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A Review on Image Enhancement Methods on Different Domains

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Abstract- Image enhancement is a process is to improve the quality of an image by improving its feature. The analysis on the low contrast image is difficult and to improve the image features such as edges, boundaries, or contrast to make a graphic display more distinct for analysis, the image enhancement process is performed on the original image. The objective of image processing is to improve the quality and features of the image for analysis and recognition. In the field of image enhancement, the contrast enhancement is one of the challenging and interesting image processing area. The enhancement process improves the quality and features of the image such as edges, boundaries and contrast so that they can be detected for analysis purpose. The enhancement techniques can be broadly applied on three domains i.e. spatial, frequency and fuzzy domain. The objective of this paper is to present a review on various image enhancement techniques on three different domains and to evaluate their performance.

Keywords – *Edge Detection, Fuzzy technique, Medical image, Edge sharpening, Median filtering, Low contrast image, Histogram equalization, HSV, Image enhancement.*

I. INTRODUCTION

The process of an image to make the result more convenient to a certain application than the original image is called image enhancement. The analysis on the low contrast image is difficult and to improve the image features such as edges, boundaries, or contrast to make a graphic display more distinct for analysis, the image enhancement process is performed on the original image. The enhancement process improves the quality and features of the image such as edges, boundaries and contrast so that they can be detected easily but it does not increase the inherent information content of the image data. The selecting or quantifying the criterion for image enhancement is difficult and, therefore, a large number of image enhancement techniques are empirical and require interactive procedures to obtain satisfactory results.

With the invention of new technology, we can manipulate images with certain systems. Manipulation of the images can be categorized into three types namely:

- Image Processing
- Image analysis
- Image understanding.

Image Processing[11] can be defined as the systems where the input is in the form of images where processing methods have been applied that produces output in the form of images. Image processing involves operations such as denoising, color contrast enhancement and image edge detection etc. Image Analysis[11] is defined as the system that accepts image as input where certain methods have been applied that provides the measurements of the image as an output. These measurements includes parameters such as the size of the pixel, the size of the image, pixel length etc. Image understanding [11] provides a system where input image is processed with certain methods and the outputs determine the high level description of the image. This high level description helps in more understanding of the image and also helps in extracting the more useful information from the given input image. Images, captured in low contrast condition encounter a serious problem in recognition system and analysis. In order to get better result from the analysis, the contrast enhancement is an important part of image processing. Image quality improvement is a process of improving the contrast and edge sharpness of the image. Contrast enhancement and histogram processing is one of the most important digital image processing techniques and it is widely used for increasing the quality of the medical image. The histogram based techniques are much less expensive when compare to the other methods and because of its simplicity and better efficiency, these algorithms are widely used for contrast enhancement of images. Many contrast enhancement algorithms are existing, but the development of a new algorithm which would produce better images than the existing one is a challenging problem. Several image enhancement algorithms have been proposed to overcome the uncertainties encountered during transmission and acquisition of the images.

Sometimes these uncertainties or vagueness are caused by low contrast in the images. Therefore, it is necessary to represent and resolve uncertainty effectively to improve the contrast.

II. VARIOUS IMAGE ENHANCEMENT TECHNIQUES

The image enhancement techniques improve the visual appearance of the given image or convert the input image into better form for better analysis by machines as well as humans. Various enhancement techniques are as follows:

- Spatial domain methods
- Frequency domain methods
- Fuzzy domain methods

A. Spatial domain methods

Image processing techniques based on spatial methods operate directly on pixels. These methods modify the pixel values according to rules depending on original pixel value i.e. local or point process. The complexity of the spatial based domains are low and simple which are generally used in real time implementations. Numerous methods exist to compare or combine the pixel values with their immediate or neighbouring pixels. Consider the original image f(x,y), transformation T can be applied to obtain the resultant or processed image g(x,y) as:

$$g(x,y) = T[f(x,y)] \quad (1)$$

where operator T is defined over neighborhood pixels of (x,y) and T is applied to each pixel (x,y) to obtain g output at that point.

