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An AIHT based Histogram Equalization Algorithm for Image Contrast Enhancement

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Abstract: Histogram Equalization (HE) is an effective technique for contrast enhancement. However, the traditional HE method usually results in extreme over-enhancement, which causes the unnatural look and visual artifacts in the processed image. To solve the problem, we propose a novel Modulated Histogram Equalization (MHE) image contrast enhancement algorithm based on Adaptive Inverse Hyperbolic Tangent (AIHT) algorithm. The AIHT has long been known that the Human Vision System (HVS) heavily depends on details and edges in understanding its perception of scenes. The new method is capable of doing image contrast enhancement adaptively and globally, while extruding the details of objects simultaneously.

Keywords: Adaptive Inverse Hyperbolic Tangent (AIHT), Histogram Equalization (HE), human visual perception, image contrast enhancement, Modulated Histogram Equalization (MHE) contrast enhancement

INTRODUCTION

Apparent or perceived contrast is basic perceptual attribute of an image. Images are captured at low contrast in a number of different scenarios. The main reason for this problem is poor light conditions. Because of the poor photographical environment can produce a too dark or too bright image and is inappropriate for visual inspection. The simple way to improve the contrast of an image is to modify its pixel value distribution, or histogram.

The research about human visual perception is called as Human Visual System (HVS). Adaptation means that the signals from our photoreceptors are processed to amplify weak signals and weaken strong signals, thereby preventing saturation. The eye is a complex biological device. The functioning of a camera is often compared with the workings of the eye, mostly because both focus the light from external objects in the visual field into a light-sensitive medium. In the case of the camera, this medium is film or an electronic sensor; in the case of the eye, it is an array of visual receptors (Rodiek, 1988). According to the laws of optics, this simple geometrical similarity means that both eyes and a CCD camera function as transducers. (Acharya and Ray, 2005) research the image processing: principles and applications. Russ (2002) propose the image processing handbook: fourth edition. Wald (1999) research some terms of reference in data fusion.

A common problem in digital cameras is that the range of reflectance values collected by a sensor may not match the capabilities of the digital format or color display monitor. Therefore, image enhancement techniques are generally required to make an image easier to analyze and interpret. The range of brightness values within an image is referred to as contrast. The contrast enhancement is a process that makes the image features stand out more clearly by optimizing the colors available on the display or an output device. A contrast enhancement algorithm allows users to custom design to improve image quality, representation and interpretation.

To improve the contrast and objects visibility a histogram adjustment is performed. However, by enhancing the contrast of an image through a transformation of its intensity values, the histogram equalization can amplify the noise and produce worse results than the original image, due to many pixels falling inside the same gray level range. Therefore, in this study we propose a MHE image contrast enhancement algorithm based on AIHT algorithm.

In this study, we present a modulated histogram equalization based on AIHT contrast enhancement algorithm from conjugate AIHT and HE image contrast enhance algorithm. These proposed algorithms based on Adaptive Inverse Hyperbolic Tangent algorithm as a contrast function to map from the original image into a transformed image. Use of this algorithm can improve displayed quality of contrast in the scenes and offers an efficiency way for fast computation. Experimental results show MHE algorithm have more better contrast enhancement effect and show details than AIHT and HE.

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METHODOLOGY

Contrast enhancement for an image: One of most widely used nonlinear image contrast enhancement is Histogram Equalization (HE) which intends to spread out the original image histogram across the entire gray level range. HE is a specific case of the more general class of histogram remapping methods. These methods seek to adjust the image to make it easier to analyze or improve visual quality (e.g., retinex). In Chen and Ramli (2004) developed a HE strategy that significantly enhances contrast by spreading out the histogram in a way that the brightest and darkest levels of brightness are always included. As a result, brightness saturation appears not only in quasi-homogeneous low gray levels but also in quasi-homogeneous high-gray levels. In this case, the problem of brightness saturation encountered in histogram linear contrast stretching can be avoided if the narrow range of the original histogram is properly spread out.

HE is one of the most useful forms of nonlinear contrast enhancement. When an image's histogram is equalized, all pixel values of the image are redistributed. As a result, there are approximately an equal number of pixels for each of the user-specified output gray-scale classes (e.g., 32, 64 and 256). Contrast is increased at the most populated range of brightness values of the histogram (or "peaks"). It automatically reduces the contrast in very light or dark parts of the image, which are associated with the tails of a normally distributed histogram. Histogram equalization can also separate pixels into distinct groups if there are few output values over a wide range.

