A Practical Guide to **Radiance Fields for XR** Research and Applications

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Team

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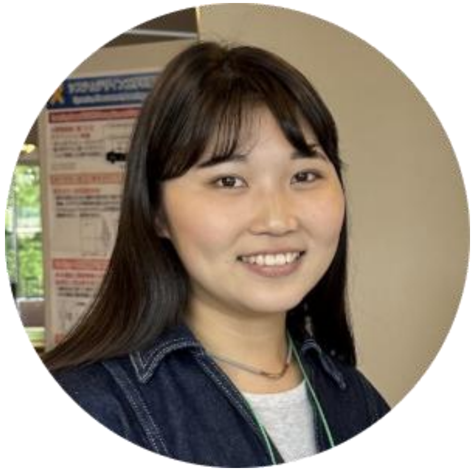


Mana Masuda
Keio University

PROGRAM

08:30 - 08:40 **Opening and Welcoming**

08:40 - 09:00 **Introduction to Radiance Fields for XR (PDF)**
Shohei Mori presents the basics of NeRF and 3DGS, and how they have evolved view synthesis compared to conventional image-based rendering approaches.

09:00 - 09:25 **Live Tutorial on NeRF for VR (PDF)**
Ke Li presents details of NeRF and immersive-ngp, demonstrating how to get a NeRF model in Unity and VR.

09:25 - 09:50 **Live Tutorial on 3DGS for VR (PDF)**
Mana Masuda presents details of 3DGS and UnityGaussianSplatting, demonstrating how to get 3DGS in Unity and VR.

09:50 - 10:15 **Interactive Discussion - Future Challenges in XR**
Shohei Mori gives a summary and shares challenges for future XR research using NeRF and 3DGS.

We also welcome the following three short presentations from the main conference:

- "*Semantics-Controlled Gaussian Splatting for Outdoor Scene Reconstruction and Rendering in Virtual Reality*", Hannah Schieber (TUM)
- "*Multi-Layer Gaussian Splatting for Immersive Anatomy Visualization*", Constantin Kleinbeck (TUM)
- "*DimSplat: A Real-Time Diminished Reality System for Revisiting Environments Using Gaussian Splats in Mobile WebXR*", Kristoffer Waldow (TH Köln)

We welcome all attendees to an interactive discussion and exchange.

Radiance Fields at VR 2025

Papers & Keynote

Monday

- 09:45-10:45 | **Keynote** | The 3D Gaussian Splatting Adventure: Past, Present and Future
- 11:15-12:15 | GaussianHand: Real-Time 3D Gaussian Rendering for Hand Avatar
- 11:15-12:15 | SplatLoc: 3D Gaussian Splatting-based Visual Localization for Augmented Reality

Tuesday

- 08:30-09:30 | Look at the Sky: Sky-aware Efficient 3D Gaussian Splatting in the Wild
- 11:15-12:15 | **Semantics-Controlled Gaussian Splatting for Outdoor Scene Reconstruction and Rendering in Virtual Reality** by Hannah Schieber, *et al.* 🤝
- 11:15-12:15 | Frequency-aware Uncertainty Gaussian Splatting for Dynamic Scene Reconstruction
- 17:15-18:15 | SRBF-Gaussian: Streaming-Optimized 3D Gaussian Splatting
- 17:15-18:15 | MPGS: Multi-plane Gaussian Splatting for Compact Scenes Rendering

Wednesday

- 08:30-09:30 | GO-NeRF: Generating Objects in Neural Radiance Fields for Virtual Reality Content Creation
- 15:15-16:15 | 360o 3D Photos from a Single 360o Input Image
- 15:15-16:15 | Fov-GS: Foveated 3D Guassian Splatting for Dynamic Scene
- **15:15-16:15 | Multi-Layer Gaussian Splatting for Immersive Anatomy Visualization** by Constantin Kleinbeck, *et al.* 🤝

Radiance Fields at VR 2025

Posters & Demos

IEEE VR 2025 SAINT-MALO, FRANCE

Monday

- Realtime-Rendering of Dynamic Scenes with Neural Radiance Fields
- Creating Virtual Environments with 3D Gaussian Splatting: A Comparative Study

Tuesday

- Human-in-the-Loop Gaussian Model Enhancement with Mobile Robotic Re-Capture
- **DimSplat: A Real-Time Diminished Reality System for Revisiting Environments Using Gaussian Splats in Mobile WebXR** by Kristoffer Waldow, *et al.* 🤝
- GaussianShopVR: Facilitating Immersive 3D Authoring using Gaussian Splatting in VR
- LIVE-GS: LLM Powers Interactive VR by Enhancing Gaussian Splatting

