A NOVEL APPROACH TO REMOVE PECTORAL MUSCLE FROM MEDIOLATERAL OBLIQUE MAMMOGRAMS WITH HYBRIDIZATION OF MSERPECTORAL AND HOUGHPECTORAL METHODS

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Abstract: **Women are losing life because of Breast cancer. Performing Breast self-examination with other screening methods such as Mammography and Ultrasound tests can increase the odds of early detection of Breast cancer. Accurate detection of this deadly disease is a challenging task. A Mammogram is a modality used to detect Breast cancer early. The Pectoral muscle significantly affects mass detection from MLO Mammogram. Pectoral removal is a difficult task because the grey level of Pectoral tissue is similar to a Breast tumor. Removal of Pectoral muscle from MLO Mammogram greatly enhances the Breast mass segmentation. This research is aimed to remove the Pectoral muscle from the Mediolateral Oblique Mammogram with a new approach and improve the accuracy. This research proposes a hybrid approach where MSERPectoral and HoughPectoral methods are combined to detect and remove Pectoral muscle.**

IndexTerms - MLO Mammogram, Pectoral muscle, MSER, MSERPectoral, Hough, HoughPectoral.

I. INTRODUCTION

Breast is formed with fatty and dense tissues. Lobes form the tissue and tube-like structures form the lobe. Lobules have milk glands; Milk glands generate milk; small ducts carry milk from milk glands to nipples. Lymph nodes run throughout the body, including the breast. Lymph nodes prevent the body from infections.

According to Cancer.net [1] statistics, female Breast cancer affected people crosses lung cancer affected people. Danger bells are ringing globally, with approximately 2,261,419 new Breast cancer cases recorded in 2020.

Mammography and Ultrasound are the usual medical tests for Breast Cancer detection. A Mammogram is the first medical test for Breast Cancer detection; it is a radiography of Breast. In Mammography, electromagnetic waves pass through the tissue, and functional constructs are projected on a film screen. For each Breast organ, two kinds of projections are obtained CranioCaudal view (CC) and Mediolateral Oblique view (MLO). Digital Mammograms can be enlarged or highlighted according to the necessity [3][4].

Mammograms are high-resolution images with the possibility of discovering masses and calcifications. Early detection of Breast cancer is possible through Mammography typically through the detection of mass or Micro calcifications [20]. Mass is a focused white area on the Mammogram. A mass may refer to a tumor, cyst, or fibroadenoma, whether it is cancerous or not. Tumors can be benign or malignant. No risk with Benign tumor since it does not spread. Benign tumor is usually in elliptical shape and will be with a well-defined structure [23]. In maximum cases, the malignant structure is not well-defined.

Mammography also highlights calcifications. Breast tissue may have calcium deposits called calcifications; Calcifications can be macro or micro; Macro calcifications are bigger and mainly with a well-defined structure. Mostly macro calcifications are non-cancerous.

Micro calcifications are specks which are less than 0.5mm in size. Radiologists consider micro calcification shape, layout and whether they are near to mass to suspect Breast cancer. If the pattern of micro calcifications is suspicious, the Radiologist recommends a biopsy.

Doctors uses the Mammogram [2] as the initial modality for detecting the mass at the early stage. A Mammogram is a radiography image through that we can visualize the inner structures of Breasts. However, much expertise and experience are required to detect cancer masses from the Mammogram. Many computer aided diagnosis systems are being used to help doctors in this regard. As far as MLO Mammogram is concerned, developing a computer aided diagnosis system to detect masses is a tough row to hoe due to the presence of Pectoral muscle.

We can see part of the Pectoral muscle in Mediolateral Oblique view (MLO) mammogram. Pectoral muscles are the crucial skeletal muscles that link the human chest with the upper arm. Because of Pectoral muscles only, humans can move their shoulders freely. Major and minor Pectorals are the two Pectoral muscles exist on both sides of breastbone.

