Role of Transients in Two-Bounce Non-Line-of-Sight Imaging

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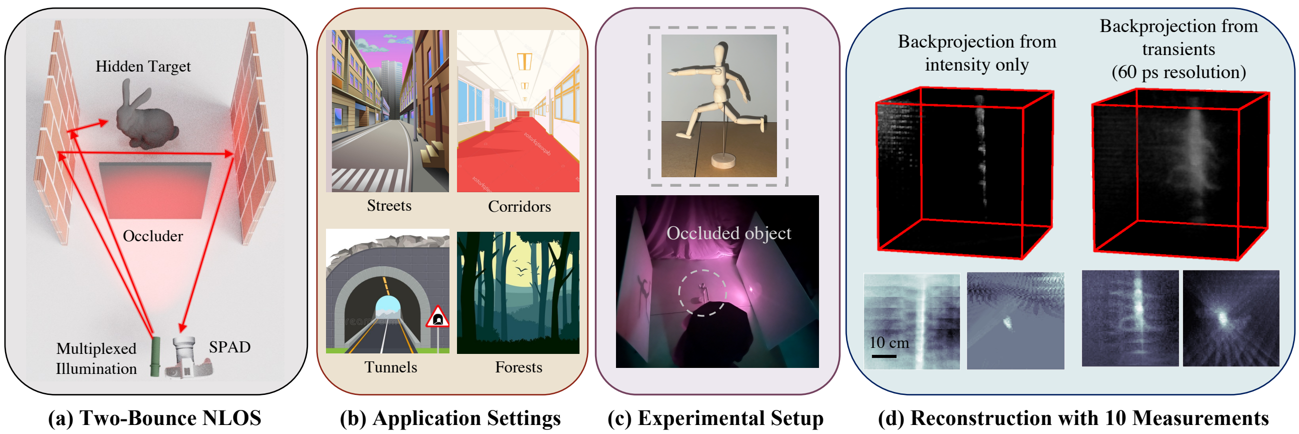

Figure 1. **Two-bounce Transient NLOS Imaging.** (a) We propose using two-bounce transients for NLOS imaging. Two-bounce signals capture information about the shadows in a scene, and use of transient information can reduce the number of measurements needed for reconstruction by using multiplexed illumination. (b) Our work can be applicable in many scenarios, such as tunnels, corridors, streets, and forests. (c)-(d) We experimentally validate the use of two-bounce transients on real objects. We show that time-of-flight information enables more robust reconstructions of occluded objects while using fewer measurements.

Abstract

The goal of non-line-of-sight (NLOS) imaging is to image objects occluded from the camera's field of view using multiply scattered light. Recent works have demonstrated the feasibility of two-bounce (2B) NLOS imaging by scanning a laser and measuring cast shadows of occluded objects in scenes with two relay surfaces. In this work, we study the role of time-of-flight (ToF) measurements, i.e. *transients, in 2B-NLOS under multiplexed illumination. Specifically, we study how ToF information can reduce the number of measurements and spatial resolution needed for shape reconstruction. We present our findings with respect to tradeoffs in (1) temporal resolution, (2) spatial resolution, and (3) number of image captures by studying SNR and recoverability as functions of system parameters. This leads to a formal definition of the mathematical constraints for 2B lidar. We believe that our work lays an analytical groundwork for design of future NLOS imaging systems, especially as ToF sensors become increasingly ubiquitous.*

1. Introduction

Non-line-of-sight (NLOS) imaging aims to reconstruct objects occluded from direct line of sight and has the potential to be transformative in numerous applications across autonomous driving, search and rescue, and non-invasive medical imaging [24]. The key approach is to measure light that has undergone multiple surface scattering events and computationally invert these measurements to estimate hidden geometries. Recent work used two-bounce light, as shown in Fig. 2a, to reconstruct high quality shapes behind occluders [15]. The key idea is that two-bounce light captures information about the shadows of the occluded object. By scanning the laser source at different points $\mathbf{l}$ on a relay surface and measuring multiple shadow images, it is possible to reconstruct the hidden object by computing the visual hull [20] of the measured shadows.

Benefits of Two-Bounce *Two-bounce* (2B) light can be captured using two relay surfaces on opposite sides of the hidden scene (Fig. 1a). This can occur in a variety of real-world settings such as tunnels, hallways, streets, and clut-