SVG-Head: Hybrid Surface-Volumetric Gaussians for High-Fidelity Head Reconstruction and Real-Time Editing

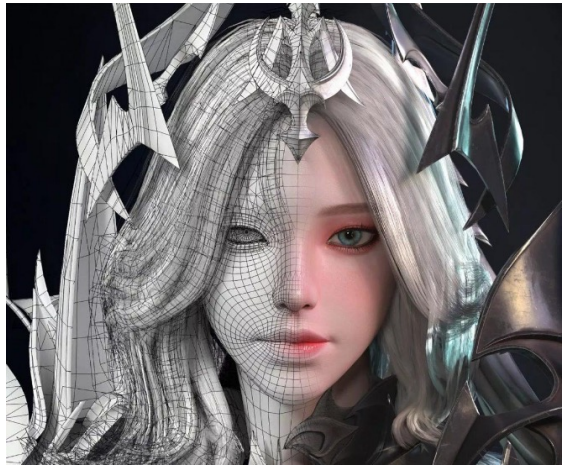
Heyi Sun[1], Cong Wang[1], Tian-Xing Xu[1], Jingwei Huang[2], Di Kang[2], Chunchao Guo[2] and Song-Hai Zhang[1]

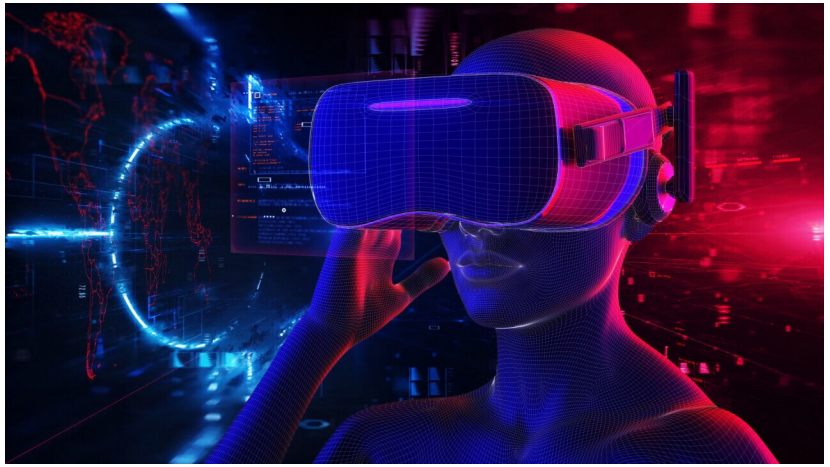
[1]Tsinghua University, [2]Tencent Hunyuan

Research Introduction

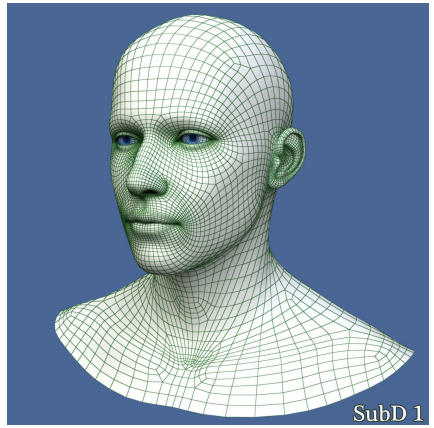
BACKGROUND

- 3D head reconstruction is a core challenge in computer vision and graphics, with applications spanning multiple domains.



