IRACST - International Journal of Computer Science and Information Technology & Security (IJCSITS), ISSN: 2249-9555
Vol. 5, No1, February 2015

Mammographic Image Enhancement Techniques-A Survey

Dr. Nedhal A. Al-Saiyd[1], Sameera M. Talafha[2]

Computer Science Dept., Faculty of Information Technology, Applied Science University, Amman Jordan
[1]nedhal_alsaiyd@asu.edu.jo, [2]sameera.talafha@yahoo.com

***Abstract*--Mammographic image is the most effective technique for breast cancer screening and early detection of masses or abnormalities. It can detect 85 to 90 percent of all breast cancers. When mammographic image is sent to certified radiologists or surgeons for interpretation, accuracy of the results is affected by poor contrast, quiet appearance of subtle details and high percentage of blurring and noise. It is thus necessary to develop suitable enhancement techniques which are attempt to make diagnostic more obvious. As they provide a many of choices for improving the visual quality of images. This paper provides a review over the main categories of enhancement algorithms, and discusses the main ideas behind mammographic image enhancing techniques. In this paper, detailed literature surveys on the various techniques used for mammographic image enhancement are presented and the mammographic images enhancement techniques are classified according to the work done in this field**.

Index Terms—Enhancement Techniques; Mammographic Images; Denoising, Edge Sharpening; Increasing Contrast.

I. INTRODUCTION

Enhancement is one of the essential and cost effective parts in medical image processing [1]. In recent years, different types of medical imaging techniques have been widely studied and used in medical detection, and one of them is the mammographic image [2]. Mammographic image is one of emerging technological advancements that have been used in diagnosing breast diseases or revealing cancer at early stages, where it is considered as the most effective method for the detection of early breast cancer [3]. Mammographic image is the most effective technique for breast cancer screening and early detection of masses or abnormalities. It can detect 85 to 90 percent of all breast cancers. Numerous studies have shown that the treatment at the early detection stages is more effective, and it will increase the treatment options, which in turn can save patient lives [4].

Mammographic images can show lumps, calcifications, and other changes in the breast, as it is shown Figure 1. The radiologist will study the breast changes in mammographic images that look abnormal situation and identify the differences between images of breasts compare the most recent ones with past mammographic images (if exist) of a patient to check for changes [5].

With digital X-rayed mammography, the radiologist checks electronic the breast images, using special high-resolution monitors. Radiologist or surgeon can adjust the brightness, enhance the contrast, and zoom in for close-ups of the Region of Interest (ROI). Being able to manipulate medical images is one of the main benefits of digital technology. Reading, interpreting and diagnosing the gray-scale mammographic image are difficult tasks, which require special training and experience from radiologists and surgeons [6].

Tumor and subtle features detection, in digital mammographic images are difficult tasks due to the following reasons; mammographic image interpretation is a hard task due to poor contrast and high noise levels in the image that can vary up to 10-15% of the maximum pixel intensity [5]. This is a problem because the image enhancement process may undesirably enhance noise component in the image, and the lesions in mammographic images may appear quite subtle.

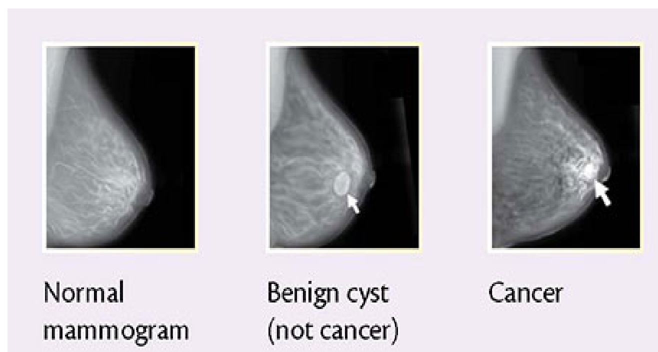

Figure 1. Mammographic images shown different breast changes [5]

There are two physiological types of breasts: dense breasts and non-dense breasts [6]. Dense breasts are the most difficult ones to analyze; the lesions in these images are often not-visible under the glandular tissues, which make the process of boundary detection a difficult task. The non-dense breasts are easier to analyses due to less fatty and glandular tissue making the lesions easily distinguishable from other parts of the breast [6].

Many enhancement methods are used to improve the visual appearance of mammographic image [7, 8, 9, 10]. Therefore, improve medical diagnosis to acquire good quality images so that the doctors can make use of these images to arrive correct conclusions. In this paper, we present an overview of mammographic image enhancement processing techniques. More specifically, processing methods based heuristic techniques of mammographic image enhancement are categorized. Thus, the contribution of this paper is to explain some of the relevant existing methods and present a new classification for all mammographic image enhancement techniques.

This paper is organized into following sections. Section 2 presents general mammographic image techniques. The techniques are presented in the next 4 sections. The spatial domain techniques are explained in sections 3. The frequency domain techniques are explained in sections 4. The hybrid techniques are explained in sections 5. The meta-heuristics techniques are presented in section 6. Finally, the conclusion is discussed in section 7.

