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COMPARATIVE ANALYSIS OF IMAGE ENHANCEMENT TECHNIQUES

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Abstract— *Image enhancement is an indispensable part of image processing. Image enhancement is the process of improving the visual quality of an image without any degeneration in the original image. The main task of image enhancement is contrast enhancement and noise reduction. There are many image enhancement techniques that seek to improve quality of digital images. According to its objective image enhancement techniques differs. But in general, image enhancement techniques can be classified as spatial domain image enhancement and frequency domain image enhancement techniques. This paper contains studies of different image enhancement techniques under spatial and frequency domain and survey and analysis, among performance of various image enhancement techniques and their applications.*

Keywords- *Image processing, Image enhancement, Spatial domain, Frequency domain, High pass filters, Low pass filters*

I. INTRODUCTION

All An Image is a matrix or function, of square of pixels. Those pixels denote the elements of an image and have some intensity or grayscale at coordinates [1]. Process of Obtaining an image of high quality or descriptive characteristics of the original image is image processing. Image processing is also striving against automatically capture of "meaningful" targets. Due to poor light and weather conditions, dark or very light background, improper equipment used for capturing with poor optics or noisy sensors images may losses information and get some distortions such as poor contrast, noise, motion blur and color misbalancing [2]. This distortion leads to low quality images.

The main objective of image enhancement in a digital image is to improve the quality of the original image or highlight some portion of the image for better human perception [3]. Image enhancement can be defined as the process of incrementing contrast while reducing noise for better looks of the images. There are lots of techniques that provide successful image enhancement. Image enhancement techniques are mostly categorized on the basis of their work specific domains that are image enhancement techniques in spatial domain and image enhancement techniques in the frequency domain. These techniques provide image enhancement task, such as contrast enhancement and filtering for removing noise from the image. There are some advanced techniques too, that automatically enhances images. Spatial domain refers to the image plane itself; it is a direct modification of pixels, or intensity value of pixels in an image. Frequency domain processing techniques are based purely on convolution theory and on manipulation in the Fourier transform of an image.

In this paper section II contains some related work that shows the literature survey based on image enhancement techniques. From the literature review image enhancement methods that were selected in this study are mainly categorized in spatial and frequency domain. Different methods with their result of MATLAB implementation of image enhancement under these two domains are given in section 3 and 4. Section 5 contains a survey analysis of these methods along with their application area. And the last section contains conclusion derived from this survey.

II. RELATED WORK

There are many advance techniques based on their functional area studied during this survey such as Retinex, haze filtering, advance histogram techniques and many more [4]. There are many methods that are particularly used for edge enhancement in some specific application domain[5]. On the bases of human visual system methods introduce in [6] are based on contrast stretching and histogram processing. Some methods are enhancing images on the bases of objects lies in that image [7]. Resolution enhancement techniques [8] are based on transformation used to improve resolution of an image. Some advance enhancement techniques are a combination of basic techniques such as contrast enhancement techniques based on histogram [9][10], the combination of histogram equalization with gamma intensity correction (CHEGIC) for face images[11].

There are lots of image enhancement techniques based on type of images such as color image enhancement [12], Medical imaging enhancement [13], and underwater image enhancement [14]. Artificial intelligence also introduces some automatic image enhancement based on neural network and fuzzy set theory [15][16]. Image processing techniques give much better performance than artificial intelligence techniques. According to image objective image processing has different enhancement technique, but achieving the best result under different situation hybridization of basic, simple and most common techniques is necessary. This paper mainly focuses on basic techniques that are realistic and radically symmetric for enhancing an image. As given in very famous book for image processing[1],and other already publish papers [17],[18],[19],[20] it is analyzed that image enhancement is a compulsory phase of preprocessing of an image. Image enhancement techniques are classified mainly in two categories spatial domain techniques and frequency domain techniques. Image enhancement techniques used to improve contrast of an image and removes noise from the image. Contrast enhancement can be achieved by manipulating grayscale of an image [21] and filters are used to remove noise from an image by applying smoothing or sharpening an image. Filters can be classified as Linear and Non-linear filters under spatial domain and High pass and low pass filters under the frequency domain.