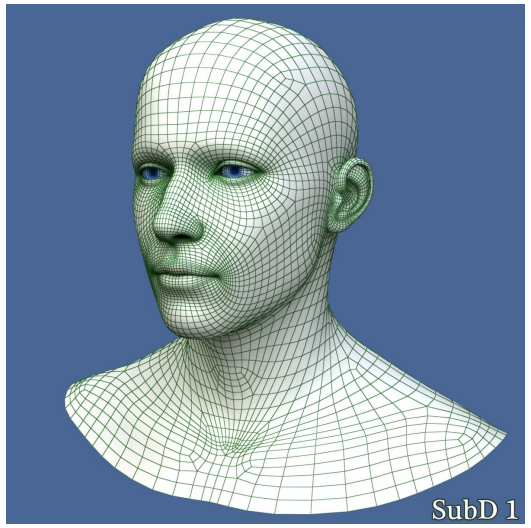


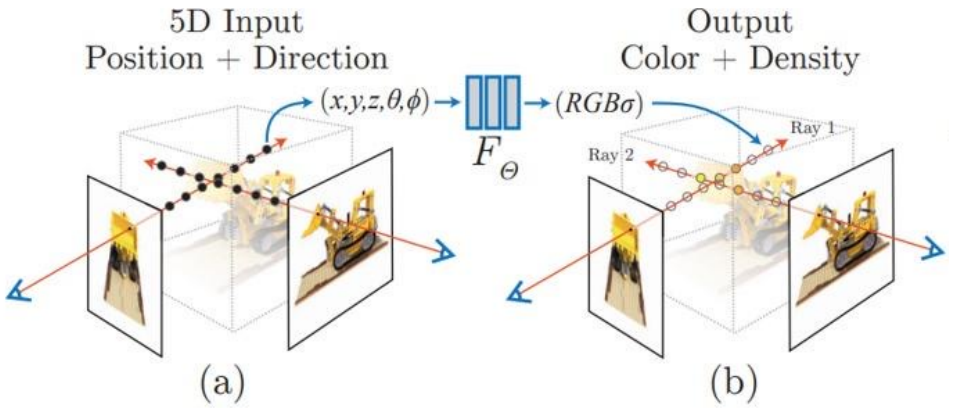
- Traditional Methods: Mesh-based approaches.
- Recent Approaches: Utilizing NeRF and 3DGS to capture high-fidelity appearance, combined with deformation fields or rigging for animation.



Research Introduction

EXISTING PROBLEMS





Traditional mesh-based methods:

- depend on high-quality geometry and detailed UV coordinates.
- struggle to represent volumetric areas.

Implicit representations:

lack an explicit structure, making real-time editing difficult.

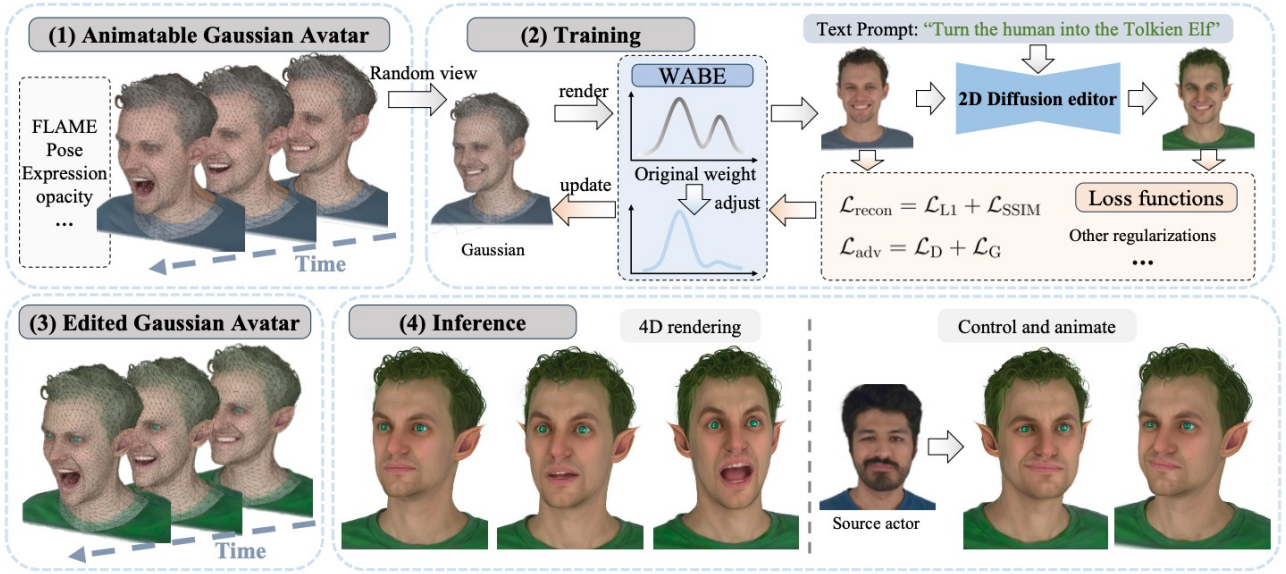
Standard 3DGS methods:

entangle geometry and texture, which also complicates editing.

