SIGGRAPH ASIA 2023 SYDNEY

EMS: 3D Eyebrow Modeling from Single-view Images

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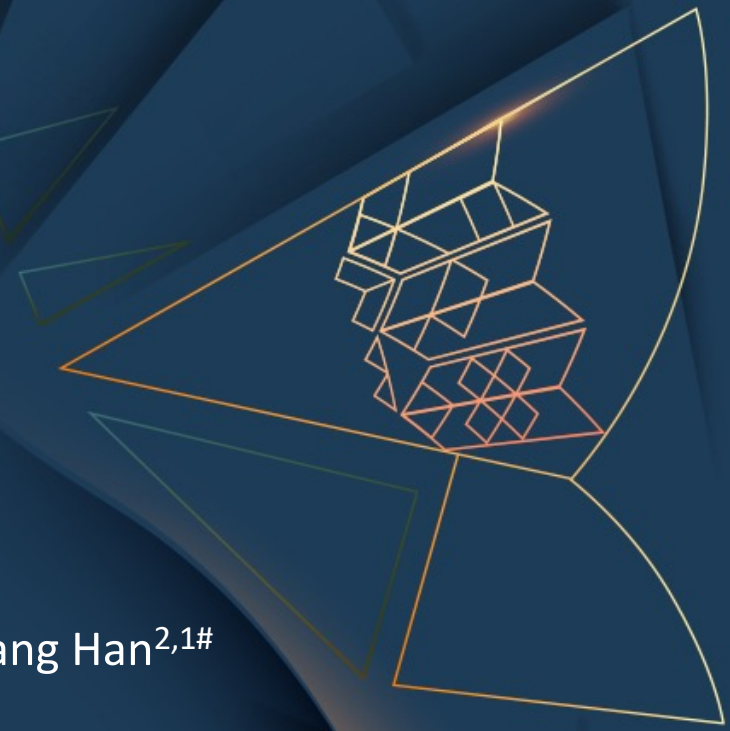
FNii, CUHKSZ[1] SSE, CUHKSZ[2] The University of Hong Kong[3]



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The 16th ACM SIGGRAPH Conference and Exhibition on Computer Graphics and Interactive Techniques in Asia

CONFERENCE 12 - 15 December 2023
EXHIBITION 13 - 15 December 2023
ICC, Sydney, Australia

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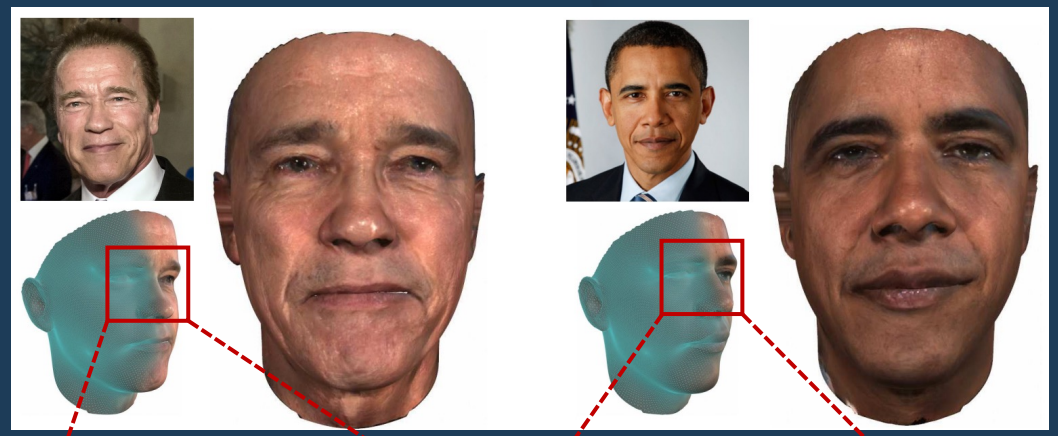
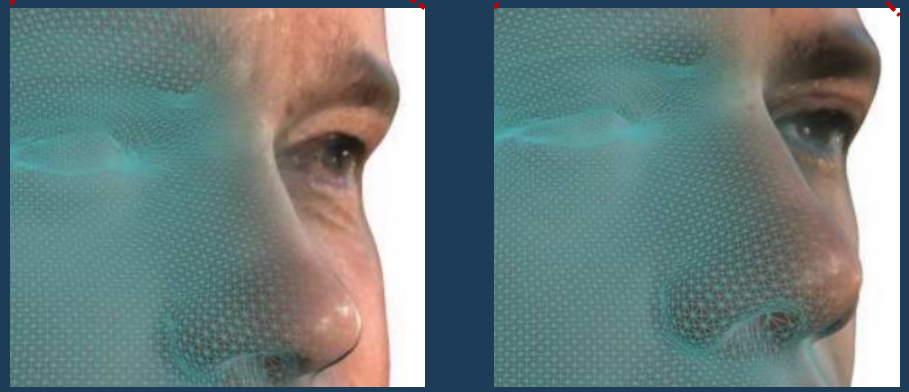
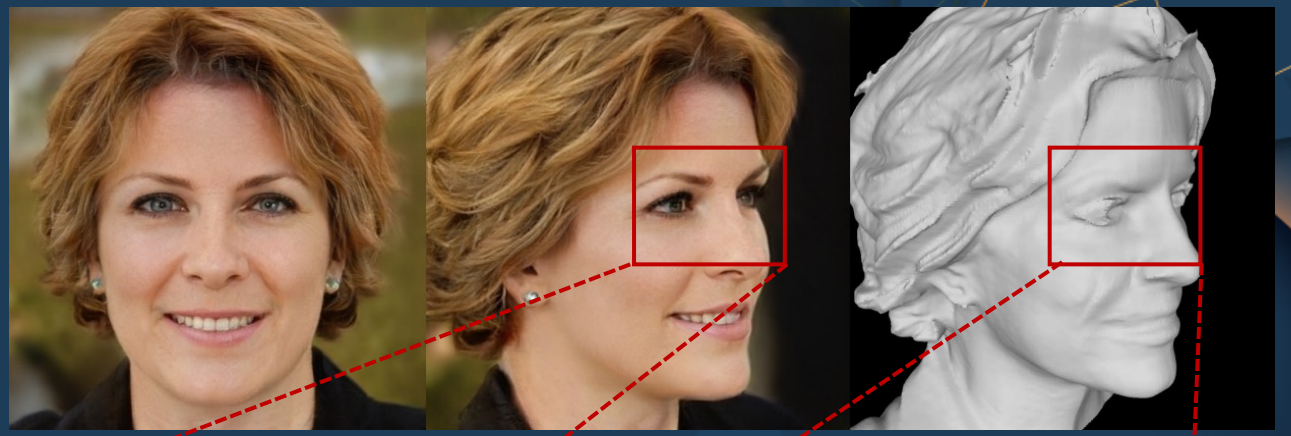
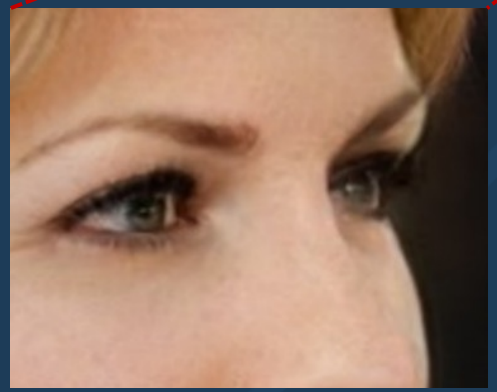
Eyebrow in Face Reconstruction





