1001 Acquisition Viewpoints
Efficient and Versatile View-Dependent Modeling of Real-World Scenes

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1. Introduction
Constructing high-fidelity 3D models of real-world scenes is an important bottleneck for many computer graphics applications. Manual modeling using CAD or animation software requires artistic talent and a huge time investment. Automated modeling based on acquiring color and depth data is a promising alternative. The typical automated modeling approach densely samples the color and geometry of the scene from several acquisition viewpoints, and then merges the datasets to obtain the scene model. However, dense depth sampling of complex scenes remains a challenging process that can take tens of minutes per acquisition viewpoint (e.g. sequential scanning in laser range finding, robust off-line correspondence computation in depth from stereo, or sequential light pattern projection in depth from structured light). This limits acquisition to a sparse set of viewpoints, and, even with careful view planning, complex scenes remain inadequately sampled.

Instead of Dense Depth sampling from a Sparse set of acquisition Viewpoints (DSDV), we propose an automated modeling approach based on Sparse Depth sampling from a Dense set of acquisition Viewpoints (SDDV). The sparse perviewpoint depth data quickly accumulates to generate models with superior scene coverage. Moreover, sparse depth can be acquired robustly and efficiently, which enables an interactive, operator-in-the-loop, acquisition pipeline. The operator detects and addresses acquisition problems right away, and aims the acquisition device such as to maximize the impact of the sparse data. This ensures that a quality model is obtained in a single scanning session. Unlike conventional DDSV modeling, our SDDV approach enables adding detail at linear cost: a quick scan can be refined at will by revisiting scene regions. Another SDDV advantage is increased robustness for the acquisition of reflective surfaces, as interactive acquisition from a dense set of viewpoints allows the operator to avoid scanning at grazing angles.

In this sketch we will:
- demonstrate the SDDV advantages in terms of coverage, redundancy, and efficiency,
- describe a SDDV implementation that acquires in minutes photorealistic models of complex scenes that fit in a 0.5m cube,
- sketch the extension to acquisition of room-sized scenes.

2. SDDV acquisition system overview
We developed a system that executes the sparse-depth dense-viewpoint automated modeling approach. We employ a hand-held acquisition device that acquires dense color and sparse depth at interactive rates. The device consists of a video camera with an attached laser system that casts a matrix of 7 x7 laser beams into the field of view of the camera. By construction, the laser beams project to disjoint image plane epipolar segments, which makes dot detection efficient and robust. Our acquisition device is attached to a mechanical tracking arm which allows 6-degree-of-freedom motion. The operator can position and orient the acquisition device freely within a sphere with a radius of 60 cm to acquire dense color (720x480 pixels) and sparse depth (7x7) samples robustly, at 15 fps.

The operator sweeps the scene with the device and monitors the acquisition process through immediate visual feedback provided on a nearby monitor. Adequate scene coverage is obtained based on the thousands of acquisition viewpoints interactively selected by the operator. The depth samples (50-100K) and the reference color frames (50-150) are combined into a view-dependent model for rendering. For each desired view frame, the rendering algorithm computes the set of visible points, triangulates in 2D the projections of the visible points, applies the inferred connectivity data to derive a view-dependent 3D triangle mesh, and colors the 3D mesh on the GPU using nearby reference frames.

3. Results
We have modeled several scenes using our SDDV modeling system. The system acquires complex scenes from thousands of viewpoints in minutes. The view dependent model produces quality novel views at interactive rates (also see figure and accompanying video and color plate). The system is versatile—it supports complex geometry and surfaces with complex reflective properties—and robust—all the models shown were acquired in a single take in one afternoon.

When compared to DDSV, the SDDV approach is an order of magnitude faster while achieving superior scene coverage and lower redundancy. Compared to a light field, our models are substantially more compact. The 3D points in the model provide a smooth morph between the reference color frames.

The system has ample depth acquisition range and the system does not require altering scene lighting conditions or displacing scene objects, which are important pre-conditions for a future extension to SDDV modeling of large environments.