

HairStep : Transfer Synthetic to Real Using Strand and Depth Maps for Single-View 3D Hair Modeling

CVPR2023 Highlight

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Outline

- Background
- HairStep
- Experiment
- Conclusion



Outline

- **Background**

- Single-view 3D Hair Modeling
- Previous Approaches
- Domain Gap

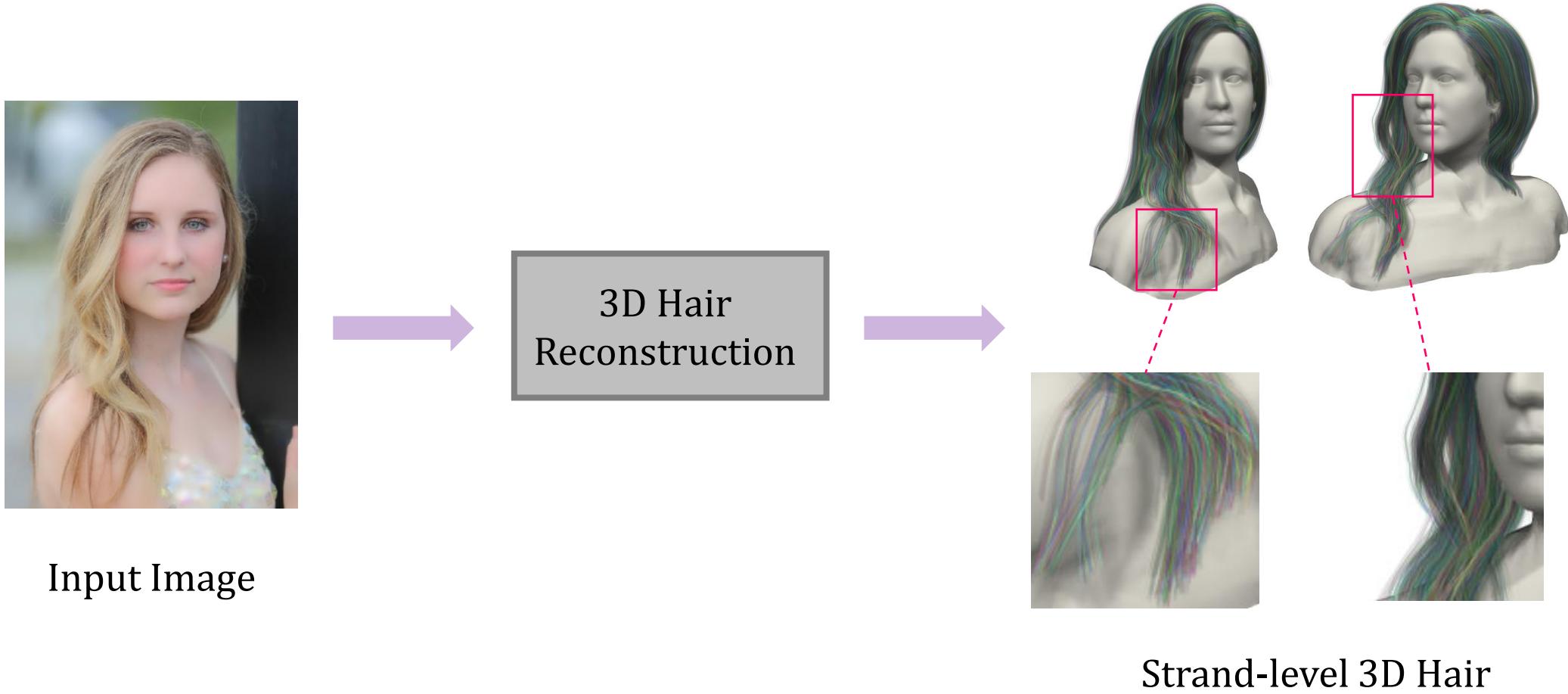
- HairStep

- Experiment

- Conclusion



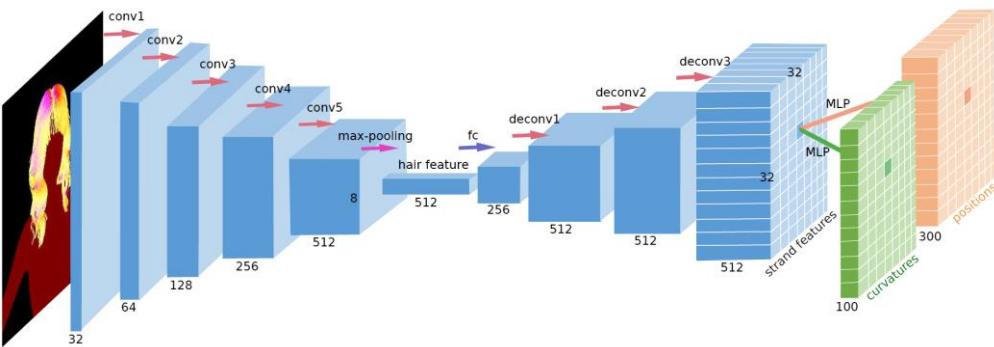