B. Frequency Domain Method (FDM):

It is a term used to describe the analysis of mathematical functions or signals with respect to frequency and operate directly on the transform coefficients of the image, such as Fourier transform, discrete wavelet transform (DWT), and discrete cosine transform (DCT). In case of the frequency domain techniques, the image enhancement is done by manipulating the transform coefficients which enables operations on the frequency content of the image, and therefore high frequency content such as edges, boundaries and other information can easily be detected and enhanced. The edges and sharp transitions in an image are due to high frequency contents in the Fourier transform whereas smooth areas of image appear due to low frequency contents of Fourier transform.

Enhancement of image f(x,y) is performed by applying frequency domain based on DFT. These techniques have limitations such as it cannot simultaneously enhance all parts of image very well and it is also difficult to automate the image enhancement procedure.

C. *Fuzzy domain methods:*

A fuzzy set is a mathematical tool for handling imprecision or vagueness [1, 2]. Let Z = {*z*} be a universal set of generic elements. A fuzzy set *Y* in Z is characterized by a membership function $\mu_Y(Z)$ that produces an association value of each element *z* in Z as positive real number in the range [0, 1]. *Y* can be expressed mathematically as follows

$$Y = \{z, \mu_Y(Z) \mid z \in Z\} \quad (2)$$

The nature of participation of the element *z* in *Y* is given by the nature of membership function $\mu_Y(Z)$. According to desired application, we can define membership function or we can use the standard functions.

Various uncertainties and functions in image processing can be easily applied using fuzzy logic. Fuzzy based image processing is collection of various fuzzy approaches that understand, represent and process the image. Ability to represent the concept of partial truthness, makes fuzzy suitable for image processing. Fuzzy approach has three main steps: fuzzification, modification of membership function values and defuzzification.

Fuzzification: Input values compared with the membership function to obtain membership values for each part of image in case of image processing. Modification of membership function values: The membership values are then combined with the defined fuzzy set operations to get weight of each fuzzy rule.

Defuzzification: The qualified output results are combined to obtain crisp output based on the defined methods. Fig1 shows the block diagram of FIP[1].

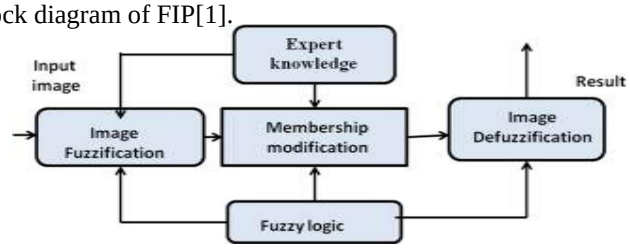

Fig1: Fuzzy Image Processing

Rules for Fuzzy Inferencing:
If x is A1 and y is B1, Then z is C1.
If x is A2 and y is B2, Then z is C2.

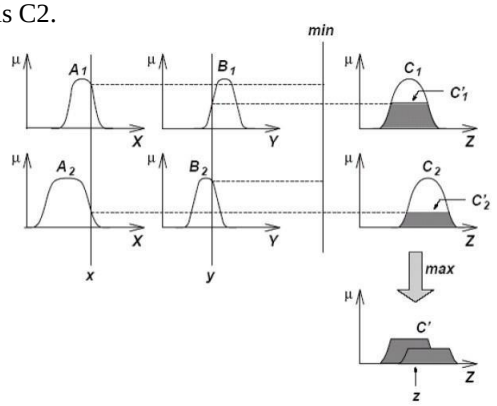

Figure.2 Rules of Fuzzy Reasoning [5]

The process of fuzzification and defuzzification are just the steps for encoding and decoding the image and hence the key point is the modification of membership value. Fuzzy based image processing depends on the fuzzy inference system being used and the input image to be processed.

III. LITERATURE SURVEY

A. Spatial Domain Techniques:

Conventional histogram based contrast enhancement technique is a powerful but limited in real time applications due to having large computational time and storage requirement. It also exhibit quality degradation due to loss of infrequency distributed pixels intensities, which may lead to loss of vital information [6]. So Tae Keun et al. [1998], has discussed a block-overlapped histogram equalization system to improve the contrast of an image sequences with numerous applications. Tang Eli Peli et al. [2003], studied global histogram equalization, which controls the intensity histogram to particular distribution only. Global histogram equalization states that image properties cannot be appropriately applied in a local context. In fact, its modification treat all regions of the image equally and, thus produce poor image detail preservation [9].

