TEST Engineering & Management

May-June 2020
ISSN: 0193-4120 Page No. 10787 - 10794

Color Image Enhancement with Brightness Preservation Using A Histogram Specification Approach

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Article Info
Volume 83
Page Number: 10787 - 10794
Publication Issue:
May-June 2020

Article History
Article Received: *19 November 2019*
Revised: *27 January 2020*
Accepted: *24 February 2020*
Publication: *19 May 2020*

Abstract:
Improving image quality is a fundamental requirement before pictorial information can be used in several real-time and manufacturing applications. For precise duplicate of the scene data, degradations ensuing in the contrast of loss should be corrected when effective histogram equalization is often used. In addition, it is also necessary to maintain the brightness of corrected image to truly represent the landscape properties. In this task, a strategy is suggested to specify an appropriate histogram profile so that the values of the image intensity are adjusted in accordance with, and the output brightness is kept close to the input image. Precisely, the equalization shape is shaped by discovery of a harmonising control threshold by mixing rectangular and triangle sections. These trials are performed using a large number of images in natural colors and compared to other available image improvement methods based on histogram. The results show that the suggested strategy will be able to achieve a wide range of performance goals, including content information, with color quality.

Keywords: *Image enhancement, Histogram, Brightness preservation.*

INTRODUCTION

Digital images are common means to carry the information from or of a scene to the user in terms of visual perceptions. Image processing techniques are therefore indispensable assets to restore degradations of the information conveyed to a viewer or a computer for further analysis. There is a wide range of scientific and engineering applications that require visual information. Examples include medical diagnosis of tomography scout images and uses in remote sensing of the earth for resource exploration [1,2]. Engineering applications of images are even more diversified. For example, imaging technology is used in ferrography to monitor machine health conditions during operation [3]. Furthermore, image processing techniques can be employed in infrared imageries [4]. In addition, vision is used in the identification and tracking of objects [5,6]. The problem of image enhancement had been tackled with focus on the preservation or enhancement of object edges in the image [7]. A color saturation boost operation is first carried out and then rectified for edge preservation. Another method was proposed which employs a morphological filter to enhance edges for an increased sharpness on the resultant image [8]. The contrast enhancement problem was also approached adopting a block-based enhancement strategy [

9,10]. These localized enhancement approaches could be more complicated in their implementations when comparing to the class of global histogram equalization methods. Image enhancement algorithms based on histogram equalization are often categorized as a statistical and global approach [11]. In essence,

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equalization attempts to re-map the intensity or other image color channels to a specified probability density. In most cases, in order to obtain the highest information content from the output image, the target density has to be uniform. It had been observed that a direct application of this scheme might introduce some undesirable artifacts; hence, alternative implementation procedures are being proposed and advanced [12].] In the context of histogram equalization implementation, there are various approaches that can be taken. For instance, empirically determined transformations can be applied [13,14]. On the other hand, it is generally a challenge to obtain the required optimal parameter settings. To this end, a non-parametric method was developed [15]. In that method, the coefficient of a modification power law was determined using the mean image intensity. The output image, while corrected to the mean intensity of the given image, may not provide an appealing perception to a human viewer. Another method was developed to enhance an input image and to maintain the same output average brightness [16]. Since that algorithm had targeted at a flattest mapping density, the complete brightness level was not fully used to convey scene information. Histogram equalization toward a uniform density, on the other hand, is able to make use of all available brightness level to represent the information captured in the image and the measured entropy would be maximized. However, it is also recognized that the uniform target density would change the average brightness to the middle of the permitted levels and when not agreeing with the mean intensity value of original image, undesirable artifacts would appear. Researchers then began to seek for techniques that preserve the original mean brightness [17]. In that original work, pixels were separated to a lower and a higher group according to their mean brightness values. The two sub-images were then equalized to a uniform density. It was also pointed out that the mean value was preserved to a certain degree. However, a perfect maintenance of mean value is not feasible even for input images of symmetrical intensity density. Variations or improvement were attempted to minimize the discrepancy between the input and enhanced image mean brightness. The input image was first separated using the mean brightness and then peaks in the input image histogram were clipped using the median of each sub-image [18]. Although the mean brightness error could be reduced, there was no solid rationale for the choice of the median value as the clipping limit. A range limitation approach was later developed [19]. Instead of equalizing the image to cover the entire allowed brightness, narrower bounds on the brightness were derived such that the resultant brightness was driven closer to that of the original image. An alternative method had adopted the weighted sum approach to tackle the mean brightness preservation problem [12]. Lower and higher intensity pixel groups were formed on the basis of the mean brightness value. Unlike the other methods, equalized groups were aggregated with the complementary groups and then weighted to produce an enhanced image. However, due to the fact that weighting factors are not always feasible, the requirement for perfect minimization of mean brightness error was relaxed to cope with feasible weights. A variation on the histogram clipping principle was further suggested [20]. The clipping limit was set as the minimum value of the histogram, median and mean. In the work therein, a potential problem exists when the median value is very low and gives a low clipping magnitude, features of pixels with the corresponding sub-group may be destroyed. Based on the available methods, a comparative

