A Review on Image Contrast Enhancement Techniques

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Abstract— **The purpose of image enhancement and image restoration techniques is to perk up a quality and feature of an image that result in improved image than the original one. Unlike the image restoration, image enhancement is the modification of an image to alter impact on the viewer. Generally enhancement distorts the original digital values; therefore enhancement is not done until the restoration processes are completed. In image enhancement the image features are extracted instead of restoration of degraded image. Image enhancement is the process in which the degraded image is handled and the appearance of the image by visual is improved. It is a subjective process and increases contrast of image but image restoration is a more objective process than image enhancement. Many research work have been done for image enhancement. In this paper, different techniques and algorithms are discussed for contrast enhancement.**

Keywords— **Image enhancement, Image quality, Digital image processing.**

I. INTRODUCTION

Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing `better' input for other automated image processing techniques [1]. 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. The choice of attributes and the way they are modified are specific to a given task. Moreover, observer-specific factors, such as the human visual system and the observer's experience, will introduce a great deal of subjectivity into the choice of image enhancement methods. There exist many techniques that can enhance a digital image without spoiling it [2].

In real time applications an enhancement technique should be capable of enhancing real color images in lesser time with lesser computational cost by reducing:

i.   the effect of haze or fog
ii. poor or uneven illumination effect on an image and
iii. noise introduced in an image.

This research review work focus on various color image enhancement techniques that improves the contrast of real time images.

Requirements of real time image enhancement techniques:

i.   It should be adaptive in nature i.e. should be able to enhance any type of images for a specific application
ii. Should enhance a image in less processing time
iii. It should utilize less computational resources

Image enhancement improves the interpretability or perception of information in images. Contrast is an important factor in any subjective evaluation of image quality. Contrast is created by the difference in luminance reflected from two adjacent surfaces. In other words, contrast is the difference in visual properties that makes an object distinguishable from other objects and the background. Due to low contrast image enhancement becomes challenging and also objects cannot be extracted clearly from dark background. Since color images provide more and richer information for visual perception than that of the gray images, color image enhancement plays an important role in digital image processing. Many algorithms for accomplishing contrast enhancement have been developed and applied to problems in image processing.

The enhancement methods can broadly be divided in to the following two categories:

• Spatial Domain Methods

• Frequency Domain Methods

Spatial-domain image enhancement acts on pixels directly. The pixel values are manipulated to achieve desired enhancement. Spatial domain techniques enhance the entire image uniformly which at times results in undesirable effects.

Frequency-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 image transform coefficients. The image is first transformed from spatial to frequency domain, and the transformed image is then manipulated. It is, in general, not easy to enhance both low-

and high-frequency components at the same time using the frequency-domain technique [3,4].

These traditional techniques thus do not provide simultaneous spatial and spectral resolution. Wavelet Transform is capable of providing both frequency and spatial resolution. Wavelet Transform is based upon small waves with varying frequency and limited duration called wavelets. Since higher frequencies are better resolved in time and lower frequencies are better resolved in frequency, the use of wavelets therefore ensure good spatial resolution at higher frequencies and good frequency resolution at lower frequencies [5]. Hence wavelet-based techniques can solve drawbacks of frequency-domain techniques by providing flexibility in analyzing the signal over the entire time range. Newly developed wavelet-based multiscale transforms include ridgelet, curvelet, contourlet and shearlet.

II. SPATIAL DOMAIN IMAGE ENHANCEMENT TECHNIQUES

In the spatial domain image enhancement technique, transformations are directly applied on the pixels. The pixel values are manipulated to achieve desired enhancement. Spatial domain processes can be expressed as:

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

where $f(x, y)$ is the input image

$g(x, y)$ is the processed image

and T is an operator on f,

defined over the neighborhood of (x, y).

Spatial domain techniques like the logarithmic transforms, power law transforms, histogram equalization are based in the direct manipulation of the pixels in image.

Spatial domain methods can again be divided into two categories:

- point processing
- spatial filtering operations

A. Gray Level Transformation

Gray level transformation is the simplest image enhancement techniques. The values of pixels, before and after processing, will be denoted by r and s, respectively, these values are related by an expression of the form

$$s = T (r)$$

where, T is a transformation that maps a pixel value r into a pixel value s.

Gray level transformations are applied to improve the contrast of the image. This transformation can be achieved by adjusting the gray level and dynamic range of the image, which is the deviation between minimum and maximum pixel value. In gray level transformations, three basic types of functions are used frequently for image enhancement: linear, logarithmic and power-law.

