Critical Analysis of Image Enhancement Techniques

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Abstract*: there has been great advancement in the image processing industries. The diversity applications and its contribution especially in the medical diagnosis, security systems, fault detection and recognition have motivated the growing of the digital image processing. However the image enhancement is massively and extensively stand as the central processing stage highly demanded. Most images taken by medical instruments and astronomical equipment, satellite images, aerial images and even real life photographs suffer from are of low quality and not easy to analyze, poor contrast and noise. it is necessary to enhance the contrast and remove the noise to increase image quality analyze basing on the demand, therefore image enhancement has taken place to improve the image quality and prepare them for analysis and further processing. In this paper we revealed the Fundamental techniques and schemes for enhancement in imaging in Spatial Domain and analyzed them and suggested the best schemes and overview direction to the future researchers at last. Image enhancement techniques improves the quality (clarity) of images for human viewing, removing blurring and noise, increasing contrast, and revealing details. The enhancement technique differs from one field to another according to its objective. The existing techniques of image enhancement can be classified into two categories: spatial domain and frequency domain enhancement.

***Keywords:* Spatial domain, Frequency domain, Wavelet, Point operation, Neighborhood operations.**

I. INTRODUCTION

Image enhancement techniques bring out the detail in an image that is obscured or highlight certain features of interest in an image. Enhancement techniques include contrast adjustment, filtering, morphological filtering, and deblurring. Image enhancement operations typically return a modified version of the original image and are frequently used as a preprocessing step to improve the results of image analysis techniques [1][2]. It is well-known that image enhancement as an active topic in medical imaging has received much attention in recent years. The aim is to improve the visual appearance of the image, or to provide a "better" transform representation for future automated image processing, such as analysis, detection, segmentation and recognition [1]-[2]. Moreover, it helps analyses background information that is essential to understand object behavior without requiring expensive human visual inspection. Carrying out image enhancement understanding under low quality image is a challenging problem because of these reasons. Due to low contrast, we cannot clearly extract objects from the dark background. Most color based methods will fail on this matter if the color of the objects and that of the background are similar. The survey of available techniques is based on the existing techniques of image enhancement, which can be classified into two broad categories: Spatial based domain image enhancement and Frequency based domain image enhancement. Spatial based domain image enhancement operates directly on pixels [1]-[2]-[3]. The main advantage of spatial based domain technique is that they conceptually simple to understand and the complexity of these techniques is low which favours real time Implementations. But these techniques generally lacks in providing adequate robustness and imperceptibility requirements. Frequency based domain image enhancement 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). The basic idea in using this technique is to enhance the image by manipulating the transform coefficients The advantages of frequency based image enhancement includes low complexity of computations, ease of viewing and manipulating the frequency composition of the image and the easy applicability of special transformed domain properties. The basic limitations including are it cannot simultaneously enhance all parts of image very well and it is also difficult to automate the image enhancement procedure. In this paper spatial domain enhancement techniques including Contrast Adjustment, Image filtering(Noise removal using wiener filter, Median filter, unmask filter),Decorretion, Morphological operations, Deblurring, ROI based Processing, Neighborhood and Block Processing, and Image Arithmetic were clearly overviewed and analyzed. These techniques can further be categorized as two operations categories namely Point Processing operation and Spatial filter operations. Traditional methods of image enhancement are to enhance the low quality image itself without embed high quality background information [1]-[2]. Frequency domain methods can again be classified into three categories: Image Smoothing, Image Sharpening, Periodic Noise reduction by frequency domain filtering. In this paper we focus on image enhancement considering only areas of spatial domain enhancement techniques. The structure of this paper is organized in such a way that Section 2 gives brief overview of some related work, in Section 3 review of spatial domain will be discussed, Section 4 gives some applications and the proposed future directions and Section 5 conclude the paper.

II. RELATED WORK

There had been various methods and techniques for image enhancement, traditionally each technique was applicable for a particular task in the imaging. The effort for image enhancement started from the point of conversion of the analogy image to the Digital image of which concept of the number of pixels as the results of sampling and impact of gray level or intensity was considered during the quantization the whole work intended for increasing Image resolution (visual appearance). However the challenge of the memory size for the image. Madhu [3] suggested that the Adaptive histogram equalization produced a better result, but the image is still not free from washed out appearance. The sharpness is poor and the background information as well as the plane is still fogged and poor in contrast. Agaian [4] suggested that the common no transform-based enhancement technique is global histogram equalization, which attempts to alter the spatial histogram of an image to closely match a uniform distribution. Histogram equalization suffers from the problem of being poorly suited for retaining local detail due to its global treatment of the image Tang [5] suggested global histogram equalization, which adjusts the intensity histogram to approximate uniform distribution. The challenge to this is that may not be appropriately applied in a local context. Global histogram modification treats all regions of the image equally and, thus, often yields poor local performance in terms of detail preservation.