Wednesday

- Extending Gaussian Splatting to Audio: Optimizing Audio Points for Novel-view Acoustic Synthesis

Demo

- LLM-powered Gaussian Splatting in VR interactions

Pipeline

https://bmild.github.io/llff/

Modeling → Scene representation → Rendering

https://www.matthewtancik.com/nerf

Image-Based & Neural Rendering Continuum

Modified from H.-Y. Shum, S.-C. Chan, and S. B. Kang, “Image-Based Rendering,” Springer (2007)

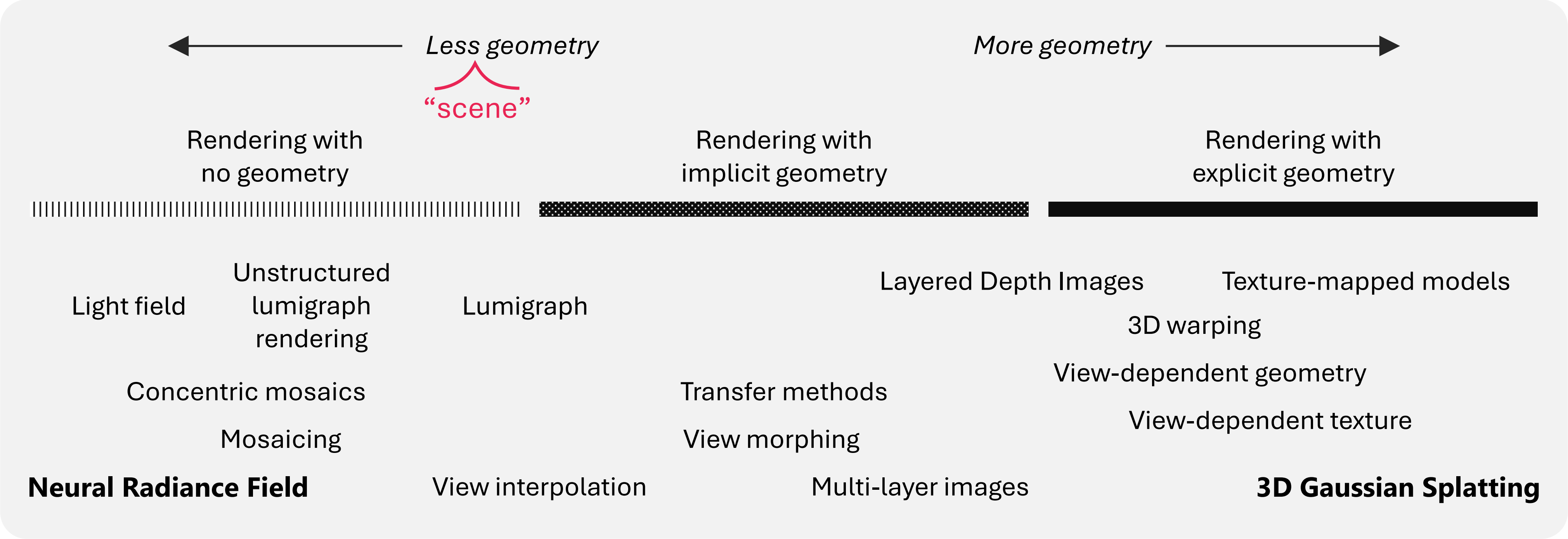


Image-Based Rendering (IBR)

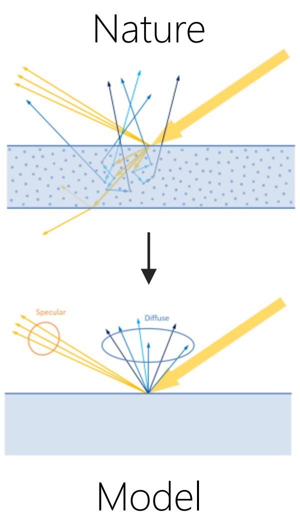
More photographs instead of precise scene models

Geometry (surface locations, visibility, deformation, etc.)
Surface properties (albedo, reflection, BRDF, etc.)

Recently, often referred to as **view synthesis**

Significantly reduced modeling effort, but still visually convincing

that comes with many known limitations...

