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Implementing Histogram Equalization and Retinex Algorithms for Image Contrast Enhancement

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Abstract: The image enhancement targets on transforming input image as better one, so that the enhanced image solve the purpose of specific application or set of objectives. Histogram equalization is a primitive and well established technique for enhancing image contrast. The existing methods are Range Limited Bi-Histogram Equalization (RLBHE) and Adaptive histogram equalization method. RLBHE works by dividing the input histogram into two independent sub-images with reference to threshold. This minimizes the intra-class variance thereby support fine separation of objects from its background. In Adaptive histogram equalization (AHE), the input source image is divided by equal number of rows and columns and the histogram for each region is calculated. The histogram of each sub region is used to perform local image enhancement. But both the RLBHE and AHE are very slow and do over enhancement of noise in the image. On the other hand, Retinex algorithms improve the sharpness, contrast and brightness of an image. It also reduces the noise level in the image. It uses OTSU-S method to threshold the images. This paper explains a walkthrough on both histogram equalization and Retinex algorithm techniques by implementing them for image contrast enhancement.

Key words: Transforming input image · Established technique for enhancing

INTRODUCTION

Image Enhancement is an obsolete part in the field of image processing. Contrast enhancement fluxes the intensity of pixel in input image to catalyze the output image with better subjective observation. The image enhancement targets the better perception of information in images for human views or provides improved input for other self-propelling image processing proficiencies. This proficiency is used to emphasize and sharpen image conspicuous parts for display and analysis. The image contrast enhancement focus on reassembling attributes of an image to exaggerate it more suitable for a observer. One traditional way of image enhancement is histogram equalization.

Histogram equalization (HE) [1] has been simple but effective image enhancement method. Despite of its nature to change the contrast of an image considerably, it also causes maddening and abnormal contrast enhancements. Brightness preserving bi-histogram equalization (BBHE) [2] and dualistic sub-image histogram equalization (DSIHE) [3] has been proposed to overcome these disputes. But they seem to fail under certain conditions. BBHE partitions the input image histogram into two parts in reference to its mean value. Next step involves equalization of each part. One of the divided sub-image is less than or equal to mean whereas the other part is greater. The DSIHE is similar to BBHE except histogram separation using median value. The input image is decomposed into two based on grey scale probability density function [4] and is followed by equalization of sub images. Another bi histogram equalization algorithm called Range Limited Bi-Histogram Equalization (RLBHE) [4] takes both contrast and brightness into account. Otsu's orderliness is used to calculate histogram threshold. The range of equalized image is limited by equating the mean output and input brightness.

In this paper we present the implementation of RETINEX based algorithms SSR and MSR along with the histogram equalization algorithms mentioned in the discussion above. RETINEX algorithms improves visual rendering of an image when lighting conditions are bad. While our eye can see colours correctly when light is low, camera and video cams can't manage well. Retinex

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algorithms are capable of filling the gap between images and human observation by enhancing the brightness, contrast, sharpness of an image. It compensates the the blurring introduced by image formation process and improves consistency of an output as illumination changes. It has better performance and preserves the original brightness quite well. One of the types of Retinex is Single Scale Retinex (SSR) Algorithm, which can either deliver dynamic range compression or tonal rendition. In SSR [5], as the result of exponential and Gaussian surround functions better dynamic range compression than neighbouring pixels is obtained.

Other major type of Retinex is Multi Scale Retinex (MSR) Algorithm. It evolved as the result of combining different weighted scales of SSR, which serves as proficient solution to preserve both the dynamic range compression and colour rendition. The details on scales such as, the number, values and weight are the strength of Multi Scale Retinex algorithms [5]. The brightness level over the entire image and dynamic image range compression purely depend on values and weight chosen.

This paper is organised as follows. Section 2 covers the introduction for histogram equalization techniques and section 3 explains about Retinex based algorithms. Section 4 compares the output of algorithms implemented. Section 5 concludes the idea of implementation and future directions.