III. SPATIAL DOMAIN TECHNIQUES

The Image contains some structure we want to extract along with uninterested or unwanted variations which we want to suppress. Image enhancement operators improves the detectability of important images details or objects by man or machines. The operators play a role of Noise reduction, Smoothing, Contrast stretching and sharpening (Edge enhancement). Spatial Domain Method in general cases referred to the spatial filtering mainly involves direct operation and manipulation of the pixel value of an image at a point or predefined neighborhood about a point (x, y). A spatial domain technique can be presented as the function

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

Where $f(x,y)$ is the input image, $g(x,y)$ is the output (processed) image, and T is an operator on f defined over a specified neighborhood about point(x,y).The simplest form of T is when the neighborhood is of the size 1×1(a single pixel).In this case the value of the g at (x,y) depends only on the intensity of f at that point, and T becomes an intensity or gray-level transformation function. The output value for this case depends only on the intensity value at a point and the transformation function is simplified

$$s = T(r) \qquad (2)$$

Where r denotes the intensity of f and s the intensity of g, both at the same coordinates (x, y) in the images. This simplest form of the image is basically known as the Point Processing .The point Processing approaches can be categorized into four categories as (a) Image Negatives in which gray level values of the pixels in an image are inverted to get its negative image. Consider the 8 bit image of the size $M \times$, the original image is subtracted from 255 to obtain the transformed output. Under this approach the transformation function becomes as

$$s = T(r) = 255 - r \qquad (3)$$

Where all parameters hold the original meanings, and the graphical presentation is as

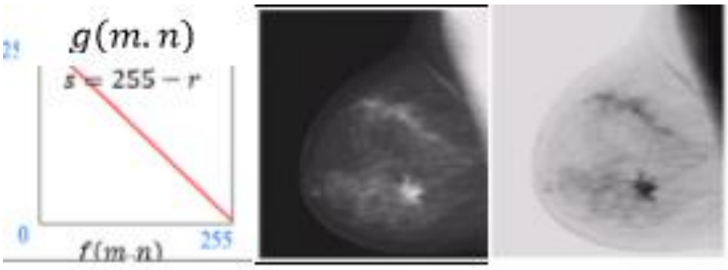


Fig1.Original image and its Negative Image

(b) Image Thresholding transformation in which let rth be a threshold value in f (x,).The Thresholding transformation function is given as

$$s = \begin{cases} 255 \; if \; r > threshold \\ 0 \; if \; r \leq threshold \end{cases} \qquad (4)$$

Image Thresholding can be achieved as in a normalized gray scale As pixel values of threshold image are either 0's or 1's, $g(x,y)$ is also named as binary image.

Fig2.Orignal images and their threshold images

(c) Log transformation maps a narrow range of low gray levels into a wider range of gray levels and compress the wider range of high gray levels into narrow range .This means the log transformation can compress the wider range of higher pixels values to a narrow one which may enable the process of the Thresholding if required. If C is the scaling factor, then log transformation can be achieved as

$$s = C \log (1 + |r|) \qquad (5)$$

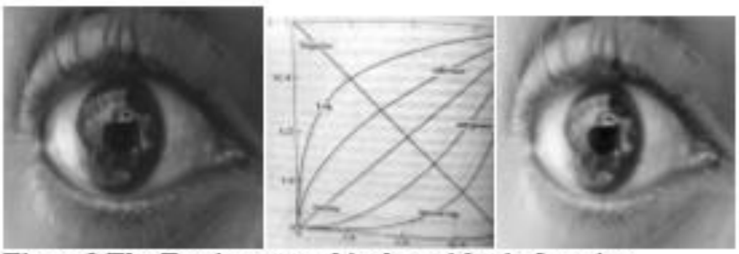


Figure3.The Eye image and its logarithmic function

(d)Power –Law (Gamma) Transformation Power –law transformations have the basic form

$$s = c * r\gamma \qquad (6)$$

Where c and γ are positive constants. If $\gamma < 1$ power law transformation maps a narrow range of dark pixel values into a wider range and wider ranges of bright pixel values to a narrow range. If $\gamma = 1$ then it becomes the identity transformation. If $\gamma > 1$ then the transformation maps in opposite direction to the curve mapped by $\gamma < 1$.

