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Fast Spectral Reflectance Recovery Using DLP Projector

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Abstract Spectral reflectance is an intrinsic characteristic of objects that is independent of illumination and the used imaging sensors. This direct representation of objects is useful for various computer vision tasks, such as color constancy and material discrimination. In this work, we present a novel system for spectral reflectance recovery with high temporal resolution by exploiting the unique color-forming mechanism of digital light processing (DLP) projectors. DLP projectors use color wheels, which are composed of a number of color segments and rotate quickly to produce the desired colors. Making effective use of this mechanism, we show that a DLP projector can be used as a light source with spectrally distinct illuminations when the appearance of a scene under the projector's irradiation is captured with a high-speed camera. Based on the measurements, the spectral reflectance of scene points can be recovered using a linear approximation of the surface reflectance. Our imaging system is built from off-the-shelf devices, and is capable of taking multi-spectral measurements as fast as 100 Hz. We carefully evaluated the accuracy of our system and demonstrated its effectiveness by spectral relighting of static as well as dynamic scenes containing different objects.

Keywords Spectral reflectance · Color switch · High temporal resolution · Spectral relighting · DLP projector · High-speed camera · Color wheel

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1 Introduction

Various computer vision tasks perceive objects by capturing images or videos. However, the appearance of objects in the captured images or videos depends on not only the objects themselves, but also on the illumination conditions and the imaging sensor, i.e., the same object may appear differently under different light sources or using different cameras. This appearance variation may result in performance degradation and even failure of existing computer vision algorithms.

Regarding light with different wavelengths, surface of objects has different reflectivity. The ratio of the spectral intensity of reflected light to incident light is known as the spectral reflectance. It is an intrinsic characteristic of objects that is independent of illumination and the type of imaging sensor. Therefore, spectral reflectance offers a direct description of objects which is useful in a lot of computer vision tasks, like color constancy (Abrardo et al. 1999), material discrimination (Tominaga and Okajima 2000), and relighting (Xing et al. 2010) etc.

To recover the spectral reflectance, what we need are the spectra of incident as well as reflected light. Special equipments are required for measuring these spectra. Furthermore, such equipments usually have low spatial resolution, e.g., one point for a spectrometer. In the case of a whole scene, a lot of effort would be required to measure the spectra of reflected light point by point.

To improve the spatial resolution, several camera-based methods have been proposed. Maloney used an RGB camera to recover the spectral reflectance under ambient illumination (Maloney and Wandell 1986). This method is limited by its low accuracy due to the limited RGB three-channel measurements. To improve accuracy, filters are attached to the light source to modulate the illumination (Cui et al. 2010), or sequentially place different band-pass filters in front of