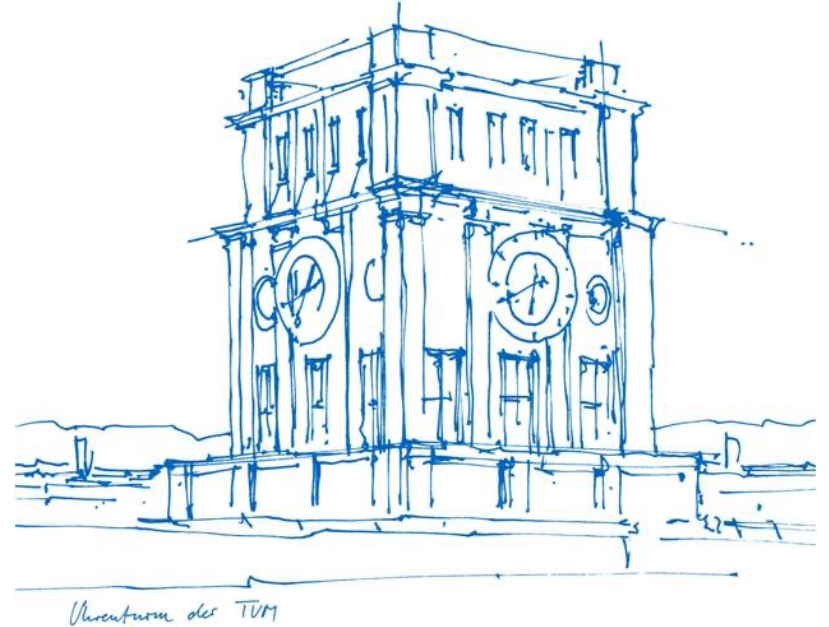


I2DGS: Physically-Based Inverse Rendering with 2D Gaussian Representations

Osama Salem & Mats Grobe

Garching, March 13th, 2026



Motivation

High-Quality Relightable 3D Assets

Goal → Given multi-view images of a real object, recover a 3D asset that can be placed under arbitrary novel lighting

Applications → AR/VR content creation, game asset production, visual effects, digital twins

Key requirement → Material properties must generalize beyond the training illumination

The output is a decomposed, material-complete 3D asset — not just a novel-view synthesis.



Disentangling Light from Material

Problem → Appearance = geometry × material × illumination — all three unknown simultaneously

Ill-posedness → Many (material, light) pairs can explain the exact same observed pixel

Consequence → Any error in one factor contaminates relighting, editing, and compositing

Without constraints, the decomposition has no unique solution.



OLAT Capture Makes It Tractable

OLAT → One point light active at a time, from many known directions around the object

Key insight → Illumination becomes a known term — only geometry and material remain as unknowns

Benefit → Each image gives a direct, low-noise BRDF observation at a specific incident angle

Trade-off → Structured acquisition setup required, but disentanglement bottleneck is broken

Known lighting turns an ill-posed problem into a well-constrained one.



Related Work

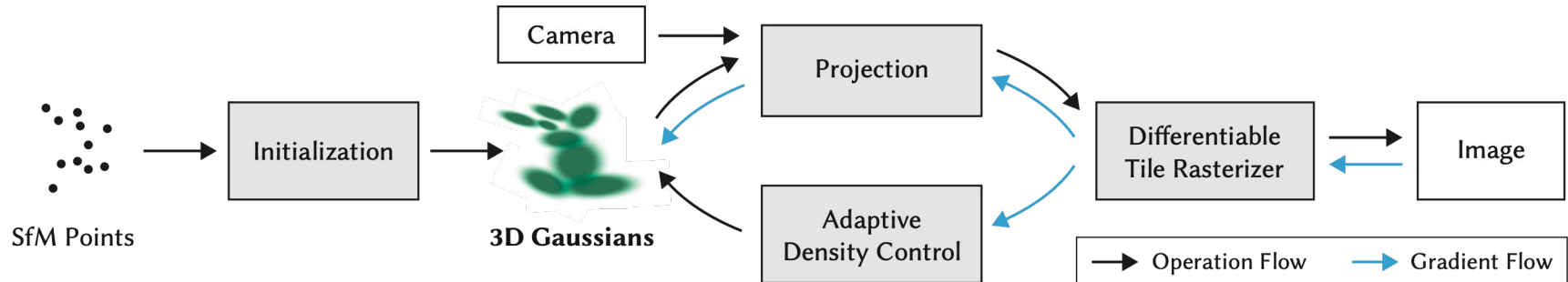
3D Gaussian Splatting (3DGS)

Explicit 3D Scene Representation

Representation → 3D Gaussians with position, scale, rotation, opacity, and color

Rendering → Projected and alpha-composited via differentiable tile rasterizer

Key Strength → Real-time rendering with high reconstruction quality



2D Gaussian Splatting (2DGS)

Geometry-Aware Surface Representation

Problem with 3DGS → Volumetric 3D Gaussians produce noisy, inconsistent surface normals — unsuitable for material decomposition



Key Idea → Replace 3D ellipsoids with 2D surfels (flat disks) embedded in 3D space — Gaussians now lie on surfaces



Benefit → Accurate, view-consistent surface normals, which are a prerequisite for physically-based rendering

Why it matters here → Reliable normals are essential for evaluating the BRDF at each surface point



Material Representation

Disney Principled BRDF

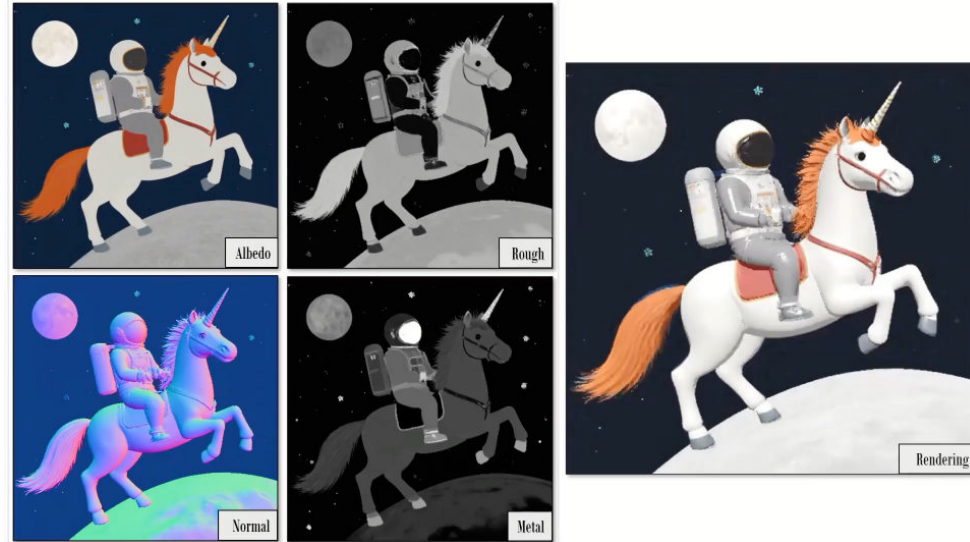
Model → Disney Principled BRDF — physically-based, generalizes across a wide range of real-world materials