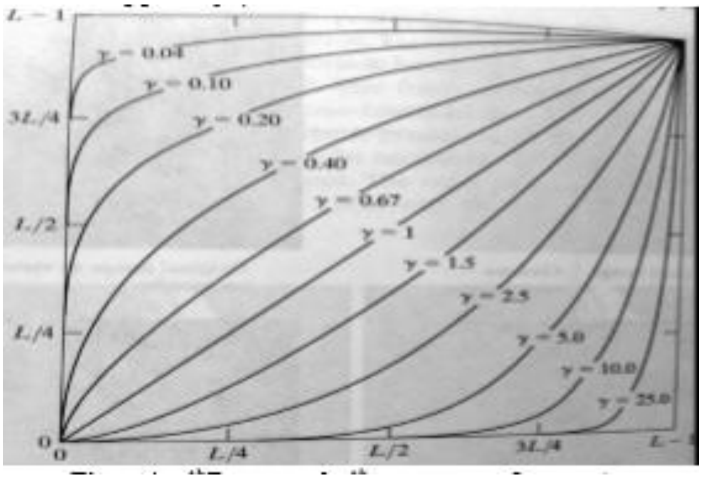
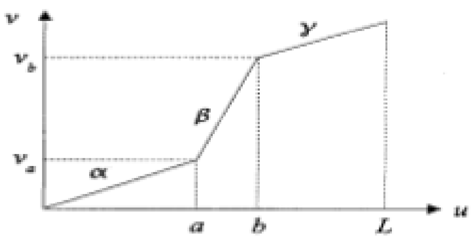


Figure4. γthPower and γth root curves for $c = 1$.

(e)Piece-Wise Linear Transformation There exist three types of the piece-wise linear transformation in the image enhancement namely Contrast Stretching, Intensity level slicing and Bit plane slicing. (i).Contrast Stretching involves processing an image to provide nice vision to human viewers. Frequently used after post processing .The technique is used as contrast enhancement process is to adjust the local contrast in different regions of the image so that the details in dark or bright regions are brought out and revealed to the human viewers. Contract enhancement is usually applied to input images to obtain a superior visual representation of the image by transforming original pixel values

$$v = \begin{cases} \alpha u & 0 \le u \le a \\ \beta(u-a)+v_a & a \le u \le b \\ \gamma(u-b)+v_b & b \le u \le L \end{cases} \qquad (7)$$



Where v the output and is the input, and parameters β,α,γ are slopes at different local regions

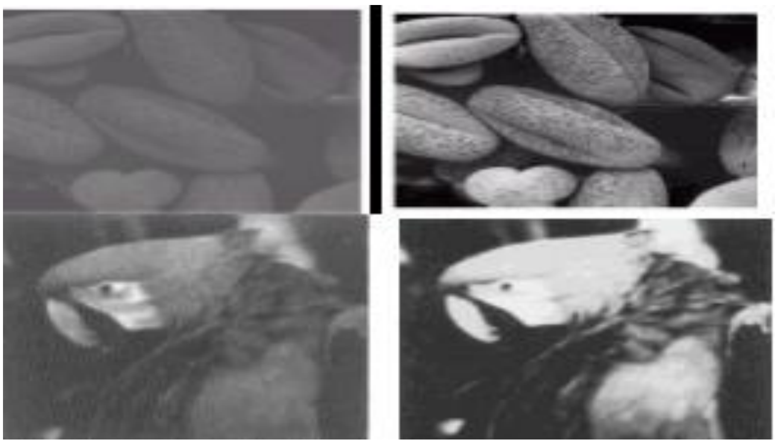


Figure 5.Original image and its contrast stretched image

This process improves the contrast by stretching the range of gray level values to span a desired range of gray level values [1]-[2] - [13]. This transformation is also called as image intensity transformation or normalization. In this paper contrast enhancement techniques can be broadly categorized into groups.

