Feasibility Study in Digital Screening of Inflammatory Breast Cancer Patients using Selfie Image

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Technical Memo

Abstract: Inflammatory breast cancer (IBC) is a rare and an aggressive breast cancer type. The primary symptoms of IBC are often misinterpreted as skin allergy or infection, hence a proper screening tool for primary IBC screening is necessary. In this study, a screening technique is developed and tested, in order to diagnose IBC patients in their early stage of disease, which will reduce the mortality rate. This technique is developed in image processing platform using a person’s selfie breast images. The screening image can be taken from one’s own cell phones. Breast area (inflammation), breast color (pigmentation) and breast texture are the screening parameters used in this study. The developed screening technique is tested for its accuracy with a set of IBC images and healthy breast images and the result shows that the screening technique is highly significant.

Index Terms: Inflammatory breast cancer, image processing, breast tumor, selfie image.

I. INTRODUCTION

Inflammatory breast cancer (IBC) is a rare but very aggressive breast tumor type among women [1]. Among the total number of breast tumor cases, only around 1% to 6% is reported to be IBC cases [2]. The IBC will be visible in the form of highly swollen breast with discoloration and rashes spread from the breast region to the chest, whereas this physical appearance happens to the third to fourth stage of cancer. The initial prognosis of this disease is difficult because it does not have a special histopathological pattern [3]. Hence it is highly challenging to diagnose the IBC in the early stage. IBC are categorized into two namely, Primary inflammatory breast cancer and Secondary inflammatory breast cancer [4]. The primary IBC is the case where sudden onset of the disease occurs without any prior indications or health issues. The rashes and swelling happens suddenly over few days. The secondary IBC is the presence of inflammatory symptoms on a previously detected masses or tumor structures [5]. The various treatment modalities used for the treatment of IBC is a combination of induced chemotherapy, radiation and surgery [6]. Primary IBC is considered to be the real clinical cases of IBC and is very difficult to diagnose due to its sudden onset with no prior indications. The primary symptoms of IBC can be misinterpreted or diagnosed as fungal or bacterial infection in many cases, hence it is necessary to develop a strategy to differentiate IBC primary symptoms with Interigo symptoms. This study develops an image processing platform to screen IBC patients using their breast photographic images. This study proves the feasibility of differentiating IBC from other skin diseases and probably can be developed as a screening tool of IBC early stage diagnosis by simple breast photographs.

In this study, an image processing platform is developed to screen patients using their selfie breast images. The convenience is that the pre-screening can be done using a selfie image. The change in breast texture, breast color and breast size are the main parameters used for developing this screening tool. These parameters were chosen since these are main symptoms of IBC [7]. The various image processing techniques like texture segmentation, color segmentation etc., are used to develop this screening tool for IBC. After successfully developing the screening platform, the efficiency is tested by using images of breast cancer patients and healthy breast images. This algorithm is developed to classify the screening candidates as IBC positive or IBC negative. This image processing platform can be developed inside the smartphones, which can potentially give them the screening result by clicking a picture and running the application. This initial study opens a new pre-screening paradigm for inflammatory breast cancer among women.
II. EXPERIMENTAL PROCEDURES AND METHODOLOGY

In this section, the experimental procedures and methodology to develop IBC screening platform is explained. The experimental procedure includes two sections. First section is to the development of the screening algorithm with a test image. Second section includes the testing and validating the developed algorithm with real IBC patient’s breast images and healthy breast images. The IBC screening platform uses digital images of breast as the input for analysis. These images are photograph images of patient’s breast taken in anterior to the breast as shown in Fig (1). The advantage of these kind of photographs is that a patient can take his/her breast selfie image and can send for analysis or can be processed at a smartphone. The convenience level is very high by selecting this mode of input image. In majority of the cases, IBC occurs in only one breast at a time, but for the analysis, the digital image should contain both right and left breast images for comparison. The various markers or parameters used in this work are change in skin texture, change in breast color (pigmentation) and change in breast area (inflammation).

![Fig 1: Digital image of IBC breast for analysis.](image)

Image courtesy: Inflammatory Breast Cancer Foundation

The two sections of experimental procedure and methodology are explained below:

A. Development of screening algorithm:

The breast digital image obtained from the patients can possibly include lot of background images, birth marks, tattoos and other body parts such as shoulders, etc. Hence the preprocessing of the images is necessary before the analysis. The region of interest for analysis is only the breast region, which will be selected and will be assigned as left and right breast as shown in Fig 2(a) and Fig 2(b).

