Chinagraph 2024

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

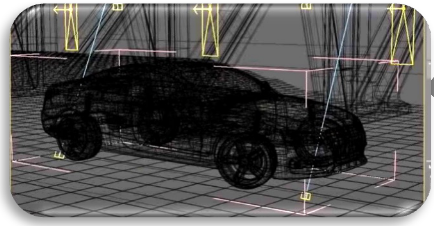
Rendering

Geometry

Materials

Light

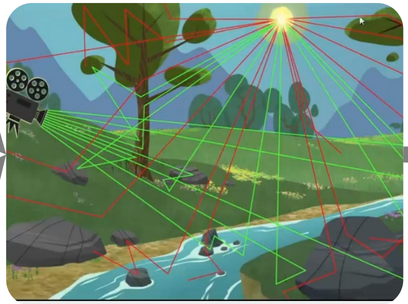
Materials



Geometries

Camera

Light sources



Rendered image

Images

Inverse Rendering

Rendering and Inverse Rendering

Appearance modeling | Light transport | Super-resolution/denoising

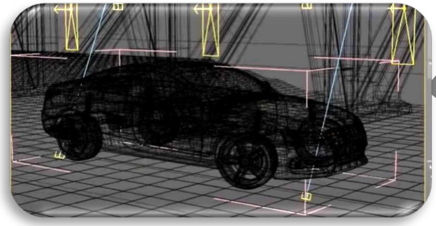
Rendering →

Geometry

Materials

Light

Materials



Geometries

Camera

Light sources

Rendered image

Images

Bridge: Differentiable rendering

← **Inverse Rendering**

Material reconstruction/generation | Geometry+material reconstruction

What's new in rendering?

Appearance modeling | Light transport | Super-resolution/denoising

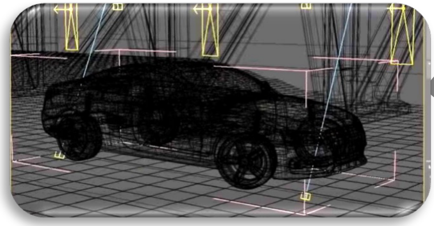
Rendering

Geometry

Materials

Light

Materials



Geometries

Camera Light sources

Rendered image

Images

New theory? "old" theory from other domains?
new tools from AI?

What's new in rendering?

Appearance modeling | **Light transport** | **Super-resolution/denoising**

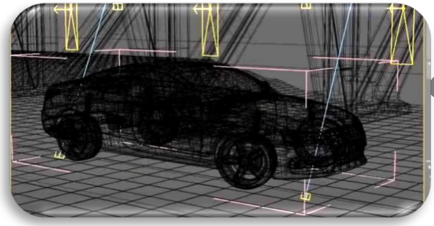
Rendering →

Geometry

Materials

Light

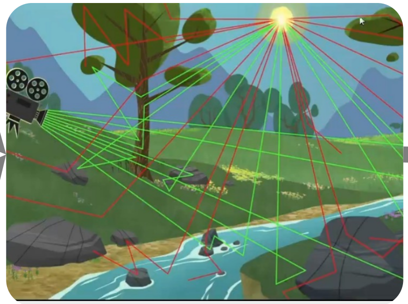
Materials



Geometries

Camera

Light sources



Rendered image

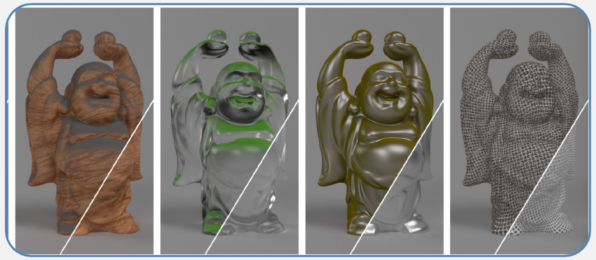
Images

New theory? "old" theory from other domains? new tools from AI?