II. COMPUTER-BASED MAMMOGRAPHIC IMAGE ENHANCEMENT SYSTEM

Image enhancement techniques are interested in improving the appearance of an image without referring to the conditions of image degradation process [11]. This will help the radiologist and surgeons by improving the possibility of interpretation and perception of mammographic image information. Image processing researchers have developed various image enhancement algorithms. Figure 2 shows the Computer-based Mammographic Image Enhancement.

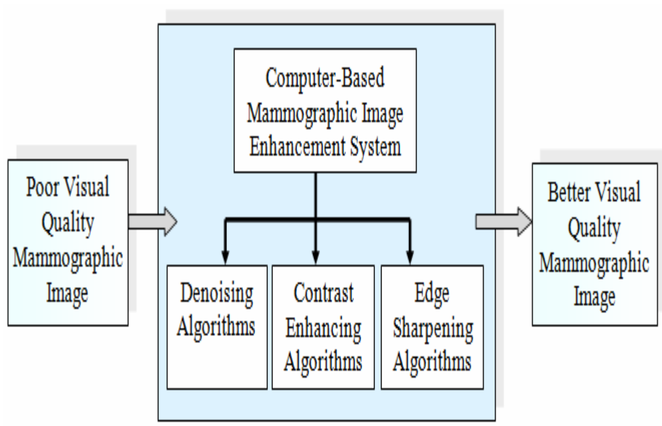

Figure 2. Computer-based Mammographic Image Enhancement

A. Image Denoising (Smoothing)

The noise in the mammographic images may adversely affect on the breast cancer detection rate and accuracy. Additive noise, Gaussian noise, impulse noise and Poisson noise are the different noise types that may degrade the quality of the image [12]. To eliminate the image noise, researchers have developed techniques that have the ability to separate the useful information from the noise.

$$x(n) = y(n) - \eta(n) \quad (1)$$

Where:

$y(n)$ is the noisy signal,
$x(n)$ is the noise-free signal, and
$\eta(n)$ is the pure noise signal.

Nonlinear filters; (such as: adaptive median, bilateral and regression, Wavelet thresholding, etc.), perform better than linear; (such as: moving average and Weiner), smoothing filters, and, and Laplacian mesh smoothing filters. The thresholding can be used in some techniques as in decomposition and empirical mode decomposition for denoising [13, 14].

B. Contrast enhancing

In mammographic image enhancement, contrast enhancement altars the brightness of an image based on non-model techniques that did not depend on the knowledge about the cause of image degradation [15]. it is done by amplify features that were clouded in the original image without amplifying noise and distorting edges, Researchers have developed many useful works through white or black stretching over adjusted and multi-scale adaptive intensity histograms, such as using Laplacian Pyramid [16, 17].

Michelson and Weber's defined Contrasts as [18]:

$$\textit{Michelson Contrast} = (Lmax-Lmin)/(Lmax+Lmin) \quad (2)$$

$$\textit{Weber Contrast} = Lmax/Lmin \quad (3)$$

Where:
Lmax: the local maximum,
L_{max} : the local maximum grayscale value of image,
L_{min}: minimum grayscale value of image.

C. Edge Sharpening

Edge is image brightness discontinuity between two reasonably smooth regions. It is characterized by gradient magnitude and direction. Laplacian, Unsharp masking; which is equivalent to adding on a fraction of Laplacian, are examples of *Edge Sharpening techniques.* Figure 3 shows the un-sharpening algorithm.

There is a group of algorithms that can enhance the image globally and over enhance the image internally and produce unsatisfactory enhancement. Consequently, enhancing the contrast and removing the noise at the same time; is considered as difficult situation and need more effort. Therefore, to enhance simultaneously the contrast of mammogram images and remove away the noise of the image, a good image enhancement technique should be well-selected to implement on the poor visual quality image. it is to improve image contrast of the mammogram images without increasing image noise.

III. MAMMOGRAPHIC IMAGE ENHANCEMENT TECHNIQUES

Mammographic image enhancement techniques have attracted many studies mainly spatial domain for gray scale that is the normal image space, direct operation on the pixel values, in which a change in position in image directly projects to a change in position in scene. Distances in image (in pixels) correspond to real distances (e.g. in meters) in scene and frequency domain that is modify the image frequency components [4, 7, 8, 11]. Spatial domain, frequency and hybrid domain techniques are used to get the desired results for enhance mammographic image [9, 12]. Recently, heuristic algorithms fuzzy logic, neural network and practical swarm optimization (PSO) have been used to increase the efficient for spatial and frequency domain techniques to enhance mammographic image [10, 13].

The techniques are studied thoroughly and in more details and are classified by the authors as it is shown in Figure 4.

