On Joint Estimation of Pose, Geometry and svBRDF from a Handheld Scanner

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Motivation

Structured light sensing (e.g. Kinect) enabled large-scale 3D reconstructions. Yet, the level of realism is limited since physical light transport is not modeled. Illumination effects such as specular reflections or shadows are baked into the texture.

Reflections and geometry are linked strongly. To use that mutual information, object geometry and material properties are best inferred jointly. We propose a novel formulation for joint pose, geometry and svBRDF estimation.

While existing approaches use alternating optimization procedures, we propose a single objective that can be optimized using off-the-shelf gradient-based solvers.

Joint Formulation

2.5D scene representation based on one reference view:

A single objective function minimized by off-the-shelf gradient-based solvers.

Optimized variables:

Joint estimation of geometry and materials requires only a rough initialization for both.

Material Assignments

\( \Psi_M \) integrates material assignments into the optimization process as a differentiable regularizer. This naturally leads to a semantically meaningful material segmentation.

Material Assignments: Decomposing the appearance of each base material.

The explicit shadow and occlusion modeling enables reconstructing strongly non-convex scenes.

Geometric Evaluation

Qualitatively and quantitatively, the proposed method recovers more details with less noise and a lower error than the baselines.

- Proposed (disjoint): alternating instead of joint optimization of geometry and materials.
- Arttec Spider scans serve as ground truth.

Pose Ablation Study

Refining the initial poses is crucial for recovering fine texture details. Top: using input poses, bottom: optimizing the poses.

Handheld Sensor

Light Source

RGB input images captured under known point light illumination.

Depth Sensor

RGB Camera

Custom built sensor rig.

Complete but coarse initial depth.

+ Fully portable, no laboratory setup for material estimation
+ For arbitrary geometry, no prior assumptions like planarity

Materials <-> Geometry

Traditionally accurate geometry reconstruction requires known appearance properties.

Likewise, accurate appearance estimation requires very well known geometry.

Joint estimation of geometry and materials requires only a rough initialization for both.

Handheld Sensor

https://github.com/autonomousvision/handheld_svbrdf_geometry

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