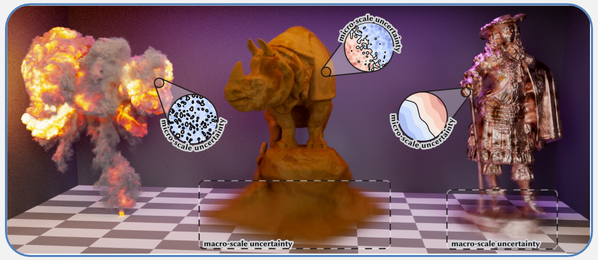
Rendering - Appearance modeling

Phyically-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]

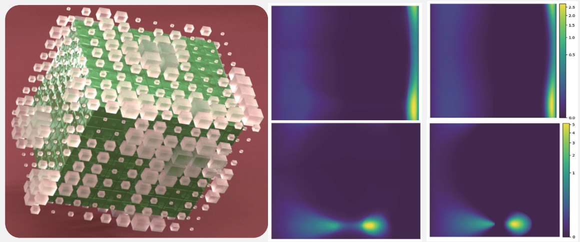


Unifying lighting transport from **surface to volume** via Gaussian process implicit surfaces
[Seyb et al. 2024]

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]

What's new in rendering?

Appearance modeling | **Light transport** | Super-resolution/denoising

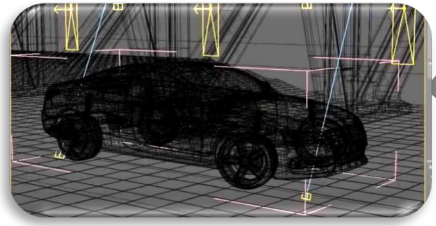
Rendering

Geometry

Materials

Light

Materials



Geometries

Camera

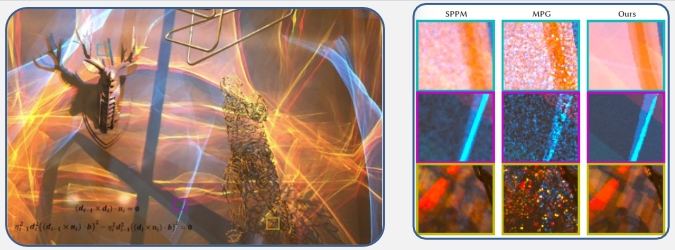
Light sources

Rendered image

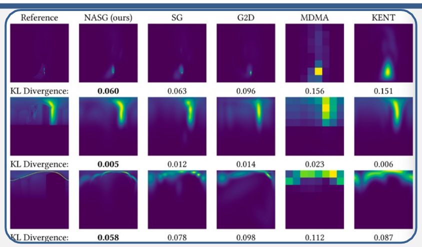
Images

New theory? "old" theory from other domains?
new tools from AI?

Rendering - Light transport



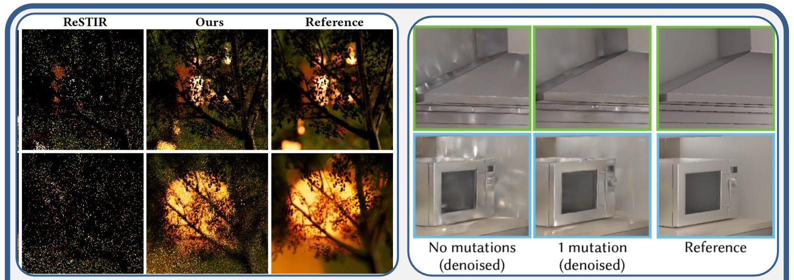
Specular polynomials, a Newton iteration-free methodology
[Fan et al. 2024]



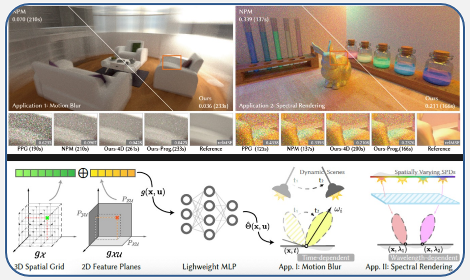
Neural path guiding by learning **NASG/SGs** with small networks.
[Dong et al. 2023, Huang et al. 2024]