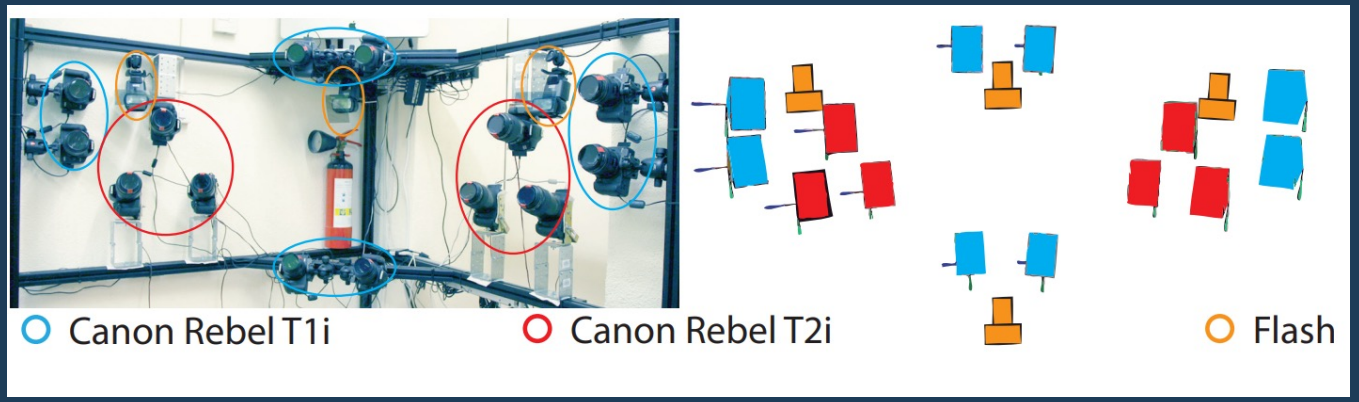


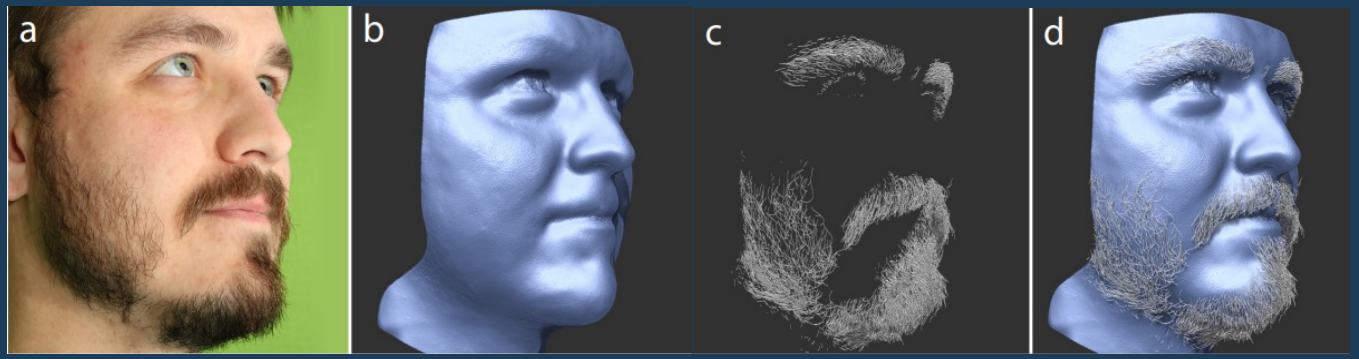


- texture-based eyebrow appearance
- no geometric fiber details

[1] Gecer, Baris, et al. "Ganfit: Generative adversarial network fitting for high fidelity 3d face reconstruction." *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*. 2019.
[2] An, Sizhe, et al. "PanoHead: Geometry-Aware 3D Full-Head Synthesis in 360deg." *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2023.

Multi-view Facial Hair Capture





- high-fidelity captured geometry
- complex hardware setups

[1] Beeler, Thabo, et al. "Coupled 3D reconstruction of sparse facial hair and skin." *ACM Transactions on Graphics (ToG)* 31.4 (2012): 1-10.
[2] Winberg, Sebastian, et al. "Facial hair tracking for high fidelity performance capture." *ACM Transactions on Graphics (TOG)* 41.4 (2022): 1-12.

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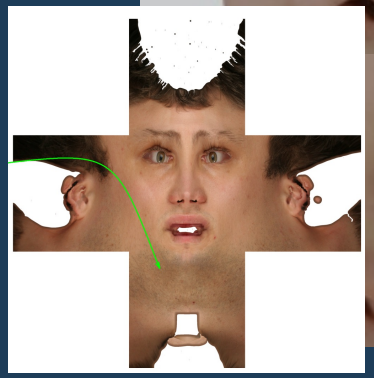
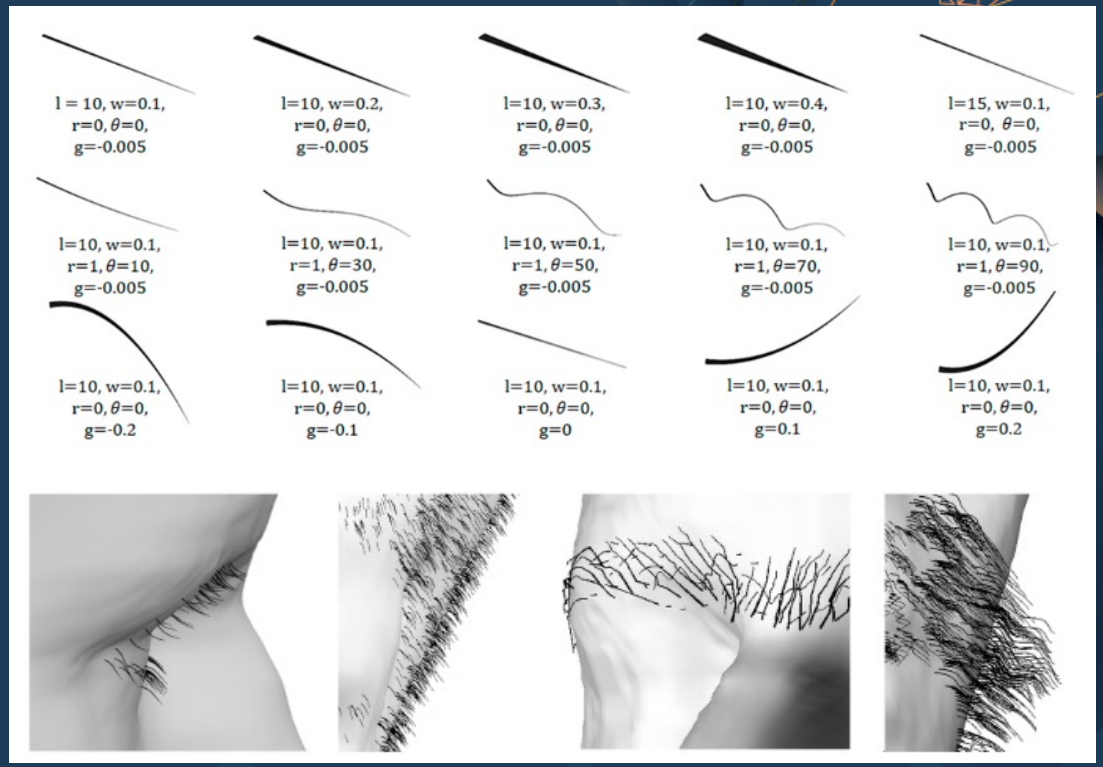
Single-input Facial Hair Modeling





✓ statistical priors ✗ texture map needed

✓ frontal-image input

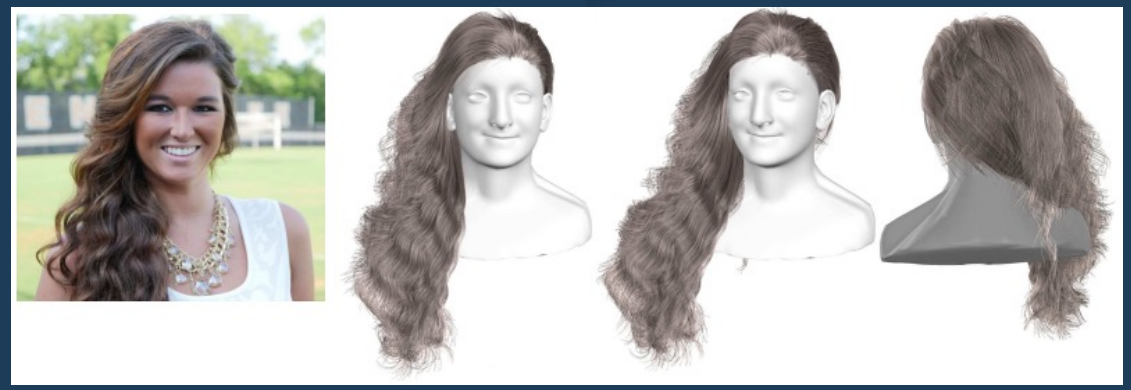
✗ unnatural artifacts

✗ ambiguity by self-occlusion

[1] Herrera, Tomas Lay, et al. "Toward image-based facial hair modeling." Proceedings of the 26th Spring Conference on Computer Graphics. 2010.

[2] Rotger, Gemma, et al. "Single view facial hair 3D reconstruction." Pattern Recognition and Image Analysis: 9th Iberian Conference, IbPRIA 2019, Madrid, Spain, July 1–4, 2019, Proceedings.