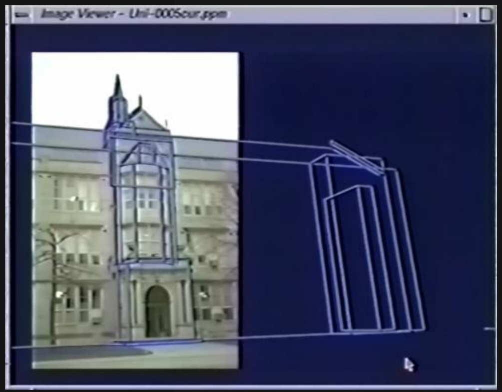


Photogrametry/scanning falls short in specular, hairs, transparency, complex sub-surface scattering, dynamics, and more...

View-Dependent Texture Mapping (VDTM)

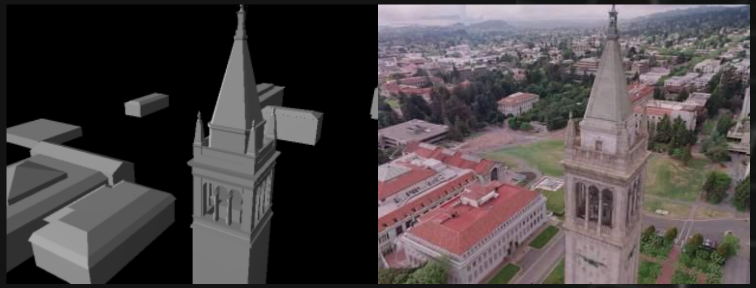
P. Debevec, Modeling and Rendering Architecture from Photographs, Ph.D. Thesis, UC Berkley, 1996.

- Each surface maintains a list of reference views, from which it is visible
- For rendering current view, reference views are projected onto the surface
- Pixels with overlaps are <u>blended</u> depending on proximity of current view to the reference views
- GPU-based <u>projective texture mapping</u> for further efficiency



GUI for manual modeling and camera/photograph registration

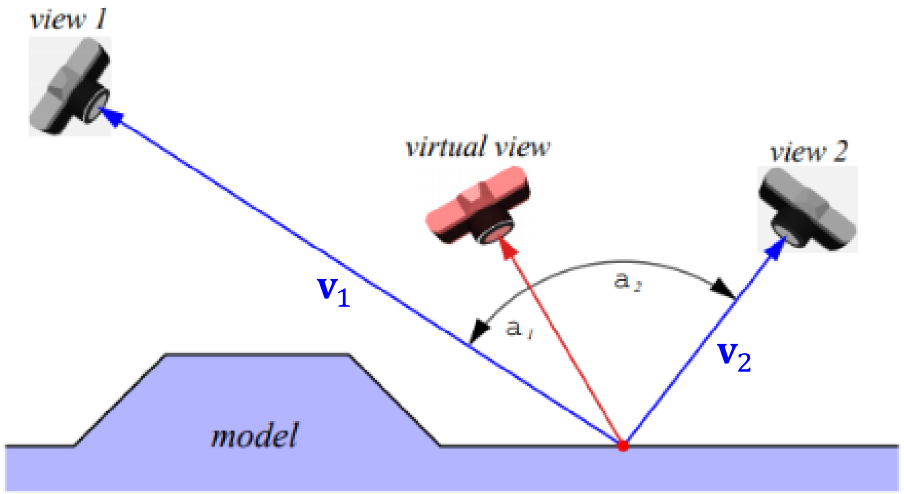
Camera/photograph registered in the scene