Every human has the external oblique abdominal muscle. The major Pectoral is the more significant muscle that originates at the collarbone and it outspreads the exterior oblique abdominal. The Pectoralis major extends across the upper part of the chest and is attached to a ridge at the rear of the humerus and the minor Pectoral lies under the major Pectoral. Both Pectorals are to assist the shoulders in moving freely.

Fig. 1.1 shows Mediolateral Oblique Mammogram, where Pectoral muscle, mass and calcifications are highlighted.
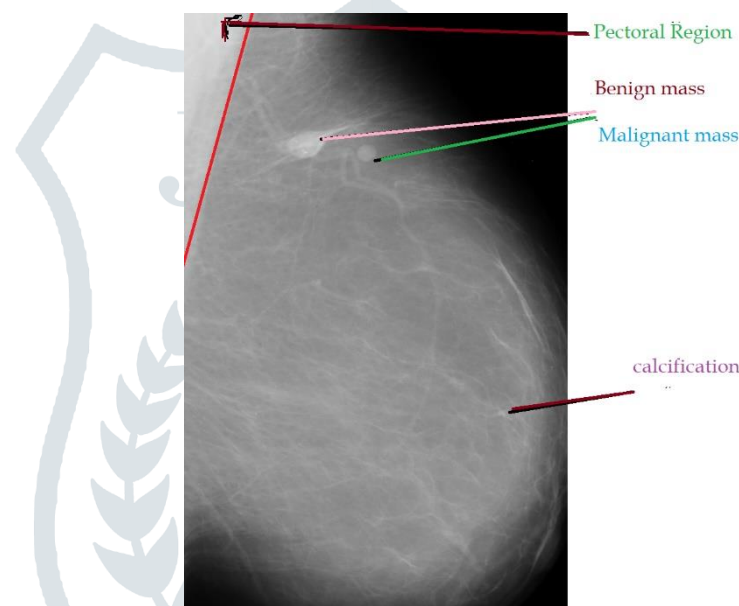

Fig 1.1 Sample Mediolateral Oblique Mammogram

In Mediolateral Oblique Mammogram segmentation, the Pectoral muscle significantly increases false positive masses because its intensity tissue is similar to the intensity of mass. So, Pectoral muscle removal is strongly suggested before detecting the masses from a Mediolateral Oblique Mammogram.

Several conventional solutions have been proposed for pectoral muscle removal [6, 15]. Segmentation, bounding box, region growing, canny, and wavelet approaches are the various approaches used to delete the pectoral muscle. Average accuracy of existing solutions is 92.6%. Pectoral muscle shape can be in triangle or parabolic form. The form and area of the Pectoral muscle are affected by the size of the Breast organ. Visibility of the Pectoral muscle is affected by operated lymph nodes and the presence of skin. It is challenging to detect Pectoral muscle if the tissue is dense. It is observed that most of the proposed approaches did not consider all the parameters mentioned above, like shape, tissue type, operated lymph nodes, presence of skin, etc., while removing pectoral muscle.

This research proposes a Novel Hybrid approach where MSERPectoral and HoughPectoral methods are combined to detect and remove Pectoral muscle.

The rest of the paper is organized as follows: Section II briefly outlines the research work carried out in the area. Section III provides proposed method pseudocode. Section IV presents the conclusion.

II. RELATED WORK

Many Pectoral Removal approaches are proposed. Critical approaches are summarised as follows. For performance analysis, Mini-MIAS database is used in all these approaches:

S. Marijeta et al. [6] used morphological operations and K-means to predict the Pectoral border. This approach received an accuracy of 68.42%, acceptable cases of 19.25% and bad cases of 12.42%.

P. S. Vikhe et al. [7] introduced a Pectoral removal technique where intensity-based thresholding is used to find boundary points of the computed Pectoral region and followed by the Least Square Error (LSE) method is used to prune the boundary points. The author claimed 87.19% accurate cases, 9.37% acceptable cases and 3.44% inaccurate cases.

M. Mughal et al. [8] suggested a wavelet-based approach to removing Pectoral muscle. This approach received an accurate cases of 77.63%, acceptable cases of 14.59% and bad cases of 7.76%. However, the proposed method is semi-automatic.