Learning-based Single-view Scalp Hair Modeling



Reconstruction problem

Curve growing problem

- **Where to start?**
  -> Hair root localization
- **How to grow?**
  -> Hair strand representation
- **When to stop?**
  -> Hair strand length determination

✓ learned priors from synthetic dataset

✗ no available 3D eyebrow data

✗ not tailor for eyebrow growing pattern

[1] Zhou, Yi, et al. "Hairnet: Single-view hair reconstruction using convolutional neural networks." *Proceedings of the European Conference on Computer Vision (ECCV)*. 2018.
[2] Wu, Keyu, et al. "Neuralhdhair: Automatic high-fidelity hair modeling from a single image using implicit neural representations." *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2022.

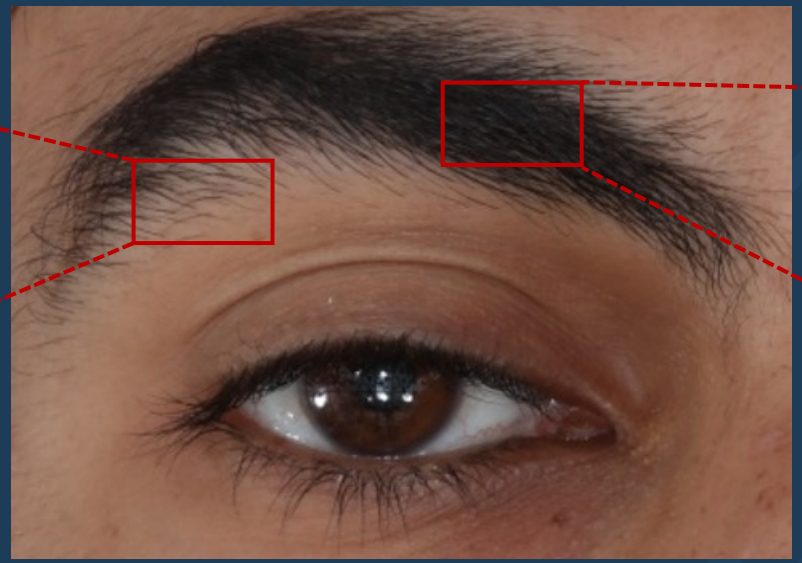
Where to start?

Trivial methods

- Pre-sampled roots on brow bone region of a fix number (like scalp hair)
- Directly detect location of roots

Solution: *RootFinder* 😁

Probably enable to examine root location

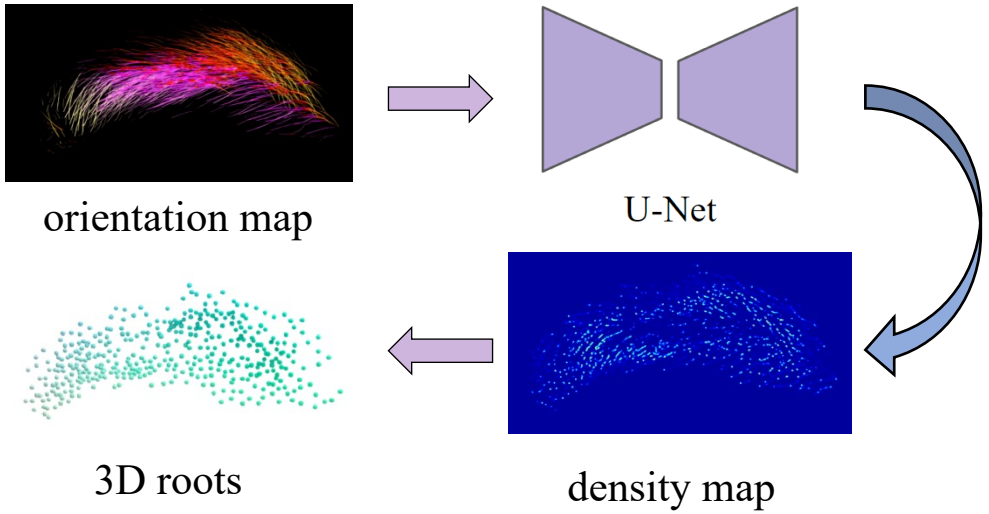


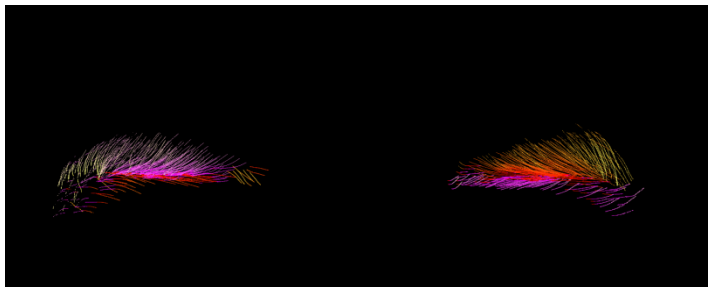
Fail to locate the exact root! 😔

Where to start?

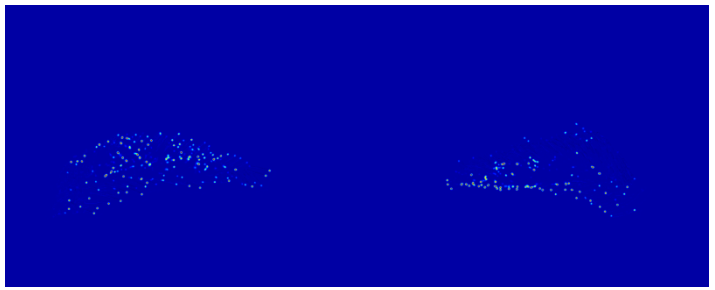
RootFinder: a **density-based** eyebrow root location method

Root localization estimation ➡ Density map prediction



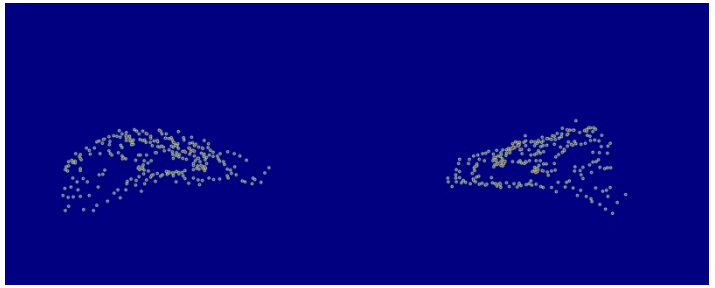


(a) Input orientation map



(b) Predict density map

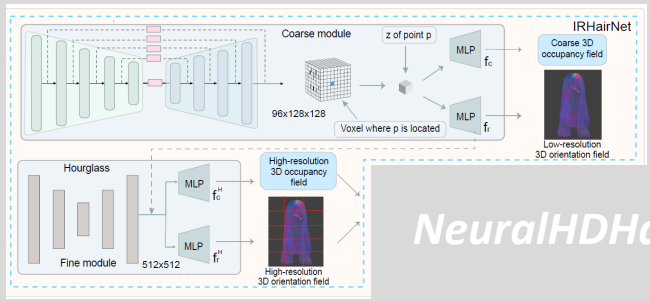
(c) 3D root points



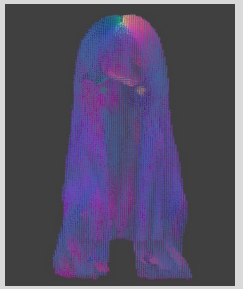
(d) GT density map

How to grow?

