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Entropy-Based Adaptive Gamma Correction for Content Preserving Contrast Enhancement

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***Abstract*—Image Contrast enhancement is improves input information to many computer vision applications. Thus, it improves feature detection process and improves efficiency of the system. In this paper, we propose a new contrast enhancement algorithm for gray and color images. The algorithm is based on adaptive gamma correction. The adaptive gamma is computed for an entropy based probabilistic distribution, which in turn is computed from histogram of low contrast image. Normalized entropy is computed at each intensity level, and used for computation of adaptive gamma values. The algorithm improves image contrast, while preserving its maximum natural contents of the image. Visual and quantitative result analysis shows the supremacy of the proposed algorithm over many of the exiting algorithms.**

Keywords—Contrast enhancement; histogram equalization; gamma correction.

I. Introduction

Contrast enhancement plays an important role in the design of many computer vision based application such as surveillance, medical diagnosis, robotics, etc. Contrast enhancement improves perception and visual quality of the image by revealing hidden details and improving visual contents of fine features. Thus, Contrast enhancement of the image makes it suitable for a specific application or an observer. The selection and modification of attributes is dependent on the application. There are several techniques proposed for image enhancement, each making certain specific changes in specific parameters of an image. Edge detection and segmentation are the methods to detect edges, corners and objects in an image. Gamma correction changes the brightness of an image based on a fixed parameter gamma. Contrast enhancement improves the visibility of an image by enhancing the difference in brightness of objects and their backgrounds. It is achieved by stretching contrast i.e. intensities are distributed over the entire range of intensities. Thus, it widens the brightness differences and utilizes almost entire dynamic range of the image gray levels.

One of the conventional techniques to achieve contrast enhancement is histogram equalization (HE) [1]. In HE, input intensities are transformed based on a cumulative distribution based on the histogram. HE works well for many images and it has very low complexity. Thus, HE is one of the most used algorithms, and researcher have always shown interest in its modifications. However, HE has some serious drawbacks, like saturation effect, ringing effects, etc. Moreover, HE tends to shift mean intensity of the input images. The shift in mean intensities may not be suitable for many applications, where preservation of mean brightness is desired. Another, popular contrast enhancement algorithm is Gamma correction [1]. In Gamma correction, intensity of pixels is modified using power law with a value of Gamma. However, deciding appropriate gamma is a challenging problems, especially when image has low contrast and high contrast both type of regions. In this work, we have addressed issue of selecting appropriate value of gamma by proposing a method to compute gamma adaptively according to local characteristics of the image.

The rest of the paper is organized as follows: section II presents brief discussion on previous works, section III presents proposed approach, section IV presents experiment results and analysis. Conclusion of the work is presented in section IV.

II. Previous Works

In this section, a brief discussion about existing approaches for contrast enhancement is presented. There have been various attempts to overcome drawbacks of HE. Kim [2] proposed an enhancement algorithm refer as Brightness Preserving Bi-Histogram Equalization (BBHE). The authors in BBHE showed that mean intensity of enhanced image is always mean of maximum and minimum intensities. Thus, the mean intensity is not preserved, which may be required in some applications. BBHE algorithm divides histogram at mean intensity, and equalized resulting sub-histograms independently. In another approach, Wang *et al.* [3] histogram division is performed at median and rest of the procedure remains similar to one in BBHE. In other approach by Chen & Ramli [4] namely Recursive Mean-Separate Histogram Equalization (RMSHE), authors extended the idea of histogram division in recursive manner to created several sub-histograms. Yet another similar approach to RMSHE is proposed by Sim *et al*. [5], referred as Recursive Sub-Image Histogram Equalization (RSIHE).

Chen and Ramli [6] tried to minimize change in mean intensity between original and enhanced images. The approach is referred as minimum mean brightness error bi-HE (MBBHE). In MBBHE, the division point is selected in such manner that the absolute mean error is minimized to achieve the division point of histogram. Huang *et al.* [7] proposed a contrast enhancement algorithm using gamma correction technique [1], referred as adaptive gamma correction with weighted distribution (AGCWD). The adaptive gamma is computed by using weighting histogram. Arici *et al.* [8] presented a framework for contrast enhancement algorithms (WAHE). In WAHE, the problem of contrast enhancement is framed as optimization problem framework converts contrast enhancement problem as an optimization problem to obtained the desired weighted histogram.