Parameters → Albedo (base color), roughness, metallic, and surface normal — recovered per surface point

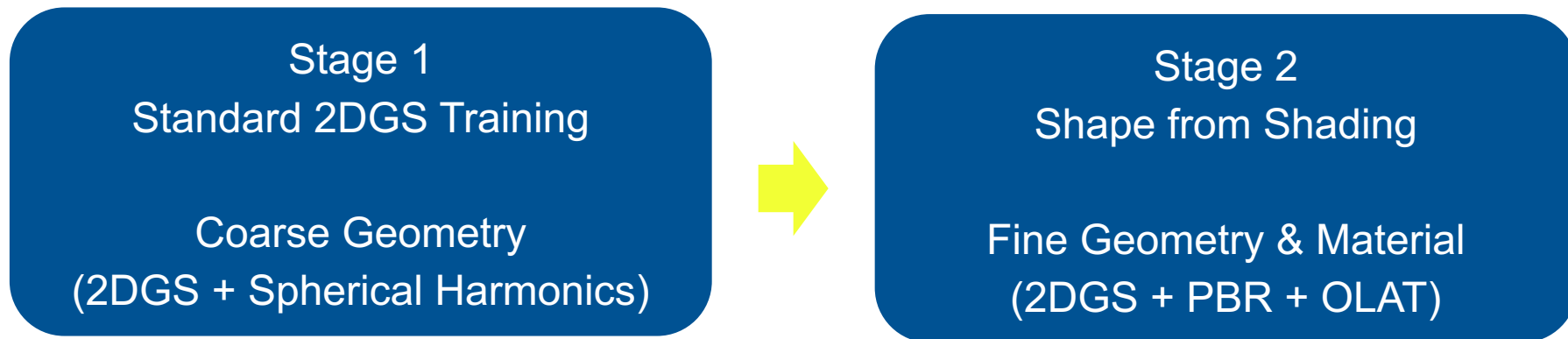
Goal → Estimate these maps from OLAT captures, where L_i is known

$$L_o(\omega_o) = \int_{\Omega} f(\omega_i, \omega_o) * L_i(\omega_i) * (\omega_i \cdot n) d\omega_i$$

$f(\omega_i, \omega_o) = \text{BRDF (what we recover)}$ · $L_i = \text{incident light (known from OLAT)}$ · $n = \text{surface normal (from 2DGS)}$



