BRDF Measurement with TDCRA

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Abstract. In this extended summary, we introduce our proposed method for BRDF measurement with a transmissive dihedral corner reflector array (TDCRA); a double-layer orthogonal micro mirror array. Our method combines a TDCRA and a projector-camera system, and achieves efficient BRDF measurement by controlling the directions of incident light rays without mechanical rotation, and capturing the outgoing light rays to various directions at once. We demonstrate that our method with the nonlinear interpolation of the captured BRDF values is useful for photo-realistic image synthesis.

Keywords: BRDF · TDCRA · projector-camera system.

1 Introduction

The reflectance properties of opaque surfaces are described by Bidirectional Reflectance Distribution Functions (BRDFs). BRDFs are useful for CV and CG applications such as visual inspection and photo-realistic image synthesis. Efficient BRDF measurement is an important issue to be addressed, because a BRDF is a four-dimensional function depending on both the incident and outgoing light directions, and therefore its measurement is time consuming in general.

In this extended summary, we introduce our proposed method for BRDF measurement with a Transmissive Dihedral Corner Reflector Array (TDCRA). The TDCRA consists of a double-layer orthogonal micro mirror array, and has the property that the light rays emitted from a point at one side bounce twice in the TDCRA, and then intersect at the symmetric point at the other side as shown in Fig. 1 (a). Our method combines a TDCRA and a projector-camera system, and achieves efficient BRDF measurement by controlling the directions of incident light rays without mechanical rotation, and capturing the outgoing light rays to various directions at once. We demonstrate that our method with the nonlinear interpolation of the captured BRDF values is useful for photo-realistic image synthesis.

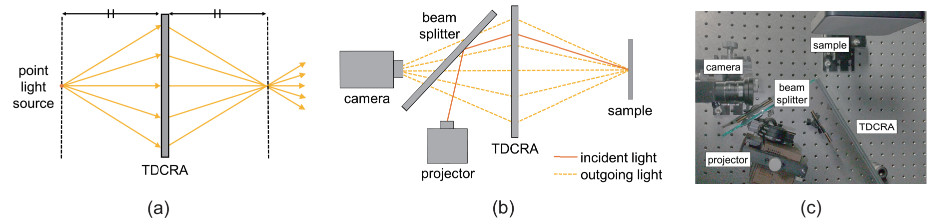

Fig. 1. Our setup: (a) a TDCRA, (b) the measurement principle, and (c) the prototype.

2 Related Work

BRDF measurement: Conventionally, gonioreflectometers [4] are used for BRDF measurement, but the measurement using them is time consuming due to its mechanical rotation and low sampling efficiency. In contrast to such straightforward measurement, image-based techniques are proposed by using spherical/cylindrical targets with uniform BRDF [5] and by using an ellipsoidal mirror [6]. Compared with those techniques, our proposed method makes use of only off-the-shelf devices and does not require such custom-order/self-built samples and devices.
TDCRA and DCRA: Recently, the TDCRA and DCRA are used for AR and MR applications. The TDCRA, originally developed for mid-air display [2], is utilized also for projection mapping with shadow suppression [3]. In addition, the DCRA is utilized for optical cloaking display [1]. Our study is a novel application of the TDCRA; we make use of it for a CV and CG application of BRDF measurement.

3 Proposed Method

Setup: Fig. 1 (b) shows the principle of BRDF measurement by using a TDCRA and a co-located projector-camera system [1]. We can illuminate a point on a sample from various directions with a projector and capture the reflected light rays from the point to various directions with a camera. Fig. 1 (c) shows our prototype setup; the TDCRA is slanted 45° in order to prevent us from projecting/observing single-bounce and no-bounce light rays.
Calibration: Our setup requires geometric and photometric calibration. First, in addition to the conventional geometric calibration of a projector and a camera, we estimate the surface normal of (the planar holder of) a sample. Specifically, we replace the sample with a mirror, and then estimate the normal on the basis of mirror reflection. Second, we correct the intensities of the reflected light rays from the point on the sample. Specifically, we use a diffuse reflectance standard

[1] In theory, a pair of Fresnel lenses can be used instead of a TDCRA. We tested the Fresnel lens pair, but it did not work well due to limited image quality.

