Lecture 25:

Inverse Rendering

Computer Graphics and Imaging

UC Berkeley CS184

What is inverse rendering?

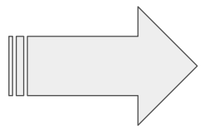
Forward rendering

Geometry

Material

Lighting

Cameras

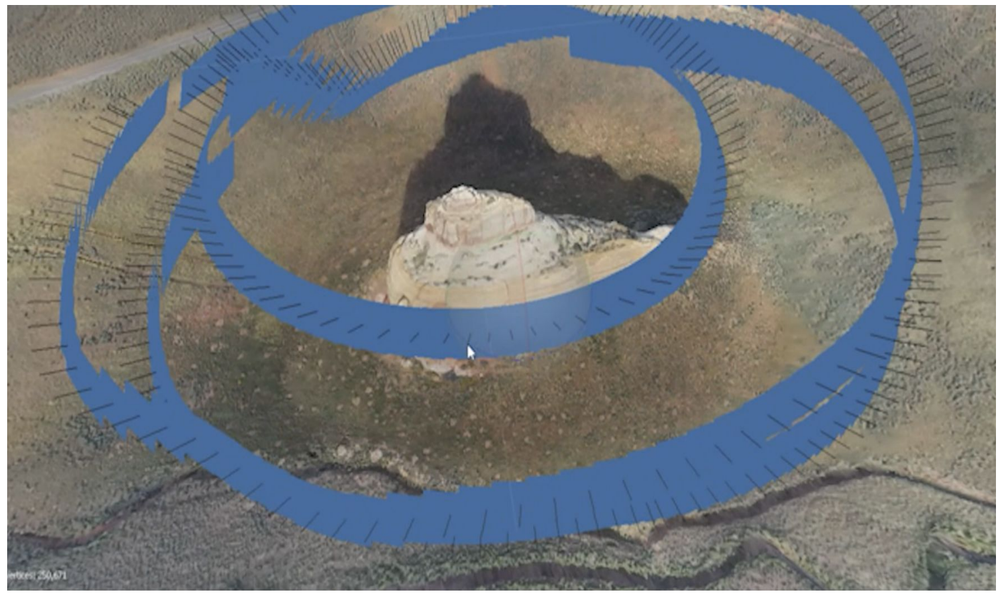


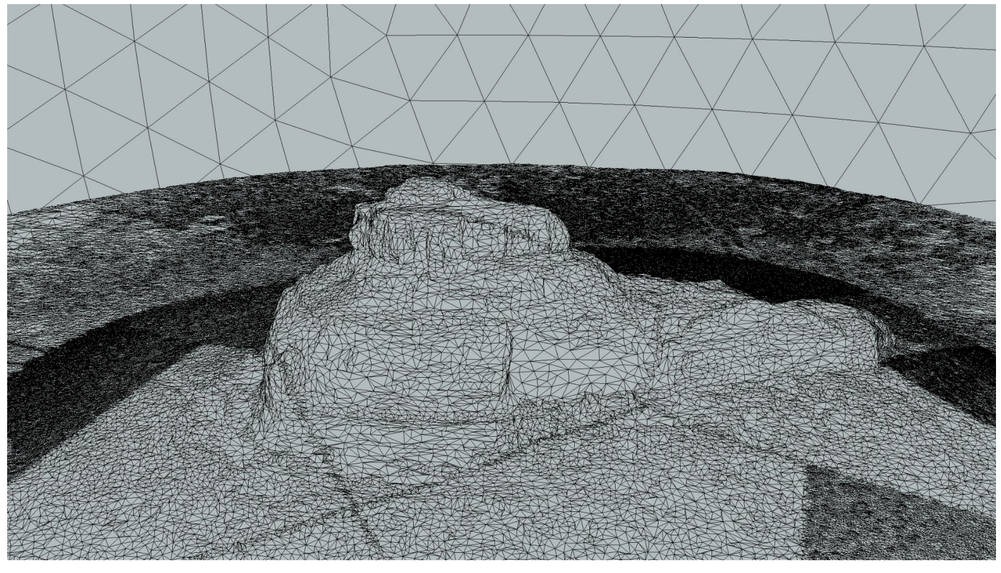
Render images

Use physically accurate models to render images.

What is inverse rendering?

