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A Survey of Emerging Trends on Medical Image Enhancement Techniques

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***Abstract*—** During image acquisition, inadequate brightness may cause poor contrast and noise in many images like medical, satellite images. So it is required to improve the contrast and eliminate the noise to increase image quality. So image enhancement is required in medical image to improvement in quality. In this paper, we describe the overview of medical image enhancement techniques, classification of image enhancement techniques, researches done in the field of medical image enhancement, shortcoming comes after reviews, Parameter used to check the quality of enhanced images, and general needs required in this field of active research.

***Keywords*—** Medical Image, Spatial Domain, Frequency Domain, Fuzzy Domain

I. INTRODUCTION

Image enhancement is one of the image processing techniques that are used to improve the quality of the image by enhancing the constant and brightness, removing noise appeared in the image etc. so that it can be converted to better form for analysis point of view by a human or machine. In the case of image enhancement we often used to increase the contrast of images that are considerably dark or light. Image enhancement techniques are those that improve the visualization of image in order to overcome the weakness of the human visual system [1].

To understand the concept of image enhancement let we denote a two-dimensional digital image of gray-level intensities by I. The image I is ordinarily represented as an M × N matrix containing indexed elements I(i, j), where $0 \leq i \leq M - 1$, $0 \leq j \leq N - 1$. The elements I(i, j) represent samples of the image intensities, usually called pixels (picture elements). For simplicity, we assume that these come from a finite integer-valued range. This is not unreasonable, since a finite word length must be used to represent the intensities. Typically, the pixels represent optical intensity, but they may also represent other attributes of sensed radiation, such as radar, electron micrographs, x rays, or thermal imagery [2].

Image enhancement simply means, transforming an image I into image J using T (see Figure 1) where T is the transformation. The values of pixels in images I and J are denoted by p and q, respectively. As said, the pixel values p and q are related by the expression [2],

$$q = T(p) \tag{1}$$

Where T is a transformation algorithm that maps a pixel value p into a pixel value q. The results of this transformation are mapped into the grey scale range or color image. If we deals with grey scale digital images, the results are mapped back into the range [0, L-1], where L=2k, k being the number of bits in the image being considered. So, for example, for an 8-bit image the range of pixel values will be [0, 255]. The same theory can be extended for the color images too [3]. Figure 1 shows the basic operation of image enhancement techniques.

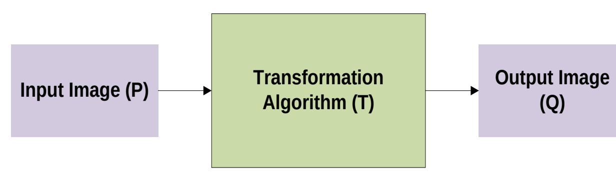

Figure 1. Image Enhancement Operation

The organization of the paper is as follows. In the next section, various image enhancement techniques are described. Section III defines the computer-based mammographic image enhancement system followed by pre-processing required for image enhancement in Section IV. Section V deals with the work done by various researchers in the field of image enhancement. Drawback of existing techniques is mentioned in Section VI. We describe objective visual quality measurements to simulate the result in Section VII. Conclusion is described in Section VIII.

II. Image Enhancement Techniques

Basically, Image enhancement is classified into three broad categories namely frequency domain, spatial domain and fuzzy domain methods. In the frequency domain method, the enhancement is conducted by modifying the frequency transform of the image. Meanwhile in the latter method image pixels are directly modified to enhance the image.

However, computing the enhancement in frequency domain is time consuming process even with fast transformation technique thus made it unsuitable for real time application [4]. One of the latest methods that are gaining popularities to enhance the image is fuzzy technique which is based on gray level mapping into fuzzy membership function. In this technique fuzzy set rules are used to modify the membership function and finally Defuzzification is applied to enhance image.

So we can say that Image enhancement techniques can be divided into three broad categories:

1. Spatial domain methods.
2. Frequency domain methods (DFT).
3. Fuzzy Domain.

A. Spatial domain methods

The spatial domain method directly manipulates the image data array, either by point processing or area processing. Basically it deals with spatial frequency, i.e. difference between the highest and the lowest values of a contiguous set of pixels. The approaches regarding image enhancement using spatial domain methods can be divided into two categories – global image enhancement and local image enhancement. Global methods are mainly histogram modifications that aim to exploit the full dynamic range of a rendering device by modifying the histogram of an image. The attractiveness is their simplicity and minor computational effort. However it is often necessary to enhance detail over a smaller area. So, the local image enhancement method plays a major role in those applications. This method can be characterized by equation 1.

$$G(x, y) = T[F(x, y)] \quad (2)$$

Where F(x, y) is input image, G(x, y) is output image and T is an operator on f, defined over some locality of f(x, y).