Histogram Equalization (HE) and Tone Mapping. Histogram Equalization is one of the most commonly used methods for contrast enhancement. It attempts to alter the spatial histogram of an image to closely match a uniform distribution. The main objective of this method is to achieve a uniform distributed histogram by using the cumulative density function of the input image. The disadvantage of the technique is not suit properly in the customer electronic Products where brightness is necessary

$Figure6. a, b, c$ $a)$ Original I, $b)$histogram equalized I , c) Adapted histogram I

Histogram specification technique is another approach for contrast enhancement. In this method, the shape of the histogram is specified manually and then a transformation function is constructed based in this histogram input image at gray levels. Image histogram is partitioned based on local minima and specific gray level ranges that are assigned to each partition. After partitioning, HE is applied on each partition [1]-[2]-[9]

Tone Mapping is another approach of contrast enhancement techniques. In this method if we want to output high dynamic range (HDR) image on paper or on a display. We must somehow convert the wide intensity range in the image to the lower range supported by the display. This technique used in image processing and computer graphics to map a set of colors to another, often approximate the appearance of high dynamic range images in media with a more limited dynamic range. Tone mapping is done in the luminance channel only and in logarithmic scale. It is used to convert floating point radiance map into 8-bit representation for rendering applications.[6]-[7]

(ii).Intensity Level or Gray level Slicing is another technique of Piecewise linear transformation in which gray or Intensity level slicing high lights certain range of gray levels in the original image. These transformations permit segmentation of certain gray level regions from the rest of the image. This technique is useful when different features of an image are contained in different gray levels (iii).Bit plane Slicing is another form of Piecewise transformation which highlights the contribution made to total image appearance by specific bits used for pixel gray levels and determines the adequacy of number of bits used to quantize each pixel in image compression. (f). Spatial Filter Operations are performed on a pixel along with its immediate neighbors; this is also called as neighborhood operations. Based on type of operations performed on the pixels spatial filters are classified into two categories: Linear and Nonlinear spatial filters. (i).Linear spatial filter process involves convolving or correlating a mask with an image i.e. passing a weighted mask over the entire image. Mask is also referred as window, template, or kernel. There are several algorithms used to provide mask for filtering, these algorithms include, averaging, Gaussian, Laplacian, motion and wiener algorithm .The averaging filter is categorized as the smoothing filter basing on the attribute. (ii).Nonlinear spatial filter are those filters in which enhanced image is not linearly related to pixels in the neighborhood of original image. Max filter is used to locate the brightest point in an image. It is a 100th percentile filter and removes salt noise whereas Min filter is used to locate the darkest point in an image. It is a 0th percentile filter and removes pepper noise and Median filter is a statistical filter used to locate the median value of the pixels. It removes salt and pepper noise. This filter provides less blur but rounds corners. The median filter is counted to be among the useful filter in the noise reduction as the part of image enhancement and commonly used to remove salt and paper noises. g) Deblurring Filtering in this paper can be considered as the special spatial domain operation which is used to restore an image, the blurring commonly caused by the motion of the camera during the image taking. The blurred image needs to be restored before used for further processing. There exist several techniques for deblurring image however the challenge occur when the blurring is associated by noises. The techniques can be categorized depending on the algorithms used for deblurring .The techniques include, wiener filter, Regularized filter, Lucy-Richardson Algorithm, and Blind Deconvolution Algorithm. Averaging (linear) and Median filters (non-linear)

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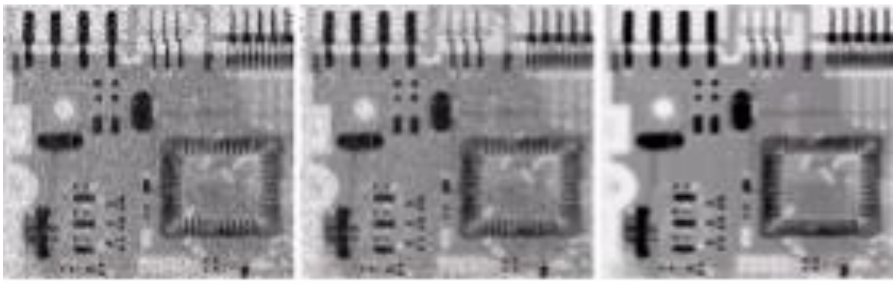

Figure*7.*a*,,*c **Original Noise image, Average filtered, Median filtered Laplacian**

$$\nabla^2 f = [f(x+1,y) + f(x-1,y) + f(x,y+1) + f(x,y-1)] - 4f(x,y)$$

Sharpened image by laplacian.