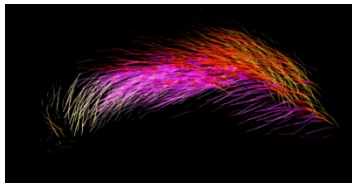
OriPredictor: using **implicit orientation field** to represent growing direction for each fiber



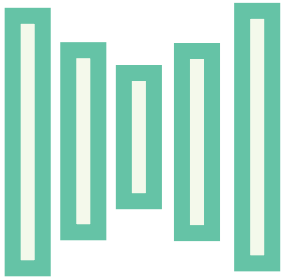
NeuralHDHair



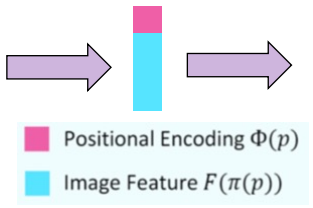
Implicit orientation field



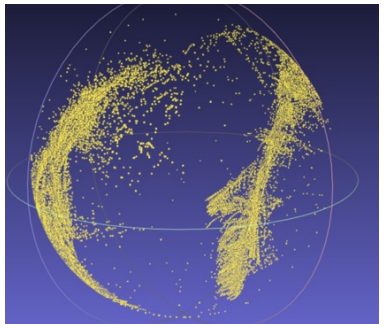
Input orientation map



Hourglass



MLP

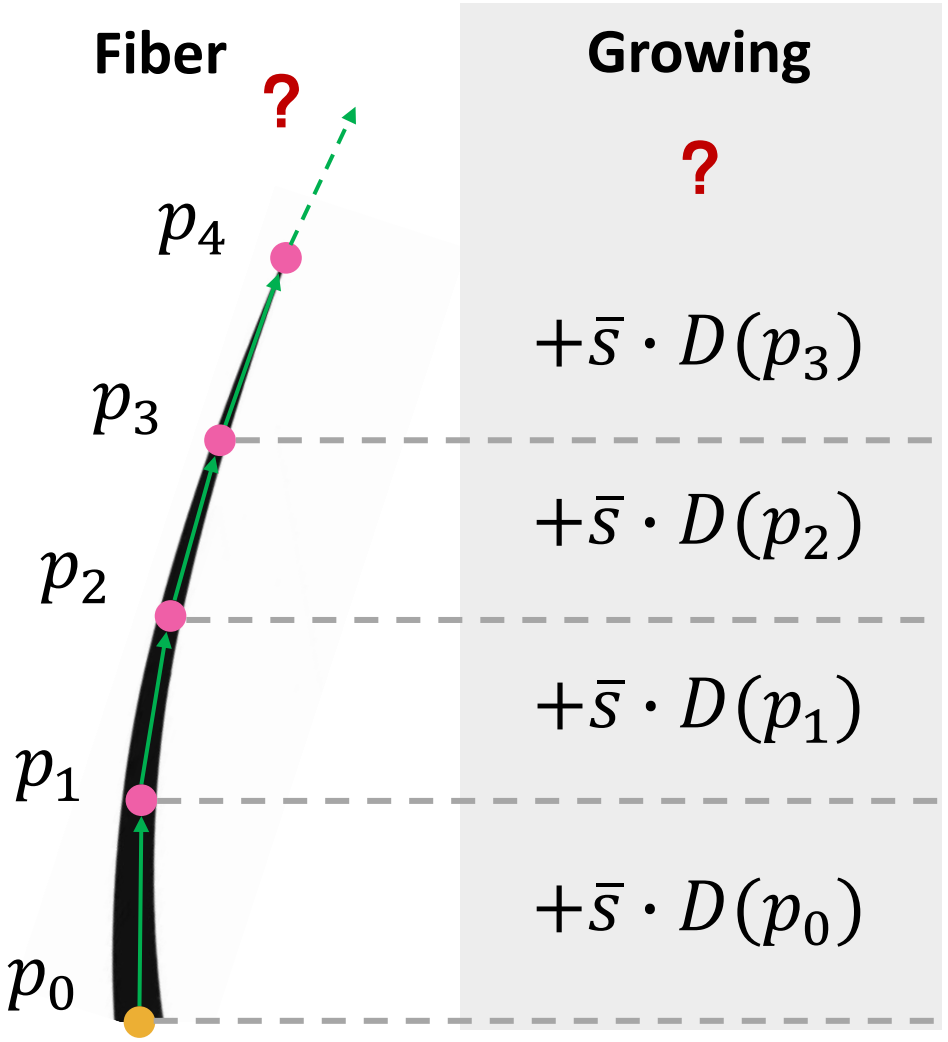


Predicted orientation field

Orientation L1-Loss

GT eyebrow geometry

How to grow?



So how to determine whether a growing fiber should end?

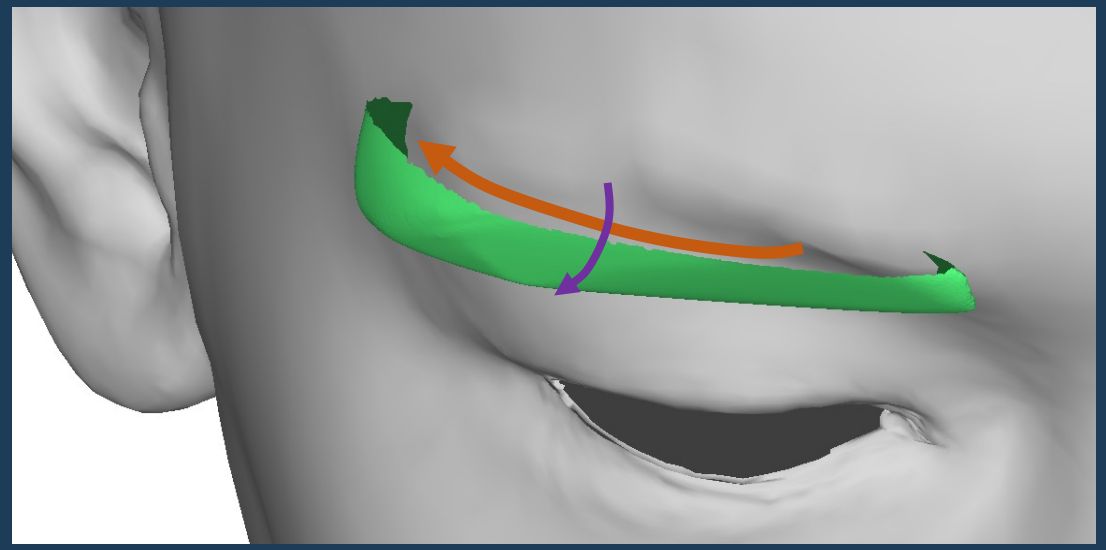
$D(p_i)$: 3D orientation of point p_i
$\bar{s}$: a fixed step

When to stop?

Previous methods

- Cut fibers growing outside the predicted coarse mesh (like scalp hair)

Solution: *FiberEnder* 😄



Eyebrow contour mesh

Out-of-plane growing direction

In-the-plane growing direction 😔

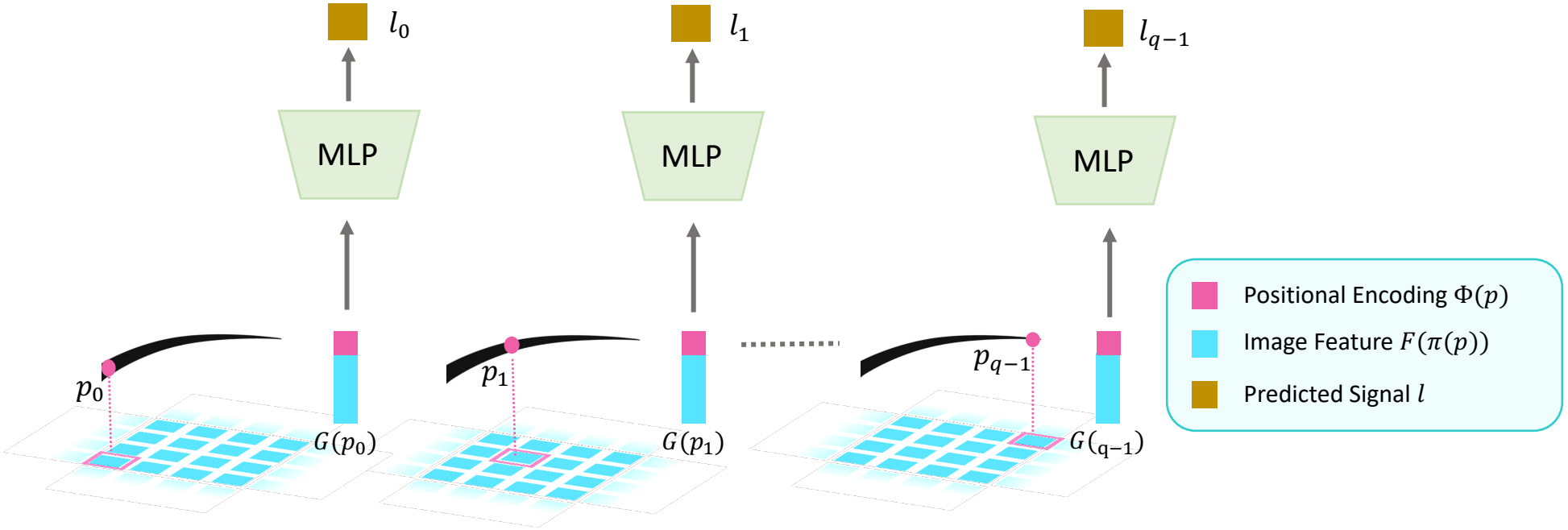
Smaller scale, need more accurate length control!