The idea of blurring an image by reducing its high frequency components or sharpening an image by increasing the magnitude of its high frequency components is intuitively easy to comprehend. Conversely, computationally, it is recurrently more efficient to implement these operations as convolutions by small spatial filters in the spatial domain.

B. Frequency domain methods

In the frequency domain [4-5] relation the discrete convolution is often more efficiently the using fast Fourier transform algorithm. In a typical image enhancement problem f(x, y) is given and the goal after computation of F (u, v) is to select H (u, v) so that the desired image given by:

$$G(x.y) = F^{-1}\{H(u,v) * F(u,v)\} \quad (3)$$

It also exhibits some highlighted attribute of f (x, y) for example ends in f (x, y) can be emphasize by using a function H (u, v) which emphasizes the high frequency components of F (u, v).

C. Fuzzy domain Methods

Fuzzy set theory is thus useful in handling various uncertainties in computer vision and image processing applications. Fuzzy image processing is a collection of different fuzzy approaches to image processing that can understand, represent, and process the image. It has three main stages, namely, image fuzzification, modification of membership function values, and Defuzzification (see Figure 2). Fuzzy image enhancement is based on gray level mapping into membership function. The aim is to generate an image of higher contrast than the original image by giving a larger weight to the gray levels that are closer to the mean gray level of the image that are farther from the mean.

The goal of image enhancement techniques is to develop a quality or contrast of an image such that enhanced image is better than the real image. Several image enhancement techniques have been proposed in both spatial and frequency domains. The rest part of research paper is organized in this way; Section 3 deals with pre processing steps for medical image enhancement. The section 4 describes the previous work done. Section 5 gives drawback of enhancement technique. Section 6 describes the quality parameters. Section 7 concluded about the research paper and its future scope.

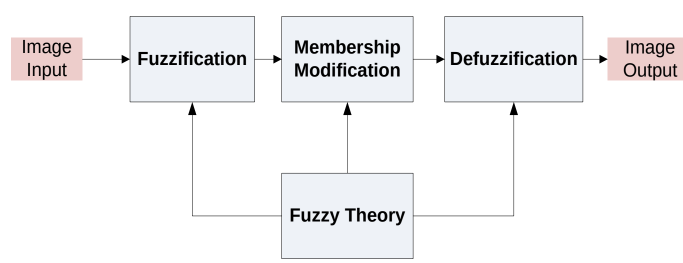

Figure 2. Fuzzy Interface System

III. 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 [6]. This will help the radiologist and surgeons by improving the possibility of interpretation and perception of medical image information. Image processing researchers have developed various image enhancement algorithms. Figure 3 shows the Computer-based medical Image Enhancement process.

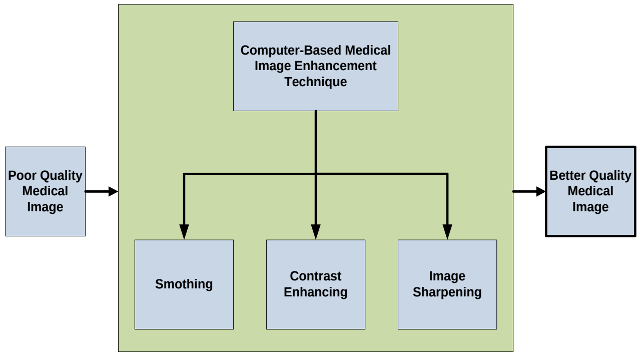

Figure 3. Computer-based Mammographic Image Enhancement

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 [7]. To eliminate the image noise, researchers have developed techniques that have the ability to separate the useful information from the noise.

$$x(n) = y(n) - \eta(n) \quad (4)$$

Where: y(n) is the noisy signal, x(n) is the noise-free signal, and η(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 de-noising [8-9].

B. Contrast enhancing

In medical 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 [10]. 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. Michelson and Weber's defined Contrasts as:

$$\text{Michelson Contrast} = (\text{Lmax} - \text{Lmin}) / (\text{Lmax} + \text{Lmin})$$

$$\text{Weber Contrast} = \text{Lmax} / \text{Lmin}$$

Where: Lmax: the local maximum,

Lmax : the local maximum grayscale value of image,

Lmin: 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. 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 medical 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.

IV. PRE-PROCESSING

Medical images are prone to irrelevant and unreliable noisy data. De-noising and image resolution enhancement techniques play a vital role in the achievement of high MR image quality. Medical images are prone to a variety of noises such as salt and pepper noise, speckle and additive Gaussian noise that ultimately affects the diagnostic value of the image being modelled. Speckle noise gets greatly affected in the contrast resolution of the MR image. So we have used median filter for the suppression of speckle noise from MR brain image.

