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Retinex-Like Method for Image Enhancement in Poor Visibility Conditions

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Abstract

Nowadays, still image and video systems are typically of limited use in poor visibility conditions such as in rain, fog, smoke, and at dawn. These situations severely limit the range and effectiveness of imaging systems because of the severe reduction in contrast. Retinex algorithm has been very popular area of research used to image enhancement. Basic idea of Retinex algorithm is to separate illumination from the reflectance in a given obtained image. In this paper, I have studied and implemented one particular Retinex-like algorithm based on bilateral filter with some supporting technique, this method associates de-noising method with Retinex algorithm and has been used in cases of severe image turbidity in air as well as image blurring with dramatic results.
Keywords: Retinex; image enhancement;bilateral filter

1. Introduction

It is always a problem to match the digital representation of a captured image with the representation in the eye of the human observer [1], there is a common discrepancy between the two, When the scene has a poor visibility condition the discrepancy became larger. Even under the best recording conditions and with the best recording equipment, it is virtually impossible to match the observed scene with the recorded image exactly. This is because both the recording equipment and the imaging devices introduce

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artifacts into the captured images. These artifacts include blurring due to the camera lens and the recording/display system characteristics, the limited dynamic range that the camera can capture, and the signal-to-noise ratio due to the thermal characteristics of the device electronics[2]. Human perception excels at constructing a visual representation with vivid color and details across the wide ranging photometric levels due to lighting variations. Thus, in order to match the recorded image to the observed image, the acquired images need to undergo some processing, such as restoration, de-blurring, enhancement in order to adequately represent the directly-observed scene. Image enhancement is a very important preprocessing stage in image processing, such as Face Recognition and Target Tracking. The aim of image enhancement is to improve the interpretability or perception of information in images for viewers, or to provide better input for other automated image processing techniques. After enhancement, we almost can get all the details of an image especially under extremely dark background.

According to the survey of available techniques[3-4], the commonly used techniques of image enhancement can be divided into two broad categories: spatial domain methods and frequency domain methods. Up to now, various techniques such as intensity transformation [5], histogram modeling [6], homomorphic filtering [7] have been proposed to enhance images degraded by irregular illumination. These methods usually enhance an input image by reducing its dynamic range and/or increasing its contrast. The intensity transformation converts the intensity levels of an input image using a specific transformation function such as linear function, or logarithmic function. The histogram modeling enhances an input image by modifying its histogram as a desired shape. The homomorphic filtering is an image enhancement method based on the image formation model that represents an input image as the product of the illumination and the reflectance. Although these Traditional methods can effectively improve the perception of information for human viewers, they still have some deficiencies, because they only enhance images in one or two aspects of them so that they can't work well. The particular Retinex approach has been introduced by Land and successfully applied to image dynamic range compression and color rendition [8-10]. The Retinex is a general-purpose image enhancement algorithm that is used to produce good visual representations of scenes. It performs a non-linear spatial/spectral transform that synthesizes strong local contrast enhancement and color constancy. Retinex theory addressed the process of separating the illumination from the reflectance in a given image and thereby compensation for non-uniform lighting. Retinex methods refer to people's stably psychological inclination when they sense the surface of the objects under the circumstance of illumination change [11].

As the Retinex method developed, nowadays the most applied algorithm is single-scale Retinex algorithm(SSR) and multi-scale Retinex algorithm(MSR) [12-14]. They are realized in terms of center/surround function. SSR algorithm only has a scale, it can't work well because of compromise between dynamic range compress and color constancy. Also MSR algorithm usually causes the distortion of color when the original image is not following with "gray world assumption".

In order to solve the above problems, this paper based on bilateral filtering algorithm proposes a Retinex-like image enhancement algorithm and comes up with adding color restoration scheme that provides good color rendition to the problem of color distortion. Experimental results demonstrate that this method works well for images captured in poor vision conditions.

The paper is organized as follows: In section 2, we describe the outline of Retinex algorithm, In section 3, we detail the Retinex-like algorithm. In section 4, we give the experimental results and comparisons with the traditional Retinex algorithms. Finally we conclude the paper.

2. Model of Retinex Algorithm

The word "Retinex" is a blend of two words "Retina" and "Cortex", suggesting that both the eyes and the brain are involved in the process. It is believed that human vision system (HVS) is subjective when it comes to color perception. Human vision system ensures that the perceived color of objective remains relatively constant under varying illumination conditions. This feature helps us identify objects. Retinex behaves as the human vision system do.