$$g(x,y) = f(x,y) - \nabla^2 f \quad (10)$$

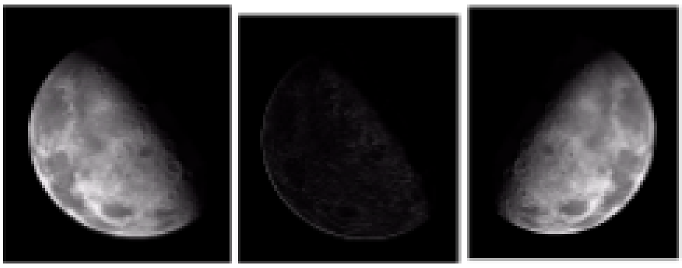

Figure 8.original image, laplacian filtered image, sharpen image

Figure9.*a*, *b*, *c and d*.

a) Is the original Image. *b*) Is the blurred and noisy image *c*).Restoration using wiener filter assuming no noise SNR=0. *d*) Restoration of Image using wiener filter considering noise SNR

h).Morphological Operators: These are operators which operate on the image for the purpose of taking care of the shape, structures. Morphological image processing (or morphology) describes a range of image processing techniques that deal with the shape (or morphology) of features in an image Morphological operations are typically applied to remove imperfections introduced during segmentation, and so typically operate on bi-level images.[11] It is clearly noted that the image enhancement process is the important process in the overall process of image analysis and therefore play a great role. Fundamentally morphological image processing is very like spatial filtering. The structuring element is moved across every pixel in the original image to give a pixel in a new processed image. The value of this new pixel depends on the operation performed. Morphological operations can be categorized into two types namely erosion and dilation. Both of these operation uses structuring element. The Morphological operations enable the process of the Boundary detection, shape and structure detection, Boundary extraction Region filling, Extraction of connected components, Thinning/thickening, Skeletonisation to be easier. However the challenge to the operation includes the reduction of the image size caused by the erosion operation and enlargement of the size by dilation. In many cases to reduce the effect of enlargement and reduction the two techniques are combined together

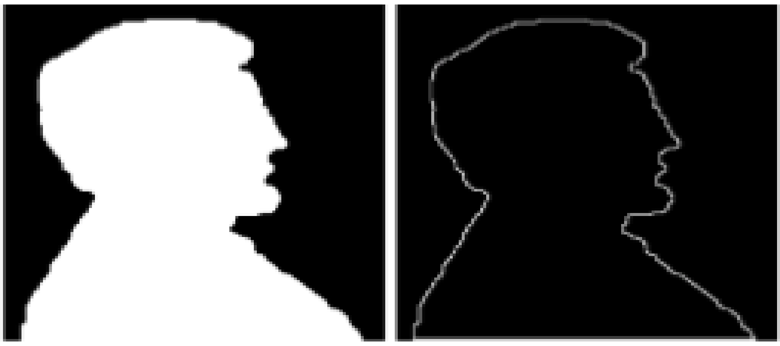

Figure 10.Boundary Extraction

The operation for the Boundary extraction is given as

$(A) = A - (A \square B)$ (11)

(i)ROI-Based Filtering -Filtering a region of interest (ROI) is the process of applying a filter to a region in an image, where a binary mask defines the region. This techniques is used to extract a particular region of the image, and along with can be used to enhance a particular region specified by mask. The scheme require the definition of the mask which slow down the speed of the processing in the most of automatic image processing system. (j).Image Arithmetic: this is the other kind of the image enhancement technique in the spatial domain which allows two or more images to add or subtract from one another. The process is commonly used to change the background of the image or processed image.

$Figure$11.a, b, c, d a) the original image, b) ROI mask, c) ROI-based filtered image, d) the arithmetic addition image

