ISSN 2249-6343
International Journal of Computer Technology and Electronics Engineering (IJCTEE)
Volume 1, Issue 2

A Comprehensive Review of Image Enhancement Techniques

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Abstract— **Image enhancement is one of the challenging issues in low level image processing. Various authors proposed various methods such as histogram equalization, multipoint histogram equalizations and pixel dependent contrast preserving, but all these method are not up to marks. Now we proposed a new technique "image pixel interdependency linear perceptron network (IPILP) for image enhancement that provides a better result for contrast enhancement with brightness preservation. Image pixel interdependency linear perceptron network (IPILP) based on curvelet transform and perceptron network. Through curvelet image transform into multiresolution mode. Then find the pixel difference for the dependency of contrast, this difference matrix work as a weight vector for perceptron network and the perceptron network is used to adjust the weight of input image or values. Image pixel interdependency linear perceptron network (IPILP) for contrast enhancement has applied on several images and we have compared the result of our method with other image enhancement methods such as histogram equalization, multi-histogram equalization and IDBPHE. To evaluate the effectiveness of proposed method, we have used the AMBE and PSNR. Absolute mean brightness error (AMBE) is used to measure the degree of brightness preservation. Smaller AMBE is better and Peak signal to noise ratio (PSNR) is used to measure the degree of contrast enhancement, greater PSNR is better. By comparing the AMBE and PSNR of our proposed method with HE, MHE and IDBPHE, we have found that proposed method is better than HE, MHE and IDBPHE.**

I. INTRODUCTION

Digital image processing is a broad subject and often involves procedures which can be mathematically complex, but central idea behind digital image processing is quite simple. The ultimate aim of image processing is to use data contained in the image to enable the system to understand, recognize and interpret the processed information available from the image pattern [1]. Image enhancement techniques improve the quality of an image as perceived by human. Generally image enhancement techniques are used to get detail that is obscured, or to highlight certain features of interest in image. In image enhancement process one or more attributes of image are modified. Image enhancement can be applied to different areas of science and engineering. Except for illumination conditions, quality of images is also affected by external noises and environmental disturbances such as ambient pressure and temperature fluctuations. Thus, image enhancement is necessary.

Approaches of contrast limited image enhancement via stretching the histograms over a reasonable dynamic range and multi-scale adaptive histogram equalizations can be developed. An adaptive algorithm is adapted to the image intensity distribution either globally or locally. By separating smooth and detail areas of an image, the algorithm is applied to each of them to avoid excessive enhancement of noises. In most cases, quality of images is affected by atmosphere medium and water medium, therefore image enhancement is required [2]. Image enhancement (IE) has contributed to research advancement in a variety of fields. Some of the areas in which IE has wide application are noted below.

1. 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.
2. In atmospheric sciences, IE is used to reduce the effects of haze, fog, mist and turbulent weather for meteorological observations. It helps in detecting shape and structure of remote objects in environment sensing. Satellite images undergo image restoration and enhancement to remove noise
3. Astrophotography faces challenges due to light and noise pollution that can be minimized by IE. For real time sharpening and contrast enhancement several cameras have in-built IE functions. Moreover, numerous software, allow editing such images to provide better and vivid results.
4. In oceanography the study of images reveals interesting features of water flow, sediment concentration, geomorphology and bathymetric patterns to name a few. These features are more clearly observable in images that are digitally enhanced to overcome the problem of moving targets, deficiency of light and obscure surroundings.
5. Medical imaging uses IE techniques for reducing noise and sharpening details to improve the visual representation of the image. Since minute details play a critical role in diagnosis and treatment of disease, it is essential to highlight important features while displaying medical images. This makes IE a necessary aiding tool for viewing anatomic areas in MRI, ultrasound and x-rays to name a few.

Numerous other fields including law enforcement, microbiology, biomedicine, bacteriology, etc., benefit from various IE techniques. These benefits are not limited to professional studies and businesses but extend to the common users who employ IE to cosmetically enhance and correct their images.

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

a) Spatial Domain Methods

b) Frequency Domain Methods

In spatial domain techniques [3], we directly deal with the image pixels. In spatial domain for getting desired output the pixel vales are manipulated. Basically in spatial domain the value of pixel intensity are manipulated directly as equation 1.1

$$G(x, y) = T [f(x, y)] \quad \ldots \quad (1.1)$$

Where f (x,y) is input image, G(x, y) is output image and T is an operator on f, defined over some neighborhood of f(x, y).

