Curvature-aware Adaptive Capture of 3D Geometry and Appearance

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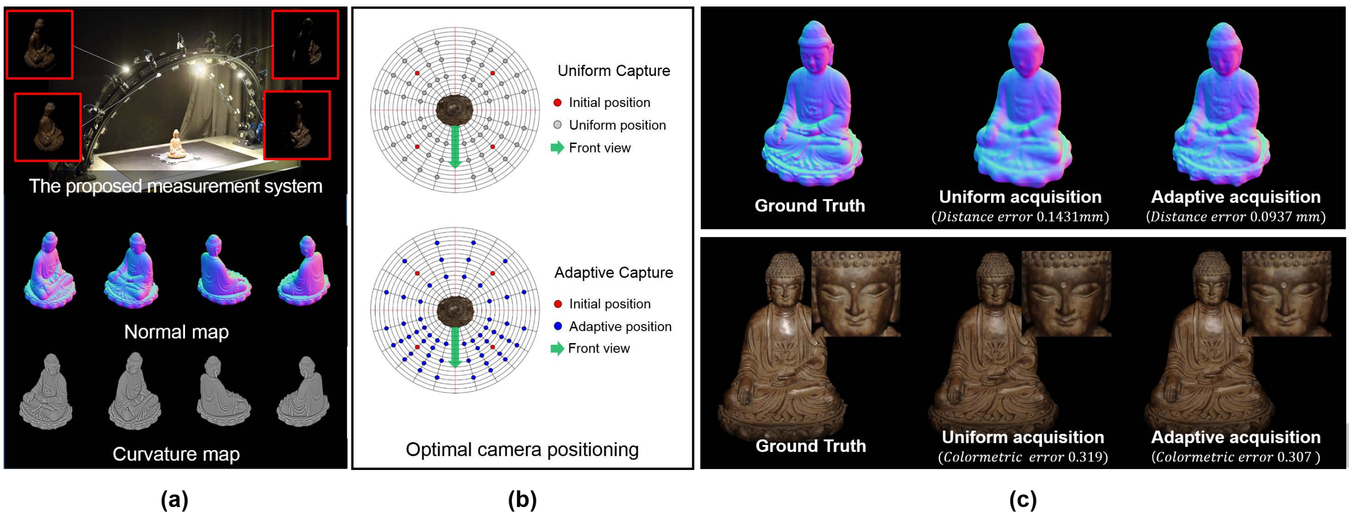

Figure 1: (a) Estimation of normal and curvature map from the propsed measurement system, (b) Uniform and adaptive camera position, (c) Experimental results of the 3D reconstruction (Top) and the svBRDF rendering (Bottom)

ABSTRACT

Various vision-based measurement systems have been developed to reconstruct the 3D shape and appearance of an object. To achieve this, a large number of the samples need to be captured. However, most of the existing measurement system requires a long acquisition time because of system complexity. Although some systems present effective acquisition strategy in the adaptive manner, they focus on only 2D planar samples so that they cannot handle complex 3D object and its reflectance property. In this paper, we present the multi-camera and multi-light source based measurement system that capture the 3D geometry and appearance simultaneously. We also proposed a novel curvature-aware acquisition strategy for reducing the acquisition time and data storage requirement. Since the proposed method can efficiently capture the appearance of 3D objects with complicated shape, expect to progress the digitization in the various field such as museum and industry.

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CCS CONCEPTS

• **Computing methodologies** → **Reflectance modeling**; *Appearance and texture representations*;

KEYWORDS

Appearance capture and modeling, 3D reconstruction, Adaptive capture

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1 INTRODUCTION

Accurate digital reproduction of real-world objects is of great importance in a wide range of applications from industry to cultural heritage. Recently, various vision-based measurement systems have been developed to reconstruct the 3D shape and appearance of an object simultaneously [Schwartz et al. 2013]. To capture the complex geometry with spatially varying reflectance properties of an object, a huge number of sample images needs to be acquired under varying view- and light-directions. Most of existing measurement

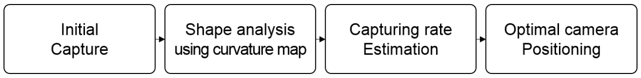

Figure 2: Flow chart of curvature aware adaptive capture

systems have caused big overhead in terms of system complexity, acquisition time and data handling. Although some research presents effective acquisition strategy of a sparse and adaptive sampling [Vávra and Filip 2016], their target objects are 2D planar samples and such systems cannot handle complex 3D objects and their reflectance properties such as self-shadowing, masking, and inter-reflection.