Single-view 3D Hair Modeling



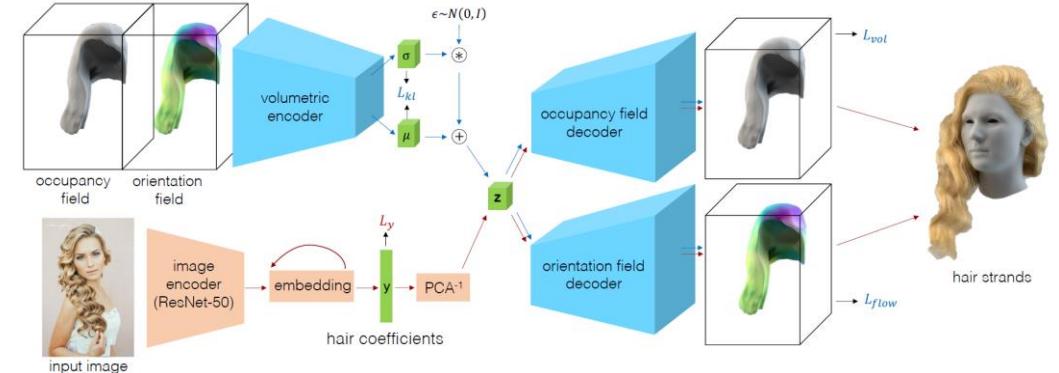
Chai et al. 2016



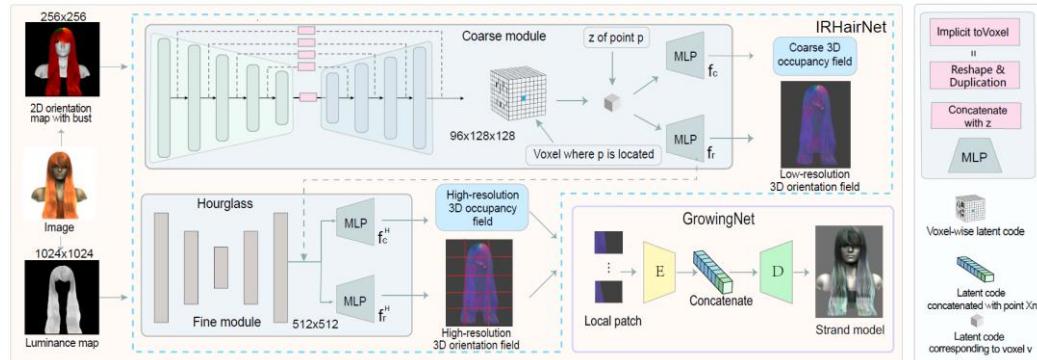
Previous Approaches



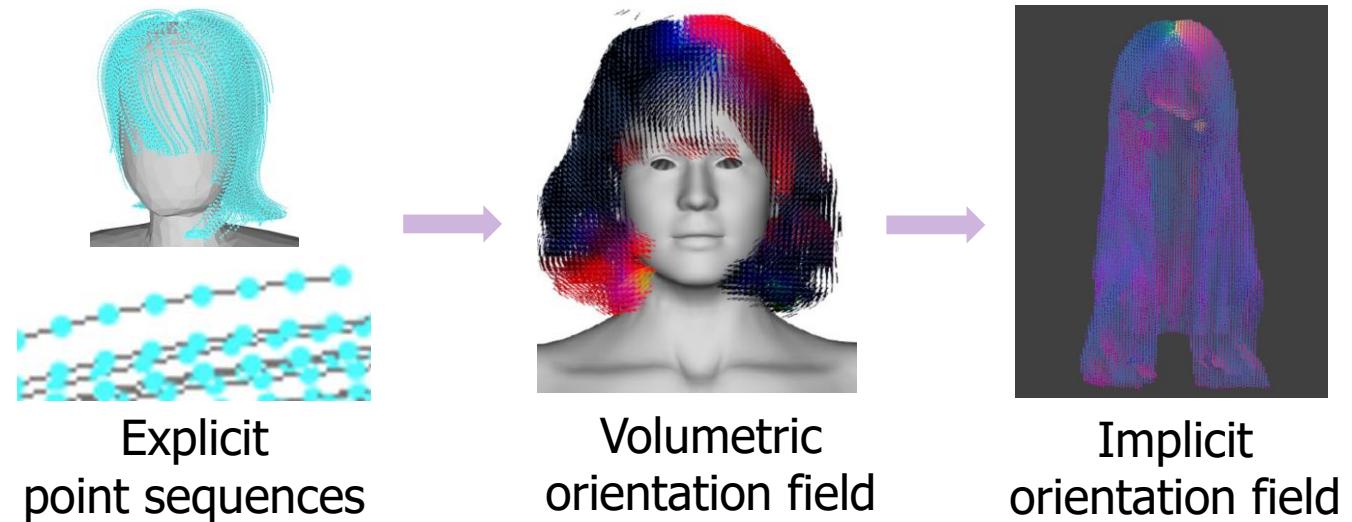
Zhou et al. 2018



Saito et al. 2018



Wu et al. 2022



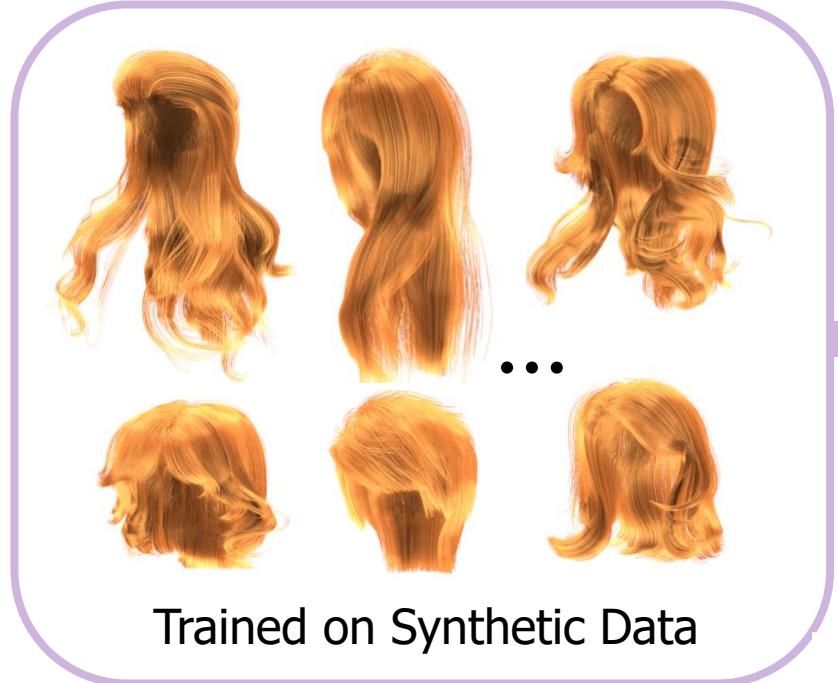
Explicit
point sequences

Volumetric
orientation field

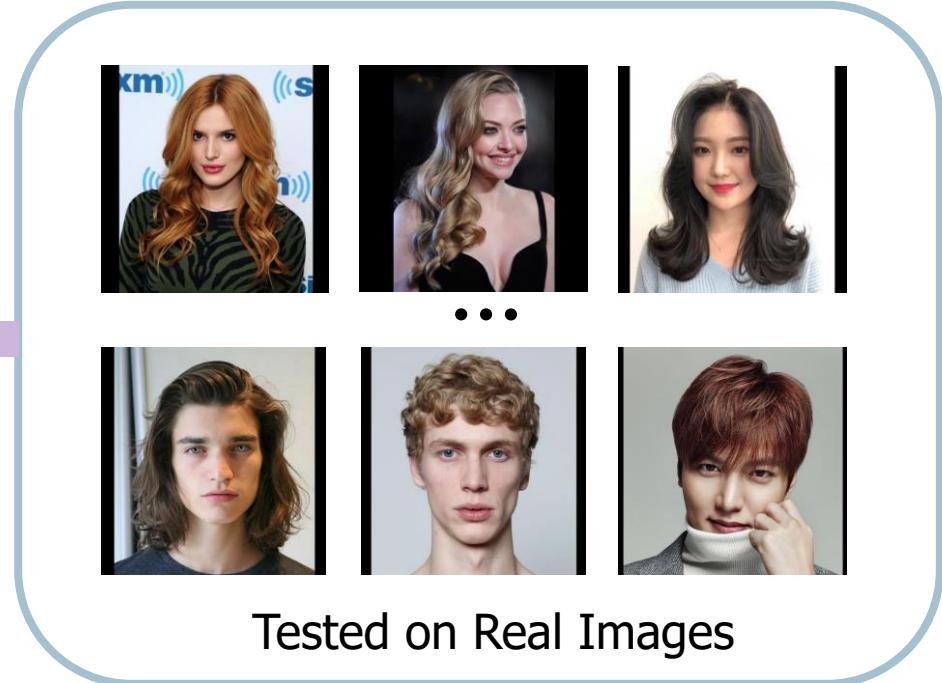
Implicit
orientation field