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. However, computationally, it is often more efficient to implement these operations as convolutions by small spatial filters in the spatial domain. Understanding frequency domain concept is important, and leads to enhancement techniques that might not have been thought of by restricting attention to the spatial. Image enhancement techniques in frequency domain are based on modifying the Fourier transform of an image. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image [4]. These enhancement operations are performed in order to modify the image brightness, contrast or the distribution of the grey levels. In the frequency domain The concept of filtering is easier to visualize. Therefore, enhancement of image f (x, y) can be done in the frequency domain, based on its DFT F (u, v). In the frequency domain the image enhancement can be done as follows:

$$G(u,v) = H(u,v)F(u,v) \ldots (1.2)$$

Where G (u, v) is enhanced image, F (u, v) is input image and H (u, v) is transfer function. There are following basic steps are applied for filtering an image in frequency domain.

1. Compute F (u, v), the DFT of input image.
2. Multiply F (u, v) by a filter function H (u, v)

$$G (u, v) = H (u. v) F (u, v).$$

3. Compute inverse DFT of the result by applying inverse Fourier transform.
4. Obtain real part of inverse DFT.

The goal of image enhancement techniques is to improve a quality of an image such that enhanced image is better than the original image. Several image enhancement techniques have been proposed in both spatial and transform domains. Image enhancement is one of the most important issues in low-level image processing. Its purpose is to improve the quality of low contrast images, i.e., to enlarge the intensity difference among objects and background.

HE techniques are widely used in our daily life, such that in the field of consumer electronics, medical image processing, image matching and searching, speech recognition and texture synthesis because it has high efficiency and simplicity [5, 6, 7, 8].

Histogram equalization (HE) is a contrast enhancement technique which distributes pixel values uniformly such that enhanced image have linear cumulative histogram [9]. The main idea of HE-based methods is to re-assign the intensity values of pixels to make the intensity distribution uniform to utmost extent. However, sometimes it also degenerate the result which is often called as washed out effect. Histogram equalization technique enhances the contrast of an image but it tends to change the brightness of image that means it does not preserve the brightness of image, because HE technique is a global operation.

To overcome the drawback of classical HE, several brightness preserving techniques have been proposed. Local histogram equalization (LHE) [10] tries to eliminate such problem. It makes use of the local information remarkably. However, LHE demands high computational cost and sometimes causes over-enhancement in some portion of the image. Nonetheless, these methods produce an undesirable checkerboard effects on the enhanced images. Thus the HE technique can enhanced the contrast of an image but it does not preserve the image brightness.

To enhance an image, a brightness preserving Bi-HE (BBHE) method was proposed in [11]. The BBHE method decomposes the original image into two sub-images, by using the image mean gray level, and then applies the HE method on each of the sub images independently, that means by this we obtain two histograms such that one contains high intensity pixels and another contains low intensity pixels. At some extent BBHE preserves brightness of image; however generated image might not have a natural appearance

. Dualistic sub-image histogram equalization (DSIHE) [12] is similar to BBHE but DSIHE uses median value as separation intensity to divide the histogram into two sub-histogram. Minimum Mean Brightness Error Bi-HE (MMBEBHE) [13] is an extension of the BBHE method. In MMBEBHE the separation intensity is minimum mean brightness error between input image and output image. The separation intensity is used to divide the histogram into two sub histogram and then applies the HE on each sub histogram independently. Recursive mean separate HE (RMSHE) [14] is an iterative technique of BBHE, instead of decomposing the image only once, the RMSHE method proposes for performing image decomposition recursively, up to a scalar r, generating 2^r sub-image. After each one of these sub-images is independently enhanced using HE method. In RMSE, when r increase the brightness increase, but number of decomposed sub histogram is a power of two. Multi-histogram equalization (MHE) [15] overcomes the drawback of bi-HE, it decomposed the input image into several sub-image and then applying the classical HE process to each one.

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MHE uses peak and valley point of histogram hence, they fall if histogram has peak and valley points nearby.

Now we proposed a new technique for image enhancement based on curvelet transform and perceptron network. Through curvelet image transform into multi-resolution mode. Then find the pixel difference for the dependency of contrast, this difference matrix work as a weight vector for perceptron network.