III. SPATIAL DOMAIN TECHNIQUES

Spatial domain is direct manipulation of image pixels. It is a manipulation or changing the image representations and also it is used in many fields such as contrast stretching, smooth and sharpening filtering images. In simple, Image enhancement in the spatial domain is transforming an image *of (x, y)* into image *g (x, y)* using *T*. Where *T* is the operator off defined over some neighborhood of *(x, y)*.

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

The spatial domain technique can be divided into four types:

3.1 Point processing operation

When the neighborhood is simply the pixel itself point processing operation are performed. The list of point processing operations is given below:

3.1.1 Image negation:

Most basic and simple operation of the image processing is generation of negative image. The negative image g (x, y) of input image I (x, y) can be generated by:

$$g(x, y) = 255 - i(x, y) \quad (2)$$

3.1.2 Contrast stretching:

Contrast is represented as the difference between intensity of two adjacent pixels. Due to the poor illumination contrast level of an image may vary that give low quality image. This technique improves the quality of an image by increasing the dynamic range of gray levels to increase the contrast of an image and expands the range of brightness values. Contrast stretching expands the range of brightness values for improving the images.

3.1.3 Gray level slicing:

Gray level slicing is a method that is used to highlight a specific range of gray levels in an image and enhance the interested features of that image such as masses of water in satellite image and enhancing the flaws in X-ray image [9]. High level values displayed in range of interest and low value for all other gray levels. This technique highlights the range of gray levels and reduces all others to a contrast level. The gray slicing techniques have two function one is it can be either highlight a group of intensities and diminish all others or it can emphasize a group of gray levels and leave the rest alone.

3.1.4 Gamma transforms:

This method is also known as a power law transforms. This method transforms range of dark input values into the range of output values and vice versa. Each input pixel transforms to a fixed power. Transforming is done by:

$$I_{out}(x, y) = c\,[I_{in}(x, y)^{\gamma}] \quad (3)$$

3.1.5 Logarithmic transformation:

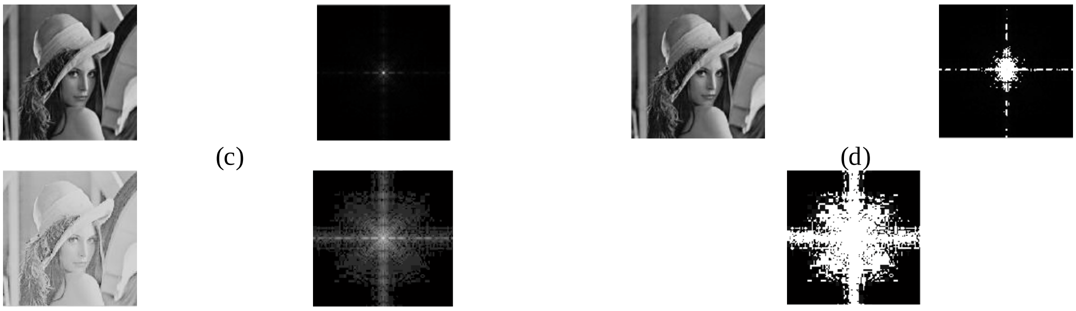
When input gray level e values have a large range of values then this method is useful. The method transforms range of low input gray levels into a wider range of output values. Log transform can be represented as:

$$I_{out}(x, y) = c * \log(1 + I_{in}(x,y)); \quad (4)$$

.

