Polarimetric Multi-View Stereo

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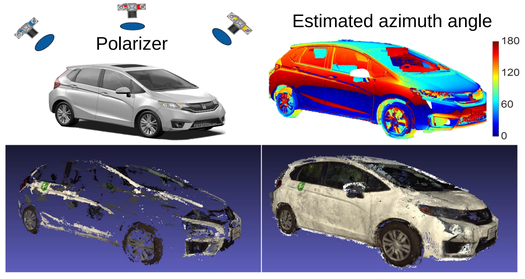
Problem Statement



Mutli-view stereo [1] Ours Polarization cameras

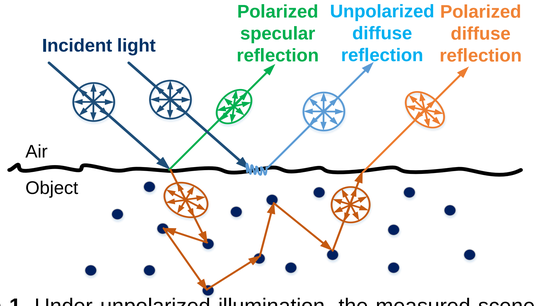
We propose a completely passive, polarization-based MVS method for 3D reconstruction of challenging scenes.

Challenges

Traditional MVS methods: Fundamentally limited to deal with textureless, non-Lambertian surfaces.

Shape from polarization: Cannot deal with real-world objects with mixed polarization.

Mixed Polarization Reflection



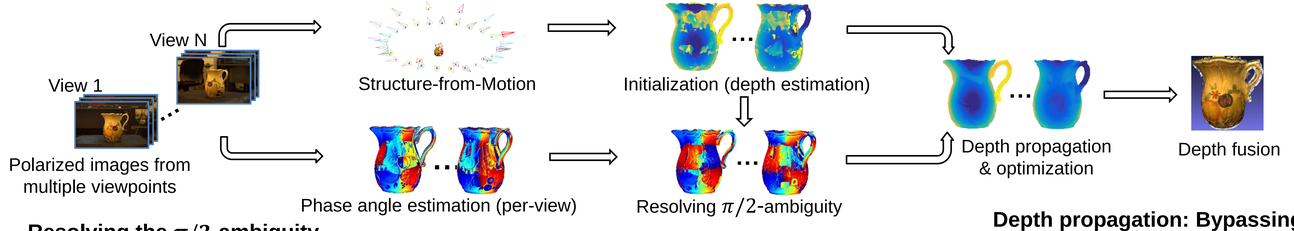
Proposition 1. Under unpolarized illumination, the measured scene radiance from a reflective surface through a linear polarizer at a polarization angle $\emptyset_{pol}$ is

$$I(\emptyset_{pol}) = \frac{I_{max}+I_{min}}{2} + \frac{I_{max}-I_{min}}{2}\cos\left(2(\emptyset_{pol}-\emptyset)\right),$$

where I_{max} and I_{min} are the maximum and minimum measured radiance. $\emptyset$ is defined as the phase angle, which relates to the azimuth angle φ as follows:

$$\emptyset = \begin{cases} \varphi & \text{if polarized diffuse reflection dominates} \\ \varphi - \frac{\pi}{2} & \text{otherwise} \end{cases}$$

Proposed Method

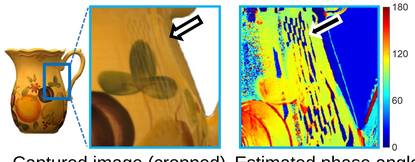


Resolving the $\pi/2$-ambiguity

A binary labeling problem via graph optimization:

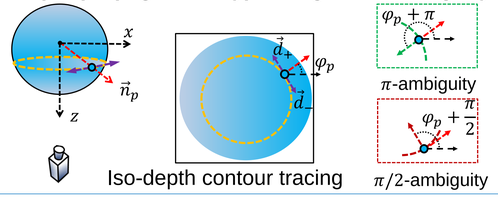
$$E(\{f_p\}) = \sum_{p\in\mathcal{P}} D(f_p) + \lambda \sum_{p,q\in\mathcal{N}} V(f_p, f_q)$$

where $D(f_p)$ is the data term, $V(f_p, f_q)$ is the smoothness term, f_p is a binary label at pixel p, $\mathcal{P}$ is the set of all pixels, and $\mathcal{N}$ is the set of all neighboring pixel pairs.



Captured image (cropped) Estimated phase angle

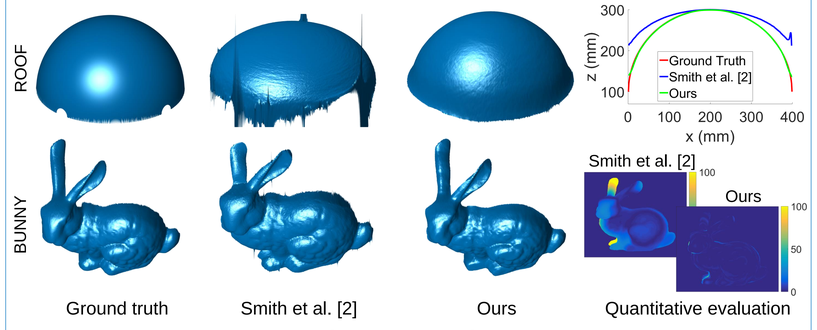
Depth propagation: Bypassing the π-ambiguity



Iso-depth contour tracing π-ambiguity $\pi/2$-ambiguity

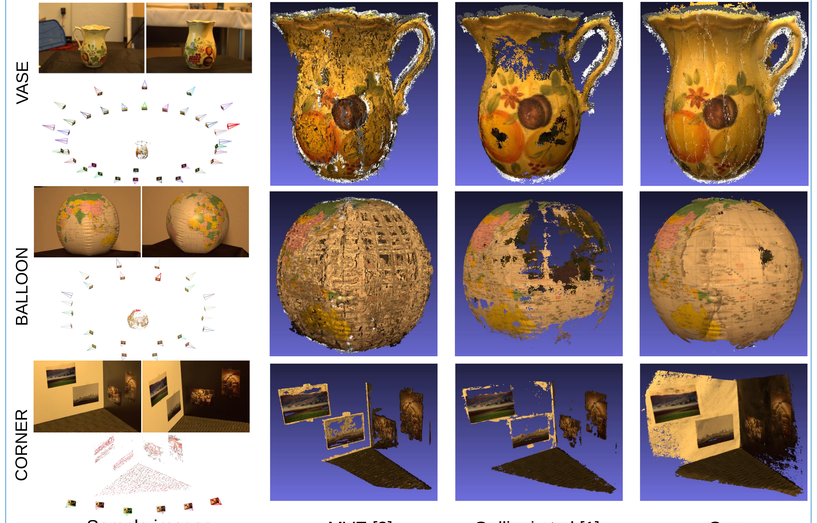
Experimental Results

Evaluation on simulated data



Ground truth Smith et al. [2] Ours Quantitative evaluation

Evaluation on real data



Sample images MVE [3] Galliani et al [1] Ours

Reference
[1] Galliani, et al. Massively parallel multiview stereopsis by surface normal diffusion. ICCV 2015
[2] Smith, et al. Linear depth estimation from an uncalibrated, monocular polarisation image. ECCV 2016
[3] Fuhrmann, et al. MVE - A multi-view reconstruction environment. Eurographics workshops 2014.

Project Page