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STUDY OF VARIOUS IMAGE ENHANCEMENT TECHNIQUES : A CRITICAL REVIEW

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ABSTRACT

The aim of image enhancement is to improve the visual appearance and quality of an image. Many images like medical images, satellite images, aerial images, images obtained from digital camera 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 and to retrieve hidden information in the image. A digital image is an aggregate of large number of picture elements which represents the brightness of different pixels .Our aim is to study various techniques used for the enhancement of images. In this paper, we present an overview of image enhancement processing techniques in spatial domain and frequency domain. More specifically, we analyze different image processing techniques.

Keywords: Digital camera, Digital image, Frequency domain enhancement, Histogram Equalization, Image Enhancement, Spatial domain enhancement.

INTRODUCTION

The purpose of image enhancement is to produce a high quality image from a low quality raw image For this, we have to use some image enhancement techniques which can bring about the desirable transformations in the given image. The survey of image enhancement techniques imply two broad classes of techniques: (1) Spatial domain transformation techniques; and (2) Frequency domain transformation techniques. Spatial transformation techniques operate directly on the picture elements. We can have global & local transformation techniques. In global techniques, we generate some transformation functions which operate on all the pixels at the same time. In local transformation, we take each element one- by- one and operate a suitable spatial filter on these pixels and continue this process for all the pixels. We can produce some specific effects on the image like revealing its finer details. Image is captured by different

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equipments like a digital camera, mobile phone, astronomical telescope, X- rays etc. This image is converted to digital form by sampling, quantization & A/D conversion. In this image, we have large number of picture elements in a frame (picture plain), which may be a square or rectangle of different aspect ratio. Each picture element in the image has some specific value of brightness or light intensity and such an image may be represented by an array of elements of dimension m x n and each element has some value of light intensity represented by a 8 bit or 16 bit register in gray scale and by 24 or 48 bits data for coloured image. Each colour i.e. red, green and blue color is represented by a 8 bit data register. In colored image we can produce very large number of colors by the vector addition of these primary colors.

1.1 Image Capturing

A digital image is an image obtained through certain sensors which are light- sensitive like Charge Coupled Devices (CCD's) or CMOS devices and which are used normally in digital cameras. Digital images, obtained by digital camera, is an aggregate of different picture elements which are present in a rectangular or square frames, which are represented by a matrix or an array of size M x N where M & N are the number of pixels along X & Y directions and these are the dimensions of light -sensitive sensors in the camera which carry small cells. These cells are sensitive to light intensity. When light falls on these cells, displacement of charge takes place and develops some voltage in proportion to light intensity falling on the cells. This voltage is converted to digital form through A/D convertor. The voltage is stored in the form of 8 bit word and saved in the memory of digital camera for a gray scale image. The number of gray levels in a 8 bit picture element are 256 which have values from 0 to 255, while for a colored image, we need 24 bits for the representation of picture elements . Each 8 bits represents red, green and blue colors which are the primary colors. We can generate very large number of colors by the combinations of these primary colors

1.2 Processing of the digital image

When we capture any image, the image may have some drawbacks due to various reasons like insufficient light while capturing image by a digital camera, unfavorable weather conditions like fog, rain or, too large sunlight condition. Due to these adverse conditions, the quality of the image taken by a camera may be poor but the quality can be improved by using some specific techniques for image enhancement.

Broadly speaking these techniques can be divided into two categories:-

1. Spatial Domain Transformation Techniques
2. Frequency Domain Transformation Techniques

1.3 Spatial Transformation Techniques

In spatial transformation, we operate directly on pixels. We can have different types of spatial transformation techniques as given below:-

