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Various Image Enhancement Techniques- A Critical Review

S.S. Bedi[1], Rati Khandelwal[2]

Assistant Professor, CSIT, MJPRU, Bareilly, India [1]

M.Tech IV[th] Semester, Student, Banasthali Vidyapith, Jaipur, India [2]

ABSTRACT: Image Enhancement is one of the most important and difficult techniques in image research. The aim of image enhancement is to improve the visual appearance of an image, or to provide a "better transform representation for future automated image processing. Many images like medical images, satellite images, aerial images and even real life photographs suffer from poor contrast and noise. It is necessary to enhance the contrast and remove the noise to increase image quality. One of the most important stages in medical images detection and analysis is Image Enhancement techniques which improves the quality (clarity) of images for human viewing, removing blurring and noise, increasing contrast, and revealing details are examples of enhancement operations. 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. In this paper, we present an overview of image enhancement processing techniques in spatial domain. More specifically, we categorise processing methods based representative techniques of Image enhancement. Thus the contribution of this paper is to classify and review image enhancement processing techniques, attempt an evaluation of shortcomings and general needs in this field of active research and in last we will point out promising directions on research for image enhancement for future research.

Keywords: Frequency based domain enhancement, Image Enhancement, Spatial based domain enhancement, Histogram Equalization.

I. INTRODUCTION

Image enhancement problem can be formulated as follows: given an input low quality image and the output high quality image for specific applications. 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. Moreover, it helps analyses background information that is essential to understand object behaviour 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 colour based methods will fail on this matter if the colour 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. 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 according to if enhanced image embed high quality background information, the existing techniques of image enhancement like spatial domain methods can again be classified into two broad categories: Point Processing operation and Spatial filter operations. Traditional methods of image enhancement are to enhance the low quality image itself. It doesn't embed any high quality background information. The reason is that in the dark image, some areas are so dark that all the information is already lost in those regions. No matter how much illumination enhancement you apply, it will not be able to bring back lost information. 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 areas of spatial domain enhancement techniques. The remainder of the paper is organized as follows. 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

Image enhancement process consists of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form better suited for analysis by a human or machine. The principal objective of image enhancement is to modify attributes of an image to make it more suitable for a given task and a specific observer. During this process, one or more attributes of the image are modified. Digital Image enhancement techniques provide a multitude of choices for improving the visual quality of images. Appropriate

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choice of such techniques is greatly influenced by the imaging modality, task at hand and viewing conditions. A familiar example of enhancement is in which when we increase the contrast of an image and filters it to remove the noise "it looks better". It is important to keep in mind that enhancement is a very subjective area of image processing. Improvement in quality of these degraded images can be achieved by using application of enhancement techniques.

The work done by various researchers for Image Enhancement are discussed here, Madhu[1] 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. Alpha rooting rendered the entire image in a dark tone. Even the outline of the clouds which was visible in case of histogram equalization is lost. Agaian [2] 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. It is also common that the equalization will over enhance the image, resulting in an undesired loss of visual data, of quality and of intensity scale. Tang [3] suggested global histogram equalization, which adjusts the intensity histogram to approximate uniform distribution. The global histogram equalization is that the global image properties may not be appropriately applied in a local context. In fact, global histogram modification treats all regions of the image equally and, thus, often yields poor local performance in terms of detail preservation. Therefore, several local image enhancement algorithms have been introduced to improve enhancement.

III. SPATIAL DOMAIN METHODS

Spatial domain techniques directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. Spatial domain techniques like the logarithmic transforms, power law transforms, histogram equalization are based on the direct manipulation of the pixels in the image. Spatial techniques are particularly useful for directly altering the gray level values of individual pixels and hence the overall contrast of the entire image. But they usually enhance the whole image in a uniform manner which in many cases produces undesirable results. It is not possible to selectively enhance edges or other required information effectively. Techniques like histogram equalization are effective in many images. The approaches can be classified into two categories: Point Processing operation (Intensity transformation function) and Spatial filter operations. An overview of some of the well known methods is discussed here. Point processing operations (Intensity transformation function) is the simplest spatial domain operation as operations are performed on single pixel only. Pixel values of the processed image depend on pixel values of original image. It can be given by the expression $g(x,y) = T[f(x,y)]$, where T is gray level transformation in point processing. The Point processing approaches can be classified into four categories as Image Negatives in which gray level values of the pixels in an image are inverted to get its negative image. Consider a 8 bit digital image of size M x N, then each pixel value from original image is subtracted from 255 as $g(x, y)=255- f(x, y)$ for $0 \leq x < M$ and $0 \leq x < N$. In a normalized gray scale, $s = 1.0 – r$. Negative images are useful for enhancing white or gray detail embedded in dark regions of an image. Fig.1 shows an example of an image negative.