Photogrammetry

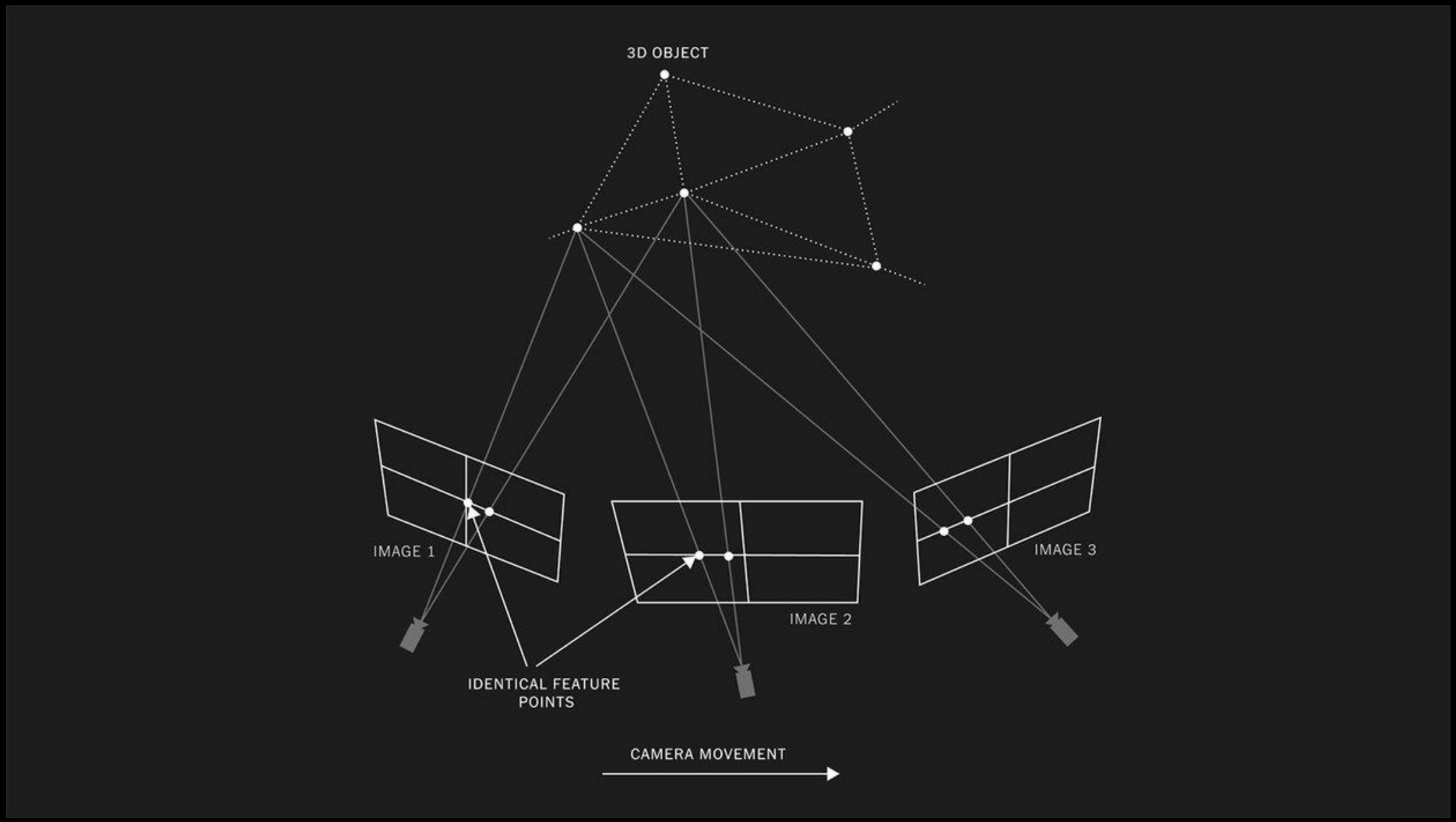




Use multiple images that **cover** a 3D space to create a **mesh** representation.

Photogrammetry Result

Photogrammetry



Photographs are taken from different points in the scene. The perceived difference in feature positions is called **parallax**, which allows us to calculate a 3D position (depth).

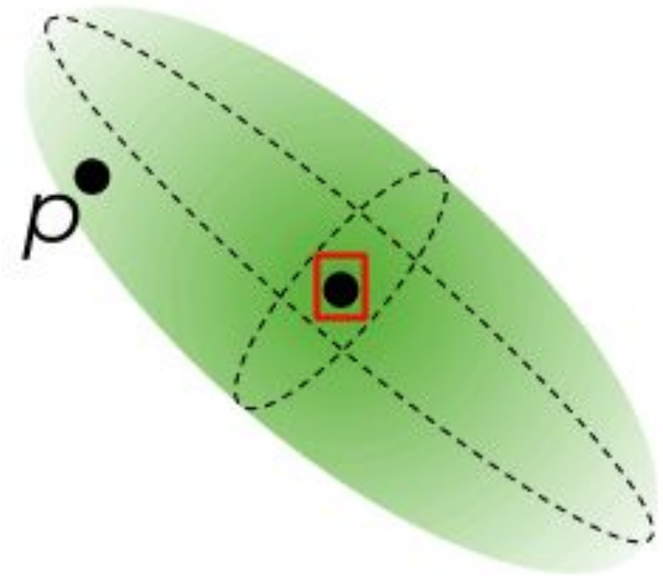
Gaussian Splatting Result

Gaussian Splatting From Point Cloud

Each 3D Gaussian is parametrized by:

- **Mean** μ interpretable as location $\mathrm{x}, \mathrm{y}, \mathrm{z}$;
- **Covariance** Σ;
- **Opacity** $\sigma(\alpha)$**,** a sigmoid function is applied to map the parameter to the [0, 1] interval;
- **Color parameters**, either 3 values for $(\mathrm{R}, \mathrm{G}, \mathrm{B})$ or spherical harmonics (SH) coefficients.

$$f_i(p) = \sigma(\alpha_i) \exp(-\frac{1}{2}(p - \boxed{\mu_i})\Sigma_i^{-1}(p - \boxed{\mu_i}))$$