1. Analyzing Texture difference:

The primary symptom of IBC is the change of texture of the breast. If a person is suspected with IBC, their breast skin surface will have a change in texture, which can be a mild dis continuity in skin surface to an open pore orange peel skin texture. The texture difference can also occur due to other medical conditions like skin allergy, infectious diseases etc. But IBC usually affects only one breast at a time [8], hence a relative texture difference value will be primary screening factor. This change in the texture of skin surface is monitored, measured and quantified in this section. The region of varying texture is analyzed using texture segmentation based on edge detection method. This process is done using the Law’s filtering technique [9]. All the preprocessed image for analysis should be converted into gray scale for further analysis. According to Law’s technique, there are three steps for analyzing texture difference.

i. Filtering the input image using texture filters

In order to do the filtering of the image based on the texture, different masks are applied to the greyscale image. These masks are defined as Law’s mask. These masks comprise of four filters, where each filter contain five vectors. The first filter is a Gaussian filter which gives a center weighted local average and is represented as L5. This filter is used to determine the change of levels in the image. The representation of level L5 filter with its five vectors is shown in equation (1).

\[ L_5 = [l_1, l_2, l_3, l_4] \]  

(1)

The second filter is a gradient filter which responds to the row or column step edges in the image. This filter also contains five vectors as well, and is represented as E5 = [e_1, e_2, e_3, e_4, e_5]. The third filter in the Law’s mask is a Laplacian of Gaussian filter (LOG) which helps in detecting spots in the image. This filter has five vectors and is...
represented as $S_5 = [s_1 \ s_2 \ s_3 \ s_4 \ s_5]$. The forth and the final filter is a Gabor filter which is used for ripple detection in images, and this filter is represented as $R_5 = [r_1 \ r_2 \ r_3 \ r_4 \ r_5]$. All the vectors of the five filters has to be defined according to level of filtering required for our application. The above-mentioned filters are one dimensional. The greyscale image is two dimensional hence a 2D convolution masks are created using the above mentioned one dimensional filtering masks. By convoluting a vertical one-dimensional vector with a horizontal one, 16 two-dimensional filters of size 5x5 were generated as given below which is shown in table (1)

$$
\begin{array}{cccc}
L_5L_5 & E_5L_5 & S_5L_5 & R_5L_5 \\
L_5E_5 & E_5E_5 & S_5E_5 & R_5E_5 \\
L_5S_5 & E_5S_5 & S_5S_5 & R_5S_5 \\
L_5R_5 & E_5R_5 & S_5R_5 & R_5R_5 \\
\end{array}
$$

Table 1: 2D convolution masks

These two-dimensional masks which are developed by 1 dimensional law’s filters will be applied to the greyscale input breast image and will perform the texture based filtering.

**ii. Obtaining texture energy measurements from the image:**

The second step of analyzing the texture difference is to compute texture energy by summing the absolute value of filtering results in local neighborhoods around each pixel. To extract texture information from an image $I_{(i,j)}$, the image was first convoluted with each two-dimensional mask mentioned above. For example, if $E_5E_5$ mask was used to filter the image $I_{(i,j)}$, the result will be a “texture image” ($T_{E5E5}$).

$$
T_{E5E5} = I_{(i,j)} \times E_5E_5
$$

(2)

According to Law’s method, all the two-dimensional masks, except $L_5L_5$ had zero mean. Thus, texture image $T_{L5L5}$ was used to normalize the contrast of all other texture images $T_{(i,j)}$. The outputs ($T$) from Law’s masks were passed to "texture energy measurements" ($M$) filters which consists of a moving non-linear window average of absolute values.

$$
M_{(i,j)} = \sum_{u=-3}^{3} \sum_{v=-3}^{3} | T_{(i+u)(j+v)} |
$$

(3)

**iii. Obtaining rotational invariance**

The final step of texture segmentation is to combine features to achieve rotational invariance. By combining the sixteen $M$ descriptors, we obtained nine rotationally invariant texture energy measurements. For example, $Y_{E5L5}$ was obtained as follows

$$
Y_{E5L5} = \frac{M_{E5L5} + M_{L5E5}}{2}
$$

(4)

The nine masks or rotational invariant texture energy measurements are shown below in Table 1. These masks were applied into the original image to obtain a result as an edge segmented filtered image as shown in Fig 2 (c) and 2 (d).

$$
\begin{array}{cccc}
Y_{E5L5} & Y_{S5L5} & Y_{R5L5} \\
Y_{S5E5} & Y_{R5E5} & Y_{E5E5} \\
Y_{R5E5} & Y_{S5S5} & Y_{R5S5} \\
\end{array}
$$

Table 2: Rotational energy masks.