FiberEnder

Fiber length determination → binary classification $L(S) = \begin{cases} 0, & \text{if S should be stopped} \\ 1, & \text{otherwise} \end{cases}$

What is possible attributes to a growing fiber?

- Pixel-aligned image feature on orientation map
- 3D position information



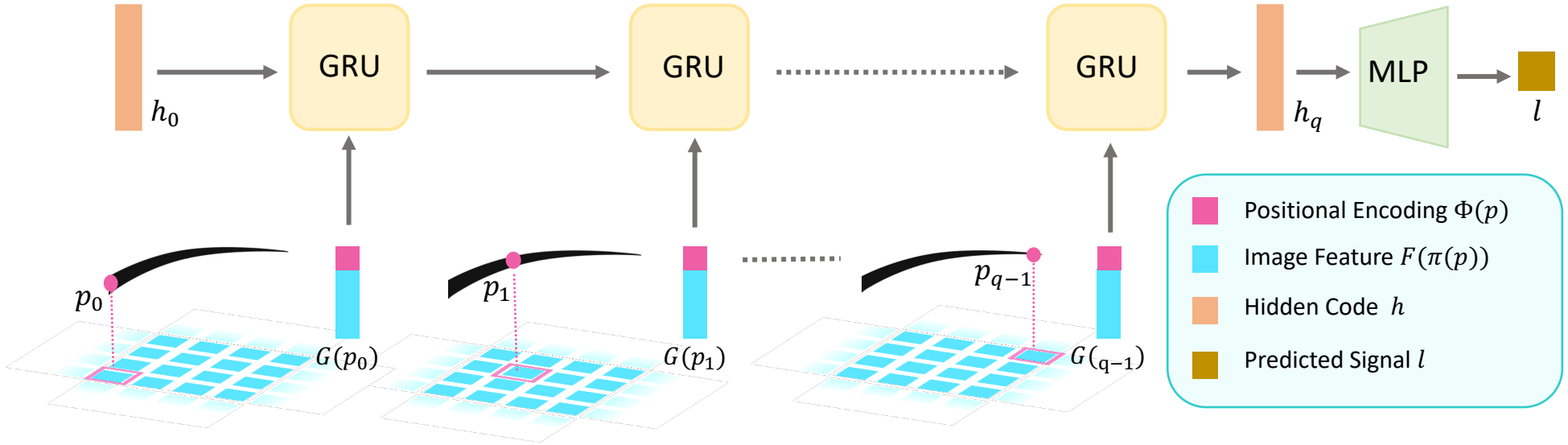
FiberEnder

Fiber length determination ➡ binary classification $L(S) = \begin{cases} 0, & \text{if S should be stopped} \\ 1, & \text{otherwise} \end{cases}$

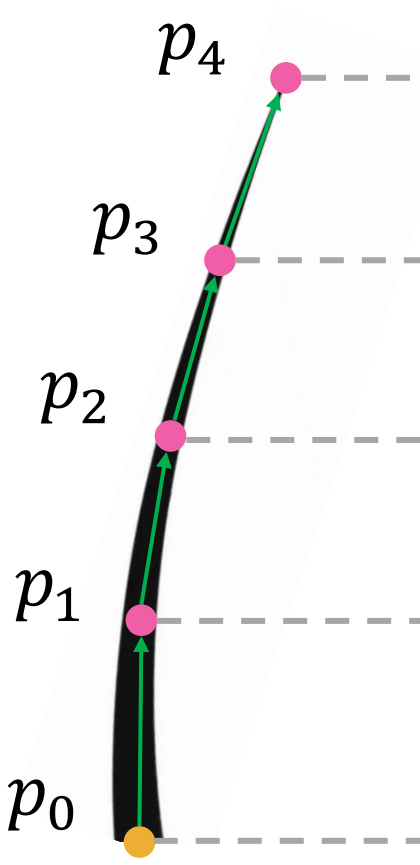
What is possible attributes to a growing fiber?

- Pixel-aligned image feature on orientation map
- 3D position information
- Historical growing hints

} **pixel-aligned** and stacked **RNN-based** *FiberEnder*

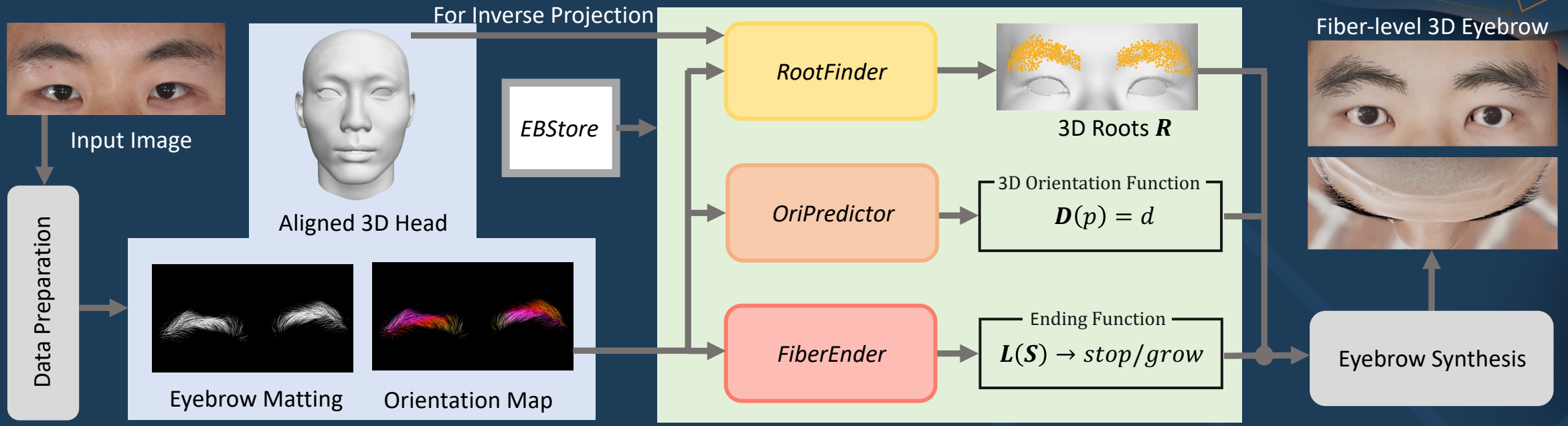


Eyebrow Synthesis

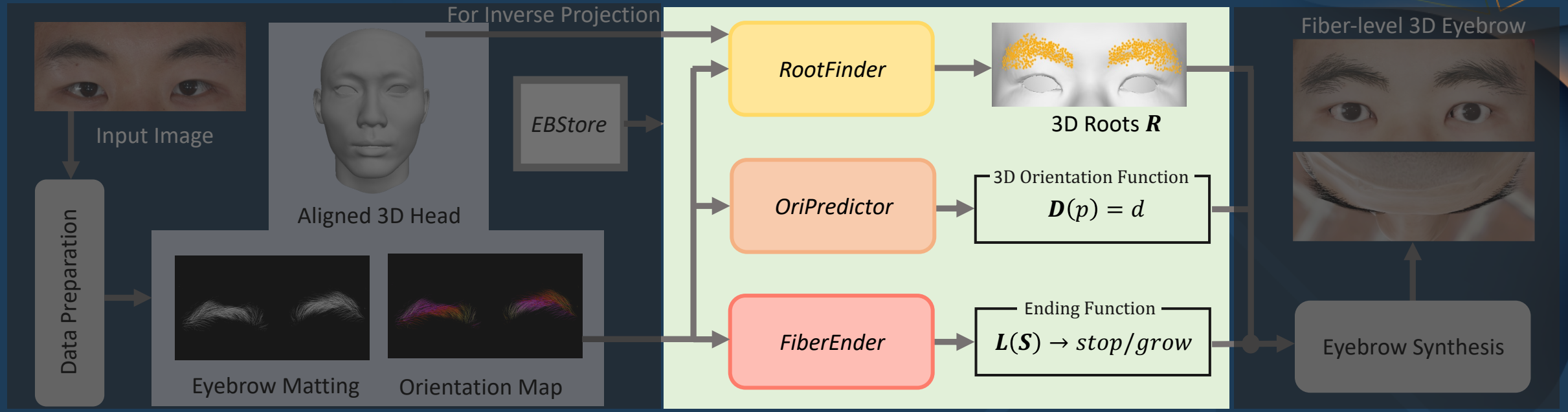


Fiber	Growing	Ending
p_4	/	$L(S_{\{j\leq 4\}}) \rightarrow end$
p_3	$+\bar{s} \cdot D(p_3)$	$L(S_{\{j\leq 3\}}) \rightarrow grow$
p_2	$+\bar{s} \cdot D(p_2)$	$L(S_{\{j\leq 2\}}) \rightarrow grow$
p_1	$+\bar{s} \cdot D(p_1)$	$L(S_{\{j\leq 1\}}) \rightarrow grow$
p_0	$+\bar{s} \cdot D(p_0)$	$L(S_{\{j\leq 0\}}) \rightarrow grow$