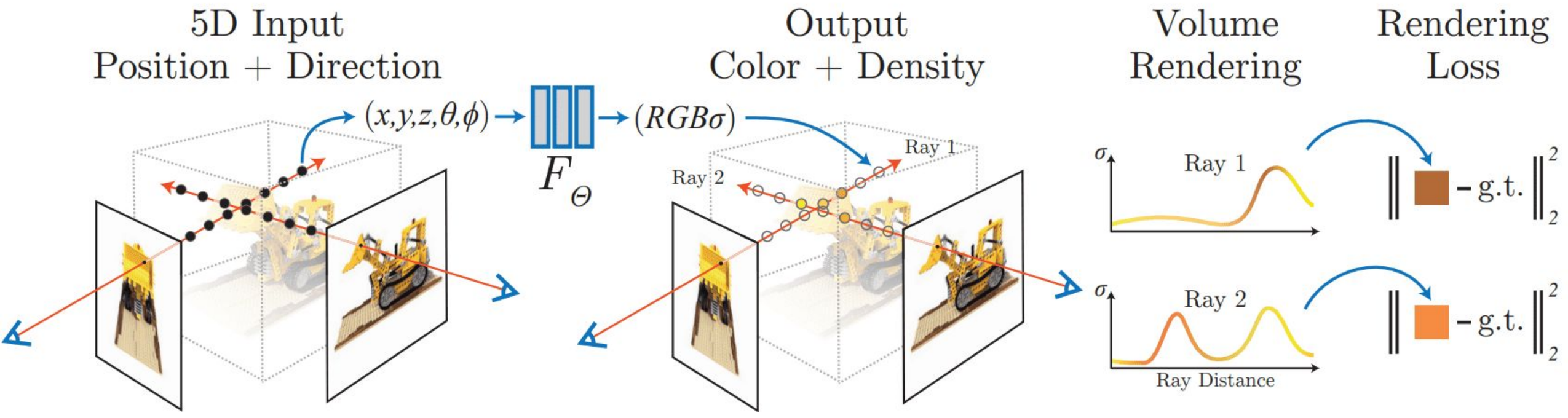


The impact of a 3D Gaussian i on an arbitrary 3D point p in 3D

Kate Yurkova, Towards Data Science

NeRF Result

Neural Radiance Fields



Inverse Rendering for Hair

Input video

Reconstruction

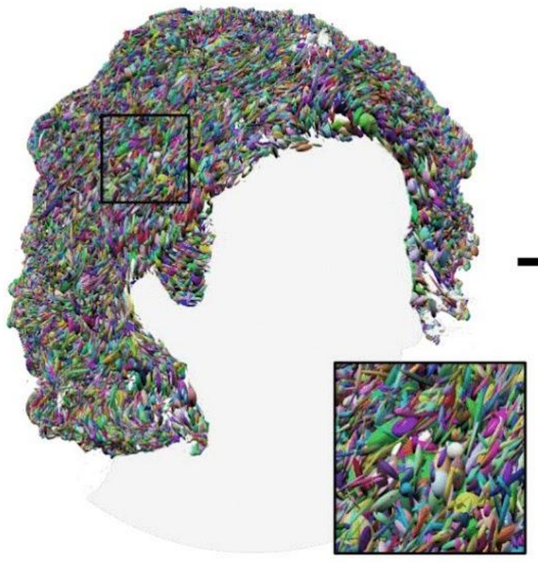
Rendering

“Gaussian Haircut ✂️”, ECCV 2024

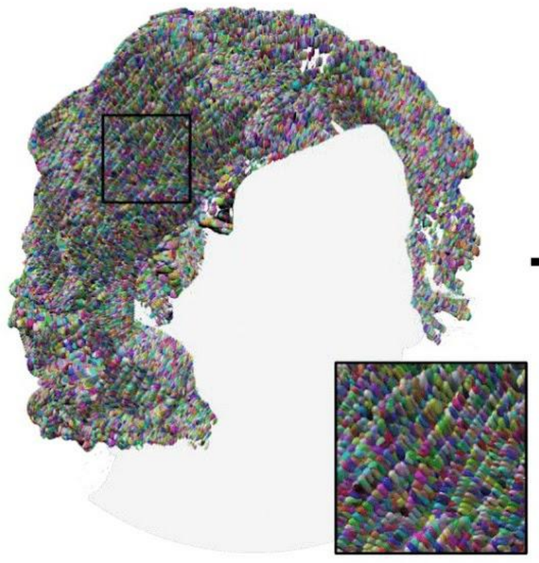
Inverse Rendering for Hair

Multi-view images

Stage 1: 3D Lifting
Unstructured Gaussians



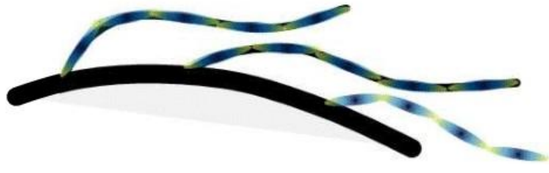
Stage 2: Strands fitting
Structured Gaussians



Strand-based Hairstyle

Unstructured Gaussians

Structured Gaussians



“Gaussian Haircut ✂️”, ECCV 2024

Gaussian Haircut

Human Hair Reconstruction with Strand-Aligned 3D Gaussians

[ECCV 2024]

Egor Zakharov [1] Vanessa Sklyarova [1,2] Michael Black [3] Giljoo Nam [3]
Justus Thies [2,4] Otmar Hilliges [1]

[1] ETH Zurich [2] Max Planck Institute of Intelligent Systems
[3] Meta [4] Technical University of Darmstadt

Inverse Rendering for Humans

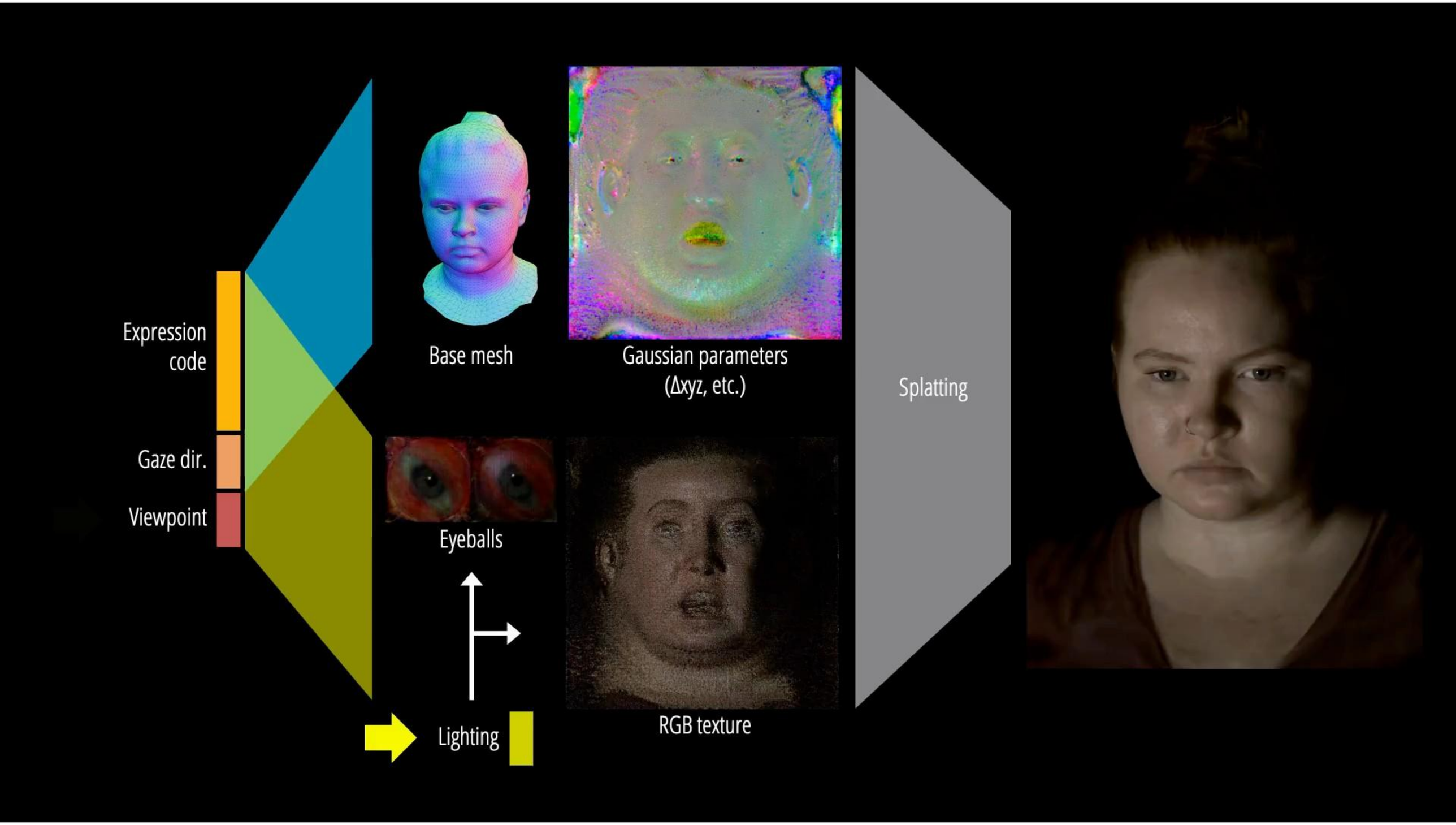
“Relightable Gaussian Codec Avatars”, CVPR 2024