Due to its robustness against impulsive type noise and edge preservation features median filter eliminates spurious data from MR images. This filter takes pixel values surrounding the pixel under consideration. Later it is numerically ordered and the current pixel value is replaced with the mid-pixel value. Another unfavourable condition associated with MR brain images is its low contrast and the presence of non-brainy tissues such as skull. Such extra cranial tissues and interferences have to be removed.

V. RELATED WORK

Medical image enhancement is an image enhancement technique that refers to increasing the intensity difference between the Region of Interest and background. Though considerable research is done in such areas, as medical image enhancement is subjective in nature and is dependent on the nature of the original images, generalized medical image enhancement technique is not yet developed. In this chapter, a detailed literature survey on the existing image enhancement techniques is provided.

In 2013, Mohammed et al suggested a new technique for enhancing medical image by spatial enhancement and power law transformation. The proposed methodology is consisting of following steps. First of all, Laplacian filter was performed to sharpen the image. Then this enhanced image was subtracted from the original image and on the resulted image Sobel filter was applied. Image smoothening was performed using an average filter. The Sobel filter and the average filter were logically ANDed. On the resultant image, Power law was performed. It was concluded that as the power law increases, the brightness of the image increases. However, further enhancement can be made using other enhancement techniques [5].

Ying Shen and Weihua Zhu (2013) had employed a machine based approach to tackle the challenge of eliminating the noise complexities of a medical image and to extract the required information in it. The machine based approach involved four stages of different algorithm to deal with the medical images. Initially, image smoothing was performed using Guassian, Mean and Gabor filters. Secondly, a mean filtering algorithm was implemented. It was based on the proposed approaches of Duba and Kart. Thirdly, the medical image enhancement was done to obtain the basic outline of the image. As the last step, a reduction algorithm was employed to obtain smooth and precise pictures. Detailed studies should be done to analyze the connection between the heart and other organs [11].

Ritika and Sandeep Kaur (2013) proposed mathematical morphology based a new method for image enhancement. Their method is based on adaptive histogram equalization technique which is used for avoiding excess amplification originally developed for medical imaging. The white and black top-hat transformation was another method used for performing morphological contrast enhancement. It was concluded by saying that various image enhancement techniques had been mentioned. The multiscale morphology approach produced good results when compared to the results of the other state of art techniques [12].

Tarun Kumar Agarwal et. al. (2014) [13] proposed a new method named "Modified Histogram Based Contrast Enhancement using Homomorphic Filtering" (MH-FIL) for medical images. In their method, they initially modify the histogram of input image using a histogram modification function and then they apply HE method for contrast enhancement on this modified histogram. After that we use homomorphism filtering for image sharpening and then to minimize the difference between input and processed image mean brightness, they normalize it [13].

N. Senthilkumaran et. al. (2014) study and compare different Techniques like Global Histogram Equalization (GHE), Local histogram equalization (LHE), Brightness preserving Dynamic Histogram equalization (BPDHE) and Adaptive Histogram Equalization (AHE) using different objective quality measures for MRI brain image Enhancement.

J. Kinani et. al. (2014) presents a fast and robust practical tool for detection of lesions with minimal user interaction. Particularly, a fuzzy image enhancement is performed on both T1 weighted magnetic resonance (MR), and Fluid attenuated inversion recovery (FLAIR) images to facilitate a better segmentation. They establish a fuzzy system that performs the intensity transformation through the implication method; after, the scalar output obtained from this system is used to separate healthy from the unhealthy structures using constrained fuzzy clustering. An advantage of this lesion detection pipeline is the simultaneous use of features computed from the intensity properties of the image in a cascading pattern, which makes the computation fast, robust and self-contained [14].

Tao Gong et. al. (2015) proposed an algorithm that improved the clonal selection algorithm in three ways. First, they designed the real coding of the MRI brain image, instead of binary coding. Second, they added the mutation distance to control the mutation progress and avoid only the local optimization. In addition, they adjust the clone selection and the mutation together in the Gauss distribution, the uniform distribution, and the chaotic distribution, rather than in only the Gauss distribution. Then they use the real MRI brain images to test the image enhancement of their improved clonal selection algorithm [15].