Domain Gap



Domain Gap



Failure Cases



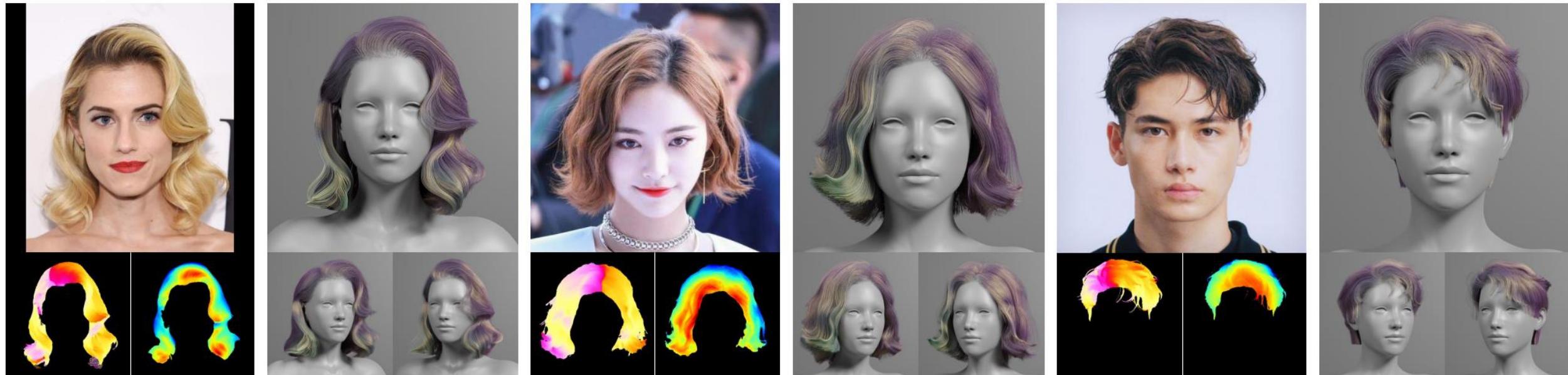
Outline

- Background
- HairStep
 - Motivation & Overview
 - Extraction of HairStep
 - Single-view Hair Reconstruction
- Experiment
- Conclusion

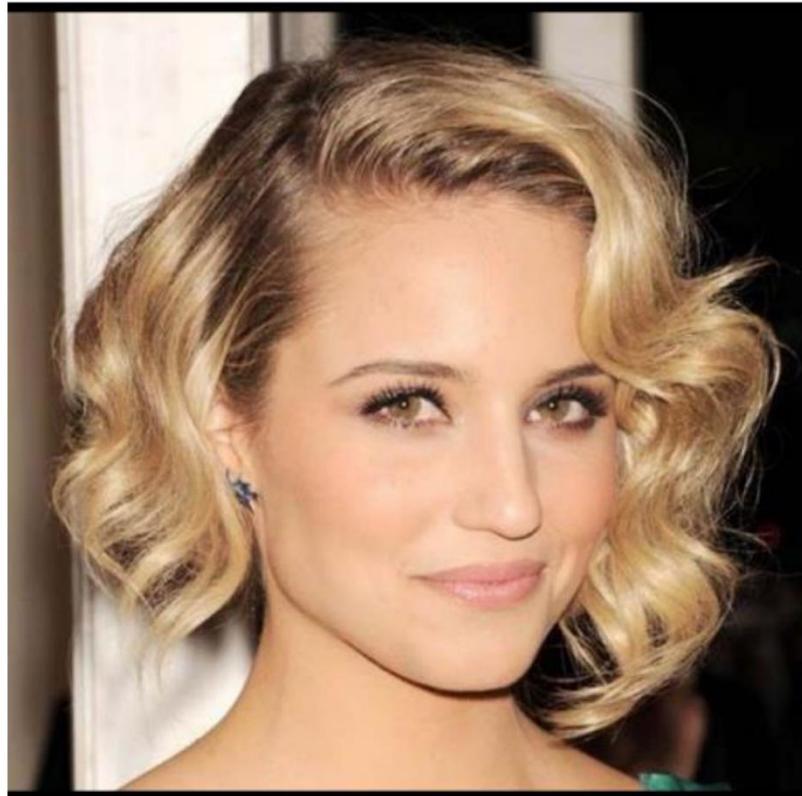


HairStep

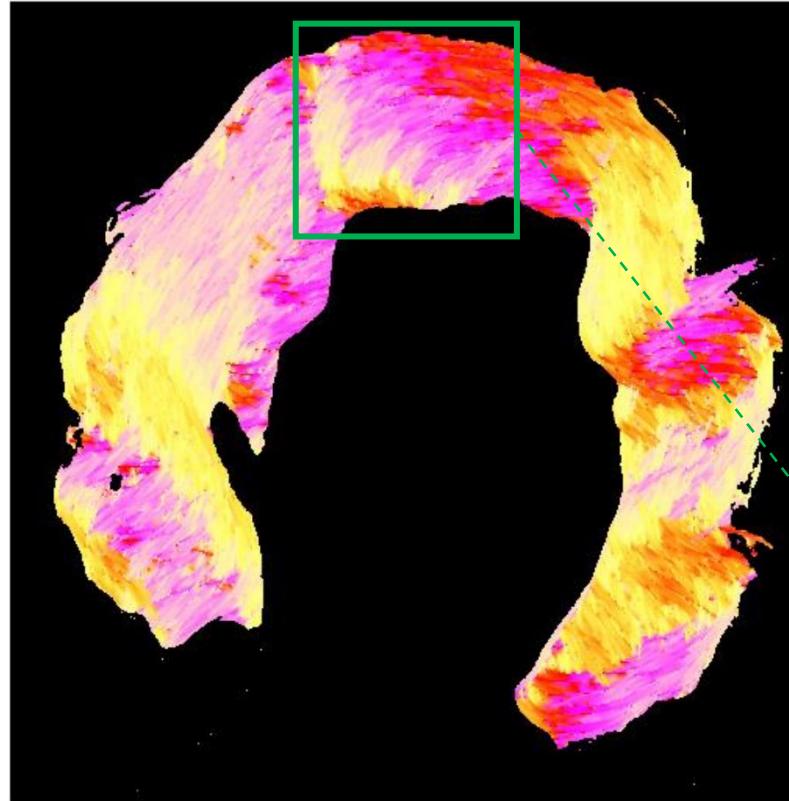
HairStep: Transfer Synthetic to Real Using Strand and Depth Maps for Single-View 3D Hair Modeling



