



渲染与逆渲染年度进展报告

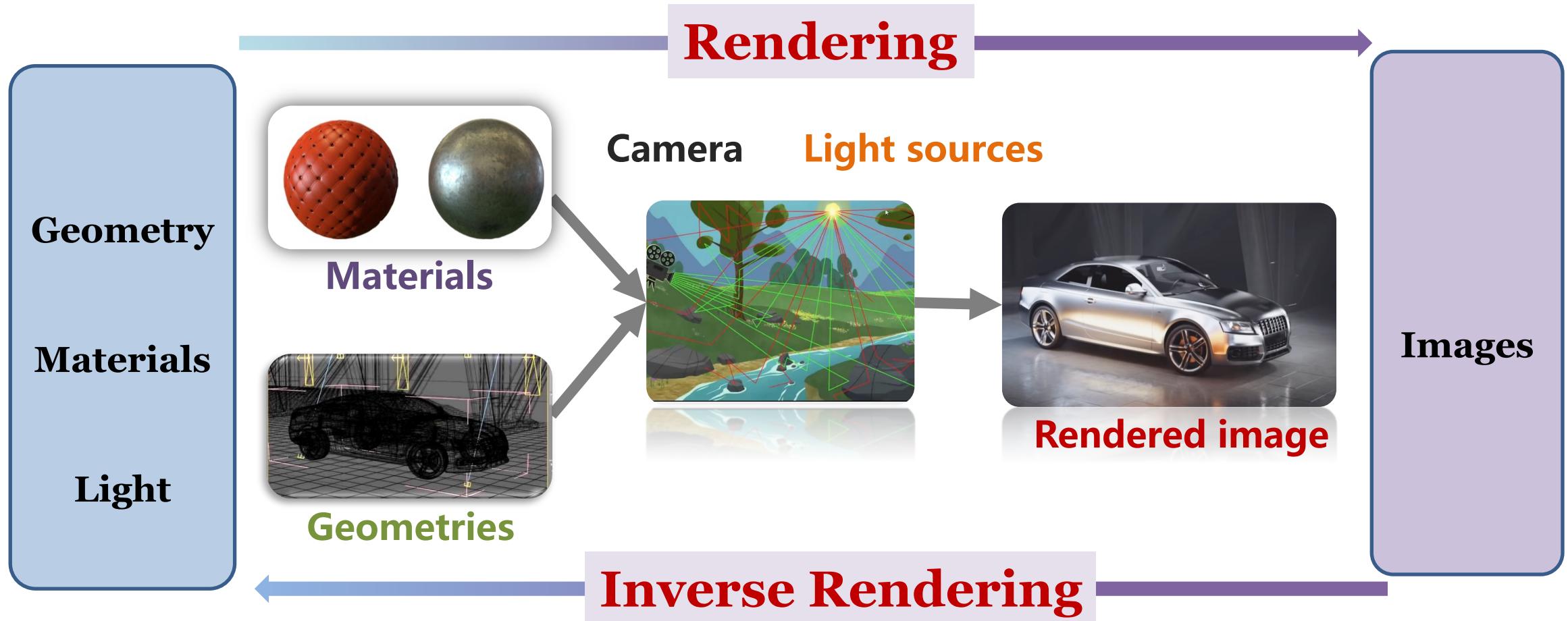
王贝贝

南京大学 智能科学与技术学院

2024.10.12

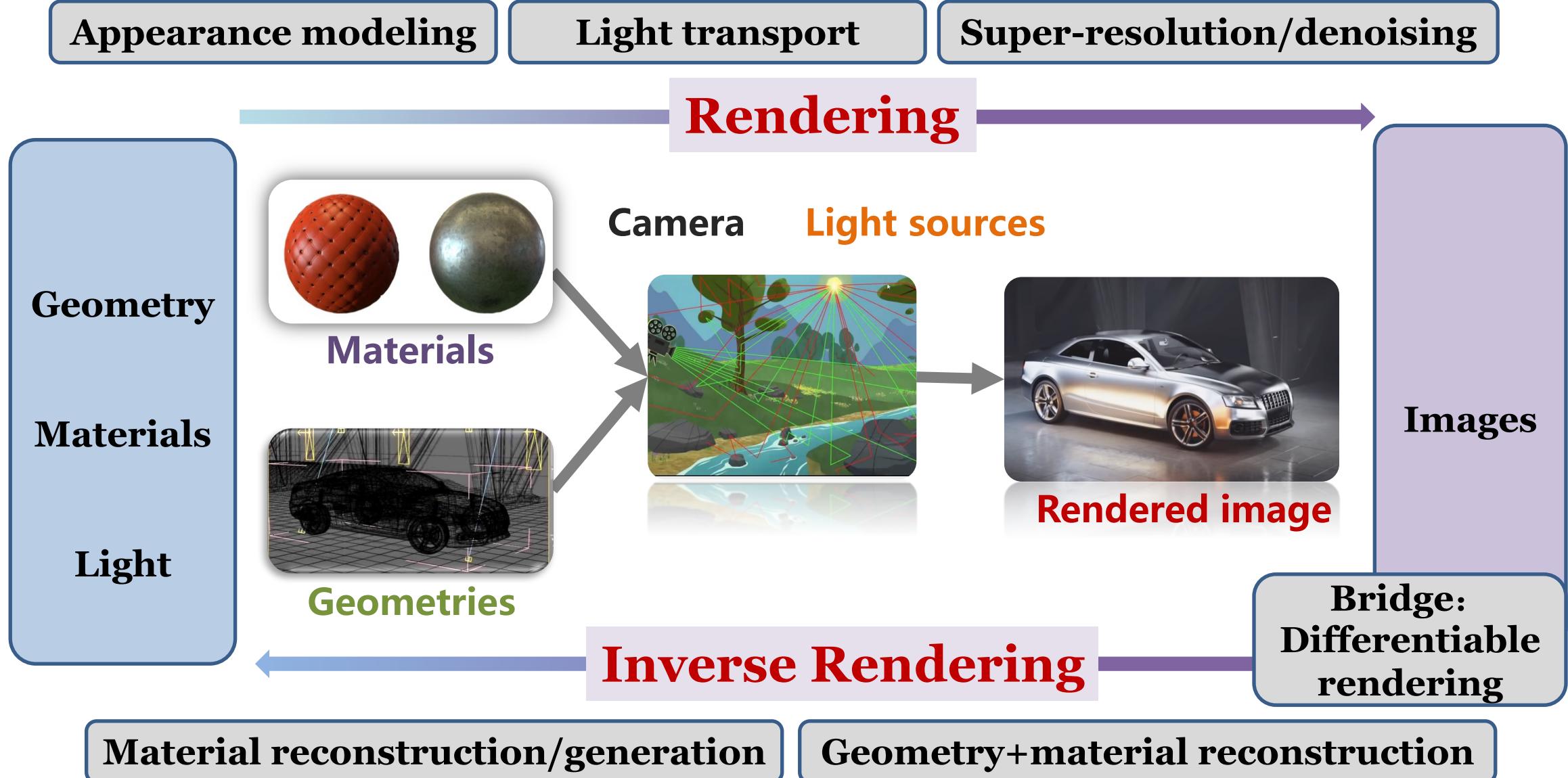


Rendering and Inverse Rendering





Rendering and Inverse Rendering





What's new in rendering?

Appearance modeling

Light transport

Super-resolution/denoising

Rendering

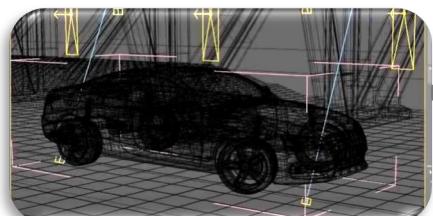
Geometry

Materials

Light



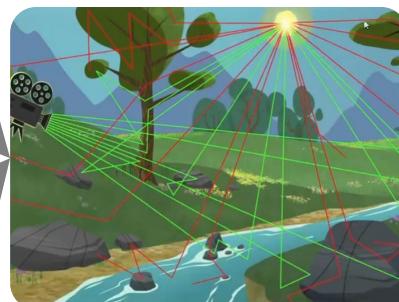
Materials



Geometries

Camera

Light sources



Rendered image

Images

New theory? “old” theory from other domains?
new tools from AI?



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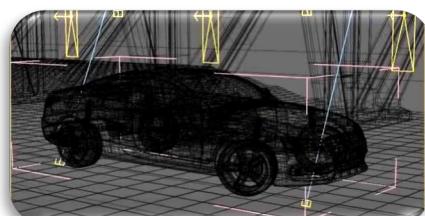