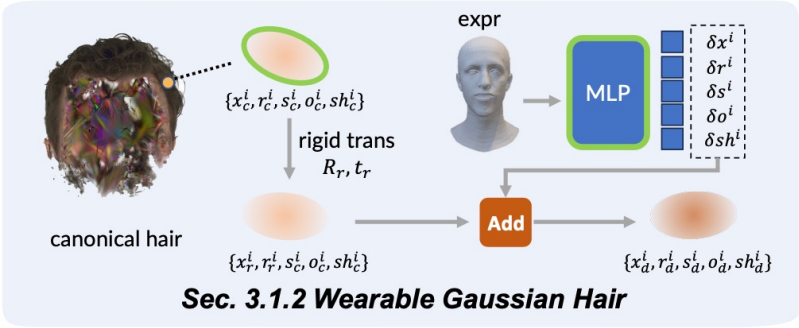
Research Introduction

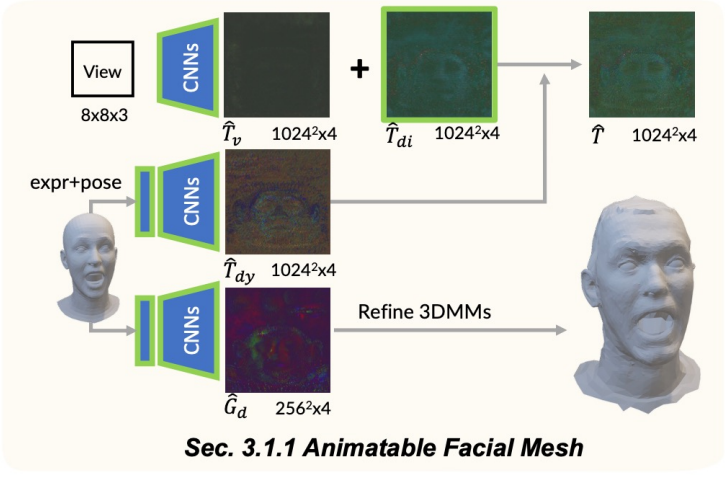
RELATED WORK

GaussianAvatar-Editor: Photorealistic Animatable Gaussian Head Avatar Editor , 3DV 2025



MeGA: Hybrid Mesh-Gaussian Head Avatar for High-Fidelity Rendering and Head Editing , CVPR 2025