Retinex is based on the following image formation model:

$$S(x,y) = L(x,y) \times R(x,y) \tag{1}$$

where the bivariate function $S(x,y)$ represents a input image, every point (x,y) in the domain is equivalent a pixel on the image. The image $S(x,y)$ is composed of two images: the illumination $L(x,y)$ and reflectance $R(x,y)$ images, then we can separate $R(x,y)$ from $L(x,y)$ in order to generating Retinex effect, the problem is known to be ill-posed mathematically. There have been many attempts to numerically estimate the illumination image.

According to different methods to estimate the illumination Retinex algorithms can be classified as single-scale Retinex, multi-scale Retinex, multi-scale Retinex with color restoration and so on.

3. Retinex-Like Algorithm

This is the algorithm we study in details in this paper. Unlike the traditional Retinex algorithms, first we transform the input image from RGB color space to HSV color space: Hue H, Saturation S, and Value V, then we extract the illumination from V layer using bilateral filter, also we add gain/offset correction to the filtered input image, Finally we map the colors back to the RGB domain. The resulting illumination can be over-enhanced sometimes, So we adjust the output of the algorithm by applying a new gamma correction which can make the output image comfortable to see.

3.1. Color Space Map

Traditional approach of color image enhancement is to deal with each color channel separately. These methods usually yield a color correction effect, sometimes these methods can cause color artifacts that exaggerate color shifts, or reduce color saturation. In view of these cases, we map the colors into a different color space, such as HSV color space, we apply the Retinex-like algorithm only to the intensity layer, and then map back to the RGB color space. Color shifts in such cases are less-likely. In addition the advantage of our algorithm is that we only have to process a single channel.

3.2. Bilateral filtering

Bilateral filter [15] is firstly proposed by Tomasi and Manduchi in 1998. The bilateral filter is also defined as a weighted average of nearby pixels in a manner very similar to Gaussian convolution. The difference is that the bilateral filter takes into account the difference in pixel value with the neighbors to preserve edges while smoothing. The key idea of the bilateral filter is that for a pixel to influence another pixel, it should not only occupy a nearby location but also have a similar value. The bilateral filter takes a weighted sum of the pixels in a local neighborhood; the weights depend on both the spatial distance and the intensity distance. In this way, edges are preserved well while noise is averaged out. Mathematically, at a pixel location x, the output of a bilateral filter is calculated as follows:

$$\tilde{I}(x) = \frac{1}{C} \sum_{y \in \Phi} \exp\left(-\frac{\|y-x\|^2}{2\sigma_d^2}\right) \exp\left(-\frac{\|I(y)-I(x)\|^2}{2\sigma_\gamma^2}\right) I(y) \tag{2}$$

Where σ_d and σ_r are parameters controlling the fall-off of weights in spatial and intensity domains, respectively, Φ is a spatial neighborhood of pixel $I(x)$, and C is the normalization constant:

$$C = \sum_{y \in \Phi} \exp\left(-\frac{\|y-x\|^2}{2\sigma_d^2} \right) \exp\left(-\frac{\|I(y)-I(x)\|^2}{2\sigma_\gamma^2} \right) \tag{3}$$

The geometric spread σ_d in the domain is chosen based on the desired amount of low-pass filtering. A large σ_d blurs more, that is, it combines values from more distant image locations. Also, if an image is scaled up or down, σ_d must be adjusted accordingly in order to obtain equivalent results. Similarly, the photometric spread σ_r in the image range is set to achieve the desired amount of combination of pixel values. To speaking in general terms, pixels with values much closer to each other than σ_r are mixed together and values much more distant than σ_r are not. If the image is amplified or attenuated, σ_r must be adjusted accordingly in order to leave the results unchanged.

An important characteristic of bilateral filtering is that the weights are multiplied: if either of the weights is close to zero, no smoothing occurs. As an example, a large spatial Gaussian coupled with narrow range Gaussian achieves limited smoothing despite the large spatial extent, the range weight enforces a strict preservation of the contours.