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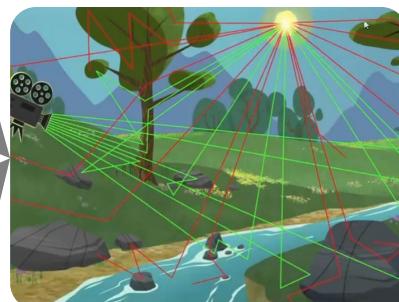
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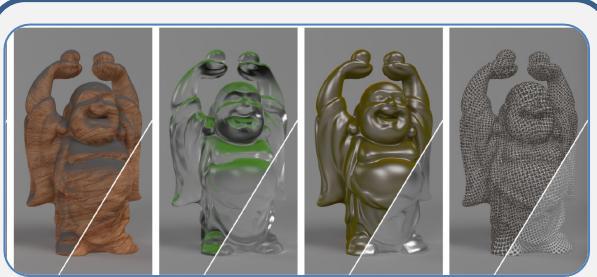


Rendering - Appearance modeling

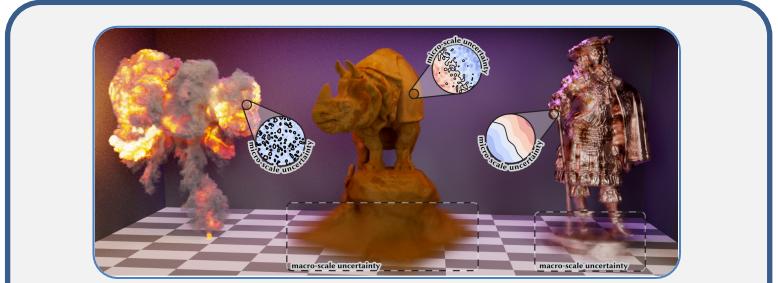
Physically-based



Practical models for **diffraction of rough fibers** and **free-space diffractions**
[Xia et al. 2023, Steinberg et al. 2024]



Micrograin BSDF model for anisotropic porous layers
[Lucas et al. 2023, 2024]



Unifying lighting transport from surface to volume via Gaussian process implicit surfaces
[Seyb et al. 2024]

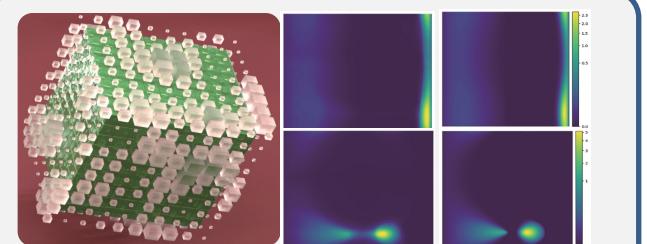
Neural-based



Neural **representation** for complex materials
[Fan et al. 2023, Zeltner et al. 2024]