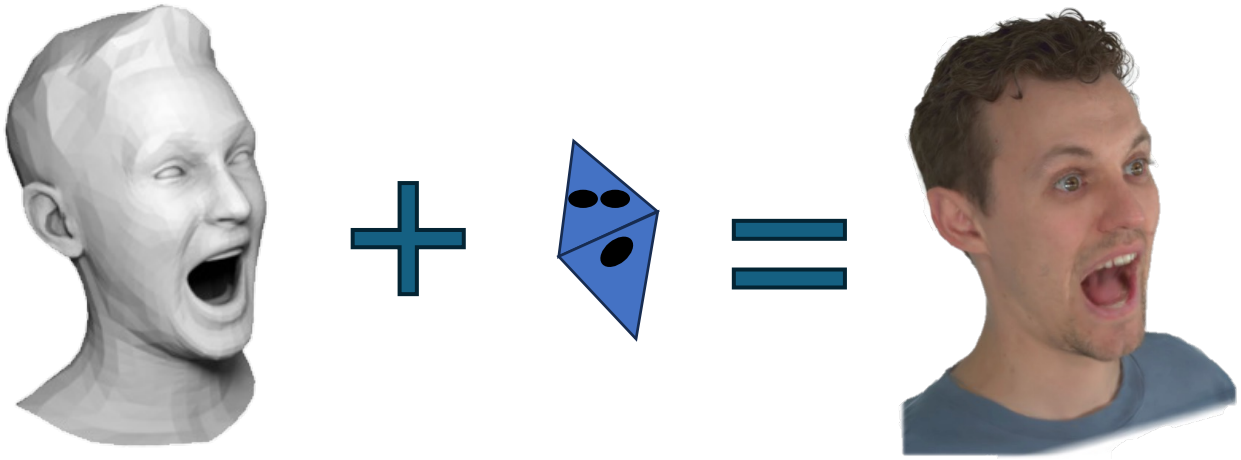




Research Introduction

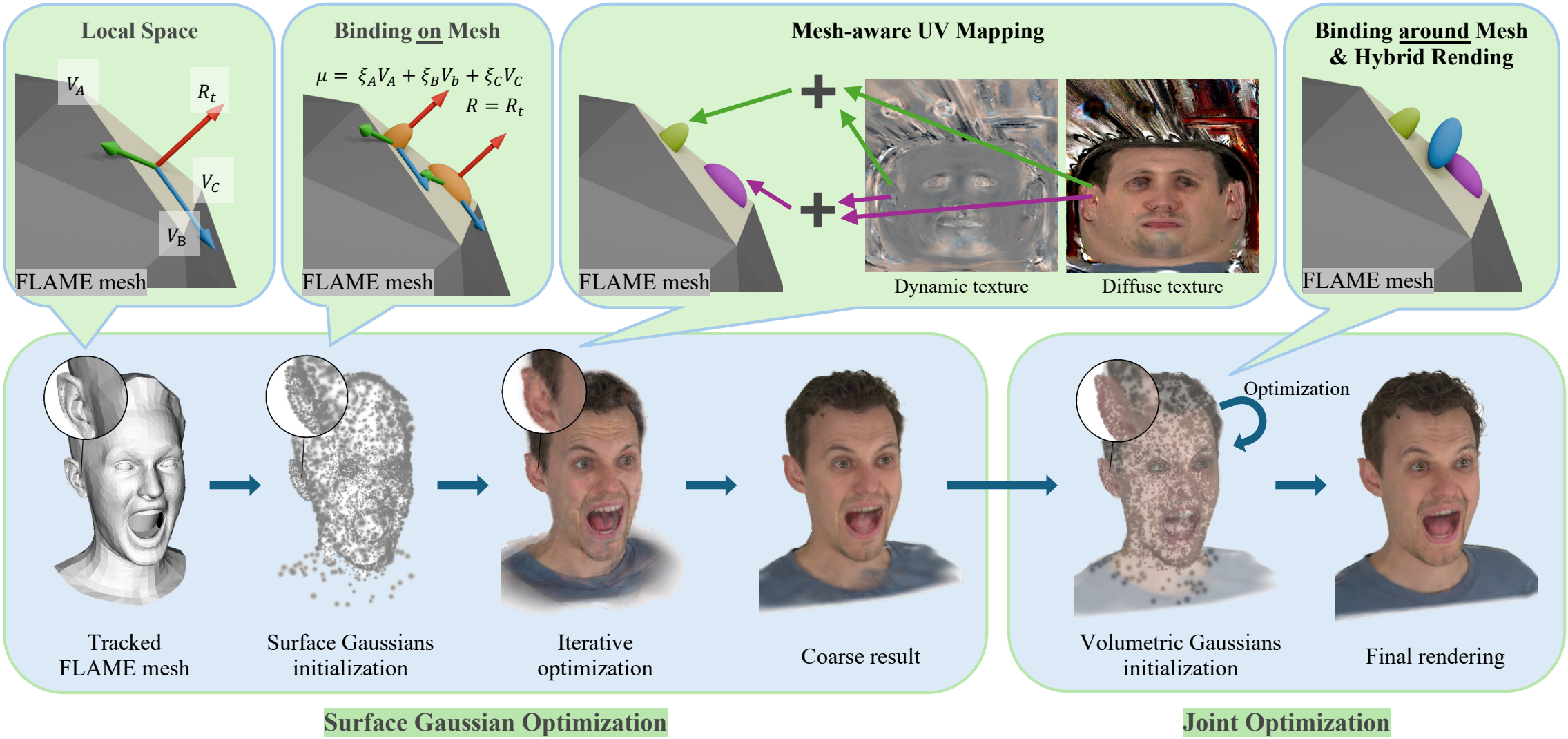
RESEARCH GOALS

- Building high-quality 3D heads that adapt to complex facial expression variations and diverse poses.
- Accurately reconstructing fine non-Lambertian facial structures (such as lips, hair, and the interior of the mouth), ensuring high visual fidelity.
- Achieving real-time rendering and driving.
- Supporting real-time interactive editing.