Pejman Rasti et. al. (2016) proposed new medical image enhancement technique that will enhance brightness and sharp the image. The proposed technique is based on stationary wavelet transform that addresses the aforementioned problem. The general structure of the proposed technique is as follows. First, the image is equalized by means of GHE. in the next step SWT is applied on the equalized medical image, we can say it as A, which further splits it into four sub-band images namely LL, LH, HL and HH. The edge information is embedded into the high-frequency sub-bands, whereas the LL sub-band contains the illumination information. Thus, separating the high frequency sub-bands from the low frequency at the final stage of the whole algorithm will enhance the distinctiveness and sharpness of the edges. At the next step, DWT is applied to both the input medical image and its LL sub-band. The image output by the illumination enhancement module does possess considerably improved illumination, but it would usually suffer from the deficiency of being slightly smoothed, due to the nature of the averaging process. For overcoming the latter drawback, the image, at the next stage, is sharpened through reincorporating the high frequency sub band into the resultant image [6].

I. Isa, S.N Sulaiman et. al.(2016) proposes a new image enhancement technique known as Average Intensity Replacement based on Adaptive Histogram Equalization (AIR-AHE) for FLAIR image based on intensities and contrast mapping techniques. The proposed algorithm consists of partial contrast stretching, contrast limiting enhancement, window sliding neighbourhood operation and new pixel centroid replacement. The fluid attenuated inversion recovery (FLAIR) sequences of MRI images which are used for segmentation have low contrast. Therefore, contrast stretching is used to improve the quality of the image. After improving the quality of image, the regions of high intensity are determined to represent potential WMH areas [7].

Gian Domenico Licciardo et. al.(2017) proposed a HDR range enhancement for medical image , in order to adapt the complexity of the processor to required performances or to constraints of different field programmable platforms. The proposed design achieves such results by the reduction of frame buffer elimination that reduces the amount of memory for processing and allows the implementation of smart image sensors. The implemented design returns state-of-the-art performances for both FPGA and std_cell implementation. Their propose method exploiting a local operator, which works following two steps on the luminance component of the LDR frame. First, they use an S-shaped function to obtain an intermediate level expansion of the original LDR frame; then a second selective expansion is carried out, in the second step, to obtain an enhancement of both lighter and darker regions of the image [8].

Pranshu Pandey et. al. (2017) published a paper highlighting the Kalman filter for image enhancement techniques. The filter can be used particularly for medical image enhancement which will increase medical advancement. Their method work as follow: first of all, Original medical image undergoes noise addition process. Then noisy image enhanced with related filters and enhancement technique. After that removal of noise with the help of Wiener Filter is applied. Next they apply Kalman filter on image followed by Enhancement of image undergoes for brightness process. Finally, apply process of construction of an image. In this paper, they add Gaussian noise to all the sample images. They use Weiner filtering process for the removal of noise but for better enhancement of an image they applied Kalman filter iteratively [9].

Elena S. Yelmanova et. al. (2017) proposed the method of image contrast enhancement on the basis of the equalization of the contrast distribution at the boundaries of objects and background on the image. Research of the well-known and proposed histogram based methods was conducted using the known no-reference contrast metrics for a series of complex images. The purpose of the work was to improve the effectiveness of contrast enhancement for complex low-contrast images with the small-size objects [10].

Research of the effectiveness of the proposed and known methods of contrast enhancement were carried out by measuring the contrast using known no-reference metrics of image contrast for the four groups of test images. Philip Joris et. al.(2018) propose a more general and data-driven approach that relies on the notion of intensity variance around each specific intensity value, simply referred to as intensity-specific variances. First, they introduce a method for estimating these variances from an image (or a collection of images) directly, which is followed by an illustration of how they can be used to define intensity-specific distance measures. Next, they evaluate the proposed concepts through various applications using both homo- and heteroscedastic CT and MR images [16].

Finally, they present results from both qualitative and quantitative analyses that confirm the working of the proposed approaches, and support the presented concepts as valid and effective tools for (pre)processing heteroscedastic medical images. in this work, they showed that medical images can have heteroscedastic tissue intensity distributions, and argued how this can have an effect on standard and widely accepted image processing methods. They demonstrated this deficiency extensively through the applications of edge detection, image quantization, and voxel classification, using standard methods to process both homo- and heteroscedastic CT and MR (T1 and T2) images.