Neural material **editing and synthesis**
[Xu et al. 2024, Tu et al. 2024]



Neural **BSDF sampling with diffusion models**
[Fu et al. 2024]



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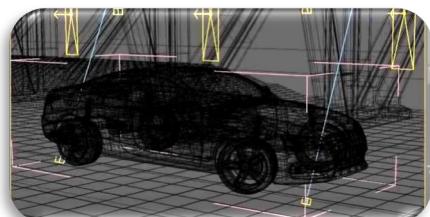
Geometry

Materials

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Materials



Geometries

Camera

Light sources



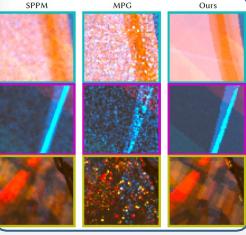
Rendered image

Images

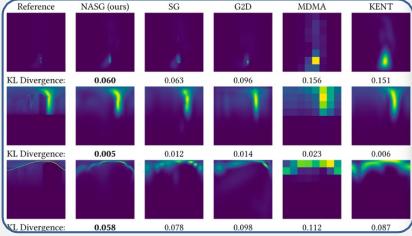
New theory? “old” theory from other domains?
new tools from AI?



Rendering - Light transport



Specular polynomials, a Newton iteration-free methodology
[Fan et al. 2024]



Neural path guiding by learning
NASG/SGs with small networks.
[Dong et al. 2023, Huang et al. 2024]



Per-object learn neural light transfer function.
[Zheng et al. 2023]

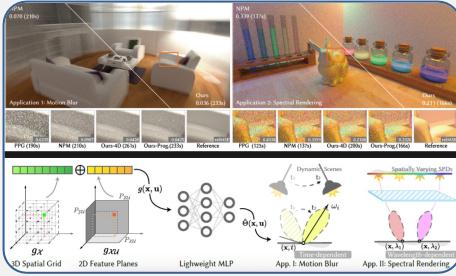
Classical

Neural-aided

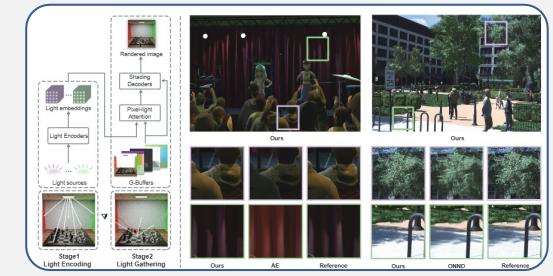
Neural



ReSTIR for **defocusing & antialiasing** / ReSTIR with **MCMC**.
[Sawhney et al., Zhang et al. 2024]



Efficient **neural path guiding** with
4D modeling.
[Dong et al. 2024]

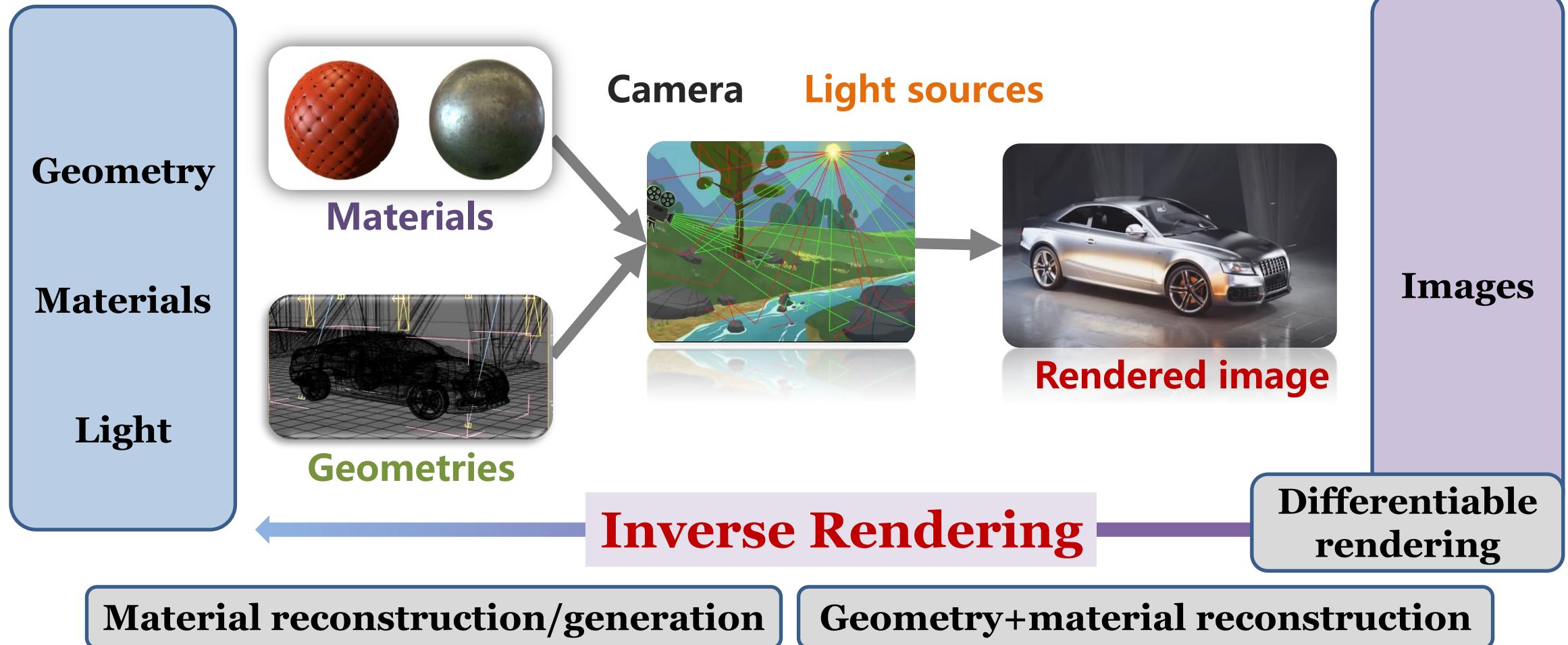


Neural representation of light sources for dynamic rendering.
[Ren et al. 2024]