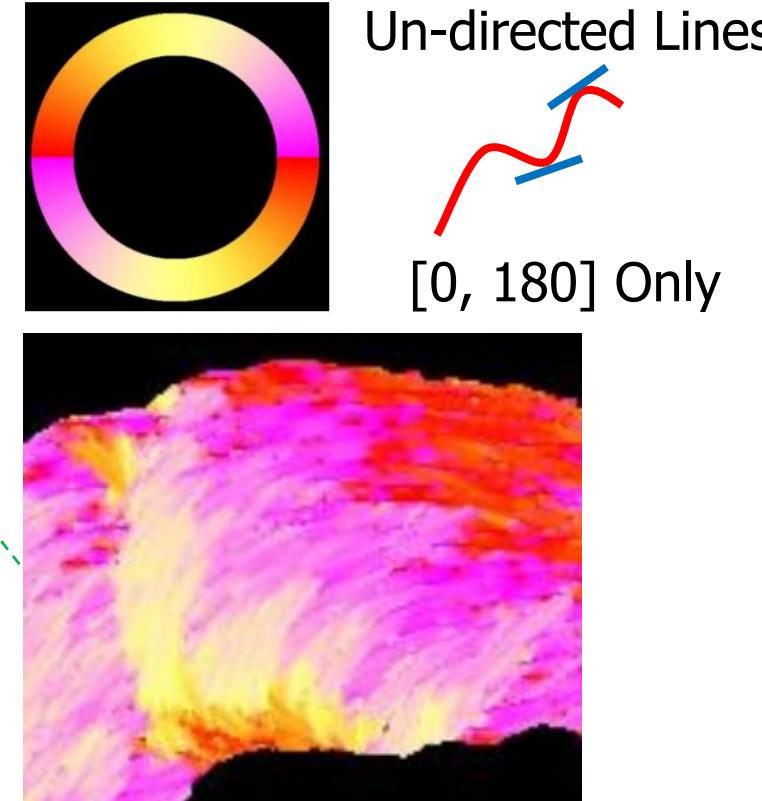
Motivation



Image



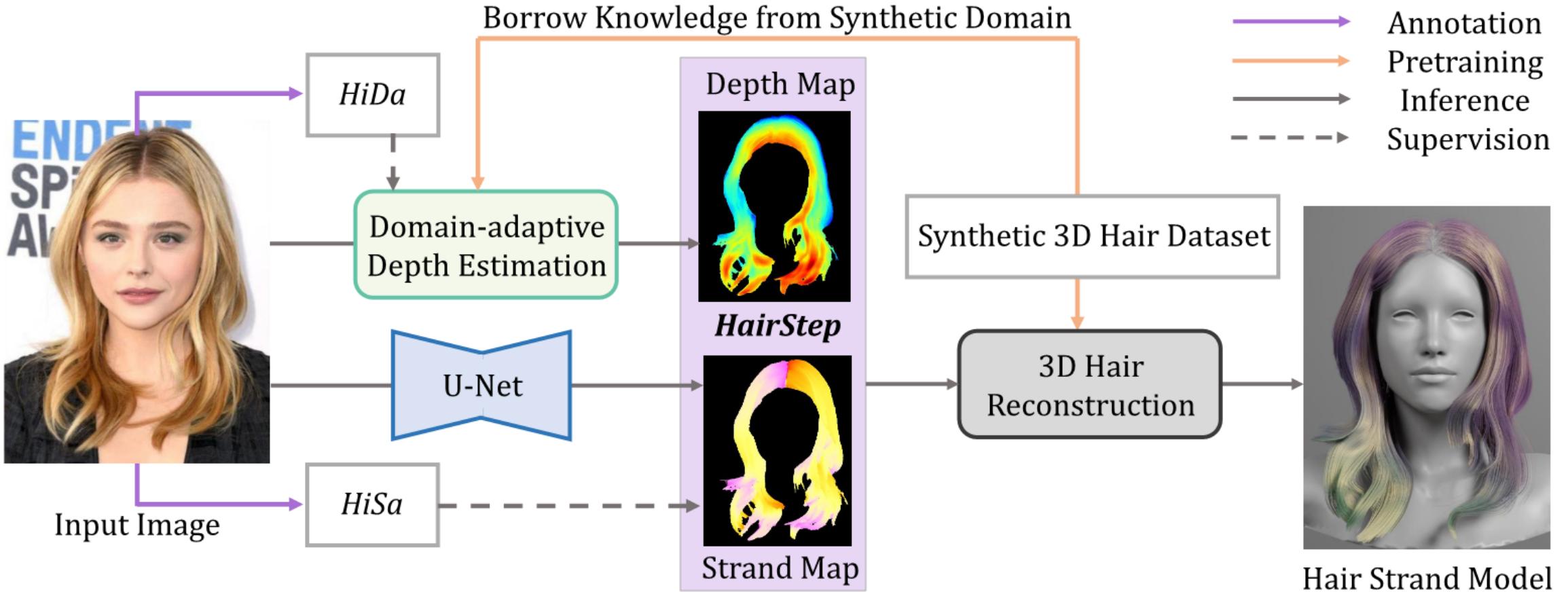
Orientation Map
from Gabor Filters



Ambiguous & Noisy!



Overview



HiSa Dataset & Strand Map



Image



Strokes



Stroke Map



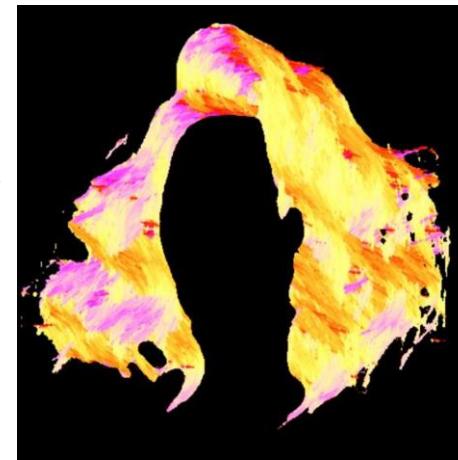
Strand Map



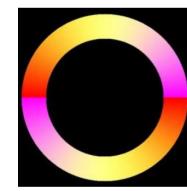
[0, 360]



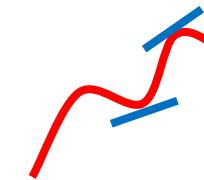
Directed
Lines



Orientation Map



[0, 180]

