



State-of-the-Art Report on

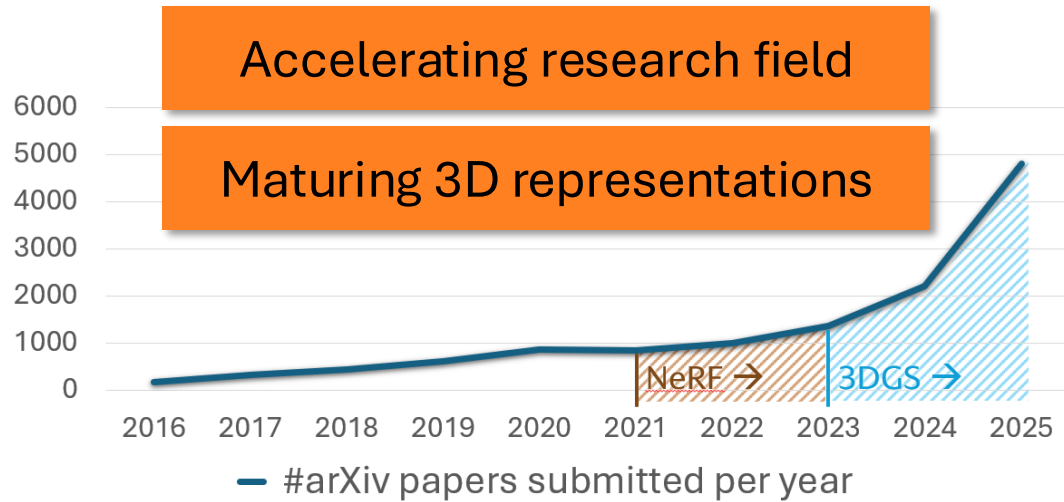
How to Build Digital Humans?

From Priors to Photorealistic Avatars

May 4th, 2026

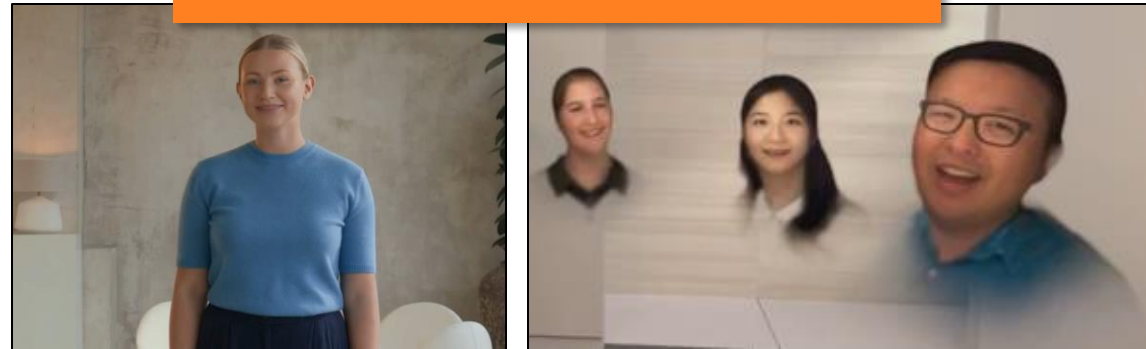
**EUROGRAPHICS
AACHEN 2026**

Current Developments on Avatars



Genie3

First commercial products



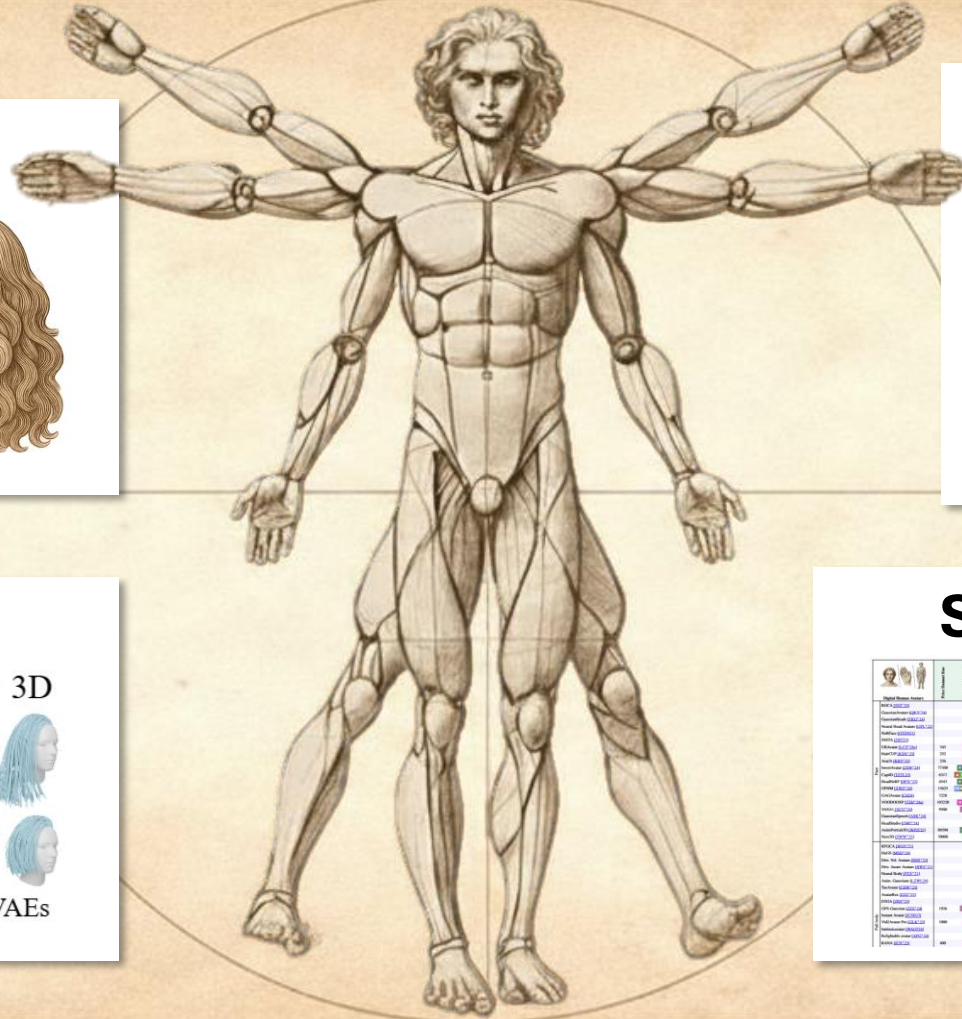
Synthesia

Apple Personas

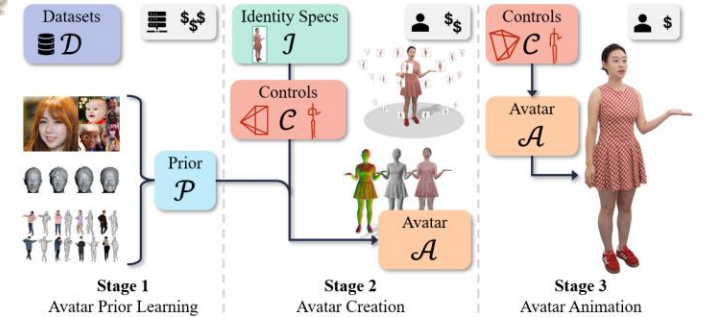


Why is this STAR interesting?