Yang et al. [2005], has discussed a non-linear image enhancement method based on Gabor filters, which allows selective enhancement based on the contrast sensitivity function of the human visual system. The image enhancement of the given approach is especially appropriate for digital applications to enhance the perceive visual feature of the images due to numerous reasons, including interpolation [10]. Angela et al. [2006], proposed an image enhancement technique for digital images captured under non-uniformed lighting conditions. The new technique constitutes three issues viz, contrast improvement, adaptive intensity enhancement, and color restoration which were considered separately to make the technique more adaptable to the image characteristics. The adaptiveness of the transfer function, depend on the mean of each pixel's neighbourhood that makes the technique more flexible and easier to control [12].

Agaian et al. [2007], suggested a global histogram equalization technique, which attempts to alter the spatial histogram of an image so as to closely match a uniform distribution. Histogram equalization poorly equalizes every local detail as it works at same level on whole image resulting in loss of visibility [14].Hossain et al. [2010], proposed a technique of medical image enhancement based on non-linear technique and the log transform coefficient histogram equalization. Log transforming histogram matching uses the truth that the relation between stimulus and perception is logarithmic. To evaluate the performance contrast measure with respect of the proposed enhancement technique, a measure of improvement based on the transform has been used as a tool. This technique improves visual quality of images that contain dark shadows due to limited dynamic range of imaging like x-ray images [16].

Sundaram et al. [2011], proposed the Histogram Modified Contrast Limited Adaptive Histogram Equalization (HM CLAHE). It can regulate the level of contrast enhancement, which regularly give the resultant image as a strong contrast and brings the location details for interpretation that is more relevant. It associates both histogram modifications as an optimization technique and Contrast Limited Adaptive Histogram Equalization. This method has been tested on Mias mammogram images. The performance of this technique is set utilizing the parameter like Enhancement Measure (EME). From the subjective and quantitative measures it's interesting this proposed technique provides better contrast enhancement with preserving the neighbourhood information of the mammogram images [19].

Chauhan et al. [2011], proposed brightness preserving weight clustering histogram equalization that protect image brightness and enhance visual effects of an image efficiently as compare to histogram equalization technique [20]. Histogram equalization has predictable technique for contrast enhancement. Histogram equalization has some limitations. Histogram equalization recovers the disparity of an image by altering the intensity level of the pixel based on the intensity of the original image. Their technique can overcome these problems.

G.N .Sagar et al. [2012], proposed image enhancement technique with filtering techniques to enhance the contrast of x-ray images which were distorted due to noise and blurring. They use different filtering techniques such as median filter to remove noise and mean filter to remove the high frequency details. They used Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) to measure the performance of the proposed technique. Not only removing noise but it also has the capable of improving the quality of the X-ray image. But it has a lot of improvement to eliminate the noise in the X-ray images completely [23].

Schouhan et al. [2013], proposed an enhancement technique, which is based on energetic stochastic resonance in spatial domain for the dark- and low-contrast images. Stochastic resonance (SR) is a phenomenon in which can improve the performance of a method for low-contrast image by adding noise. This system gives significant performance in terms of contrast and color enhancement alongside perceptual quality [27] when comparing with the existing enhancement techniques like adaptive histogram equalization, gamma correction, single-scale retinexmulti-scale retinex, modified high-pass filtering, edge-preserving multi-scale decomposition and automatic controls of popular imaging tools.

Hasikin, et al. [2013], proposed a parameterized contrast factor system which provides information on difference regarding gray-level values in local neighborhood. It divides the degraded image into bright and dark regions. Gaussian membership function is applied to the respective dark and bright regions separately. For the dark images, sigmoid functions are used to enhance the image and HSV model is used for color images to enhance them. This approach is best applicable for real time applications [28].

Faisel G. Mohammed et al. [2013], proposed a power law transformation based enhancement technique by associating Laplacian filter, average filter and Sobel filter as prior process. This technique involves steps of image blurring nd subtraction of image and after that power law transformation is applied to obtain the resultant image [29].

Mandip Kaur et al. [2013], proposed image restoring technique from a noised medical image using different denoising techniques. Gaussian, speckle, salt and pepper, rician and Brownian noise were the types of noise considered. Linear filters destroyed the fine details. There are two methods for image denoising namely spatial domain and transform domain. Bilateral filters worked effectively with high frequency areas but failed to work at low frequency areas. Bilateral filter did not remove salt and pepper noise. Bilateral filters performed better than linear filters [30].