Consider a discrete grayscale subimage {x} and let n_i be the number of occurrences of gray level i. The probability of an occurrence of a pixel of level i in the image was defined by the following Eq. (1):

$$p_x(i) = p(x = 1) = \frac{n_i}{n}, \quad 0 \le i \le L \tag{1}$$

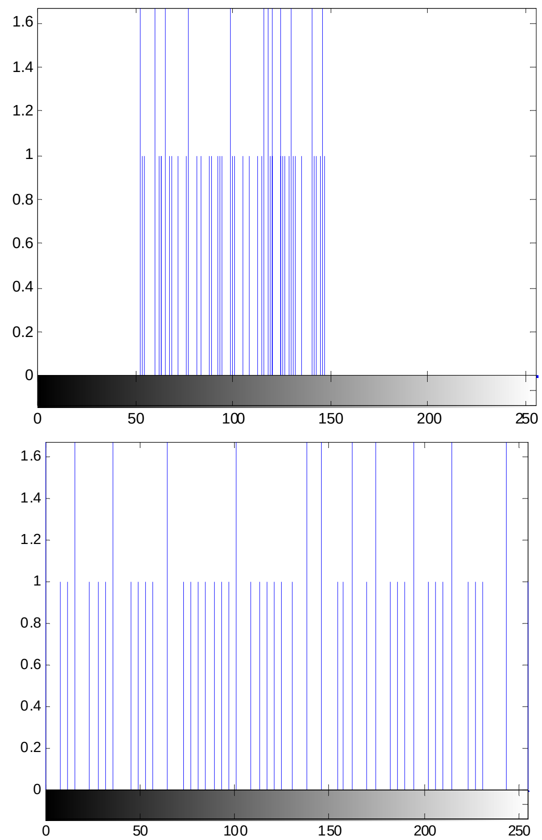
where, L being the total number of gray levels in the image, n being the total number of pixels in the image and $p_x(i)$ being in fact the image's histogram for pixel value i, normalized to [0, 1].

Let us also define $p_x(i) = p(x = i) = n_i/n 0 \le i < L$ the cumulative distribution function corresponding to p_x as Eq. (2):

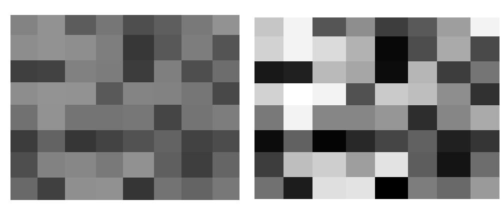
$$cdf_x(i) = \sum_{j=0}^{i} p_x(j) \tag{2}$$

which is also the image's accumulated normalized histogram.

We would like to create a transformation of the form y = T(x) to produce a new image {y}, such that its CDF will be linearity across the value range, i.e., Eq. (3):



(a) Histogram of original and equalized image



(b) Original and equalized of image

Fig. 1: Processed result by histogram equalization

$$cdf_y(i) = iK \tag{3}$$

for some constant K. The properties of the CDF allow us to perform such a transform; it is defined as Eq. (4):

$$y = T(x) = cdf_x(x) \tag{4}$$

Notice that the T maps the levels into the range [0, 1]. In order to map the values back into their original range, the following simple transformation needs to be applied on the result:

$$y' = y.(\max\{x\} - \min\{x\}) + \min\{x\} \tag{5}$$

Figure 1a shows two histograms of original and equalized image. Figure 1b shows original and equalized of image. The first histogram shows values before equalization. Comparing this histogram to the equalized histogram shows that the enhanced image gains contrast in the most populated areas of the original histogram.

A key advantage of histogram equalization method is that it is a fairly straightforward technique and an invertible operator. So in theory, if the histogram equalization function is known, then the original histogram can be recovered. The calculation is not computationally intensive. A disadvantage of the method is that it is indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal Acharya and Ray (2005) and Russ (2002)

In scientific imaging where spatial correlation is more important than intensity of signal, the small signal to noise ratio usually hampers visual detection. Histogram equalization often produces unrealistic effects in photographs; however it is very useful for scientific images like thermal, satellite or x-ray images, often the same class of images that user would apply false-color to (Acharya and Ray, 2005; Russ, 2002).

Image analysts should be aware that while histogram equalization often provides an image with the most contrast of any enhancement technique, it may hide much needed information. This technique groups pixels that are very dark or very bright into a very few gray scales. If one is trying to bring out information in terrain shadows, or if there are clouds in the image, histogram equalization may not be appropriate.

