Adaptive Colorimetric Characterization of Digital Camera with White Balance

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Abstract. A camera is an effective tool in capturing images for colorimetric use. However, the *RGB* signals generated by different cameras are not equal for the same scene. Therefore, cameras are characterized based on a CIE standard colorimetric observer. This paper proposes a new method for obtaining camera transfer matrices under different white balances using a 3×3 camera transfer matrix under a specific white balance point. As such, the proposed methods enables a camera transfer matrix under any other white balance to be obtained using the colorimetric coordinates for the phosphor primaries derived from a 3×3 linear transfer matrix under a certain white balance point. Experimental results confirmed that the proposed method produced a 3×3 linear transfer matrix under any other white balance with a reasonable degree of accuracy compared with the transfer matrix obtained by the conventional method.

1 Introduction

A color camera is a powerful acquisition tool in image processing and color communication. However, the *RGB* signals generated by a camera are generally device-dependent, i.e., different cameras produce different *RGB* responses to the tristmulus *XYZ* for the same scene. Furthermore, such *RGB* signals are not colorimetric, as they do not directly correspond to device-independent tristimulus values based on CIE color-matching functions (CMFs). The reason for this is that the spectral sensitivity of the color sensors used in cameras does not correspond to device-independent tristimulus values based on CIE CMFs [1]. Plus, the spectral sensitivity of the sensors used in different cameras varies significantly from one another. Therefore, a transform that defines a mapping between camera *RGB* signals and a device-independent color space, such as *XYZ* or CIE*LAB*, is essential for high-fidelity color reproduction.

The transform derivation process is known as camera characterization [2]. Colorimetric characterization methods can be divided into two general categories: spectral sensitivity based and color target based. With spectral sensitivity-based characterization [3], the camera spectral sensitivity needs to be measured using specialized apparatus, such as a monochromator and radiance meter. Meanwhile, color target-based characterization [4]-[8] only requires

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a known target, making it more practical. Plus, polynomial regression is usually adopted for model derivation. Yet, a camera has a different colorimetric characterization according to the white balance established by the photographing conditions. Therefore, tedious experiments are required to obtain a camera transfer matrix under various white balance points for the same camera [2].

Accordingly, the current paper proposes a new method for obtaining camera characterization under different white balances using a camera transfer matrix under a specific white balance point. Experimental results confirm that the proposed method can produce a 3×3 linear transfer matrix under any other white balance with a reasonable degree of accuracy when compared with the transfer matrix obtained by the conventional method.

2 Conventional Colorimetric Characterization of Digital Camera

Colorimetric characterization methods can be divided into two general categories: (a) spectral sensitivity based and (b) color target based. With spectral sensitivity-based characterization, the camera spectral sensitivity needs to be measured using specialized apparatus, such as a monochromator and radiance meter. A relationship needs to be found between the camera spectral sensitivity and CIE CMFs. This relationship can then be used to transform the camera RGB values into XYZ values. As such, the basic concept of color target-based characterization is to use a reference target that contains a certain number of color samples. These color samples are then imaged by a camera and measured by a spectrophotometer to obtain the RGB values and their corresponding XYZ values. Methods such as three-dimensional lookup tables with interpolation and extrapolation [4]-[6], least squares polynomial modeling [7], and neural networks [8] are typically used to derive the transformation between the camera RGB values and the XYZ values. However, color target-based characterization is more widely used, as it only requires a known target, which makes it more practical. Plus, polynomial regression is adopted for model derivation.

Device characterization by polynomial regression with least squares fitting has already been adequately explained by many other researchers [2], [9], [10]. In particular, Hong et al. [2] studied camera characterization using variable polynomial regression with least squares fitting and found that camera characterization accuracy is reliable when the number of training samples is over 60.

However, as previously mentioned, a camera will have a different colorimetric camera characterization according to the white balance established by the photographing conditions. Therefore, tedious experiments are needed to obtain a camera transfer matrix using over 60 training samples under various white balance points for the same camera. Also, the training samples must be uniformly spread within the camera's color gamut. Therefore, a simple and soft method is required for the characterization of a commercial camera. As such, this paper proposes a new method for obtaining camera characterization matrices under different white balances using a camera characterization matrix under a specific white balance point.