Meta

Relightable and Animatable Avatars

View-dependent normals

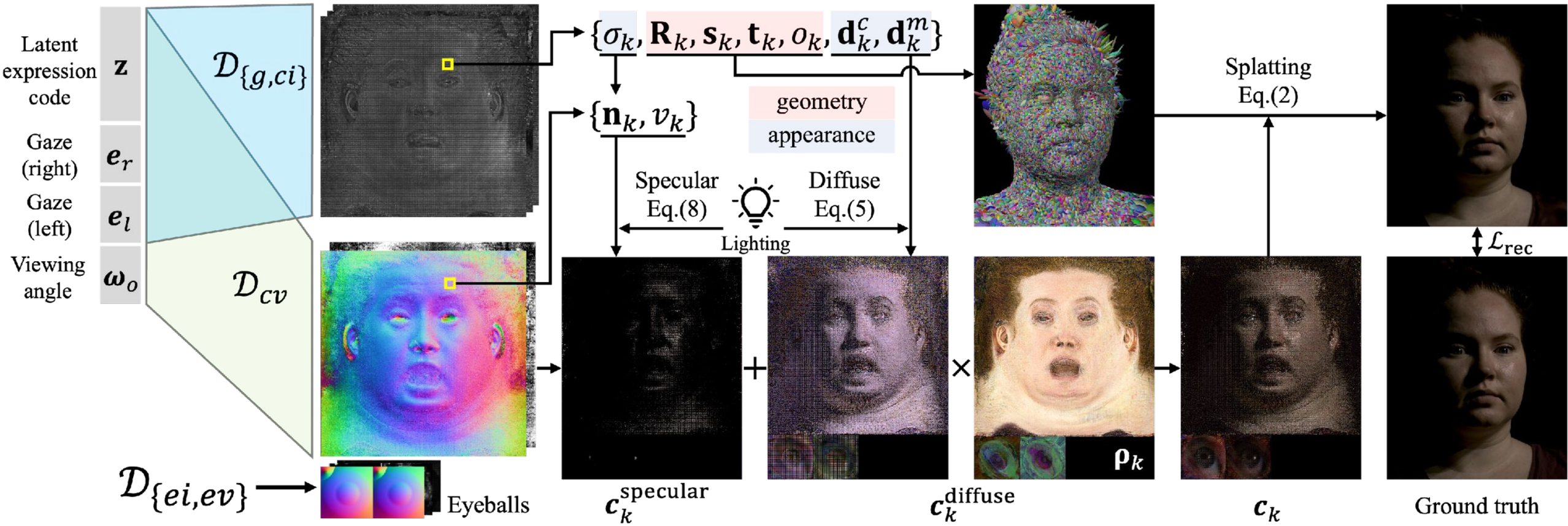
Inverse Rendering for Humans



“Relightable Gaussian Codec Avatars”, CVPR 2024

Meta

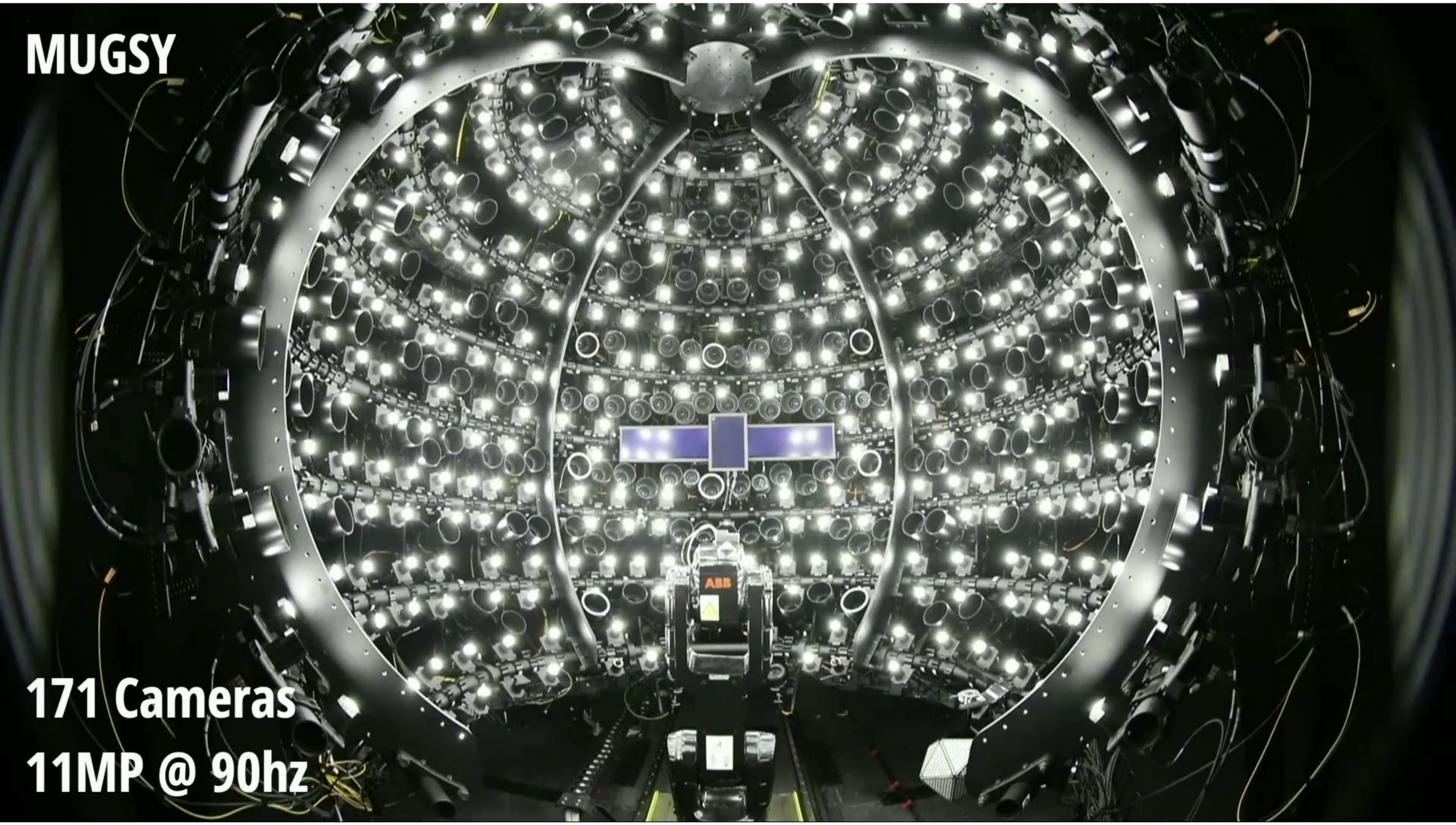
Inverse Rendering for Humans



“Relightable Gaussian Codec Avatars”, CVPR 2024

Meta

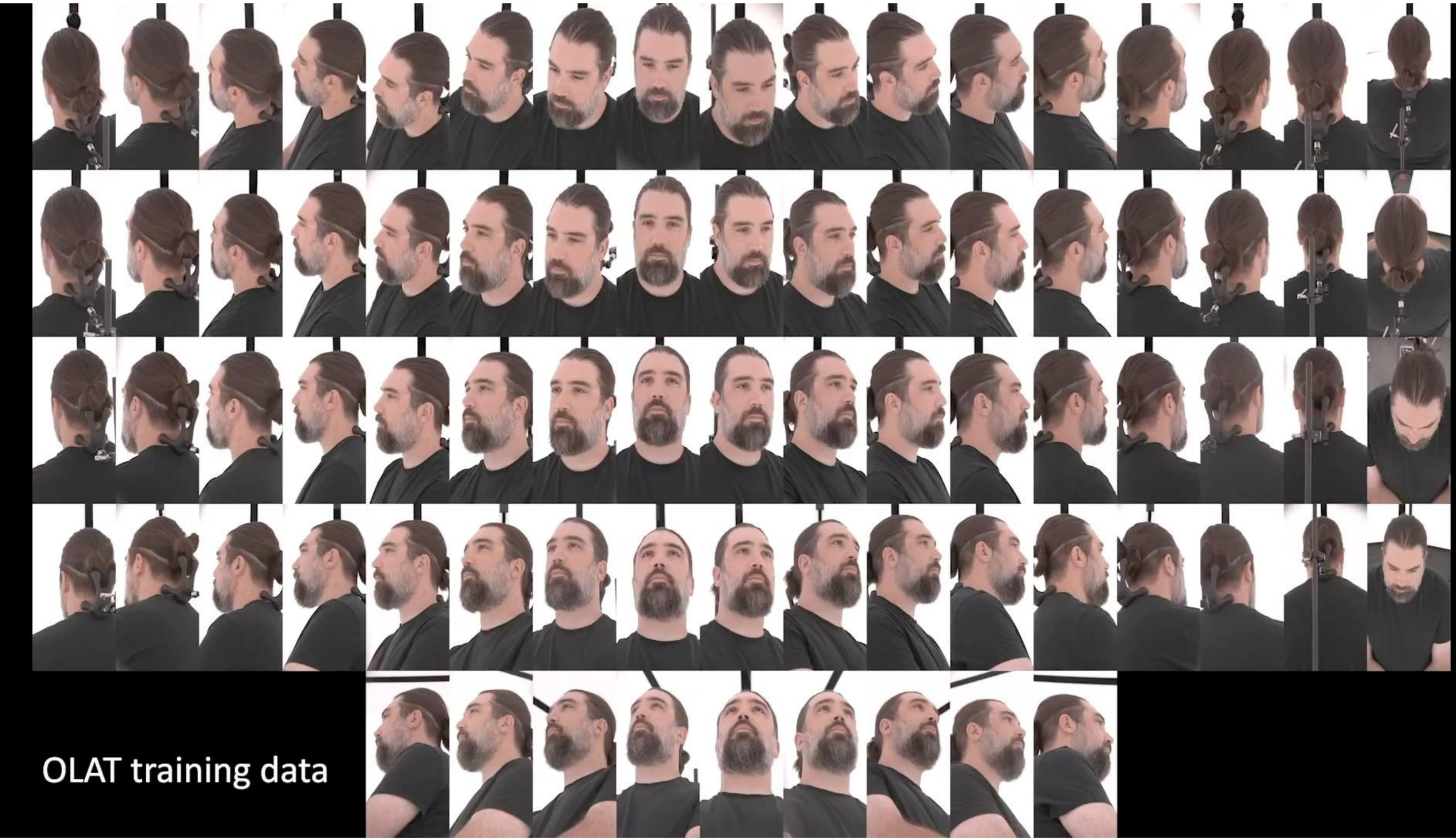
Inverse Rendering for Humans



https://www.uploadvr.com/meta-codec-avatars-iphone-scan/