Kalyan Chatterjee et al. [2013], presented a neuro-fuzzy inference system to obtain the clear image. Histogram equalization is used for contrast enhancement. Image enhancement using histogram equalization was best suited for medical images [31].

B. Frequency Domain Techniques:

Jha et al. [2012], proposed a contrast enhancement technique using scaling of internal noise of a dark image on discrete cosine transform (DCT) domain. Due to insufficient illumination, this transition is effected by the inner noise present and could be modelled with a general bit able system exhibiting dynamic stochastic resonance. This system adopts a near adaptive processing and significantly enhances the image contrast and color information while ascertaining good perceptual quality. This technique gives remarkable performance with regards to relative contrast enhancement, visual quality and colourfulness of the enhanced image when compared with the existing enhancement techniques such as modified high-pass filtering, adaptive histogram equalization, multi-contrast enhancement, color enhancement by scaling, and multi-contrast enhancement with dynamic range compression [24].

Anamika Bharadwaj et al (2012) suggested a novel approach to medical image enhancement based on wavelet transform. Initially, the medical image was decomposed into with the help of haar transform and then the sub-images were also decomposed using high frequency. The decomposed image and the sub-image were then added together so as to apply soft threshold method to the noise present in the resultant image. Then the high frequency coefficients were enhanced by different weights and the enhanced image was filtered using some filtering techniques. It was concluded that the image obtained in this process seems to be very clearer which is very important in medical diagnostic purposes [25].

Maragatham et al. [2013], proposed an algorithm to distinguish an image into different contrast level. The input image is classified either as low contrast or as high contrast image using this technique. If the classified image is low contrast, it can be enhanced by utilizing the Stochastic Resonance principle. The outcomes

demonstrate that the proposed automated procedure enhances the low contrast image better in comparison to conventional enhancement methods [32].

Nercessian et al. [2013], proposed an image enhancement technique with the advantages: the integration of both luminance and contrast masking phenomena, the extension of human visual system-based image enhancement approaches to the stationary and dual-tree complex wavelet transforms, and an immediate way of adjusting overall brightness, the extension of non-linear mapping schemes to human visual system inspired multi-scale contrast coefficients, and achieving dynamic range compression image enhancement direct multi-scale enhancement framework. Experimental results demonstrated the ability of the proposed algorithm to attain simultaneous local and global enhancements [33].

C. Fuzzy Domain Techniques:

Pal S. K. et. al. [1980], proposed a fuzzy properties extracting method corresponding to pixels in the spatial domain of the image and successively applied the fuzzy „contrast intensification‟ operator for modification of pixels intensity in fuzzy property plane of the image. The performance of this method is evaluated with different indexes of fuzziness for English script input image [3].

Pal S. K et. al. [1981], proposed a model for enhancement of grey-tone image using the concept of fuzzy sets. It associates steps: primary enhancement, smoothing, and then final enhancement. The steps include the extraction of fuzzy properties corresponding to pixels and then successive applications of the fuzzy operator "contrast intensifier" on the property plane. The reduction of the "index of fuzziness" and "entropy" for different enhanced outputs is demonstrated for an English script input [4].

H. D. Cheng et. al. [1999], proposed a fuzzy entropy principle and fuzzy set theory based adaptive fuzzy direct contrast enhancement method.. They used edge gradient operator and S-function as membership function to find the edge value of an image [7].

Farbiz H. R. et. al. [2000], proposed a new fuzzy-logic-control based filter with the ability to remove impulsive noise and smooth Gaussian noise, which simultaneously preserve the edges and image details efficiently [8].

M. Hanmandlu et. al. [2006], presented a fuzzy based enhancement technique in order to enhance the given colored image with the gaussian membership function which fuzzifies the image in spatial domain. A global contrast intensification operator (GINT) is also introduced which comprises three different parameters namely, fuzzifier, intensification parameter, and the crossover point. HSV model is implemented i this paper and the color component is left unmodified. This approach provided a visual improvement to the under-exposed images [13].Harish kundra et. al. [2009], proposed a filtering technique which remove the noise and improve the contrast of an image. To achieve this goal fuzzy-logic-control based approach is used. The filter is tested on the colored images [15].