Gaussian mixture modelling (GMM) of histogram is by Celik and Tardi [9] to achieve sub-divisions of the original histogram of the image. The points of division are taken at the intersection of component Gaussian distributions. Sub-divisions of the histogram are equalized thereafter to achieve contrast enhancement. Abdoli *et al.* [10] presented a greedy approach to model histogram as a mixture of Gaussian and presented contrast enhancement algorithm based on that. These algorithms perform well in some images, but fails in other cases.

In recent developments in the field of the contrast enhancement, Parihar and Verma [11] proposed an autamated approach for histogram divisions using entropy. This algorithm solves, the long pendinding problembs of optimal divions of histogrm. The algorithm results in natural divisiions, thus gives natural looking contrats enhanced images. Niu *et al.* [12] presented a contrast enhancement method based on entropy maximization, while keeping tone preserved. In this algorithm, an objective is framed, in order to maximize information content in the image, with constrained in tone continuity. Liu *et al.* [13] proposed a self-adaptive algorithm for contrast enhancement of satellite images based on histogram compacting transform**.** The algorithm uses dual-gamma transform for contrast enhancement of black and white regions. Parihar *et al.* [14] proposed a fuzzy contextual information based approach to achieve natural improved contrast of the images. The defines new fuzzy properties of image using local features of pixels.

III. PROPPOSED APPROACH

In this section, the proposed algorithm is discussed in detail. The contrast enhancement can be achieved by increasing the intensity difference between adjacent pixels [14]. However, increasing intensity difference is a critical task. An inappropriate increment in the intensity difference may lead to an unnatural-looking image, with artifacts. In other words, the intensity difference between neighboring pixels should not disturb the natural characteristics of the input image. The proposed algorithm uses entropy computed at each intensity to capture local characteristics of the image, and to compute adaptive gamma values. The Adaptive gamma values transforms each intensity according to their local entropy and results in natural looking images. The details of the proposed approach are given in the following sections.

A. Entropy based Probabalistic distribution

The proposed approach is intended to enhance contrast of the image preserving its information content. This approach is an improvement over the previous contrast enhancement techniques as it focuses on retaining maximum information content along with brightness of the image, not completely focusing on stretching contrast. The strategy used to enhance contrast of the image is to first preprocess the histogram by the following procedure. The intensities with high value of probability density function are adjusted to have comparatively low values and vice versa for low-valued intensities. Let the size of input image I be $M \times N$ and let it have L discrete grey levels. The intensity histogram of I is represented as H. The normalized histogram is given as:

$$p(\mathrm{r}_k) = n^k / MN \tag{1}$$

Where n_k is the number of pixels with intensity r_k, $k \in \{0,1,...,L-1\}$. The entropy of $\mathbf{H}$ is given as:

$$E_I(\mathbf{H}) = -\sum_{k=0}^{L-1} p(\mathrm{r}_k) \log p(\mathrm{r}_k) \tag{2}$$

Now, let us define an incremental entropy for each intensity level. Entropy at each intensity level is given as:

$$E(\mathrm{r}_k) = -\sum_{i=0}^{k} p(\mathrm{r}_i) \log p(\mathrm{r}_i) \tag{3}$$

Entropy at an intensity is normalized to obtain probabilistic distribution. The maximum value of entropy at an intensity is entropy of histogram i.e.

$$\max_k \{E(\mathrm{r}_k)\} = E_I(\mathbf{H}) \tag{4}$$

Thus, normalized entropy at an intensity is given as:

$$p_E(\mathrm{r}_k) = E(\mathrm{r}_k) / E_I(\mathbf{H}) \tag{5}$$

The probabilistic distribution of entropy at intensity values is given as:

$$\mathbf{p}_E = \{ p_E(\mathrm{r}_k) | 0 \le k \le L-1 \} \tag{6}$$

B. Entropy based Adaptive Gamma Correction

In this section, we proposed a content adaptive parameter “gamma” computed by using entropy based probabilistic distribution. The adaptive gamma is used to enhance the contrast of the image. The adaptive gamma is computed as given below:

$$\gamma(r_k) = 1 - p_E(r_k) \tag{7}$$

Thus, a set of adaptive gamma values for each intensity is defined as:

$$\mathbf{\Gamma} = \{ \gamma(r_k) | 0 \le r_k \le L-1 \} \tag{8}$$

Let $\mathbf{J}$ is the contrast-enhancement image obtained by the proposed algorithm, and s_l is the general intensity level in $\mathbf{J}$, where $l \in \{0,1,...,L-1\}$. The contrast-enhanced image $\mathbf{J}$ is obtained as

$$s_l = r_{L-1} \left(r_k / r_{L-1} \right)^{\gamma(r_k)} \tag{9}$$

where r_{L-1} is maximum intensity level e.g. 255 for the 8-bit gray image. The algorithm is extended to color images using HSV model [15]. The contrast enhancement of color images can be effectively achieved by using only luminance component. Thus, only V component is used for color images.

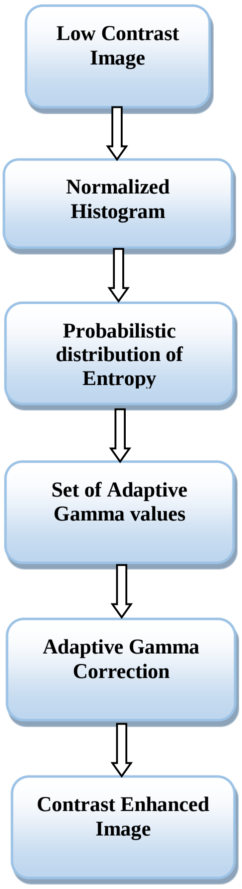


Fig. 1. Block digram representation of the proposed approach.

IV. Experimental Result and Analysis

Exhaustive experimentation analyzes the performance of the proposed algorithm. The standard image data bases: Berkeley image database [16], USC-SPI image database [17], and Kodak lossless true color image suite [18], are used as a source of images. The experiments are performed on large set of images to include nearly all kind of images. The proposed algorithm is compared with well-established as well as state-of-art contrast enhancement algorithms: HE [1], BBHE [2], MBBHE [6], and AGCWD [15]. These algorithms are implemented with default parameter suggested in respective papers, for comparison purpose. The qualitative measure and visual assessment, both are used to compare the performance of various the contrast enhancement algorithms.

A. Quantitative assessment

The quantitative assessment of contrast of an image is not an easy task. There have been several attempts to quantify the visual quality of an image. However, none of the algorithms gives universally accepted results. In many cases, a poor quality image may get a better score (quantitative measure) than visually good quality image. However, a qualitative measure is always desirable in scientific experimentations. Thus, the quantitative assessment is performed by using normalized discrete entropy.

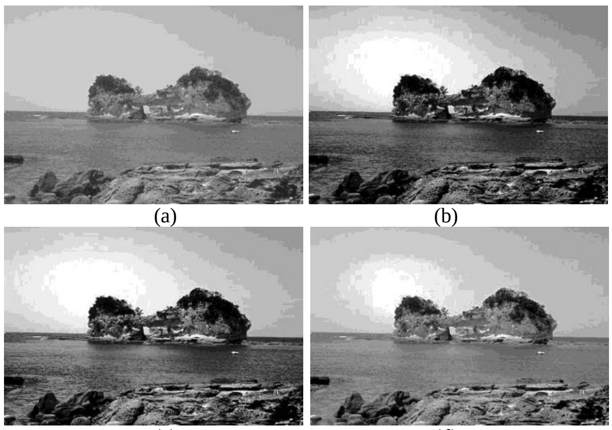
TABLE I. Normalised discrete entropy values

Image	HE	BBHE	MBBHE	AGCWD	Proposed
Island	0.4557	0.4604	0.4012	0.4828	0.4711
Plane	0.4771	0.4827	0.4639	0.4905	0.4911
Caps	0.4442	0.4436	0.4831	0.4765	0.4881
Tower	0.4490	0.4489	0.4491	0.4538	0.4918
House	0.4471	0.4518	0.4429	0.4322	0.4535

The normalized discrete entropy gives measure of information contained in image. Entropy might be good measure of contrast as in contrast enhancement, we try to obtain hidden information. Table I contains normalized discrete entropy values for different images obtained by various algorithms. Component . The values of normalized discrete entropy lie in [0, 1] and a higher value reflects the better contrast. The quantitative results are shown for five sample images out of a large set of images from the standard image databases. Table I shows that the proposed algorithm gives better normalized discrete entropy except few cases.