Meta

Inverse Rendering for Humans



“DifFRelight”, SIGGRAPH Asia 2024

EYELINE STUDIOS™
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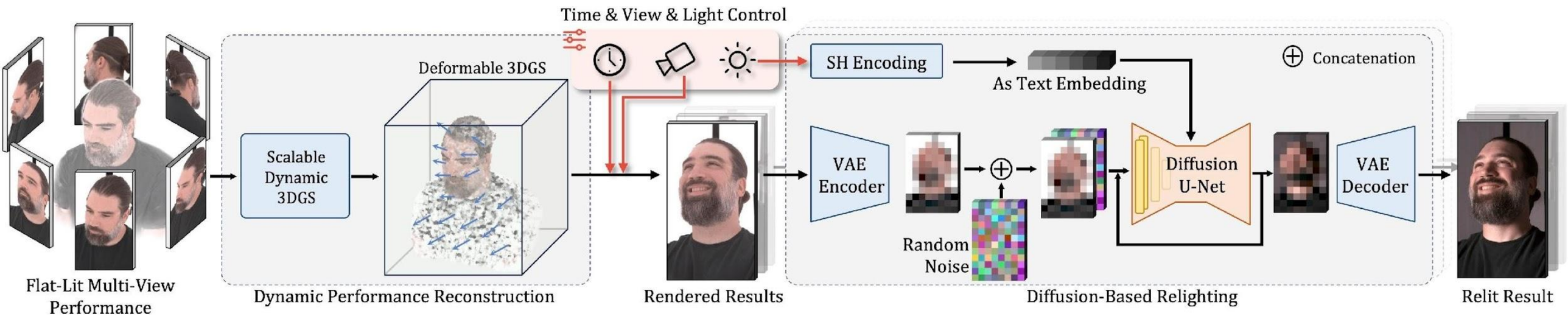
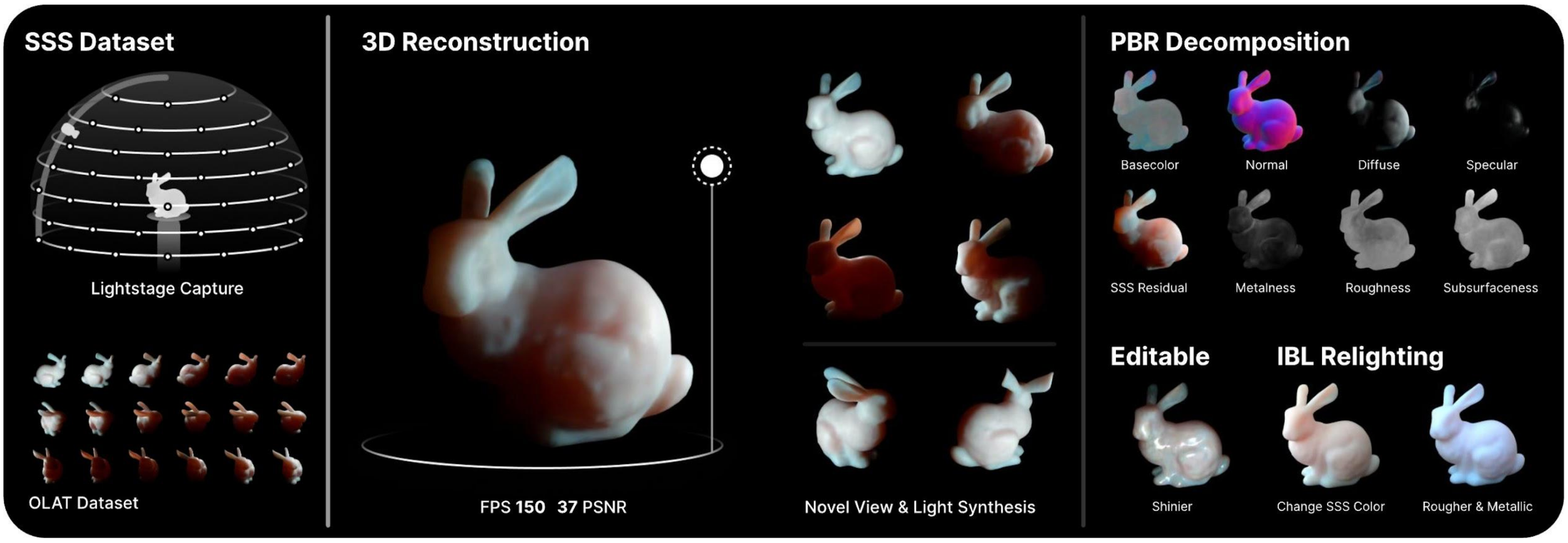
Inverse Rendering for Humans



Inverse Rendering for Objects



“Subsurface Scattering for Gaussian Splatting”

SSS GS

Subsurface Scattering
for Gaussian Splatting