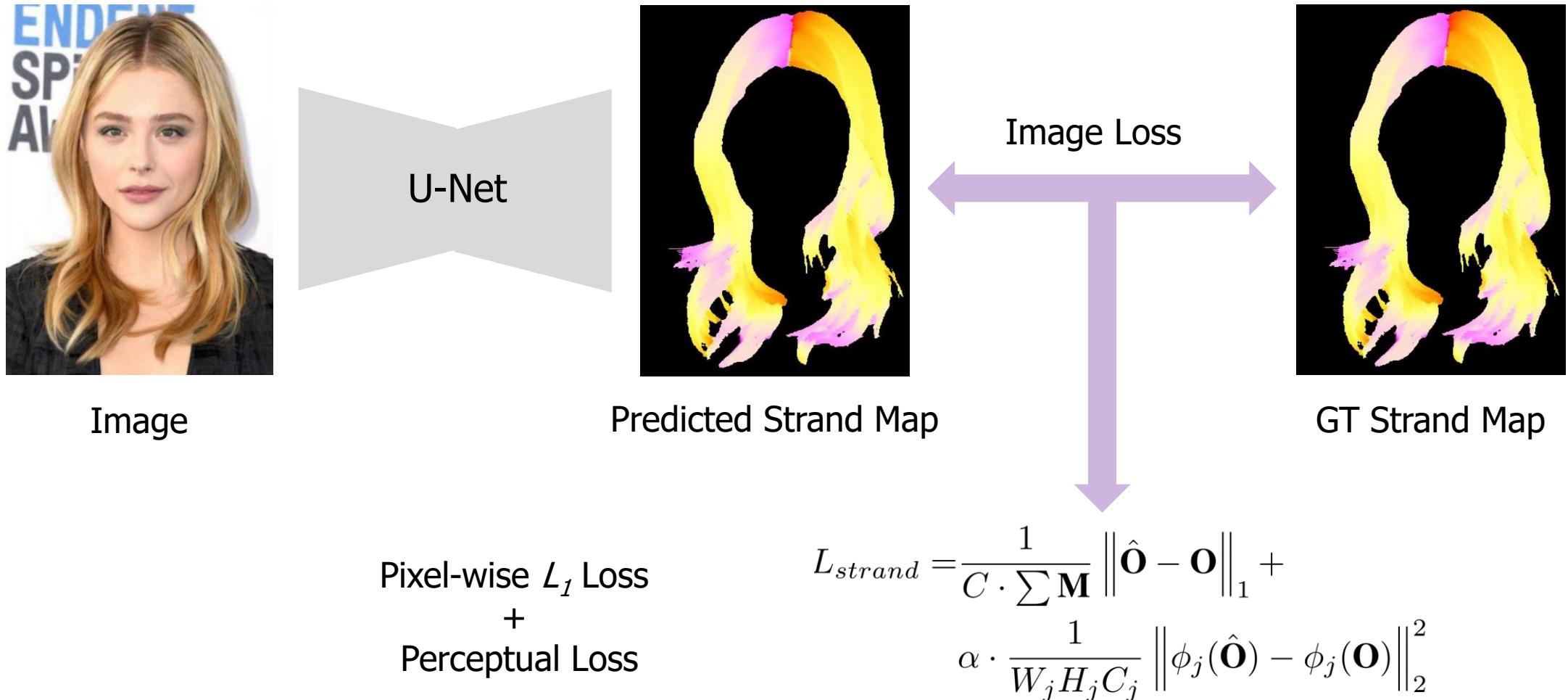


Un-directed
Lines

300 vector curves
from hair roots to hair ends



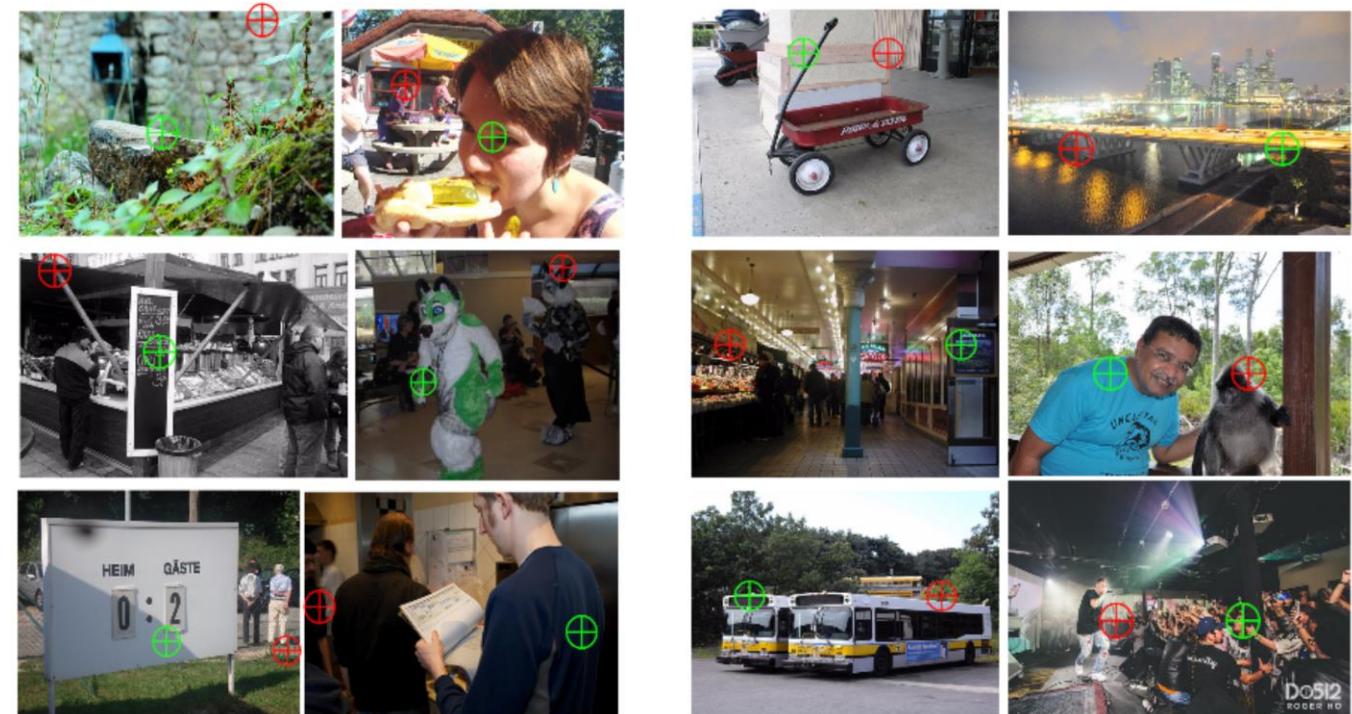
Extraction of Strand Map



HiDa Dataset & Relative Depth



How to **annotate depth** of hair?



