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Contrast enhancement of brightness-distorted images by improved adaptive gamma correction☆

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A R T I C L E I N F O

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A B S T R A C T

As an efficient image contrast enhancement (CE) tool, adaptive gamma correction (AGC) was previously proposed by relating gamma parameter with cumulative distribution function (CDF) of the pixel gray levels within an image. ACG deals well with most dimmed images, but fails for globally bright images and the dimmed images with local bright regions. However, such two categories of brightness-distorted images are universal in real scenarios, such as those incurred by improper exposure and white objects. In order to attenuate such deficiencies, in this paper we propose an improved AGC technique. The novel strategy of negative images is used to realize CE of the bright images, and the gamma correction modulated by truncated CDF is employed to enhance the dimmed ones. As such, local over-enhancement and structure distortion can be alleviated effectively. Extensive qualitative and quantitative experimental results show that our proposed method yields consistently good CE results.

1. Introduction

Contrast enhancement (CE) refers to the image enhancement on contrast by adjusting the dynamic range of pixel intensity distribution [1]. CE plays an important role in the improvement of visual quality for computer vision, pattern recognition and digital image processing. In real applications, we usually encounter digital images with poor contrast or abnormal brightness, which may result from different factors, such as the inexperience of taking photographs and the inherent deficiency of imaging devices. The capturing scenes with low or high illuminance intensity may also lead to reduced contrast quality. Despite of visual quality degradation, low contrast might hinder the further applications of a digital image, including image analysis and understanding, object recognition and digital printing, etc. As such, it is essential to enhance the contrast of such distorted images before further applications.

Existing CE techniques can be categorized into pixel-domain [2–12] and transform-domain ones [13–17] according to the data domain they are applied to [6]. The former relies on pixel intensity operation, while the latter implements CE in the transformation domain of an image, such as discrete cosine transform (DCT) [13–15], Wavelet [16] and Curvelet [17].

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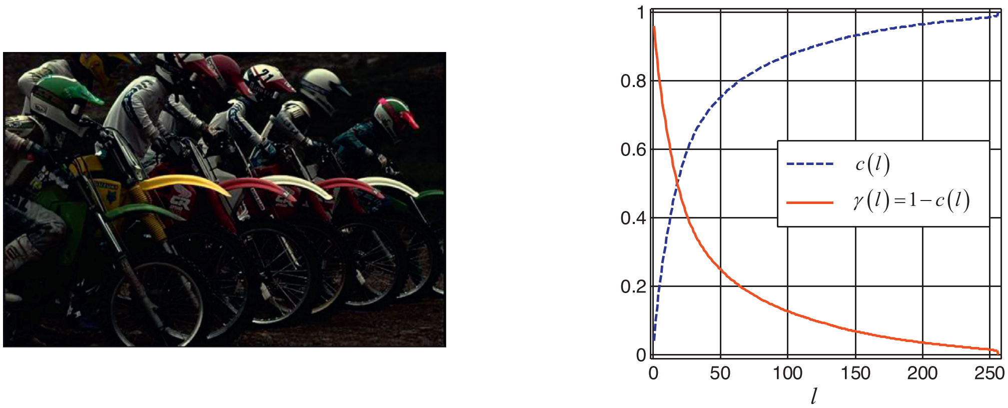

(a) (b)

Fig. 1. CDF-based adaptive gamma parameter. (a)(b) Example dimmed image and its adaptive gamma curve. Here, the intensity channel is referred.

Generally, the pixel-domain CE techniques might be used more widely in real applications due to low requirements on computational cost and parameter setting.

There exist a large category of pixel-domain CE techniques based on the redistribution of gray levels, such as histogram equalization (HE) and its related methods [1–3]. HE implements pixel intensity mapping by directly equalizing the cumulative distribution function (CDF) of the input image's gray level histogram, which becomes as uniform as possible after CE. Despite the merit of high computational efficiency, HE owns the limitation to incur over-enhancement if high peaks exist in the input histogram [4]. In order to attenuate such deficiency, the improved local HE [2] and brightness preserving bi-HE [3] are developed. As another influential work, Arici et al. propose a general histogram modification (HM) framework for CE, which is considered as an optimization problem [4]. It minimizes a cost function which includes the penalty of histogram deviation from primary to uniform histograms, histogram smoothness and black & white stretching. Although HM successfully avoids the unnatural look caused by excessive enhancement, its enhancement results are rather sensitive to parameter setting. Gaussian mixture model is also proposed to model the image intensity distribution which is partitioned into several intervals [5]. Pixel gray levels in each interval are mapped to the appropriate output interval according to dominant Gaussian component and interval-wise CDF. Although good visual effects are gained, such a method has a high computational cost.

Recently, the spatial entropy-based contrast enhancement (SECE) is proposed to incorporate the spatial distribution of pixel intensities into the design of mapping function [6]. After dividing an input image into non-overlapped blocks, the distribution of spatial entropy is first calculated from blockwise 2D spatial histograms, and then equalized for implementing CE. SECE can consistently yield visually improved and pleasing outputs without attractive distortions, regardless of the available contrast on input images. However, as pointed out in the later improvement works [7,8], SECE is found to enjoy the insufficient enhancement strength limit. In [9], noisy low-light images are enhanced by recurring to structure-texture-noise decomposition model of images. Besides, human visual perception [18,19] and advanced machine learning techniques, such as deep learning [20], are also used to design efficient CE algorithms.

Gamma correction is also a popular pixel-domain CE method, which is cost-effective and good at dealing with bright and dimmed images [1,11,12,21]. However, the manual selection of appropriate gamma values is often time-consuming. As for adaptive gamma correction (AGC), the gamma parameter is modulated by the statistics extracted from images, and therefore set automatically. Huang et al. proposed the AGC with weighting distribution (AGCWD) by setting gamma as a function of CDF [11]. AGCWD behaves well in enhancing dimmed images which own low average brightness and seem black, as shown in Fig. 1(a).

In this paper, we focus on the CE of brightness-distorted images which own a relatively high or low global intensity. The existing AGC techniques are revisited and improved formally. We find that such methods are incapable to be directly used to enhance globally bright images, and the image structure in local bright regions may be lost in enhancing dimmed images. In order to attenuate such deficiencies, we propose an improved AGC method by integrating the strategies of negative images and CDF truncation. Substantial test results verify the effectiveness and efficacy of our proposed method in enhancing both dimmed and bright types of contrast-distorted images.

The rest of this paper is organized as follows. AGC is revisited and analyzed detailedly in Section 2, followed by the improved AGC scheme proposed in Section 3. Section 4 shows experimental results. The conclusion is drawn in Section 5.

2. Prior works on adaptive gamma correction

In [11], a typical AGC method is proposed by relating gamma parameter with CDF. The transformed pixel intensity T(l) is computed as