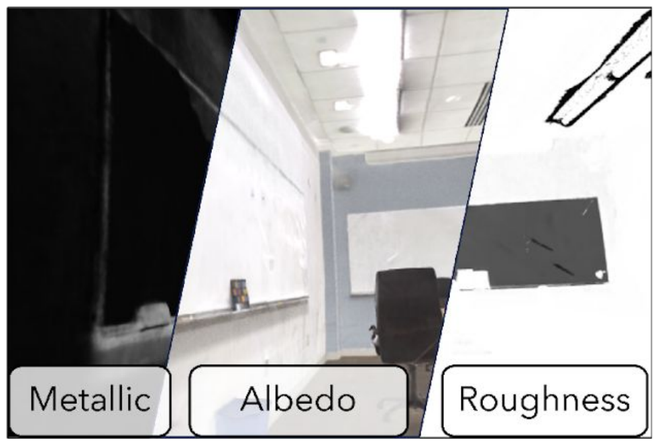
Inverse Rendering for Scenes

Input LDR Images

IRIS

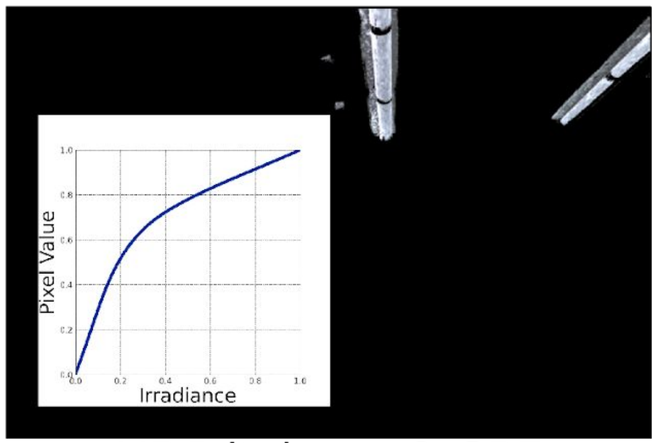
Geometry

Relighting



Surface material

Relighting



HDR lighting & CRF

Object Insertion

"IRIS: Inverse Rendering of Indoor Scenes"

Inverse Rendering for Scenes

Applications

- Relighting 1
- Relighting 2
- Object Insertion
- Original Lighting

“IRIS: Inverse Rendering of Indoor Scenes”