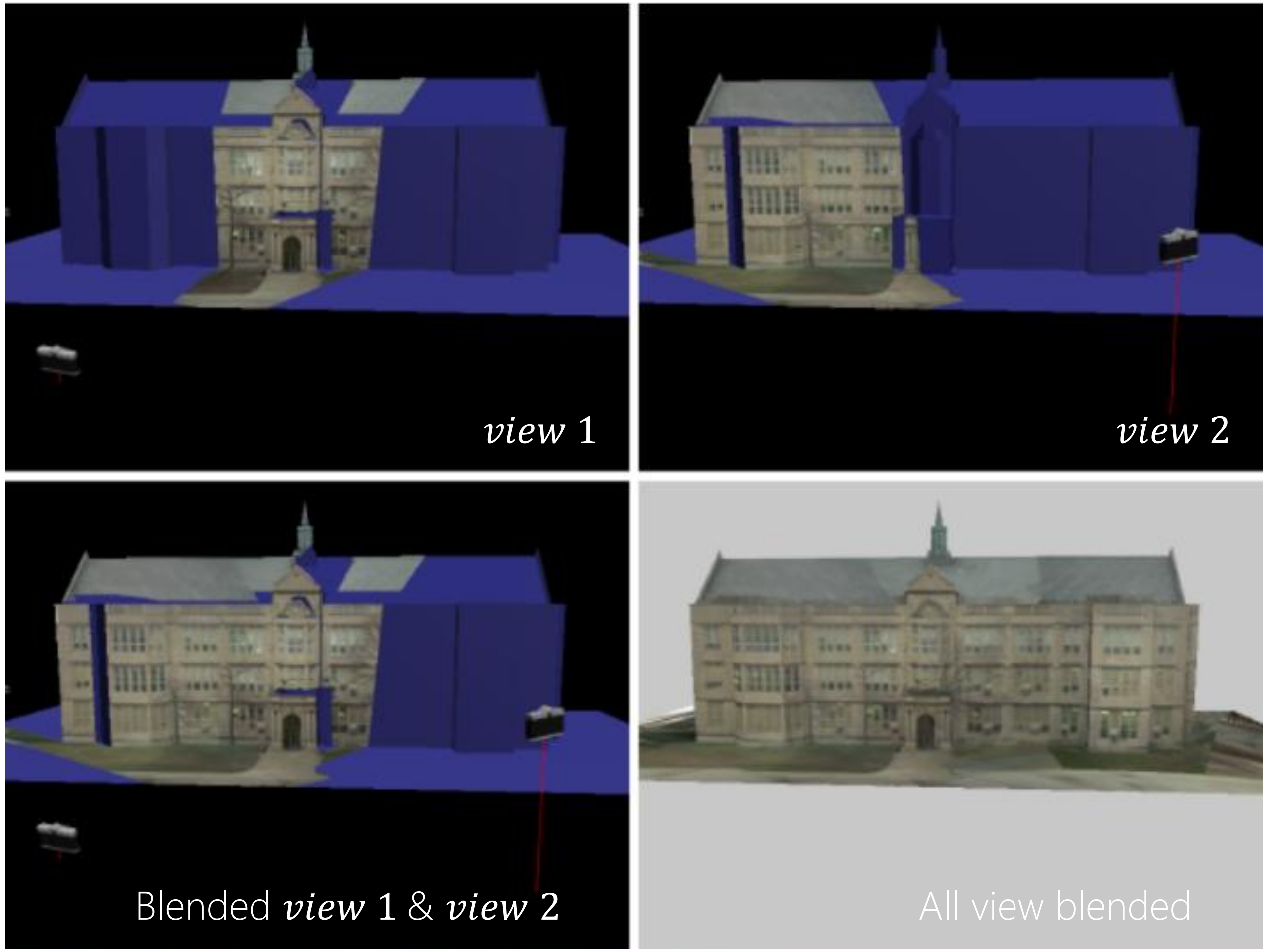


Blending Photographs

P. Debevec, Modeling and Rendering Architecture from Photographs, Ph.D. Thesis, UC Berkley, 1996.

- Calc. $\mathbf{v}_1$, $\mathbf{v}_2$, and $\mathbf{v}$
- Calc. a_1 and a_2
- Calc. weights (w_1 and w_2)
- Blend *view* 1 and *view* 2
  - $virtual\ view = w_1 * view\ 1 + w_2 * view\ 2$





Limitation in IBR

- Choices are
  - Poor 3D reconstruction + More images → More storage
  - Accurate 3D reconstruction + Fewer images → More computation

  } Not preferable to XR

- Select *k* „nearest“ views per vertex
  - View switching artifacts
  - Views selection during photographing and rendering with care!

- No defacto-standard solutions
- Very few open source projects (especially, in XR)