evaluation of commonly used color spaces for color images was conducted [21]. The work reported there suggested utilizing the green color space during histogram equalization where this channel is a close approximation to the image brightness. In addition to separating the image into high and low brightness sub-images as aforementioned, contrast enhancement could also be accomplished by modifying and specifying a

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target density profile in histogram equalization. For instance, the input histogram was smoothed using an intensity-based window width [22]. The strategy reported therein can be further extended to return an output image brightness which is adjusted to that of the input image. In this work, a new method is proposed to reduce the difficulties encountered in choosing a proper sub-image division threshold. First, the mean brightness of the input image is calculated. Then depending on its magnitude as compared to half of the maximum intensity, a target histogram that balances the histogram areas over the desired mean is specified. The input image is then equalized, guaranteeing a mean brightness close to the input image. Histogram equalization for brightness preservation While attempts had been made to restore image contrasts from Degraded sources, researchers had paid attention to drawbacks found on the histogram equalization method where the resultant mean brightness is deviated from the input image. This effect gives rise to loss of a true representation of the scene and often causes artifacts as observed by human viewers. A class of techniques to maintain the brightness was then developed. Their salient features are reviewed below.

METHODOLOGY

Conventional Histogram Equalization

Let an input image be given as I = {I (u, *v*)} ∈ [0, L - 1], where (u, *v*) is the pixel coordinate and I (u, *v*) ∈ Z is the pixel intensity or brightness ranging from 0 to L - 1. For an 8-bit digital image, L= 28= 256. The image resolution is U × V width-by-height and u = 1,· · · , U, *v* = 1, · · ·, V. A histogram is formed and then normalized to Give the probability density, from

$$I_{\min} = I_m - \Delta I$$

$$I_{\max} = I_m + \Delta I,$$

$$\Delta I = \min\{I_m, 2 \times I_m - (L-1)\}.$$

gathering the number of pixels n(i) that have intensity value i, that is [11]

$$h(i) = \frac{n(i)}{UV}.$$

A cumulative distribution function is formed from

$$c(i) = \sum_{j=0}^{i} h(j),$$

Where $\sum_i c(i) = 1$. The enhanced image contains pixels whose values are modified according to

$$I_{enh}(i) = (L-1) \times c(i),$$

assuming that the desired minimum and maximum intensities are 0 and L - 1. The probability density would obey a uniform distribution and the mean intensity becomes (L - 1)/2. This differs from the original image and is generally considered undesirable.

Truncated Histogram Equalization

If the enhancement objectives are to increase the image contrast and to maintain the resultant mean brightness, then it is possible to truncate the range of intensities used in the equalization process [23]. Let the mean brightness I_m be

$$I_m = \frac{1}{UV} \sum_{u,v} I(u,v), \quad I_m \in \mathbb{Z},$$

then a range $I_{min} \sim I_{max}$ is determined from

Furthermore, the whole image is equalized within the range I_{min}~I_{max} using the transformation

$$I_{enh}(i) = I_{\min} + (I_{\max} - I_{\min}) \times c(i).$$

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Because it is permitted that $I_{min} > 0$ and $I_{max} < L - 1$ the equalization range is said to be truncated. Furthermore, since all pixel intensities are confined in the symmetric range about I max, brightness maintenance can be achieved. However, due to the limited range, the output image contrast may be below a desired level.

Other than specification approach solely focusing on improving image contrast using histogram equalization while maintaining the output mean brightness that is closer to the input image, a pipelined procedure is developed to full fill these objectives. The motivation is three-fold. Firstly, an increase in image contrast is required. Secondly, the output mean brightness should be made close to the original value. Finally, over-enhancement has to be reduced and without reducing its colourfulness and saturation for color input images. The first two objectives can be accomplished by adopting the histogram specification strategy. The third objective is achieved by incorporating a dynamic range stretching operation in a pre-processing stage. A block diagram of the proposed histogram specification approach is shown in fig. 1