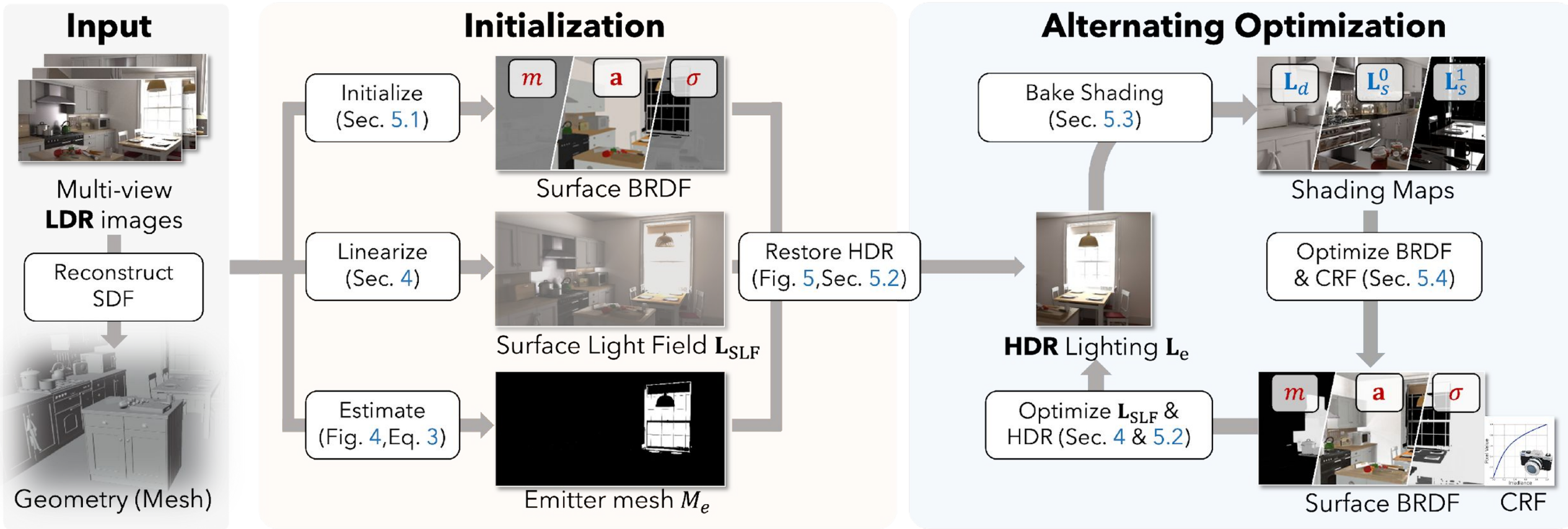
Inverse Rendering for Scenes

Results

- Diffuse Reflectance $\mathbf{k}_d$
- Material Reflectance $\mathbf{a}'$
- Roughness σ
- Metallic m
- Tonemapped HDR Emission $\mathbf{L}_e$
- Rerendering $\mathbf{L}$

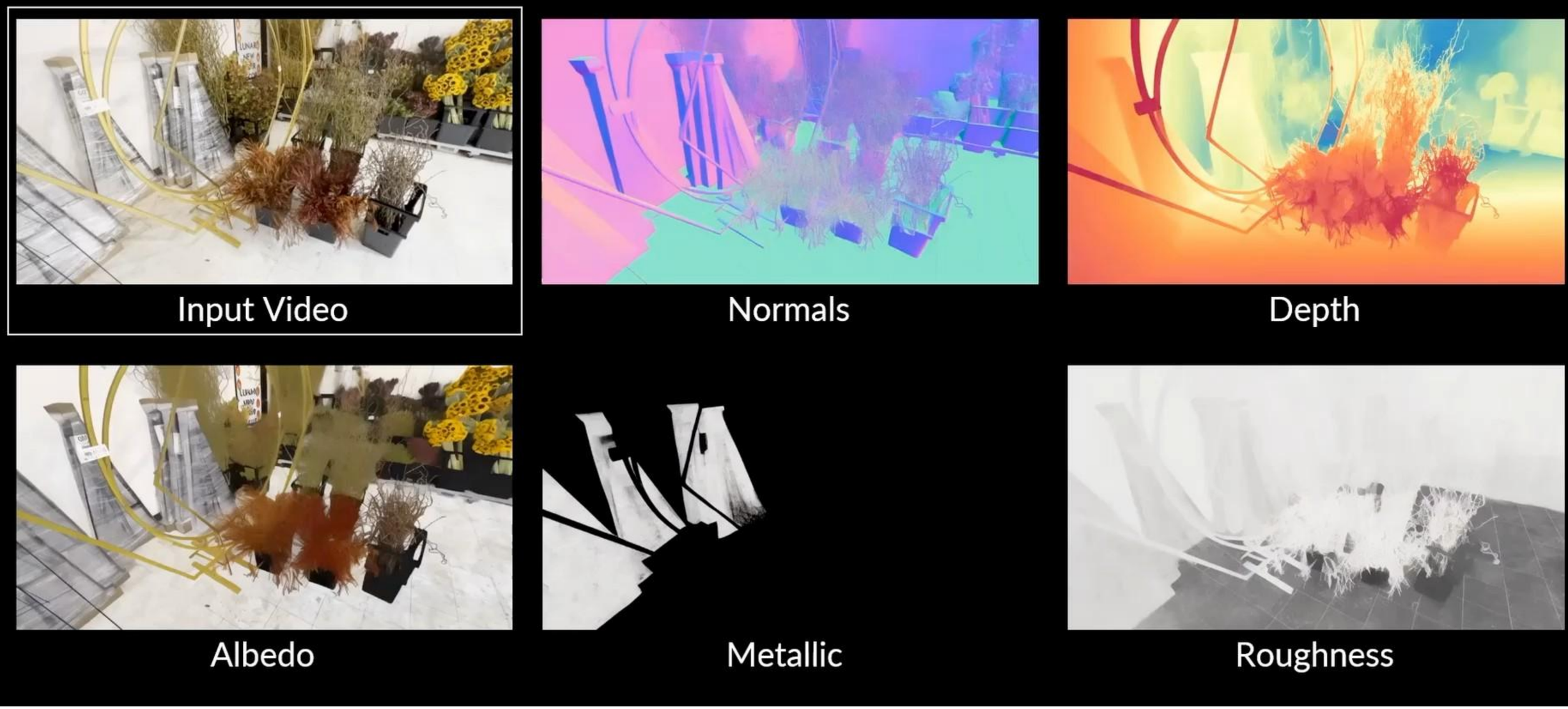
"IRIS: Inverse Rendering of Indoor Scenes"

