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Image Enhancement Using Sub Image Edge Based Histogram Equalization

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Abstract

In this study, image enhancement is well established area in image processing. The objective of image enhancement is to improve the perceptual information of the image. A novel sub image edge based histogram equalization method has been proposed. This algorithm undergoes the following steps. The image is made through the gradient operator for the detection of edges of the image and image is divided into two through the mean of histogram of the image. By doing this, the transformation function will depend on the intensity of the pixels of the edges which are detected. This method improves the low contrast area in the image and does not enhance the brighter area in the image. This method avoids excessive enhancement of the image. Experimental results shows that entropy is better for sub image edge based histogram equalization than standard histogram equalization.

Keywords: Image Enhancement, Histogram Equalization, Edge Detection, Entropy.

Introduction

Image enhancement is one of the most substantial areas of computer technology. In general, image processing is evaluation and progression of pictorial information. The purpose of image processing is to upgrade the pictorial information for the human perception, autonomous machine application and also for efficient storage and transmission. The important applications of image processing are image enhancement, image sharpening and restoration, pattern recognition and so on [1].

Image enhancement plays a vital role in image enhancement and video processing. It is one of the most fundamental issues in low level image processing. The image enhancement intention is to augment the quality of the low contrast image so that the resultant image is more appropriate than original image. It is extensively used in medical image fields, as well as a preprocessing step in speech recognition and image video processing applications. In image enhancement, histogram equalization is most frequently used technique. The elemental idea of histogram equalization is to redistribute the intensity values of pixels which compose a uniform intensity distribution. Histogram equalization (HE) [2] is understandable and very adequate in upgrading the low contrast image alone when the image has a single object and no apparent contrast difference between object and background [3].

This method commonly enhances the global contrast of images, particularly when the essential data of the image is presented by close contrast values. Histogram equalization transforms the histogram of the original image into a smooth uniform histogram with a mean value that lies in center of the gray level range [4]. Histogram equalization is also known for shifting the mean brightness of the resultant image. Due to this change in brightness, unnecessary visual artifacts are unavoidable [5]. Histogram equalization is done by efficiently distributing the most frequent intensity values in the histogram. This distributed histogram which acts as the transfer mapping function to the input image. This method becomes a failure in adjusting the local contrast and producing over enhancement of the input image [6].

Another imperative concern in image enhancement is edge detection. Edge information is the elemental in image analysis and computer vision applications [7]. Edge detection is basically, a method of segmenting an image into regions of discontinuity. The key objective of edge detection is to extract the significant feature from the edge of an image. This can be done by usage of differential operators to enhance the quality of the edges in the image. The operators are designed with high spatial frequency enhancement algorithm. This algorithm which makes use of the first order or second order edge detectors to enhance the original image and to form an edge enhancement map [8].

Edge Detection are understandable to compute and run promptly, but responsive to noise disturbance which makes low effectiveness on edge detection [9]. Edge detection allows user to observe the features of an image where there is more or less abrupt change in gray scale or texture indicating the end of one region in the image and the beginning of another. Edge detection is used in many practical applications like medical imaging, computer, locating data in satellite images, automatic traffic controlling systems, study of anatomical structure, pattern recognition, finger printing and iris biometric identification [10] [11].

Robust He Transformation Function

A. Conventional Histogram Equalization

The course of the histogram equalization is to expand the contrast of a given image uniformly throughout the entire available dynamic range. In histogram equalization, the probability density function (PDF) being is manipulated. It changes the probability density function of a given image into that of a uniform probability density function i.e. extents out from the low pixel value to highest pixel value [12]. This can be established easily when probability density function is a continuous function. Since digital image is discrete in nature, probability density function is discrete function. Let us consider a given image *I* and the dynamic range for an intensity *i* varies from I_0 to I_{L-1} [13].The probability density function for the given image is given by

$$p(i) = \frac{n_i}{N} \text{ for } k = 0,1.....,L-1 \tag{1}$$

Where *N* is the total number of pixels in the given image and *n* is the number of occurrence of intensity *i* in the given image [13].

In histogram equalization, the transformation function $T_1(x)$ which map the given image into the entire dynamic range of [I_0, I_{L-1}] and it is given by [13]

$$T_1(x) = I_0 + (I_{L-1} - I_0) \sum_{i=X_0}^{x} p(i) \tag{2}$$

An example of an image which is transformed by equation *(2)* is shown in Fig. 1. Fig. 1(b) shows that output image processed by standard histogram equalization method.

(a) (b)

Figure 1: (a) Input Image. (b) Output Image after HE Process.

Now, lets us consider a case that the intensity of a given image is inversed and then the probability density function is calculated by using the equation *(1)*. The transformation function $T_2(x)$ for the inverse image is obtained by the following equation [13]

$$T_2(x) = I_0 + (I_{L-1} - I_0)\left(1 - \sum_{k=x}^{I_{L-1}} p(k)\right) \tag{3}$$

An example is shown in Fig. 2 which is processed by the equation *(3)*. In Fig. 2(b) shows how the inverse image intensity has been equalized and in Fig. 2(c) shows re-inverse of the output which will not be same as one which is obtained by the equation *(2)*.

(a) (b) (c)

Figure 2: (a) Inversion of the Input Image. (b) Output Image after HE Process. (c) Inverted Image of 2(b).

Now, a new transformation function $T_3(x)$ can be obtained by averaging the transformation functions formed from equation *(1)* and *(2)* [13].

$$T_3(x) = \frac{1}{2}(T_1(x) + T_2(x))$$

$$T_3\,(x) = I_0 + (I_{L-1} - I_0)\left(0.5p(i) + \sum_{k=I_0}^{x-1} p(k)\right) \tag{4}$$

The results obtained using the equation *(4)* is shown in Fig. 3. As shown in figure, the resultant image which is obtained proves that equation *(4)* transformation function performs better than equations *(2)* and *(3)* [13].