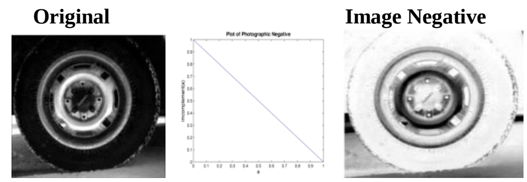

Fig. 1. Original image and its negative image

Another technique is Image Thresholding transformation in which let r^{th} be a threshold value in f(x, y). 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. These are particularly useful in image segmentation to isolate an image of interest from back ground. Moon image can be isolated from black ground in binary image as shown in Fig 2.

Fig 2. Original Image and its threshold Image

Next kind of transformation is the Log transformation which maps a narrow range of low gray levels into a wider range of gray levels i.e. expand values of bright pixels and compress values of dark pixels. If C is the scaling factor, then log transformation can be achieved as $s = C \log (1+|r|)$. Logarithmic image of a cameraman reveal more detail as shown in Fig.3.

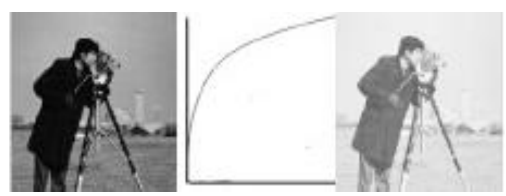

Fig. 3 DFT of image and its logarithmic

Inverse logarithmic transformations map a wide range of gray level values into a narrow range of gray level values i.e. expand values of dark pixels and compresses values of bright pixels. Log and inverse log operations are particularly used when gray level values of an image have extremely large range and small range respectively. Logarithmic Transformations can be used to brighten the intensities of an image (like the Gamma Transformation, where gamma < 1). More often, it is used to increase the detail (or contrast) of lower intensity values. They are especially useful for bringing out detail in Fourier transforms. In Power Law (Gamma) transformation the relation between pixel values of f(x, y) and g(x, y) in this transformation is given by $s = c r^{\gamma}$, 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. Family of possible transformations on varying γ with c=1 is shown in Fig.4.

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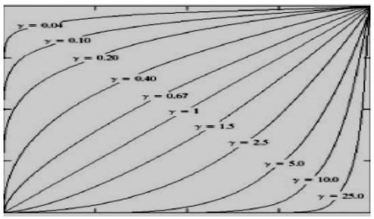

Fig 4. γ^{th} power and γ^{th} root curves for c=1.

Piecewise-linear transformation function is an arbitrary user defined transformation as shown in Fig 8. Based on setting of (r1, s1) and (r2, s2) different types linear transformations can be achieved.

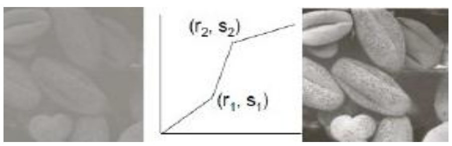

Fig. 5 Original image and its stretched image

There are three types of Piecewise linear transformations: Contrast Stretching, Intensity level slicing and Bit plane slicing. Contrast Stretching is one of image enhancement techniques involves processing an image to make it look better to human viewers. It is usually used for post processing by modifying contrast or dynamic range or both in an image. The aim of 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 using a transform function of the form as g(x, y)=T[r(x, y)] where g(x, y) and r(x, y) are the output and the input pixel values at image position. This process improves the contrast by stretching the range of gray level values to span a desired range of gray level values. This transformation is also called as image intensity transformation or normalization. Let a, b be the minimum and maximum pixel values of f(x, y) and c, d be the minimum and maximum pixel values of g(x, y). Normalization can be achieved by scaling each pixel in original image value as s=(r-c) (b-a)/ (d-c) + a. The existing techniques of contrast enhancement techniques can be again sub divided into two groups: direct and indirect methods. Direct methods define a contrast measure and try to improve it. Indirect methods on the other hand, improve the contrast through exploiting the underutilized regions or the dynamic range without defining a specific contrast term. In this paper contrast enhancement techniques can be broadly categorized into groups: Histogram Equalization (HE), 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 advantages of the HE include it suffers from the problem of being poorly suited for retaining local detail due to its global treatment of the image small- scale details that are often associated with the small bins of the histogram are eliminated. The disadvantage is that it is not a suitable property in some applications such as consumer electronic products, where brightness preservation is necessary to avoid annoying artifacts. The equalization result is usually an undesired loss of visual data of quality and of intensity scale.

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. To more clearly show contrast enhancement of HE based we attempt a brief review of existing systems of contrast enhancement methods. Table 1 show a brief survey of HE – based.