2. **Analyzing color difference analysis**
Color change in the breast skin is one of the main indicators of IBC cancer. Hence discoloration has been used another parameter for IBC screening in this work. The breast color varies from person to person according to their general skin tone, hence a single breast analysis will be difficult. Instead, here in this work the breast color difference is analyzed and compared between both the breasts to get a quantified marginal value. The Canny edge detection algorithm [10] is used to extract features of the digital image.

i. **Smoothen the image to reduce noise**

The first step is to reduce the noises in the image. A first order derivative Gaussian filter will be applied to the image to smoothen the image [11]. The Gaussian filter can be expressed in equation (5). This Gaussian filter is for a kernel size \((2k+1) \times (2k+1)\). For our application, we used a 5X5 filter to smoothen the image.

\[
F_{(i,j)} = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{(i-k+1)^2 + (j-k+1)^2}{2\sigma^2}\right)
\]  

(5)

This Gaussian filter is convoluted with the input image to reduce the noise. For an input image \(I_{(i,j)}\) can be convoluted to produce a smoothened image as represented as \(\hat{I}\) as shown in equation (6).

\[
I'_{(i,j)} = F_{(i,j)} \times I_{(i,j)}
\]  

(6)

ii. **Calculating the intensity gradients**

The Canny edge algorithm uses four different filters to calculate the intensity gradient in an image for the horizontal \((G_x)\), vertical \((G_y)\) and two diagonal directions respectively. Inside this algorithm, they use a specific edge operator like Sobel and retrieve a first derivative value for horizontal \((G_x)\) and vertical direction \((G_y)\). The total intensity gradient \((G)\) of the image is calculated using the below equation (7).

\[
G = \sqrt{G_x^2 + G_y^2}
\]  

(7)

iii. **Performing edge thinning**

The edge thinning is performed by suppressing the non-maximum values. After applying gradient, there is a high chance than some of the edge will be blurred and will not be able to differentiate to obtain any feature of the image. In this section if the edge values are less than local minima, it will retrieve as zero. After performing this technique, the representation of real edges of the image will be more specific and clear.

iv. **Edge map hysteresis**

To get the proper edge map hysteresis thresholding is employed which will link between the weak and strong edges. The weak edges are taken into consideration if and only if it is connected to one of the strong edges or else it is eliminated from the edge map. The strong edge is the one whose pixel is greater than the high threshold and weak edge is one whose pixel value between high and low threshold.

3. **Analysis of size difference**

The IBC affected breast will be inflated because of the lymph node infection. This inflammation can be of different grade such as low inflammation to highly inflated cases. Other clinical cases of inflated breast is during lactation or pregnancy period but in the case of IBC, which will affect only one breast in most of the cases, the affected breast will only be inflated whereas the other one remains the same size. This difference in the area of the left and right breast will be calculated and quantified to analyze the size difference.

B. **Obtaining the quantified value for testing parameters**

After getting a texture analyzed image, the texture difference between right and left breast have to be quantified. Converting the texture analyzed image into binary image which elevates the orange peeled texture region. Counting the non-zero elements for each breast will give a quantified texture value. Taking absolute difference between the texture values of both the breasts will give the rate of change of texture, \(dT\) as shown in fig 2(e) and fig 2(f).
Fig 2: Texture analysis output images (a) Left breast input image (b) Right breast input image; (c) Edge detected filtered image – left breast (d) right breast (e) Edge variation region selected using thresholding –left breast (d) right breast.

The edge detected image will clearly show the regions of color difference, hence the image will be segmented based on the color. The region of color variation will be quantified as binary pixel count. The left and right breast color pixel count will be subtracted to get the color difference value \( dC \). The color based edge segmented images for original image is shown in Fig 3(a) and (b).

Fig 3. Color based edge detection output image (a) Left breast (b) Right breast

The area of both the breast is measured by calculating the number of pixel in the binary image of the breast. Both the areas of left and right breast are calculated and the absolute difference is measured, which gives the quantified inflammation rate \( dA \).

C. Testing the IBC screening tool

After developing the image processing platform for inflammatory breast cancer screening, several digital images were collected for both healthy and IBC breast from various clinical cases. A total of 13 clinical cases were considered for testing the IBC screening tool. Each image is analyzed using the screening tool, to determine the parameters, such as \(dT, dC \) and \( dA \).

D. Classification of IBC cases

The IBC parameters such as texture difference, color difference and area difference can have a wide range of values since the input is a personalized digital image of breast, which does not have a standard image pattern. Hence the classification of IBC cases based on the data set is done by averaging the parameter values for each case. The average value of parameters is considered as classification factor as given below:
The threshold value is for classifying the IBC cases is been selected based on the classification factor values obtained from the digital images tested using the screening tool.

III. RESULT AND DISCUSSIONS

The IBC screening tool is used to analyze 13 clinical cases which include both IBC and healthy breast images. The quantified parameter values for each case is given in Table 3.