(a)

(b)



(c) (d)

(e) (f)

Fig. 1 (a) Original image lena, galaxy, the result of (b) image negation, (c) Contrast stretching, (d) Gray level slicing, (e) Logarithmic Transform (f) Gamma transforms

3.2 Histogram Processing

The histogram is real time image processing tool because it plays an important role in image enhancement, image enhancement and image compression. Histogram plot represents the frequency of occurrence of all gray-level in the image, the horizontal axis corresponds to gray level value. Histogram plot shows that how the values of individual pixel in an image are distributed. Histogram function can be given as :

$$H(r_k) = (n_k)/n \qquad (6)$$

Histogram equalization and Histogram matching are two efficient methods of histogram processing to produce a much better image from original image these two methods are used to modify the histogram of original images for enhancing that image.

3.2.1 Histogram equalization:

Histogram equalization stretches the histogram of an image. All pixel values of the image are transforms in such a way that an equal number of the pixel map to each of the user specified output gray level scales when the image's histogram equalized. It automatically increased contrast to peak range of brightness values and decrease the contrast in very light or dark parts of the image. This method is only best suitable for input image with poor contrast only. In other cases the adaptive histogram equalization is preferred. In adaptive histogram equalization, image is divided into several rectangular domains, and then equalizing histogram and modify levels so that match across boundaries. For better result, it also used with interpolating function.

3.2.2 Histogram Matching:

Histogram matching is also known as histogram specification. Histogram matching is a method to generate an image with specified histogram. This is one of the better approaches because the result of this method is predictable and easy to implement. The output of this method can be achieved in three steps: 1. Find the histogram of the input image and determine its equalization transformation, 2. Use the specified pdf of the output image to obtain the transformation function, and last 3. Find inverse transformation. Histogram matching also enables to match the gray scale distribution in one image to gray scale distribution in another image.

(a) (b)

***Fig.2 Result of (a)* Histogram equalization (b) Histogram matching**

3.3 Filtering

Image filtering is a preprocessing step of image enhancement. It is used to perform operations like smoothing, sharpening and removing noise from images. The filtering is performed on pixels along with its neighborhood pixels. Based on operation perform on pixels the spatial filter can be classified as linear and nonlinear spatial filters.

3.3.1 Linear spatial filters:

Linear filtering is a process of twining a convolution kernel with an image. Twining can be done by multiplying, adding, manipulating and passing kernel values over an entire image. The kernel is also known as window, template or more general mask. It is represented as a m x n matrix. In general linear convolution for image f(x,y) with mask w(a,b) can be achieved by:

$$g(x,y) = f(x+a,y+b)\ w(a,b) \qquad (5)$$

Linear filters perform two functions for enhancing image quality smoothening image and sharpening image. According to these two operations, filters are further categorized as Low pass filters(LPF) and High pass filters.

Low pass filters replace every kernel pixel in original image by averaging of all the pixels in its local neighborhood pixels. LPF filters are also known as neighbourhood averaging. The mechanism of LPF is the preservation of the smooth region while removing sharp variation using blurring effect. Mean filter is noise reduction. In weighted average filter pixels nearer to centre are more weighted than distant pixels. Gaussian filter is at removing noise drawn from a normal distribution.

High pass filters perform a sharpening operation on an image. Sharpening is used to highlight fine details in an image and enhance blurred images. Sharpening is a useful pre-processing tool in many applications such as medical imaging, electronic printing. A classic implementation of 3x3 HPF's convolution kernel contains 8/9 at its centre and all others have -1/9. The sum of the coefficients is zero, so that when the kernel is operating in an area with slowly varying gray-levels, the output of the mask is zero or very small and thus low frequencies are removed from the image. So the result is that the global contrast of the image is significantly reduced. High pass filtering method overcome the problems of classical method is high boost filtering. In this method, high frequencies emphasized and lower frequencies are relatively maintained as it is. This can be achieved by:

$$\text{Highpass} = \text{original} - \text{lowpass} \qquad (6)$$

The sharpening can be accomplished by spatial differentiation. Image differentiation enhances edges and other noise and blurred area with varying gray level values. Isomorphic filters are filters that uses a two-dimension and second order derivative for image sharpening, whose response is independent of discontinuity direction in an image. One of the simple isomorphic filter is Laplacian But the derivation gives effect of sharpening in the image.