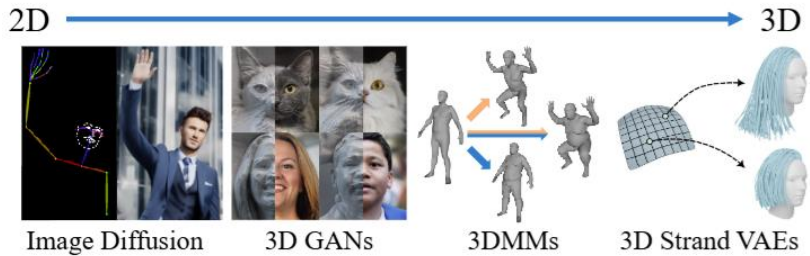
Five Body Parts



Avatar Framework



Human Priors



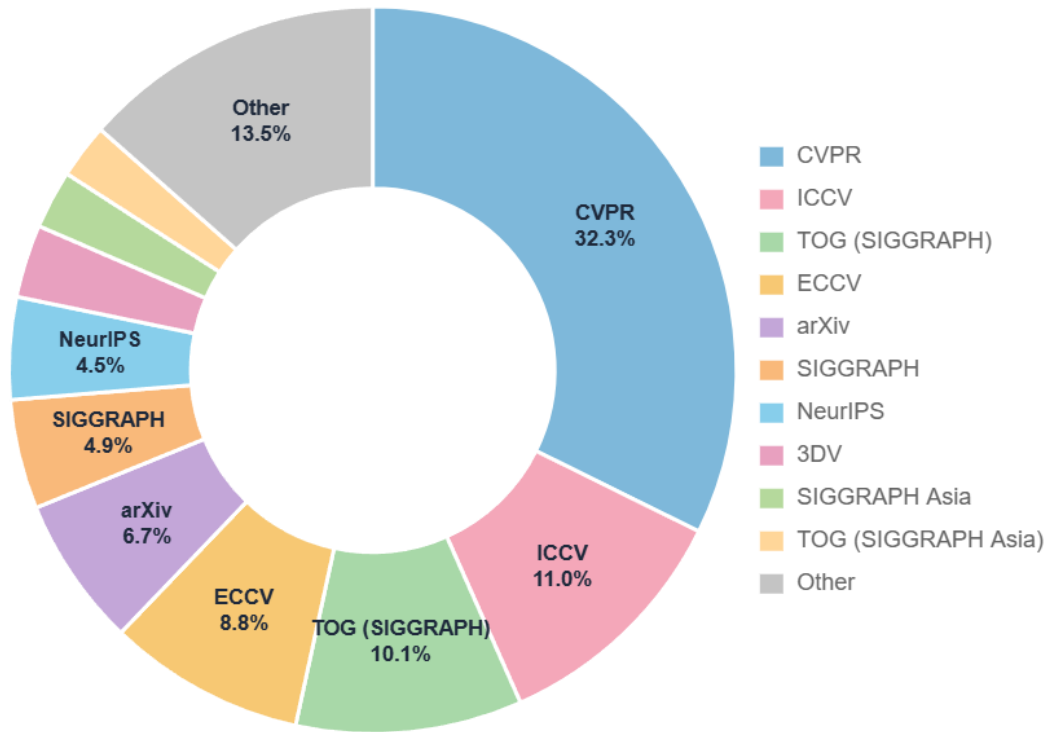
Scope

Avatar Name	Avatar Type	Avatar Style	Avatar Color	Avatar Hair	Avatar Eyes	Avatar Mouth	Avatar Nose	Avatar Ears	Avatar Neck	Avatar Torso	Avatar Arms	Avatar Legs	Avatar Feet
Avatar 1	Male	Realistic	Blue	Black	Blue	Red	Black	Black	Black	Black	Black	Black	Black
Avatar 2	Female	Cartoon	Red	Blonde	Green	Blue	Black	Black	Black	Black	Black	Black	Black
Avatar 3	Male	Realistic	Green	Black	Blue	Red	Black	Black	Black	Black	Black	Black	Black
Avatar 4	Female	Cartoon	Blue	Blonde	Green	Blue	Black	Black	Black	Black	Black	Black	Black
Avatar 5	Male	Realistic	Red	Black	Blue	Red	Black	Black	Black	Black	Black	Black	Black
Avatar 6	Female	Cartoon	Green	Blonde	Blue	Red	Black	Black	Black	Black	Black	Black	Black
Avatar 7	Male	Realistic	Blue	Black	Green	Blue	Black	Black	Black	Black	Black	Black	Black
Avatar 8	Female	Cartoon	Red	Blonde	Blue	Red	Black	Black	Black	Black	Black	Black	Black
Avatar 9	Male	Realistic	Green	Black	Blue	Red	Black	Black	Black	Black	Black	Black	Black
Avatar 10	Female	Cartoon	Blue	Blonde	Green	Blue	Black	Black	Black	Black	Black	Black	Black