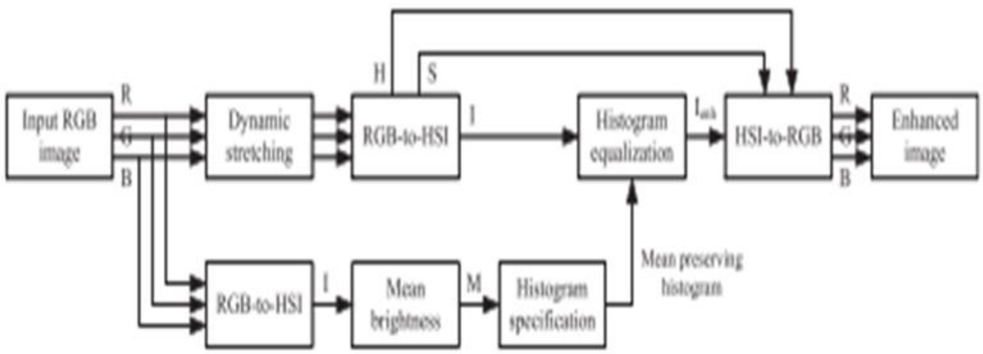

Fig. 1 Proposed block diagram for brightness preserving histogram equalization

approach

Dynamic-range Stretching

Given a color image in the conventional red-green-blue (RGB) format, the color may not be in an ideal condition and degradation may be caused by illumination color casts. While stretching individual color channels, the color content is distributed across the allowable magnitude ranges. Thus, a dynamic range stretching in all color components provides a restoration of color degradations. We have the stretched color channels obtained from

$$C(u, v) \leftarrow \frac{C(u, v) - C_{\min}}{C_{\max} - C_{\min}},$$

Where $C \in \{R, G, B\}$ denotes the color channels. C_{max} and C_{max} are the permitted minimum and maximum values. The result after dynamic range stretching ensures that most of the allowed color magnitudes are covered. However, it is noted that stretching changes the mean brightness from the original image.

The input image is applied to an RGB-to-HSI convertor. The output of the converter also contains three channels which are the hue (H), saturation (S) and intensity (I). They are more suitable to describe the perception perceived by a human viewer. In particular,

Histogram specification for mean brightness preservation

the I-channel is the brightness as regarded by the viewer. From the I-channel, the reference mean brightness is calculated as

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$$M = I_m = \frac{1}{UV}\sum_{u,v} I(u, v).$$

This mean value is then applied to derive the specified profile in the form of a histogram used in the equalization process.

Case A: target mean brightness greater than half-max Intensity

Consider a given input image converted to the HSI format and the I-channel is extracted to obtain the mean brightness. In Fig. 2(a), for example, the mean brightness M is greater than half-max intensity $(L-1)/2$

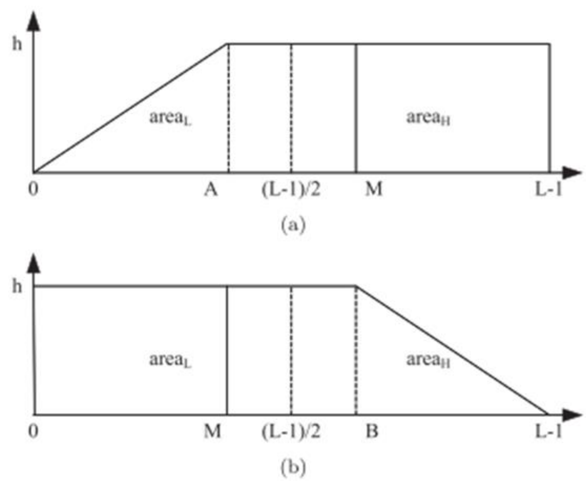

Fig. 2 Histogram profile specified according to mean brightness (a) mean brightness greater than half-max intensity (b) mean brightness less than half-max intensity

In order to increase the mean brightness of the lower intensity group pixels, an inclined profile starting from the control point A and reduces to zero intensity is suggested. By the principle of center moment, the lower and higher areas divided by the mean value should be balanced. The areas are

$$area_L = hM - \frac{hA}{2}$$
$$area_H = h(L-1-M).$$

Then the balance condition requires

$$area_L = area_H \Rightarrow hM - \frac{hA}{2} = h(L-1-M).$$

After some calculation, we have a profile control point A given by

$$A = 2(2M - (L-1)).$$

Consider, when $A = 0$, we have a complete uniform density. This situation corresponds to

$$M = \frac{L-1}{2}|_{A=0}$$

Which is the lower bound of the case considered here. On the other hand, when A = L - 1, then

$$M = \frac{3(L-1)}{4}|_{A=L-1.}$$

This occurs when the profile becomes a triangle. For input mean brightness greater than this value, the constructed profile is not able to drive the mean brightness to its required value. However, for image mean brightness above this limit, the image can be considered as over-exposed