B. Contrast Stretching

Low-contrast images can result of poor illumination, lack of dynamic range in the imaging sensor or even wrong camera. One of the simplest piecewise linear functions is a contrast-stretching transformation. The basic idea behind contrast stretching is to increase the dynamic range of the gray levels in the image being processed. In contrast stretching, upper and lower threshold are fixed and the contrast is stretched between these thresholds. It is contrast enhancement method based on the intensity value as shown:

$$I_0(x, y) = f (I(x, y))$$

where, the original image is $I(x, y)$, the output image is $I_0(x, y)$ after contrast enhancement. The transformation function T is given by

$$s = T (r)$$

C. Histogram Processing

Intensity transformation functions based on information extracted from image intensity histograms play a basic role in image processing.

With L total possible intensity levels in the range [0, G], the histogram of a digital image is defined as the discrete function

$$h(r_k) = n_k$$

where r_k is the kth intensity level in the interval $[0, G]$

n_k is the number of pixels in the image whose intensity level is r_k. it is useful to work with normalized histograms, which is obtained by dividing all elements of $h(r_k)$ by the total number of pixels in the image, which we denote by n.

III. FREQUENCY DOMAIN IMAGE ENHANCEMENT TECHNIQUES

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 (low pass filter, high pass filter and homomorphic filter) rather than convolve in the spatial domain, and take the inverse transform to produce the enhanced image. The idea of blurring an image by reducing its high frequency components or sharpening an image by increasing the magnitude of its high frequency components is intuitively easy to understand.

A. Smoothing Filters

The noises, edges and other sharp transitions in the gray level contribute significantly to the high frequency. Hence smoothing or blurring is achieved by attenuating a specified range of high frequency components in the transform of a given image, which can be done using a lowpass filter. A filter that attenuates high frequencies and retains low frequencies unchanged is called lowpass filter. Since high frequencies are blocked, this results a smoothing filter in the spatial domain.

Three are three types of lowpass filters: Ideal lowpass filter, Gaussian lowpass filter and Butterworth lowpass filter.

B. Sharpening Filters

Sharpening filters emphasize the edges, or the differences between adjacent light and dark sample points in an image. A highpass filter yields edge enhancement or edge detection in the spatial domain, because edges contain many high frequencies. Areas of rather constant gray level consist of mainly low frequencies and are therefore suppressed. A highpass filter function is obtained by inverting the corresponding lowpass filter. An ideal highpass filter blocks all frequencies smaller than r_0 and leaves the others unchanged. The transfer function of lowpass filter and highpass filter can be related as follows:

$H_{hp}(u, v) = 1 - H_{lp}(u, v)$

where $H_{hp}(u, v)$ and $H_{lp}(u, v)$ are the transfer function of highpass and lowpass filter respectively.

IV. COLOUR IMAGE ENHANCEMENT

Color images provide more and richer information for visual perception than that of the gray images. Color image enhancement plays an important role in Digital Image Processing. The purpose of image enhancement is to get finer details of an image and highlight the useful information. During poor illumination conditions, the images appear darker or with low contrast. Such low contrast images needs to be enhanced. In the literature many image enhancement techniques such as gamma correction, contrast stretching, histogram equalization, and Contrast-limited adaptive histogram equalization (CLAHE) have been discussed. These are all old techniques which will not provide exact enhanced images and gives poor performance in terms of Root Mean Square Error (RMSE), Peak Signal to Noise Ratio (PSNR) and Mean Absolute Error (MAE). Use of the old enhancement technique will not recover exact true color of the images. Recently, Retinex, Homomorphic and Wavelet MultiScale techniques have been popular for enhancing images. These methods are shown to perform much better than those listed earlier.

V. RELATED WORK

A. Image Enhancement Using Fourier Transform

Arunachalam et al. [6] in 2015 implemented two-dimensional Fast Fourier Transform (FFT) and Vedic algorithm based on Urdhva Tiryakbhyam sutra. The algorithm was presented using MATLAB program. The input image was divided into blocks and two-dimensional FFT was applied to enhance or filter the image. The proposed two-dimensional FFT design was based on using Urdhva Tiryakbhyam sutra. FFT computations using Vedic multiplication sutra gave a significant performance as compared to the conventional FFT.

Ramiz and Quazi [7] in 2017 proposed a hybrid method which was very effective in enhancing the images. Initially, frequency domain analysis was done followed by spatial domain procedures. The performance of the proposed method was assessed on the basis of two parameters i.e. Mean Square Error (MSE) and Peak Signal to noise ratio (PSNR). Their proposed algorithm provided better PSNR and MSE.

B. Image Enhancement Using Wavelet Transform

Panwar and Kulkarni [8] in 2014 provided a technique of image resolution enhancement based on SWT and DWT. The proposed technique was compared with conventional and state-of-art image resolution enhancement techniques. They have also provided subjective and objective comparison of resultant images and PSNR table showed the superiority of the proposed method over conventional methods.