Histogram Equalization Techniques

Brightness Preserving Bi-Histogram Equalization Method: Yeong-Teag Kim proposed Brightness Preserving Bi-Histogram Equalization method [2] based on the Mean value. It include partitioning an image X into two sub images, X_L and X_U. This can be represented as

$$X = X_L \circledcirc X_U$$

The probability density of X_L and X_U are defined below as functions

$$P_L (X_K) = n^K{}_L / n_L \text{ where } K=0, 1, 2, \ldots\ldots\ m$$
$$P_U (X_K) = n^K{}_U / n_L \text{ where } K=m+1, \ldots\ldots\ L-1$$

The variables $n^K{}_L$ and $n^K{}_U$ are used to represent the respective numbers of X_K. n_L and n_U are the total numbers of samples in X_L and X_U. The technique adopted is similar to the histogram equalization. The decomposed images are equalized independently and composed later as single image. The output of the BBHE is expressed as

$$Y = \{Y (i, j) \}$$
$$= f_L (X_L) \circledcirc f_U (X_U)$$

BBHE aims at preserving the mean brightness of the input image along with the image contrast enhancement. The mean input brightness is equalized to the mean output.

Dualistic Sub-Image Histogram Equalization: Unlike BBHE, DSIHE technique adopted by Yu Wang et al. for image enhancement is based on the Median value [3]. This algorithm also follows the decomposition of image X so that, two sub-images, X_L and X_U are obtained. The probability distribution function of sub images X_L and X_U are given as

$$X_L = \{ X (i, j) / X (i, j) < X_e, \forall X (i, j) \in X$$

$$X_U = \{ X (i, j) / X (i, j) \leq X_e, \forall X (i, j) \in X$$

The histogram equalization of the sub images are done with the transform functions obtained based on the cumulative distribution function, $f_L (X_k) = X_0 + (X_{e-1} - X_0) c (X_k)$ and $f_U (X_k) = X_e + (X_{L-1} - X_e) c (X_k)$. The resultant of the dualistic sub-image histogram equalization DSIHE, is expressed as

$$Y = \{Y (i, j)\} = f_L (X_L) \cup f_U (X_U)$$

Range Limited Bi-Histogram Equalization: Chao Zuo et al. proposed RLBHE which is based on choosing a proper threshold for histogram equalization and determination of upper and lower bounds for the same [4]. The optimal threshold to separate the two classes of pixels in a image is calculated from weighted sum of variances between the pixel classes,

$$\sigma^2 (X_T) = W_L(E(X_L) - E (X))^2 + W_U (E(X_U) - E(X))^2$$

The mean brightness of the resultant image is considered important and it is not affected by the technique adopted and is represented as

$$E (Y) \quad E (X) = X_m = \sum_{j=0}^{L-1} X_j\, p (Xj)$$

Retinex Algorithms: The two major types of RETINEX algorithms includes SSR (Single Scale Retinex) Algorithm and MSR (Multi Scale Retinex) Algorithm. Retinex is an image enhancement algorithm that is used to enhance the contrast, brightness and sharpness of an image through dynamic range compression. These algorithms include non linear spatial/spectral transformation, which has proven the better image quality.

SSR (Single Scale Retinex): The single scale Retinex (SSR) algorithm was proposed by Jobson et al. The SSR proficiency is defined as follows

[R, L] = single scale retinex(X, hsiz, normalize)

where, X stands for the image and hsiz denotes the parameter that controls Gaussian filter bandwidth.

