Camera Response Function Estimation and Application with a Single Image

Li Fu and Yue Qi

State Key Laboratory of Virtual Reality Technology and Systems, Beihang University, Beijing 100191, China
{fuli,qy}@vrlab.buaa.edu.cn

Abstract. Camera response function (CRF) relates scene irradiance to image intensities. Estimation of CRF is a fundamental and necessary step in many computer vision applications such as the generation of high dynamic image, bidirectional reflectance distribution function (BRDF) estimation etc. In the paper, we compute CRF from a color image and edit images based on CRF to enhance contrast and change exposure of images. This method selects suitable edge windows with two uniform color regions, and is based on the empirical prior on camera response functions. The method uses only one color image rather than a set of images. The experiments show our estimation result is accurate.

Keywords: Camera response function, contrast, exposure.

1 Introduction

Most cameras are designed to have a non-linear mapping from the scene radiance to the image intensity. There might be several reasons, for example[1], the analog-digital converter might not work linearly, a gamma correction is applied, a correction is applied to make the image more visually appealing, and a white balance is applied to compensate for different light temperatures. The Camera Response Function (CRF) is used to describe the non-linear mapping.

Estimating the CRF is an essential work in computer graphics and computer vision. Many computer vision algorithms assume that image intensities are linearly related to scene irradiance. Some algorithms require precise measurements of scene irradiance to recover the scene properties, such as, construction of high dynamic range images [2, 3, 4], color constancy [5, 6], and recovery of BRDF from images [7]. The CRF is closely related to the image effects, for example, the contrast and exposure. The CRF can be edited to improve the image effects.

Our work is to estimate the camera response function from a single image captured from any camera under any light condition. Meanwhile, we improve the image effects based on the CRF. Most of previous methods require as input a set of registered images taken with varying camera exposures. Accurate calibration results can be obtained using these techniques; however, they require too limiting requirements.
The remainder of the paper is organized as follows: in Sec.2, we review previous work on radiometric calibration. In Sec.3, we introduce our method to compute the camera response function. In Sec.4, we edit the image effects using CRF. Then we evaluate our method with experiments in Sec.5 and conclude with discussions about our algorithm and future work in Sec.6.

2 Related Work

Several different approaches for radiometric camera calibration are proposed before. Using the popular GretagMacbeth ColorChecker as the specific calibration object, CRF is estimated in [8]. Some methods use images acquired by a static camera with varying exposure times to compute the camera response function [9, 10].

In recent years, the methods of covering the camera response function using one image were proposed. These methods exploit image characteristics that reflect the non-linearity introduced by the camera response function. Lin et al. [19] perform the response function based on measured RGB distribution at color edges. Lin and Zhang [11] deal with a single grayscale image by using the histograms of edge regions. Matsushita and Lin [12] use the asymmetric profiles of noise distributions to compute the response function. Ng and Chang [13] use the geometry invariance theory to do this.

Several approaches estimate non-linear camera response functions from images acquired in uncontrolled conditions; further, the images are captured with different cameras. Diaz and Sturm [14] use an unstructured set of images to recover the camera’s geometric calibration and a 3D scene model. With these inputs, the camera response function is estimated for each image. Luong et al. [15] also use a 3D model of the images scene, to compute the camera response function and estimate the illumination, and unlike [14], they use a linear model for CRF’s and require that the images be taken with the same camera under controlled conditions.

Different models for response function were proposed, such as gamma curve [16], polynomial [17], non-parametric [2], and PCA model [18].

3 Estimating the Camera Response Function with One Image

3.1 Background of CRF

The camera response function $f$ relates the scene irradiance $R$ to the image intensity $I$:

$$I = f(R) \quad (1)$$

In the paper, we deal with the image intensity rather than scene radiance, so we solve directly for the inverse response function $g = f^{-1}$. It is assumed reasonably that the response function $f$ is invertible because the image intensity $I$ increases monotonically with respect to scene radiance $R$. 