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

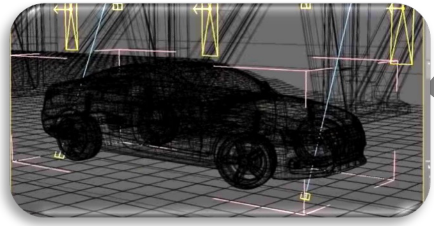
New geometry respresentation (3D Gaussian), new AI tools (diffusion models)

Geometry

Materials

Light

Materials



Geometries

Camera

Light sources

Rendered image

Images

Inverse Rendering

Differentiable rendering

Material reconstruction/generation

Geometry+material reconstruction

Inverse Rendering

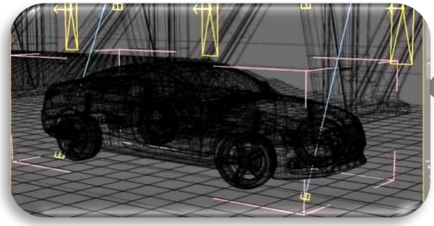
New geometry respresentation (3D Gaussian), new AI tools (diffusion models)

Geometry

Materials

Light

Materials



Geometries

Camera

Light sources

Rendered image

Images

Differentiable rendering

Inverse Rendering

Material reconstruction/generation

Geometry+material reconstruction

Material Reconstruction

How to reduce ambiguity?

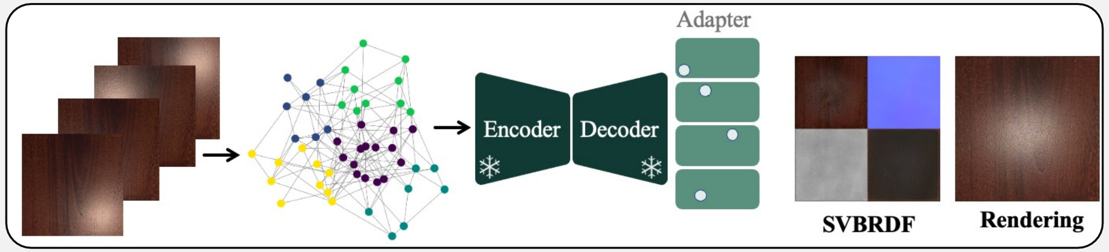
Material Reconstruction

Capture strategy:

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

[Wang et al. 2024]

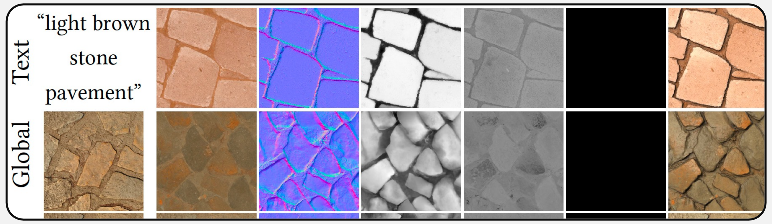
Feature modeling:



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

[Luo et al. 2024]

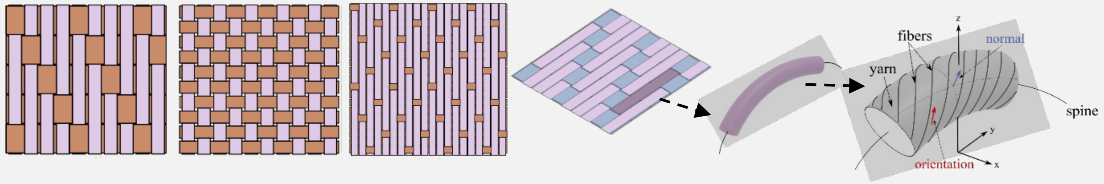
Neural network:



Diverse conditions by **diffusion models**

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

Specific models for fabrics :