II. HISTOGRAM PROCESSING

Histogram processing is used in image enhancement the information inherent in histogram can also used in other image processing application such as image segmentation and image compression. A histogram simply plots the frequency at which each grey-level occurs from 0 (black) to 255 (white). Histogram processing should be the initial step in preprocessing. To produce a much better image histogram equalization and histogram specification (matching) are two methods widely used to modify the histogram of an image. The histogram is a discrete function that is shown in figure 2.1 Histogram represents the frequency of occurrence of all gray-level in the image, that means it tell us how the values of individual pixel in an image are distributed. Histogram is given as-

$h(r_k) = n_k/N$ ………(2.1)

Where r_k and n_k are intensity level and number of pixels in image with intensity r_k respectively.

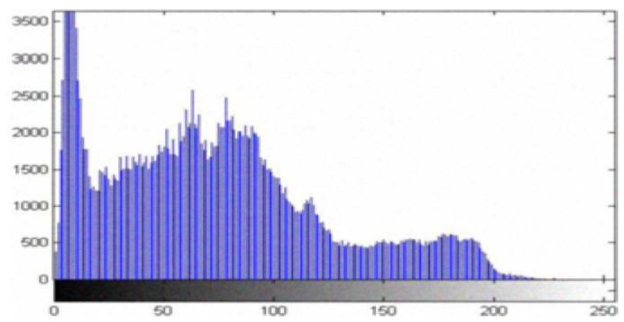

Fig 1. Histogram

A. *Histogram Equalization*

Histogram equalization [16] is a common technique for enhancing the appearance of images. Suppose we have an image which is predominantly dark. Then its histogram would be skewed towards the lower end of the grey scale and all the image detail is compressed into the dark end of the histogram. If we could `stretch out' the grey levels at the dark end to produce a more uniformly distributed histogram then the image would become much clearer.

Histogram equalization stretches the histogram across the entire spectrum of pixels (0 – 255). It increases the contrast of images for the finality of human inspection and can be applied to normalize illumination variations in image understanding problems. Histogram equalization is one of the operations that can be applied to obtain new images based on histogram specification or modification. Histogram equalization is considered a global technique. This process is quite simple and for each brightness level j in the original image, the new pixel level value (k) is calculated as given in equation 2.2

$$K = \sum_{i=0}^{j} \frac{N_i}{T} \text{ ……………………………}$$

Where the sum counts the number of pixels in the image with brightness equal to or less than j, and T is the total number of pixels .The main purpose of histogram equalization is to find gray level transformation function T to transform image f such that the histogram of T(f) is ‘equalized’ .

B. *Local Enhancement*

Previous methods of histogram equalizations and histogram matching are global. So, local enhancement [17] is used. Define square or rectangular neighborhood (mask) and move the center from pixel to pixel. For each neighborhood, calculate histogram of the points in the neighborhood. Obtain histogram equalization/specification function. Map gray level of pixel centered in neighborhood. It can use new pixel values and previous histogram to calculate next histogram.

C. *Log Transformations*

The log transformation maps [18] a narrow range of low input grey level values into a wider range of output values. The inverse log transformation performs the opposite transformation. Log functions are particularly useful when the input grey level values may have an extremely large range of values.Sometimes the dynamic range of a processed image far exceeds the capability of the display device, in this case only the brightest parts of the images are visible on the display screen. To solve this problem an effective way to compress the dynamic range of pixel values is to use the Log Transformations, which is given by,

$$g(x, y) = c \cdot \text{Log}(1 + r)) \text{ ……………. (2.3)}$$

Where c is constant and it is assumed that $r \geq 0$.

This transformation maps a narrow range of low-level grey scale intensities into a wider range of output values. Log Transformations is used to expand values of dark pixels and compress values of bright pixels. Inverse log transform function is used to expand the values of high pixels in an image while compressing the darker-level values.Inverse log transform function maps the wide range of high-level grey scale intensities into a narrow range of high level output values.

D. *Thresholding Transformations*

Thresholding transformations [19] are particularly useful for segmentation in which we want to isolate an object of interest from a background. Image threshold is the process of separating the information (objects) of an image from its background, hence, thresholding is usually applied to grey-level or color document scanned images.