The flow chart of the core of the algorithm is as follows:

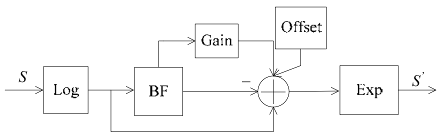


Fig. 1. Flow chart of Retinex-like based on bilateral filtering

S represents the V layer of input image in HSV space, we first implement log operation to S, the result is named logS, then we get the detail layer image DetailImg by subtracting filtered image BaseImg using bilateral filter from logS, Gain is calculated by the formula:

$$\text{Gain=3/Range} \tag{4}$$

Which Range represents the dynamic range of base layer image BaseImg, Offset is calculated by formula:

$$\text{Offset=-Max*Gain} \tag{5}$$

Which Max represents the maximum value of base layer image. In this paper, the bilateral filter parameters used are $\sigma_d = 8$, $\sigma_r = 0.2$.

3.3. New Gamma Correction

Gamma correction is a traditional method of image enhancement. It operates a nonlinear redistribution of the input of the input value. This gives the image a brighter appearance. The result is that darker zones become clearly visible but the risk is to overexpose brighter zones and to lose details because of the excessive compression of the higher values. The smaller is γ the stronger is the effect. Hence, we should use a small γ for small input values, to brighten up the dark zones, and a larger one for larger input values to limit the influence on already luminous. We introduce a new gamma correction function with $i^{\gamma(i)} = i^{a*i+a}$, the chosen of γ is linear in i .

We can change the shape of the curve operating on the only free parameter a , this allows us to decide which part of the histogram has to be enhanced. For values $a \le 0.5$ the curve lies always above the $y = x$ function and the enhancement is accentuated for smaller values as desired, while it is limited for higher values; for $a > 0.5$ the curve intersects $y = x$, and also the higher values can be enhanced. In this paper we choose $a = 0.6$, so the smaller values and the higher values are enhanced simultaneously.

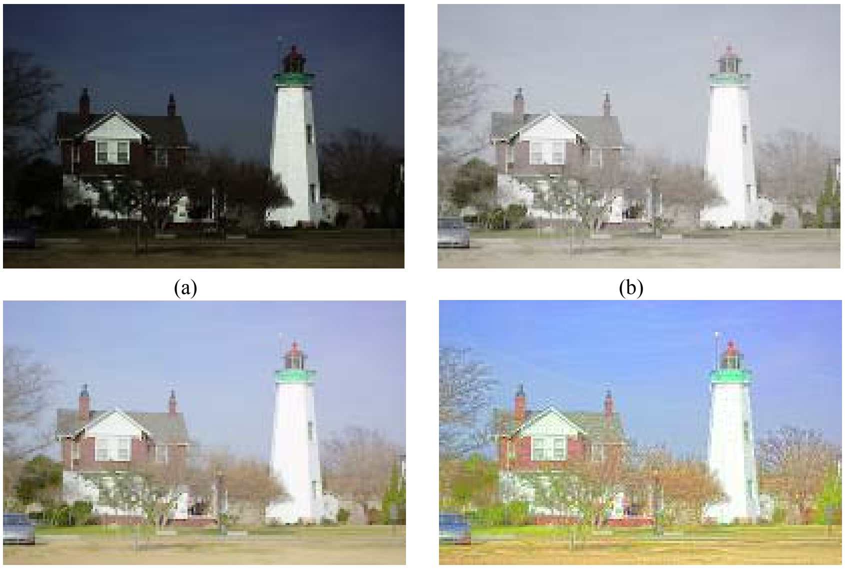
4. Experimental Results and Conclusions

In this section, we have implemented our technique using test image on a 3.0GHz Pentium 4 using Matlab7.1. Image enhancement by Retinex-like algorithm is compared with that by conventional Retinex algorithm. Test results have been illustrated in Fig. 2 and Fig 3.

(a) (b)

(c) (d)

Fig. 2. (a) Original image; (b)Enhanced by MSR algorithm; (c) Enhanced by MSRCR; (d) Enhanced by Retinex-like algorithm.



(a) (b)

(c) (d)

Fig. 3. (a) Original image; (b)Enhanced by MSR algorithm; (c) Enhanced by MSRCR; (d) Enhanced by Retinex-like algorithm.

It can be seen from Figure 4 and 5 that MSR algorithm usually causes color distortion, MSRCR algorithm gives a good color rendering, however, it can't work well for details in the dark areas. The Retinex-like algorithm proposed in this paper is a reasonably good method of image enhancement in poor visibility conditions that simultaneously provides dynamic range compression, color consistency and lightness rendition, also its denoising process may provide good noise removal. To conclude, the Retinex-like image enhancement algorithm is markedly superior to traditional Retinex algorithms. Its dramatic performance with a strong increase in local contrast and overall sharpness, especially in scenes of poor visibility, make it a prime image enhancement method.

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