Differentiable Rendering Pipeline

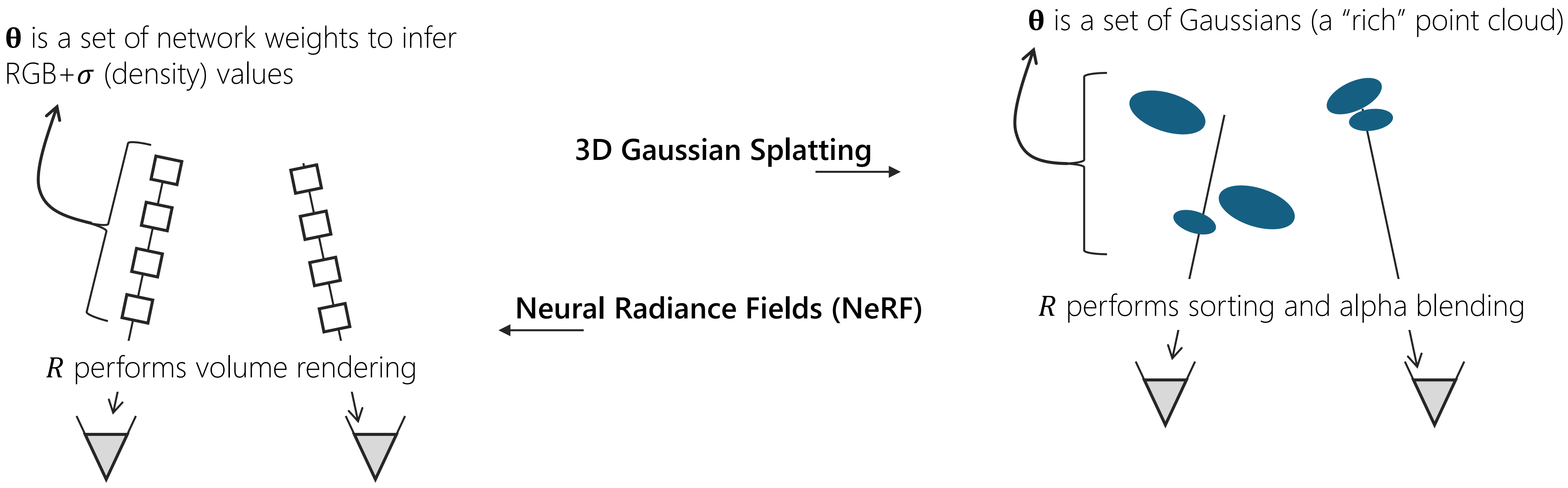
$R(\boldsymbol{\theta}) = \mathrm{I}'$

- A set of scene parameters $\boldsymbol{\theta}$ is given
  - $\boldsymbol{\theta}$ can be points, voxel, mesh, implicit (or network parameters), Gaussians, etc.
- A differentiable renderer R calculates an image I' from $\boldsymbol{\theta}$
- Calculate the loss between the rendered image I' and its ground truth I
  - Auto-grad backpropagates to reflect the loss to the scene parameters $\boldsymbol{\theta}$

R provides an "interpretation" to $\boldsymbol{\theta}$ so that $\boldsymbol{\theta}$ can represent a scene and optimization framework tries to find the best $\boldsymbol{\theta}$ through evaluations of generated image I' by comparing it with its ground truth I (i.e., $\mathrm{Loss}(\mathrm{I}', \mathrm{I})$, that is *analysis by synthesis*)