Pipeline


For Inverse Projection
Input Image
Data Preparation
Aligned 3D Head
EBStore
Eyebrow Matting
Orientation Map
RootFinder
OriPredictor
FiberEnder
3D Roots $\boldsymbol{R}$
3D Orientation Function
$\boldsymbol{D}(p) = d$
Ending Function
$\boldsymbol{L}(\boldsymbol{S}) \rightarrow stop/grow$
Eyebrow Synthesis
Fiber-level 3D Eyebrow

Pipeline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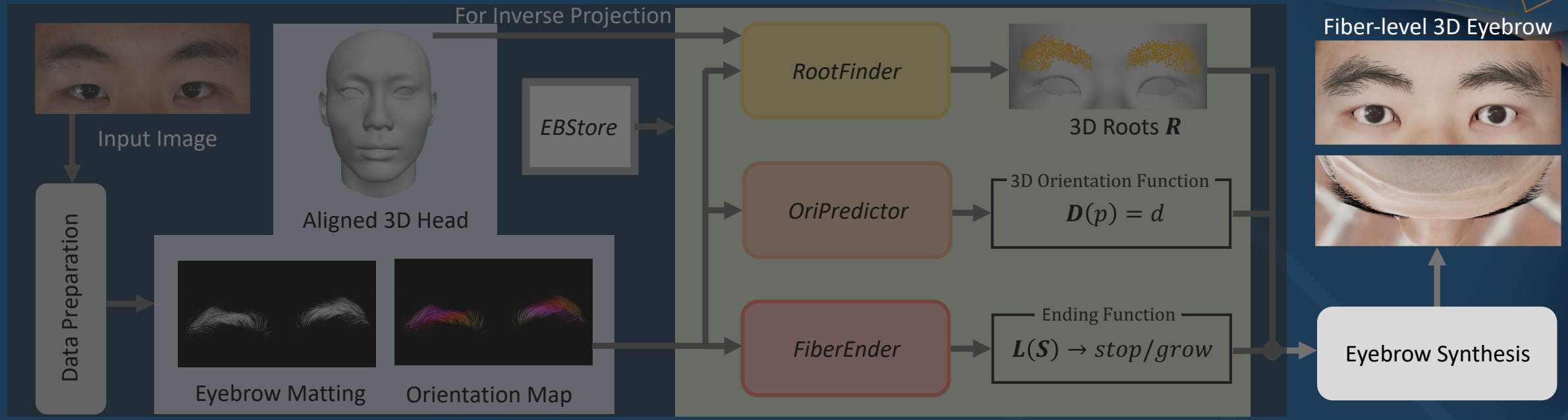
Fiber-level 3D Eyebrow
Eyebrow Synthesis

Pipeline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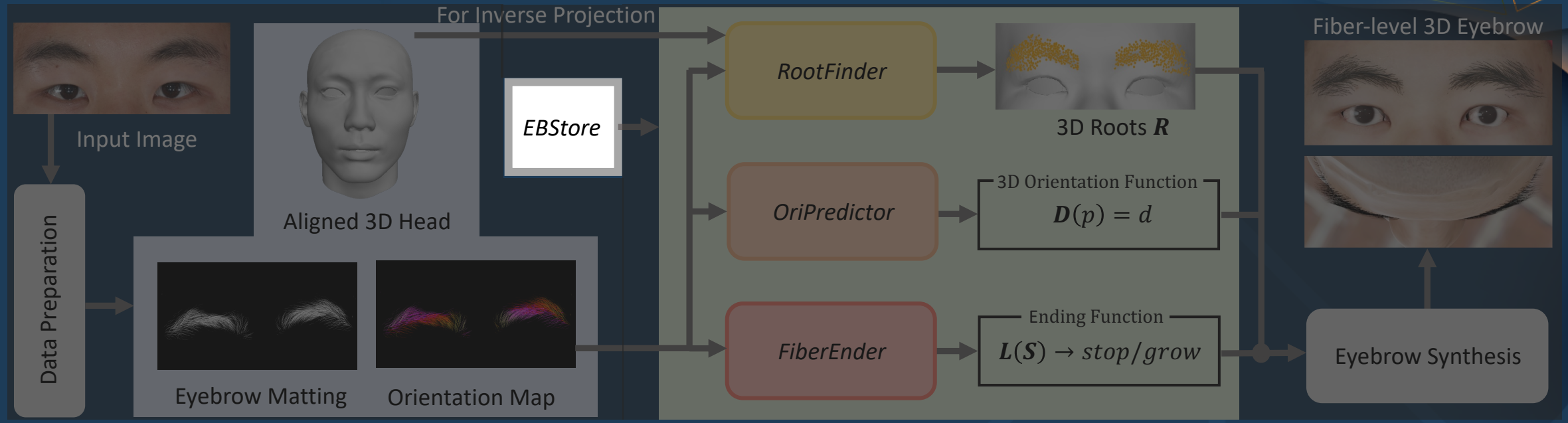
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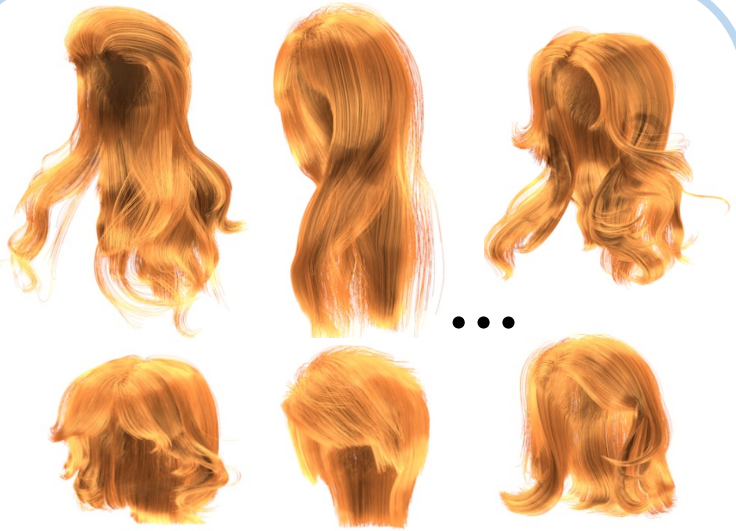
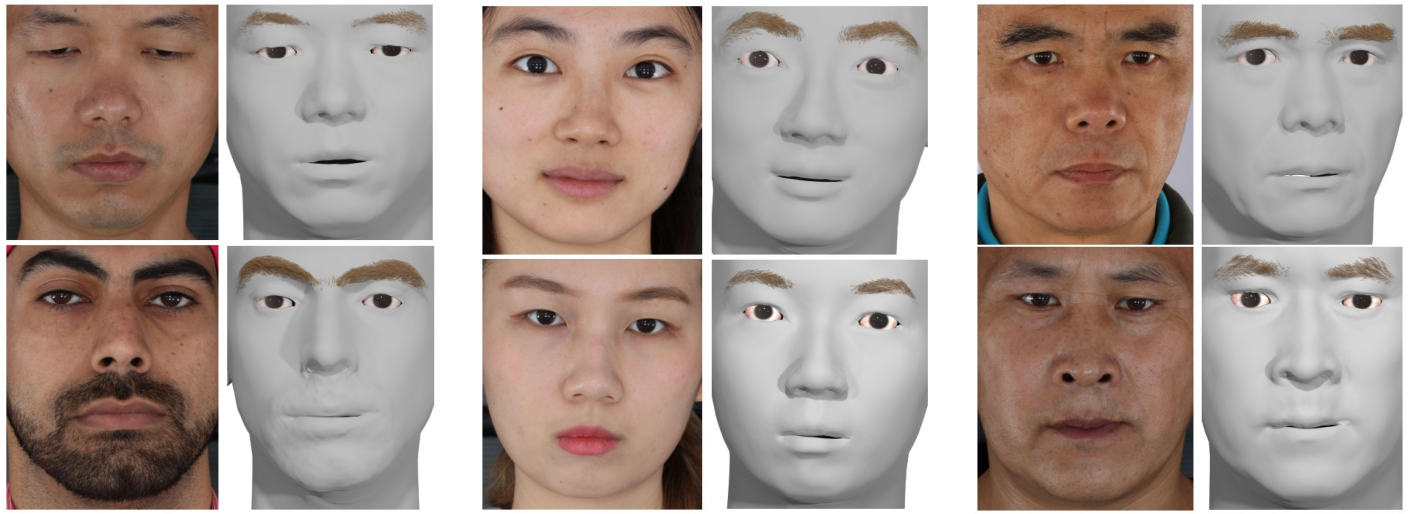
Eyebrow Synthesis