Method

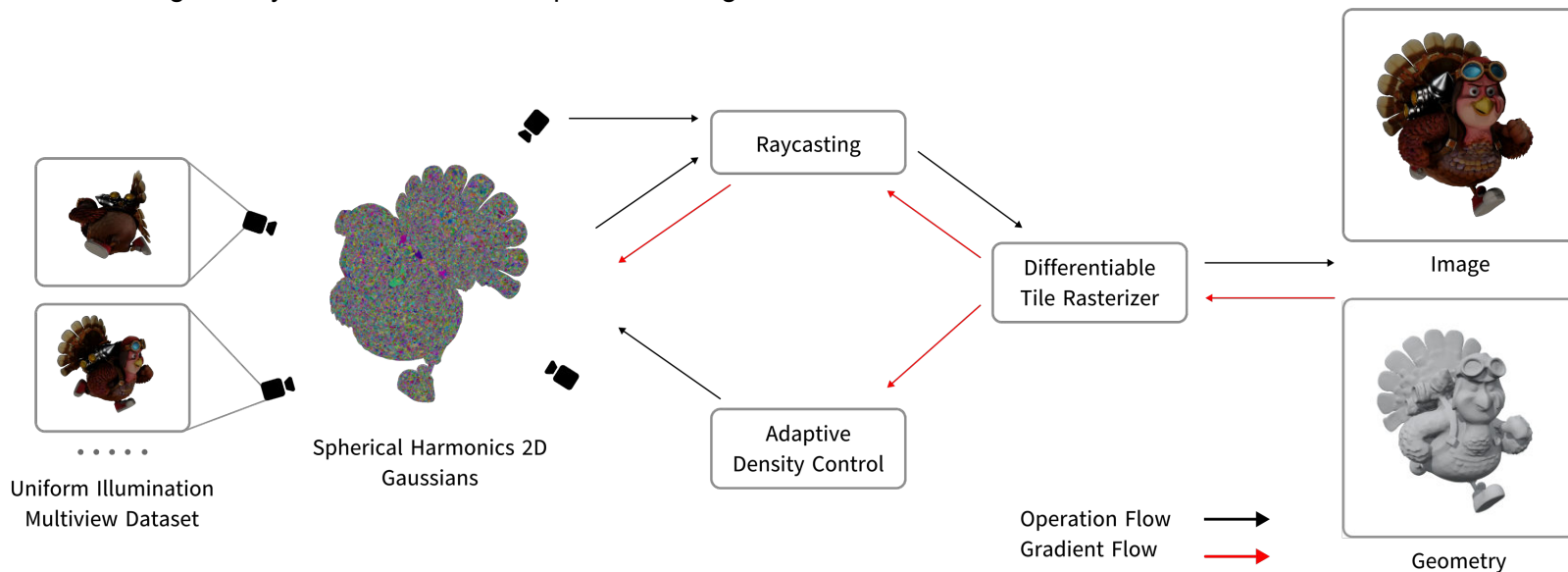


Stage 1 – Coarse Geometry

Input → Multi-view RGB images, SfM initialization

Training → Standard 2DGS with spherical harmonics

Output → Coarse geometry + surface normals → passed to Stage 2

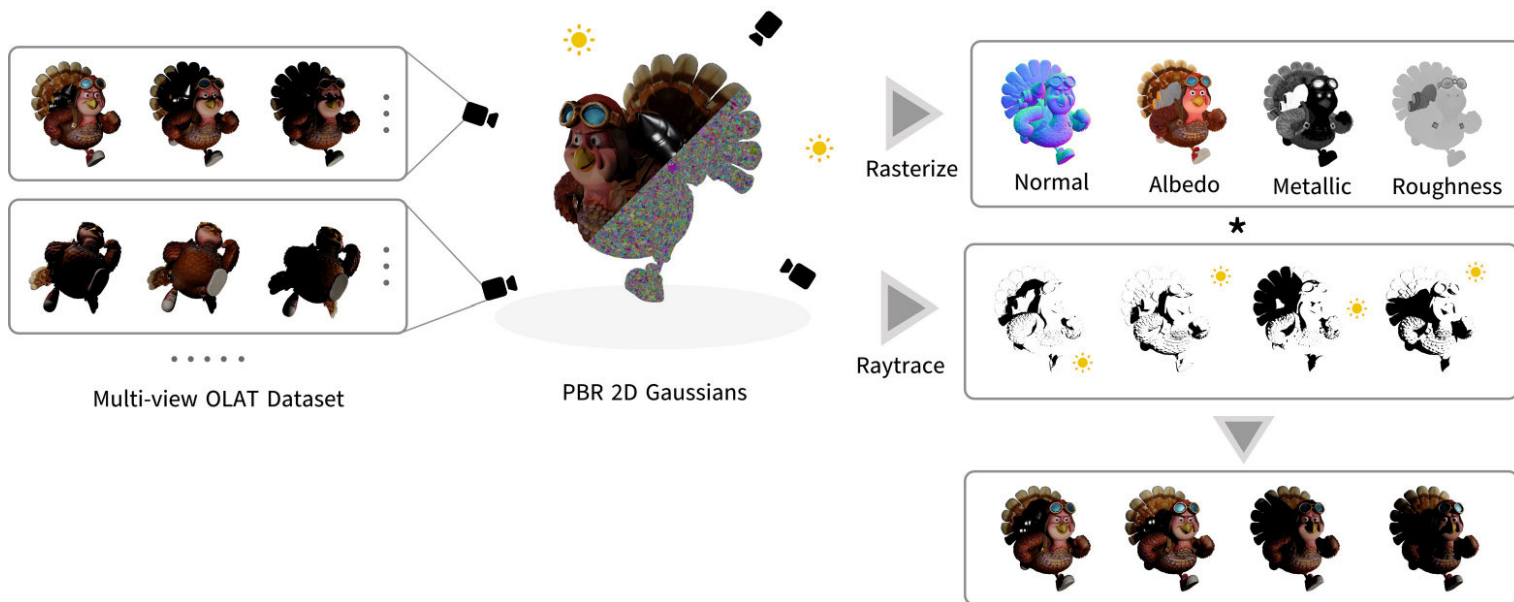


Stage 2 – Shape From Shading

Input → Coarse 2DGS geometry + Multi-view OLAT Dataset

Key Changes → SH replaced with Disney BRDF per surfel + Raytracing

Output → Albedo, roughness, metallic, normals



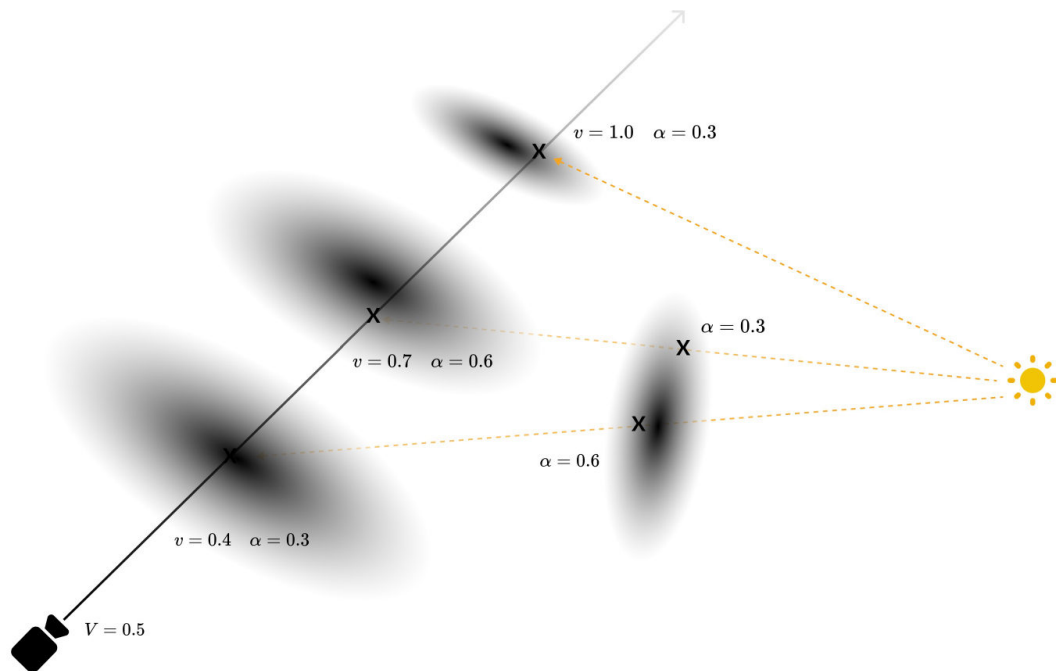
Stage 2 – Shadow Estimation via Ray Tracing

Surfel Approximation → Each surfel represented as 8 triangles for BVH construction

Shadow Ray → Cast from each rasterized intersection toward the OLAT light via BVH

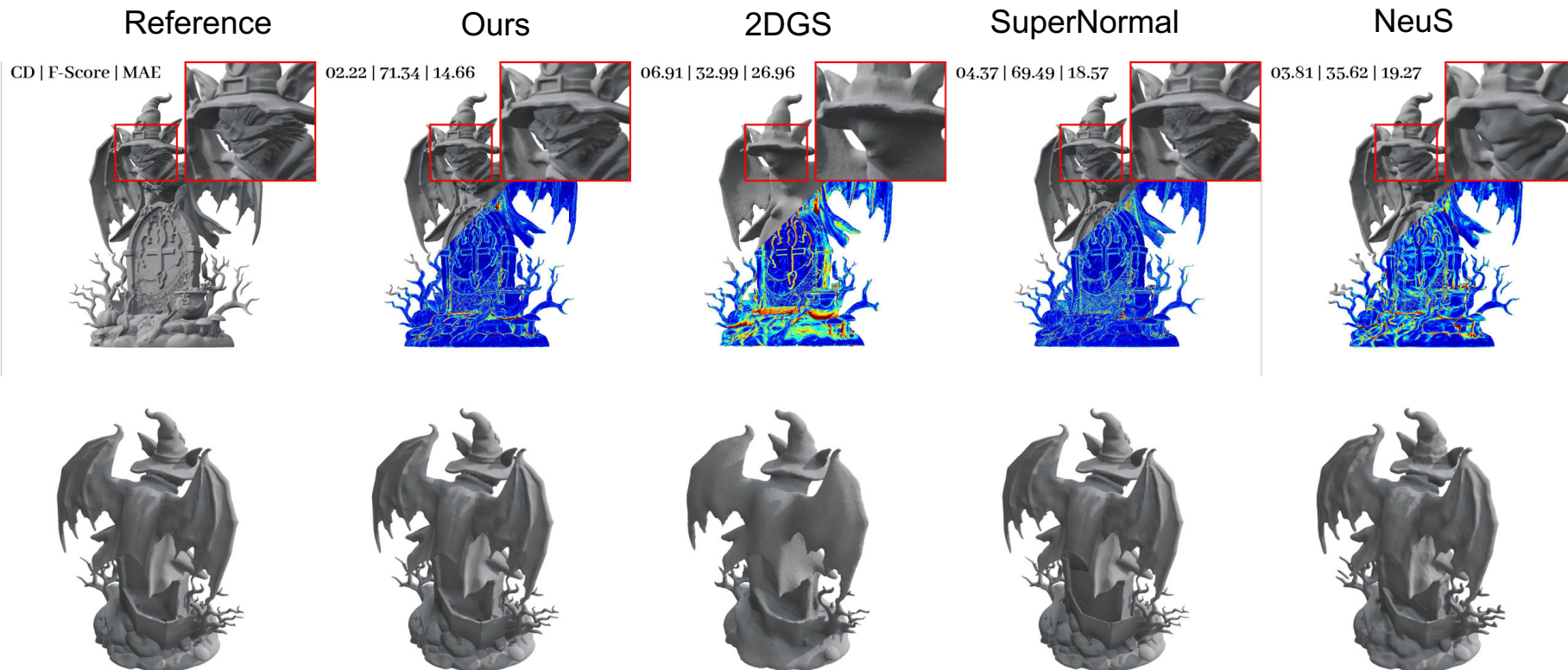
Transmittance → Occluder opacities alpha-blended along shadow ray → per-intersection visibility V_i