Syeda Iffat Naz et al. [10] used Global thresholding and Weak Boundary Approximation technique to detect the Pectoral where-in the mean intensity of either the left quarter or right quarter of an image based on the orientation of the Mammogram is taken as the global threshold, and then the image is filtered accordingly. Then the Pectoral muscle is detected based on computed slope. Obtained accuracy of this approach is 92.86, 4.97 acceptable accuracy score and 2.17% unacceptable cases.

Saeid Asgari Taghanaki et al. [11] proposed a Pectoral approach based on Geography rules and region growing technique. This approach detects Pectoral muscles irrespective of their shape. It gave exact results for 67% of cases, optimal results for 18%, and adequate cases are %5. The remaining 10% are unacceptable cases.

Samuel Rahimeto et al. [12]· found a method for removing Pectoral muscle where-in Otsu's muti-thresholding algorithm filters the bright region, which is the detected Pectoral muscle. The author obtained the Pectoral muscle detection accuracy as 93.36%.

Enas Mohammed Hussein Saeed et al. [13] introduced an approach where Bounding Box and Region Growing techniques are merged to get more accurate results. Here, the result is given in terms of area difference between actual and Bounding Box, Region Growing and Merged one. According to the resultant analysis, merged approach gave better accuracy. The author claimed that the accuracy score as 98%, combining perfect matching and acceptable cases.

Pascal Vagssa et al. [14] used Hough transform to detect the Pectoral muscle borderline. The author got the results of 93.8% acceptable accuracy and 6.2% unacceptable cases.

G Vaira Suganthi et al. [15] proposed one Pectoral removal approach where-in active segment and intensity thresholding techniques are used to find the border between the Pectoral and the remaining part of the Breast region. The proposed approach received a 92.55% accuracy score. However, the proposed method may not give consistent results because it finds Pectoral boundaries based on the highest intensity in each row.

III. PROPOSED METHODOLOGY

The Pectoral is a thick muscle situated at the chest of the human body. It sits behind the Breast. The problem with Pectoral muscle is that its features like intensity look similar to masses. So, there is the highest possibility for the Pectoral muscle/part getting selected as a mass. Hence, better to remove the Pectoral muscle before detecting Breast masses for cancer.

In the proposed method, the Hybrid approach is used to remove the Pectoral muscle. MSERPectoral and HoughPectoral methods are used combinedly to detect the Pectoral muscle areas.

A total of three steps are applied here. In step1, the image's big contour is cropped to remove the label artefacts, and the left and right black background parts are also removed because the black parts do not give any information. In step 2, the proposed approach detects the pectoral region if exists. In step 3, the detected pectoral region is pruned and then deleted.

A. Preprocessing:

Original Mediolateral Oblique Mammogram may have artefacts like labels, different backgrounds. Mediolateral Oblique Mammograms have both right-oriented and left-oriented images. Preprocessing of Mediolateral Oblique Mammogram is an essential step to remove any artefacts if present and background also to be deleted. MLO Mammogram orientation is also to be set in the proper direction. Preprocessed Mediolateral Oblique Mammogram exhibits better quality and size also reduced significantly; in turn, this will improve the processing speed of further steps. Image cropping and Image flipping are the two preprocessing steps applied here.