In this paper, we present a flexible measurement system that captures the shape and the appearance of a 3D object with relatively a small number of the sample images while preserving the quality of the reconstruction result. The proposed measurement system consists of the camera-arc and the light-arc which can cover the full hemispherical range over the target object by rotating and capturing the sample images at the user-defined position. Using this system, we propose a novel curvature-aware acquisition strategy that selectively measures the sample images depending on the analysis of the target geometry. The result demonstrate that our method reduces the acquisition time and data storage requirements.

2 CURVATURE-AWARE ADAPTIVE CAPTURE

The key idea of the proposed acquisition strategy is to take more sample images at the camera position from which more complex geometrical parts of the target object are visible. Figure 2 shows the flowchart of the proposed curvature-aware adaptive capture.

To analyze the geometric complexity of an object, we first select four different camera positions with 90° angular interval to capture the entire surface of an object. At each camera position, we take four sample images under different light directions and reconstruct the normal map using the photometric stereo [Woodham 1980]. Using 4×4 initial sample images, we compute the curvature map at each initial camera position as shown in Figure 1-(a). The geometric complexity of each image is defined by the average curvature κ_i in the $i-th$ curvature map. We set the total number of sample images N and then the number of the samples to be taken from each view can be determined by the following equation:

$$N_i = N \times \frac{\kappa_i}{\sum_{i=1}^{4} \kappa_i} \tag{1}$$

Then N_i nearest camera positions of initial position are selected using the K-Nearest Neighbors (KNN) algorithm to measure the additional sample images. Finally, we perform adaptive capture at estimated optimal camera position as shown in Figure 1-(b).

3 RESULTS

We measure the *Buddha* model which has complex geometry and reflectance property. In our experiment, more sample images were captured in the front of the *Buddha* model due to the high average of curvature as shown in Table 1.

Initial View	Average curvature(κ_i)	Number of sample(N_i)
$(45°, 45°)$	0.1554	21
$(45°, 135°)$	0.1503	21
$(135°, 45°)$	0.0664	9
$(135°, 135°)$	0.0679	9

Table 1: Capturing rate of *Buddha* model

To demonstrate the efficiency of our method, we compare it with the uniform acquisition strategy. We perform 3D reconstruction and svBRDF rendering using these sample images. As shown in Figure 1-(c), the adaptive method can reconstruct the detail of the 3D model better than the uniform method when using the same number of images. Likewise the rendering result using our method reproduces the higher fidelity color of the original object.

4 CONCLUSION AND FUTURE WORK

In this paper, we developed a multi camera and multi light source based measurement system to capture the 3D geometry and appearance. We also proposed a novel curvature-aware acquisition strategy for efficient capture of the both geometry and appearance. Our method can be applied to various fields since it can rapidly capture the appearance of 3D objects with complicated shape. We plan to extend our method by considering reflectance property of an object to find optimal position of the camera and light directions.

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REFERENCES

Christopher Schwartz, Ralf Sarlette, Michael Weinmann, and Reinhard Klein. 2013. Dome ii: A parallelized btf acquisition system. In *Proceedings of the Eurographics 2013 Workshop on Material Appearance Modeling: Issues and Acquisition*. Eurographics Association, 25–31.

R Vávra and J Filip. 2016. Minimal Sampling for Effective Acquisition of Anisotropic BRDFs. In *Computer Graphics Forum*, Vol. 35. Wiley Online Library, 299–309.

Robert J Woodham. 1980. Photometric method for determining surface orientation from multiple images. *Optical engineering* 19, 1 (1980), 191139–191139.