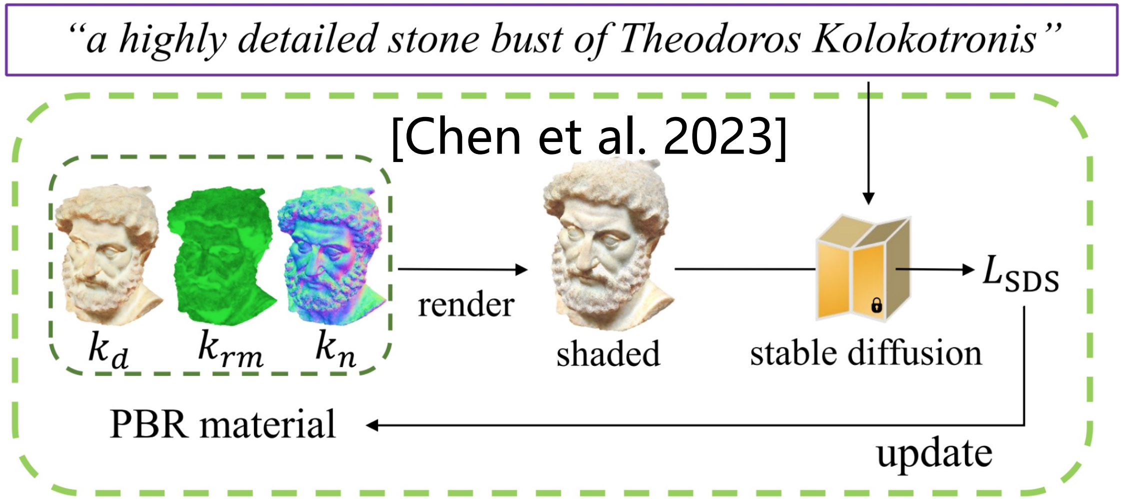
Procedural geometry for regularization.

[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]



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

Geometry and light-aware generation:
Reduce the light **baked-in** issue
DreamMat [Zhang et al. 2024b]

Texture-conditioned generation:
Generate PBR maps from given sparse images with personalized geometry-aware score distillation
TextureDreamer [Yeh et al. 2024]

Inverse Rendering

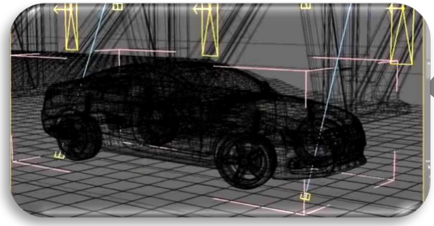
New geometry respresentation (3D Gaussian), new AI tools (diffusion models)

Geometry

Materials

Light

Materials



Geometries

Camera

Light sources

Rendered image

Images

Inverse Rendering

Differentiable rendering

Material reconstruction/generation

Geometry+material reconstruction

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

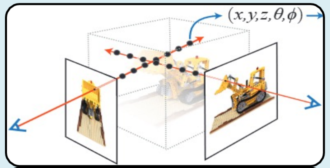
Neural Light
- Direct & Indirect
- High flexibility+

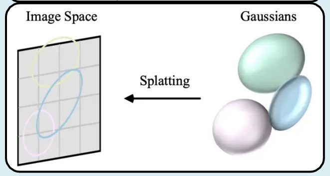
Spherical Gaussians
- Direct Illumination
- Fewer parameters
- Loss high-frequency details

Radiance Field – Material & Light Entangle
- Learn a color to replace material & light
- Easy to optimize
- Cannot achieve relighting

