Polar-Photometric Stereo Under Natural Illumination
Supplementary Material

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This supplementary material includes: 1. more details on our camera configuration, and 2. additional experimental results on both synthetic and real data.

1. Real Data Acquisition

As off-the-shelf polarization camera only measures the linear polarization states (*i.e.*, $S_3 = 0$), we need to use a quarter-wave retarder to measure the full-Stokes vector with circular polarization state (*i.e.*, non-zero S_3). Fig. 1 shows our camera configuration. Specifically, the camera we use is a mono-chrome polarization camera (FLIR Blackfly S Polar-Mono). We use 25mm lens with aperture size $f/8$. We mount a quarter-wave retarder (Thorlabs AQWP10M-580) with an automated linear slider in front of the lens to capture two images: one with the retarder, and one without. The fast axis of the retarder is aligned with the x-axis of the polarization camera. Assume the two set of polarization images are decoded as $\{I^0, I^{45}, I^{90}, I^{135}\}$ (without retarder) and $\{\bar{I}^0, \bar{I}^{45}, \bar{I}^{90}, \bar{I}^{135}\}$ (with retarder). We can compute the full-Stokes vector as $S_0 = I^0 + I^{90}$, $S_1 = I^0 - I^{90}$, $4S_2 = I^{45} - I^{135}$, and $S_3 = S_0 - 2\bar{I}^{45}$.

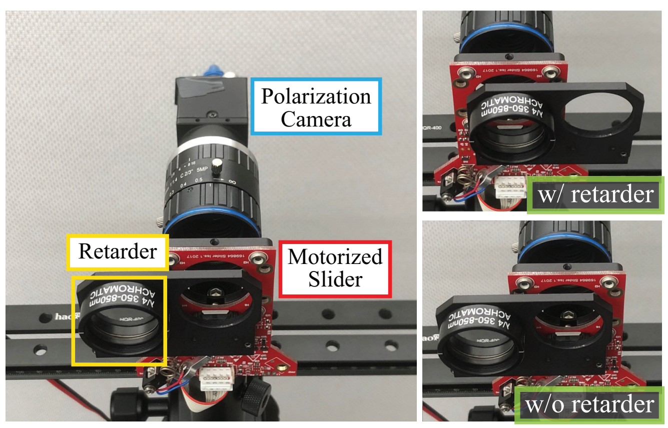


Figure 1. Camera configuration for measuring the full-Stokes vector.

2. Additional Experiment Results

In this section, we show additional results on both synthetic and real data.

Additional Synthetic Results. Here we show more results on simulated data rendered with different materials and environment maps. Specifically, we use six materials (Spectralon, White Billiard, Zro2, Feak Pearl, White Scilicon, and Pom) in the KAIST pBRDF dataset [1] and six environment maps from the light probe datasets [2] and [5]. We set the ratio between overall environment light and our controlled light $\beta = 0.5$. Fig. 2 shows our normal reconstruction results and their errors.

Quantitative evaluation on real data. We perform quantitative evaluation on real-captured data of a plastic ball. Specifically, we compare with photometric stereo (PS) under different settings: 1) PS_1: use three images taken in a dark room;