1.31 Contrast Stretching

1.32 Negative image or complimentary image transformation

1.33 Log and power law transformation (Non-linear transformations)

1.34 Linear and Piecewise-Linear Transformations

1.35 Gama correction

1.36 Histogram Processing

1.37 Spatial filtering for smoothing of image involving convolutional techniques

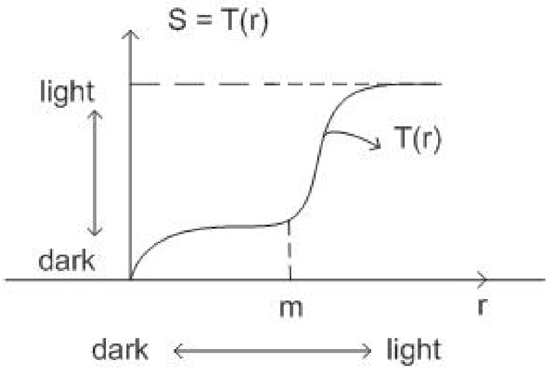

Figure 1: Transformation curve for gray level

1.4 Contrast Stretching: Contrast stretching (often called normalization) is a simple image enhancement technique that attempts to improve the contrast in an image by 'stretching' the range of intensity values. For an 8 bit image, there are 256 gray levels. Level 0 or close to zero represent dark portion of the image and gray level 255 or close to it represents the bright portion of the image. The difference between maximum and minimum values of gray levels is called its dynamic range. If this dynamic range is confined to a narrow range , the contrast of the image would be low. As a result, the quality of the image would be poor and we need to increase the dynamic range. We can apply a *linear scaling function* to the image pixel values. So, contrast stretching is a simple image enhancement technique that attempts to improve the contrast in an image by 'stretching' the range of intensity values..

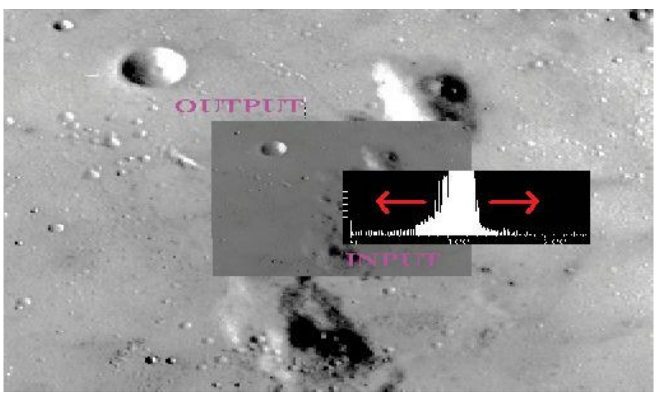

Figure 2: Contrast stretching for histogram spreading

Before the stretching can be performed, it is necessary to specify the upper and lower pixel value limits over which the image is to be normalized. For example, for 8-bit gray level images, the maximum and minimum values of gray levels would be 0 and 255. But in the actual given image, let the lower and the upper limits, up to which we want to extend the contrast be say , *a* and *b* respectively.

The simplest sort of normalization then scans the image to find the lowest and highest pixel values currently present in the image. Let us call these values as *c* and *d*. Then each pixel *P* is

$$P_{out} = (P_{in} - c)\left(\frac{b-a}{d-c}\right) + a$$

Where P_{in} are the input pixel values and P_{out} are the output pixel values. Values below 0 are set to 0 and values above 255 are set to 255. Putting the values of P_{in} in the relation (1) we can calculate the values of P_{out} and achieve the objective of contrast extension It is a linear extension .

1.5 Negative image : Sometimes negative images are required in medical investigations These can be obtained by using the transformation s= [(L-1) –r], where the level is in the range [0,L-1] . It can be seen that every pixel value from the original image is subtracted from the figure 255. The resultant image becomes negative of the original image. Negative images are useful for enhancing white or detail embedded in dark regions of an image.

Figure 3: A negative image of a man

1.6 Image Thresholding: Another technique is Image thresholding transformation in which we have only two values of pixels. These can be termed binary transformation as pixel values of thresh-hold images are either 0's or 1's . Such an image can also be called as black & white image and have only 2 gray levels i.e 0 or 255. For converting a gray level image to a black and white image, we need to change all gray levels below the threshold value to 0 and all the gray levels above the threshold value to 255.