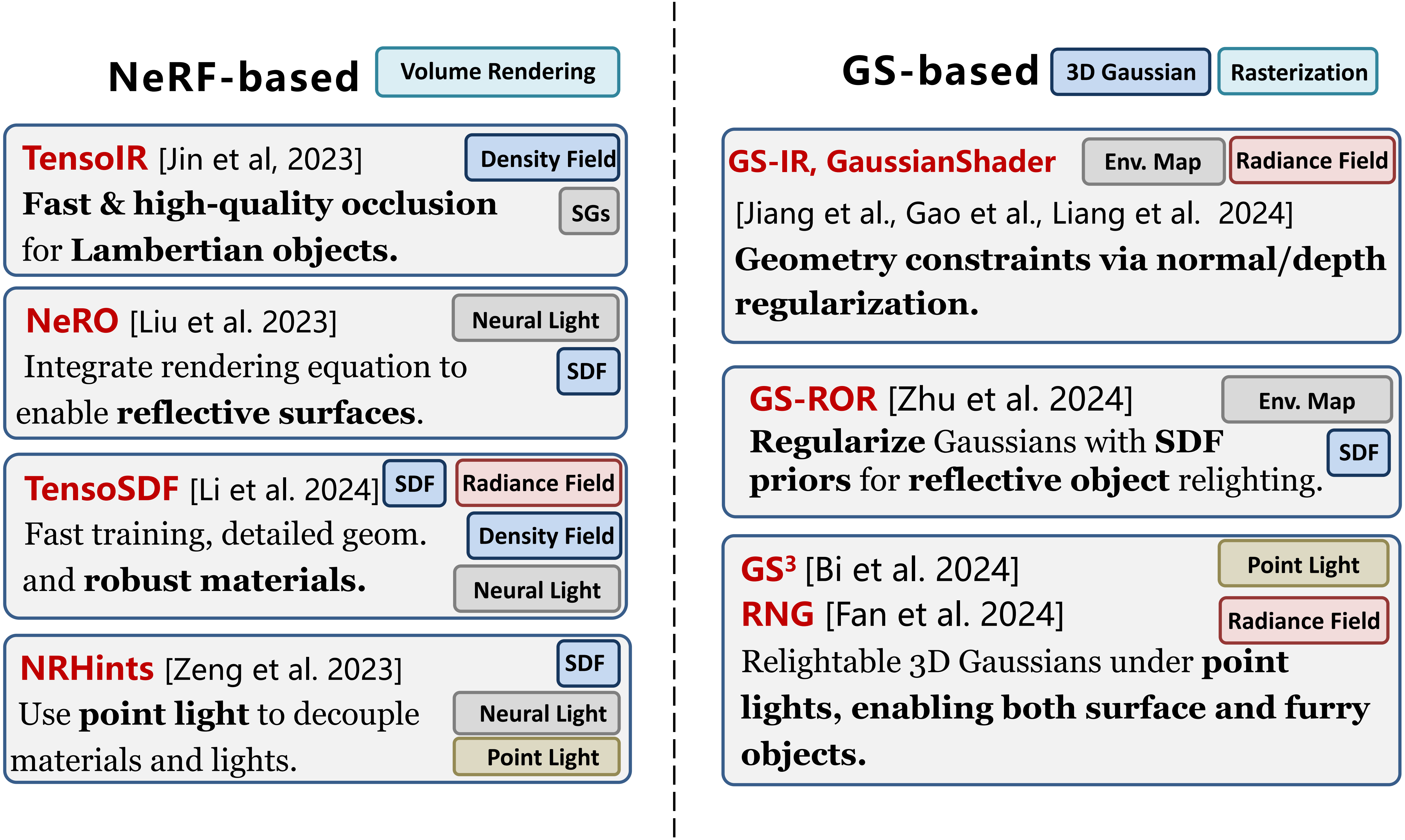
Render

Volume Rendering
- Expensive to eval
- Easy to fit modern graphics pipeline





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


NeRF-based
Volume Rendering
TensoIR [Jin et al, 2023]
Density Field
SGs
Fast & high-quality occlusion for Lambertian objects.
NeRO [Liu et al. 2023]
Neural Light
SDF
Integrate rendering equation to enable reflective surfaces.
TensoSDF [Li et al. 2024]
SDF
Radiance Field
Density Field
Neural Light
Fast training, detailed geom. and robust materials.
NRHints [Zeng et al. 2023]
SDF
Neural Light
Point Light
Use point light to decouple materials and lights.
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
SDF
Regularize Gaussians with SDF priors for reflective object relighting.
GS³ [Bi et al. 2024]
RNG [Fan et al. 2024]
Point Light
Radiance Field
Relightable 3D Gaussians under point lights, enabling both surface and furry objects.