Inverse Rendering

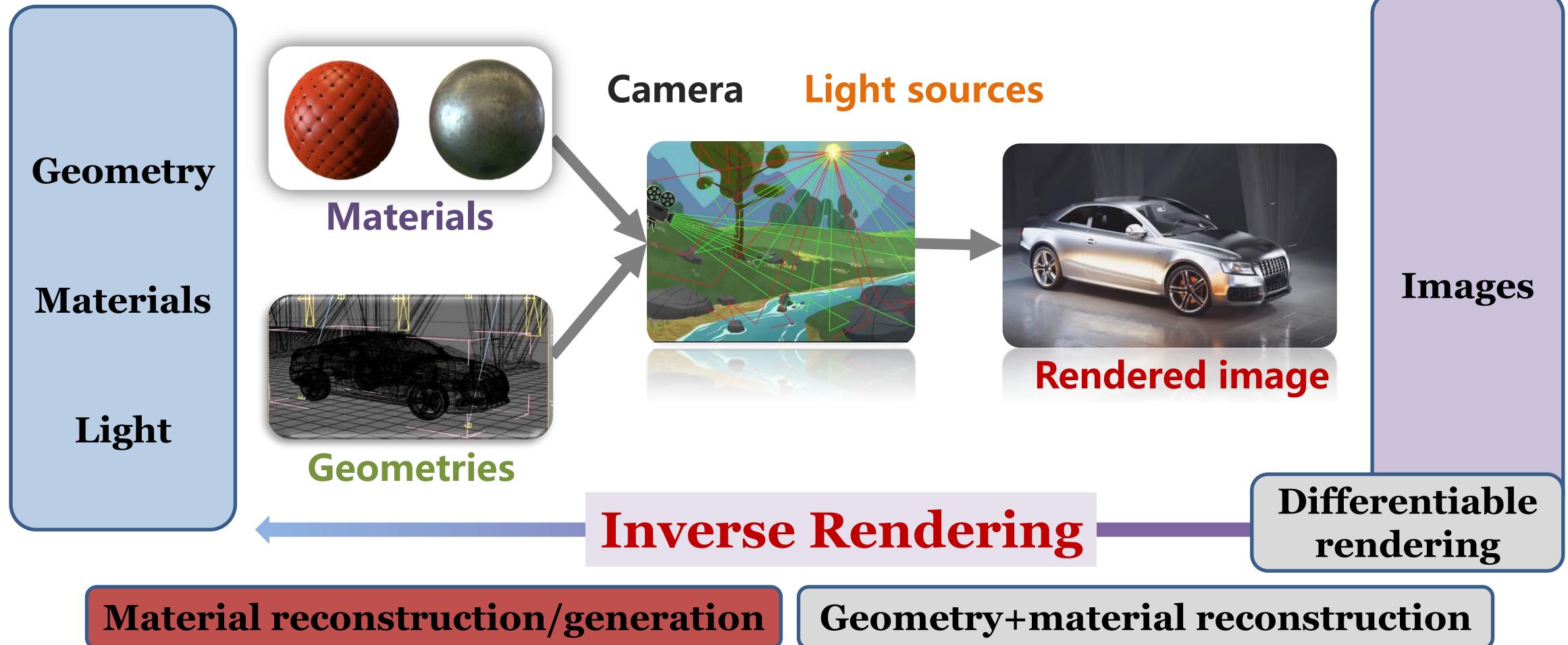
New geometry representation (3D Gaussian),
new AI tools (diffusion models)





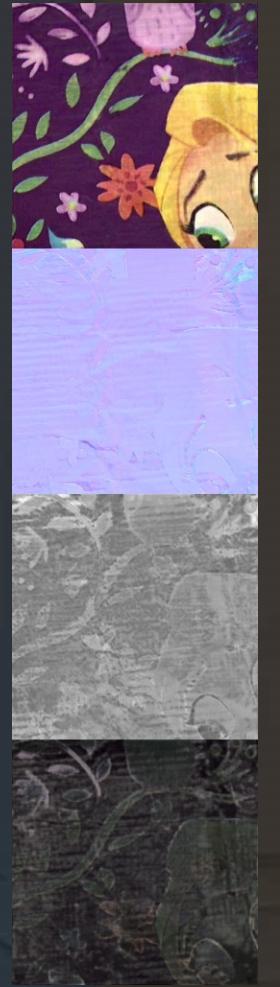
Inverse Rendering

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Material Reconstruction



How to reduce ambiguity?