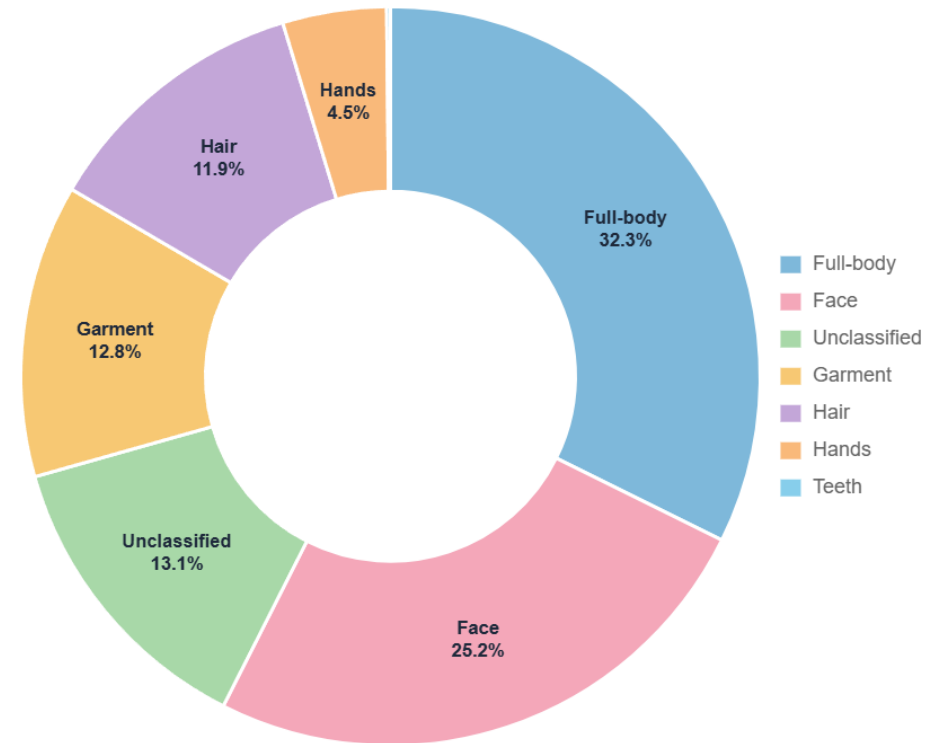


STAR Coverage

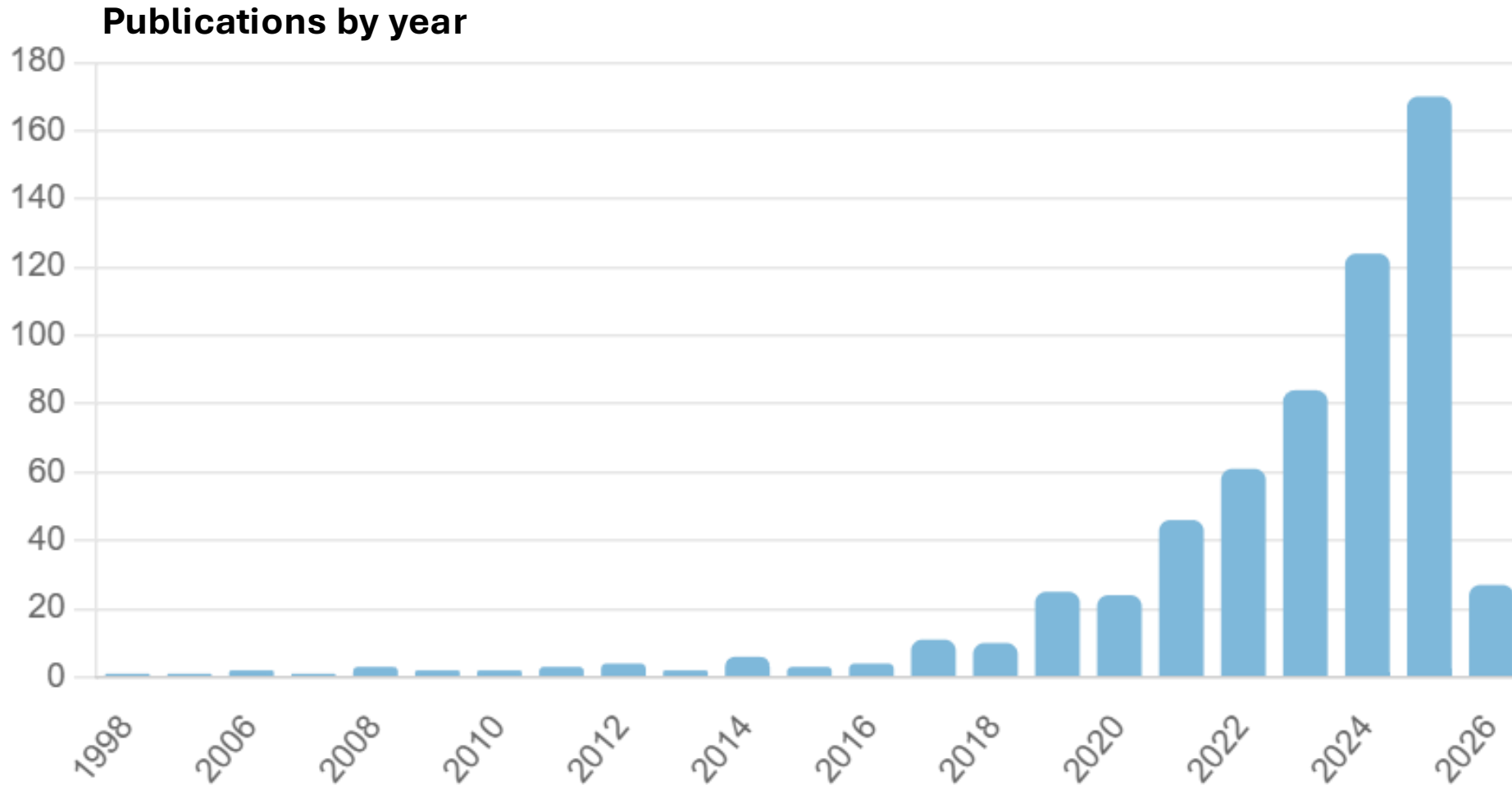
616 publications



All body parts

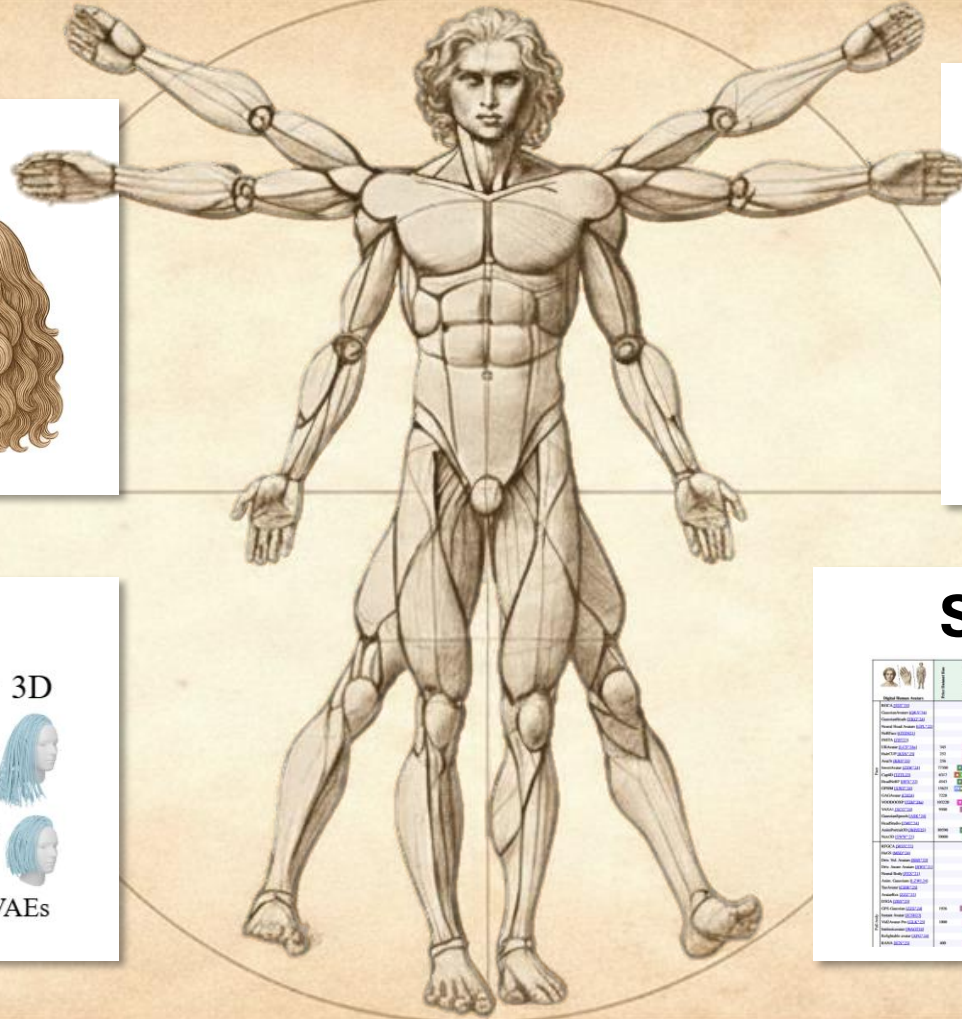


STAR Coverage

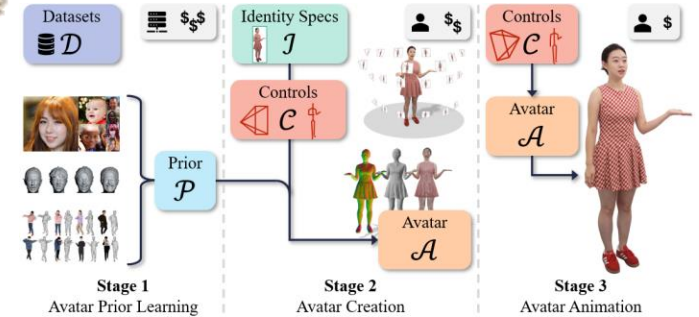


Why is this STAR interesting?

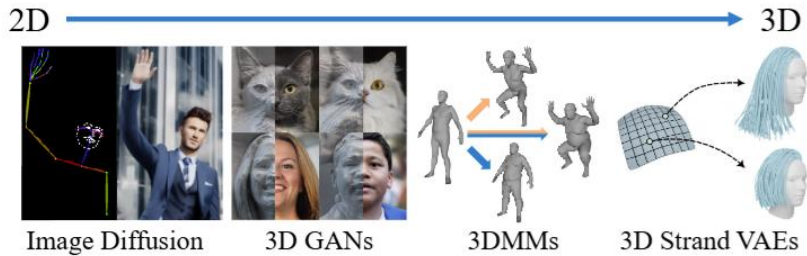
Five Body Parts



Avatar Framework



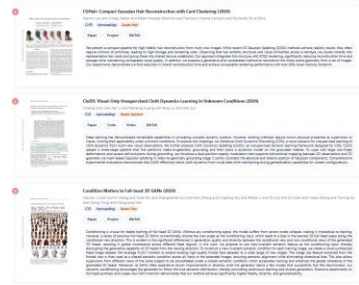
Human Priors



Scope

Avatar Name	Avatar Type	Avatar Style	Avatar Color	Avatar Hair	Avatar Eyes	Avatar Mouth	Avatar Skin	Avatar Body	Avatar Limbs	Avatar Feet
Avatar 1	Male	Realistic	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Avatar 2	Female	Cartoon	Red	Red	Red	Red	Red	Red	Red	Red
Avatar 3	Male	Realistic	Green	Green	Green	Green	Green	Green	Green	Green
Avatar 4	Female	Cartoon	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Avatar 5	Male	Realistic	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple
Avatar 6	Female	Cartoon	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
Avatar 7	Male	Realistic	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink
Avatar 8	Female	Cartoon	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
Avatar 9	Male	Realistic	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green	Light Green
Avatar 10	Female	Cartoon	Light Purple	Light Purple	Light Purple	Light Purple	Light Purple	Light Purple	Light Purple	Light Purple

Website



How to build
Digital Humans

STAR Website



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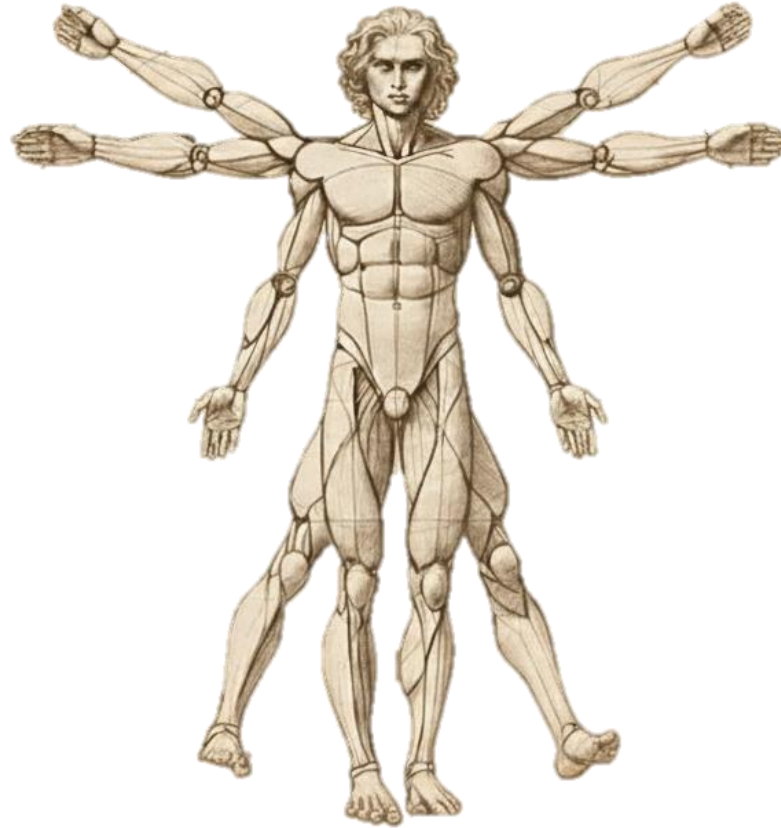
<https://wojciechzielonka.com/how-to-build-digital-humans/>



How to build
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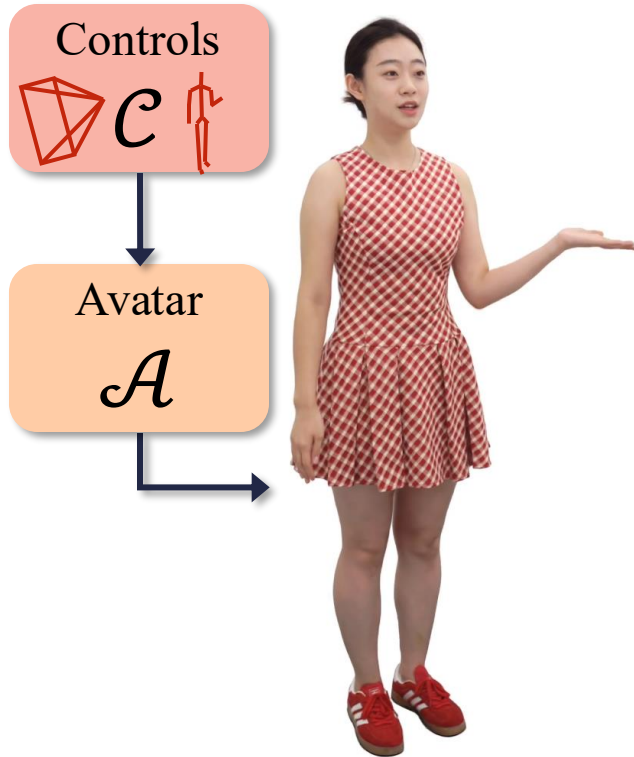
Tobias Kirschstein - May 4th, 2026

What is an Avatar?