Inverse Rendering

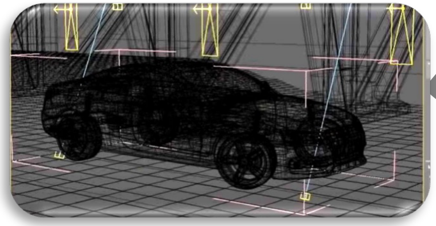
New geometry respresentation (3D Gaussian), new AI tools (diffusion models)

Geometry

Materials

Light

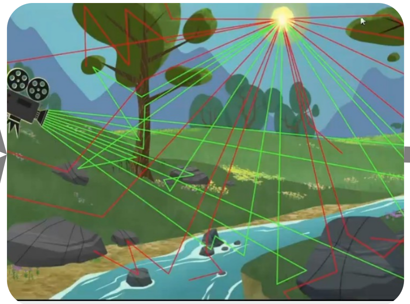
Materials



Geometries

Camera

Light sources



Rendered image

Images

Inverse Rendering

Differentiable rendering

Material reconstruction/generation

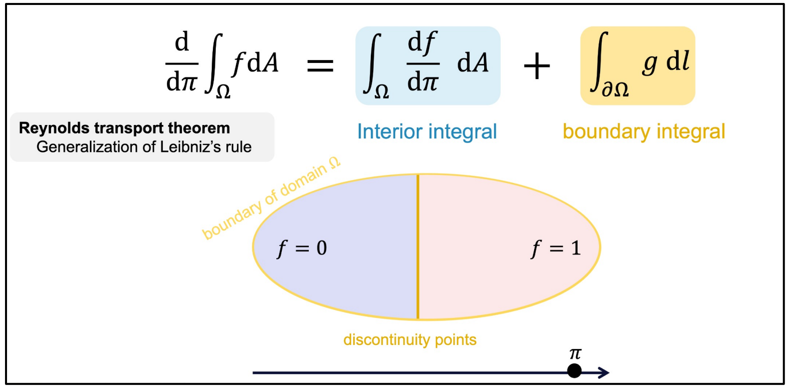
Geometry+material reconstruction

Differentiable Rendering

Geometry representation:
From **mesh** to **implicit geometries.**
[Zhou et al. 2024]

Differentiating subject:
From **radiance** to **variance**.
[Yan et al. 2024]

(a) Ordinary (b) Derivative



[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！

欢迎大家关注和支持EGSR 2025，相聚在丹麦！

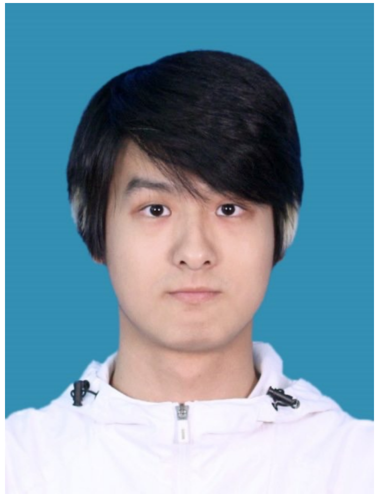
Beibei.wang@nju.edu.cn

https://wangningbei.github.io/

The slides will be available soon.

李子轩

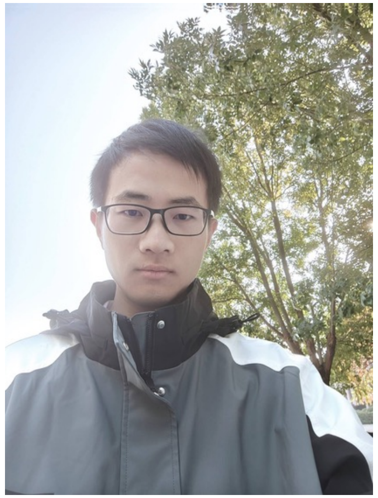
朱作良



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