Image Crop

In this process, we crop the Breast region from the original Mediolateral Oblique Mammogram Image using the Otsu method. The process of image cropping is explained through pseudocode1.
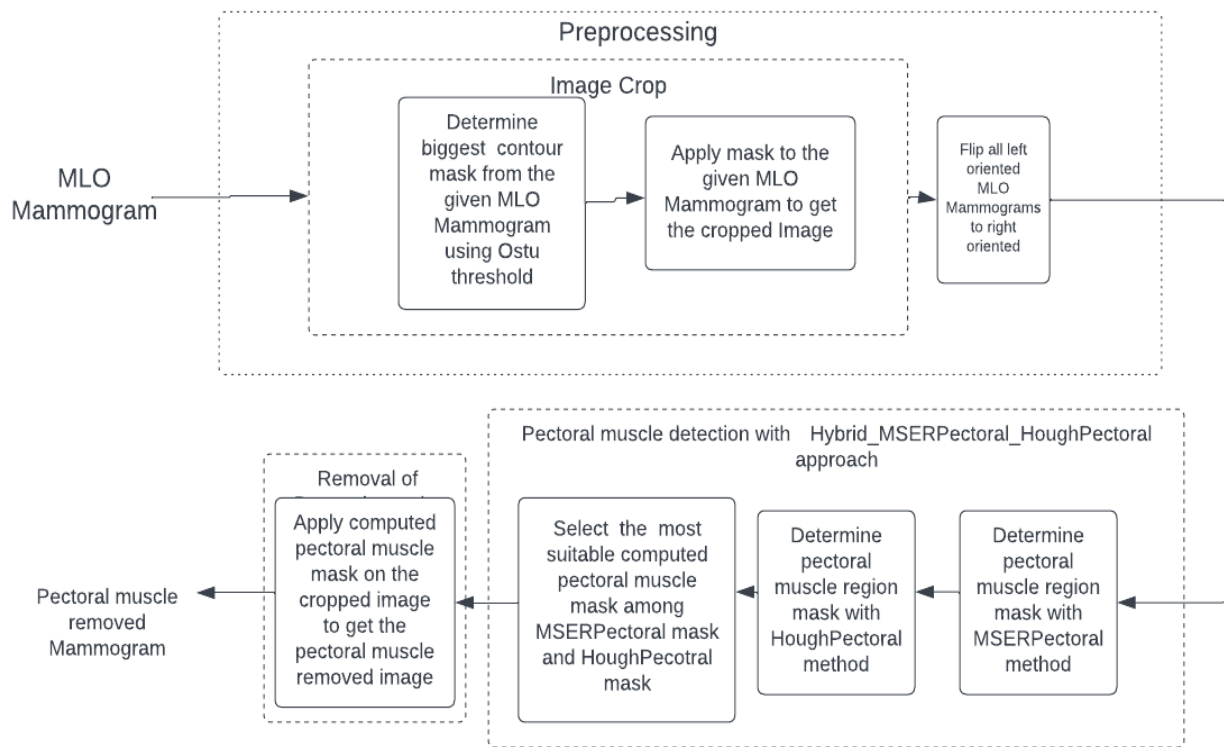
Fig.3.1 Block diagram of Proposed approach to detect and remove pectoral muscle from Mediolateral Oblique Mammogram

Ostu thresholding is the global thresholding technique that determines the threshold by minimizing weighted variance within the class. The method analyses the image histogram and segments the items by minimizing the variance for each category. After Otsu thresholding, morphological operations are applied like morphology close to remove small regions, morphology open to separate the breast from other parts, and morphology dilate to compensate for Otsu threshold for not getting some areas.

Pseudocode 1: ImageCrop(I)

Input: Original Image I

Output: Cropped image Icrop

Step 1: Apply GaussianFilter on I to remove noise

Step 2: Apply the Otsu method to the noise-free I

Step 3: Select the most prominent(biggest) contour in I after morphological operations

Step 4: Find the bounding rectangle of the largest contour

Step 5: Crop the required breast region image by the bounding rectangle values; Icrop from I

Step 6: Return Icrop

B. Flipping of the cropped image.

After cropping, in the resultant image, the Pectoral region will be either in the top left or top right corner of an image. Before detecting the Pectoral region, the orientation of the resultant image is changed so that all images will be right-oriented. So, all left-oriented images have to be flipped to the right oriented.

Pseudocode 2 is for flipping the image. This pseudocode is to flip the cropped Mammogram if it is left-oriented.

Pseudocode 2: Imageflip(I_{crop})

Input: I_{crop}

Output: Flipped image if it is left-oriented; otherwise, passed image is returned as it is

Step 1: Find the height and width of cropped image

step 2: Determine the mean of the top left corner of size 10% height x 10% width of cropped image

step 3: Flip the image if it is left oriented

step 4: Return the image

B. Pectoral Muscle detection

After preprocessing, the resultant Mediolateral Oblique Mammogram image is noise-free, cropped and right-oriented. A Hybrid approach is proposed here where MSERPectoral and HoughPectoral methods work together on preprocessed images to detect Pectoral muscle.