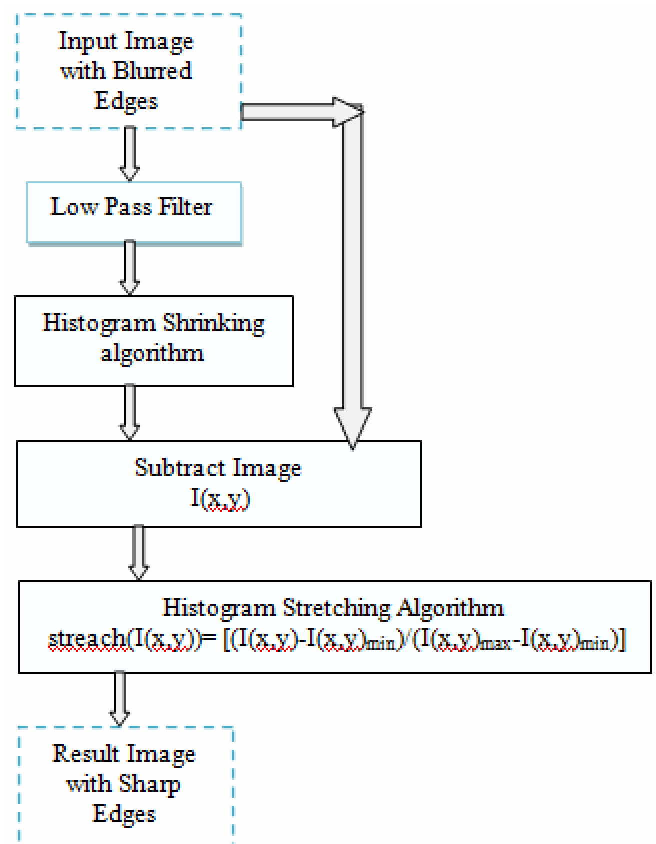

Figure 3. un-sharpening algorithm

IV. SPATIAL DOMAIN TECHNIQUES

In spatial domain techniques, it is directly deal with the image pixels [2]. The pixel values are manipulated to get most desirable enhancement results. The point processing methods are the best fundamental, earlier elementary image processing operation and are applied essentially for contrast enhancement. Image negative is worked for improving white detail integrated in dark places and has some application in medical imaging. Histogram Equalization (HE) is mostly used technique to enhance in mammographic images [4, 7, 14, 19]. Pisano (1998) [20] used the Contrast Limited Adaptive Histogram Equalization (CLAHE) in order to determine whether such a method can improve the detection of stimulated speculations in dense mammographic image. Herminger et al. (2001) [21, 22] is compared between CLAHE and Histogram-based Intensity Windowing (HIW), in order to determine which of them outperforms the other in the detection of stimulated masses in dense mammographic image. Where, the best HIW setting performed better than the performance with the best CLAHE settings was no different from that with no processing. Cheng, H. D., et al., (2004) [19] have been improved the Global Histogram Equalization (GHE) by using multi-peak HE combined with local information(multi-peak GHE).The results demonstrate that the method can enhance the mammographic image effectively than GHE. Thangavel K., et al., (2005) [23] used HE as a part of a pre-processing step for mammographic images enhancement. Hence the work extended to test the presence of mammographic images in the presence of noise and control over the level of enchantment that deals with the adjustment of features. In 2011, the histogram modified local contrast enhancement have been suggested [24], to alter the level of contrast enhancement, which in turn gives the output image a strong contrast and also brings the local details present in the original image for more relevant interpretation. It incorporates a two stage processing both histogram modifications as an optimization technique and a local contrast enhancement technique. This technique has been provided optimum results by giving better contrast enhancement and preserving the local information of the original mammographic image and the method has increased the detect-ability of micro-calcifications present in the given mammographic image. Al-Kindi, S. G., et al., (2011) [25] proposed a Hybrid Repetitive Smoothing Sharpening Technique(HRSS), that aims to highlight sudden changes in the mammographic image intensity, with the benefits of iterative image smoothing, which is applied to remove random noise from mammographic images. Where, this technique eliminates the disadvantages of each of the two sharpening and smoothing techniques resulting. Rajesh, K., et al., (2012) [26] used that CLAHE presented the good results of enhancement mammographic image to find out the calcium levels. Pandey, A., et al. (2013) [27] suggested a new technique for enhancement of digital mammographic image using a Volterra Filter (VF) that provides better enhancement of lesions in comparison to other HEs techniques. In 2013, Bhateja V., et al., [28] used truncation of VFs series to the first non-linear terms for enhancement the mammographic image. VFs provide contrast enhancement, suppressing the ill-effects of background noise, and preserving the edges.

V. FREQUENCY DOMAIN TECHNIQUES

Frequency domain techniques are suitable for the images that are based on frequency components and works on the orthogonal transformation of the image rather than the image itself [2]. Figure 5 shows the steps of frequency domain. There are two main components magnitude and phase in the orthogonal transform of the image. The magnitude represents the frequency content of the image. The phase component is used to restore back the image to its spatial domain. Frequency domain techniques are based on modifying the spectral transform of an image; as in discrete cosine transform, discrete Fourier transform, etc. The high frequency contains the information of edges and sharp transitions, with faster grey level changes. The low frequency consists the general information appeared in image over smooth areas [12].