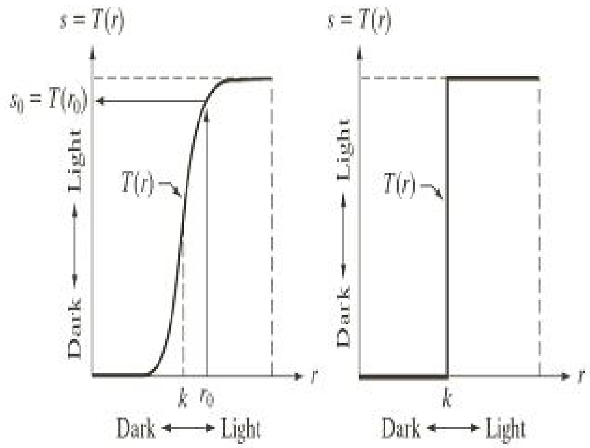

Figure 4: (a) Nonlinear-stretching (b)Image thresholding

1.7 Linear and Nonlinear Transformations: We can have some linear and non-linear transformations in image processing like log transformations ,power transformations ,anti-log transformations n^{th} root transformations These are shown in Figure below. We can adjust the transformation variables according to our requirement so as to get a good quality image.

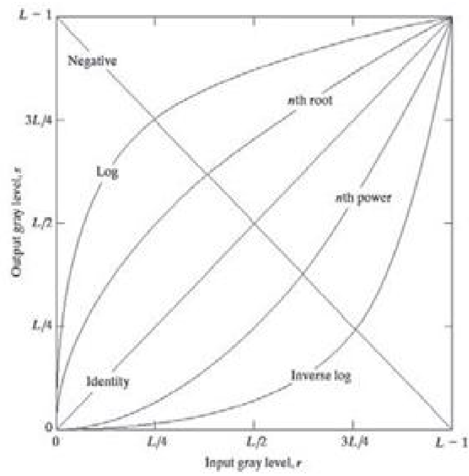

Figure 5: Gama correction curves Non-linear curves & Negative image transformation curve

1.8 Logarithmic Transformations: The general form of the log transformation is *s = c * log (1 + r).* Log functions are particularly useful when the input gray level values have an extremely large range of values and due to which some portion of the image is washed out, so dynamic range can be compressed as per our requirement. On the other hand, when the dynamic range is limited, it can be enlarged through anti-log transformation.

1.9 Powers-Law Transformations & Gama corrections: The *nth* power and *n*th root curves are shown in Figure5 . It is given by the expression, $s = cr^{r}$ where c and r are the positive constants. This transformation function is also called as *gamma* correction. For various values of γ, different levels of enhancements can be obtained. This technique is commonly called as *Gamma Correction.*

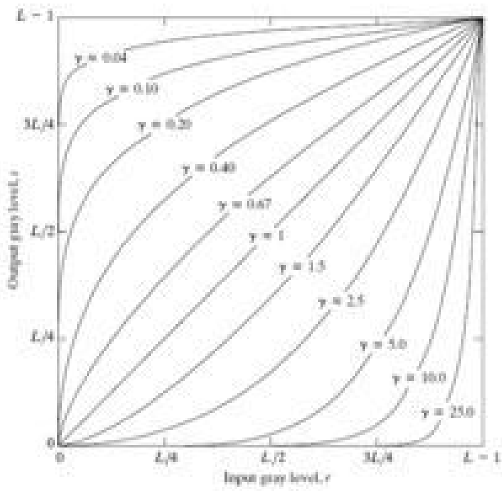

Figure 6: Curves for Gama correction

Figure 7: Effect of contrast enhancement

We can notice that, different display monitors, display images at different intensities and clarity. That means, every monitor has built-in gamma correction in it with certain gamma ranges .A good monitor automatically corrects all the images displayed on it for the best contrast to give user the best experience.