*Depth-in-the-wild
Relative depth*



HiDa Dataset & Relative Depth



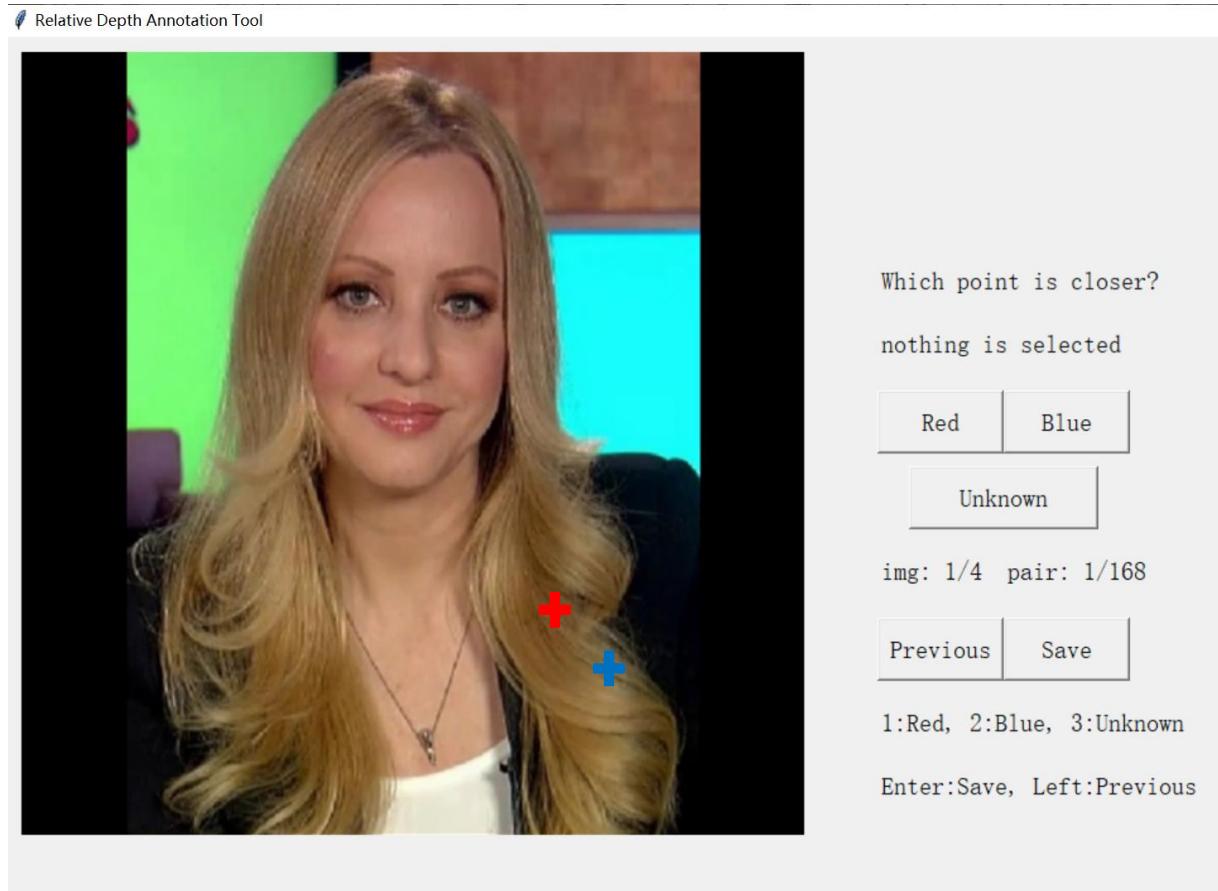
Sample Pairs in Neighbors of Super-pixels