Visibility Image → V_i values composited along the camera ray → full visibility image

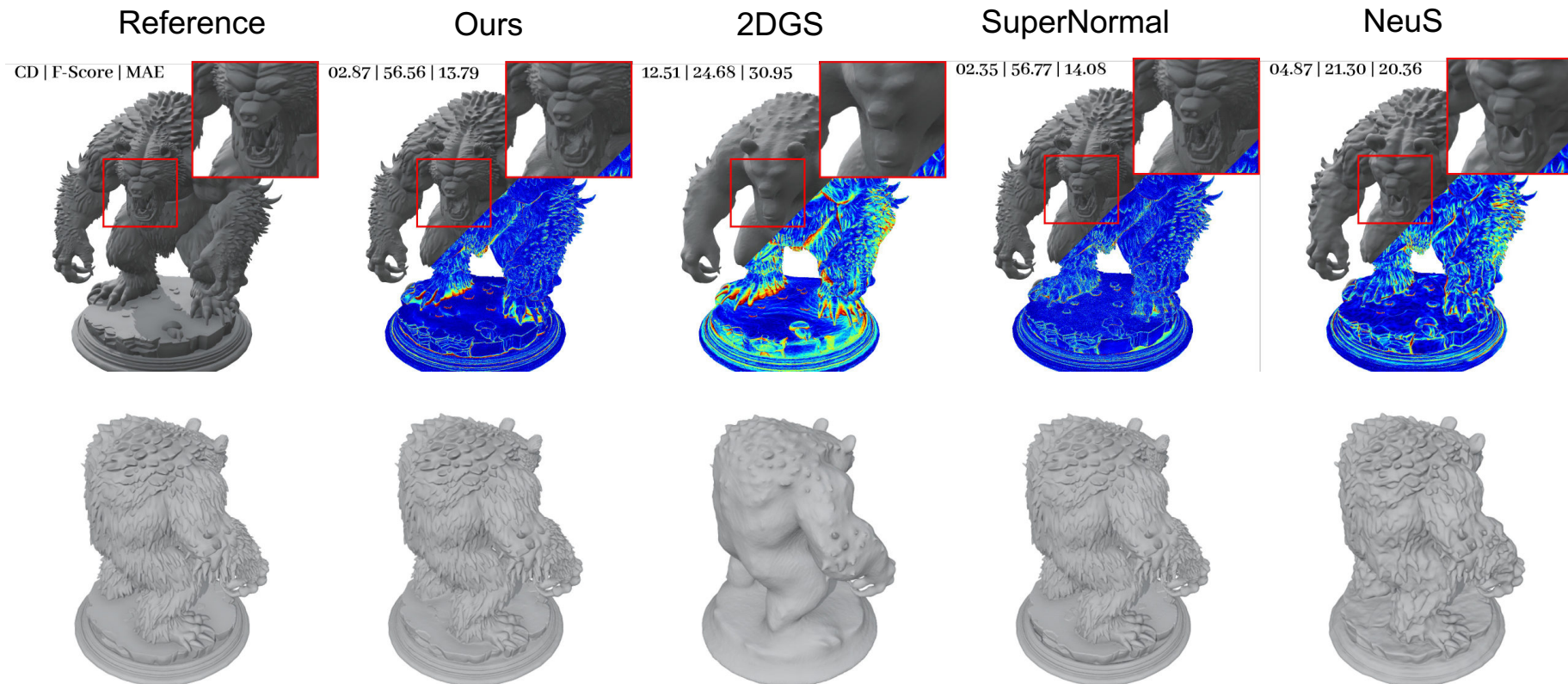


Evaluation & Ablations

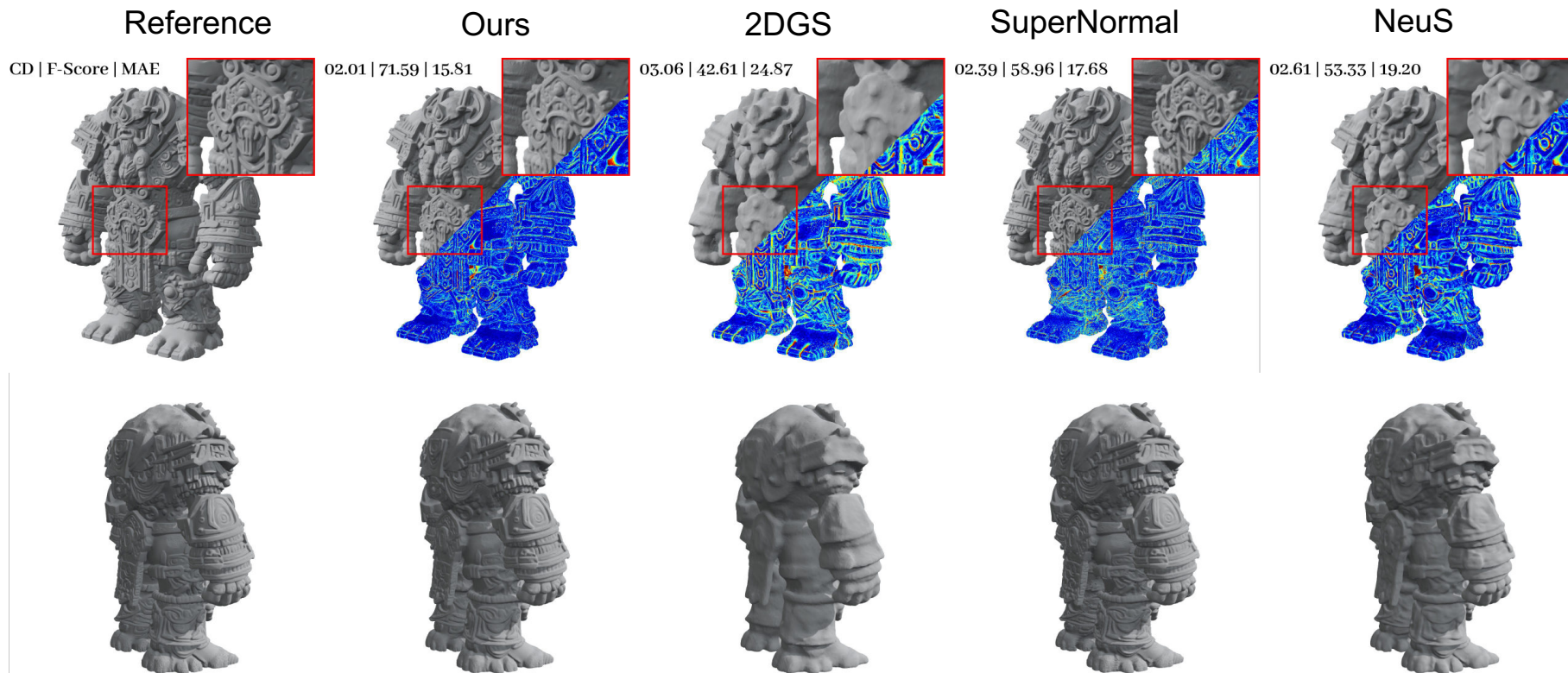