Duan and Qiu (2004) extended this idea to color images, but the equalized images are not visually pleasing for most cases (Duan and Qiu, 2004). When the equalization process is applied to grayscale images or the luminance component of the color images, regions with overstated contrast usually create visually annoying artifacts. In this case, the visually unsatisfactory results caused by equalization are not acceptable because they give the image an unnatural appearance.

Modulated Histogram Equalization (MHE) image contrast enhancement algorithm: Data fusion is a formal framework in which data originating from different sources combined in one synthetic visual product. It aims at obtaining information of greater quality; the exact definition of 'greater quality' will depend upon the application (Wald, 1999). A particular case of data fusion is image fusion. A general definition of image fusion is given as "Image fusion is the combination of two or more different images to form a new image by using a certain algorithm" (Genderen and Pohl, 1994; Clark and Yuille, 1990; Santamaria and Gomez, 1993). The linear fusion approach is to simply combine two images into a single image by using a linear equation as Eq. (6):

$$If_{used}(x,y) = \alpha I_{method-A}(x,y) + (1-\alpha) I_{method-B}(x,y) \tag{6}$$

where α is a constant ranging from 0 to 1.0. Since α is less than or equal to 1, the contrast of the fused image is at most equal to but not greater than the contrasts of the processed image by method A and the processed image by method B.

In order to improve observation quality, we presented modulated histogram equalization image contrast enhancement based on AIHT algorithm (Yu *et al*., 2009; Yu *et al*., 2010). We apply multiple process concepts to image contrast enhancement and its processed result has a similar modulation effect. Our approaches were developed to integrate the information coming from multiple images to create fused images where the content is more suitable for human perception. The law of multiple proportions is one of the fundamental laws of stoichiometry. The law states as that chemical elements combine, they do so in a ratio of small whole numbers.

We processed original image by AIHT and HE algorithm. Second, Then the enhanced result will be multiply by the α and β of weight parameter, respectively and integrate output of both multiplied result. The enhanced output image Enhance_MHE integrate output of both AIHT and HE result by the α and β of weight parameter, respectively. The Enhance_Multiple approach for processing input image x, is described by Eq. (7):

$$\text{Enhance\_MHE} = \alpha \times \text{AIHT}(x) + \beta \times \text{HE}(x) \tag{7}$$

where α and β is less the weight of AIHT and HE, respectively, x is luminance of input image. The α and β have to satisfied $\alpha + \beta = 1$ and that $0 \le \alpha \le 1$ and $0 \le \alpha \le 1$.

The processed result has similar Frequency Modulation (FM) effect of signal processing conveys information over a carrier wave by varying its instantaneous frequency.

IMPLEMENTATION AND EXPERIMENTAL RESULTS

Various types of histogram distributions images-underexposures, midexposures and overexposures images-were tested under this proposed method. Experiment results demonstrate that the effectiveness and qualities by using this method. These images include some poor contrast types of daily life images which can not be fixed by conventional contrast methods. Those images can be further categorized into outdoor and indoor images. The above images belong to four extreme types of images which are dark image, bright image, back-lighted image and low-contrast image. The conventional contrast enhancement algorithms and the proposed enhancement algorithm have been implemented in Matlab code of MathWorks version R2010a. A 2.83 GHz Intel Core 2 Quad PC with 2 GB RAM of hardware platform was used for this simulation.

The processed result has similar Frequency Modulation (FM) effect of signal processing conveys information over a carrier wave by varying its instantaneous frequency.

Experimental results demonstrate of the MHE method is capable to improve AIHT algorithm alone where they are lacking of the contrast enhancement capability and also make a correction for HE where it may cause the excessive contrast enhancement and produced a serious chromatic aberration problem. In summary, the proposed MHE algorithm outperforms conventional HE and AIHT algorithms for the contrast and details of image.

CONCLUSION

We apply the AIHT and HE advantage to present a modulated histogram equalization based on AIHT contrast enhancement algorithm from conjugate AIHT and HE image contrast enhance algorithm. These proposed algorithms based on Adaptive Inverse Hyperbolic Tangent algorithm as a contrast function to map from the original image into a transformed image. Use of this algorithm can improve displayed quality of contrast in the scenes and offers an efficiency way for fast computation. Experimental results show MHE algorithm have more better contrast enhancement effect and show details than AIHT and HE.

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