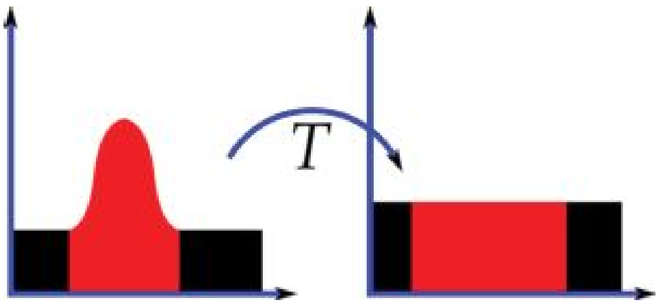

Figure 8 Illustrating histogram before and after Equalisation

2 . Histogram Equalization

Histogram is the graph between gray levels and the number of pixels corresponding to that gray level.(i.e. frequency). It can be drawn by using MATLAB program or other software programs. The main purpose of drawing histogram is to know about the dynamic range of the image so that we may device some techniques for the proper modification of its contrast. There are many image enhancement techniques which have been proposed and developed. One of the most popular image enhancement methods is Histogram Equalization (HE). HE becomes a popular technique for contrast enhancement because this method is simple and effective. HE technique can be applied in many fields like medical image processing, radar image processing, and sonar image processing. The basic idea of HE method is to re-map the gray levels of an image based on the image's gray levels cumulative density function. (CDF) . HE flattens and stretches the dynamic range of the resultant image In HE; we obtain approximately a uniform probability density function (PDF). However, HE is rarely employed in consumer electronic applications such as video surveillance, digital camera, and television, since HE tends to introduce some annoying artifacts and unnatural enhancement, including intensity saturation effect. One of the reasons for this problem is that HE normally changes the brightness of the image significantly, and thus makes the output image to become saturated with very bright or dark intensity values.

In order to overcome the aforementioned problems, mean brightness preserving, histogram equalization based techniques have been proposed in the literature. Generally, these methods separate the histogram of the input image into several sub-histograms, and the equalization is carried out independently in each of the sub-histograms. For example, brightness preserving bi-histogram equalization (BBHE) [3], divides the input histogram into two subsections based on the mean value. Later, minimum mean brightness error bi-histogram equalization (MMBEBHE [4]) has been proposed by Chen and Ramli to preserve the brightness ''optimally''. MMBEBHE also separates the histogram into two subsections. However, MMBEBHE performs the separation based on the threshold level which would yield a minimum difference between the input mean value and the output mean value which is called minimum mean brightness error [MMBE]. Another technique is the Dualistic sub-image histogram equalization (DSIHE)[5], which has been proposed by Wang et al. [7], that also separates the input histogram into two sub-sections. But separation is based on the median value. Wadud and Kabir [11] proposed a new class of histogram partitioning named as Dynamic Histogram Equalization (DHE). The DHE partitions the original histogram based on local minima and then, assigns a new dynamic range to each sub-histogram. Ibrahim and Kang [12], proposed a method brightness preserving dynamic histogram equalization (BPDHE) similar to DHE, which is extension of the DHE. BPDHE applies Gaussian-smoothing filter before the histogram partitioning process is carried out. The BPDHE uses the local maxima as the separating point rather than the local minima used in DHE. Ibrahim and Kang claimed that the local maxima are better for mean brightness preservation. (QDHE)[13-14] method was proposed by Ooi and Nor for better contrast enhancement. QDHE partitions the histogram into four sub- histograms using the median value of intensity and then clips the histogram according to the mean of intensity occurrence of the input image and finally a new dynamic range is assigned to each sub-histogram before each sub histogram is equalized. Ooi and Nor [14] also proposed *Adaptive Contrast Enhancement Methods* with brightness preserving which comprised of two methods named as Dynamic Quadrants Histogram Equalization Plateau Limit (DQHEPL) and Bi-Histogram Equalization Median Plateau Limit (BHEPL-D). DQHEPL is extension of RSIHE,which divides the histogram into four sub- histograms, and then assigns a new dynamic range and finally implements clipping process. BHEPL-D is the extension of the BHEPL except that it clips the histogram using the median of the occupied intensity. Chang and Chang [15] presented a simple approach for contrast enhancement named as Simple Histogram Modification Scheme (SHMS). This method modifies the histogram by changing the values of two boundary values of the support of the histogram. A new method named as Background Brightness Preserving Histogram Equalization (BBPHE) [16] has been proposed by Tan et.al. The partition method used by BBPHE is based on background levels and non-background levels range. After partition, each sub-image is equalized independently, and then combined into the final output image. It is claimed that the background levels are only stretched within the original range, hence, the over -enhancement can be avoided by BBPHE