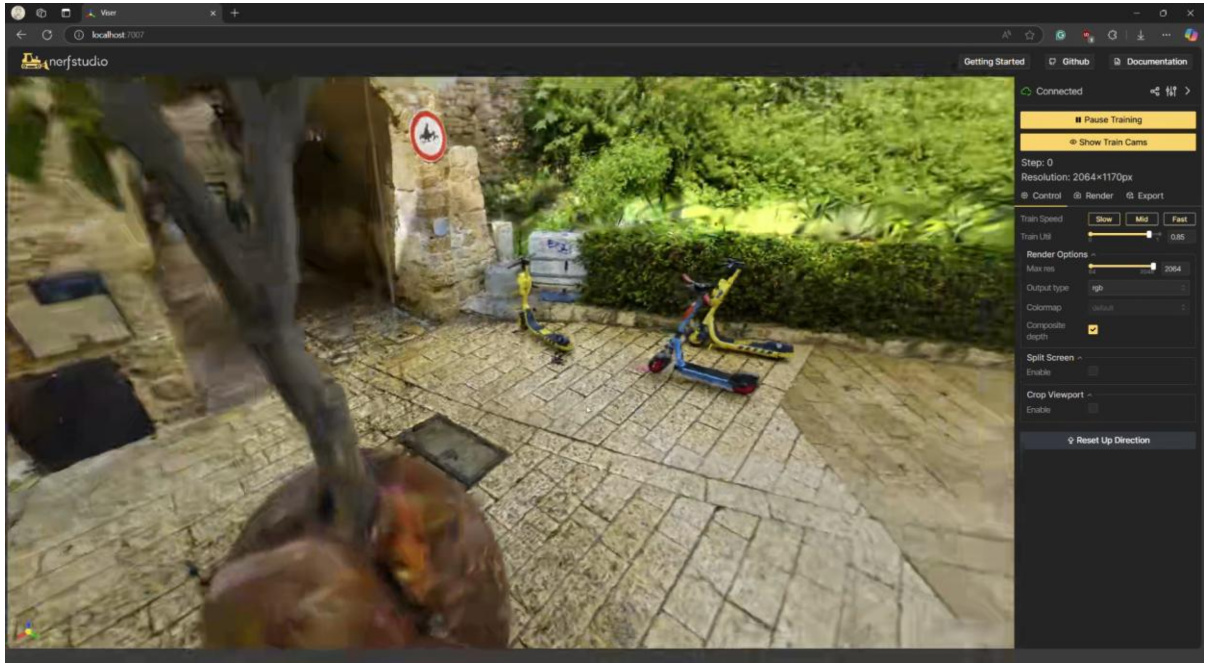
Differentiable Rendering Pipeline

$R(\boldsymbol{\theta}) = \mathrm{I}'$



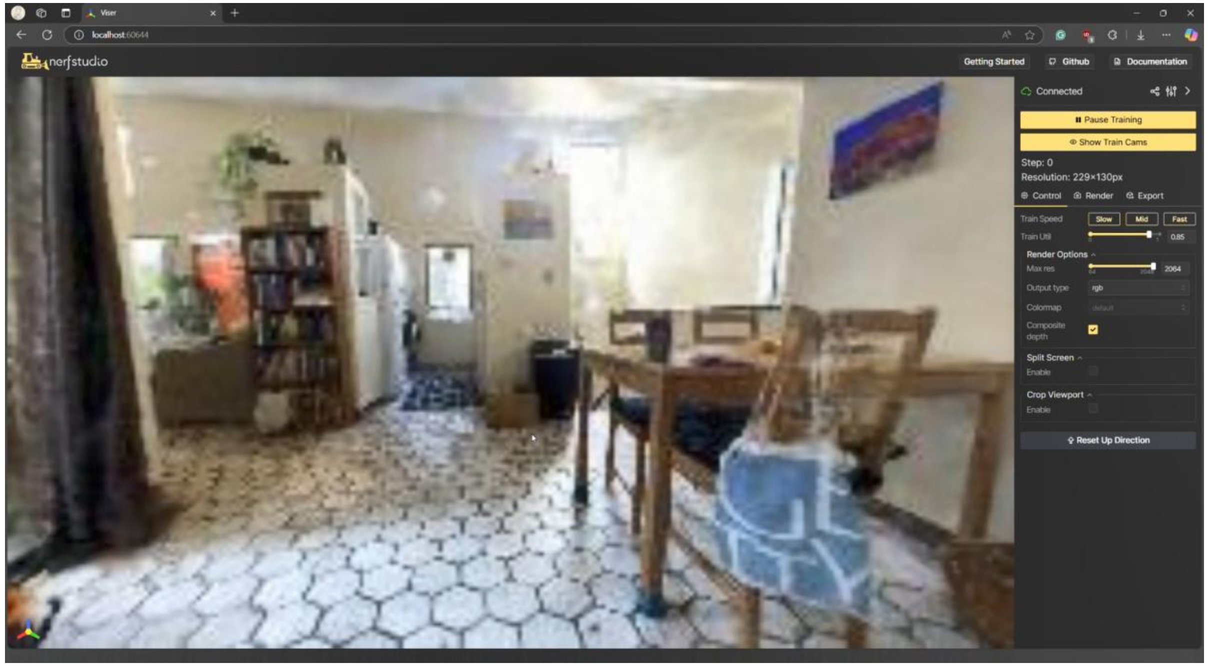
NeRF vs. 3DGS

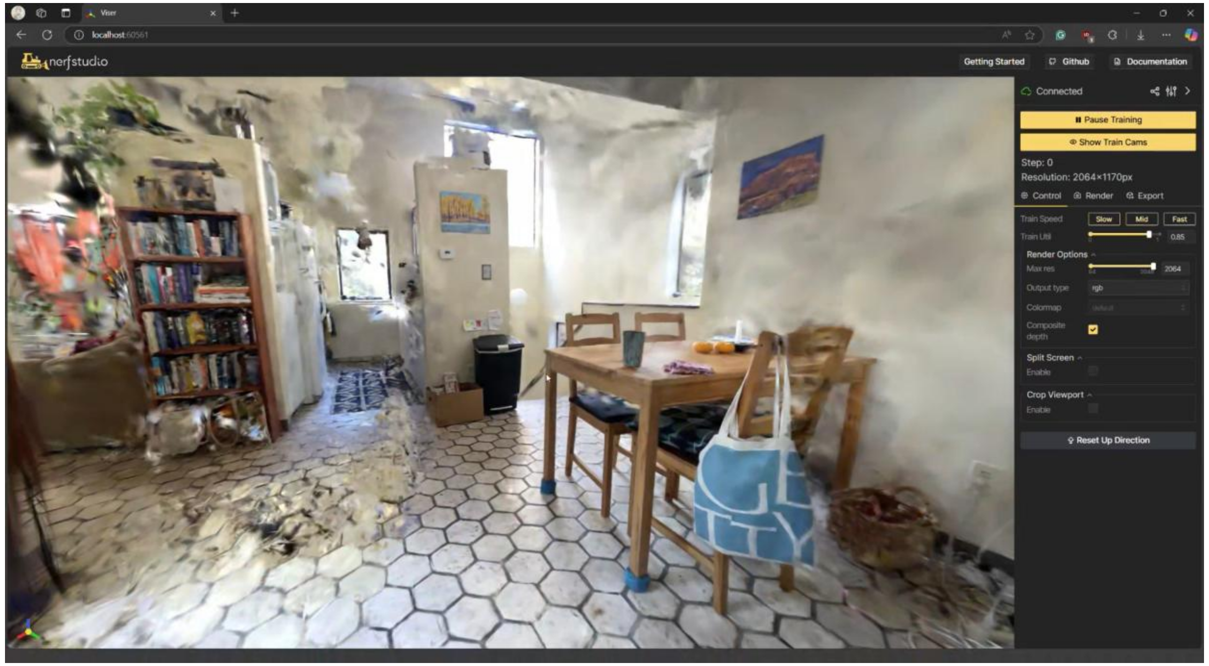
nerfstudio
Getting Started
Github
Documentation
Connected
Pause Training