1250 Images

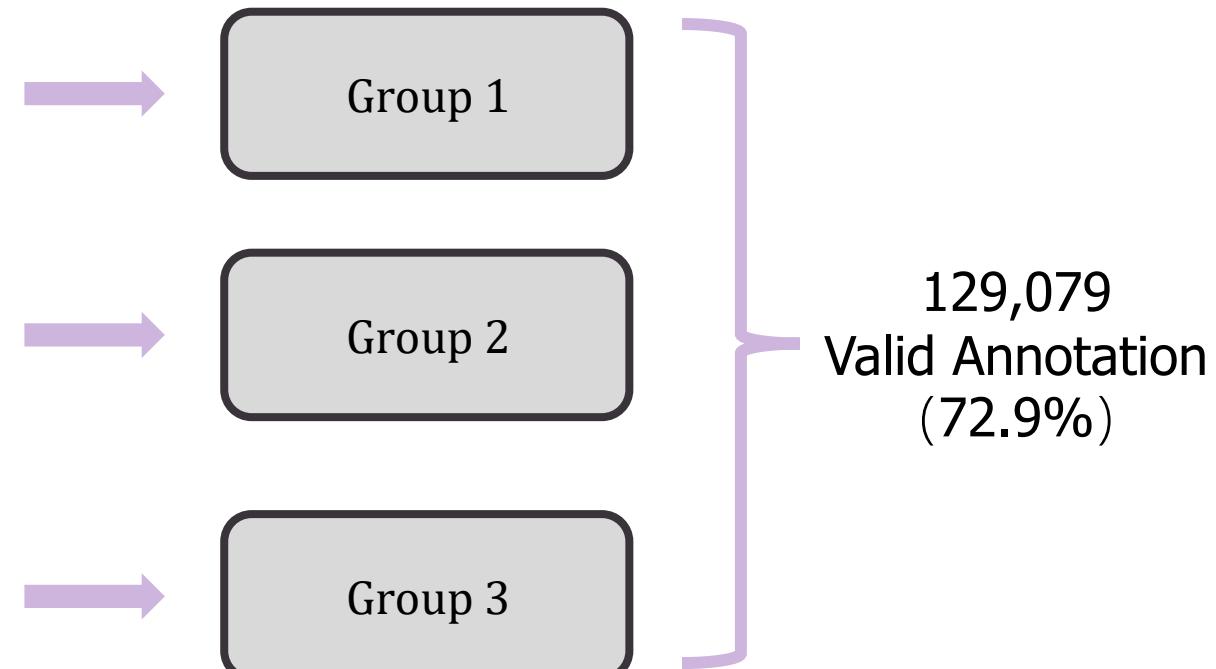
177,074 Pixel Pairs



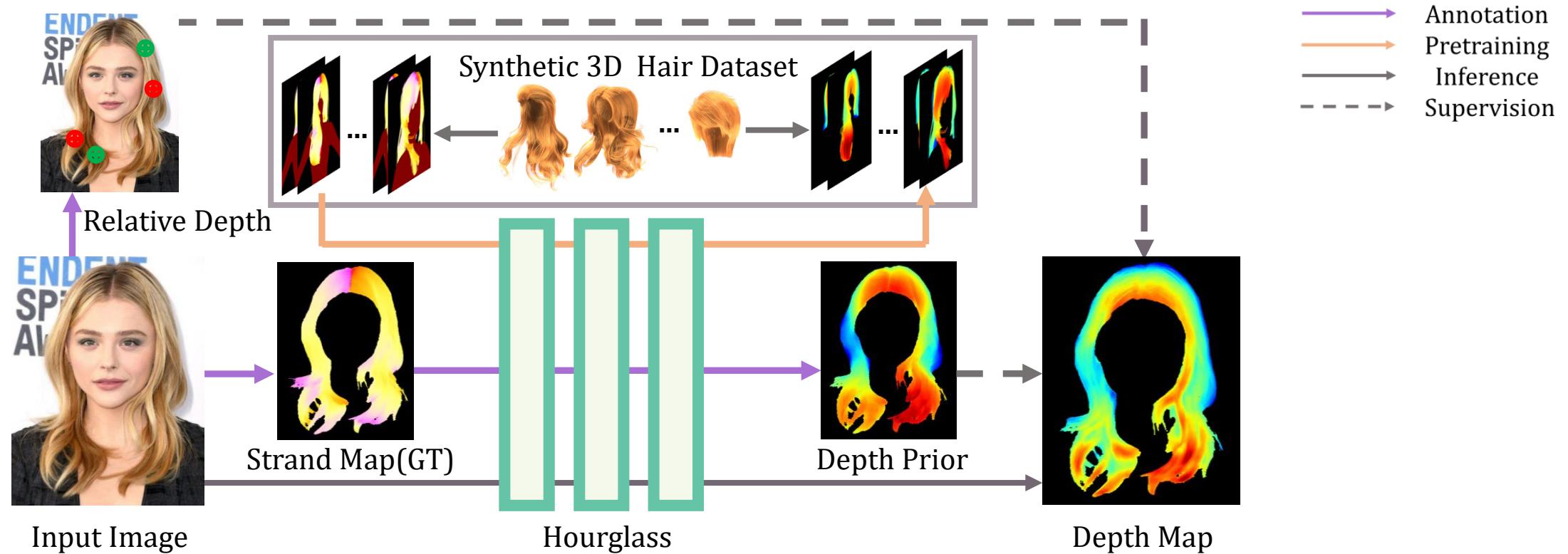
HiDa Dataset & Relative Depth



Annotation Tool



Domain-Adaptive Depth Estimation

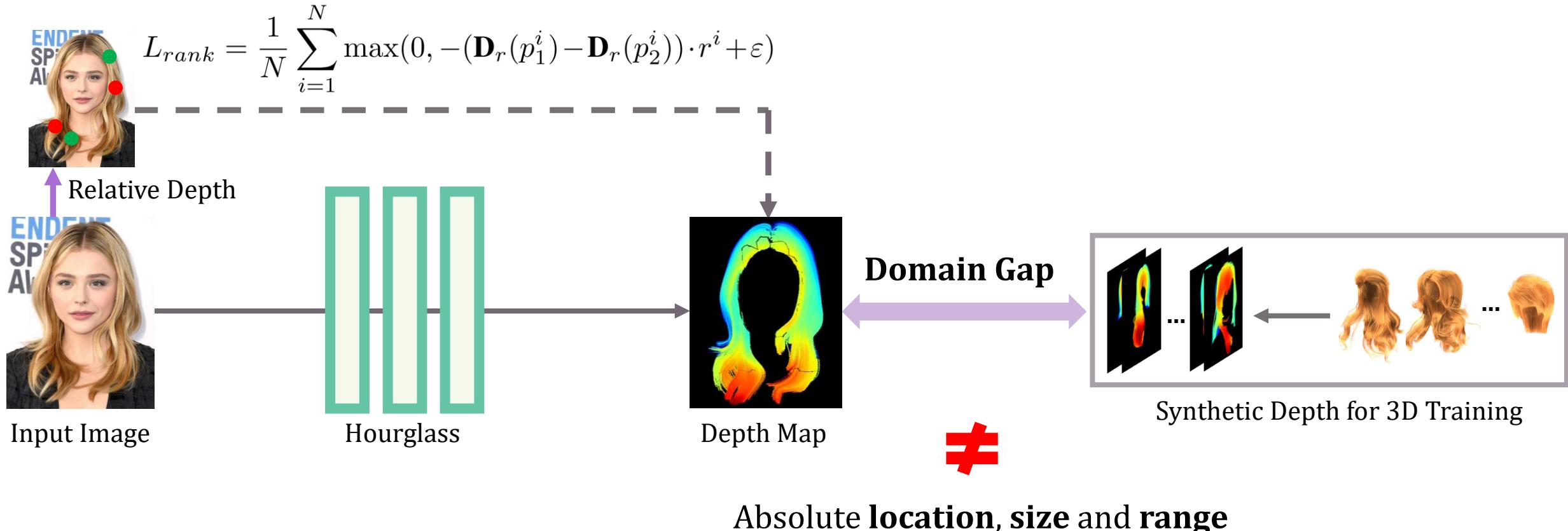


$$L_{rank} = \frac{1}{N} \sum_{i=1}^N \max(0, -(\mathbf{D}_r(p_1^i) - \mathbf{D}_r(p_2^i)) \cdot r^i + \varepsilon)$$

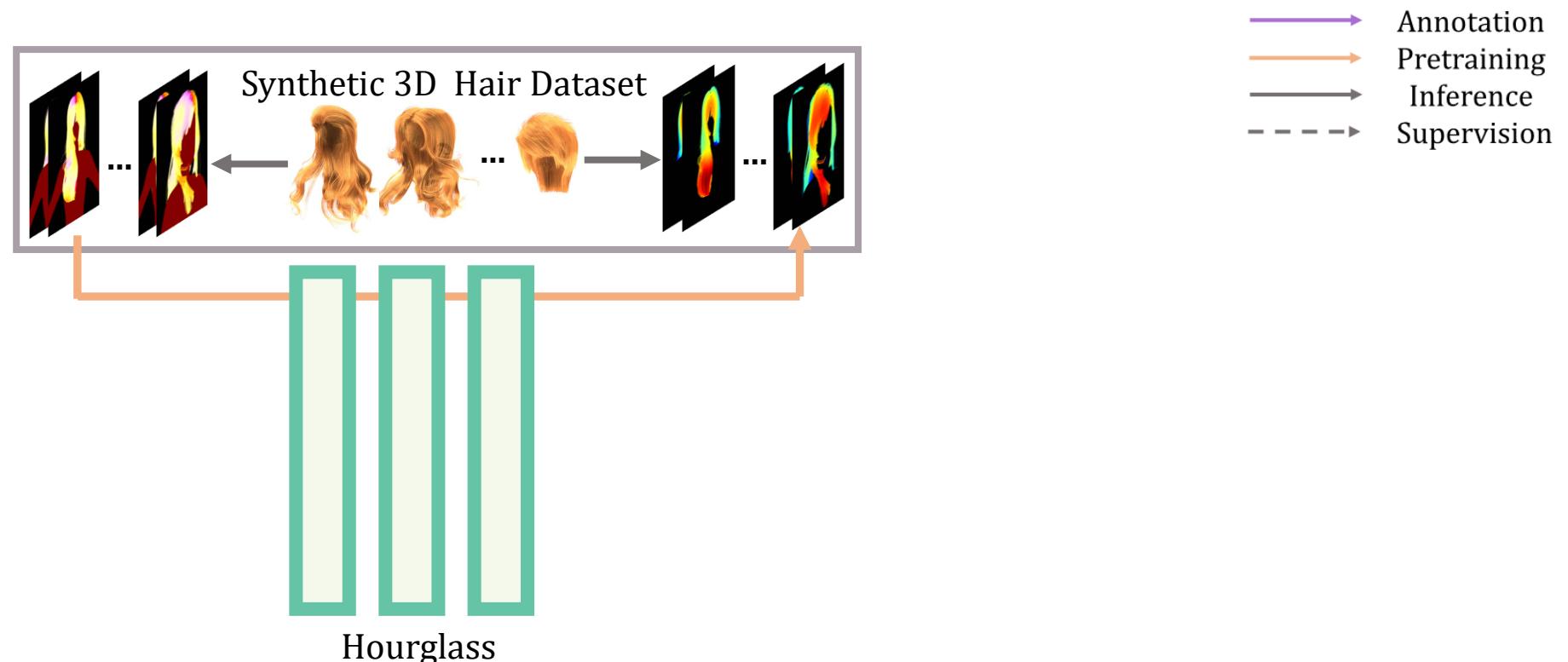
$$L_{depth} = \beta \cdot \|\mathbf{D}_r - \bar{\mathbf{D}}\|_1 + L_{rank}$$



