Multifrequency Time of Flight in the Context of Transient Renderings

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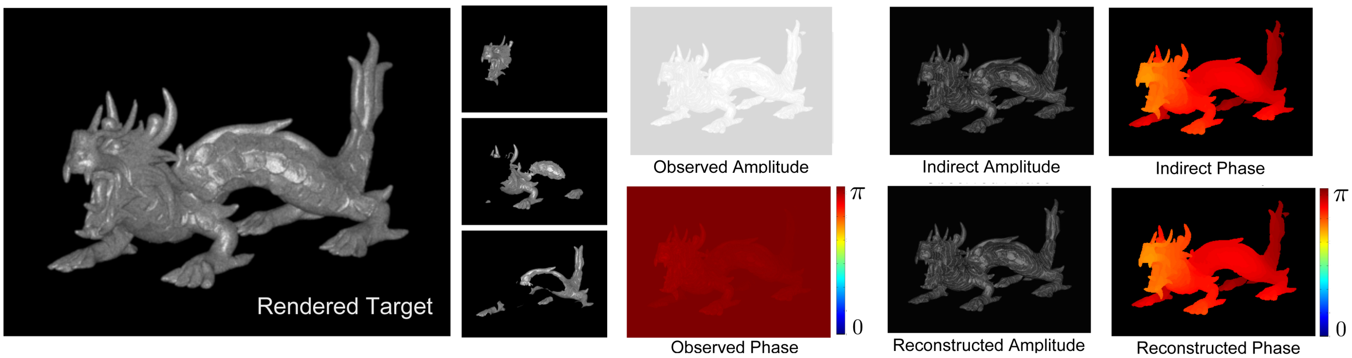

Figure 1: *Dragon behind Transparency. In this scene, a dragon model (leftmost) – exhibiting specularities and occlusions – is placed behind a screen. Using our time resolved renderings, we can capture different time slots of light washing over the model. The reconstructions (bottom right) are exact in the noiseless case.*

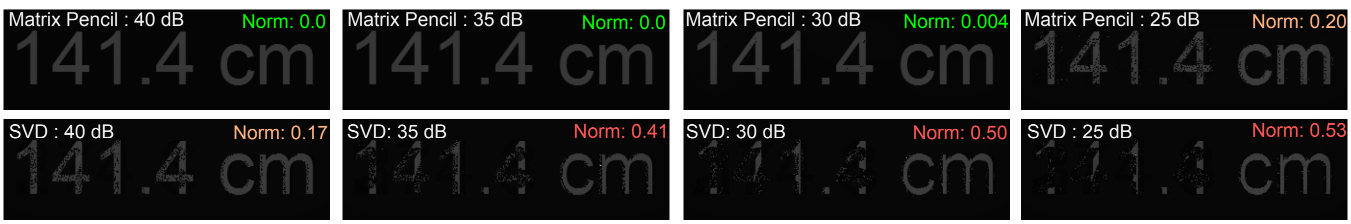

Figure 2: *We compare our approach to existing SVD-based methods on the $K = 3$ bounce cases. The norm is taken with respect to the original component from the renderings. Note that the Matrix Pencil at 25 dB SNR is comparable to the existing approach at 40 dB SNR.*

1 Introduction

The emergence of commercial time of flight (ToF) cameras for realtime depth images has motivated extensive study of exploitation of ToF information. In principle, a ToF camera is an active sensor that emits an amplitude modulated near-infrared (NIR) signal, which illuminates a given scene. The per-pixel phase difference of the modulation between reflected light and a reference signal determines the path length, and hence a depth map, of the scene.

Although ToF ranging has several benefits over other methods, such as stereo, structured light, and laser scanning, it still suffers from severe systematic errors [Kolb et al. 2009]. In particular, the ToF principle assumes that the light travels directly between the camera and the object. However, because the sensor illuminates the entire scene, multiple paths can contribute to a measurement. This multipath interference (MPI) corrupts the depth measurement, which comprises a nonlinear combination of the components.

2 Contributions

- We establish a new method for unmixing component phases and returning the corresponding amplitudes. Our approach draws upon several principles from signal processing to perform per-pixel unmixing of a measured range image. We increase the dimensionality of our measurement by acquiring depth maps at different modulation frequencies.
- By disentangling phases and amplitudes we are able to increase the accuracy of time of flight range maps.
- Our approach is able to decompose a scene by characterizing light paths in terms of bounces and pathlengths (Figure 1, 2).
- We analyze existing hardware and demonstrate the relationship between amplitude, phase and frequency for mixed pixels.

We demonstrate comparisons to the state of the art, e.g., [Godbaz et al. 2012] (Figure 2) and provide a rendering dataset for experiments. We envision application scenarios in range imaging of partially occluded objects (Figure 1), corners, and imaging outside the field of view.

References

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