Mammographic Image Contrast Enhancement through the Use of Moving Contrast Sweep

Zailani Mohd Nordin, Nor Ashidi Mat Isa, Umi Kalthum Ngah,
and Kamal Zuhairi Zamli

School of Electrical and Electronic Engineering,
Universiti Sains Malaysia,
Seri Ampangan, 14300 Nibong Tebal,
Pulau Pinang, Malaysia
zailani_mohd_nordin@hotmail.com, ashidi@eng.usm.my,
umi@eng.usm.my, eekamal@eng.usm.my

Abstract. Low contrast in mammographic image has always made detection of subtle signs such as the presence of micro calcification within dense tissue a challenge. Therefore, numerous researches have been conducted on contrast enhancement technique for mammographic image. However, most of these methods focus on enhancing specific range of intensity level producing an enhanced version of the original image. This paper proposes a new approach in dealing with contrast enhancement for mammographic images. Instead of producing just a single image, the approach proposed here will generate multiple different images where each of them corresponds to different range of intensity level. These images will then be combined together to form frames of a moving video which would display seamless transition from one intensity level to another. As a result, the radiologist who is performing visual inspection of the image can sweep through the entire range of intensity level of the image which has been contrast enhanced.

Keywords: Mammogram, Mammography, Mammographic, Contrast Enhancement, Contrast Sweep.

1 Introduction

Breast cancer is one of the most common types of cancer among women reported all over the world. It is also the most frequent type of cancer reported among Malaysian women. Based on a report by National Cancer Registry of Malaysia in 2003[1], around 30% of reported cases of cancer for women in Malaysia is attributed to breast cancer. One of the best tools used to detect early signs of breast cancer is mammography. The low doses of X-rays used in mammography are capable of detecting microcalcifications (MCC), one of the earliest signs of breast cancer as well as the presence of other abnormalities. However, one of the biggest challenges with mammography is that the produced image tends to be low in contrast making the detection of MCC difficult especially in regions with dense tissue. Quite a number of studies have been conducted on contrast enhancement techniques especially in the area MCC detection [2].

High contrast in an image means that the difference between one intensity level to its adjacent value is high. The ability to project the difference between intensity levels is important because it determines the amount of details which can be perceived by the observer. The differences in these intensity levels must be big enough before they are distinguishable by human eye [3].

Traditionally, contrast enhancement is done on an image by taking the image and running it through the contrast enhancement process to produce an enhanced version of the image. Morrow et al. [4] proposed the use of region base contrast enhancement technique by firstly identifying the region for feature of interest through the use of the seed growing technique. The contrast between the region of interest and its background was then enhanced to create greater separation between their intensity levels which would make the region of interest more visible to the observer. Laine et al. [5] proposed the use of dyadic wavelet analysis for image enhancement. The image was decomposed into multiresolution representation and processed through linear and non-linear operators which would enhance significant features in the image. Veldkamp et al. [6] proposed the used of local contrast enhancement with adaptive noise equalization which was proven to be more effective than using a fixed noised equalization alone. Contrast enhancement steps performed in the method proposed by Nunes et al. [7] was done by increasing the intensity level of pixels which have high probability of being related to MCC while the intensity level of pixels which most likely represent tissue was decreased. Cheng et al.[8] employed the use of fuzzy logic in contrast enhancement to enhance selected feature such as MCC while keeping the noise amplification to a minimum. Scharcanski et al. [9] proposed the used of adaptive local contrast enhancement technique. The enhancement was done adaptively, based on the gray level and noise value.

All contrast enhancement methods mentioned above have the same common goal i.e. to enhance regions having features of interest. Their advantages lie in their capability to target specific range of intensity levels to be enhanced which represent features of interest, a feat that may not be possible with a simple contrast enhancement technique. The simple contrast enhancement technique need to be performed globally or the range of intensity level need to be specified by the user and then enhanced manually, making it less effective compared to the methods above.

The method proposed here demonstrates that the effectiveness of a simple contrast enhancement technique can be increased through the use of a moving contrast sweep. Instead of producing the result in the form of a single contrast enhanced image, the method proposed here will produce multiple images which has been enhanced at different intensity levels. These images can then be combined to form frames for a moving video which will show seamless transition between intensity levels which have been contrast enhanced.

2   Methods

Sample images are obtained from Hospital University Sains Malaysia (HUSM), Kubang Kerian. They are actual mammographic images which have been digitized for our analysis. The programming routine which is described here is done through MATLAB.