Sumathi and Murthi [9] in 2016, proposed a new satellite image resolution enhancement technique based on the interpolation of the high frequency sub bands obtained by discrete wavelet transform (DWT) and the input image. The proposed technique had been tested on satellite benchmark images. The quantitative and visual results showed the superiority of the proposed technique over the conventional and state of art image resolution enhancement techniques.

Arya and Sreeletha [10] in 2016 provided image resolution enhancement methods using multi-wavelet and interpolation in wavelet domain. They discussed about improvement in the resolution of satellite images based on the multi-wavelet transform using interpolation techniques. The quantitative metrics (PSNR, MSE) of the image calculated showed the superiority of DWT-SWT technique.

Badgujar and Singh [11] in 2017 proposed an efficient systematic approach to enhance underwater images using generalized histogram equalization, discrete wavelet transform and KL transform. The proposed system provided properly enhanced underwater image output and the quality of the image was up to the mark regarding contrast and resolution. The PSNR value of the image was higher than other methods like DWT-KLT, DWT-SVD and GHE.

C. Image Enhancement Using Complex Wavelet Transform

Kaur and Vashist [12] in 2017 proposed a hybrid approach algorithm using DTCWT, NLM filter and SVD for Medical Image Enhancement and had been tested on a set of medical images. In their method, firstly, The medical input image was decomposed using DTCWT. Less artifacts were generated with the help of DTCWT compared to that of DWT because of nearly shift invariance characteristic of DTCWT. Further image quality was improved using NLM filtering approach and SVD was used for to get originality of image and obtain a better quality image both quantitatively and qualitatively. Simulation results showed that proposed technique outperforms other conventional techniques for improving

visual quality of medical images for proper manual interpretation and computer based diagnosis.

HemaLatha and Vardarajan [13] in 2017 presented a image resolution enhancement of LR image using the dualtree complex wavelet transform. In their method, dual tree complex wavelet transform was applied to low resolution (LR) satellite image. Further, the high resolution (HR) image was reconstructed from the low resolution image, together with a set of wavelet coefficients, using the inverse DT-CWT. Finally, the inverse dual tree complex transform was taken. Output was high resolution image and the DT-CWT had better performance in terms of PSNR, RMSE, CC and SSIM compared to DWT technique.

D. Image Enhancement Using Curvelet Transform

Kumar [14] in 2015 proposed a new method to enhance the colour image based on Discrete Curvelet Transform (DCT) and multi structure decomposition. Experimental results showed that this method provided better qualitative and quantitative results.

Farzam and Rastgarpour [15] in 2017 presented a method for image contrast enhancement for cone beam CT (CBCT) images based on fast discrete curvelet transforms (FDCT) that work through Unequally Spaced Fast Fourier Transform (USFFT). Their proposed method first used a two-dimensional mathematical transform, namely the FDCT through unequal-space fast Fourier transform on input image and then applied thresholding on coefficients of Curvelet to enhance the CBCT images. Consequently, applying unequal-space fast Fourier Transform lead to an accurate reconstruction of the image with high resolution. The experimental results indicated the performance of the proposed method was superior to the existing ones in terms of Peak Signal to Noise Ratio (PSNR) and Effective Measure of Enhancement (EME).

E. Image Enhancement Using Shearlet Transform

Fan et al. [16] in 2016 proposed a novel infrared image enhancement algorithm based on the shearlet transform domain to improve the image contrast and adaptively enhance image structures, such as edges and details. Experimental results showed that the proposed algorithm could enhance the infrared image details well and produced few noise regions, which was very helpful for target detection and recognition.

Tong and Chen [17] in 2017 presented a multi-scale image adaptive enhancement algorithm for image sensors in wireless sensor networks based on non-subsampled shearlet transform. The performance of the proposed algorithm was evaluated both objectively and subjectively and the results showed that the visibility of the images was enhanced significantly.

Favorskayaa and Savchinaa [18] in 2017 investigated a process of dental image watermarking based on discrete shearlet transform. The proposed watermarking technique was tested on 40 dental gray scale images with various resolution. The experiments showed the highest robustness to the

rotations and proportional scaling and the medium robustness to the translations and JPEG compression. The SSIM estimators were found high for the rotation and scaling distortions that showed good HVS properties.

VI.CONCLUSION

Image enhancement is an essential preprocessing step in many real time image processing applications. Enhancement of Images is done by many approaches and choice of every approach depends on the type of images. Among all histogram equalization techniques multi histogram equalization techniques improves the contrast and brightness of the images. As analyzed, there are various factors which can affect image quality. Some of them are noise, sharpness, distortion, contrast, color accuracy, dynamic range, exposure accuracy, lens flare, etc. These factors must be kept in mind while choosing or designing any image enhancement algorithm.

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