MSERPectoral is an adaptive MSER(Maximally Stable Extremal Region) technique that detects the Pectoral region of the Mediolateral Oblique Mammogram. HoughPectoral is another technique that can detect Pectoral muscle accurately for cases where Mediolateral Oblique Mammogram contains a slope-like shape, as shown in the following fig.3.2 with a red line.

Fig.3.2 MLO cropped Mammogram wit slope like shape shown with red line

For some very dense Mediolateral Oblique Mammogram images, MSERPectoral gives almost the entire breast as the Pectoral region, and HoughPectoral also does not work directly. In such cases, HoughPectoral is to be applied to the MSERPectoral detected region.

In the general MSER algorithm[9,24], a series of thresholds are applied – one for each threshold level. Later, the thresholding of the image at every threshold level is processed, creating a sequence of black and white images. At one extreme end white image and at the other extreme end black image is generated. In between, connected components grow and merge. The MSER algorithm is modified to fasten the process, which is only applied through dozens of grey levels. MSER works both ways, from black to white(MSER-) and white to black(MSER+). Because of these two, there will be unnecessary duplicates and thus modified to process from white to black(MSER+) only. A detailed example is shown in Figure 3.3.
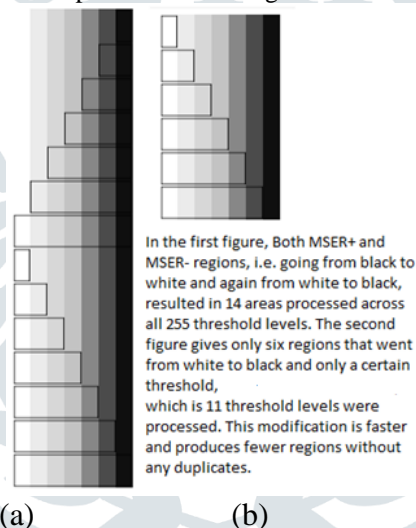

In the first figure, Both MSER+ and MSER- regions, i.e. going from black to white and again from white to black, resulted in 14 areas processed across all 255 threshold levels. The second figure gives only six regions that went from white to black and only a certain threshold, which is 11 threshold levels were processed. This modification is faster and produces fewer regions without any duplicates.

(a)   (b)

Fig.3.3 (a): Both MSER+ and MSER-regions (b) MSER+ regions with only certain threshold levels

The bounding box in each row indicates the MSER region. In Fig.3.3(b), the MSER is only processed through a set of threshold levels [from 255 to 50 with a gap of 20, which is 11 threshold levels]. The default endpoint is 50 because with respect to the observation, the Pectoral intensity will have an intensity of at least 50 and above.

For example, if the mean of a breast image results in 110, then the lower threshold is kept at 90, which is 110-20 i.e nine threshold levels are processed. 20 is subtracted from the mean just in case not to eliminate MSER regions that are stable near the mean levels. Then the stable connected components are resulted after processing through these threshold levels, which obtains very few images compared to the general MSER. The modified MSER is faster and outputs only the necessary images without duplicating. These images are further filtered, as shown in step 6 of algorithm 3, which contains only the pectoral region. The pectoral region is defined by the regions which contain the top left corner. The region should contain the top left corner, and the height of the region should be less than the Height of the image-100 as the Pectoral will be of a height of utmost image height - 150.

The entire process is written in algorithms. Pseudocode 3 is the overall algorithm that shows summarised steps.

Pseudocode 3: Hybrid_MSERPectoral_HoughPectoral(I)

Input: Original Image I

Output: pectoralMask

Step 1: Crop the Image I to get cropped image Icrop

Step 2: Flip the cropped image Icrop if it is left oriented

Step 3: Determine Pectoral muscle region mask using MSERPectoral method

Step 4: // True Pectoral muscle region mask height is less than the actual breast height

      Filter true Pectoral muscle region mask from the Pectoral mask found in the step 3.

