Reduced Illumination Patterns for Acquisition of Specular and Diffuse Normal Maps

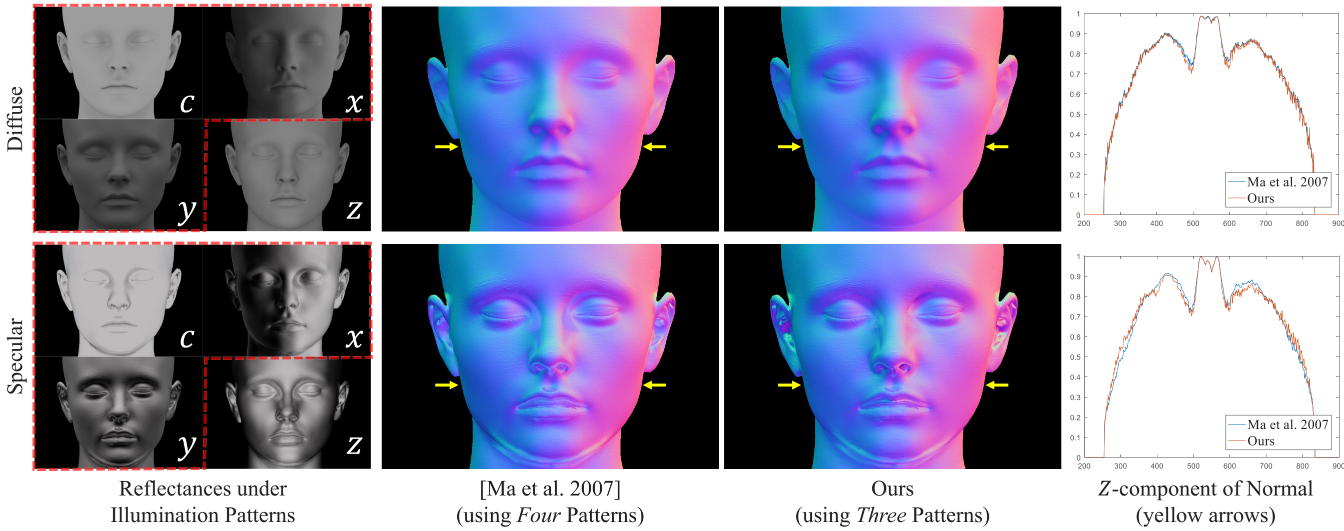

Figure 1: *Comparison of diffuse and specular normal maps from [Ma et al. 2007] using four patterns (XYZ-gradient and constant patterns) and our method using three patterns (without Z-gradient pattern). The yellow arrows indicate the locations of the scan line for the plots.*

1 Introduction

Ma et al. [2007] proposed a method to acquire diffuse and specular surface normal maps of an object using four spherical gradient illumination patterns. The method is derived from the insight that the centroid orientation of diffuse or specular reflectance distribution correspond to the surface normal or reflected direction, respectively. They showed that the method is suitable for real-time normal capture using time-multiplexed illumination due to the low number of patterns needed.

However, there is a redundancy in these four illumination patterns for computing surface normal. They needed only three spherical gradient patterns defined in a [-1, +1] range to estimate the first moment of the reflectance function, but it was impossible to emit illumination with negative intensity. Thus, they additionally used a constant pattern as a fourth illumination pattern, which led to the redundancy of the method.

In this work, we propose an efficient computational method to acquire diffuse and specular normal map with *three* types of illumination patterns by removing the redundancy of [Ma et al. 2007]. By analyzing the relationship between four reflectances under XYZ-gradient and constant patterns for both diffuse and specular reflection, our method obtains a fourth reflectance from the other three reflectances and acquires surface normal using only three illumination patterns. Experimental results on synthetic images show our method gives comparable result to [Ma et al. 2007] qualitatively and quantitatively.

2 Our Approach

Here we briefly explain how the reflectance L_z can be constructed from other three reflectances L_x, L_y and L_c for both diffuse and specular reflection.[1]

For Lambertian surface reflection, L_z can be computed as follows:

$$L_z = \sqrt{\frac{4}{9}L_c^2 - L_x^2 - L_y^2}. \qquad (1)$$

[1] Please see the supplementary material for more details.

For specular surface reflection, L_z can be computed as follows:

$$L_z = \begin{cases} +\sqrt{L_c^2 - L_x^2 - L_y^2} & \text{if } r_z^d > 0 \\ -\sqrt{L_c^2 - L_x^2 - L_y^2} & \text{otherwise,} \end{cases} \qquad (2)$$

where the diffuse reflected direction $\vec{r}^d = 2(\vec{n}^d \cdot \vec{v})\vec{n}^d - \vec{v}$, $\vec{n}^d$ is a diffuse normal, and $\vec{v}$ is a view direction.

Then, from the four reflectances (three observed reflectances and a computed reflectance), a normal map can be obtained in the same way as [Ma et al. 2007]. In the experiments, we used shifted gradient patterns to avoid the problem of negative intensity.

3 Results and Discussion

We compared the surface normal from [Ma et al. 2007] and our method using the synthetic images generate by physics-based renderer (mitsuba-renderer) for diffuse and specular reflection. Figure 1 shows that the normal map of our method is qualitatively very similar to that of [Ma et al. 2007]. We also measured PSNRs of the results for quantitative comparison, and obtained 31.18dB for a diffuse normal and 22.43dB for a specular normal.

Since our method is based on [Ma et al. 2007], it fails similarly when there is inter-reflections, self-shadowing, rotationally asymmetric reflectance lobe, or wide specular lobe. Figure 1 shows both of the methods fails in the self-shadowed region such as the corner of nose.

The reduced number of illumination patterns allows more efficient real-time normal capture using time-multiplexed illumination. Also, it helps better registration between images when we acquire high-quality diffuse and specular normals for dynamic facial expressions. Our method can also be applied to other methods based on [Ma et al. 2007].

References

MA, W.-C., HAWKINS, T., PEERS, P., CHABERT, C.-F., WEISS, M., AND DEBEVEC, P. 2007. Rapid acquisition of specular and diffuse normal maps from polarized spherical gradient illumination. In *Proceedings of the 18th Eurographics conference on Rendering Techniques*, Eurographics Association, 183–194.