Case B: target mean brightness less than half-max intensity

The situation of this case is depicted in Fig. 2(b). Now the areas of the low and high sub-image on the histogram are

$$area_L = hM$$

$$area_H = h(L-1-M) - \frac{h(L-1-B)}{2}.$$

The balanced condition requires

$$area_L = area_H \Rightarrow hM = h(L-1-M) - \frac{h(L-1-B)}{2}.$$

The control point B becomes

$$B = 4M - (L-1).$$

When B = 0, we have a triangular profile and the resultant mean value is

$$M = \frac{L-1}{4}|_{B=0}.$$

This corresponds to the bound where below which a match of input-output mean brightness cannot be established. However, for images whose mean intensity is so low may be regarded as not intelligible. When $B = L - 1$, then

$$M = \frac{L-1}{2}|_{B=L-1},$$

Which equals to the half maximum intensity range as expected

Final Process

Depending on the characteristics of the input image, one of the above profiles is generated. The other source to the equalization stage is the I-channel converted from the range stretched RGB channels.

Let the profile generated be $h_A(i)$ or $h_B(i)$, which confirms to the specification either case A or B. For case A, $M > (L-1)/2$

$$h_A(i) = \begin{cases} i, & 0 \le i < A \\ A, & A \le i < L \end{cases}.$$

The specified histogram further normalized giving

$$h_A(i) \leftarrow \frac{h_A(i)}{\sum_{i=0}^{L-1} h_A(i)}.$$

For case B, $M < (L-1)/2$ then

$$h_B(i) = \begin{cases} B, & 0 \le i < B \\ L-1-B, & B \le i < L \end{cases}.$$

After normalization, the histogram becomes

$$h_B(i) \leftarrow \frac{h_B(i)}{\sum_{i=0}^{L-1} h_B(i)}.$$

The specified histogram is employed in the equalization process for the I-channel. We have the enhanced image given by

$$I_{enh}(u,v) = (L-1) \times c(i),$$

where

$$c(i) = \begin{cases} \sum_{j=0}^{i} h_A(j), & M > (L-1)/2 \\ \sum_{j=0}^{i} h_B(j), & M < (L-1)/2 \end{cases}$$

After the equalization, the output is combined with the hue (H) and saturation display, (S) signals and re-converted back to the RGB format for storage or transmission [11].

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RESULTS

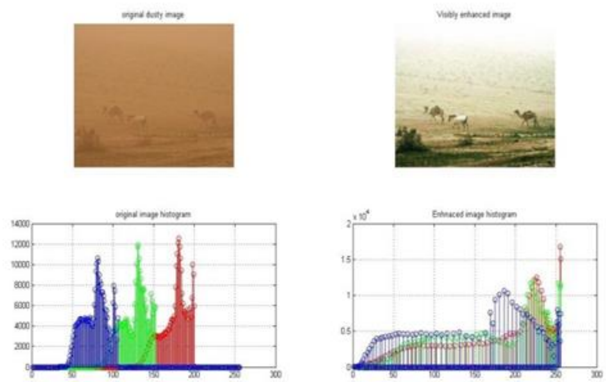

Figure 3 : enhanced image

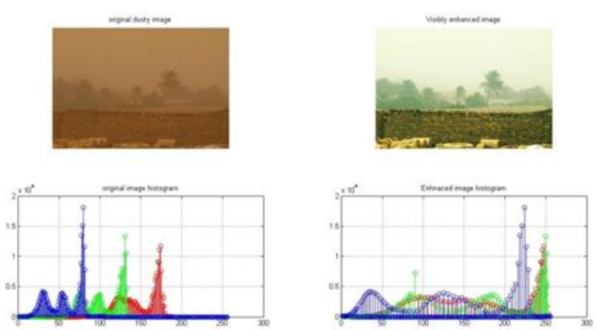

Figure 4 : enhanced image

CONCLUSION

An approach had been presented in this paper that directly specifies a profile for histogram equalization-based image contrast enhancement. The proposed method makes use of a linear adjustment of the target histogram taking into account to minimize the difference between the mean brightness between the input and enhanced image. This method removes the need to separate the image into sub-groups and simplifies the equalization process to a single run. Furthermore, a rationalized choice of threshold was formulated where a balancing condition was met. Thus, fulfilling the requirement for minimum input-output brightness error. The process was integrated into a pipelined framework that catered for mitigating colourfulness and saturation reductions. Experiments on a large data set of natural images reveals that although there is no single technique that can perform best in all performance criteria, results had shown that the technique developed in this work is able to provide color image enhancement that is both qualitatively and quantitatively satisfactory.

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