(a) (b)

Figure 3: (a) Output Image after Equation *(4)* without Inversion of Input Image. (b) Output Image after Equation *(4)* With Inversion of Input Image.

B. Sub Image Histogram Equalization

In Standard Histogram Equalization, the brightness of the resultant image has changed abruptly. In order to overcome this drawback, the histogram of the input image is divided into two parts. For the sub division of histogram, the mean value I_M of the histogram is calculated. The two sub images has dynamic range of [I_0,I_M] and [I_{M+1} ,I_{L-1}]. The probability density function for the two sub images are $p_L(i)$ and $p_U(i)$ respectively. Further, the transformation function for the sub images is obtained from the equation *(4)*. The proposed transformation function for the sub images is given

$$T_4(x) = (I_0 + (I_M - I_0)\left(0.5p(i) + \sum_{k=I_0}^{x-1} p_L(k)\right) \tag{5}$$

$$T_5(x) = (I_{M+1} + (I_{L-1} - I_{M+1})\left(0.5\,p(i) + \sum_{k=I_{M+1}}^{x-1} p_U(k)\right) \quad (6)$$

The results for equations *(5)* and *(6)* are shown in Fig. 4. As presented in figure, the subsequent image which is obtained proves that equations *(5)* and *(6)* transformation functions perform better than equation *(4)*.

(a) (b)

Figure 4: (a) Output Image after Equations *(5)* and *(6)* without Inversion of Input Image. (b) Output Image after Equation *(5)* and *(6)* with Inversion of Input Image.

Edge Detection For Equalization

Edge detection is a fundamental tool for feature detection and extraction which goal to identify points in an image where brightness of image changes sharply and finds discontinuities. The objective of edge detection substantially reduces the data in the image and preserves the structural properties of the image for further image processing. The most frequently used method for edge detection is enhancing the quality of the edge by a first order edge detector. Generally, gradient based operator is used for edge detection [8]. They are used for gaining the boundaries of object in images. There are some classical edge detector which are commonly used are Sobel, Roberts, Prewitt operators [11].

Sobel operator is a two dimensional discrete spatial gradient measurement technique on an image. It convolves the input image with kernel and computes the gradient magnitude and direction. It makes use of a pair of 3×3 convolution mask. The convolution mask is generally smaller than the original images. When the convolution mask is larger, error due to effects of noise is reduced by local averaging within the neighborhood of the mask. Sobel edge detector operator and Prewitt edge detector operator is used for horizontal and vertical edge detection techniques [11]. Robert operator computes the sum of the squares of the difference between diagonally adjacent pixels through discrete differentiation and then calculate approximate gradient of the image. The input image is convolved with 2×2 kernels of operator and gradient magnitude and directions are computed [10].

Roberts edge detector operator which has smaller efficient area than other mask. Sobel edge detector operators are more sensitive to diagonal edges rather than horizontal and vertical edges. Prewitt edge detector operators are more sensitive to horizontal and vertical edges rather than diagonal edges [14]. Fig. 5 shows that the effect of the edge detector which is used in the various histogram equalization process. This figure shows that how the edge detection operation makes identification of the edge and then processing by histogram equalization which makes enhancement of the low contrast in image.

(a) (b) (c) (d)

Figure 5: (a) Input Image. Edge Detection operation for (b) HE Process. (c) Equation *(4)*. (d) SIEBHE process.

Sub image edge based histogram equalization (SIEBHE) is designed for some areas of the image have to improve the contrast and others where the contrast has to reduce. It does not enhance the brighter spot in the image. In standard histogram equalization improves the contrast as well as enhances the noise in the image. But, sub image edge based histogram equalization does not enhance the noise in the image. The sub image edge based histogram equalization does work better than standard histogram equalization in areas of large number of dark pixels.

For sub image edge based histogram equalization, the original image is made to find the edges of the image by using gradient based operator i.e. a convolution mask is made to slide over the image calculating square pixels at a time. Then the subsequent image is sub-divided into two sub images. Further, the sub images are equalized by the equations *(5)* and *(6)*.

Simulations Results

The sub image edge based histogram equalization performs better than standard histogram equalization which is quantitatively measured by the metric entropy. Entropy computes the average overall data content of the input image in bits per pixel [1]. Entropy is expressed as

$$Entropy = -\sum_{i=0}^{L-1}\left[p(i)\times\log p(i)\right] \qquad (7)$$

where *p(i)* is the PDF of the input image at intensity *I* and L is number of gray levels in the given image.

The entropy results of standard histogram equalization and sub image edge based histogram equalization are compared and results are tabulated. Greater value of entropy means that image contains more data.

Table 1: Entropy Results

Images	**Original image**	**HE**	**Sub Image Edge Based HE**
Cameraman	7.01	5.87	6.41
Coins	6.32	5.39	5.92
Pout	5.76	5.72	5.73
Tire	6.93	5.64	5.88
Eight	4.88	4.31	4.57
Rice	7.01	5.87	6.50
Circuit	6.94	5.95	6.43
Moon	5.51	4.31	4.87

Conclusion

In this study a method in histogram equalization technique, sub image edge based histogram equalization is discussed. The comparative results show that the sub image edge based histogram equalization technique improves the necessary contrast of the image. Standard histogram equalization enhances the image as well as the noise of the image. The experimental results of several images indicates that sub image edge based histogram equalization performs better than standard histogram equalization in terms of enhancing only the required low contrast of the input image and preserving the dark contrast of the image from further enhancement.

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