What is an Avatar?

An Avatar is a **function** $\mathcal{A}(\cdot)$ that takes **control signals** \mathcal{C} and synthesizes **images/videos** I



$$\mathcal{A}(\mathcal{C}) \rightarrow I$$



What are Control Signals \mathcal{C} ?

Controls

- Viewpoint
- Body Pose
- Expression
- Lighting
- ...



Yang et al. "VRMM", SIGGRAPH 2024



What are Control Signals \mathcal{C} ?

Controls



...

Formally:

$$\mathcal{C} = \{ \mathcal{M}, \pi [\overset{\text{Motion control}}{\mathcal{M}}, \overset{\text{lighting}}{\mathcal{L}}] \}$$

viewpoint

In practice:

$$\mathcal{C} = \{ \text{anything humans find intuitive} \}$$

Assume control signals \mathcal{C} given!



2D vs 3D Avatars

2D Avatars

- Direct synthesis of pixels

$$I = \mathcal{A}_{2D}(C)$$

Note: can be still viewpoint controllable!

3D Avatars

- Factorize image formation into:
 1. Create 3D representation S
 2. Render with renderer \mathcal{R}

$$S = f_{3D}(\mathcal{M}, \mathcal{L})$$
$$I = \mathcal{A}_{3D}(C) = \mathcal{R}(S, \pi)$$



Video World Model



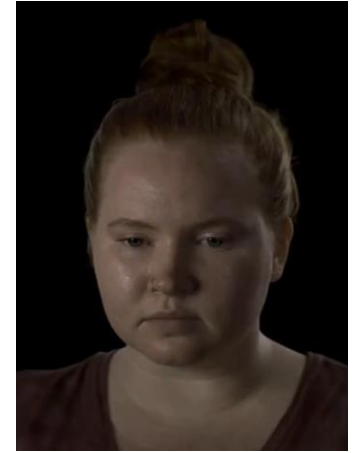
Genie3

NeRF



Weng et al. "HumanNeRF",
CVPR 2022

3DGS



Saito et al.
"Relightable Gaussian
Codec Avatars", CVPR 2024

A_{2D}

A_{3D}



Video Model as Neural Renderer

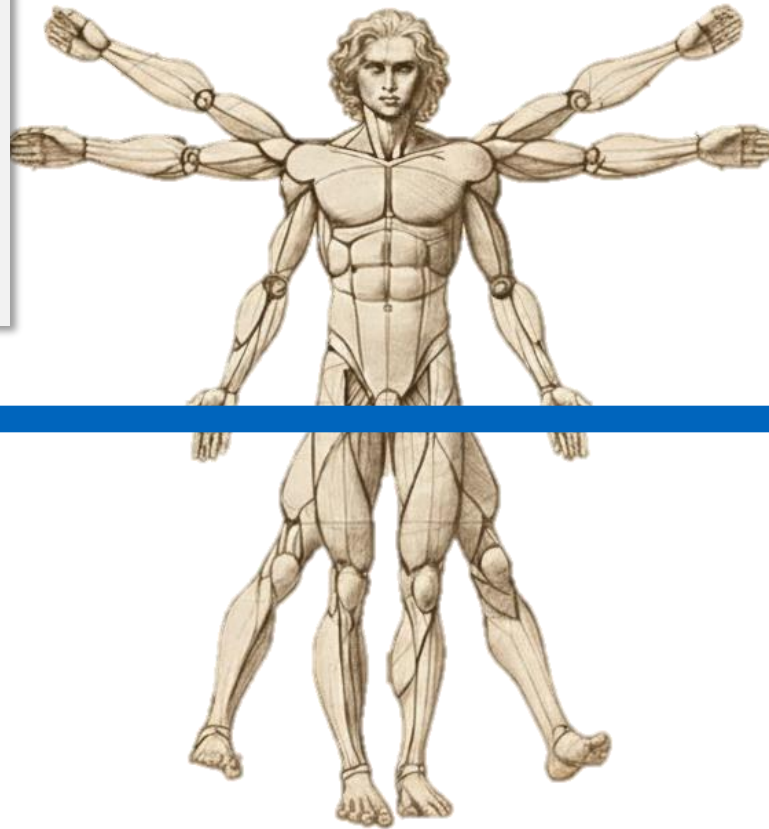


Cao et al. "Uni3C", SIGGRAPH Asia 2025



2D vs 3D Avatars

- + Generalization
- + Visual Quality
- Consistency
- Expensive



- + Speed
- + Consistency
- Generalization

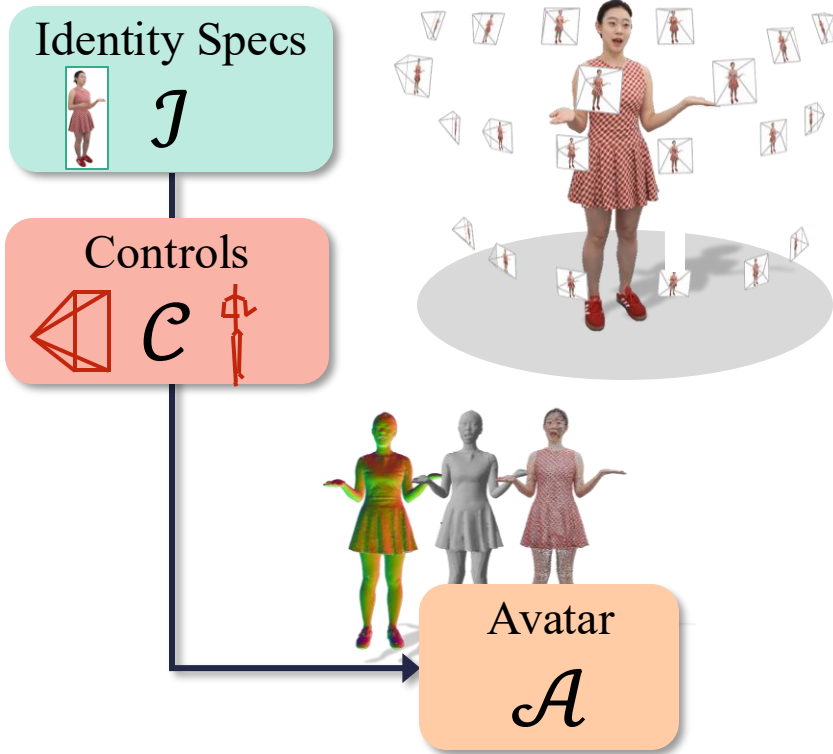
\mathcal{A}_{2D}



\mathcal{A}_{3D}



How to Create an Avatar \mathcal{A} ?



Avatar Creation Process

Given:

- Identity specifications \mathcal{J}
- Corresponding control signals \mathcal{C}

Produce:

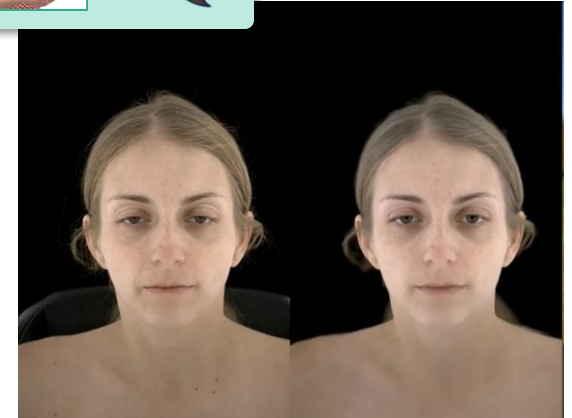
- Avatar \mathcal{A}



What are Identity Specifications \mathcal{I} ?



Lin et al. “LayGA”, SIGGRAPH 2024



Kim et al. “HairCUP”, ICCV 2025

Identity Specs



Images



Text



Clothing



Hair Style



Random Sample

...