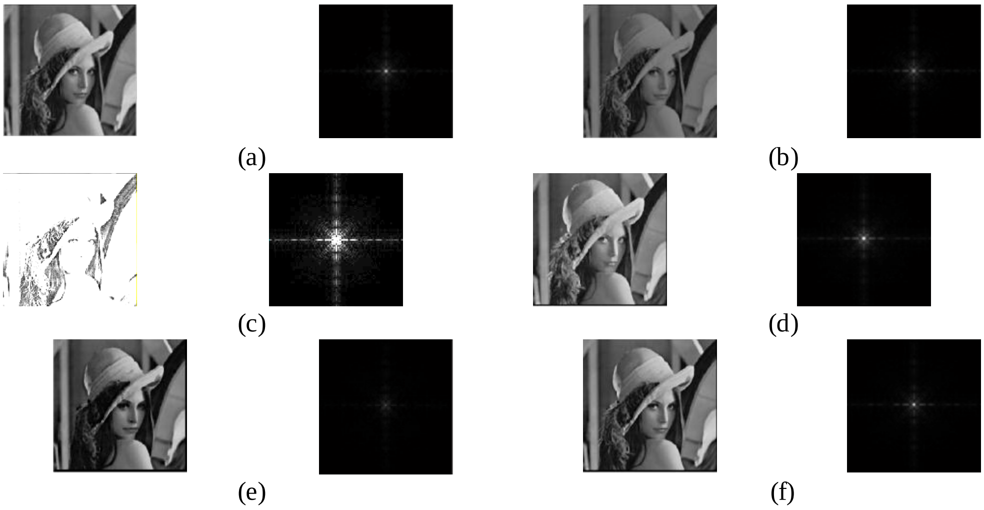


Fig. 3 Result of (a) Filter image mask 1/9 [box], (b) Filter image mask 1/16 [Weighted mask], (c) Laplasian Transform, (d) maximum filtering, (e) minimum filtering, (f) median filtering

3.3.2 Non Linear spatial filters:

These filters operate on some neighborhood of every pixel at a location (x,y). The nonlinearity is expressed in the computation of the maximum gray-level(Max filter), the median gray-level(Median filter) or the minimum gray-level(Min filter) of all the pixels in the neighborhood.

Max filter locates the brightest pixels in an image. It is a 100th percentile filter and removes salt noise. Perform by:

$$g(x,y)=\max\{f(x+a,\ y+b)\} \text{ for } a,b = -1,0,+1 \qquad (7)$$

Min filter locates the darkest pixels in an image. It is a 0th percentile filter and removes pepper noise. Performed by:

$$g(x,y)=\min\{f(x+a,\ y+b)\} \text{ for } a,b= -1,0,+1 \qquad (8)$$

Median filter is a statistical filter locates the median value of the pixels. It removes salt and pepper noise. This filter provides less blur, but round corners. Performed by:

$$g(x,y)=\text{median}\{f(x+a,\ y+b)\} \text{for } a,b= -1,0,+1 \qquad (9)$$

IV. FREQUENCY DOMAIN TECHNIQUES

Frequency domain techniques are based purely on the convolution theorem to change the image position. Frequency domain techniques are based on the manipulation of the orthogonal transform of the image rather than the image itself. The image is in the form of the frequency domain, the image is computed into Fourier transform. In frequency domain it is easy to visualize the aspect of filtering. The frequency domain enhancement of image f (m,n) can be based on its DFT $F(u,v)$. Here the convolution kernel may be computationally unattractive. Here a transfer function H(u,v) is directly designed and implement the enhancement in the frequency domain as follows where G(u,v) gives enhanced image of original image F(u,v) with transform function H(u,v):

$$g(u,v) = H(u,v)F(u,v) \qquad (10)$$

Homomorphic filter is based on the special case of a class of system known as homomorphic system. The key approach of this filter is separation of the illumination $i(x,y)$ and reflectance $r(x,y)$ components after that apply homomorphic filter function $H(u,v)$ on that component separately. Homomorphic filter function is :

$$S(u,v) = H(u,v)\, F_i(u,v) + H(u,v)F_r(u,v) \qquad (11)$$

In frequency domain edge and sharp pixels with gray values in an image contribute to the high-frequency content of its Fourier transform. Regions that are relatively uniform gray values in an image contribute to the low-frequency content of its Fourier transform. Therefore In frequency domain image enhancement techniques can be categorized as Low pass