Inverse Rendering for Scenes



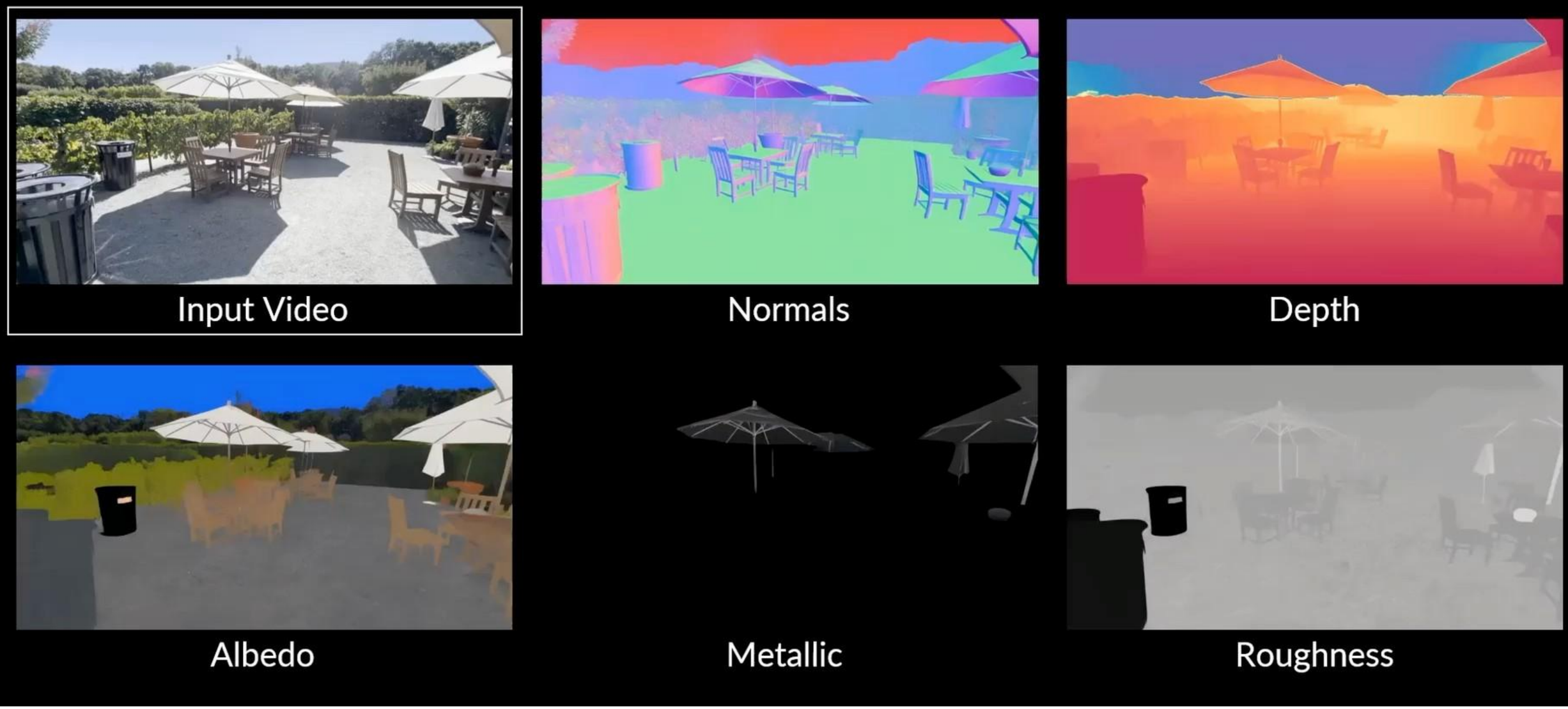
"IRIS: Inverse Rendering of Indoor Scenes"

Inverse Rendering for Scenes



“DiffusionRenderer”, CVPR 2025

Inverse Rendering for Scenes



“DiffusionRenderer”, CVPR 2025


Introducing DIFFUSIONRENDERER, a GenAI-powered
framework for delighting and relighting

Inverse Rendering for Scenes

Object Insertion

Hover over each image to see the background without the virtual object.

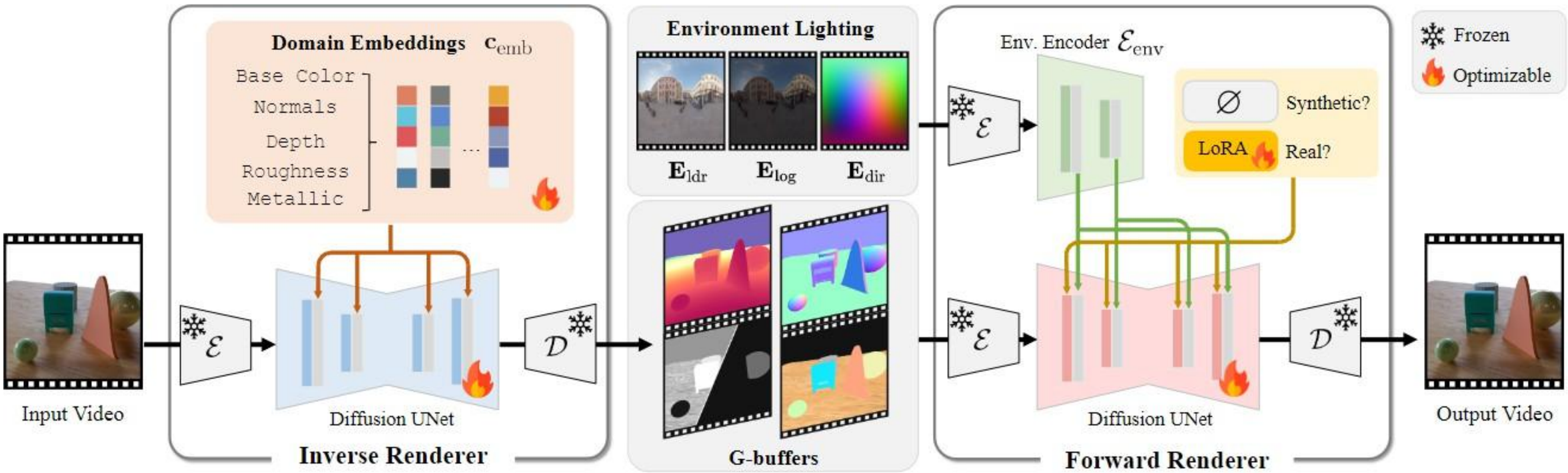
“DiffusionRenderer”, CVPR 2025

Inverse Rendering for Scenes

Rendered Object Insertion

“DiffusionRenderer”, CVPR 2025

Inverse Rendering for Scenes



"DiffusionRenderer", CVPR 2025

Acknowledgments

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