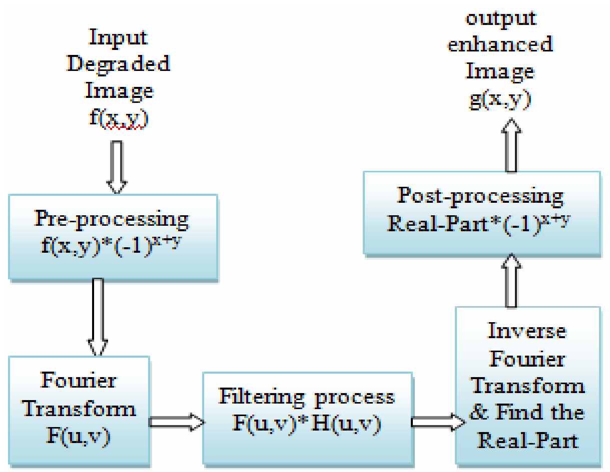

Figure 5.Steps of Frequency Domain Filtering

Sakellaropoulos, P., et al., (2002) [10] suggested a method for mammographic image de-noising and contrast enhancement based on dyadic WT. Where, the de-noising is accomplished by adaptive thresholding, taking into account local signal and noise standard deviation and enhancement contrast by local non-linear gain operator. In 2008, Mencattini, A., et al., [16] proposed the technique for de-noising and contrast enhancement. It deals with the noise characterization under the assumption of a heteroscedastic signal–dependent noise model. Sophisticated noise variance estimation algorithm is applied using estimators and nonlinear regressions. After that, wavelet thresholding is performed in order to obtain the relationship between noise variance and pixel intensity values that is used within a multi-scale de-noising algorithm. Multi-scale edge representation and wavelet analysis together with image sharpening are widely used for the contrast enhancement and de-noising algorithms. Gorgel, P., et al. (2011) [29] suggested method for mammographic image enhancement based on wavelet transform and homomorphic filtering. Initially, homomorphic filter is applied on wavelet coefficients. Then the details of wavelet coefficients that associated with noise and edges are manipulated by Gaussian and variables of Laplacian, respectively. The considered coefficients are compressed and enhanced using these variables with a shrinkage function. Lastly adaptive thresholding are used to retain the fine details of the mammographic image and the noise is suppressed. Multi-wavelet method for noise suppression and enhancement in digital mammographic images is described in 2011 by Mohideen, K., et al., [30, 23]. At first, the image is pre-processed to enhance its local contrast and clarifications of subtle details. Image enhancement is accomplished depend on the multi-wavelet transform. At each scale, the noise is suppressed by Laplacian Random Variables (LRV). Sakellaropoulos, P., et al., (2013) [31] proposed the algorithm for improved contrast enhancement and de-noising in mammographic image. First, mammograms are decomposed using discrete WT. Detail sub-bands are the boosted to increase the contrast. However it makes noisy mammographic image though the contrast improved. The difference between the original mammograms and noisy mammograms is used to identify spatial noise location in the detail sub-bands. The localized noises are decreased adaptively. To estimate the performance of the proposed algorithm, Peak Signal to Noise Ratio (PSNR) is used. Kidsumran, V., et al., (2013) [32] proposed the algorithm for enhancement mammographic image using de-noising in wavelet coefficients. First, mammographic image is decomposed by WT. Second, the ratio between approximate sub-band and detail sub-band as signal-to-noise ratio (SNR) is computed. Finally, detail sub-band which have the ratio lower than the criteria are boosted to improve mammographic image contrast while detail sub-bands. The results demonstrate that the method can enhance the mammographic image effectively than GHE and the conventional HEs methods. Hussain, M., (2014) [33] proposed the method that used Fast Dyadic Wavelet Transform (FDyWT) for the enhancement of mammographic image for multi-scales analysis, normalized Tsallis entropy for reduction the noise , a non-linear function for contrast enhancement and a power law transformation for background suppression.

VI. HYBRID DOMAIN TECHNIQUES

Problems with HE can be artifacts and overall brightness change in the resulting mammographic image [9, 25]. Many HEs have been alternated to counter the effects of range expansions [26, 27]. Frequency domain techniques bring about tonal changes in the images and can also generate unwanted artifacts in many states, as it is not likely to enhance all parts of the mammographic image in a balanced manner [28]. Moreover, the complexity in implementation of the frequency domain techniques compared to the spatial domain technique becomes an additional limitation. So if frequency domain and spatial domain enhancement technique are combined, where in the frequency domain technique complements the spatial domain technique in order to optimize the advantages and minimize the limitations of both the techniques [9, 29].

Mencattini, A., et al., (2008) [16] proposed the hybrid algorithm for mammographic image de-noising using method combining dyadic wavelet information with mathematical morphology to improve the diagnosis in the micro-calcification detection. Amutha, S., et al., (2011) [17] suggested the method combined wavelet and morphological techniques for enhancement mammographic image. This algorithm has been investigated which is very effective in reducing the speckle noise. SNR is used to estimate the performance of the proposed method.