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Material Reconstruction

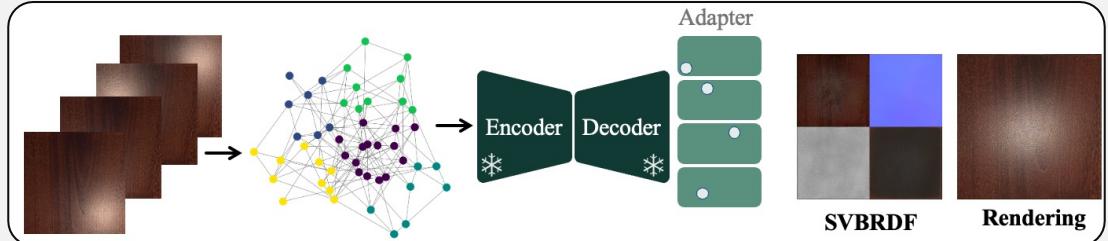
Capture strategy:



The **far-field image** has **specular only**.

[Wang et al. 2024]

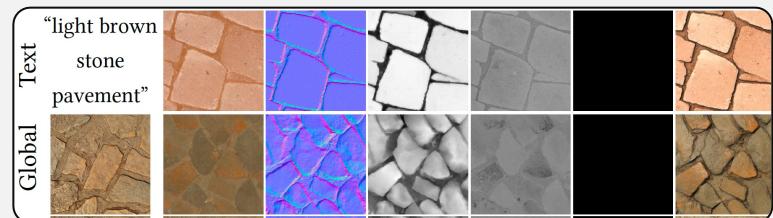
Feature modeling:



Graph CN to model **correlation** of inputs.

[Luo et al. 2024]

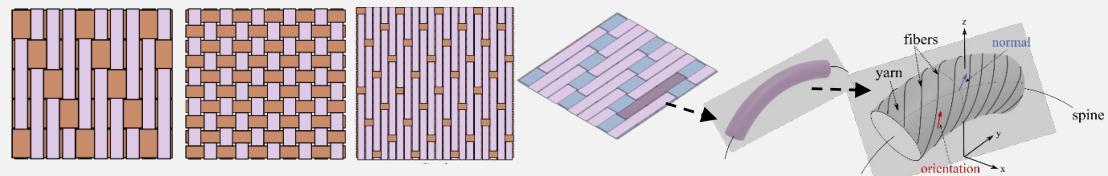
Neural network:



Diverse conditions by **diffusion models**

[Sartor et al. 2023] [Vecchio et al. 2024]

Specific models for fabrics :



Procedural geometry for regularization.

[Tang et al. 2024]



Material Generation

Implicit texture prior:

A deep convolutional-PBR neural representation for SDS optimization

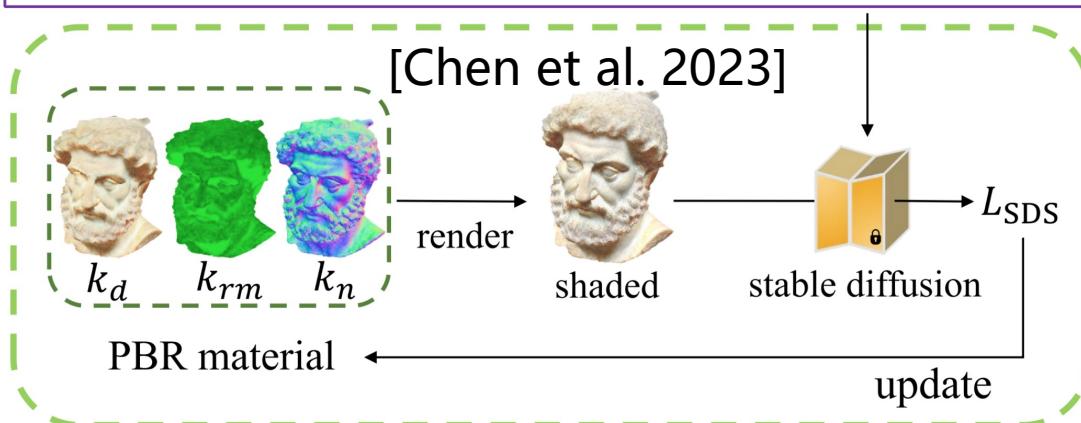
Paint it [Youwang et al. 2024]

Segment-aware generation:

Albedo map generation, and **material graph** for other maps.

Mapa [Zhang et al. 2024a]

“a highly detailed stone bust of Theodoros Kolokotronis”



Geometry and light-aware generation:

Reduce the light **baked-in** issue

DreamMat [Zhang et al. 2024b]

Given a 3D mesh, generate PBR materials with pre-trained diffusion models via SDS or its variants.

Texture-conditioned generation:

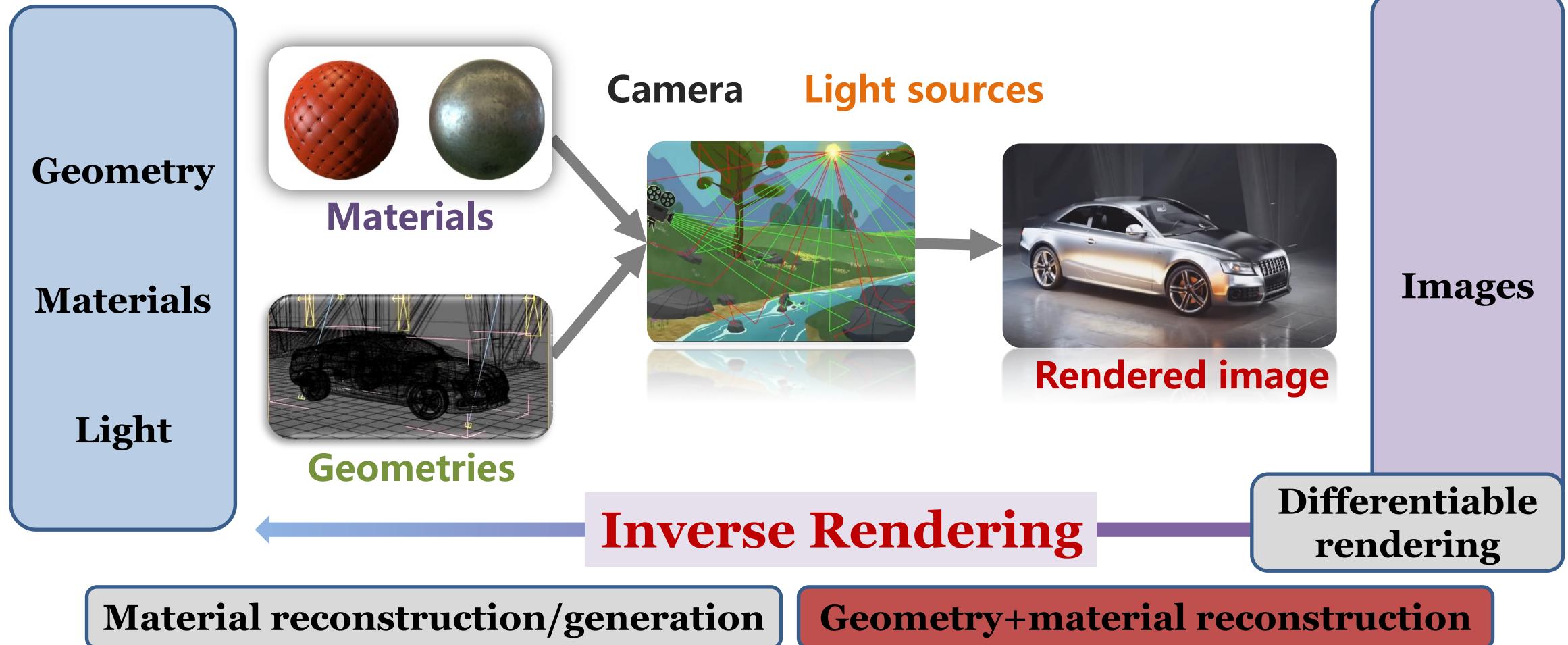
Generate PBR maps from given sparse images with personalized geometry-aware score distillation

TextureDreamer [Yeh et al. 2024]



Inverse Rendering

New geometry representation (3D Gaussian),
new AI tools (diffusion models)





Inverse Rendering

Geometry

Density Field

- Flexible
- Non-surface objects
- Under-constrained

SDF

- Surface only
- With constraints

3D Gaussian

- Detail-preserved
- Discontinuity

Reflectance Field – Material & Light Decouple

Material

Analytical Model

- Fewer parameters
- Limited capability

Neural Model

- Wide-range materials
- Ambiguity & overfitting

Light

Image

- Direct Illumination
- High flexibility

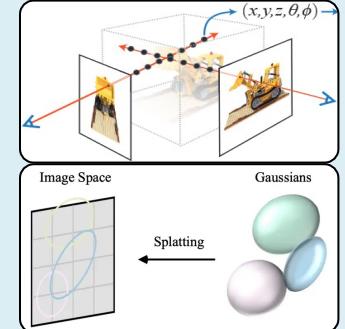
Neural Light

- Direct & Indirect
- High flexibility+

Render

Volume Rendering

- Expensive to eval
- Easy to fit modern graphics pipeline



Radiance Field – Material & Light Entangle

- Learn a color to replace material & light
- Easy to optimize
- Cannot achieve relighting

Rasterization

- Fast/Real-time
- Difficult to fit modern graphics pipeline

NeRF-based

Volume Rendering

TensoIR [Jin et al, 2023]

Density Field

Fast & high-quality occlusion
for Lambertian objects.

SGs

NeRO [Liu et al. 2023]

Neural Light

Integrate rendering equation to enable
reflective surfaces.

SDF

TensoSDF [Li et al. 2024]

SDF

Radiance Field

Fast training, detailed geom.
and **robust materials**.

Density Field

Neural Light

NRHints [Zeng et al. 2023]

Use **point light** to decouple
materials and lights.

SDF

Neural Light

Point Light

GS-based

3D Gaussian

Rasterization

GS-IR, GaussianShader

Env. Map

Radiance Field

[Jiang et al., Gao et al., Liang et al. 2024]

Geometry constraints via normal/depth
regularization.

GS-ROR [Zhu et al. 2024]

Env. Map

Regularize Gaussians with **SDF**
priors for **reflective object** relighting.

SDF

GS³ [Bi et al. 2024]

Point Light

RNG [Fan et al. 2024]