(a) (b)

Fig.4 Result of (a) Homomorphic filter (b) Fourier transforms

Filtering and High pass filtering same as linear filtering in spatial domain. But mechanism in both domains is far different from each other, although they have the same name.

4.1 Low pass filtering

In low pass filter smoothening of an image in the Frequency domain can be performed by attenuating the high-frequency content of its Fourier transform. On the bases of transfer function low pass filters in the frequency domain categorized in three LPF methods.

4.1.1 Ideal low pass filter:

Transfer function for An ideal low pass filter with cutoff frequency r_0 is :

I.
$$H(u,v) = \begin{cases} 1, & \text{if } \sqrt{u^2+v^2} \le r_0 \\ 0, & \text{if } \sqrt{u^2+v^2} > r_0 \end{cases} \qquad (12)$$

(a) (b)

Fig.5 Result of Ideal low pass filter with (a) Cof 20 and (b) Cof 70

The amount of frequency components passed by the filter in ideal LPF determines by the cutoff frequency r_0. The smaller the value of r_0, more the number of image components eliminated by the filter. Choosing cutoff frequency is very important in all LPF.

In general, the value of r_0 is chosen such that most components of interest are passed through, while most components not of interest are eliminated. The most general way to establish a set of standard cut-off frequencies is to compute circles which enclose a specified fraction of the total image power.

4.1.2 Butterworth low pass filter:

A 2D Butterworth low pass filter has transfer function:

$$H(u,v) = \frac{1}{1 + \left[\frac{\sqrt{u^2 + v^2}}{r_0} \right]^{2n}} \tag{13}$$

Here n is filter order and r_0 is cutoff frequency which is chosen as given in above technique. This technique is more suitable for smoothing image as compared to ideal LPF.

(a) (b)

Fig.6 Result of Butterworth low pass filter with (a) Cof 20 and (b) Cof 70

4.1.3 Gaussian low pass filter:

It is most popular and efficient method among low pass filtering methods. The form of a Gaussian low pass filter in 2D is given by :

$$H(u,v) = e^{-D^2(u,v)/2\sigma^2} \tag{14}$$

where $D(u,v) = \sqrt{u^2 + v^2}$ is the distance from the origin in the frequency plane. The parameter σ measures the spread or dispersion of the Gaussian curve. As Large the value of σ, larger the cutoff frequency and milder the filtering.

(a) (b)

Fig.7 Result of Gaussian low pass filter with (a) Cof 20 and (b) Cof 70

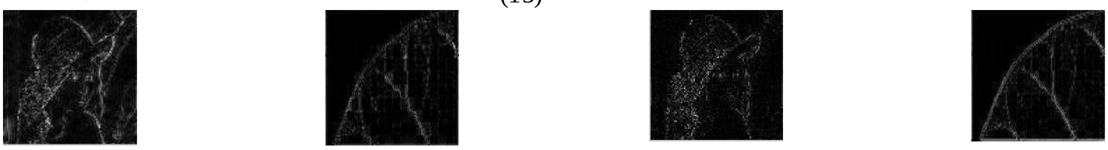
4.2 High pass filtering

In high pass filtering image sharpening in the Frequency domain can be done by attenuating the low-frequency content of its Fourier transform. On the bases of transfer function high pass filters in the frequency domain categorized in three HPF methods. Each method gives the opposite result with respect to their low pass filtering methods.