Show Train Cams
Step: 0
Resolution: 229×130px
Control
Render
Export
Reset Up Direction



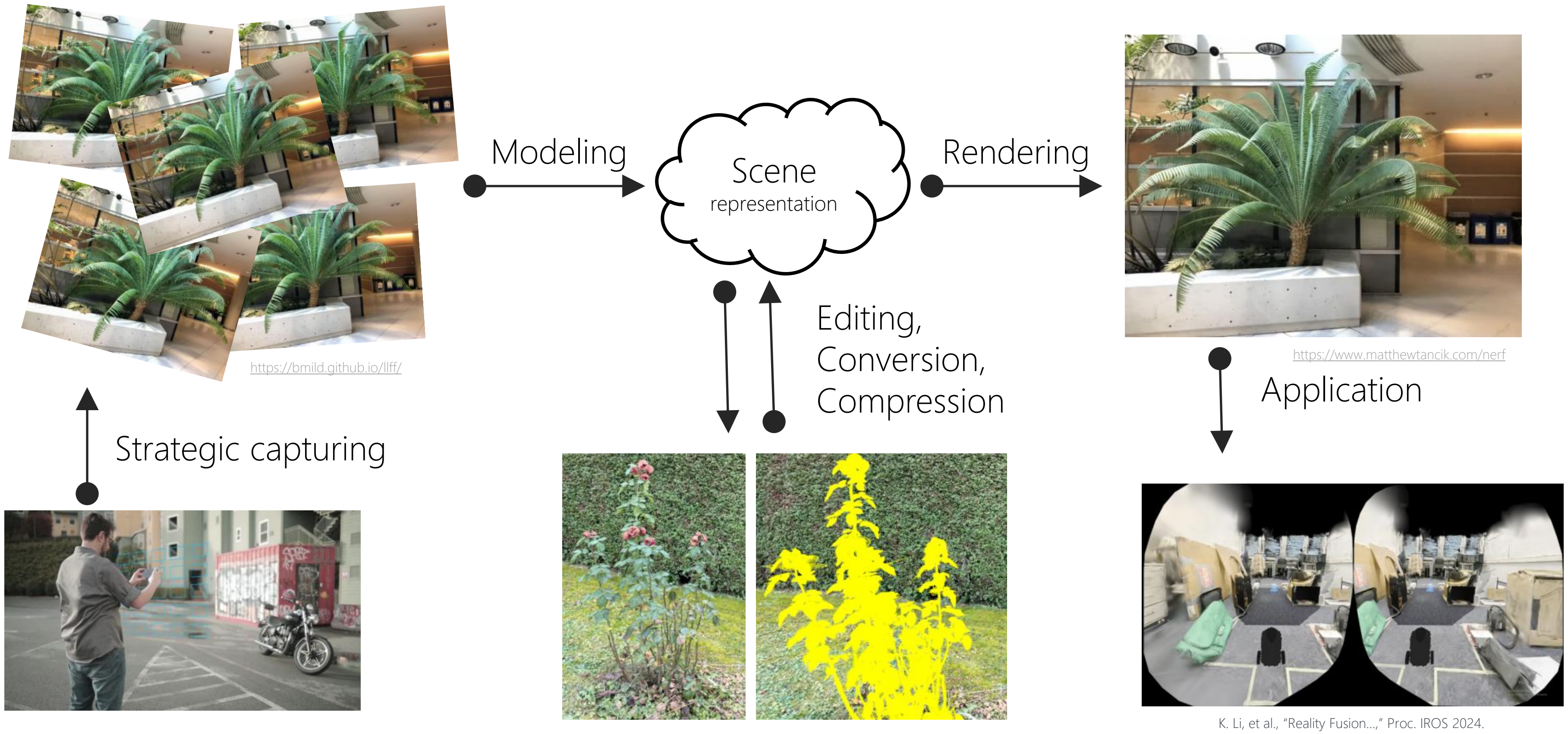
nerfstudio
Getting Started
Github
Documentation
Connected
Pause Training
Show Train Cams
Step: 0
Resolution: 2064×1170px
Control
Render
Export
Reset Up Direction