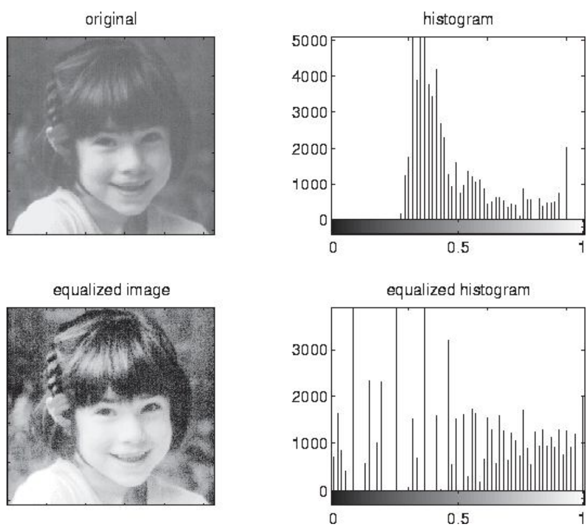

Figure 9: Original low contrast image & after HE, change in contrast

Figure 10: Illustrating the histogram of a flower

Histogram specification: It 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 on this histogram .The procedure for specified histogram is:-

a. Determine the transformation $s_k = T(r_k)$ that can equalize the original image histogram $p_r(r)$;

b. Determine the transformation $S_k = G(b_k)$ that can equalize the desired image histogram $p_b(b)$; and

c. Perform transformation $G^{-1}[T(r_k)]$.

Through specified histogram, we can make the histogram curve as per our requirement

3 Frequency domain methods

In an image, as we move from one pixel to the next, there would be a change in its gray level values. If the change is fast, the image would have more high frequency components. If there is slow variation in gray levels, the image would have more low-frequency components. So in an image, we have a band of frequency components. By using some filters, we can change the values of some frequency components of the image as per our requirement. Image enhancement in the frequency domain is straightforward. We simply compute the Fourier transform of the image to be enhanced, multiply the result by a filter transformation function (rather than convolving as in the spatial domain), and take the inverse transform to produce the enhanced image .We can have the following transformation functions in frequency.

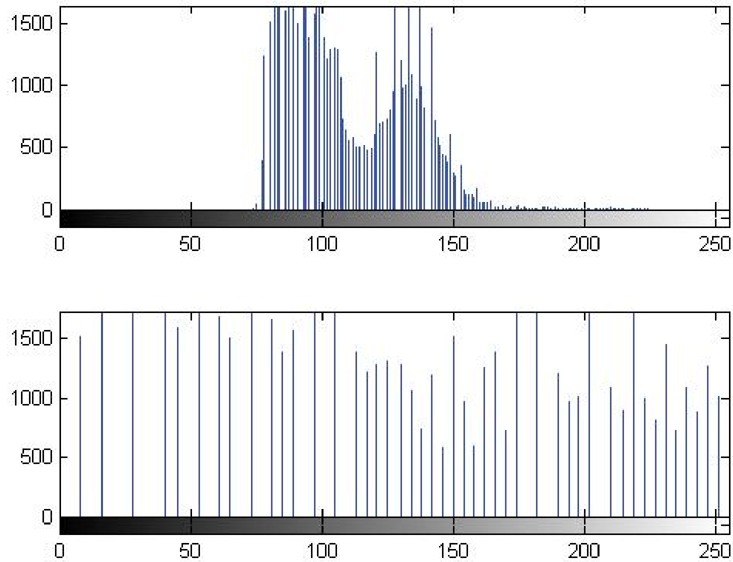

Figure 11: Effect of contrast stretching on histogram

4. Filtering:

Different types of filters can be designed:

(1) Low pass filters; and (2) High pass filters.