4.2.1 Ideal high pass filter:

Transfer function for an ideal low pass filter with cutoff frequency r_0 is*:*

$$H(u,v) = \begin{cases} 0, & \text{if } \sqrt{u^2 + v^2} \le r_0 \\ 1, & \text{if } \sqrt{u^2 + v^2} > r_0 \end{cases} \tag{15}$$



(a) (b)

Fig.8 Result of Ideal high pass filter with (a) Cof 20 and (b) Cof 70

4.2.2 Butterworth low pass filter*:*

A 2D Butterworth low pass filter has transfer function:

$$H(u,v) = \frac{1}{1 + \left[\frac{r_0}{\sqrt{u^2 + v^2}} \right]^{2n}} \quad (16)$$

(a) (b)

Fig.9 Result of Butterworth high pass filter with (a) Cof 20 and (b) Cof 70

4.2.3 Gaussian High pass filter:

It is most popular and efficient method among low pass filtering methods. The form of a Gaussian low pass filter in 2D is given by :

$$H(u,v) = 1 - e^{-D^2(u,v)/2\sigma^2} \quad (17)$$

where $D(u,v) = \sqrt{u^2 + v^2}$ is the distance from the origin in the frequency plane. The parameter σ measures the spread or dispersion of the Gaussian curve.

(c) hp20 Hp70

Fig.10 Result of Gaussian high pass filter with (a) Cof 20 and (b) Cof 70

V. COMPARATIVE ANALYSIS

The implementation result given above shows impact of various image enhancement techniques on a same input image. It is hard evaluating that which one is best among all, because each method gives better results in their application area. From the observation of result, some conclusions are drawn about method's efficiency in particular application is shown in following table:

TABLE I
A BRIEF SURVEY OF IMAGE ENHANCEMENT TECHNIQUES

Method Name	Key Points	Application Domain
Image Negation	-Improving white detail lies in dark regions	Medical imaging such as x-ray, Traffic monitoring.
Contrast stretching and Gray level slicing	- Best for general-purpose contrast manipulation.	General purpose usage, works each kind of images.
Gamma Transform	- Performs an expansion of gray levels so they are only	Dark images Such as satellite images, traffic monitor
Log Transform	-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.
Histogram Processing	- Stretches the contrast by matching, matching the gray-level values uniformly.	LCD display device; Low Quality video, image processing
Linear low pass spatial Filters	- Convolution filters used for blurring and Noise reduction -Have corresponding frequency domain filters.	-Applicable in each domain for object extraction, bridging small gaps in line or curves etc.
Linear High	-Highlight fine detail, Sharpening images	-Electronic printing, medical imaging,

passes spatial Filters	removes noise and blurred areas.	industrial inspection, autonomous guidance in military systems.
Non-linear spatial filters	-Mask used to determine the proper substitution of a "good" pixel value. -Hard to interpret effect in the frequency domain.	Preserves edges, Removes impulse noise, Avoid excessive smoothing.
Low Pass Filters	-Smoothen image by attenuating the high-frequency content of its Fourier transform.	Applicable in each domain for preprocessing in object extraction, bridging small gaps in line or curves etc.
High Pass Filters	-Sharpen the image by attenuating the high-frequency content of its Fourier transform.	Edge enhancement, removes noise, highlight fine details.

Although in this paper computational cost of the enhancement methods did not discuss, but it may play a critical role in choosing a method for real-time applications. Despite the effectiveness of each of these algorithms when applied separately, in practice one has to devise a combination of such methods to achieve more effective image enhancement.

VI. CONCLUSION

Image enhancement methods offer a wide variety for modifying images to achieve high quality images, but choice of such techniques is a dependent on task, image content, observer characteristics, and viewing conditions. This paper has discussed about different enhancement techniques along with successful implementation using MATLAB tool with relevant output. And also noises were removed from an image. All the techniques give better results in their application domain. This paper considers only basic image processing techniques for image enhancement; future scope will be of devising a combination of these basic methods and efficient image enhancement using artificial intelligence techniques such as neural network.

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