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Study of Foreground-Background Contrast Enhancement in Color Image

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1. Introduction

Image enhancement, especially image contrast enhancement is one of the most important issues in image processing, pattern recognition and computer vision. Contrast enhancement increases the total contrast of an image by making light colors lighter and dark colors darker at the same time, so that the quality of an image is improved for visual perception of human beings. Lots of effective color image enhancement methods were proposed. Based on histogram equalization, as the well-known contrast enhancement methods, Buzuloiu et al.[1] proposed an adaptive neighbourhood histogram equalization method, and Trahanias et al.[2] proposed a 3D histogram equalization method in RGB cube. Lu [3] proposed a contrast enhancement method based on multi-scale gradient transformation. However, there is no one "quintessential" enhancement algorithm which is capable of improving the acuity of any type of image [4]. In these research works, the relationship between foreground and background is hardly considered. Foreground is commonly defined as the nearest part of a scene in an image. It is regarded as the most important part and receiving a lot of attention. On the other hand, background is defined as the part of a scene that lies behind objects in the foreground. This paper proposes an image enhancement method that focuses on enhancing foreground and the contrast between foreground and background. To foreground, an enhancement model based on human visual system is applied on luminance of the pixels. Then, background luminance is adjusted according to the enhancement result of foreground, so as to enhance the contrast between foreground and background. In addition, we apply a non-linear transform on saturation component so as to make the image more vivid. The experiment result showed that our method successfully enhanced the color images.

2. Algorithm

Among the three components of HSV color space, hue is the attribute of a color which decides which color it is. For the purpose of enhancing a color image, hue should not be changed for any pixel [5]. In Yang's research, they have paid attention to the effect of lumination and saturation to color image enhancement [6]. In our method, we keep hue preserved and apply the improving only to lumination and saturation.

2.1 Image Segmentation

Image segmentation is a process to classify image pixels into foreground area and background area. Figure 1 shows an example of segmentation result:

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Fig. 1 Image Segmentation

2.2 Foreground Processing

According to Weber's law, just the noticeable difference of brightness of the human visual system is proportional to the average of the background [7]. To human visual system, the contrast is not obvious in very bright region and very dark region [8]. Kobayashi et al [9] proposed a logarithmic function based reverse-S-shape transform model based on human visual system. In our method, we use an enhanced Reverse-S-Shape Transform model, adaptive to human visual system. We assign two thresholds m and M ($0<m<M<1$) and divide the range of V into three parts:[0, m], [m, M], (M, 1). If $V < m$ or $V > M$, we do not convert and simply set $V' = V$. Otherwise, we use the transform model described by Eq. (1):

$$R(A) = \log \frac{A - K_1}{K_2 - A} \qquad (1)$$

In Eq. (1), A indicates the input luminance value and R indicates the output result. K1 and K2 are parameters. K1 must be less than the minimum of input A and K2 must be larger than the maxim of input A. As input $I \in [m, M]$, we can simply assure the validity of the equation by setting $K1 < m < M < K2$.

We compute the threshold m and M to assure:

1. Most of the luminance values are between m and M. The values out of the range [m, M] are not converted.

2. The range [m, M] should not be too small. If the range is too small, even if most values are in the range and converted, they do not change clearly because the results are also in [m, M].

The computing algorithm includes the following three steps:

1. Assign two constant m0, M0, which satisfy $0 <= m0 < M0 <= 1$, and $M0 - m0 > 0.6$. For instance, $m0 = 0.1$, $M0 = 0.9$.

2. Compute m1 and M1 which satisfy that there are just 5% of values are less than m1 and 5% larger than M1.

3. Set $m = \min(m0, m1)$, $M = \max(M0, M1)$.

The algorithm assures that at least 90% values are converted and the conversion range is large enough.

The following steps show the contrast enhancement algorithm of the V component:

1. Compute R for each input luminance value A in range [m, M] by Eq. (1).

2. Normalize R by Eq. (2):

$$R' = \frac{R - Rmin}{Rmax - Rmin} \quad (2)$$

The Rmax and Rmin are the maxium and the minium value of all the R got by Eq. (2) in step 1.

3. Convert them to the appropriate range and get the new luminance values A'. In our method, the output range is [m, M], the same as the input range. As the range of R' is [0, 1], it is convenient to get A' by Eq. (3).

$$A' = R' * (M - m) + m \quad (3)$$

2.3 Background Processing

Background area is enhanced by a similar algorithm with foreground area but the luminance range is not changed. If the range is also enhanced to [0, 1], the contrast between background and foreground will not clearly improve.

Set V_{bmin} and V_{bmax} as the minim and maxim luminance value of pixels in foreground area respectively.

1. Normalize the luminance value V to [0, 1] by Eq.(4):

$$V_{norm} = \frac{V - V_{bmin}}{V_{bmax} - V_{bmin}} \quad (4)$$

2. Convert V_{norm} to V'_{norm} by the enhanced Reverse-S-Shape Transform described in section 2.2.

3. Map V'_{norm} to $[V_{bmin}, V_{bmax}]$ by linear transform Eq.(5):

$$V' = V_{bmin} + V'_{norm}(V_{bmax} - V_{bmin}) \quad (5)$$

2.4 Saturation Processing

The purpose of saturation adjustment is to make the color image soft and vivid. The best way to enhance the saturation contrast of a given image is to histogram equalize the saturation distribution of the image. However, the image resulting from applying saturation histogram equalization could be rather unnatural. [10]. In our method, we normalize saturation adjust the it by Eq. (6).

$$S' = S^{a} \quad (6)$$

Here a is a coefficient in range (0, 1). In [16] this transform is also used and proved to be affective.

3. Experiment Results

(a) Original Image (b) Proposed Method

Fig. 2

To test the performance of our method, we apply our method to a low contrast color image and compare the result with global non-linear contrast enhancement method. Figure 2 shows the experimental result. (a) is a low contrast image with a bowl in a dark background. (b) shows a more smooth and natural result with enhanced contrast, which showed that our image enhancement method can successfully enhance the color image.

4. Conclusion and Remaining Issues

This paper has proposed a color image enhancement method that segments the image into foreground area and background area and apply different enhancement method to different areas. It turns out that the proposed image enhancement method constitutes a successful enhancement of color images with low contrast. However, there are still some remaining issues. The algorithm is limited to low contrast image and is not adaptive to some certain images which are not easy to distinct foreground and background. Secondly, the relationship between luminance value and saturation is not considered in our enhancement method. Another topic is that sometimes the color contrast enhancement requires changing color and the hue component should also be adjusted. These issues are our next research topics.

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