Geometry Evaluation – Bat



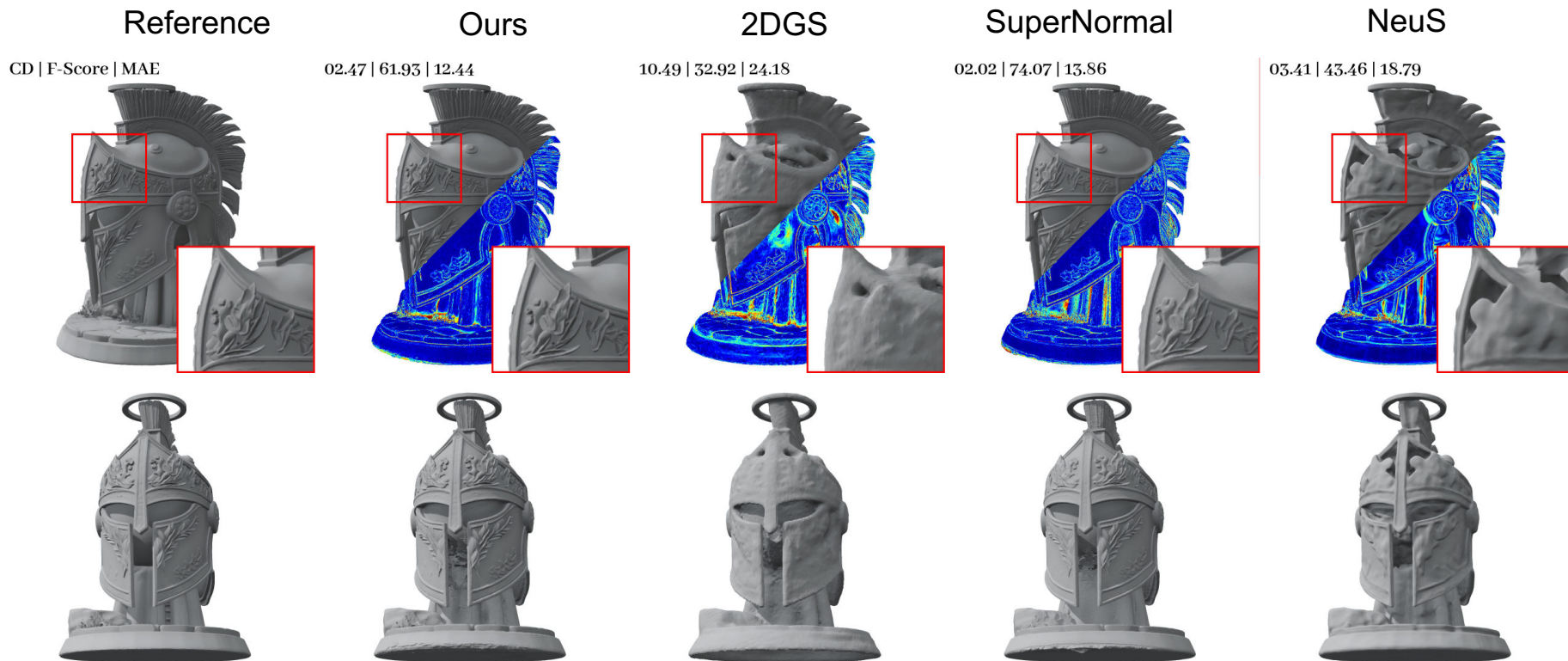
Geometry Evaluation – Bear



Geometry Evaluation – Green Monster



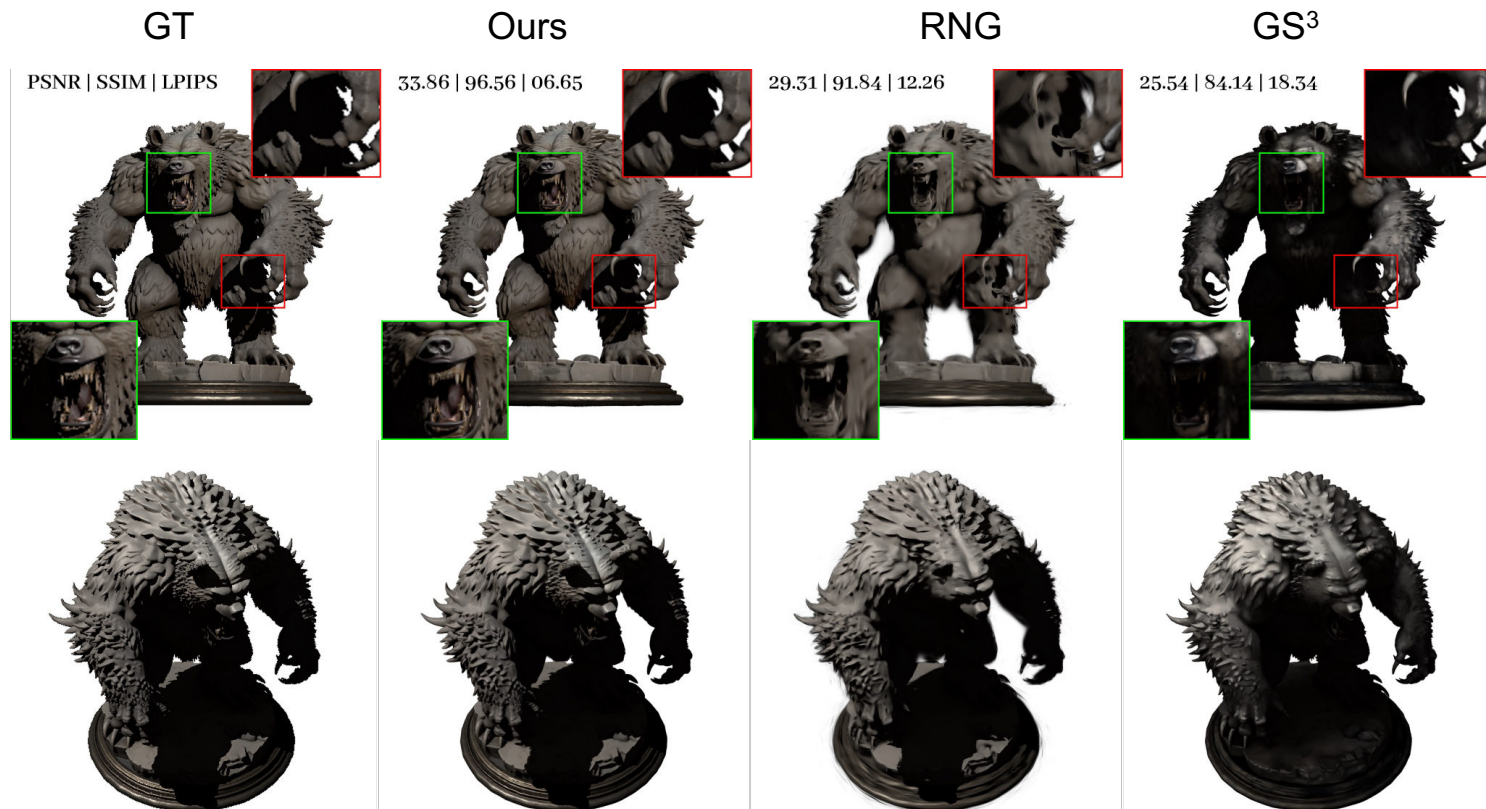
Geometry Evaluation – Helmet