Avachat, A. V., et al. (2012) [14], suggested the algorithm that blends WT and CLAHE for contrast enhancement. In this algorithm, the input mammographic image is decomposed into its low frequency and high frequency components by WT technique. Decomposed coefficients from several bands are then manipulated. Manipulation of decomposed images depends of using the CLAHE algorithm. Elsawy, N., et al., (2012) [34] presented the contrast enhancement algorithm for mammographic image. The algorithm performs Band-Limited Histogram Equalization (BLHE) for certain intensity band of the mammographic image histogram. According to the opinion of radiologist (subjective image quality metrics), the algorithm showed promising performance when applied on several mammographic images. In addition, the algorithm was combined with a wavelet-based contrast enhancement method to further improve its performance.

In 2012, Kumar, N. H., et al., [35] suggested enhancement method for mammographic images based on modified mathematical morphology and bi-orthogonal WT. The method have been adopted a level dependent threshold for thresholding the detail coefficients of WT. To estimate the performance of the proposed method, Contrast Improvement Index (CII) and Edge Preservation Index (EPI) (objective image quality metrics) are used. The method is presented yields significantly better image quality when compared with other contemporary methods.

Zhang, X., et al. (2013) [36] presented the method combined Multi-Structuring Elements (MSEs) based top-hat transformed and wavelet-based de-noising approach to enhance the individual micro-calcifications in mammographic image. The micro-calcifications are firstly enhanced by using multi-structure elements morphological processing (spatial domain). Then, the candidates of micro-calcifications are refined by a multilevel wavelet reconstruction approach (frequency domain). Finally, micro-calcifications are detected based on their distributions feature.

VII. META- HEURISTIC-BASED MAMMOGRAPHIC IMAGE ENHNCEMENT TECHNIQUES

Various mammographic image enhancement algorithms have been proposed [1, 8, 9, 4, 30]. HE and WT are well-known methods for enhancing mammographic image. Recently, several modern heuristic algorithms are used to increase the efficient to the traditional methods. Meta- heuristic algorithms are inspired by nature having many interacting agents, PSO, neural network, and fuzzy have been devised to deal with the limitation of traditional enhancement methods for mammographic image [10, 13, 31, 32].

Mohan, S., et al., (2013) [15] proposed a PSO based local contrast modification CLAHE algorithm. The CLAHE method can limit the noise enhancement. Local contrast modification CLAHE algorithm is optimizes using the PSO algorithm. The new histogram is different from the normal histogram because intensity of each pixel is limited by user selectable maximum. Rahmati, P., et al., (2010) [37] used fuzzy logic to develop the CLAHE algorithm. Fuzzy Contrast Limited Adaptive Histogram Equalization (FCLAHE) has been used to enhance contrast mammographic image. The filter (used in preprocessing stage) eliminates noise and intensity in homogeneities in the background while retaining the natural gray level variations of mammographic images within suspicious lesions, before applied Catarious Segmentation Method (CSM). AbuBaker, A. (2012) [38] proposed neural network and fuzzy logic (neuro-fuzzy) technique to enhance the individual micro-calcifications in mammographic image. The most important advantage by using the hybrid neuro-fuzzy technique is reduced the processing time needed to execute 43,046,721 activation rules to be processed in 201 µS which increases the performance of the proposed Computer Aided Design (CAD) system in enhancing the individual micro-calcifications in the mammographic images. On the other hand meta-heuristic algorithm is increased the efficient of frequency domain techniques. In 2012, Khehra, B. S., et al. [39] Proposed algorithm that is combined approach with fuzzy logic and wavelet for contrast enhancement. The proposed contrast enhancement approach utilizes wavelet transform to decompose the mammographic image, and then approximation coefficients are modified by fuzzy contrast enhancement approach and detail coefficients are by non-linear transformation. Finally, inverse wavelet transform is applied on modified coefficients to obtain the enhanced mammographic image.

VIII. CONCLUSION

Image enhancement techniques have a crucial role in the success or the failure of the mammographic image enhancement. The techniques are useful in modifying the gray level values of individual pixels to better visual quality of the entire image. This will help the radiologist and surgeons by improving the possibility of interpretation and perception of mammographic image information. It also assists to and to detect irregular shaped. Digital mammographic images can be stored, copied without any loss of information, and transmitted and received quickly across a network. This paper explains in details the main types of mammographic enhancement algorithms. The mammographic images enhancement techniques are classified according to the work done in this field.

ACKNOWLEDGMENT

The authors are grateful to the applied science private university, Amman-Jordan, for the full financial support granted to cover the publication fee of this research article.

REFERENCES

[1] G. Dougherty, Medical Image Processing: Techniques and Applications. New York: Springer, 2011.

[2] A. C. Bovik, Handbook of Image and Video Processing (2nd Edition.). Boca Raton, CRC Press, 2011.