Balasubramaniam et. al. [2011], proposed a fuzzy inference system based contrast enhancement of gray level images. They have used triangular fuzzy membership function for converting pixel domain to fuzzy property domain. They proposed a new method of generating the fuzzy if-then rules specific to a given image based on the local information available to be used by a fuzzy inference system. To this end, a partial histogram and not a complete histogram thus saving on computational costs [17].

O.P. Verma et. al. [2011], proposed two new transformation functions to enhance the under and over-exposed regions of an image. Rectangular hyperbolic function and S-function are used for the under-exposed regions, and over-exposed regions. Enhancement purpose uses the HSV color model normally. The S-function allows more flexible control for the given regions. The proposed technique is efficient in terms of time required for getting best possible results [21].

Kannan P. et. al. [2012], presented two approaches for the enhancement of dark sports images. Low contrast images may occur because of poor lightning conditions or small dynamic range of imaging systems. The methods proposed here are fuzzy rule based method and then applying sigmoid functions for the dark and bright inputs. The approach used for enhancement is splitting the color images into RGB planes and applying membership functions to each of the plane. The RGB planes are then concatenated to obtain the resultant enhanced mage. Sigmoid approach is beneficial, since it is flexible; the contrast factors can be adjusted until a satisfactory result is obtained [22].

Reshmalashmi C et. al. [2013], proposed an enhancement method with a new contrast enhancement algorithm, which maps elements from pixel plane to membership plane. Shortcomings of existing contrast enhancement techniques are rectified with the help of a mathematical tool called 'Fuzzy set'. This paper proposes an alternative membership function to map elements defined on the cross over point of fuzzy set [26].

Jaspreet Singh Rajal, [2013], proposed a fuzzy gray scale enhancement technique for low contrast image corrupted by Gaussian noise. The degradation of the low contrast image is mainly caused by the inadequate lighting during image capturing and thus eventually resulted in non uniform illumination in the image. The

proposed method has better performance than available methods in the enhancement of noisy images and has been validated by the performance measures like MSD, PEOIR etc [34].

Madhu et al. [2013], discussed various enhancement schemes are used for enhancing a new fuzzy logic and histogram based algorithm for enhancing low contrast color images has been proposed. It is based on two important parameters M and K, where M and K are the average intensity value of the image which is calculated from the histogram and K is the contrast intensification parameter. The given RGB image is converted into HSV color space to preserve the chromatic information contained in the original image. Under the control of the parameters M and K is stretched to enhance the image only the V component. The performance of the different contrast enhancement algorithms are evaluated based on the visual quality, CII and the computational time. Fuzzy Logic method is suitable for contrast enhancement of low contrast color images on the basis of the performance analysis, we advocate which our proposed [35].

Mahashwari T. et. al. [2013], presented a fuzzy based method for image enhancement. On the basis of the classification: dark, bright and gray, membership functions are applied by following a global approach. The resultant image obtained is modified and clear [36].

IV. GAPS IN LITERATURE

In this paper, a survey on various image enhancement techniques on different domains has been done. From the survey, it has found that

- Spatial domain image enhancement techniques namely Mean filter, Median filter and Laplacian of Gaussian filters are widely used for contrast enhancement in medical X-ray images. Edges plays significant role in vision processing but image enhancement technique may change the edges too. Therfore, it leads to degraded edges. Histogram based enhancement techniques namely AHE, CLAHE provide better enhancement than conventional spatial domain techniques.
- The existing transform domain based techniques introduce the color artefacts and Gaussian noise in the enhanced image. The traditional methods pay no attention to the regions or objects present in the image and enhancement is performed by predefined rules thus resulting in color imbalance of the output image. Haar transform based image enhancement technique provides better results than the spatial domain techniques.
- The existing fuzzy based image enhancement techniques have used an adjustment factor *k* statically and it is found to be satisfactory at *k*=128 which is only feasible for very low contrast images' enhancement and hence over contrast images when enhanced result in loss of information.

V. CONCLUSION

This paper is a presentation of a study on various image enhancement techniques. The review has shown that there are still many improvements required in the available techniques to handle different kind of images. This paper has shown that no particular technique is effective for every kind of images or image data set. To overcome the limitations of existing techniques, a new technique by using existing member function or new member function of fuzzy set theory will be proposed in near future which will evaluate *K* factor of fuzzy based enhancement automatically and will concentrate on edge restoration to find the best similarity value among the given set of values which will represent the image in more efficient manner.

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