Table1. Details of work done on Medical Image Enhancement

Authors	Year of Publication	Method	Effectiveness
Mohammed et al.	2013	Power law transformation on Spatial Enhancement	1. Brightness of the image increases. 2. Sharpens the image.
Ying Shen and Weihua Zhu	2013	Gaussian, Mean and Gabor based filters.	1. Eliminating the noise complexities. 2. Smoothen the image.
Ritika and Sandeep Kaur	2013	Adaptive histogram equalization and Top-Hat transformation.	1. Avoiding excess amplification. 2. Morphological contrast enhancement.
Tarun Kumar Agarwal et. al.	2014	Modified Histogram Based Contrast Enhancement using Homomorphic Filtering.	1. Image sharpening. 2. Low contrast enhancement

			3. Normalize the brightness.
J. Kinani et. al.	2014	Fuzzy system Based on intensity transformation through the implication method.	1. Facilitate a better segmentation in image. 2. Fast computation
Tao Gong et. al.	2015	Clonal selection algorithm and the mutation together in the Gauss distribution, the uniform distribution, and the chaotic distribution.	1. Use real coding instead of binary code for MRI image. 2. Reduce the calculation complexity.
Pejman Rasti et. al.	2016	Stationary wavelet transform	1. Enhances the illumination of the low-low sub band image. 2. Enhanced edges of image.
I. Isa, S.N Sulaiman et. al	2016	Average Intensity Replacement based on Adaptive Histogram Equalization	1. Improve the quality of the low contrast image. 2. Regions of high intensity are determined correctly.
Gian Domenico Licciardo et. al	2017	New Application Specific Image Processor for HDR medical image	1. Capable to process images at different resolutions up to 4K. 2. Reduces the amount of memory for processing 3. Allows the implementation of smart image sensors.
Pranshu Pandey et. al.	2017	Medical Images enhancement using Kalman Filter	1. Analyze the medical images more accurately 2. Overcome issues of noise, bad quality and low intensity in medical image.
Elena S. Yelmanova et. al.	2017	Histogram-based methods using the known no-reference contrast metrics.	1. Contrast enhancement for complex images with the low contrast small-size objects. 2. Automatic contrast enhancement on the basis of the analyzing of contrast kernels.
Philip Joris et. al	2018	Preprocessing of Heteroscedastic Medical Images	1. Correctly Tissue intensity distributions. 2. Useful tools for (pre) processing heteroscedastic medical images.

VI. DRAWBACK OF EXISTING TECHNIQUES

Medical image which has low contrast or is too bright, so the experts cannot analysis that image due to poor representation of data in the image.

If the contrast of an image is highly concentrated on a specific range, e.g. a dark image, the information may be lost in those areas which are excessively and uniformly concentrated.

Due to the low level of contrast, image feature cannot be proper visualized. Sometime many approaches, in certain cases, are unable to detect low contrast edges present in medical images.

VII. QUALITY PARAMETERS

Each and every method shown above is compared by statistical point of view by using some standard quality measures.

A. Peak signal to noise ratio (PSNR)

The PSNR depicts the measure of modification in the original image. This metric is used for discriminating between the original and enhanced image.

The easy computation is the advantage of this measure. It is formulated as:

$$PSNR = 10 \log (L-1)^2 / MSE$$

Where MSE is MEAN SQUARE ERROR.

The method should not significantly amplify the noise level and thus a high value of PSNR is required a low value of PSNR shows that the constructed image is of poor quality.

B. Absolute Mean Brightness Error (AMBE)

Difference in mean brightness between two images is calculated by Absolute Mean Brightness Error. AMBE is defined as the difference between the input and output mean. Mathematical expression to calculate AMBE between two images is given as:

$$AMBE = |X_m - Y_m|$$

where X_m and Y_m are mean brightness of input and processed image respectively.

C. Entropy

Discrete entropy E(X) measures the richness of details in an output image after enhancement.

$$E(p) = -\sum_{k=0}^{L-1} p(k)\log_2 p(k)$$

D. Weber contrast

The Weber contrast is normally used in small fields on a large uniform background. It is one of the oldest luminance contrast statistics, Weber Contrast, is also often used for these patterns (small, sharp-edged graphic objects like symbols and text characters on larger uniform backgrounds):

$$C_w = \frac{L_s - L_b}{L_b}$$

where L_s is the luminance of the symbol and L_b is the luminance of the immediately adjacent background.

E. Contrast (C)

The enhanced image must obtain optimum image contrast (C) to distinguish between the object and the background. The contrast for enhanced image ought to be close to the contrast of the original image to attain good image quality. C is calculated using following equation.

$$C = \sqrt{\sum_{m=0}^{L-1} (m - m_{avg})^2 p(m)}$$

VIII. CONCLUSION

Medical Image enhancement offers a wide variety of approaches for enhancing medical images to achieve visually acceptable images. In this paper, recent survey on various techniques for medical image enhancement is presented. The paper shows the technique used by researcher with its effectiveness. The paper also discusses the disadvantage of the previous image enhancement technique. The quality parameters have described to test the performance of enhanced images.

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