IV. FREQUENCY DOMAIN METHODS

Frequency domain techniques are based on the manipulation of the orthogonal transform of the image rather than the image itself. Frequency domain techniques are suited for processing the image according to the frequency content. The principle behind the frequency domain methods of image enhancement consists of computing a 2-D discrete unitary transform of the image, for instance the 2-D DFT, manipulating the transform coefficients by an operator M, and then performing the inverse transform. The orthogonal transform of the image has two components magnitude and phase. The magnitude consists of the frequency content of the image. The phase is used to restore the image back to the spatial domain. The usual orthogonal transforms are discrete cosine transform, discrete Fourier transform, Hartley Transform, wavelet Transform etc. The transform domain enables operation on the frequency content of the image, and therefore high frequency content such as edges and other subtle information can easily be enhanced. Frequency domain which operate on the Fourier transform of an image. □ Edges and sharp transitions (e.g. noise) in an image contribute significantly to high frequency content of Fourier transform Low frequency contents in the Fourier transform are responsible to the general appearance of the image over smooth areas. The concept of filtering is easier to visualize in the frequency domain. Therefore, enhancement of image (x,y) can be done in the frequency domain based on DFT. This is particularly useful in convolution if the spatial extent of the point spread sequence h(x, y) is large then convolution theory. $(x,y) = h(x,y)$ □ $f(x,y)$ where $g(x,y)$ is enhanced image. Usual orthogonal transforms are discrete cosine transform, discrete Fourier transform, Hartley Transform etc. The transform domain enables operation on the frequency content of the image, and therefore high frequency content such as edges and other subtle information can easily be enhanced. Frequency domain which operate on the Fourier transform of an image. □ Edges and sharp transitions (e.g. noise) in an image contribute significantly to high frequency content of Fourier transform. □ Low frequency contents in the Fourier transform are responsible to the general appearance of the image over smooth areas. The concept of filtering is easier to visualize in the frequency domain. Therefore, enhancement of image $f\ (x,\ y)$ can be done in the frequency domain based on DFT. This is particularly useful in convolution if the spatial extent of the point spread sequence $h\ (x,\ y)$ is large then convolution theory.

$(x,y) = h(x,y)$ □ $f(x,y)$ (12)

Where (x,y) the enhanced Image.

The General Block Diagram for the Frequency domain enhancement procedures is as given below.

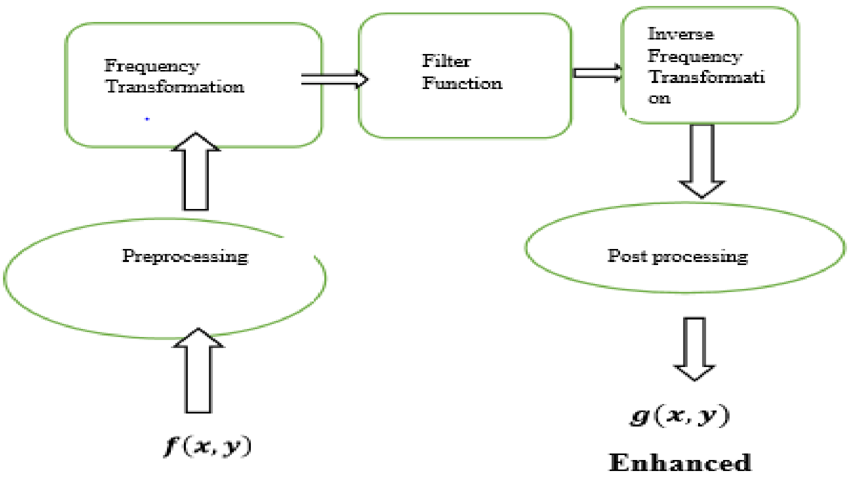

Figure 12

One of the recent improved algorithm for the image enhancement in the frequency domain is the one provided by Dr. Muna. The algorithm uses the wavelet transform as illustrated below

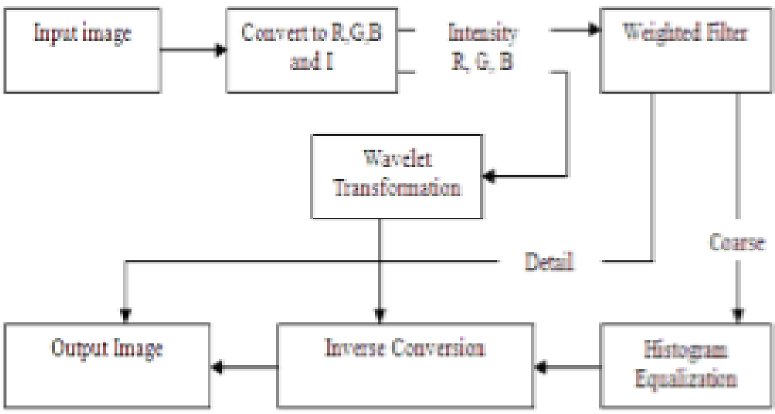

Figure 13

The weighted filter is given by

$$\hat{X}(k)=\frac{\sum_{n=-w}^{w}W(k,n)X(k-n)}{\sum_{n=-w}^{w}W(k,n)} \quad (13)$$

