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A Practical Approach to 3D Scanning in the Presence of Interreflections, Subsurface Scattering and Defocus

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Abstract Global or indirect illumination effects such as interreflections and subsurface scattering severely degrade the performance of structured light-based 3D scanning. In this paper, we analyze the errors in structured light, caused by both long-range (interreflections) and short-range (subsurface scattering) indirect illumination. The errors depend on the frequency of the projected patterns, and the nature of indirect illumination. In particular, we show that long-range effects cause decoding errors for low-frequency patterns, whereas short-range effects affect high-frequency patterns.

Based on this analysis, we present a practical 3D scanning system which works in the presence of a broad range of indirect illumination. First, we design binary structured light patterns that are resilient to individual indirect illumination effects using simple logical operations and tools from combinatorial mathematics. Scenes exhibiting multiple phenomena are handled by combining results from a small ensemble of such patterns. This combination also allows detecting any residual errors that are corrected by acquiring a few additional images. Our methods can be readily incorporated into existing scanning systems without significant overhead in terms of capture time or hardware. We show results for several scenes with complex shape and material properties.

Keywords Structured light 3D scanning · Interreflections · Subsurface scattering · Defocus · Global illumination · Indirect illumination · Light transport · Projectors

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1 Introduction

Structured light triangulation has become the method of choice for shape measurement in several applications including industrial automation, graphics, human-computer interaction and surgery. Since the early work in the field about 40 years ago (Will and Pennington 1971; Minou et al. 1981; Posdamer and Altschuler 1982), research has been driven by two factors: reducing the acquisition time and increasing the depth resolution. Significant progress has been made on both fronts (see the survey by Salvi et al. 2010) as demonstrated by systems which can recover shapes at close to 1000 Hz (Zhang et al. 2010) and at a depth resolution better than 30 microns (Gühring 2001).

Despite these advances, the applicability of most structured light techniques remains limited to *well behaved scenes*. It is assumed that scene points receive illumination only directly from the light source. For many real world scenarios, this is not true. Imagine a robot trying to navigate