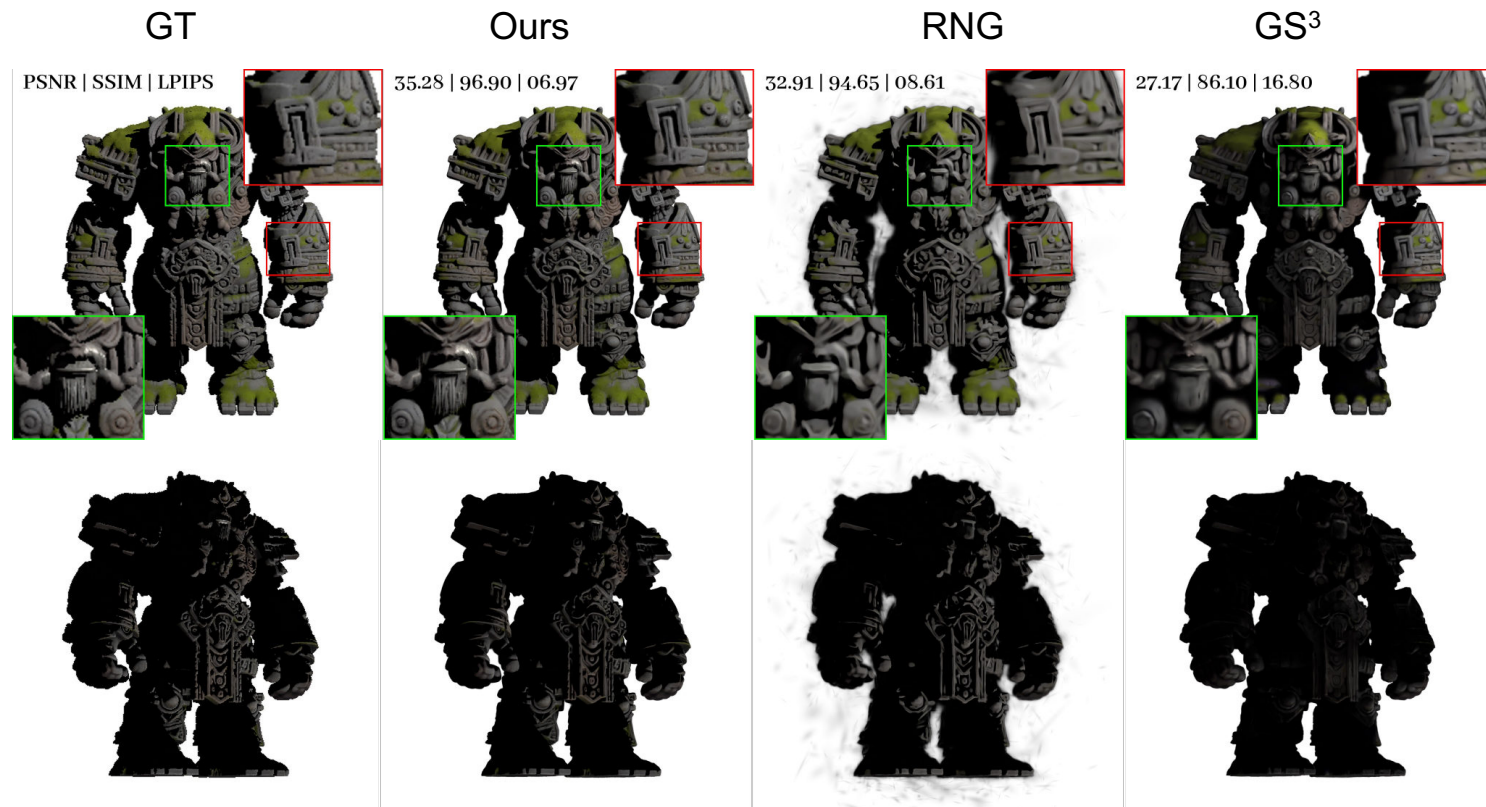
Relighting Evaluation – Bat



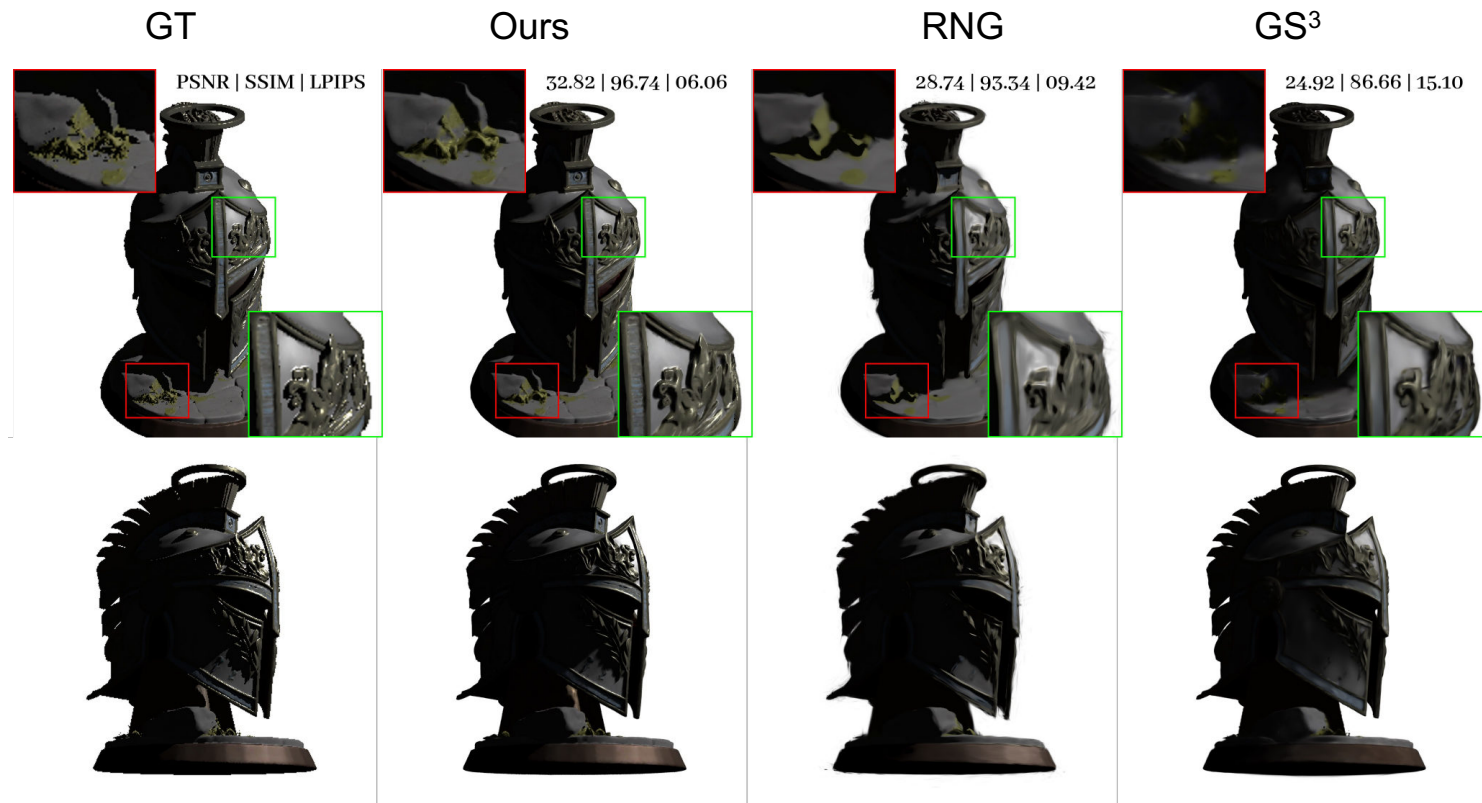
Relighting Evaluation – Bear



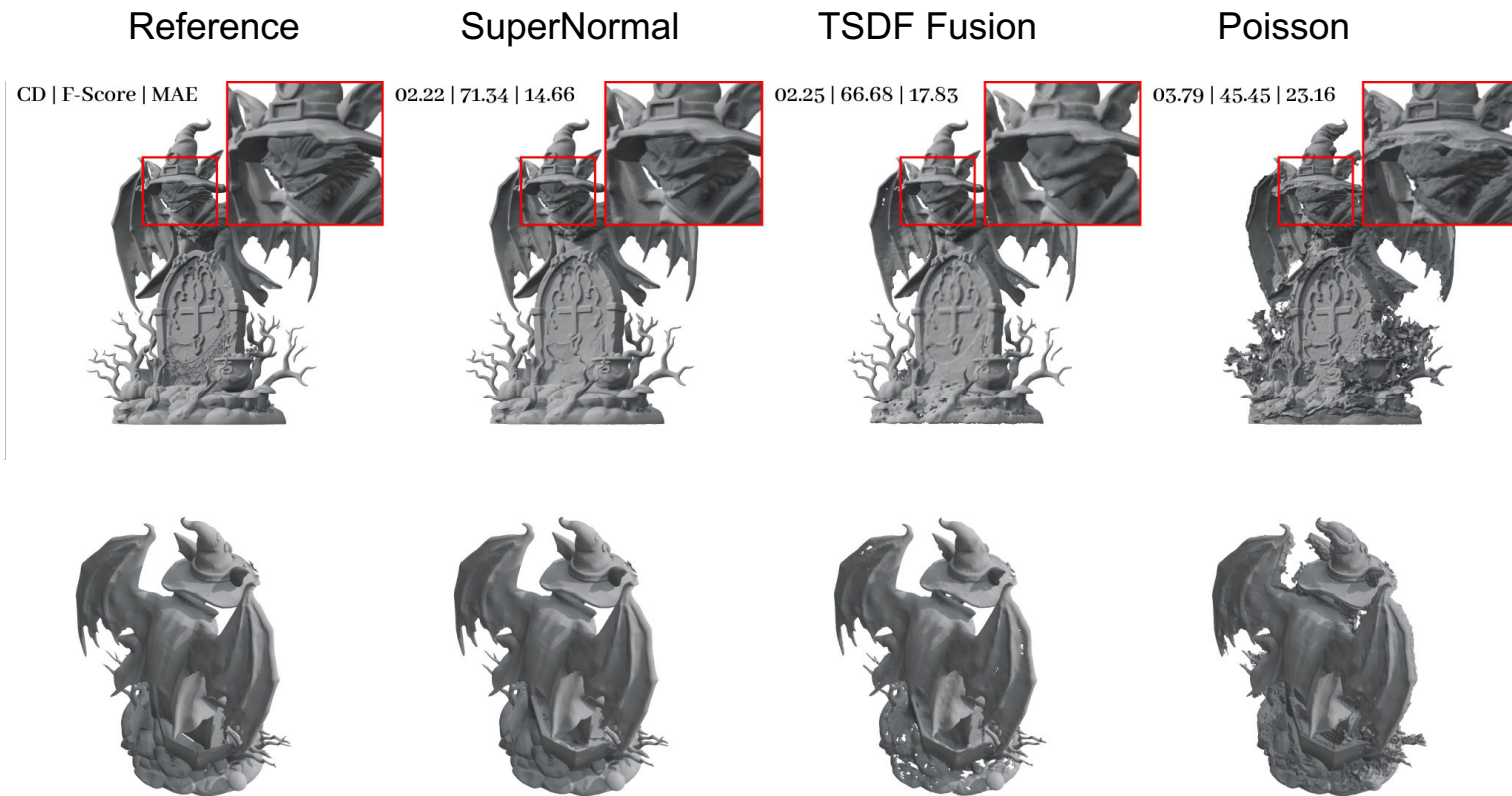
Relighting Evaluation – Green Monster