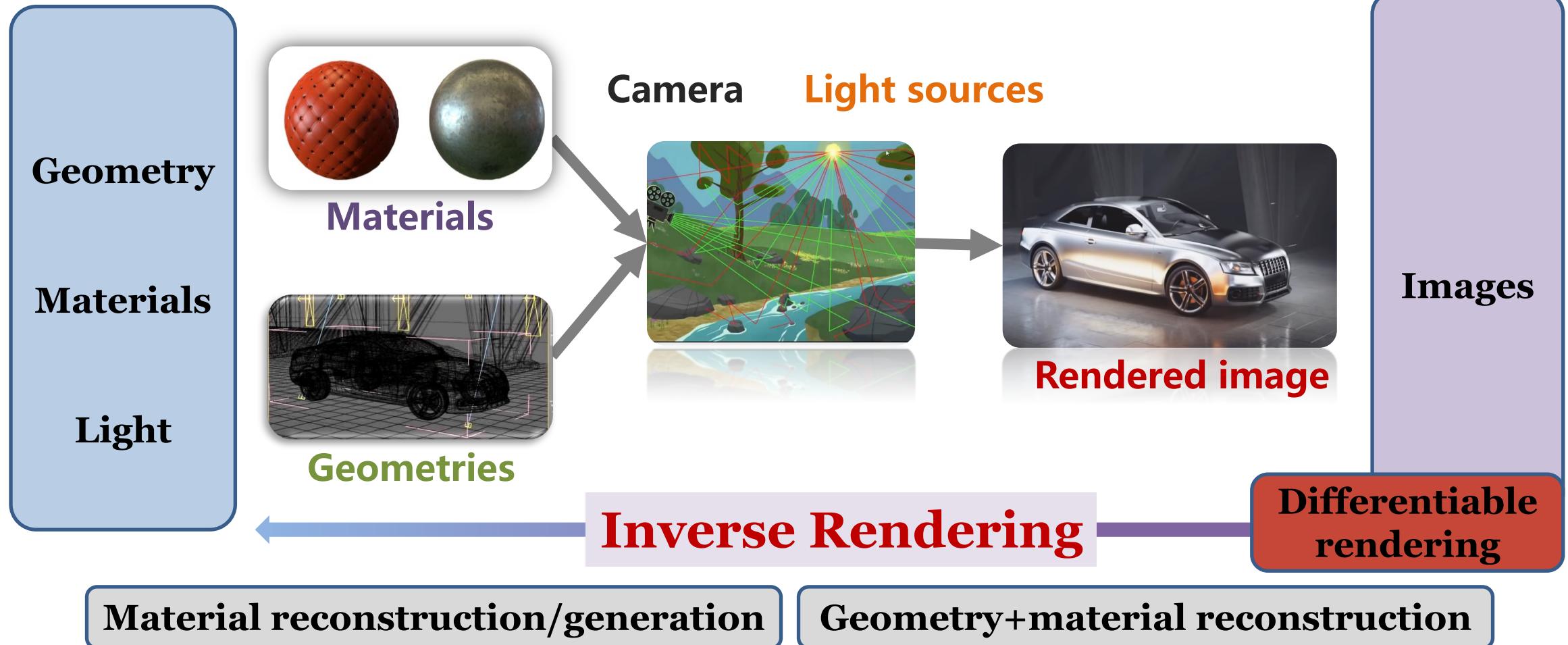
Radiance Field

Relightable 3D Gaussians under **point
lights, enabling both surface and furry
objects**.



Inverse Rendering

New geometry representation (3D Gaussian),
new AI tools (diffusion models)



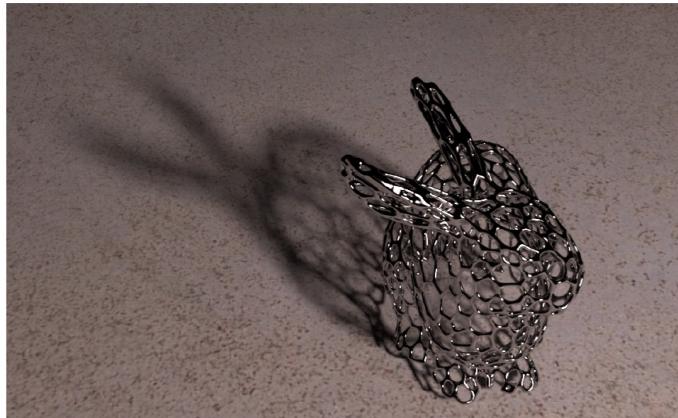


Differentiable Rendering

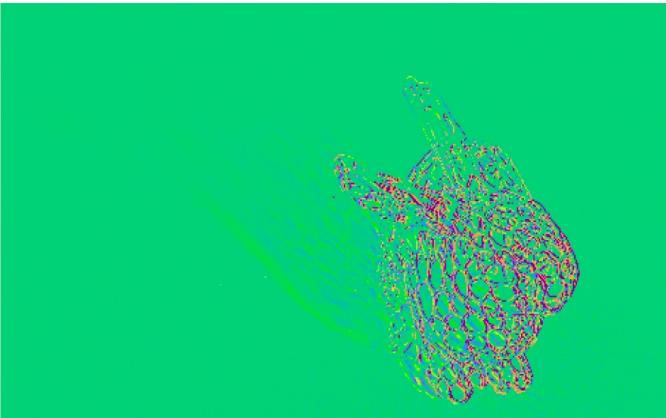
Geometry representation:

From **mesh** to **implicit geometries**.

[Zhou et al. 2024]



(a) Ordinary

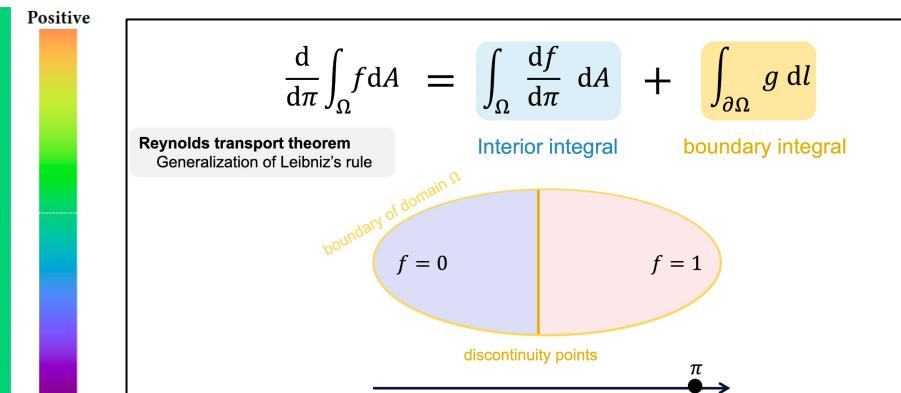


(b) Derivative

Differentiating subject:

From **radiance** to **variance**.