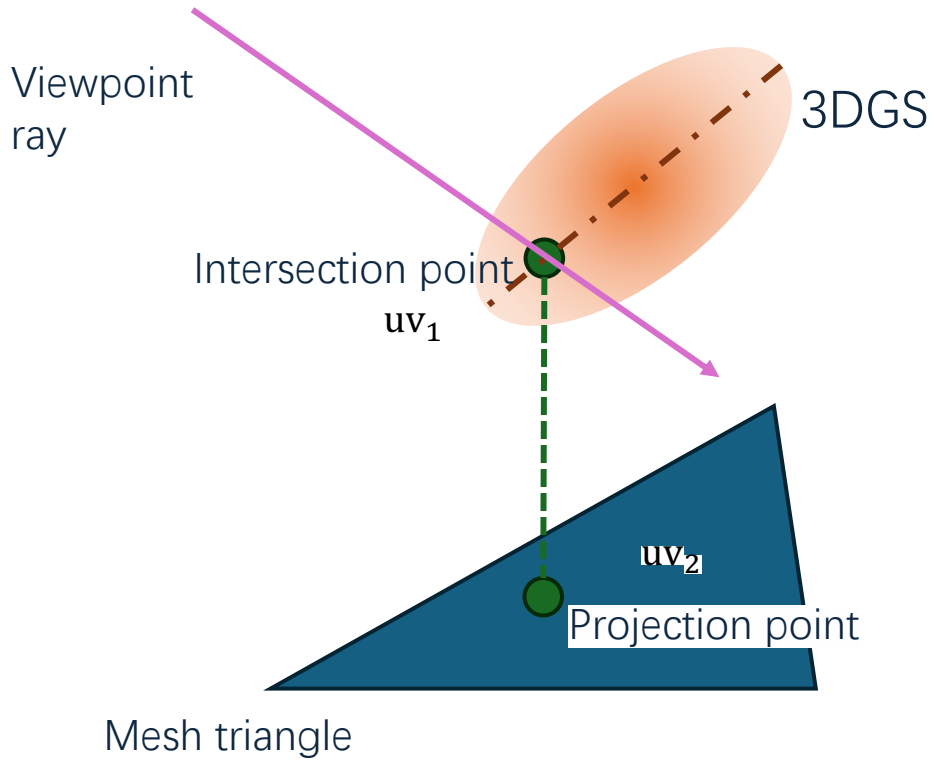
SVG-Head

PIPELINE



SVG-Head

MESH-AWARE UV MAPPING



(While surface Gaussians should be fixed on the mesh surface, the illustration is for convenience of visualization.)

Define $\mathbf{uv}_1 = \mathbf{uv}_2$, and calculate $\mathbf{uv}_2$ using barycentric interpolation with the UV coordinates of the mesh vertices predefined by the FLAME model.

To enhance real-time rendering performance, the interpolation process is compressed into an affine transformation. The affine matrix for each triangle is precomputed, and the UV coordinates of each surface Gaussian center (which can be directly computed through interpolation) are used, along with the vector from the surface Gaussian center to the intersection point, to precisely compute the UV coordinates of the intersection point (as shown in Equation 3.7 of the paper).