Figure14.image and output enhanced image

The results of this algorithm shown to be very promising as shown above

V. APPLICATION

Image enhancement is used for improving the quality of images. The typical applications of image enhancement are in Aerial imaging, Satellite imaging, Medical imaging, Digital camera application, remote sensing, However Image Enhancement techniques are technically recently used in forensics, Astrophotography, Fingerprint matching, etc. The better result for Image enhancement has also used in real time enhancement of neuro evolution of augmenting. IE techniques when applied to pictures and videos help the visually impaired in reading small print, using computers and television, and face recognition. Color contrast enhancement, sharpening and brightening are just some of the techniques used to make the images vivid. In the field of e-learning, IE is used to clarify the contents of chalkboard as viewed on streamed video; it improves the content readability. Medical imaging uses this for reducing noise and sharpening details to improve the visual representation of the image. This makes IE a necessary aiding tool for reviewing anatomic areas in MRI, ultrasound and x-rays to name a few. In forensics IE is used for identification, evidence gathering and surveillance. Images obtained from fingerprint detection, security videos analysis and crime scene investigations are enhanced to help in identification of culprits and protection of victims.

VI. ANALYTICAL OBSERVATIONS

The point processing methods are most primitive, yet essential image processing operations and are used primarily for contrast enhancement. Image Negative is suited for enhancing white detail embedded in dark regions and has applications in medical imaging [figure1]. Power-law transformations are useful for general purpose contrast manipulation. For a dark image, an expansion of gray levels is accomplished using a power-law transformation with a fractional exponent. Log Transformation is useful for enhancing details in the darker regions of the image at the expense of detail in the brighter regions the higher-level values. For an image having a washed-out appearance, a compression of gray levels is obtained using Power-law transformation with γ greater than 1. The histogram of an image (i.e., a plot of the gray level frequencies) provides important information regarding the contrast of an image. Histogram equalization is a transformation that stretches the contrast by redistributing the gray-level values uniformly [figure6].The adaptive histogram equalization has improved features compared to the normal equalization and therefore become very useful in the study of the texture and particular features of the images

The linear and non- spatial filtering methods, are usefully in the smoothing and removing the noises. The averaging method was the basic smoothing algorithm but has been found to produce unpromising results compared to the median filter which removed completely the salt and paper noises [fig.7] .The wiener filter is powerful filter used for image restoration and noise removing. It has been used for restoration of the blurred image frequently caused motion of the position and location of the camera. The Gaussian filter is useful in removing the randomly Gaussian noises, and since its distribution is mathematically presented and modeled then it is frequently used, however the researches show that many noises are not modeled in Gaussian modelling. The laplacian filter is applied quiet successfully in sharpening of the image; moreover enable to improve the contrast [figure8]

Morphological Operation contributed enough to the enhancement after segmentation, despite the tendency of reducing the size of the localized image by erosion and increasing the size by dilation still the method is powerful in the smoothening and reshaping the image and It's application in boundary extraction [figure10], thinning and thicken, filling and Skeletonisation .In graphics and video segmentation is frequently applied.

The ROI-based Filtering is effective image enhancement technique, it helps to analyses the texture, and features locally without concentrating on the other parts of the image, this type of the filter is at great applied in medical image of which a particular location of the image is required to be analyzed and dialogized

VII. CONCLUSION

Image enhancement algorithms offer a wide variety of approaches for modifying images to achieve visually acceptable images. The choice of such techniques is a function of the specific task, image content, observer characteristics, and viewing conditions. The review of Image enhancement techniques in spatial domain have been successfully accomplished and is one of the most important and difficult component of digital image processing and the results for each method are also discussed. Based on the type of image and type of noise with which it is corrupted, a slight change in individual method or combination of any methods further improves visual quality. In this survey, we focus on survey the existing techniques of image enhancement, which can be classified into two broad categories as spatial domain enhancement and Frequency domain based enhancement. We show the existing technique of image enhancement and discuss the advantages and disadvantages of these algorithms. Although we did not discuss the computational cost of enhancement algorithms it may play a critical role in choosing an algorithm for real-time applications. The recent developments methods of image enhancement and point out promising directions on research for image enhancement in spatial domain for future research. The future scope will be the development of adaptive algorithms for effective image enhancement using Fuzzy Logic and Neural Network, However the researchers works on the possibility of improving the adapted wavelet to enable the filtering to the better quality

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