The basic idea behind this technique is to develop a programming routine which opens up an image file, processed it through contrast enhancement techniques which could be sourced from an existing technique or a new one and then generate multiple enhanced images. Each image corresponds to a specific range of intensity level enhancement. The enhancement process is then repeated over the entire range of intensitities. The resulting images can then be layered on top of each other, forming moving video frames displaying seamless transition between intensity levels. This study focuses on mammographic images which are in gray scale format. If the image file uses color format, it must first be converted to gray scale before it can be processed through this methods.

The programming routine in this method is executed with the following parameters:

a. The file name of the input image,
b. The type of contrast enhancement to be used and
c. The sweep range of the intensity level where contrast enhancement will be performed.

There are two options for usage i.e. the full range of 0-255 or specifying a range of interest. Whatever the case may be, the lower and the upper limit of the intensity level range need to be specified. The steps of the sweep need to be ascertained too. This means that we can sweep every intensity levels within the range will be swept or by specifying the level value, it may be skipped. Finally, the spread of the intensity level which will determine the strength of the contrast need to be stated. A few more parameters may be added to the routine if a more complex contrast enhancement technique is desired.

2.1 Normalization

The first step to be executed after the image loading would be to normalizing the histogram so that the intensity level is evenly distributed across the histogram. These steps would help to simplify the contrast enhancement technique to be used. Performing normalization prior to performing contrast enhancement is not uncommon in this field. Cheng et al. [6] used histogram normalization with a predefined intensity level range prior to performing their contrast enhancement technique. Our histogram normalization technique is similar to the above method except that the intensity level range is determined adaptively in our approach. The normalization equation would be as follows:

$$j = \frac{i - i_{min}}{i_{max} - i_{min}} \times T \qquad (1)$$

In equation 1, i represents the value of original intensity level and j represents the new intensity after the normalization process. i_{min} represents the minimum intensity value while i_{max} the maximum intensity value; both having significant amounts of pixels. T represents the total number of intensity level which can be represented in an image. For an 8-bit grayscale image this value would be 255.

The maximum and minimum intensity value in our approach is determined by counting whether the intensity level has a significant amount of data. In this case, the

value which has been chosen to determine the significance of the intensity level is the number of pixel represented by the intensity level must be at least 0.00005% of the total number of pixels in the image. In our approach, we start measuring the amount of data represented by each intensity level starting from the highest possible level which is 255. We then start to work our way down the intensity level until we find a level which has a significant amount of data. This similar process is repeated from the lowest possible level in determining the minimum value for the intensity level.

The normalized image is then processed through contrast enhancement algorithm starting from the lowest intensity level in the range. For every single iteration, the intensity level is increased by the number of steps as specified at the beginning of the routine. For each iteration, the processed image is saved onto a file which records the intensity level as its name. For example if a full range (0-255) of the intensity level is being used with increment steps of 1, a total of 255 files will be generated where each one of them corresponds to an individual intensity level.

2.2   Contrast Stretching

For this paper, a simple non-linear contrast enhancement technique is used to redistribute the pixel intensity. The contrast enhancement technique used here is given by the equation 2:

$$j = \begin{cases} i & \text{if } i = i_x \\[2mm] \dfrac{i^s}{(i_x)^s} \times i_x & \text{if } i < i_x \\[4mm] 1 - \left(\dfrac{(1-i)^s}{(1-i_x)^s} \right) \times (1-i_x) & \text{if } i > i_x \end{cases} \tag{2}$$

In equation 2, i represents the value of the original intensity level and j represents the new intensity after the execution of the contrast enhancement process. i_x represents the targeted intensity level where the contrast enhancement is focused upon and s represents the spread magnitude of the intensity level which determines the strength of the contrast. This variable allows configurable contrast strength in the routine.

On a fairly fast workstation such as a quad core workstation, the time taken for this iterative process may take a few seconds or up to a few minutes depending upon the complexity of the contrast enhancement algorithm used and the size of the image.