[Yan et al. 2024]



[Zhang et al. 2020]

Boundary integral estimator:

From **path integral sampling** to **MCMC**.

[Xu et al. 2024]

Acceleration of sampling:

Path guiding to differentiable rendering.

[Fan et al. 2024]



Summary

➤ **Rendering**

- Appearance modeling: physically-based models vs. neural-based models
- Light transport: classical / neural aided / pure neural

➤ **Inverse Rendering**

- Speed and quality of NeRF vs. 3D Gaussians
- A big gap between the forward and inverse rendering in terms of shading models / appearance quality



感谢大家的聆听！

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<https://wangningbei.github.io/>

This slide will be available soon.



李子轩



朱作良



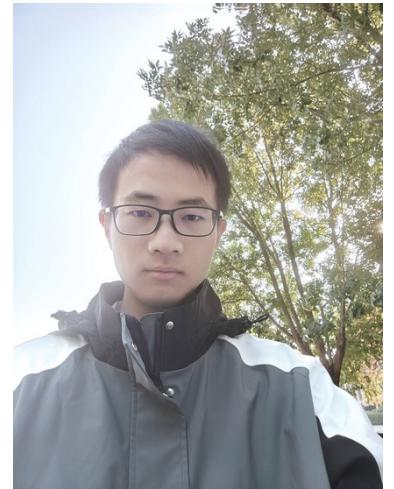
樊家辉



罗迪



王子雄



汤英杰





References – Appearance Modeling

- [Xia et al. 2023] A Practical Wave Optics Reflection Model for Hair and Fur
- [Steinberg et al. 2024] A Free-Space Diffraction BSDF
- [Lucas et al. 2024] A Fully-correlated Anisotropic Micrograin BSDF Model
- [Seyb et al. 2024] From microfacets to participating media: A unified theory of light transport with stochastic geometry
- [Fan et al. 2023] Neural Biplane Representation for BTF Rendering and Acquisition
- [Zeltner et al. 2024] Real-Time Neural Appearance Models
- [Xu et al. 2024] A Dynamic By-example BTF Synthesis Scheme
- [Tu et al. 2024] Compositional Neural Textures
- [Fu et al. 2024] BSDF Importance Sampling using a Diffusion Model



References – Light transport

[Fan et al. 2024] Specular Polynomials

[Sawhney et al. 2024] Decorrelating ReSTIR Samplers via MCMC Mutations

[Zhang et al. 2024] Area ReSTIR: Resampling for Real-Time Defocus and Antialiasing

[Dong et al. 2023] Neural Parametric Mixtures for Path Guiding

[Huang et al. 2024] Online Neural Path Guiding with Normalized Anisotropic SphericalGaussians

[Dong et al. 2024] Efficient Neural Path Guiding with 4D Modeling

[Zhen et al. 2024] NeLT: Object-Oriented Neural Light Transfer

[Ren et al. 2024] LightFormer: Light-Oriented Global Neural Rendering in Dynamic Scene



References – Material Reconstruction

[Wang et al. 2024] NFPLight: Deep SVBRDF Estimation via the Combination of Near and Far Field Point lighting

[Luo et al. 2024] Correlation-aware Encoder-Decoder with Adapters for SVBRDF Acquisition

[Sartor et al. 2023] MatFusion: a Generative Diffusion Model for SVBRDF Capture

[Vecchio et al. 2024] ControlMat: A Controlled Generative Approach to Material Capture

[Tang et al. 2024] Woven Fabric Capture with a Reflection-Transmission Photo Pair



References – Material Generation

[Chen et al. 2023] **Fantasia3D: Disentangling Geometry and Appearance for High-quality Text-to-3D Content Creation**

[Yeh et al. 2024] **TextureDreamer: Image-guided Texture Synthesis through Geometry-aware Diffusion**

[Zhang et al. 2024a] **MaPa: Text-driven Photorealistic Material Painting for 3D Shapes**

[Zhang et al. 2024b] **DreamMat: High-quality PBR Material Generation with Geometry- and Light-aware Diffusion Models**

[Youwang et al. 2024] **Paint-it: Text-to-Texture Synthesis via Deep Convolutional Texture Map Optimization and Physically-Based Rendering**



References – Inverse Rendering

[Liu et al. 2024] NeRO: Neural Geometry and BRDF Reconstruction of Reflective Objects from Multiview Images

[Li et al. 2024] TensoSDF: Roughness-aware Tensorial Representation for Robust Geometry and Material Reconstruction

[Jiang et al. 2024] GaussianShader: 3D Gaussian Splatting with Shading Functions for Reflective Surfaces

[Liang et al. 2024] GS-IR: 3D Gaussian Splatting for Inverse Rendering

[Gao et al. 2024] Relightable 3D Gaussian: Real-time Point Cloud Relighting with BRDF Decomposition and Ray Tracing



References – Differentiable Rendering

[Zhou et al. 2024] Path-Space Differentiable Rendering of Implicit Surfaces

[Yan et al. 2024] Differentiating Variance for Variance-Aware Inverse Rendering

[Xu et al. 2024] Markov-Chain Monte Carlo Sampling of Visibility Boundaries for Differentiable Rendering

[Fan et al. 2024] Conditional Mixture Path Guiding for Differentiable Rendering

[Zhang et al. 2020] Path-Space Differentiable Rendering