[3] C. H. Lee, D. D. Dershaw, D. Kopans, P. Evans, B. Monsees, D. Monticciolo and L. W. Burhenne, “Breast Cancer Screening With Imaging: Recommendations From The Society of Breast Imaging and The ACR on The Use of Mammography, Breast MRI, Breast Ultrasound, and Other Technologies for The Detection of Clinically Occult Breast Cancer”, Journal of The American College of Radiology, Vol.7, No.1, PP.18-27, 2010.

[4] T. Tarver, “Cancer Facts & Figures”, American Cancer Society (ACS). Journal of Consumer Health on the Internet, PP.366-367, 2013.

[5] National Cancer Institute, “Getting Your Mammogram Results: What Can Mammogram Shows?”, Mar. 25, 2014. Available At: http://www.cancer.gov/cancertopics/screening/understanding-breast-changes/mammogram.

[6] M. L. Antonie, O. R. Zaiane, and, A. Coman, “Application of Data Mining Techniques for Medical Image Classification”, MDM/KDD, PP. 94-101, 2001.

[7] S. Singh, and R. Al-Mansoori, "Identification of Regions of Interest In Digital Mammograms", Journal of Intelligent Systems, Vol.10, No.2, PP.183-217, 2000.

[8] G. S. Muralidhar, "Computer-Aided Analysis and Interpretation of Breast Imaging Data", PhD. Dissertation Presented to the Faculty of the Graduate School of The University of Texas at Austin, University of Texas, Dec. 2012 .

[9] H. Schiabel, V. T. Santos, and M. F. Angelo, “Segmentation Technique for Detecting Suspect Masses in Dense Breast Digitized Images as a Tool for Mammography CAD schemes”, In Proceedings of the 2008 ACM symposium on Applied computing, PP. 1333-1337, Mar, 2008.

[10] P. Sakellaropoulos, L. Costaridou, and G. Panayiotakis, "Wavelet-Based Spatially Adaptive Method for Mammographic Contrast Enhancement”, Physics in Medicine and Biology, Vol. 48, No. 6, PP. 787-790, 2003.

[11] G. Noel, K. Djouani, and Y. Hamam, "Graph-based Image Sharpening Filter Applied to Image Denoising", International Journal of Smart Home, Vol. 5, No. 2, April, 2011.

[12] S. O. Mundhada, and V. K. Shandilya, "Spatial and Transformation Domain Techniques for Image Enhancement", International Journal of Engineering Science and Innovative Technology (IJESIT), Vol. 1, Issue 2, PP. 213-216, Nov. 2012. Available At: http://www.ijesit.com/Volume%201/Issue%202/IJESIT201211_32.pdf.

[13] S. Singh and N. R. Prakash, "Modified Adaptive Median Filter for Salt & Pepper Noise", International Journal of Advanced Research in Computer and Communication Engineering Vol. 3, Issue 1, PP. 5067-5071, January 2014. Available At: http://www.ijarcce.com/upload/2014/january/IJARCCE4H__a_singh_modified.pdf

[14] A. Mencattini, M. Salmeri, R. Lojacono, M. Frigerio, and F. Caselli, "Mammographic Images Enhancement and De-noising for Breast Cancer Detection Using Dyadic Wavelet Processing", IEEE Transactions on Instrumentation and Measurement, Vol.57, No.7, PP.1422-1430, 2008.

[15] A. V. Avachat, "Wavelet Based Contrast Limited Histogram Equalization for Contrast Enhancement of Digital Mammography", IEEE Transaction on Information Technology Biomedicine, Vol. 17, No.6, PP.950-961, 2012.

[16] S. Mohan and T. R. Mahesh, "Particle Swarm Optimization Based Contrast Limited Enhancement for Mammogram Images",. In Intelligent Systems and Control (ISCO), 2013 7th International Conference on IEEE, PP. 384-388, 2013.

[17] N. H. Kumar, S. Amutha, and D. R. Babu, "Enhancement of Mammographic Images using Morphology and Wavelet Transform", International Journal of Computer Technology & Applications, Vol.3, No.1, 2012.

[18] Preethi S.J, , K. Rajeswari, Membership Function Modification for Image Enhancement Using Fuzzy Logic", International Journal of Emerging Trends & Technology in Computer Science (IJETTCS), Volume 2, Issue 2, March – April 2013.

[19] H. Cheng, and X. Shi, "A Simple and Effective Histogram Equalization Approach to Image Enhancement", Digital Signal Processing, Vol.14, No.2, PP 158-170, 2004.

[20] M D. Pisano, "Contrast limited adaptive histogram equalization Image Processing to Improve the Detection of Stimulated Speculation in Dense mammograms", Journal of Digital Imaging, PP.193-200, 1998.

[21] K. R. K. Reddy, S. T. Krishna, Y. Gangadhar, and S.Rajan, "Novel Enhancement Techniques for Mammograms Using Histogram", International Journal of Power Control Signal and Computation (IJPCSC),Vol. 4,No.2,PP.1-6, 2012.

