Edge Map, HorzRefLine, RightVerLine, Height, PlottingList)

If PlottingList ≠ NULL

Then PECTORAL-MUSCLE-BOUNDARY-SMOOTHING (PlottingList)

Return 1

y ← y - 1

Return 0

TRAVEL (Edge Map, HorzRefLine, RightVerLine, Height, PlottingList)

Back track Stack ← New Stack to store coordinates

Local Stack ← New Stack to store coordinates

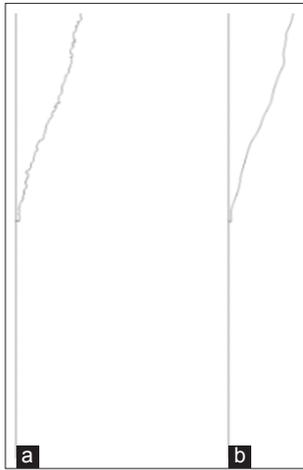


Figure 5: (a and b) Detected pectoral boundary and smooth boundary

Privy ← Holding the immediate previously traversed coordinate

Curt ← Holding current coordinate

Privy ← NULL

Count ← 1

Back track Stack. Push (PlottingList [1].x, PlottingList [1].y)

While $x \neq \text{HorzRefLine}$ AND $y \neq \text{Height} * (2/3)$ AND Back track Stack \neq Empty

Do $x \leftarrow \text{PlottingList} [\text{Count}].x$

$y \leftarrow \text{PlottingList} [\text{Count}].y$

Count ← Count + 1

Flag ← 0

If Edge Map $[x, y+1] = 0$ AND ($\text{Prev}.x \neq x$ OR $\text{Prev}.y \neq y+1$)

Then PlottingList [Count].x ← x

PlottingList [Count].y ← y+1

Flag ← 1

If Edge Map $[x+1, y+1] = 0$ AND ($\text{Prev}.x \neq x+1$ OR $\text{Prev}.y \neq y+1$)

Then If Flag = 0

Then PlottingList [Count].x ← x+1

PlottingList [Count].y ← y+1

Flag ← 1

Else Local Stack.Push (x+1, y+1)

If Edge Map $[x+1, y] = 0$ AND ($\text{Prev}.x \neq x+1$ OR $\text{Prev}.y \neq y$)

Then If Flag = 0

Then PlottingList [Count].x ← x+1

PlottingList [Count].y ← y

Flag ← 1

Else Local Stack. Push(x+1, y)

If Edge Map $[x+1, y-1] = 0$ AND ($\text{Prev}.x \neq x+1$ OR $\text{Prev}.y \neq y-1$)

Then If Flag = 0

Then PlottingList [Count].x ← x+1

PlottingList [Count].y ← y-1

Flag ← 1

Else Local Stack. Push(x+1, y-1)

If Edge Map $[x, y-1] = 0$ AND ($\text{Prev}.x \neq x$ OR $\text{Prev}.y \neq y-1$)

Then If Flag = 0

Then PlottingList [Count].x ← x

PlottingList [Count].y ← y-1

Flag ← 1

Else Local Stack. Push(x, y-1)

If Edge Map $[x-1, y-1] = 0$ AND ($\text{Prev}.x \neq x-1$ OR $\text{Prev}.y \neq y-1$)

Then If Flag = 0

Then PlottingList [Count].x ← x-1

PlottingList [Count].y ← y-1

Flag ← 1

Else Local Stack. Push(x-1, y-1)