Zhou et al. “HeadStudio”, ECCV 2024



Sun et al. “Next3D”, CVPR 2023



Under-constrained Avatar Creation

Single Input Image



360° Complete Avatar

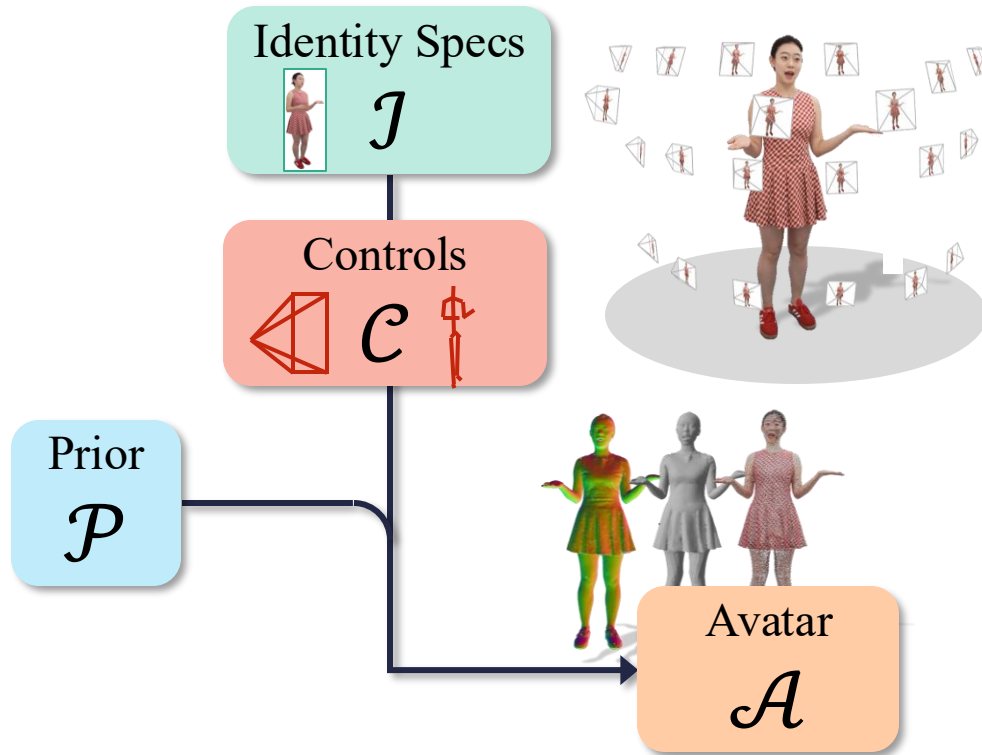


Kirschstein et al. “*FlexAvatar*”, CVPR 2026



How to build
Digital Humans

Under-constrained Avatar Creation



Avatar Creation Process

Given:


- Identity specifications \mathcal{J}
- Corresponding control signals \mathcal{C}
- Human Prior \mathcal{P}

Produce:

- Avatar \mathcal{A}



What is a Human Prior \mathcal{P} ?

Datasets
 \mathcal{D}



Prior
 \mathcal{P}

- Models distribution of human appearance / shape / motion
- Distilled from large-scale dataset of human examples

Goal: In-paint aspects of the avatar that were not described by **Identity Specifications \mathcal{I}**



Common Types of Human Priors \mathcal{P}

2D 3D

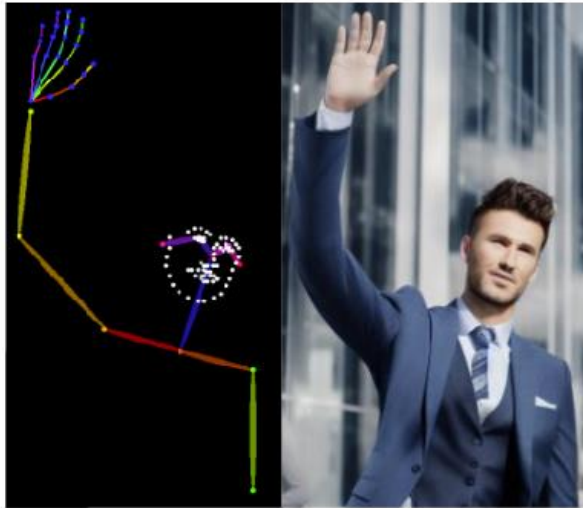
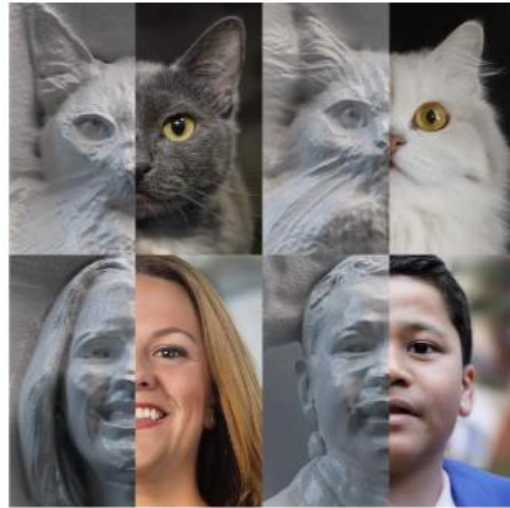
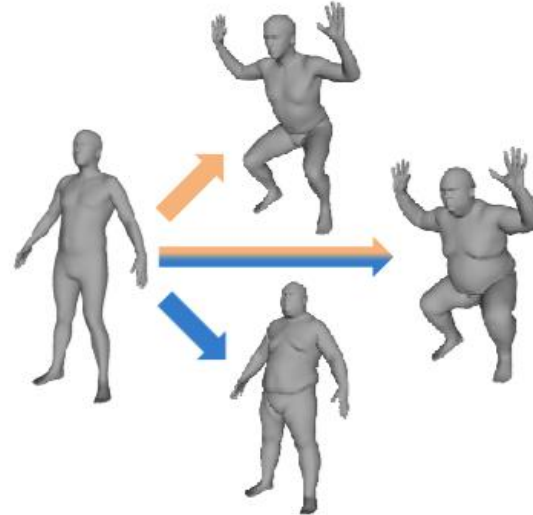


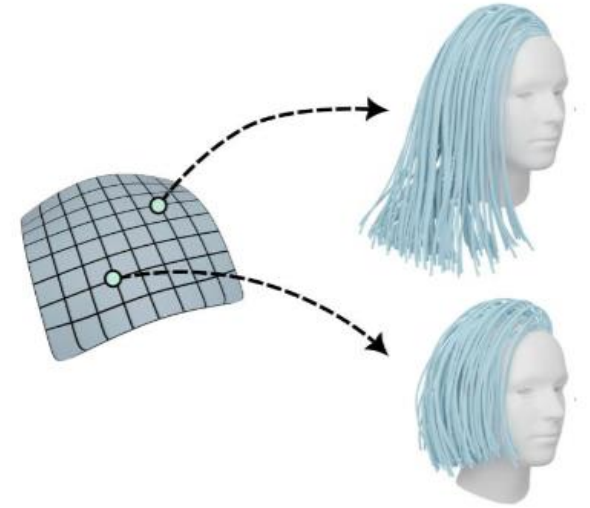
Image Diffusion



3D GANs



3DMMs



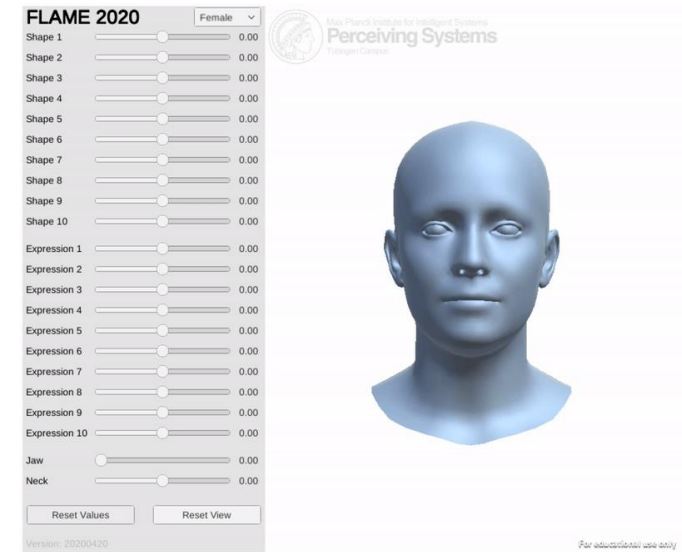
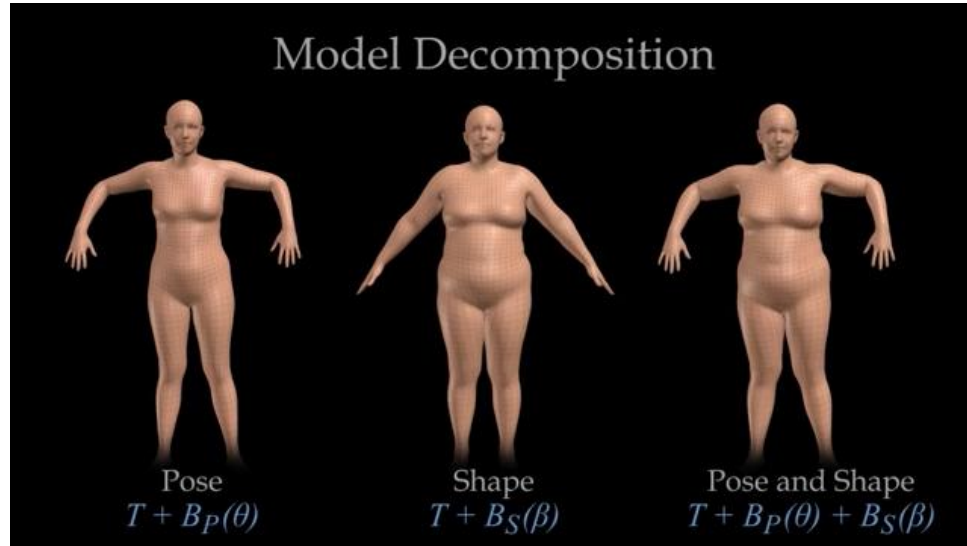
3D Strand VAEs



