Determining Parameters in Contrast Limited Adaptive Histogram Equalization

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Abstract. Contrast Limited Adaptive Histogram Equalization (CLAHE) is an adaptive histogram equalization which was proposed by K. Zuierveld. Block size and clip limit are used to control the quality of results of CLAHE, but have been experimentally determined by users. In this paper, we propose a method to determine two parameters of the CLAHE considering the characteristics of entropy of image. Experimental results show that the proposed method enhances images with very low contrast.

Keywords: Contrast limited adaptive histogram equalization, Entropy.

1 Introduction

Histogram equalization is to get an image with uniformly distributed intensity levels over the whole intensity scale. Histogram equalization might produce the worse quality of result image than that of the original image since the histogram of the result image becomes approximately uniform [1]. Large peaks in the histogram can be caused by uninteresting area. So, histogram equalization might lead to an increased visibility of unwanted image noises. This means that it does not adapt to local contrast requirement; minor contrast differences can be entirely missed when the number of pixels falling in a particular gray range is relatively small

An adaptive method to avoid this drawback is block-based processing of histogram equalization. In this method, image is divided into sub-images or blocks, and histogram equalization is performed to each sub-images or blocks. Then, blocking artifacts among neighboring blocks are minimized by filtering or bilinear interpolation [2,3,4].

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The CLAHE [2] introduced clip limit to overcome the noise problem. The CLAHE limits the amplification by clipping the histogram at a predefined value before computing the CDF. The value at which the histogram is clipped, the so-called clip limit, depends on the normalization of the histogram and thereby on the size of the neighborhood region. The redistribution will push some bins over the clip limit again, resulting in an effective clip limit that is larger than the prescribed limit and the exact value of which depends on the image.

2 Determination method of parameters for the CLAHE

We proposed a new method to determine two parameters of the CLAHE: block size and clip limit based on the entropy of an image. Image entropy becomes relatively low when histogram is distributed on narrow intensity region while image entropy becomes high when histogram is uniformly distributed. Therefore, the entropy of the histogram equalized image becomes higher than that of the original input image.

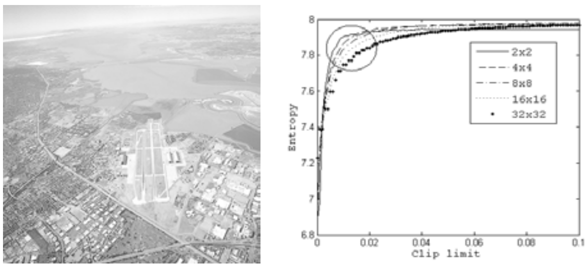
Discrete entropy [5] is defined as

$$H(X) = -\sum_{i=1}^{N} p(x_i)\log_2 p(x_i) \tag{1}$$

Where $p(x_i)$ is the normalized probability of the gray level x_i.

Key idea of the proposed approach comes from the observation of the curve of image entropy vs. subjective quality of the results of the CLAHE with different parameters.

Fig. 1 shows that the entropy curve of CLAHE results with different clip limits and block size.



(a) (b)

Fig. 1. (a) Aerial image (b) Entropy curve with different parameters

From the experiments, it is observed that the image quality rapidly changes on the circled region of the curves shown in Fig. 1, and the parameters determined at the point with maximum curvature produce subjectively good quality of the image. The fitting of entropy curve is needed because the curve is not a monotonic function. We used the fitting method such as fitoutputfun() and fminsearch() in Matlab [6].

The entropy curve is fitted by the equation below:

$$f(x) = c_1 e^{\lambda_1 x} + c_2 e^{\lambda_2 x} . \qquad (2)$$

We determine the clip limit, where the point has maximum curvature on entropy vs. clip limit curve. Let clip limit be x(t) and entropy be y(t). Also x(t) and y(t) can be twice-differentiable. Curvature κ is defined as [7]

$$\kappa = \frac{x'y'' - y''x'}{\sqrt[3]{x'^2 + y'^2}} . \qquad (3)$$

First, we determine the clip limit where the point has maximum curvature on entropy vs. block size (8x8) curve for computational efficiency. Second, the block size is determined with the clip limit determined above. Finally, we apply the CLAHE with these clip limit and block size to the input image.

3 Experimental Results

We present the results of the proposed method to determine the CLAHE's parameters. The proposed method is applied to two different types of images: bright image and dark image. We analyzed average intensity, Root Mean Square (RMS) contrast, and entropy of HE and the CLAHE.

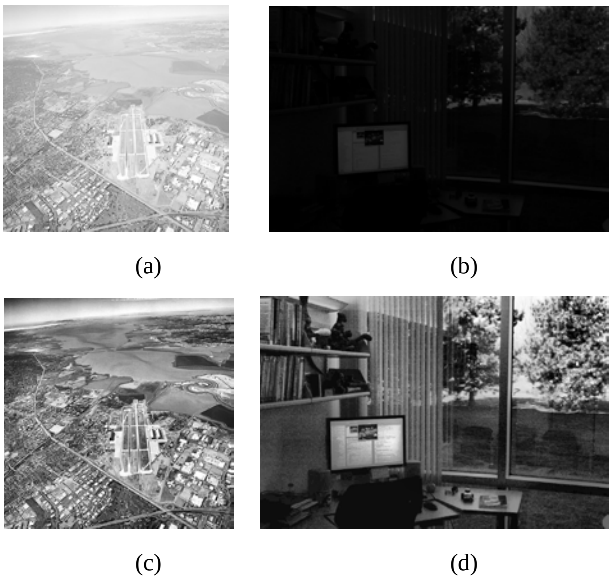


Fig. 2. Input images: (a) Aerial image(764x768) (b) Office image(903x600) Output images: (c) CLAHE(CL=0.014, BS=2x2) (d) CLAHE(CL=0.048, BS=4x4)

Table 1. Experimental results of Aerial image

	Average Intensity	RMS contrast	Entropy
Aerial	197.2	0.42	6.87
HE	127.7	0.50	5.92
The proposed Method	136.2	0.50	7.94

Table 2. Experimental results of Office image

	Average Intensity	RMS contrast	Entropy
Office	10.6	0.20	4.87
HE	128.4	0.50	4.58
The proposed Method	81.6	0.47	7.41

3 Experimental Results

In this paper, we propose a method to determine two parameters of the CLAHE based on the characteristics of entropy curves: clip limit vs. entropy and block size vs. entropy. We analyze experimental results using the criteria, such as average of intensity, RMS contrast, and entropy. Experimental results show that the proposed method enhances images with very low contrast

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