Relighting Evaluation – Bat



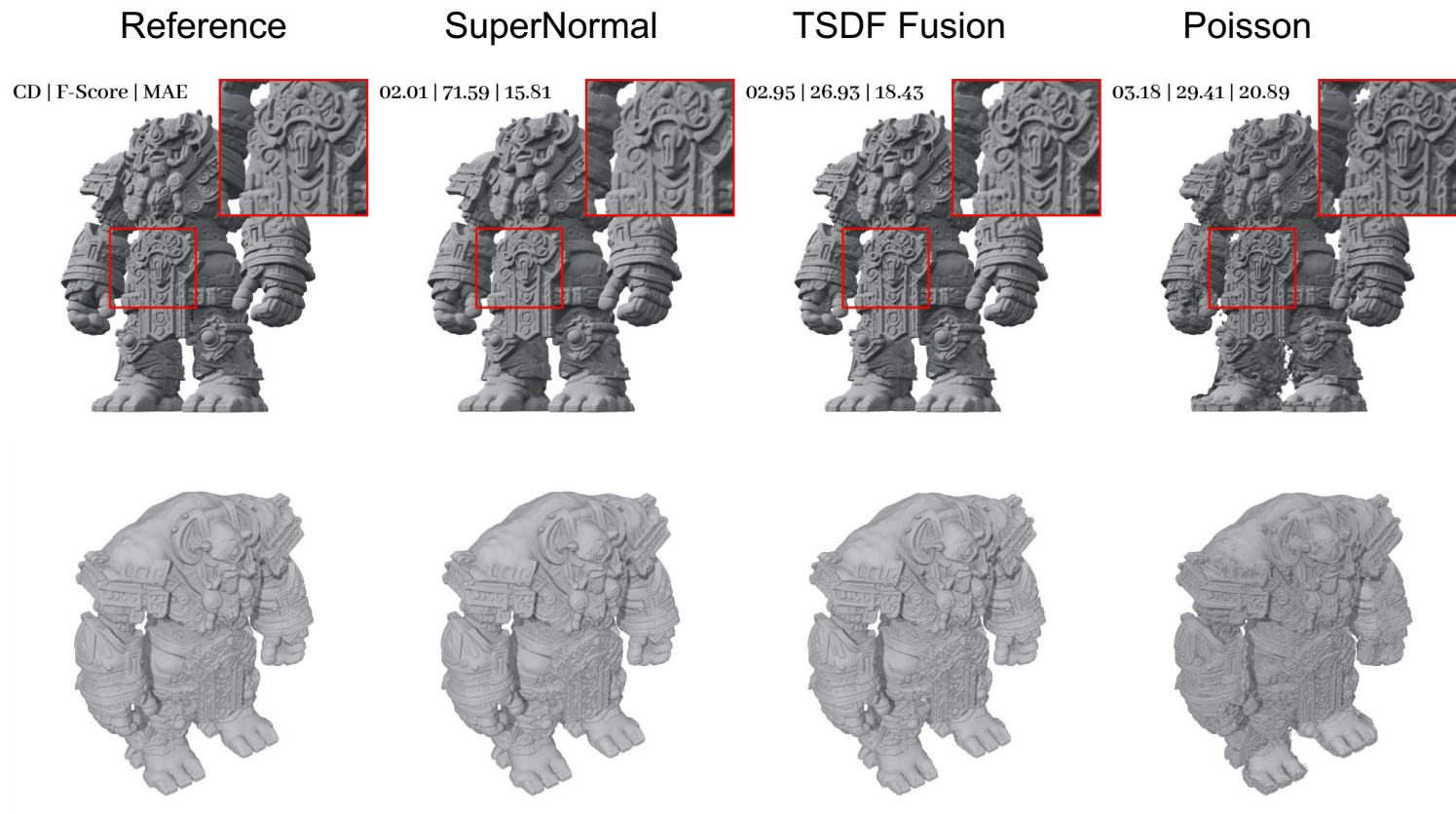
Surface Extraction Ablation Study – Bat



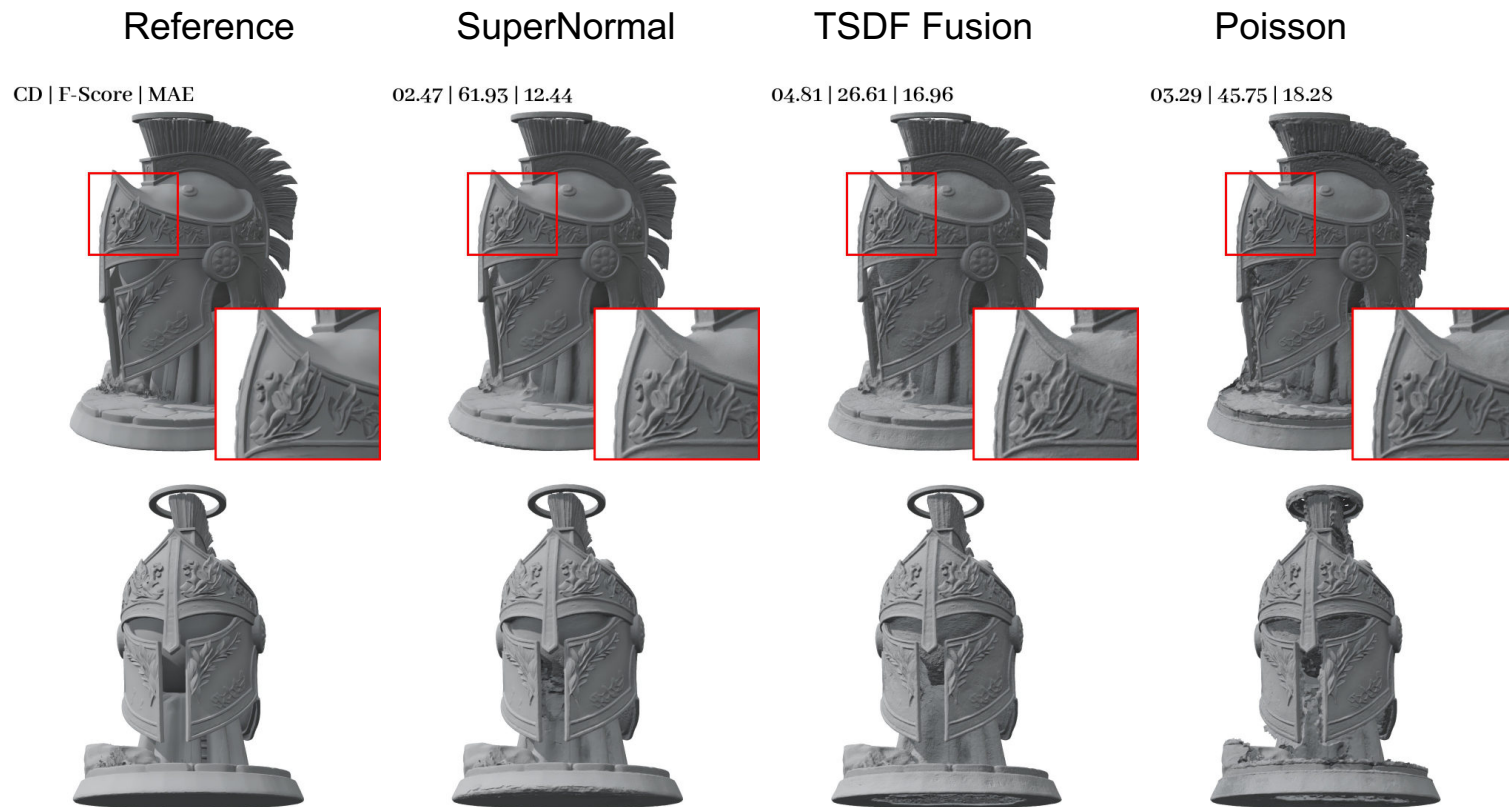
Surface Extraction Ablation Study – Bear



Surface Extraction Ablation Study – Green Monster



Surface Extraction Ablation Study – Helmet





Thank you for your attention

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Garching, March 13th, 2026