NeRF vs. 3DGS





Pipeline


Modeling
Scene
representation
Rendering
https://bmild.github.io/llff/
Strategic capturing
Editing,
Conversion,
Compression
https://www.matthewtancik.com/nerf
Application
K. Li, et al., "Reality Fusion...," Proc. IROS 2024.

Capture Tools

- Scaniverse
  - 3DGS (local processing)
  - iOS (with LiDAR) / Android
    - Real-time 3DGS on iOS
  - Free of charge
- Polycam
  - 3DGS (server processing, up to 100 images)
  - iOS (with LiDAR) / Android
- COLMAP / GLOMAP
  - Defacto standard for research
  - Python interface

Next-up

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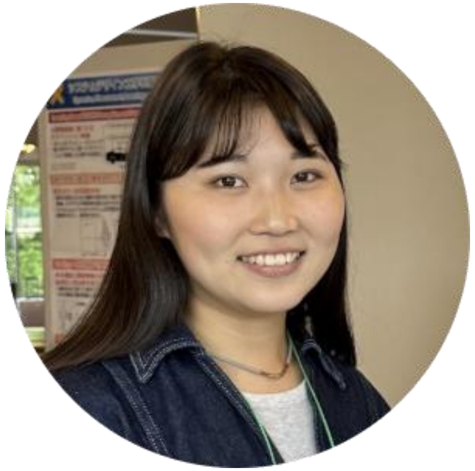

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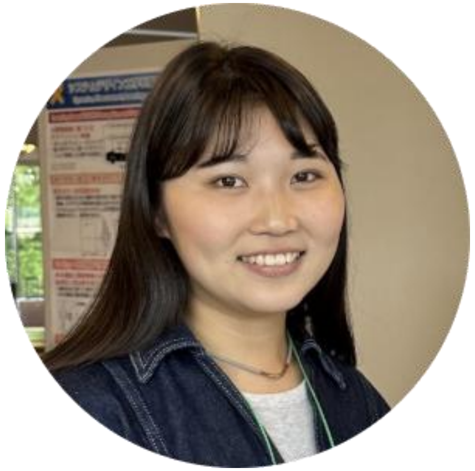
Next-up

Neural Radiance Fields
Immersive-ngp
(Unity + VR + Instant-ngp)

Ke Li
University of Hamburg



3D Gaussian Splatting
UnityGaussianSplatting
(Unity + VR + 3DGS)

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Future Directions

Topics around Radiance Fields

- **Interactive Experiences**: Education, Training, Telepresence / Collaboration / Avatar
- **User-centric rendering**: Foveated Rendering / VST-HMD
- **Benchmarking**: Quality Assessment / Toolkit
- **Multi-modal**: Haptics / Audio
- **Content Editing**: Style Transfer / Style Edit / Relighting / Diminished Reality
- **Content Generation**: Text to 3D (content / scene) / Content Generation
- **Spatial Registration**: Tracking / SLAM / Bundle adjustment
- **Dynamic Capture**: 4D / Performance / Dynamics
- **Optimization Techniques**: Faster Rendering / Few-shot / Streaming / Compression