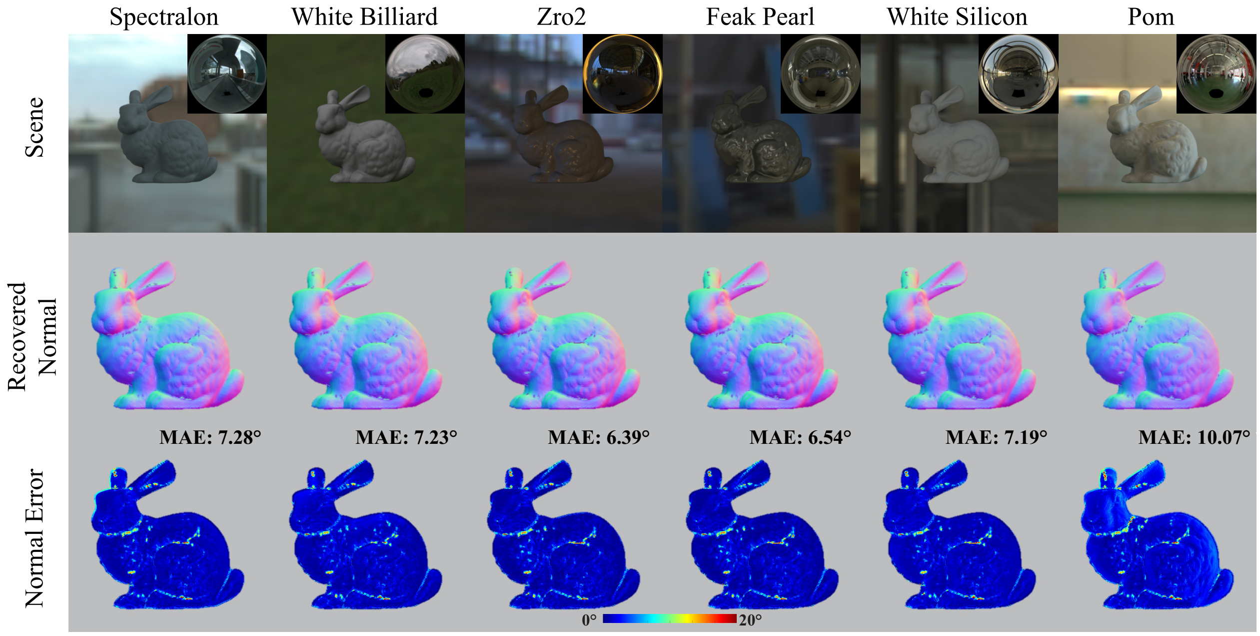
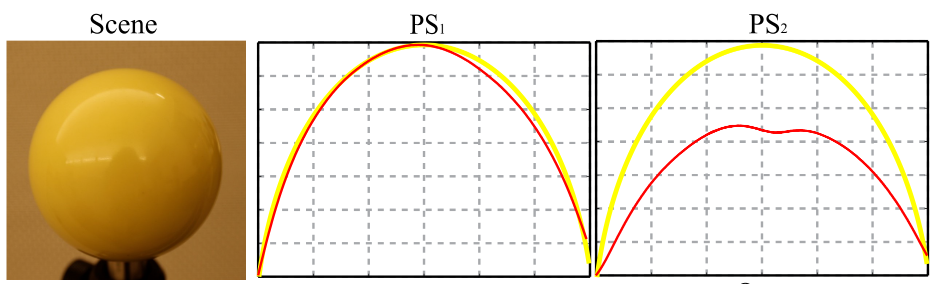
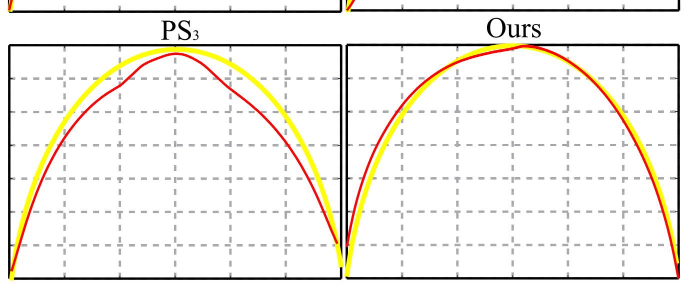


Figure 2. Additional normal estimation results on synthetic data.





Normal Error

Method	MAE
PS_1	7.61°
PS_2	26.51°
PS_3	11.02°
Ours	8.05°

Figure 3. Quantitative comparison results on a real scene.

2) PS_2: use three images taken in natural environment; and 3) PS_3: use three images taken in natural environment plus one extra image with the environment light only (for background subtraction). Camera and light sources are calibrated in these experiments. Fig. 3 shows averaged normal errors (mean angular error or MAE) and cross-section plots of the integrated sphere in comparison with the ground truth (the yellow curve). We can see that our method is more accurate PS conducted with environment lighting (even with background subtraction). Our accuracy is comparable to PS conducted in dark room.

Additional real results. As the angle of linear polarization (AoLP) is critical to normal estimation, we first show a comparison of AoLPs that obtained in two different ways: directly measured under environment light vs. fused with our extra controlled lights (see Fig. 4). We can see that our fused AoLPs are largely enhanced and can provide more reliable polarimetric cue. In Fig. 5 we show more normal reconstruction result of different objects under various environment illuminations in Fig,5. We also compare our results with two SfP-based method ([3] and [4]).