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Change of Texture, $dT$</th>
<th>Change of Area, $dA$</th>
<th>Change of color, $dC$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1++</td>
<td>2434</td>
<td>2495.3</td>
<td>1260</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>1.875</td>
<td>91</td>
</tr>
<tr>
<td>3++</td>
<td>3732</td>
<td>3821.2</td>
<td>334</td>
</tr>
<tr>
<td>4+</td>
<td>21609</td>
<td>22264.0</td>
<td>9367</td>
</tr>
<tr>
<td>5</td>
<td>182</td>
<td>190.375</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>557</td>
<td>579.5</td>
<td>15</td>
</tr>
<tr>
<td>7++</td>
<td>365</td>
<td>363.37</td>
<td>293</td>
</tr>
<tr>
<td>8</td>
<td>63</td>
<td>67.25</td>
<td>93</td>
</tr>
<tr>
<td>9+</td>
<td>270</td>
<td>288.75</td>
<td>1230</td>
</tr>
<tr>
<td>10</td>
<td>79</td>
<td>84.25</td>
<td>92</td>
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<tr>
<td>11</td>
<td>7</td>
<td>14.25</td>
<td>21</td>
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<tr>
<td>12++</td>
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<td>1753.1</td>
<td>634</td>
</tr>
<tr>
<td>13++</td>
<td>8760</td>
<td>9009.5</td>
<td>1541</td>
</tr>
</tbody>
</table>

Table 3: Analysis of breast image using IBC screening tool. “++” denotes the clinically IBC cases

The texture variation between left and right breast on IBC patients shows a very big value and the number increases as the severity of the cancer, whereas the normal breast shows very small texture difference range. Some overlap of parameter values could happen because of natural skin texture issues of a human being. This proves that, change of texture is a significant parameter to differentiate IBC and healthy breast. The change of area, $dA$ is a highly significant parameter, since the difference in the values of healthy and IBC breast as very well seen in Table 1. The cancer affected breast will vary in its size from the normal breast, which is the primary symptom of inflammatory breast cancer. But in default, according to anatomy, the left and right breast will never be of same size even in a healthy patient, which shows some difference in size values, $dA$ even for healthy breasts. Left and right breast of a women should be of same skin color, except for the presence of some birth marks, moles or tattoos. These natural or manmade identification marks produce some value in change of color parameter, $dC$ in healthy breasts. Even in normal healthy breasts, the change of color can be 0 too as shown in a case study in Table 1. In table 1, the $dC$ values are of high range for breast cancer cases and it proves that this parameter is the highly significant IBC screening marker tool.

The classification factor is calculated for all the cases and is shown in Table 4. The threshold value is selected to be 340. The cases which have classification value above 340 will be IBC and below 340 will be classified as a normal case. Except one case which becomes false positive, rest all the cases are classified accurately as compared to the clinical classification.

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Clinical classification</th>
<th>Classification factor</th>
<th>Screening Tool Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IBC</td>
<td>2063.1</td>
<td>IBC</td>
</tr>
<tr>
<td>2</td>
<td>Normal</td>
<td>32.29167</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3</td>
<td>IBC</td>
<td>2629.067</td>
<td>IBC</td>
</tr>
<tr>
<td>4</td>
<td>IBC</td>
<td>17746.67</td>
<td>IBC</td>
</tr>
<tr>
<td>5</td>
<td>Normal</td>
<td>124.125</td>
<td>Normal</td>
</tr>
<tr>
<td>6</td>
<td>Normal</td>
<td>383.8333</td>
<td>IBC++</td>
</tr>
<tr>
<td>7</td>
<td>IBC</td>
<td>340.4567</td>
<td>IBC</td>
</tr>
<tr>
<td>8</td>
<td>Normal</td>
<td>74.41667</td>
<td>Normal</td>
</tr>
<tr>
<td>9</td>
<td>IBC</td>
<td>596.25</td>
<td>IBC</td>
</tr>
<tr>
<td>10</td>
<td>Normal</td>
<td>85.08333</td>
<td>Normal</td>
</tr>
<tr>
<td>11</td>
<td>Normal</td>
<td>14.08333</td>
<td>Normal</td>
</tr>
<tr>
<td>12</td>
<td>IBC</td>
<td>1362.7</td>
<td>IBC</td>
</tr>
<tr>
<td>13</td>
<td>IBC</td>
<td>6436.833</td>
<td>IBC</td>
</tr>
</tbody>
</table>

Table 4: Breast images classified using classifying factor. **+** indicates the false positive case.

IV. CONCLUSION

This feasibility study proves the ability of certain parameters to screen IBC patients on their stage of disease. Change in texture, change in color and change in area are very strong and significant parameters to classify the inflammatory breast cancer patients. In this work, an effective IBC screening tool is developed and different clinical cases are screened using this tool. The classification factor is defined and calculated based on the screening tool parameter values obtained. This classification of the inflammatory breast cancer using selfie image is done using the above mentioned classification factor values. The initial testing proves that the IBC screening tool have an accuracy of 92.3% in classifying the tumor cases based on the selfie image.

V. REFERENCES