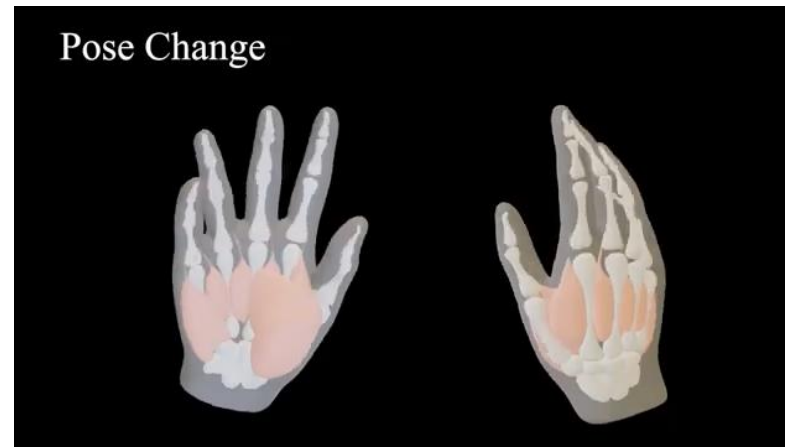
3D Morphable Models (3DMMs)

SMPL

FLAME

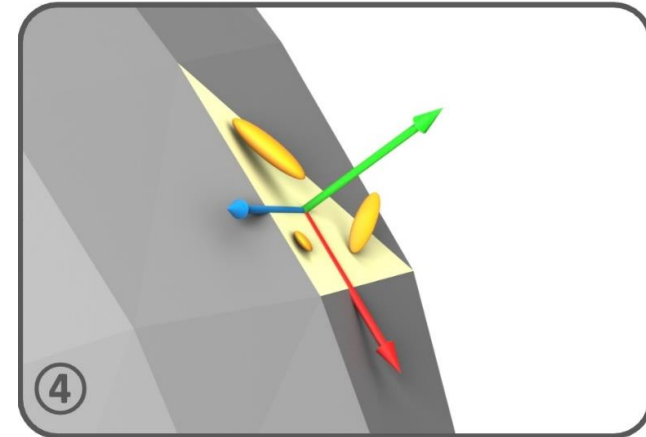


NIMBLE



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3DMM Prior: Explicit Surface Geometry



 **Technique:**

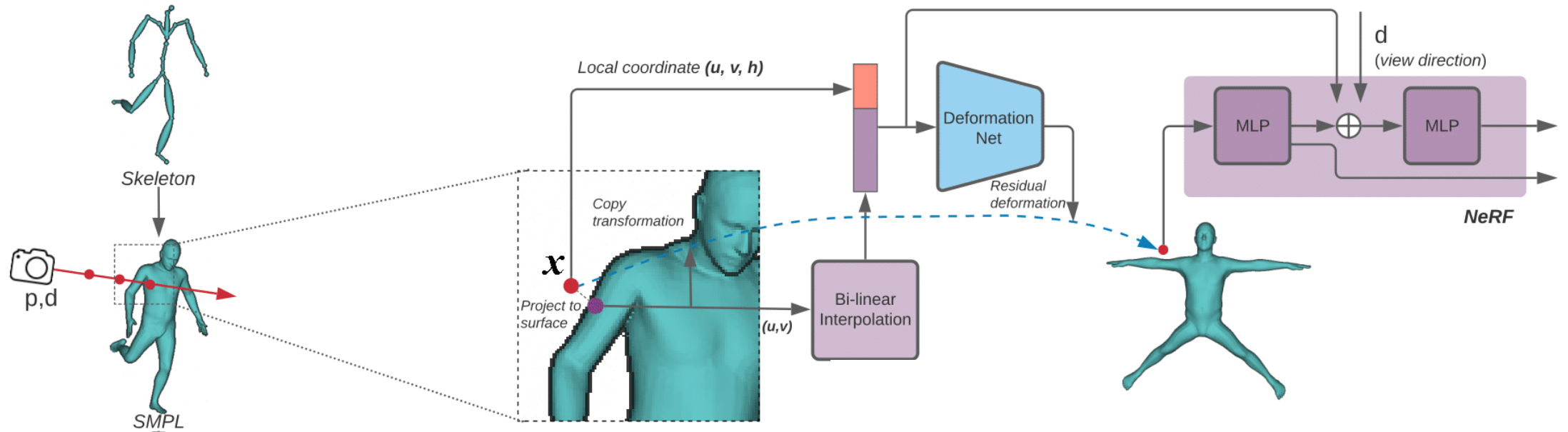
Define 3D primitives
relative to 3DMM mesh

Qian et al. "GaussianAvatars", CVPR 2024



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3DMM Prior: Motion



Liu et al. "Neural Actor", SIGGRAPH Asia 2021

💡 Technique:

Derive **3D deformation field** from 3DMM movement to model animations



3DMM Prior: Disentanglement



Driving video



Sun et al. "Next3D", CVPR 2023

💡 Technique:

Achieve **Motion transfer** by only copying 3DMM expression /pose parameters to avatar

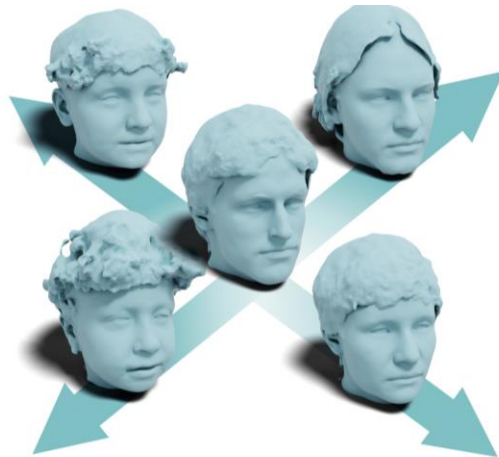


Newer 3DMMs

SDF-based

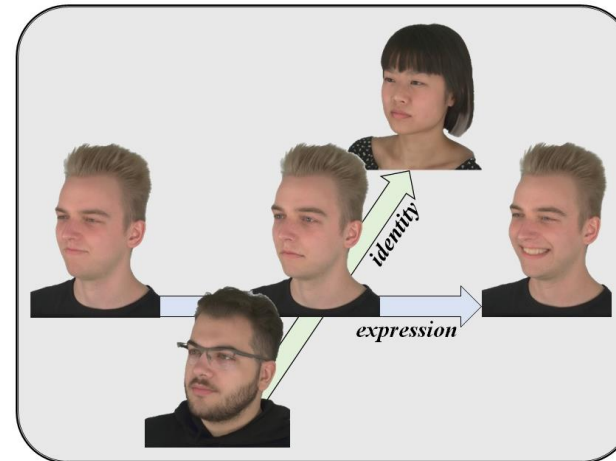


Giebenhain et al. “NPHM”, CVPR 2023



Potamias et al. “ImHead”, ICCV 2025

3D Gaussian-based



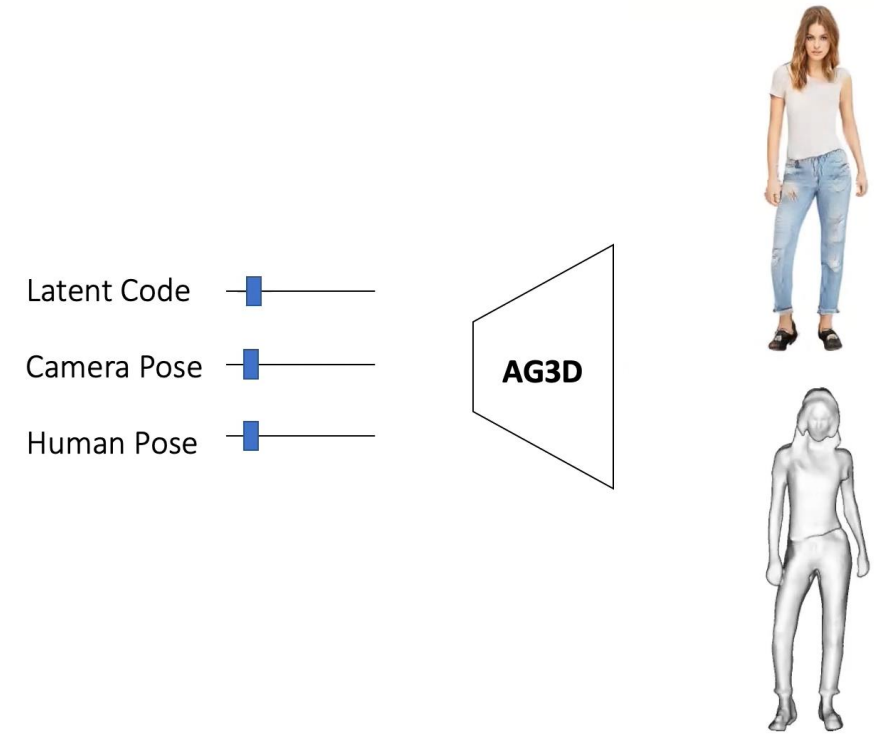
Xu et al. “GPHM”, ECCV 2024



3D Generative Adversarial Networks (3D GANs)