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International Journal of Computer Technology and Electronics Engineering (IJCTEE)
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Thresholding can be categorized into two main categories: global and local. Global thresholding methods choose one threshold value for the entire document image, which is often based on the estimation of the background level from the intensity histogram of the image; hence, it is considered a point processing operation. Global thresholding methods are used to automatically reduce a grey-level image to a binary image. The images applied to such methods are assumed to have two classes of pixels (foreground and background). The purpose of a global thresholding method is to automatically specify a threshold value T, where the pixel values below it are considered foreground and the values above are background. A simple method would be to choose the mean or median value of all the pixels in the input image, the mean or median will work well as the threshold, however, this will generally not be the case especially if the pixels are not uniformly distributed in an image.

Local adaptive thresholding uses different values for each pixel according to the local area information. Local thresholding techniques are used with document images having non-uniform background illumination or complex backgrounds, such as watermarks found in security documents if the global thresholding methods fail to separate the foreground from the background. This is due to the fact that the histogram of such images provides more than two peaks making it difficult for a global thresholding technique to separate the objects from the background, thus; local thresholding methods are the solution.

E. Contrast Stretching

To expand the range of brightness values in an image the contrast enhancement techniques are used, so that the image can be efficiently displayed in a manner desired by the analyst. The level of contrast in an image may vary due to poor illumination or improper setting in the acquisition sensor device. Therefore, there is a need to manipulate the contrast of an image in order to compensate for difficulties in image acquisition. The idea behind contrast stretching is to increase the dynamic range of the gray levels in the image being processed. The idea is to modify the dynamic range of the grey-levels in the image. Linear Contrast Stretch is the simplest contrast stretch algorithm that stretches the pixel values of a low-contrast image or high-contrast image by extending the dynamic range across the whole image spectrum from 0 – (L-1).

F. Un-sharp Masking

In the un-sharp masking (UM) approach for image enhancement, a fraction of the high-pass filtered image is added to the original one to form the enhanced image [20]. The input/output relation for the un-sharp masking filter can be written as follows:

$$x' = x + \lambda z \quad \text{.................. (2.4)}$$

Where x *and* x' are the inputs, output images and λ is a positive constant which controls the fraction of the high-pass filtered image z to be added to the input image; see figure 2.2. This is a simple method, but it has two major drawbacks. First it enhances the noise present in the image. Second, it enhances too much the sharp transitions which lead to excessive overshoot on sharp edges.

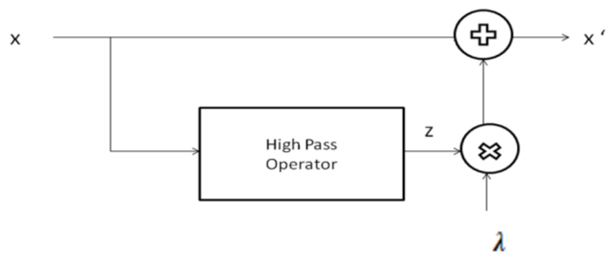

Fig 2.The un-sharp masking structure.

III. PROPOSED IMAGE ENHANCEMENT METHOD

In digital image processing various techniques have proposed to enhance the quality of image such as histogram equalization, multi-histogram equalization and pixel dependent contrast preserving. Now we proposed a novel image enhancement technique “image pixel interdependency linear perceptron network (IPILP) for image enhancement that provides a better result for contrast enhancement with brightness preservation.

1. The proposed Image Pixel Interdependency Linear Perceptron Network (IPILN) technique uses Gaussian filter, curvelet transform and perceptron network. Basically our proposed technique involves three steps that are below.

Image Filtration: The Gaussian filter is used to obtain a row image from input image.

2. Image Transformation: Transformation is a process that is used to convert a signal from one domain to another without the loss of information. In our approach we are using a multi-resolution curvelet transform. To transform the row image, the curvelet transform is used that is a multidirectional transform.

3. Perceptron Network: To adjust the weight of input image, the concept of perceptron network is used. In perceptron network to adjust the weight, the learning factor is used which vary from 0 to 1.

A simple block diagram of proposed method is shown in figure 3.