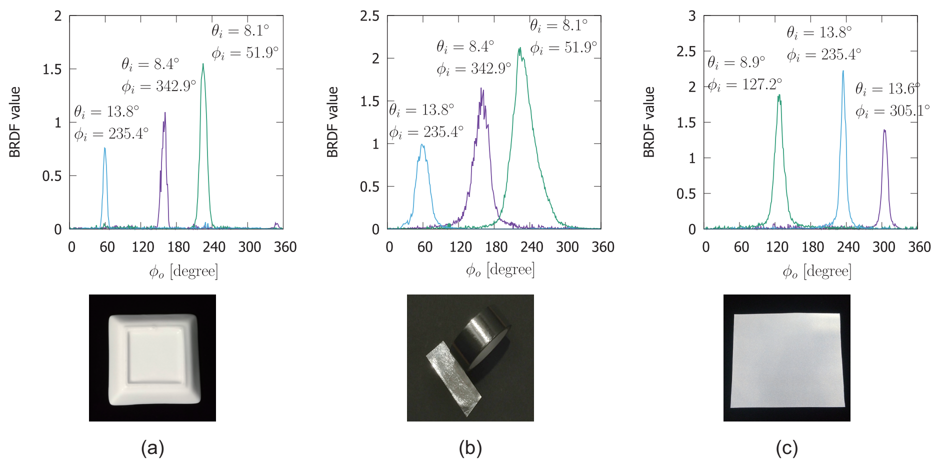

Fig. 2. The slices of the captured BRDFs: (a) a ceramic plate, (b) a metallic tape, and (c) a lens-based retroreflector.

as a sample, and correct the intensities so that they obey the cosine law of illumination and the Lambert's cosine law.

Interpolation: Because the resolution of light source directions is relatively low, the linear interpolation of the acquired BRDF values with respect to light source directions does not work well for sharp lobes due to specular and retro reflections. Accordingly, we nonlinearly interpolate the captured images with respect to light source directions. Specifically, we fit a scaled two-dimensional Gaussian distribution to a specular/retro reflection lobe, and then interpolate the parameters of the distribution.

4 Experiments

Results: We used a TDCRA from Asukanet [2]. Fig. 2 shows the slices of the captured BRDFs: (a) a ceramic plate, (b) a metallic tape, and (c) a lens-based retroreflector. Here, we denote the zenith and azimuth angles of incident and outgoing light rays by (θ_i, ϕ_i) and (θ_o, ϕ_o), and show how the BRDF values behave with respect to ϕ_o when $\theta_i = \theta_o$ and ϕ_i are fixed. We can see that the specular and retro reflections have peaks when $\phi_o = (\phi_i \pm \pi)$ and ϕ_i respectively as expected. In addition, we can see that the difference of surface roughness values between the ceramic plate and the metallic tape are captured; the wider the distribution is, the larger the surface roughness is.

Applications: Fig. 3 shows the images synthesized from the captured BRDF of the ceramic plate. To demonstrate the effectiveness of our proposed method, in particular the nonlinear interpolation of BRDF values, we synthesized the images under a single light source direction from the BRDF values acquired

(a) (b)

Fig. 3. The synthesized images of the ceramic plate: (a) the nonlinear interpolation and (b) the linear interpolation of the acquired BRDF values.

under three different light source directions. We can see that (a) the nonlinear interpolation works well, but (b) the linear interpolation fails; we can see three specular peaks instead of one.

5 Conclusion and Future Work

In this extended summary, we introduced our proposed method for efficient BRDF measurement with a TDCRA. Our method combines a TDCRA and a projector-camera system, and achieves efficient BRDF measurement by controlling the directions of incident light rays without mechanical rotation, and capturing the outgoing light rays to various directions at once. We demonstrated that our method with the nonlinear interpolation of the captured BRDF values is useful for photo-realistic image synthesis. Our future study includes measuring a wider range of angles of incident and outgoing light rays by rotating a sample.
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