2.3   Moving Video

The image files are then layered on top of each other to form frames of a moving video. This would provide a seamless transition between intensity levels making it visibly easier to see. Currently, an off the shelf movie editing software is being used for this task. However, further development is being planned in future to develop a customized tool for this task. This would allow greater freedom to the user in having
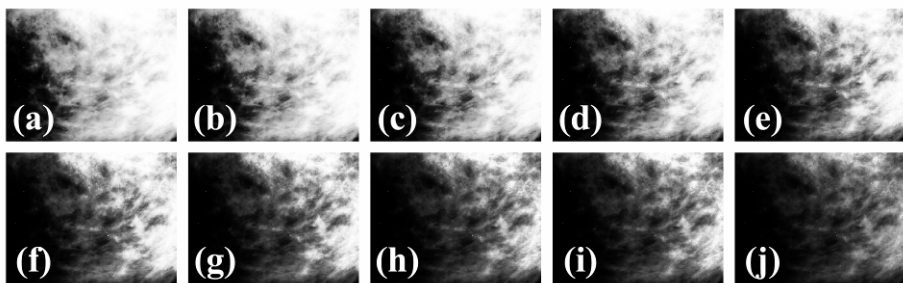
Fig. 1. Multiple images generated at multiple different intensity levels: (a)70 (b)90 (c)110 (d)130 (e)150 (f)170 (g)190 (h)210 (i)230 (j)250

greater flexibility and control to browse through the moving video frame. Figure 1 shows the transition of multiple frames of a sample image which has been contrast enhanced at different intensity level.

3   Results and Discussions

This method shows that MCC within mammographic image residing in different areas within the tissue can be exposed by performing contrast enhancement at different intensity levels.

Figure 2(a) shows the normalized version of the sample image 1. Clusters of MCC at the bottom left region of the image can reasonably be observed but clusters of MCC at the top right region are vague. Figure 2(b) shows contrast enhancement at intensity level of 150. Clusters of MCC at the bottom left region can be observed much clearly but clusters of MCC at the top right region cannot be detected at all. Figure 2(c) shows contrast enhancement at the intensity level of 255. Clusters of MCC at the top right region can now be clearly observed.
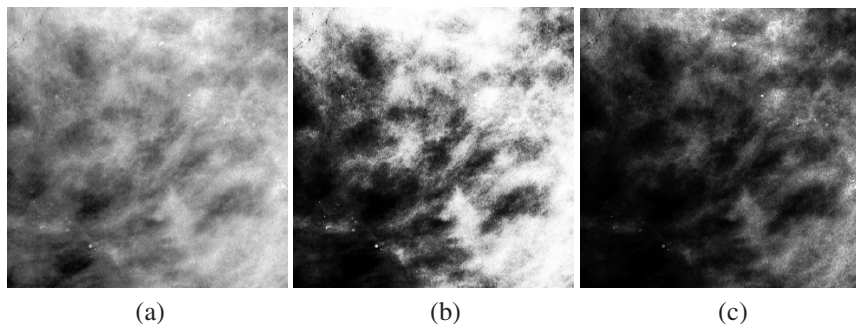

(a)   (b)   (c)

Fig. 2. (a)Image sample 1 which has been normalized (b) Image sample 1 which has been contrast enhanced at intensity 150 (c) Image sample 1 which has been contrast enhanced at intensity 255

Figure 3(a) shows the normalized version of the sample image 2. Clusters of MCC at the top left region of the image can vaguely be observed. Figure 3(b) shows contrast enhancement at the intensity level of 242. The clusters of MCC have become much more evident.
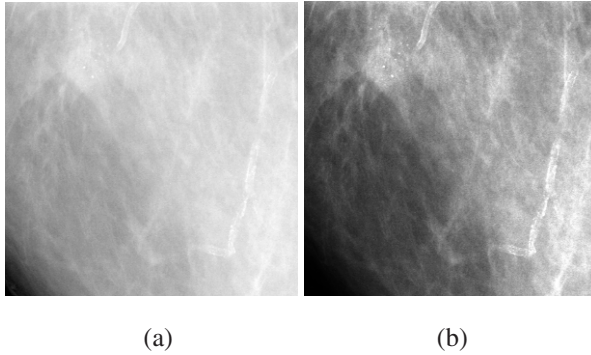

(a)   (b)

Fig. 3. (a)Image sample 2 which has been normalized (b) Image sample 2 which has been contrast enhanced at the intensity of 242