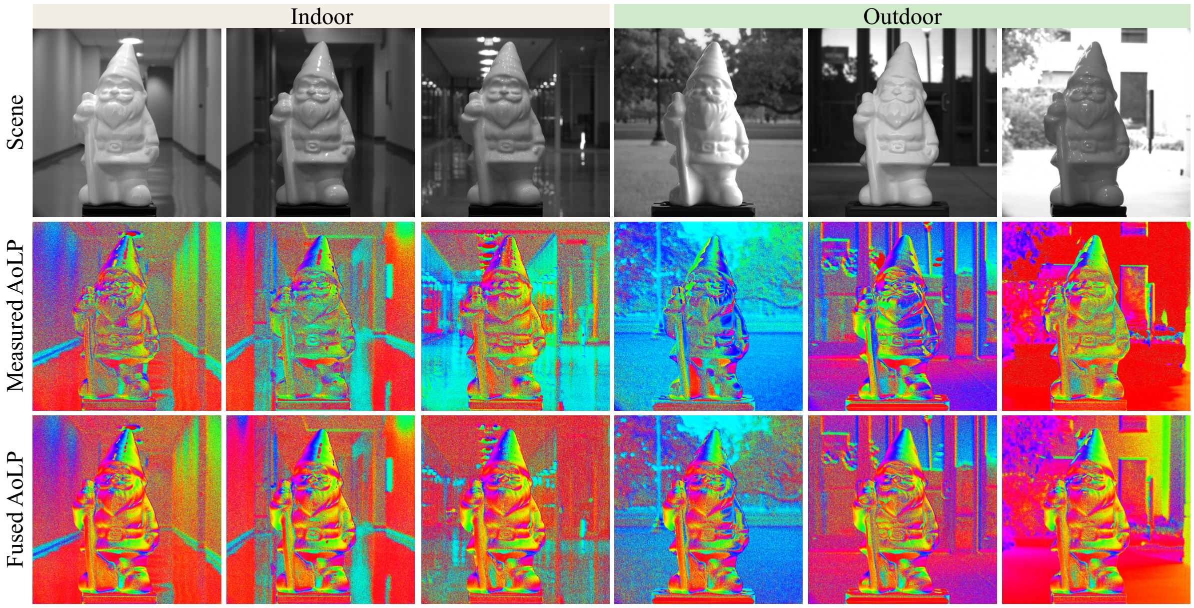


Figure 4. Comparisons of AoLPs (directly measured vs. fused) of the same object under various environments.

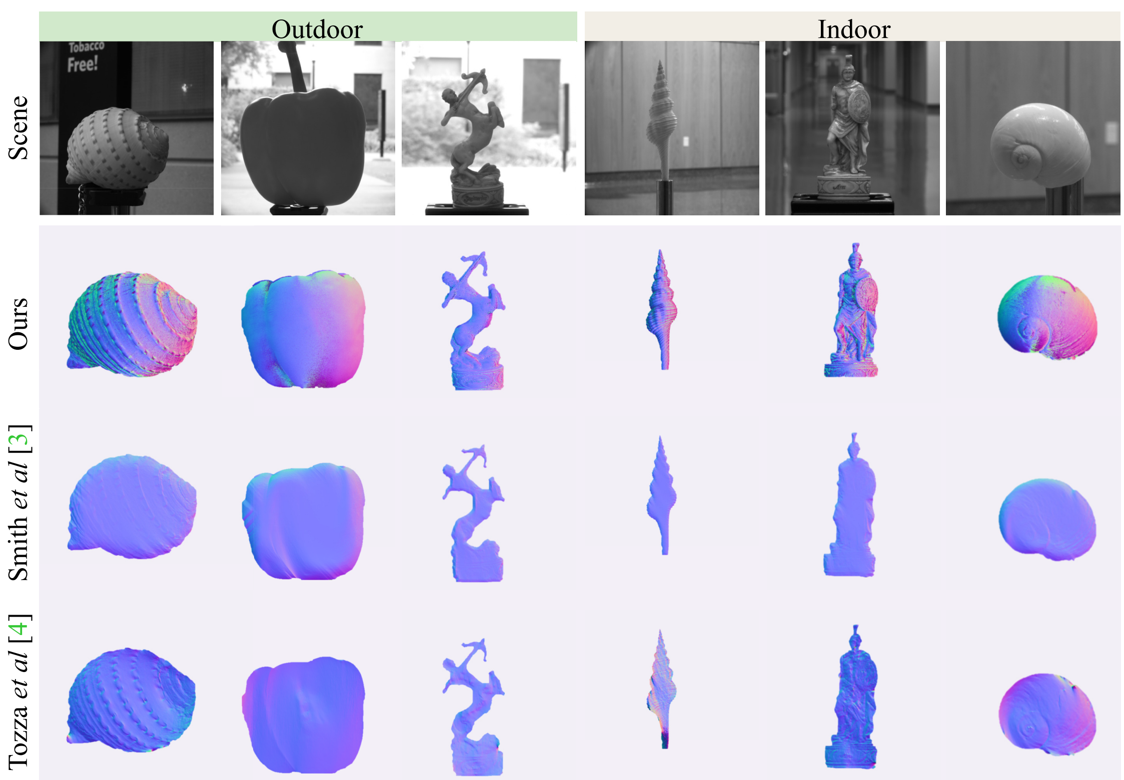


Figure 5. Additional normal estimation results in comparison with state-of-the-art SfP methods.

References

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