SSR is defined for a point (x, y) in an image as [5]

$$R_i(x, y) = \log I_i(x, y) - \log [F(x, y) * I_i(x, y)], \; i = 1, \dots S$$

By using Gaussian surround function to F(x,y), the normalized surround function,

$$F(X, Y) = K e^{-\{((x*x)+(y*y))/(c*c)\}}$$

where c is the Gaussian surround constant, that is referred to as the scale of the SSR and K is selected such that

$$\int\int F(x, y)\, dxdy = 1.$$

The image distribution is the product of scenes reflectance and illumination

$$I_i(x, y)\; S_i(x, y)\; r_i(x, y)$$

where S (x, y) i is the spatial distribution of illumination and r (x, y) i is the distribution of scene reflectance [5].

$$R_i(x, y) = \log [S_i(x, y)\, r_i(x, y)/(\overline{S_i(x,y) ri(x,y)})]$$

Multi Scale Retinex (MSR): The multi scale retinex (MSR) algorithm [6] is an extension of the single scale retinex algorithm again proposed by Jobson et al. The MSR proficiency is expressed as functions below

Y = multi scale retinex(X, hsiz, normalize).

In MSR algorithm, the scaling values play the vital role. The variation is done in number of scales used and weight of the scales. In the above expression X denotes the input image and hsiz is the value which control the Gaussian filter bandwidth. The usage of proficient scaling value c in function F(x,y) controls the balance between colour rendition and dynamic range compression. The customization in multi scale retinex, which include number of scales N and weighted different scales also helps in achieving the same. This quality of MSR algorithm rises the question about optimized scale values. Fixed image partition along with scales of 15,18 and 250 are used.

MSR is an extended SSR with the multiple kernel windows of the different sizes. The output of MSR is a weighted sum of several different SSR outputs. The Multi-scale retinex algorithm is given by [5] as

$$R_i(x, y) = \sum_{n=1}^{N} w_n R_{ni}, \qquad i = 1, \dots, S$$

where $R_{ni}(x, y) = \log I_i(x, y) - \log [F_n(x, y) * I_i(x, y)]$

$$R_i(x, y) = \sum_{n=1}^{N} w_n \log I_i(x, y) - \log [F_n(x, y) * I_i(x, y)], \; i = 1, \dots, S$$

N and S are the number of scales and the number of spectral bands, respectively. Here $R_{ni}(x, y)$ denotes a retinex output associated with the n-th scale for an image, $I_i(x, y)$ and $F_n(x, y)$ denote a surround mission. The surround mission is given by the following [5]

$$F_n(x, y) = K_n e^{-\{((x*x)+(y*y))/(c_n*c_n)\}}$$

and

$K_n = 1 / (\Sigma_x \Sigma_y F(x, y))$ is the normalization factor.

Implementation and Comparision: The implementation of histogram equalization techniques and Retinex algorithm based techniques for image contrast enhancement is done and the sample outputs of images are shown below in Figure 1. The image (a) of figure 1 is the original images taken. The output images clearly shows th contrast enhancements with respect to the algorithms employed. The outputs of histogram equalization algorithms increases the contrast of image with the limitation of poorly visible features on images. This is shown in image (b), (c) and (d) of figure 1. On the other hand retinex based algorithms incrases the contrast with the better visible features. Images (e) and (f) in figure 1 stands as evidence for retinex algorithms.