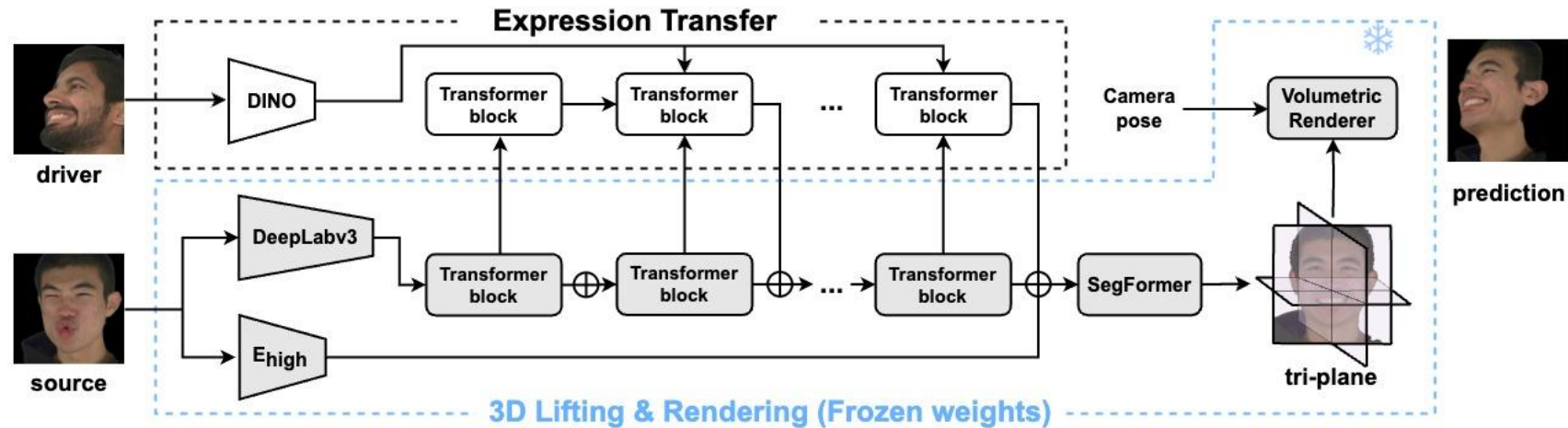
Chan et al. “EG3D”, CVPR 2022



Dong et al. “AG3D”, ICCV 2023



3D GAN Prior: Use pre-trained models



Tran et al. "VOODOO XP", SIGGRAPH Asia 2024

VR Telepresence



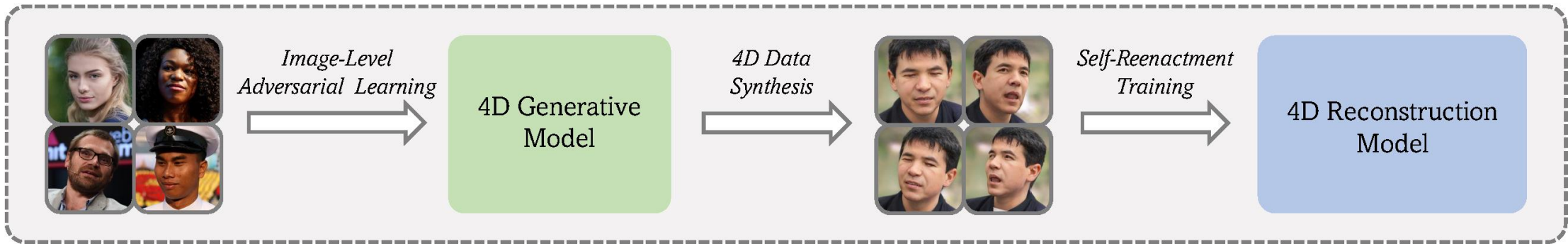
💡 Technique:

Improve **generalization** capabilities by building on top of a pre-trained 3D GAN Inverter



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Digital Humans

3D GAN Prior: Synthetic Data Generation



Deng et al. "Portrait 4D", CVPR 2024

Technique:

Use a 3D GAN to
generate large-scale 4D training data



Image / Video Diffusion Models



FLUX image generator



WAN video model



Diffusion Prior: Dataset Extension



Reference Image(s)



Generate images
with MMDM



Generated Images



Fit 4D Gaussian
avatar



Real-time 4D Avatar

Taubner et al. "CAP4D", CVPR 2025

 **Technique:**

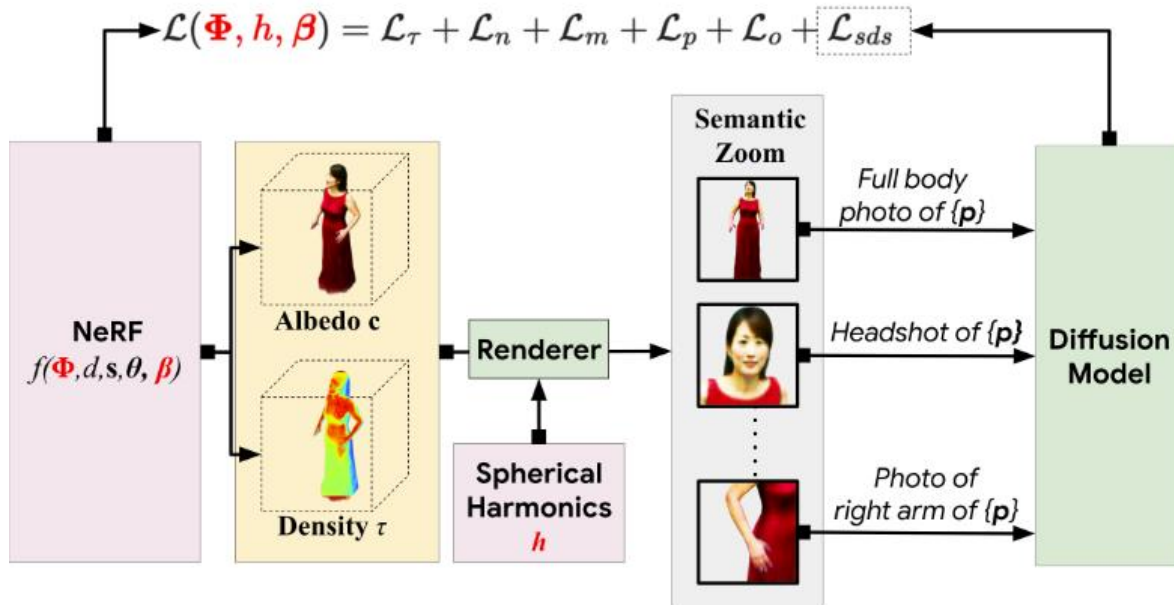
Fine-tune 2D diffusion model to
predict more images for avatar creation