Step 5: Determine Pectoral muscle region mask using HoughPectoral method

Step 6: If true Pectoral muscle region mask is detected by both MSERPectoral method as well as HoughPectoral method:

      Then select greater area Pectoral muscle region mask as the final mask

    Else

     Select the Pectoral muscle region mask of either MSERPectoral or HoughPectoral method based on whichever works

Step 7: Prune the resultant pectoralMask with the w-h triangle

Step 8: if both MSERPectoral method and HoughPectoral methods does not work :

      Then apply HoughPectoral approach on pectoral muscle region mask returned by MSERPectoral method

     If HoughPectoral method return a pectoral muscle region mask

      Then return computed Pectoral muscle region mask

     Else return nil

According to Pseudocode 3, MSERPectoral and HoughPectoral methods will be applied individually on cropped MLO Mammogram images to detect the Pectoral muscle regions. Both approaches may detect, or one may detect, or both may fail to detect the Pectoral muscle region. If the MSERPectoral process works, pruning is done on MSERPectoral detected region. If both ways work, the resultant MSERPectoral and HoughPectoral detected region areas are compared, and whichever region area is more is considered as the Pectoral muscle region.

The w-h triangle mentioned in step 7 is a simple triangle to prune some of the extra masses attached to the MSER region's Pectoral mass. It occurs in a few cases where some large mass will be close to the Pectoral and gets included in the MSER region. We are taking the max of the regions; there is a higher chance this will be considered, and then it is pruned with a triangle.

If only the MSERPectoral method detects the Pectoral muscle region, it gets pruned and deleted from the cropped image. MSERPectoral method does not work if the MLO Mammogram is fully dense and this method returns almost the entire breast image where the height of those regions will equal that of the breast.

If both methods do not work, the final step is applying HoughPectoral method on max of the Pectoral region mentioned in step 3, i.e. obtained by MSERPectoral that contains Pectoral region without filtering. If none of the above steps gives a region, then the algorithm outputs no Pectoral.

B.i MSERPectoral

MSERPectoral is the novel method that detects Pectoral muscle. It is the centre of the proposed approach.It returns the most significant stable connected component in the Pectoral region. MSERPectoral is an adaptive technique that detects only the Pectoral region. It works based on the existing Maximally Stable Extremal Regions Technique. The current Maximally Stable Extremal Regions Technique computes all stable connected components of an image for all intensity thresholds from 0-255 of an image[18]. However, the MSERPectoral adaptive method determines stable parts of the Pectoral region across only a few threshold levels to make it quicker.

It determines all stable connected components in the Pectoral region and returns the largest area region. Stable connected components area variation is local minimum. The local minimum of stable connected components is nearly identical over a delta (Δ) range of thresholds.
Area variation is computed using the following formula:

$$variation_{th} = \frac{(area_{th+\Delta} - area_{th-\Delta})}{area_{th}}$$

where $area_{th+\Delta} = area_{th}$ if $th+\Delta > th_{max}$
$area_{th-\Delta} = area_{th}$ if $th-\Delta < 0$

Pseudocode 4: MSRPectoral(I_{crop})

Input: I_{crop}

Output: Pectoral Muscle Region or None

Step 1: Find all connected components of the Pectoral muscle in an Image; for each threshold th in the set of threshold levels adaptive to the breast image and add them to component Tree. Sweep these thresholds of intensity levels decreasing from white(255) to black. Filter the component regions as described in Pseudocode 3.

Step 2: Determine Component area variation for each component within the range of Δ (Delta) thresholds and add it to variation list

Step 3: From the variation List, select regions with a local minimum

Step 4: Find largest Pectoral region

Step 5: Return largest Pectoral region

The modified MSER algorithm is implemented in Matlab with parameters MaxAreaVariation, MinArea and MaxArea. The MinArea is set to exclude very tiny regions, and the Max area is setting maximum region area so that if the region's area is greater than Max area, then the region is excluded. Sometimes MSER will give the entire breast as the region; in those cases, this Max area parameter is useful. The most critical parameter is MaxAreavariation which specifies Maximum area variation between extremal regions at varying intensity thresholds. A more significant number of areas are returned when this value is increased, although they can be less stable. Stable regions are very similar in size over a range of intensity thresholds.