[22] B. M. Hemminger, S. Zong, K. E. Muller, C. S. Coffey, M. C. DeLuca, R. E. Johnston, and E. D. Pisano, "Improving the Detection of Simulated Masses in Mammograms Through Two Different Image-Processing Techniques", Academic Radiology, Vol.8, No.9, 845-855, 2001.

[23] K.Thangavel, M.Karnan, R.Sivakumar, A. Kaja Mohideen, Ant Colony System for Segmentation and Classification of Micro-calcification in Mammograms", International Journal on Artificial Intelligence and Machine Learning, Vol 5, Issue 3, Pages 29-40, 2005.

[24] M. Sundaram, K. Ramar, N. Arumugam, and G. Prabin, "Histogram Modified local Contrast Enhancement for Mammogram Images", Applied Soft Computing, Vol.11, No.8, PP.5809-5816, 2011.

[25] S. G. Al-Kindi, and G. A. Al-Kindi, "Breast Sonogram and Mammogram Enhancement Using Hybrid and Repetitive Smoothing-Sharpening Technique", IEEE 1st Middle East Conference on Biomedical Engineering (MECBME), PP. 446-449, 2011.

[26] K. Rajesh Kumar Reddy, S. Thulasee Krishna, Y. Gangadhar, S.Rajan, "Novel Enhancement Techniques For Mammograms Using Histogram Equalization", International Journal of Power Control Signal and Computation (IJPCSC),Vol. 4 No. 2, April- June -2012

[27] A. Pandey, A. Yadav, and V. Bhateja, "Design of New Volterra Filter for Mammogram Enhancement", Proceedings of the International Conference on Frontiers of Intelligent Computing: Theory and Applications (FICTA), PP.143-151, 2013.

[28] V. Bhateja, S. Urooj, A. Pandey, A. Lay-Ekuakille, and M. Misra, "Improvement of Masses Detection in Digital Mammograms Employing Non-linear Filtering", IEEE International Multi-Conference on Automation, Computing, Communication, Control and Compressed Sensing (iMac4s), PP. 406-408, 2013.

[29] P Gorgel, A Sertbas , ON Ucan, "A wavelet-based mammographic image denoising and enhancement with homomorphic filtering", Journal of Medical Systems, Vol. 34, No. 6, PP. 993-1002, Dec 2010.

[30] K. Mohideen, A. Perumal, N. Krishnan, and M. Sathik, "Image De-noising and Enhancement Using Multi-wavelet with Hard Threshold in Digital Mammographic Images", International Arab Journal of e-Technology, Vol.2, No.1, PP- 49-55, 2011.

[31] P. Sakellaropoulos, L Costaridou, and G Panayiotakis, "A wavelet-based spatially adaptive method for mammographic contrast enhancement", Journal of Physics in Medicine and Biology, Vol. 48, No. 6, PP. 787-803, 2013.

[32] Kidsumran, W. "Contrast enhancement mammograms using denoising in wavelet coefficients", International Joint Conference on Computer Science and Software Engineering (JCSSE), PP. 82 - 86, 2013

[33] M. Hussain, "Mammogram Enhancement Using Lifting Dyadic Wavelet Transform and Normalized Tsallis Entropy", Journal Of Computer Science and Technology, Vol. 29, No. 6), PP. 1048–1057 Nov. 2014.

[34] N. Elsawy, M. S. Sayed, F. Farag, and G. K. Gouhar, "Band-limited Histogram Equalization for Mammograms Contrast Enhancement", 2012 IEEE Cairo International Conference In Biomedical Engineering (CIBEC), Cairo International, PP. 154-157, 2012.

[35] R. Kumar Reddy, S. T. Krishna, Y. Gangadhar, and S. Rajan, "Novel Enhancement Techniques for Mammograms Using Histogram.", International Journal of Power Control Signal and Computation (IJPCSC),Vol. 4, No.2, PP.1-6, Apr-Jun. 2012. Available at: http://www.ijcns.com/pdf/ijpcsc2012-18.pdf

[36] X. Zhang, N. Homma, S. Goto, Y. Kawasumi, T. Ishibashi, M. Abe, and M. Yoshizawa, "A Hybrid Image Filtering Method for Computer-Aided Detection of Microcalcification Clusters in Mammograms", Journal of Medical Engineering, PP.1-8, 2013.

[37] P. Rahmati, G. Hamarneh, D. Nussbaum, and, A. Adler, "A New Preprocessing Filter for Digital Mammograms", In Image and Signal Processing. Proceedings of the Springer Berlin Heidelberg, PP. 585-592, 2010.

[38] A. AbuBaker, "Neuro-Fuzzy Approach to Micro-calcification Contrast Enhancement in Digitized Mammogram Images", The International Journal of Multimedia and Its Applications (IJMA), Vol.4, No.5, PP.61-75, 2012.