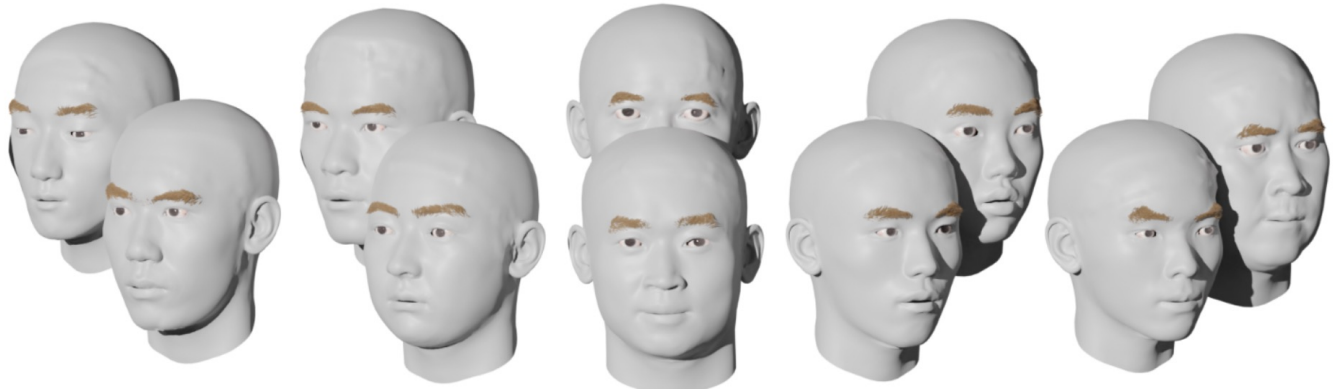
EBStore



Synthetic 3D scalp hair dataset

Hard to collect 3D model from Internet 😔

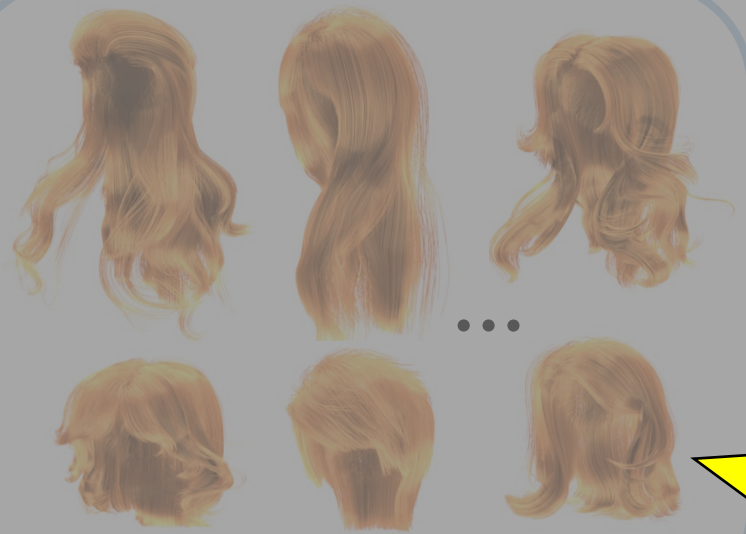




***EBStore** Dataset*: the **first** 3D synthetic eyebrow dataset that contains **400 high-quality models** manually created by artists

[1] Hu, Liwen, et al. "Single-view hair modeling using a hairstyle database." *ACM Transactions on Graphics (ToG)* 34.4 (2015): 1-9.

EBStore



Hard to collect 3D model from Internet

Coming to open-source!!

***EBStore** Dataset*: the **first** 3D synthetic eyebrow dataset that contains **400 high-quality models** manually created by artists

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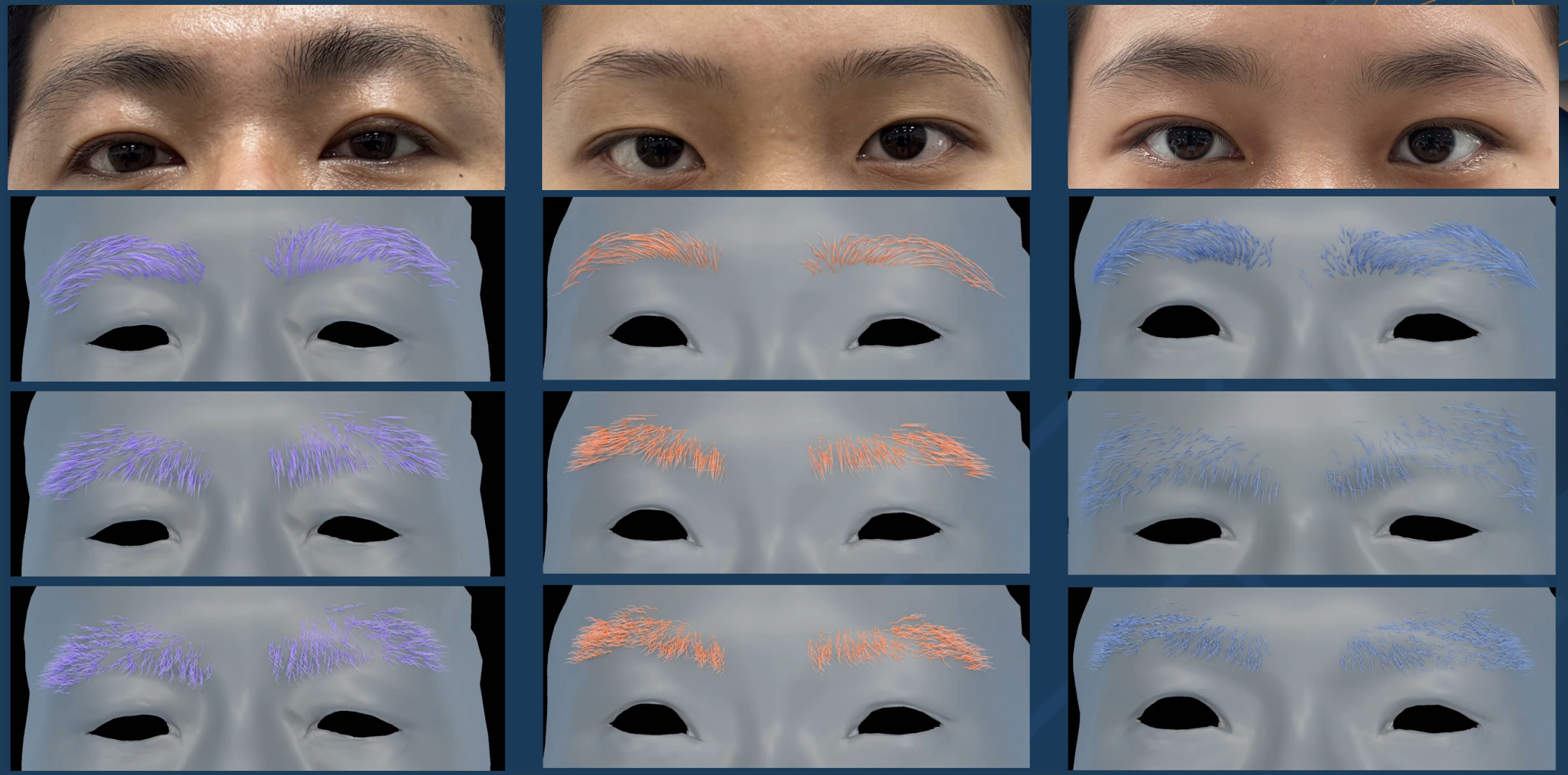
Comparison with Rule-based Facial Hair Reconstruction