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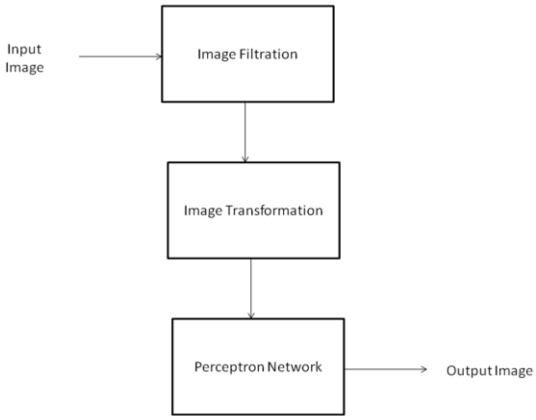

Fig 3. Block Diagram of Proposed Method

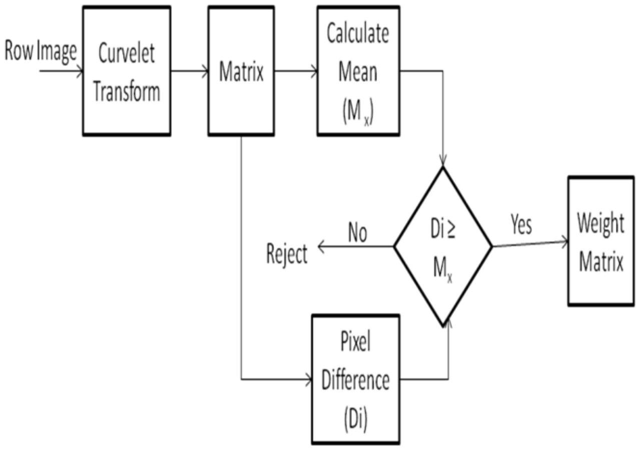

Fig 5. Image Transformation

A. *Image Filtration*

The image filtration is a pre-processing step in image enhancement that reduces the noise from input image and obtains a row image .The pre-processing for image filtration is shown in figure 4.

Fig 4 Image Filtration

In this work Gaussian filter is used to reduce the noise interference from input image. Gaussian filter is windowed filter of linear class; by its nature is weighted mean. Gaussian distribution, or normal distribution, is really a function of probability theory. Often this function is referenced as bell-function because of its shape. Gaussian filter is calculated by using the following equation 4.1

$$G(i,j) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(-\frac{i^2+j^2}{2\sigma^2}\right) \ldots\ldots\ldots (4.1)$$

Where σ is the standard deviation in the area of mask size, (i, j) are the coordinates relative to the center of the filter.

B. *Image Transformation*

To transform a row image into multi-resolution mode, the curvelet transform function is used. It enables directional analysis of images in different scales. The curvelet transform, like the wavelet transform, is a multi-scale transform, with frame elements indexed by scale and location parameters. Unlike the wavelet transform, it has directional parameters, and the curvelet pyramid contains elements with a very high degree of directional specificity. The overall process of image transformation is shown in figure 5.

Image transformation is done in many steps that are as follows.

(A) Row image is converted in a matrix form by using the curvelet transform that is a multi- directional transform.

(B) Calculate the mean value of matrix and the mean value are used as a threshold value. The mean value is calculated by equation

$$M_x = \sum_{i=0}^{m} \frac{x_i}{n} \qquad \ldots\ldots\ldots\ldots\ldots\ldots$$

(C) Calculate the pixel difference by using gradient decent method. The gradient decent is based on minimization of error E defined in terms of weight and activation function of network.

(D) Compare the pixel difference with mean value .If pixel difference is grater than mean vale then, pixel difference value is selected for weight matrix, otherwise is rejected.

IV. CONCLUSION AND FUTURE WORK

In image enhancement field various techniques have proposed to enhance the quality of image such as histogram equalization, multi-histogram equalization and pixel dependent contrast preserving. We proposed a novel image enhancement technique “image pixel interdependency linear perceptron network (IPILP) for image enhancement that provides a better result for contrast enhancement with brightness preservation. IPILP uses the curvelet and perceptron network for image enhancement. The curvelet transform is used to transform an image into multi-resolution mode and perceptron network is used to adjust the weight of input image or values. Our proposed method for contrast enhancement has applied on several images and compared the result of our method with other image enhancement methods .To evaluate the effectiveness of proposed method, by using two parameters namely AMBE and PSNR, the proposed method is compared with the existing methods namely HE, MHE and IDBPHE, mathematically proved that the proposed method is better than other contrast enhancement methods. In the process of calculating the pixel difference some values are

ISSN 2249-6343
International Journal of Computer Technology and Electronics Engineering (IJCTEE)
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rejected but these values are part of actual image data. Now in future we can work to calculate the pixel difference in the proper process and can be minimize the time complexity of perceptorn network.

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