<p>If Edge Map $[x-1,y] = 0$ AND (Prev.x \neq x-1 OR Prev.y \neq y)</p> <p>Then If Flag = 0</p> <p>Then PlottingList [Count].x \leftarrow x-1</p> <p>PlottingList [Count].y \leftarrow y</p> <p>Flag \leftarrow 1</p> <p>Else Local Stack. Push(x - 1,y)</p> <p>If Edge Map $[x-1,y+1] = 0$ AND (Prev.x \neq x OR Prev.y \neq y+1)</p> <p>Then If Flag = 0</p> <p>Then PlottingList [Count].x \leftarrow x-1</p> <p>PlottingList [Count].y \leftarrow y+1</p> <p>Flag \leftarrow 1</p> <p>Else Local Stack. Push(x-1,y +1)</p> <p>If Flag = 1</p> <p>Then While Local Stack \neq Empty</p> <p>Do Back track Stack. Push(Local Stack. Pop)</p> <p>Else Found \leftarrow 0</p> <p>While Found = 0 AND Back track Stack \neq Empty</p> <p>Do Curt \leftarrow Back track Stack. Pop</p> <p>i \leftarrow Count - 1</p> <p>While i > 0 AND Found = 0</p> <p>Do If PlottingList [i] = Curt</p> <p>Then Found \leftarrow 1</p> <p>PlottingList[Count]=Curt</p> <p>Prev =Curt</p> <p>If x = HorzRefLine</p> <p>Then Return PlottingList</p> <p>Else If y = Height*(2/3) AND Back track Stack = Empty</p> <p>Then Return NULL</p>	<p>PECTORAL-MUSCLE-BOUNDARY- SMOOTHING (PlottingList)</p> <p>New Image \leftarrow New Image containing smooth pectoral Muscle Boundary</p> <p>$\Delta \leftarrow$ The Fixed Discrete Interval</p> <p>i \leftarrow Holding a Coordinate</p> <p>Loop i \leftarrow PlottingList [1] to PlottingList.Count</p> <p>Do NewImage \leftarrow CURVE-LINE (NewImage, i, i+Δ)</p> <p>ii \leftarrow + Δ</p> <p>Return NewImage</p> <p>CURVE-LINE (NewImage, i, i + Δ)</p> <p>//Function to draw the curve between two coordinates</p> <p>Return NewImage</p> <p>CURVE-LINE (NewImage, i, i + Δ)</p> <p>//Function to draw the curve between two coordinates</p> <p>Return NewImage</p>
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RESULTS ANALYSIS

The algorithm has been applied over all the 322 mammograms in MIAS database and other available databases that cover every type of breast shape, size, and type including deformities, asymmetries, and abnormalities.

Results obtained after execution of the proposed algorithm on MIAS database mammogram image are shown in Figures 6-8.

CONCLUSION

The proposed region-based and edge-based method for pectoral muscle detection and suppression has been discussed. The results obtained over MIAS database and other available datasets have shown excellent output. The algorithms are used to accurately identify pectoral muscle and suppress the pectoral muscle successfully without losing any information from the rest of the mammogram.

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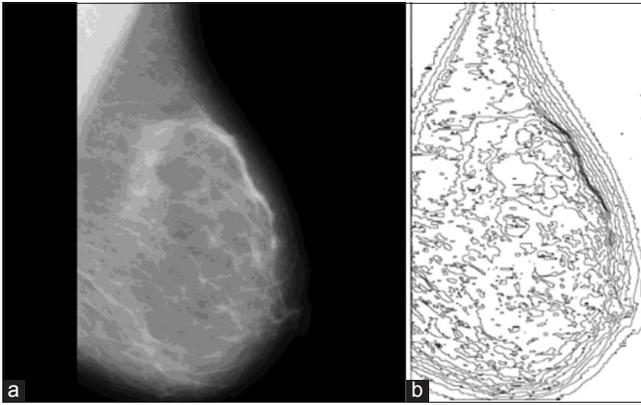


Figure 6: (a and b) Original mammogram and corresponding edge map

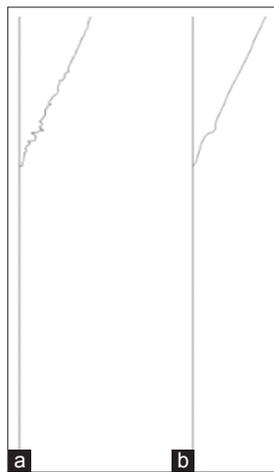


Figure 7: (a and b) Detected pectoral boundary and smooth boundary

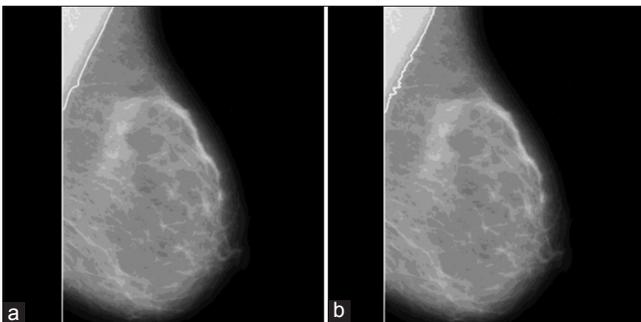


Figure 8: (a and b) Detected pectoral boundary and ground truth superimposed on original mammogram

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