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 colours 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. The two main aims of tone mapping algorithm: Preserving image details and providing enough absolute brightness information in low dynamic range tone mapped image. 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. 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. spatial Filter Operations are performed on a pixel along with its immediate neighbours; this is also called as neighbourhood operations. Based on type of operations performed on the pixels spatial filters are classified into two categories: Linear and Nonlinear spatial filters. Linear spatial filter process involves convolving a mask with an image i.e. passing a weighted mask over the entire image. Mask is also referred as window, template, or kernel. Non linear spatial filter are those filters in which enhanced image is not linearly related to pixels in the neighbourhood 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.

IV. FREQUENCY DOMAIN TECHNIQUES

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

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Author	Year	Operating Domain	Model	Processing techniques	Application
Agaian SS[7]	2007	Spatial domain	HE based Logarithmic transform LTHS	Log reduction zonal magnitude technique; Logarithmic transform histogram shifting	Traffic monitoring; Security Surveillance
Hao Hu[8]	2010	Spatial domain	Content adaptive video processing model	Content classification and adaptive processing	Computer vision
Tarik Arici[9]	2009	Spatial domain	HE based modification	Histogram modification framework, content adaptive algorithm	LCD display device; Low quality video
Sangkeun Lee[10]	2007	Spatial domain	Dynamic range compression	Discrete Cosine transform(DCT); Retinex theory	Image/video compressing
Viet Anhnguyen[11]	2009	Spatial domain Transform domain	Cauchy distribution model; AC transform coefficient	Video reconstructed from multiple compressed copies of video content	Compression video
R.C. Gonzalez[12]	2008	Spatial domain	HE	Global Histogram Equalization	Image/ Video Security Surveillance
Xuan Dong[13]	2010	Spatial domain	Image Inverting Model	Inverting the input low lighting video; dehaze algorithm	Traffic monitoring; Medical imaging
Shan Du[14]	2010	Spatial domain	ARHE model	Adaptive Region based Method	Face Recognition
A.A Wadud M[15]	2007	Spatial domain	Dynamic Histogram equalization	Dynamic Histogram Equalization technique	Medical Image, Low quality video
Boudraa A.O[16]	2008	Spatial domain	2DTKEO model	2D Teager- Kaiser Energy Operator	Medical image; Satellite image
David Menotti[17]	2007	Spatial domain	MHE model	Multi histogram equalization methods	Image processing
Sara Hashem[18]	2010	Spatial domain	Improve HE	Genetic algorithms	Compute high dynamic range image processing
George D[19]	2009	Spatial domain	Improve HS and HE	Histogram based image enhancement	Image processing

Table 1. A Brief Survey of Histogram Enhancement Techniques

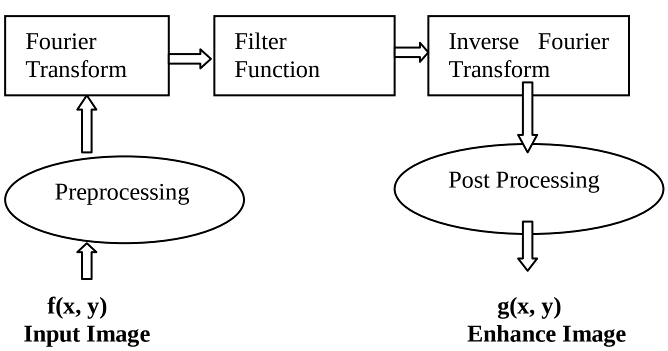
usual orthogonal transforms are discrete cosine transform, discrete Fourier transform, Hartley Transform etc. The transform domain enables operation on the frequency content of the image, and therefore high frequency content such as edges and other subtle information can easily be enhanced. Frequency 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.

$$g(x, y)= h(x, y) * f(x, y)$$

where g(x, y) is enhanced image.



V. APPLICATIONS

Image enhancement is used for enhancing a quality of images. The applications of image enhancement are Aerial imaging, Satellite imaging, Medical imaging, Digital camera application, Remote sensing, Image Enhancement techniques used in many areas such as 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. 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. 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 a 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.

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. We also have described 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.

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Dr. S. S. Bedi is an active researcher in the field of Image processing. Currently working as Assistant Professor in the Department of Computer Sciene at MJP Rohilkhand University, Bareilly (U.P.), India. He has done his Ph.D from IIIT, Gwalior (M.P.) and M.Tech from Thapar University, Punjab. He has published many papers in International Conferences and Journals.

Rati Khandelwal received MCA degree from MJP Rohilkhand University, Bareilly (U.P.) in 2006. Currently she is pursuing M.Tech degree in Computer Science from Banasthali University, Jaipur (Rajasthan.) Her research interest includes Image Processing .She has published many papers in International Journals.