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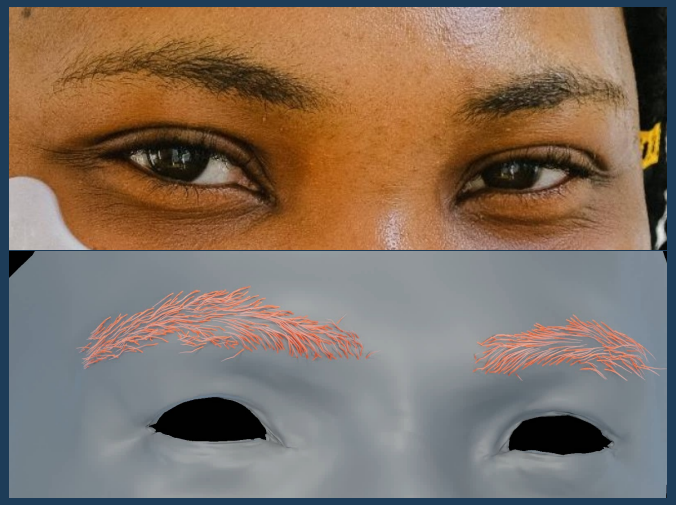
More Results on Diverse Skin and Hair Color

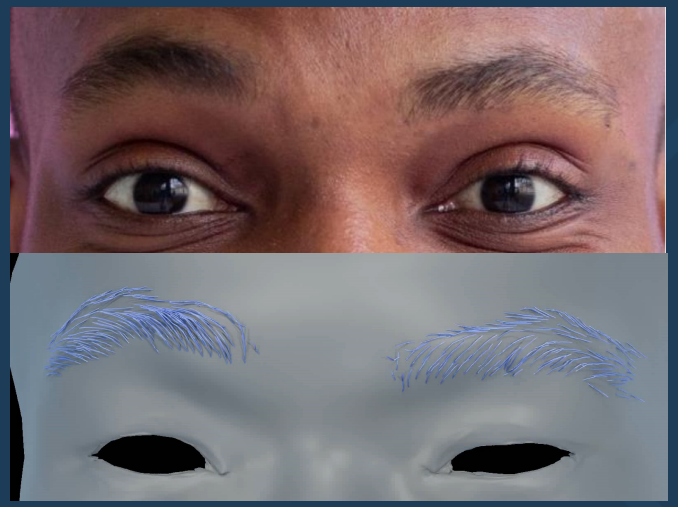
Real images

3D eyebrows

Real images

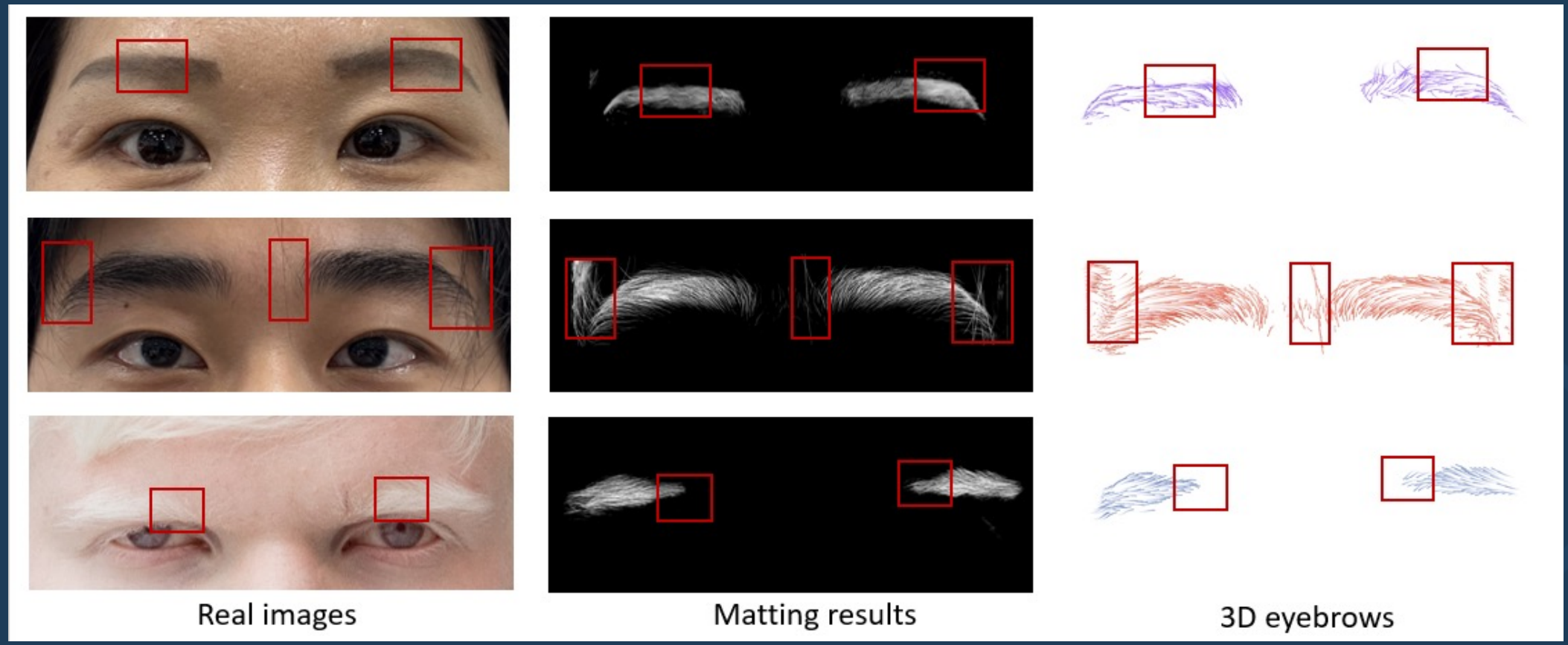
3D eyebrows





Contributions & Limitations

- The **first learning-based** framework ***EMS*** for eyebrow modeling
- **New modules** for eyebrow root point localization ***RootFinder*** and fiber length determination ***FiberEnder***
- The **first high-quality** 3D synthetic eyebrow **public** dataset ***EBStore***



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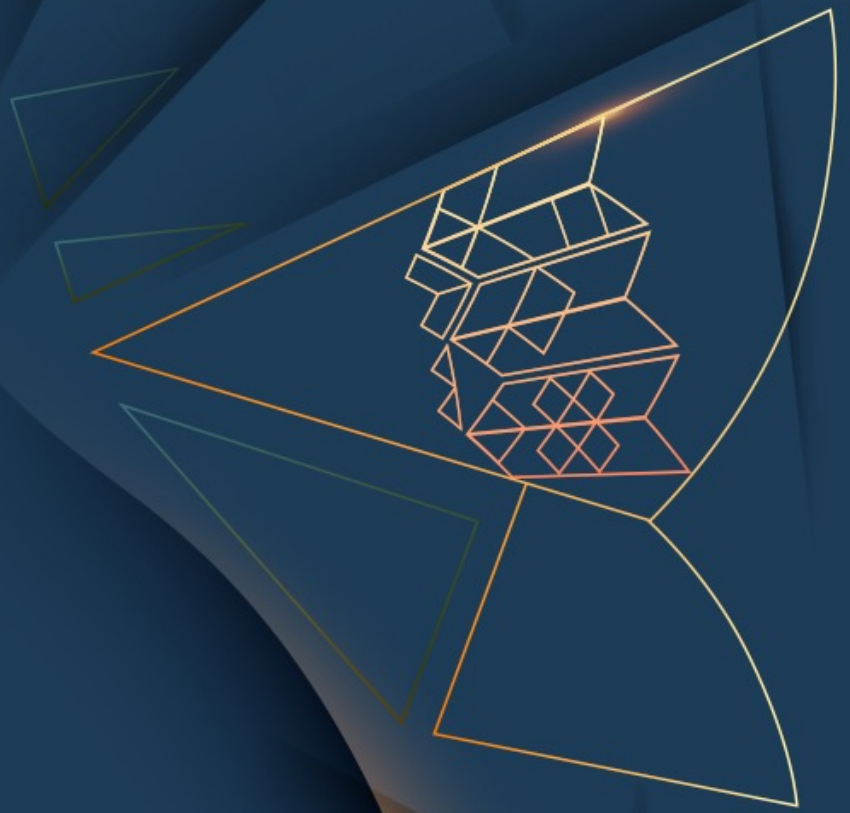

Thanks for your listening!