Experimental Validation

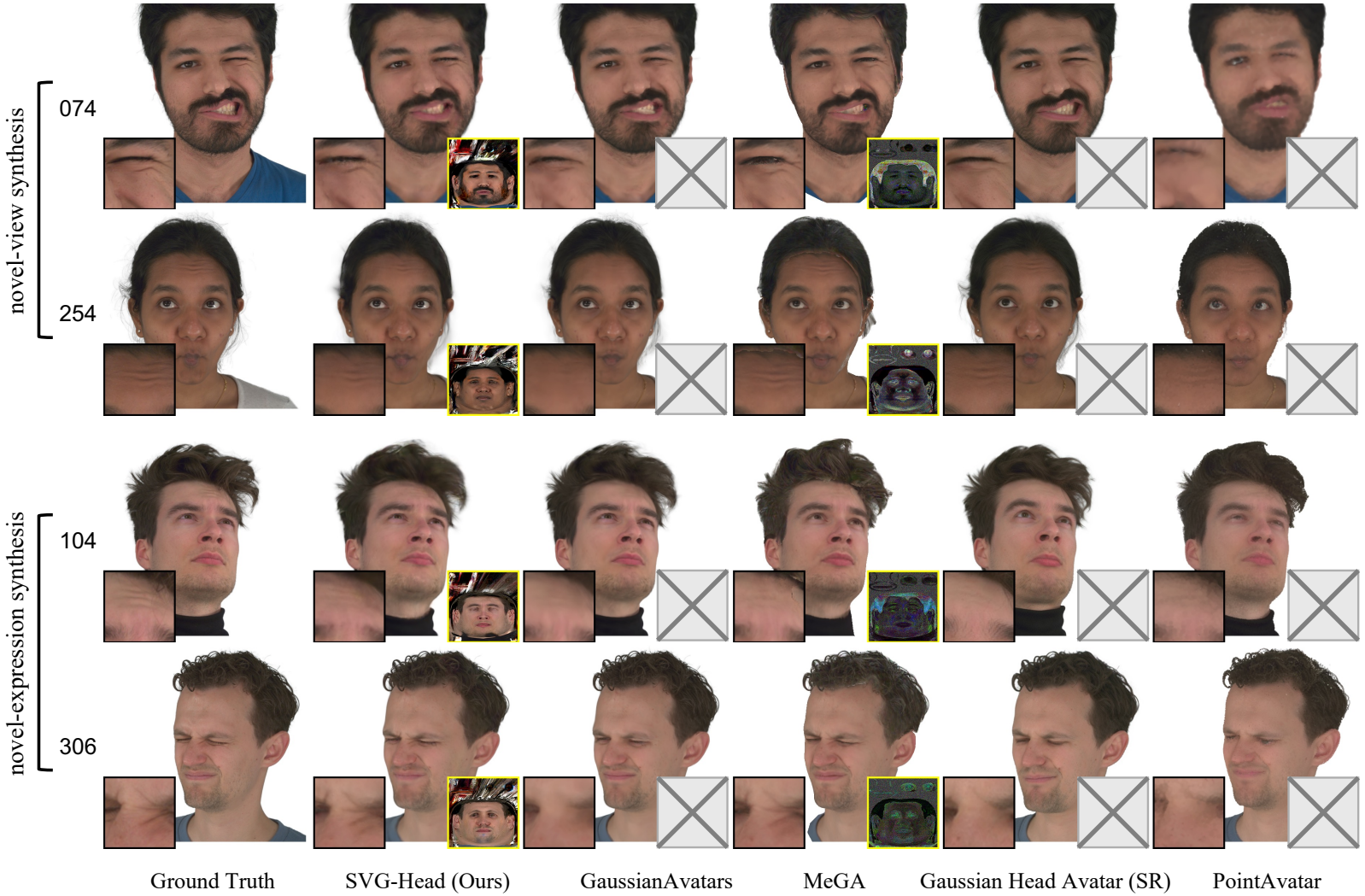
RECONSTRUCTION: QUANTITATIVE COMPARISON

Table 1. **Comparisons with State-of-the-Art Methods.** SVG-Head obtains the best metrics among editable reconstruction methods, as well as metrics comparable to non-editable reconstruction methods. Green indicates the best and yellow indicates the second.

Method	Editing	Novel-View Synthesis			Novel-Expr. Synthesis		
		PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓
PointAvatar	✗	25.8	0.893	0.097	23.4	0.884	0.102
Gaussian Head Avatar	✗	29.5	0.894	0.084	22.5	0.853	0.144
GaussianAvatars	✗	31.6	0.938	0.065	26.0	0.910	0.076
MeGA*	✓	15.2	0.853	0.207	17.4	0.867	0.181
SVG-Head (Ours)	✓	30.3	0.931	0.078	26.0	0.910	0.087