Figure 4(a) shows the normalized version of the sample image 3. Clusters of MCC at the top right region of the image are reasonably visible but those at the bottom left region are quite vague. Figure 4(b) shows contrast enhancement at the intensity level of 195. The cluster of MCC at the top right-hand region has become even more evident but not the ones at the bottom left-hand region. Figure 4(c) shows contrast enhancement at the intensity level of 250. The clusters of MCC at the bottom left region have become more defined.
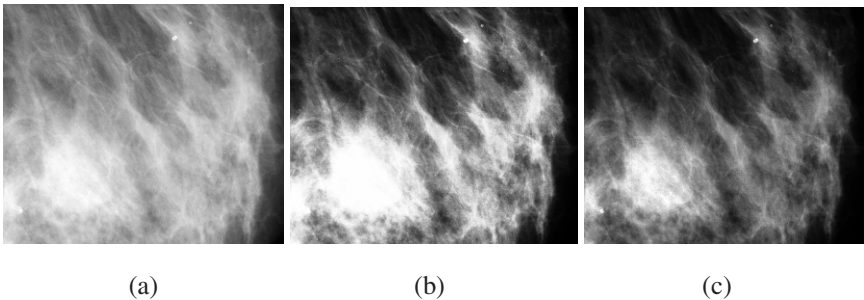

(a)   (b)   (c)

Fig. 4. (a) Image sample 3 which has been normalized (b) Image sample 3 which has been contrast enhanced at intensity 195 (c) Image sample 3 which has been contrast enhanced at intensity 250

The sample image shows that MCC residing in different regions within the breast tissue would require contrast enhancement to be performed at different intensity levels. Through this approach we can sweep through different intensity level seamlessly while at the same time, easily exposing clusters of MCC within different regions of

the image. This approach can be combined with other existing contrast enhancement, denoising techniques and other image sharpening techniques, making them even more effective in exposing the MCC. However, further development is still required in developing a more refined software taking into consideration the need for a user friendly and flexible environment necessary for users while allowing a much greater degree of control over the image enhancement process.

4 Conclusion

Based on the method proposed in this paper, it has been demonstrated that simple contrast enhancement technique which were previously not very effective in exposing MCC within mammographic images may now be put to a greater use. Previously, the detection of MCC in the cases displayed shown would require a more complex contrast enhancement technique. However, through the method proposed in this study, a simple contrast enhancement technique would be just as effective. Furthermore, it is also simple to use. The radiologist who performs the visual inspection does not need to configure the various contrast enhancement parameters while using it. Instead all that is needed is to sweep through the entire range of intensity levels to find any suspicious signs within the mammographic image.

Acknowledgement

References

1. Lim, G.C.C., Yahaya, H.: Second Report of the National Cancer Registry - Cancer Incidence in Malaysia. National Cancer Registry (Retrieved January 5, 2008) (2003), http://www.acrm.org.my/publications.htm
2. Rangayyan, R.M., Ayres, F.J., Desautels, J.E.: A Review of Computer Aided Diagnosis of Breast Cancer – Towards the Detection of Subtle Signs. Journal of the Franklin Institute 344, 312–348 (2007)
3. Gonzalez, R.C., Woods, R.E.: Digital Image Processing, 2nd edn. Prentice Hall, New Jersey (2002)
4. Morrow, W.M., Paranjape, R.B., Rangayyan, R.M., Desautels, J.E.: Region Based Contrast Enhancement of Mammograms. IEEE Transactions on Medical Imaging 11(3), 392–406 (1992)
5. Laine, A., Fan, J., Schuler, S.: Contrast Enhancement by Dyadic Wavelet Analysis. In: 16th Annual International Conference of the IEEE, pp. 10a–11a (1994)

6. Veldkamp, W.J.H., Karssemeijer, N.: Normalization of Local Contrast in Mammograms. IEEE Transactions on Medical Imaging 19(7), 731–738 (2000)
7. Nunes, F.L.S., Schiabel, H., Benatti, R.H., Stamato, R.C., Escarpinati, M.C., Goes, C.E.: A Method to Contrast Enhancement of Digital Dense Breast Images Aimed to Detect Clustered Microcalcifications. In: IEEE International Conference on Image Processing, vol. 1, pp. 305–308 (2001)
8. Cheng, H.D., Xu, H.: A Novel Fuzzy Logic Approach to Mammogram Contrast Enhancement. Information Sciences 148, 167–184 (2002)
9. Scharcanski, J., Jung, C.R.: Denoising and Enhancing Digital Mammographic Images for Visual Screening. Computerized Medical Imaging and Graphics 30, 243–254 (2006)