Acquiring Short Range 4D Light Transport with Synchronized Projector Camera System

Extended Abstract

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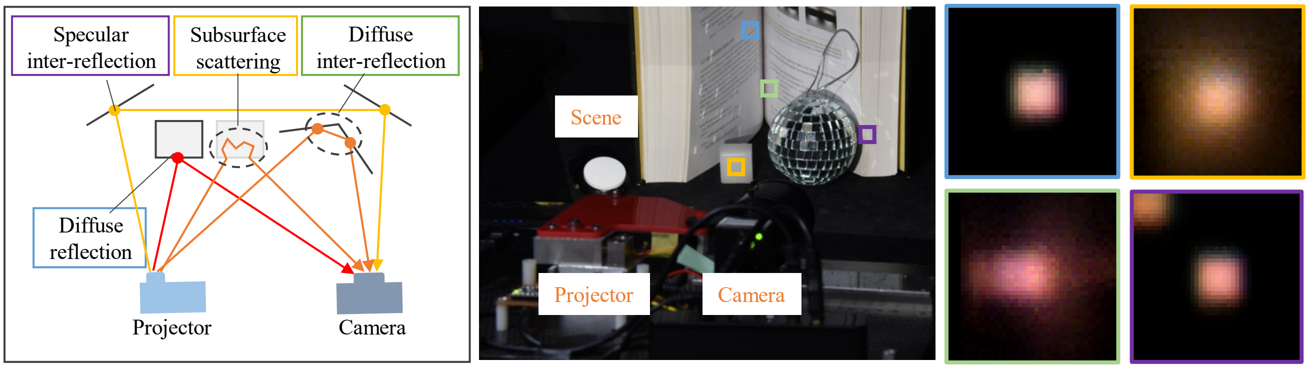

(a) Light transport in the scene. (b) Setup. (c) Acquired profile.

Figure 1: Light transport and its acquisition.

ABSTRACT

Light interacts with a scene in various ways. For scene understanding, a light transport is useful because it describes a relationship between the incident light ray and the result of the interaction. Our goal is to acquire the 4D light transport between the projector and the camera, focusing on direct and short-range transport that include the effect of the diffuse reflections, subsurface scattering, and inter-reflections. The acquisition of the light transport is challenging since the acquisition of the full 4D light transport requires a large number of measurement. We propose an efficient method to acquire short range light transport, which is dominant in the general scene, using synchronized projector-camera system. We show the transport profile of various materials, including uniform or heterogeneous subsurface scattering.

CCS CONCEPTS

- **Computing methodologies** ⟶ *Active vision*;

KEYWORDS

Light transport, Projector camera system

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1 INTRODUCTION

The behavior of the light-ray from a light source to a camera in a scene must be acquired to connect the real-world and the virtual-world consistently in computer graphics, because the behavior tends to be complicated reflecting the interaction between the scene and the light. The evolution of the incident light is represented by the light transport which indicates the interaction of the scene such as the number of the reflection bounces, refraction angles and scatterings. Therefore, the light transport provides a meaningful information for scene understandings. However, the acquisition of

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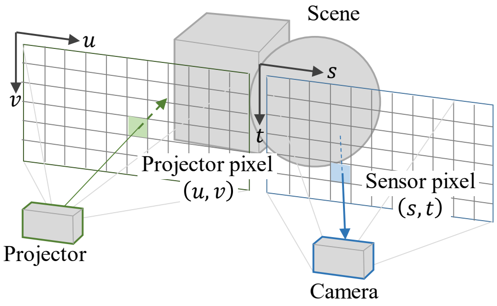

Figure 2: 4D Light Transport.

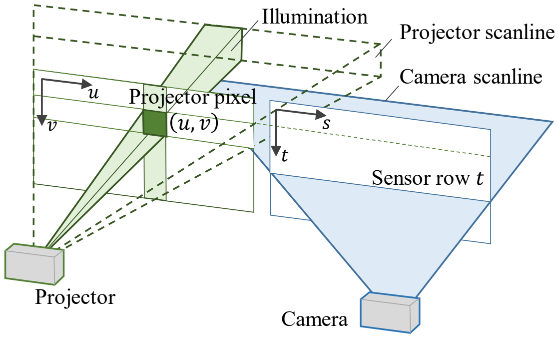

Figure 3: Illustration of the measurement.

full light transport is challenging since it requires a large number of measurement.

In this paper, we propose an efficient method to acquire short range light transport, which is dominant in the general scene as assumed in several works [1, 3, 4], using synchronized projector-camera system.

2 ACQUISITION OF 4D SHORT RANGE LIGHT TRANSPORT

A 4D light transport $T(u, v, s, t)$, which is shown in fig. 2, describes how the light from the projector pixel (u, v) is received by the sensor pixel (s, t) after the interaction with the scene. The light transport like shown in fig. 1(a) is characterized by the distance that the light travels in the scene. Direct transport is the transport of the light that bounce only once in the surface of the object as with diffuse reflections. In short range transport, the light that travels short distance as a result of subsurface scattering or diffuse inter-reflections. The light that travels long distance as with specular inter-reflections is considered as long range transport.

We acquire the short range 4D light transport by extending [2]. They acquire 3D light transport from a projector row v to a sensor pixel (s, t) with a rectified projector camera system. The raster-scan of the laser projector is synchronized to the rolling shutter of the camera and they utilize synchronization delay to acquire the 3D light transport of desired offset between a projector row v and a sensor row t. This measurement allows us to acquire only short-range light transport between two close rows by setting small synchronization delay.

As illustrated in fig. 3, in order to acquire 4D light transport instead of 3D, we project a vertical line at a projector column u instead of a white pattern in the method so that only a pixel (u, v) is illuminated by the projector when the corresponding sensor row t is exposed. By sweeping the vertical line over the scene, the 4D light transport from projector pixels of all combinations of u and v.

3 EXPERIMENTS

In our prototype, a Celluon PicoPro projector (resolution 1280×720) and an IDS UI-3250CP (resolution 1600 × 1200) are aligned on a same plane in parallel with a baseline of 50 mm. The rolling shutter is triggered by the VSYNC signal generated by the projector after being processed by the sync circuit.

In fig. 1(c), we show the profile (2D slice of 4D light transport at a specific camera pixel) of the different light transport in the scene (fig. 1(b)). A profile of a book surface (blue box) is almost an impulse response to the rectangle illumination since it exhibits diffuse Lambertian reflection. A profile of wax (yellow) has larger extent compared with the book surface since subsurface scattering is dominant. In the corner of the book (green), the profile has large extent in the horizontal direction due to diffuse inter-reflection between pages, and gradually decreases according to the distance from the center according to the power of the inter-reflection. Finally, in the purple box on the book surface, the left-top of the profile has high intensity due to the specular inter-reflection from the disco-ball in addition to the effect of diffuse reflection in the center area.

4 CONCLUSION

We have proposed the measurement of short range 4D light transport using the synchronized projector camera system. We demonstrate the acquisition of different types of light transport and show the profiles exhibit the characteristic of the transport.

An extension of this work could be to find applications. An acquisition of appearance (e.g. subsurface scattering) is promising since our method is robust to ambient light due to short exposure.

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