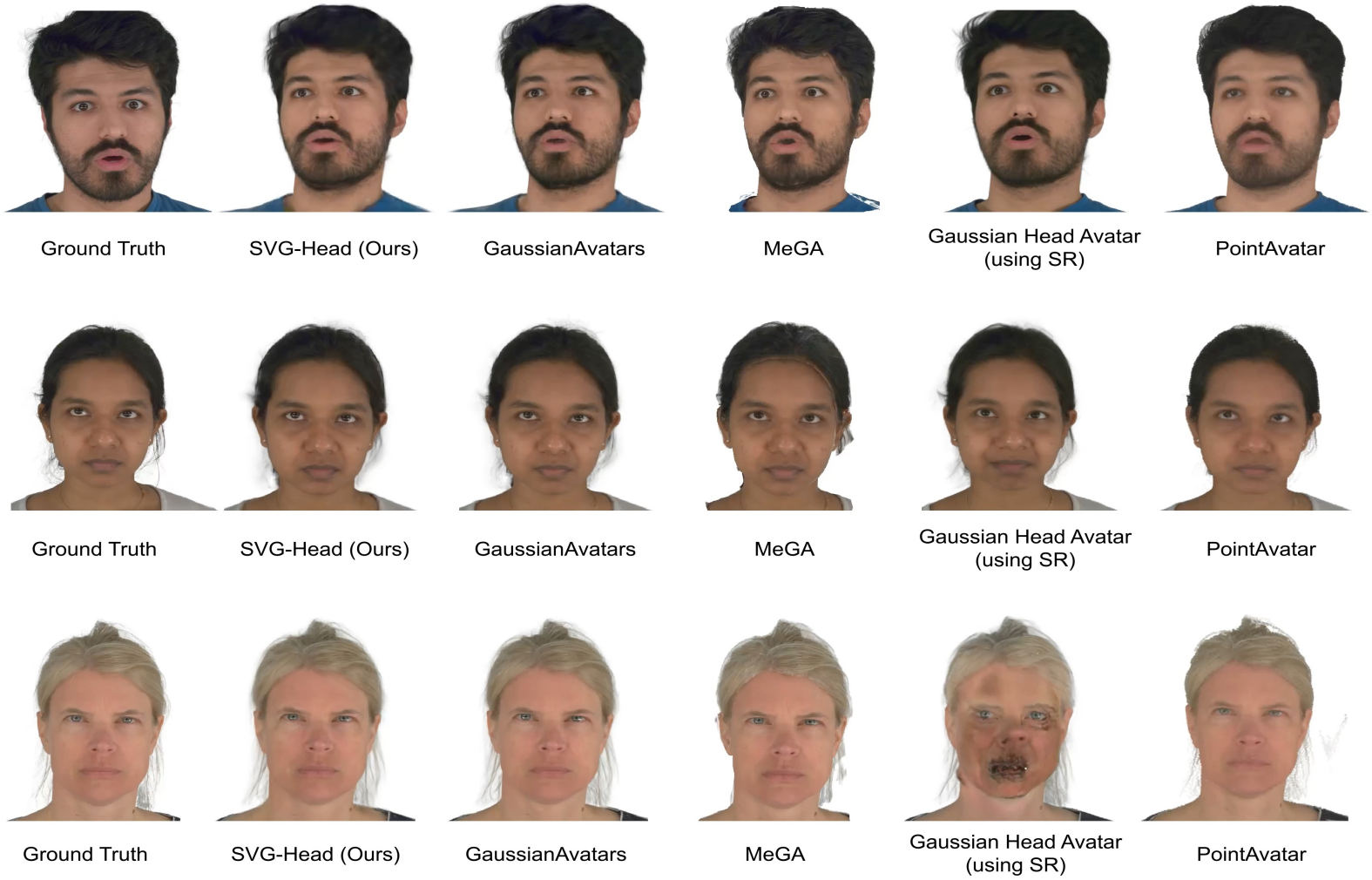
Experimental Validation

RECONSTRUCTION: QUALITATIVE COMPARISON



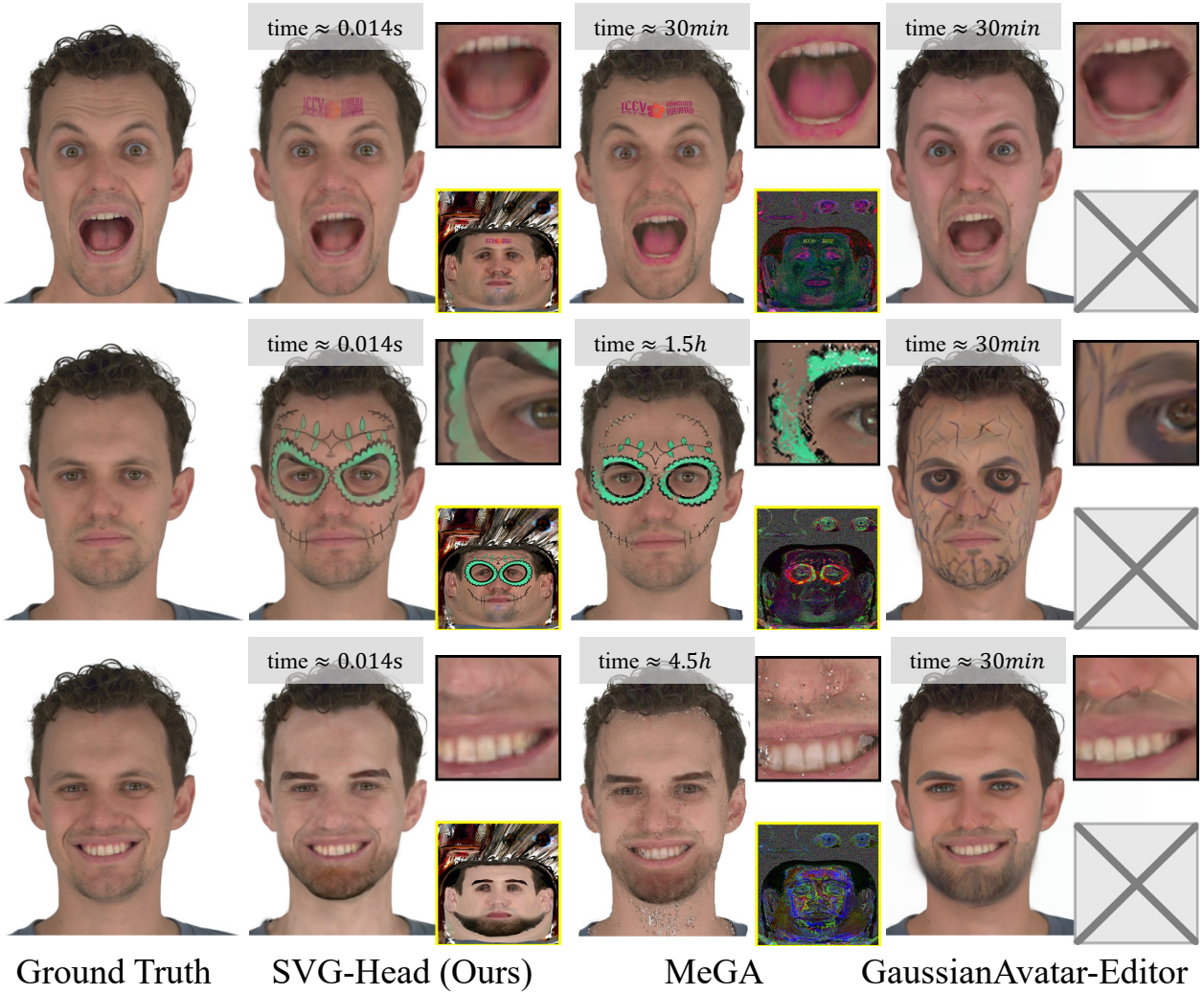
Experimental Validation

RECONSTRUCTION: EFFECT DEMONSTRATION



Experimental Validation

EDITING: QUALITATIVE COMPARISON



References

- Qian S, Kirschstein T, Schoneveld L, et al. GaussianAvatars: Photorealistic Head Avatars with Rigged 3D Gaussians[C]//Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR). 2024.
- Wang C, Kang D, Sun H Y, et al. MeGA: Hybrid Mesh-Gaussian Head Avatar for High-Fidelity Rendering and Head Editing[C]//Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR). 2025.
- Xu T X, Hu W, Lai Y K, et al. Texture-GS: Disentangling the Geometry and Texture for 3D Gaussian Splatting Editing[C]//Computer Vision – ECCV 2024. In: Leonardis A, Ricci E, Roth S, et al. (eds) ECCV 2024. Lecture Notes in Computer Science, vol 15083. Springer, Cham, 2025: 1-11.
- Liu X, Luo K, Li H, et al. GaussianAvatar-Editor: Photorealistic Animatable Gaussian Head Avatar Editor[C]//CoRR. 2025.