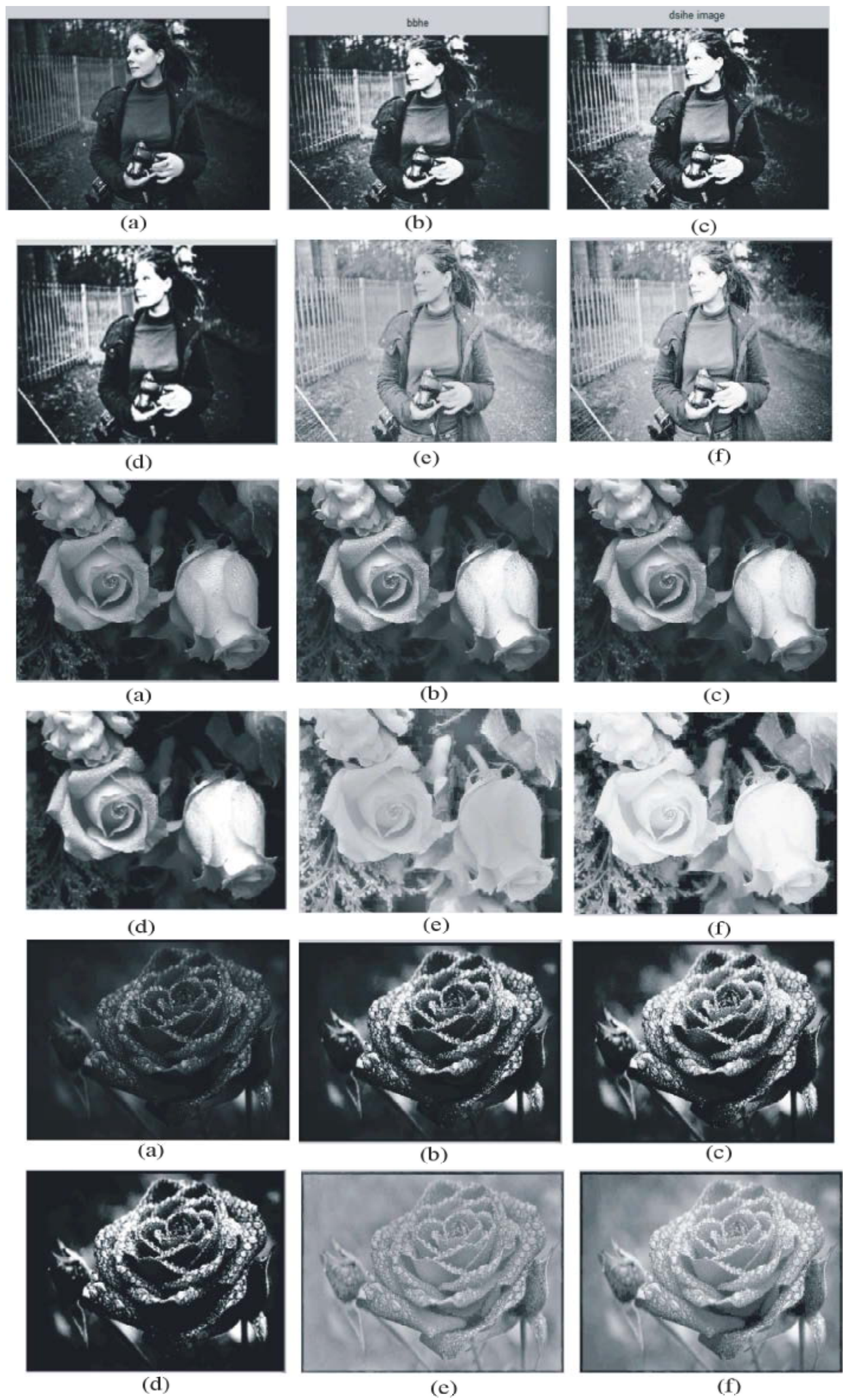

Fig. 1: (a) Original Image
(b) BBHE
(c) DSIHE
(d) SSR
(e) MSR

CONCLUSION

The implementation of histogram equalization and retinex algorithm based techniques concludes optimal contrast enhancement while using retinex algorithms over the other. The output images shown above stands as the result. The drawbacks of previous orderliness are: In BBHE and DSIHE, the Equalization technique reduces the pixel quality and in RLBHE, Variation in grey-scale image during Histogram, loose the definition on the edges in objects. Over Enhancement of Noise in the image and Increased in Brightness level of background image is also the outcome of histogram equalization techniques. Retinex algorithms trounce all these drawbacks and gives better contrast enhancement to images.

Future work can be focused on processing and restoring colors in video frames using Multi-Scale Retinex with Color Restoration (MSRCR) algorithm [10-11] which is one of the types in RETINEX Algorithm.

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