B.ii HoughPectoral Method

Pseudocode 5 is for the HoughPectoral method. The HoughPectoral method determines the Pectoral muscle region based on Hough lines; the Houghline technique uses Canny edges to detect initial Breast edges. Hough lines are detected for the given Mediolateral Oblique Mammogram based on those edges. The Hough line with the shortest length is selected from a set of computed Hough lines. The x-intercept, the y-intercept, is computed based on the Hough line angle with the x-axis and the returned distance.

Pseudocode 5: HoughPectoral(Image)
Input: Image
Output: Hough Pectoral Region
Step 1: Determine Hough lines
Step 2: Sort Hough lines in ascending order wrt dist
Step 3: Select the shortest Pectoral line from the list found in step 2
Step 4: Determine angle of shortest Pectoral line //Pectoral line angle wrt x-axis
Step 5: Determine x-intercept from the Pectoral line found in step 4
Step 6: Determine y-intercept from the Pectoral line found in step 4
Step 7: Find the Pectoral polygon with these intercept values.
Step 8: return Pectoral polygon

Houghline basics: According to the Cartesian coordinate system, $y=mx+c$ is the line equation. However, this form cannot represent vertical lines. So, the HoughLine approach uses the polar coordinate system to represent a line. The equation $r=x\cos\theta+y\sin\theta$ is line equation in the polar coordinated system, where r represents the perpendicular distance from the line to the origin and θ is an angle among this the horizontal axes and perpendicular line[25]. It is shown in the following figure:
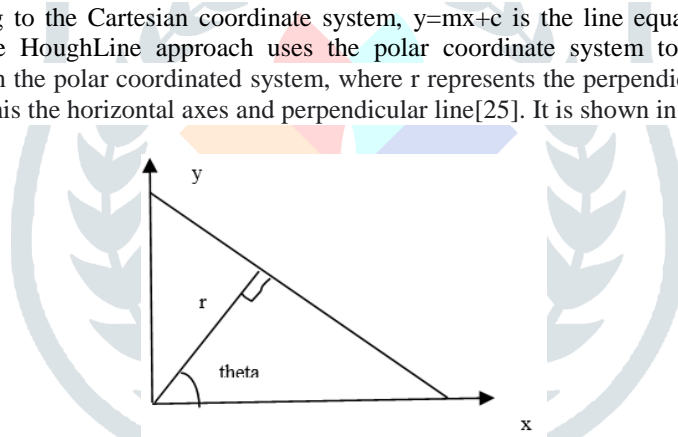

Fig 3.4 Houghline coordinates representation

In Hough space, a single point represents a line. θ and r are the two dimensions of Hough space; every line in Hough space is represented in the polar form where θ ∈ [0, 180] and r ≥ 0. Each (θ, r) represents a line.

Once the Pectoral muscle is detected, it is removed from Icrop Image. Following is the pseudocode for Pectoral muscle removal.
Pseudocode 6: PectoralRemoval
Output: Pectoral Removed Image
Step 1: Read Original Image(I)

Step 2: Find Final_Pectoral_Mask using Hybrid_MSERPectoral_HoughPectoral approach

Step 3: If Final_Pectoral_Mask= nil, go to Step 6; else, continue with Step 4

Step 4:Remove Pectoral from the cropped image by applying the Final pectoral black Mask to the Cropped Ima

Step 5: Output Pectoral Removed image Iprd goto step 7

Step 6: Output "No Pectoral Present in the image"

Step 7: Stop

IV. CONCLUSION
    This paper proposed a highly accurate and practical Hybrid approach that detects the Pectoral muscle region irrespective of its shape and quality of visibility. The hybrid approach comprises modified MSERpectoral and HoughPectoral methods with much filtering to obtain the Pectoral region. It could even check whether a Mammogram contains or not the pectoral. Future work is to implement the proposed approach.

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