Diffusion Prior: Score Distillation Sampling



Kolotouros et al. “*DreamHuman*”, NeurIPS 2023



💡 **Technique:**

Use 2D diffusion model as a **loss function** to supervise via text



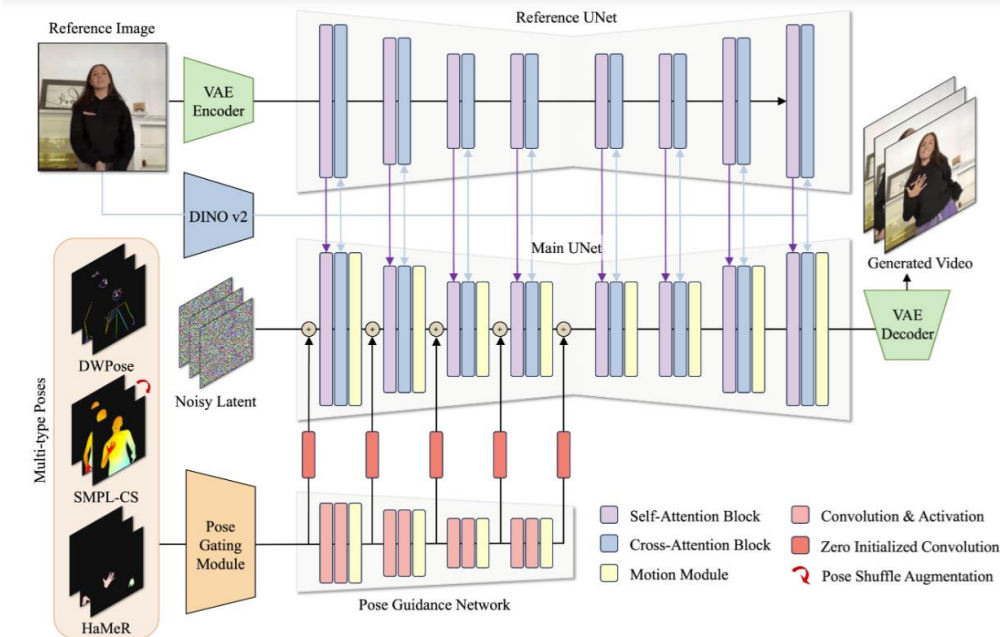
Diffusion Prior: Neural Renderer



Cao et al. "Uni3C", SIGGRAPH Asia 2025

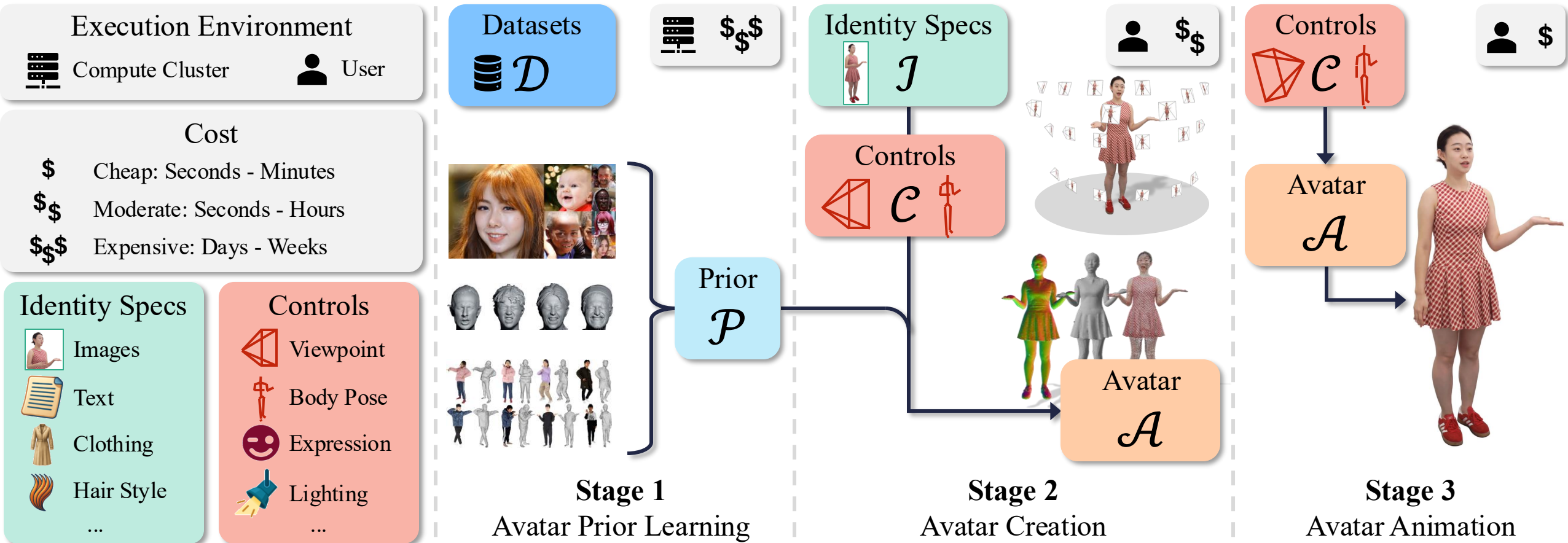
💡 Technique:

Condition 2D diffusion model on **3DMM / pointcloud renderings** to create human videos with **animation and viewpoint control**



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A common Avatar Framework

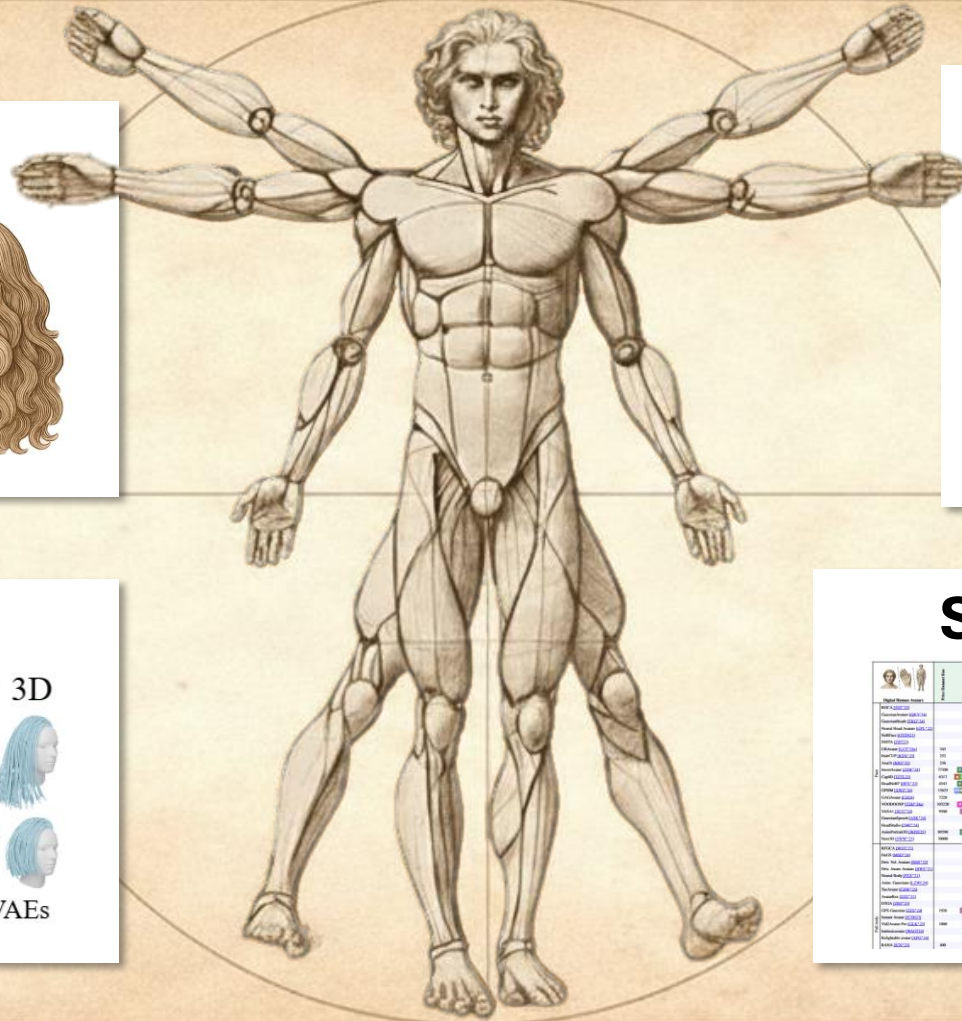


Thank you for your attention!

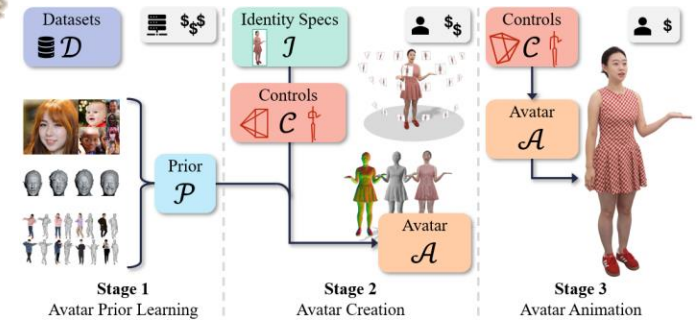
STAR website



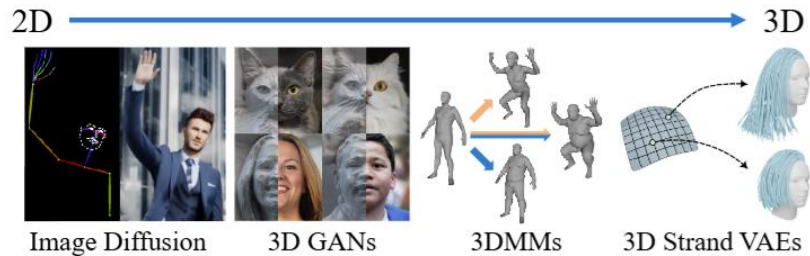
Five Body Parts



Avatar Framework

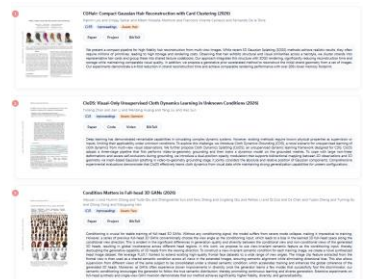


Human Priors



Scope

Website



How to build
Digital Humans

Digital Humans - Schedule

Time	Speaker	Talk
13:20	 Matthias Nießner	History of Avatars
13:35	 Shunsuke Saito	Scaling Digital Humans
13:50	 Tobias Kirschstein	STAR Taxonomy
14:05	 Marc Habermann	Towards Generalized Physical Avatars and the Role of Foundation Models
14:20	 Justus Thies	Digital Humans in Motion
14:35	 Organizers	STAR Summary