Low pass Filter: Low pass filtering involves the elimination of the high frequency components in the image. It results in blurring of the image (and thus a reduction in sharp transitions associated with noise). An ideal low pass filter would retain all the low frequency components, and eliminate all the high frequency components. Edges and sharp transitions in the gray levels contribute to the high frequency contents of its Fourier transform. Low pass filter smoothens an image.

High pass filter: A high pass filter attenuates the low frequency components without disturbing the high frequency information in the Fourier transform domain and it can sharpen edges and can deliver high definition information of the image

5 Spatial Filters

The use of Spatial masks for image processing is called spatial filtering The masks used are called spatial filters. The basic approach is to take the sum of products between the gray levels of the pixels and the intensities of the pixels under the mask at a specific location in the image (2D convolution). The masks are of sizes 3*3, 5*5,7*7 etc . The process of spatial filtering consists simply of moving the filter mask from point to point in an image. At each point(x, y), the response of the filter at that point is calculated using a predefined relationship. Spatial Filters can be distinguished as Smoothing linear filters, sharpening filters. The response of smoothing, linear spatial filter is simply the average of the pixels contained in the neighborhood of the filter mask. These filters sometimes are called averaging filters. They are also referred to as low pass filters. Sharpening filters are high pass filters which are used for highlighting the fine details in the image like display of corners. In the low pass filters, all the weights of the mask are positive while in the high mask filter ,the weights are positive at the centre and negative at the outer portion of the mask.

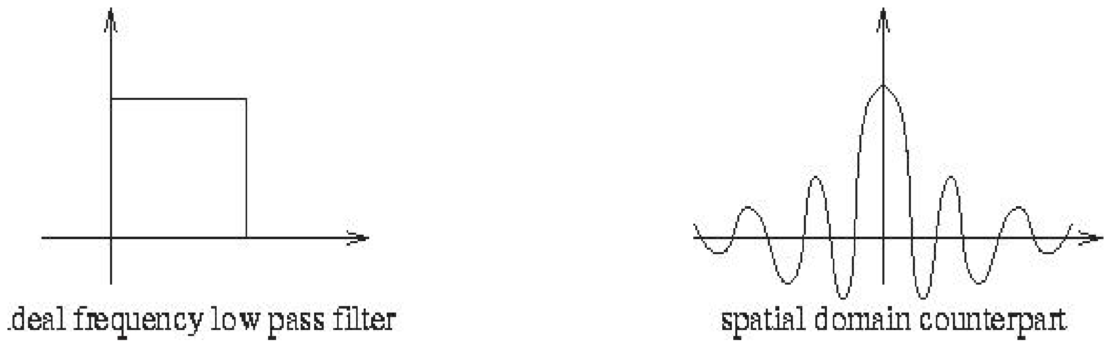

Figure 12 : Low pass Filter

5.1 *Median Filters*: The objective of a median filter is to achieve noise reduction instead of blurring. This method is especially effective when the noise pattern has spike-like components and the characteristic to be preserved is edge sharpness. In this method, we take the median of the mask coefficients and replace the pixel with the median value so that we can reduce the noise.

5.2 *Derivative Filters*: The low pass filters cause blurring of the image But the derivative filters does opposite to it. They are used for revealing high definition components in the image. There can be different types of derivative filters like Robarts, Prewitts ,Sobels etc

CONCLUSION

Image enhancement techniques offer a wide variety of approaches for modifying images to achieve visually acceptable images and to improve the quality of the images. The choice of such techniques is a function of the specific task, image content, observer characteristics, and viewing conditions. The point processing methods are most primitive, yet essential image processing operations are used primarily for contrast enhancement. Negative Image 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 level 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 in the higher-level values. For an image having a washed-out appearance, a compression of gray levels can be used by 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. Only the global histogram equalization can be done completely automatically. Although we did not discuss the computational cost of enhancement algorithms in this paper, it may play a critical role in choosing an algorithm 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.

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