[39] B. S. Khehra, and A. P. S. Pharwaha, "Integration of Fuzzy and Wavelet Approaches Towards Mammogram Contrast Enhancement", Journal of The Institution of Engineers (India): Series B, Vol. 93, Issue 2, PP.101-110, Jul. 2012.

AUTHORS PROFILE

Dr. Nedhal A. Al-Saiyd. She got her B.Sc. degree in Computer Science from University of Mosul-Iraq in 1981, M.Sc. and PhD degrees from University of Technology, Baghdad-Iraq in 1989 and 2000 respectively. She is an Associate Prof. at Computer Science Dept., Faculty of Information Technology, in the Applied Science University, Amman, Jordan. She has got more than 24 years of teaching experience. Her research interests include: Software Engineering, Ontology Engineering, Intelligent Systems, User Authentication, Security and Speech Processing.

Sameera M. Talafha. She obtained her B.Sc. degree in computer science from University of Jordan, Amman-Jordan in 2012, and M.Sc. degrees in Computer Science from Faculty of Information Technology, in the Applied Science University, Amman, Jordan in 2015. Her research interests include: Mammographic Image Enhancement, Genetic Algorithms, and Image Processing systems.

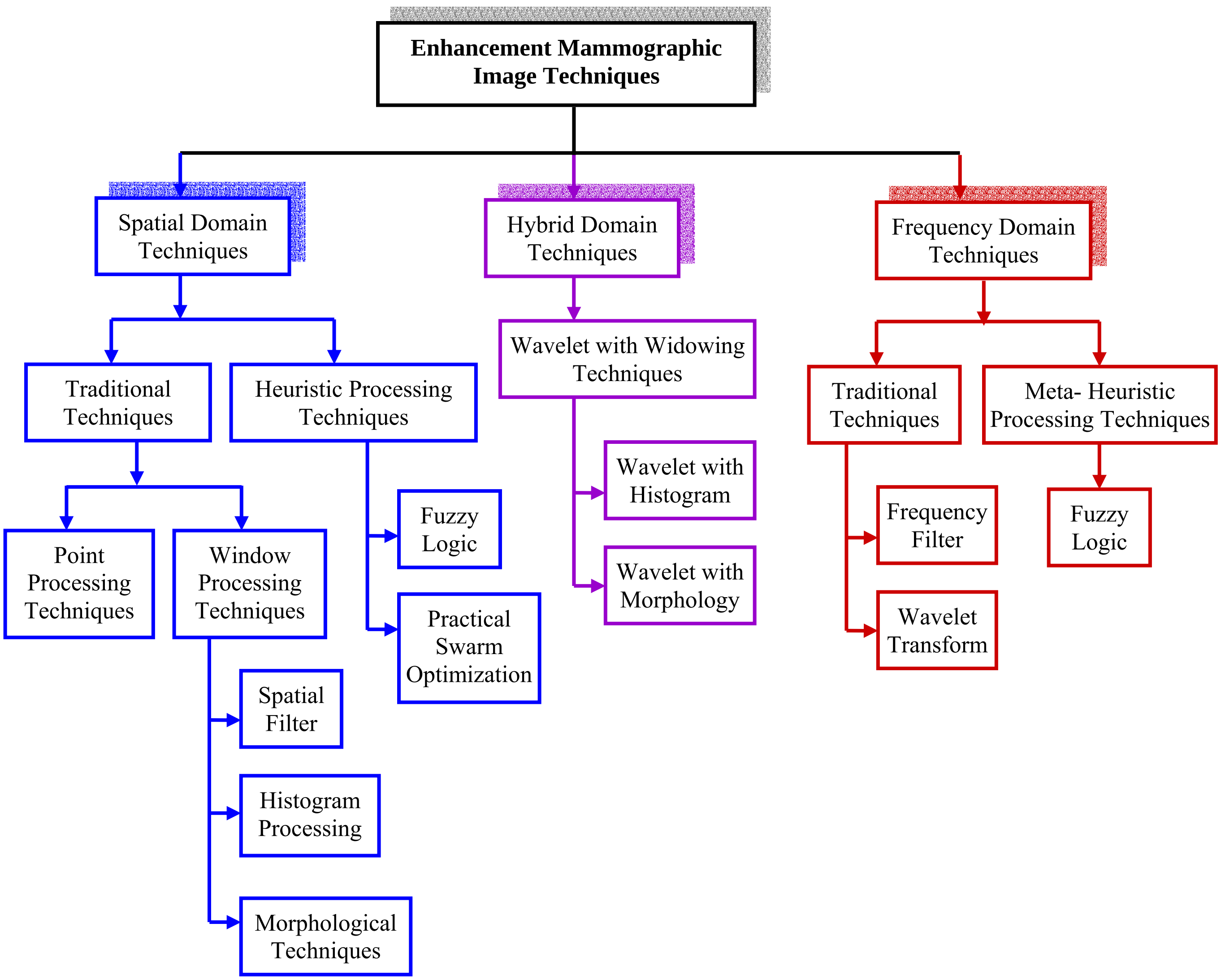

Figure 4. Classification for mammographic images enhancement techniques