B. Visual assessment

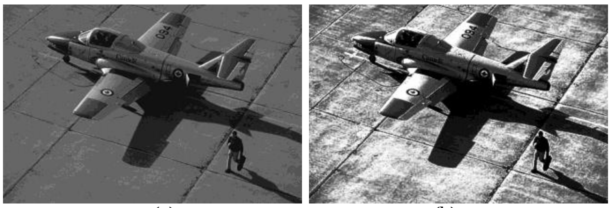
The quantitative measures are not sufficient to measure the performance of the contrast enhancement algorithms. These measures often give better scores for over-enhanced or noisy images. Thus, a visual analysis of gray and color images is presented in this section. The results for various algorithms are shown in Fig. 1-2. It can be easily observed that the proposed algorithm outperforms nearly all other algorithms. One may easily notice the artifacts introduce by other algorithms especially in background regions of the image.

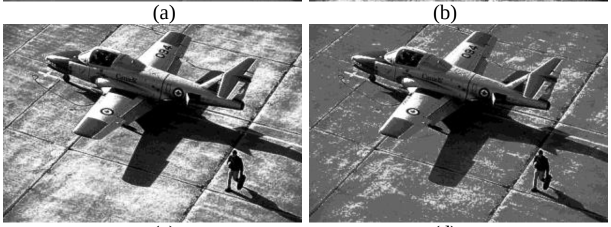


(a) (b)
(c) (d)


(e) (f)

Fig. 2. "Island" image (a) Original image; contrast enhanced image by: (b) HE, (c) BBHE, (d) MBBHE, (e) AGCWD, (f) proposed.


(a) (b)


(c) (d)

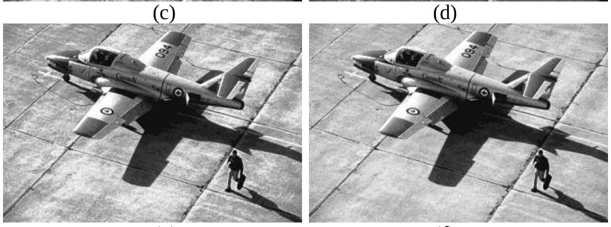
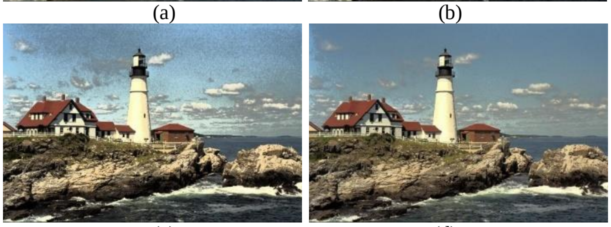

(e) (f)

Fig. 3. "Plane" image (a) Original image; contrast enhanced image by: (b) HE, (c) BBHE, (d) MBBHE, (e) AGCWD, (f) proposed.


(a) (b)


(c) (d)


(e) (f)

Fig. 4. "Tower" image (a) Original image; contrast enhanced image by: (b) HE, (c) BBHE, (d) MBBHE, (e) AGCWD, (f) proposed.

The algorithms HE, BBHE, and MBBHE, all shows artefacts. The artifacts can be noticed in the sky region especially. In gray images rigging effects may be easily noticed. In Fig. 4, color of sky and cloud has changed. AGCWD gives much-improved result, but few artefacts are present, especially near clouds. The proposed algorithm again produced a natural looking good contrast image.

The quantitative and visual analysis shows that the proposed algorithm outperforms many of the contrast enhancement algorithm. The results of the AGCWD are comparable to the proposed algorithm in some cases, but it produced visually inferior results for few images as well.

V. Conclusions

In this paper, a new algorithm is proposed for image enhancement. The algorithm computes an entropy based adaptive Gamma values, applies Gamma correction to achieve desired contrast enhancement in the images. The main advantage of this approach lies in the preprocessing of histogram as it allows to restore the image content and also, the adaptive gamma correction method uses probability distribution to calculate gamma values. Experimental results show that this algorithm enhances images without any noticeable unwanted artifacts and thereby restoring natural brightness and entropy of the image. The results of the proposed algorithm are analyzed visually and quantitatively. The comparison of performance with other traditional and state-of-art algorithms shows that its shows significant improvement over existing algorithms and gives comparable results.

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