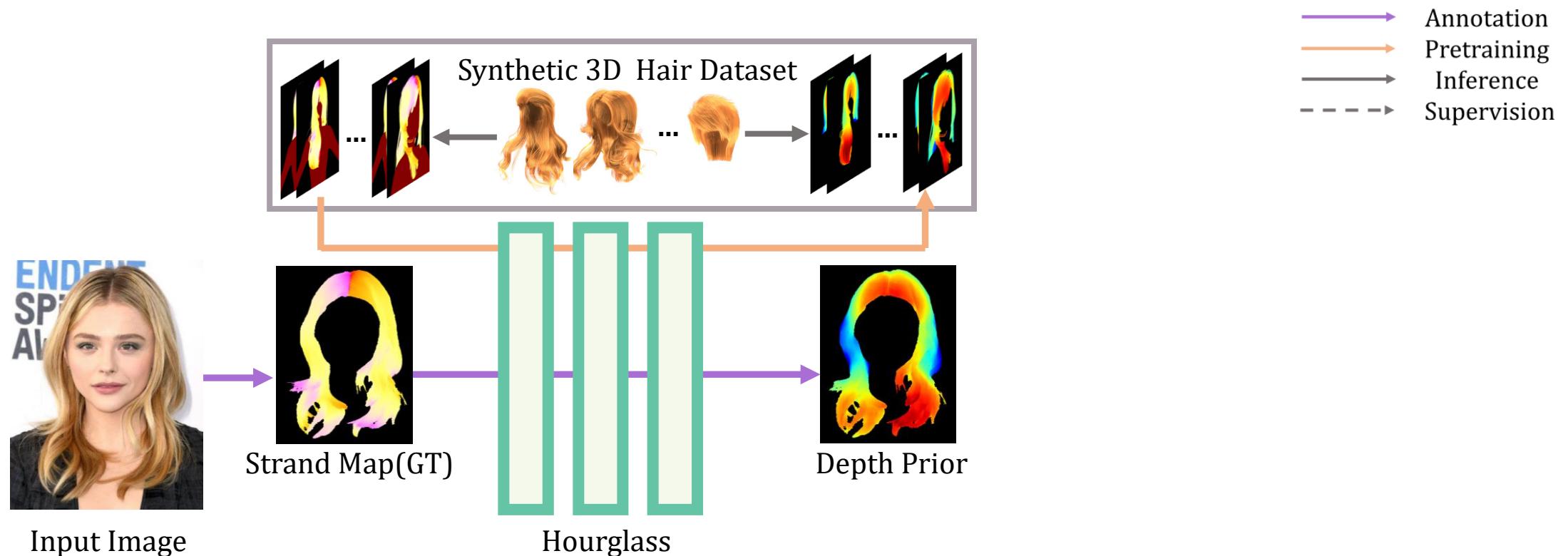
Domain-Adaptive Depth Estimation



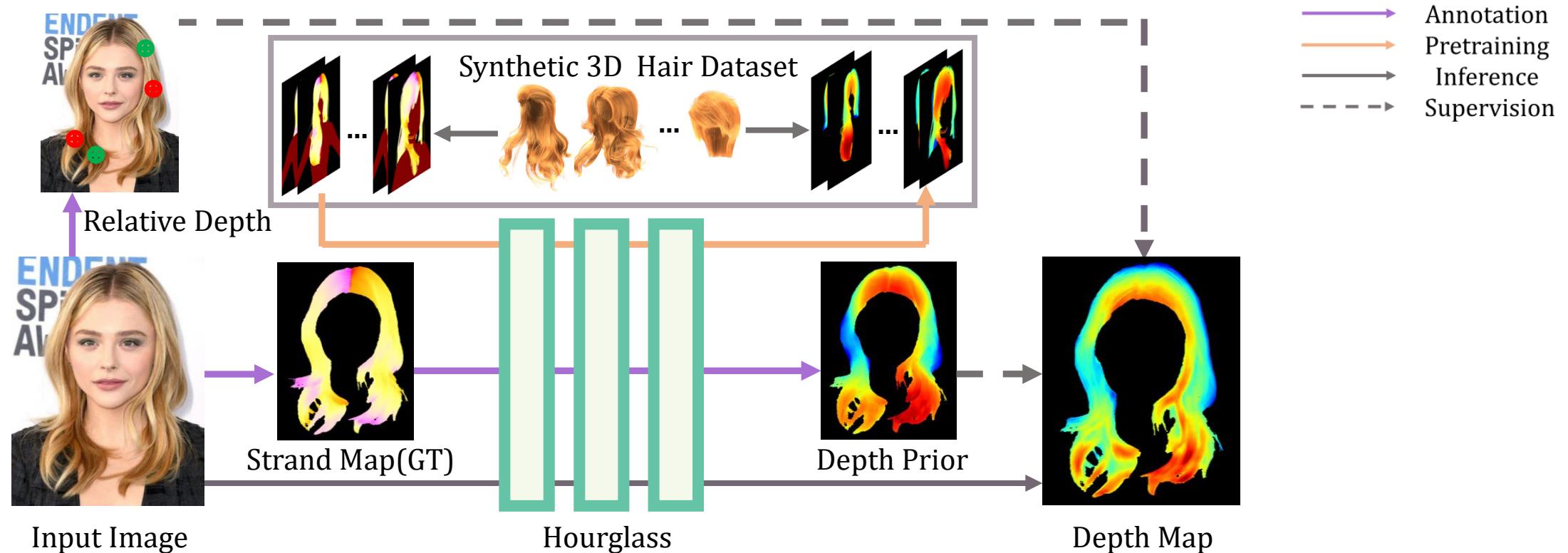
Domain-Adaptive Depth Estimation



Domain-Adaptive Depth Estimation



Domain-Adaptive Depth Estimation

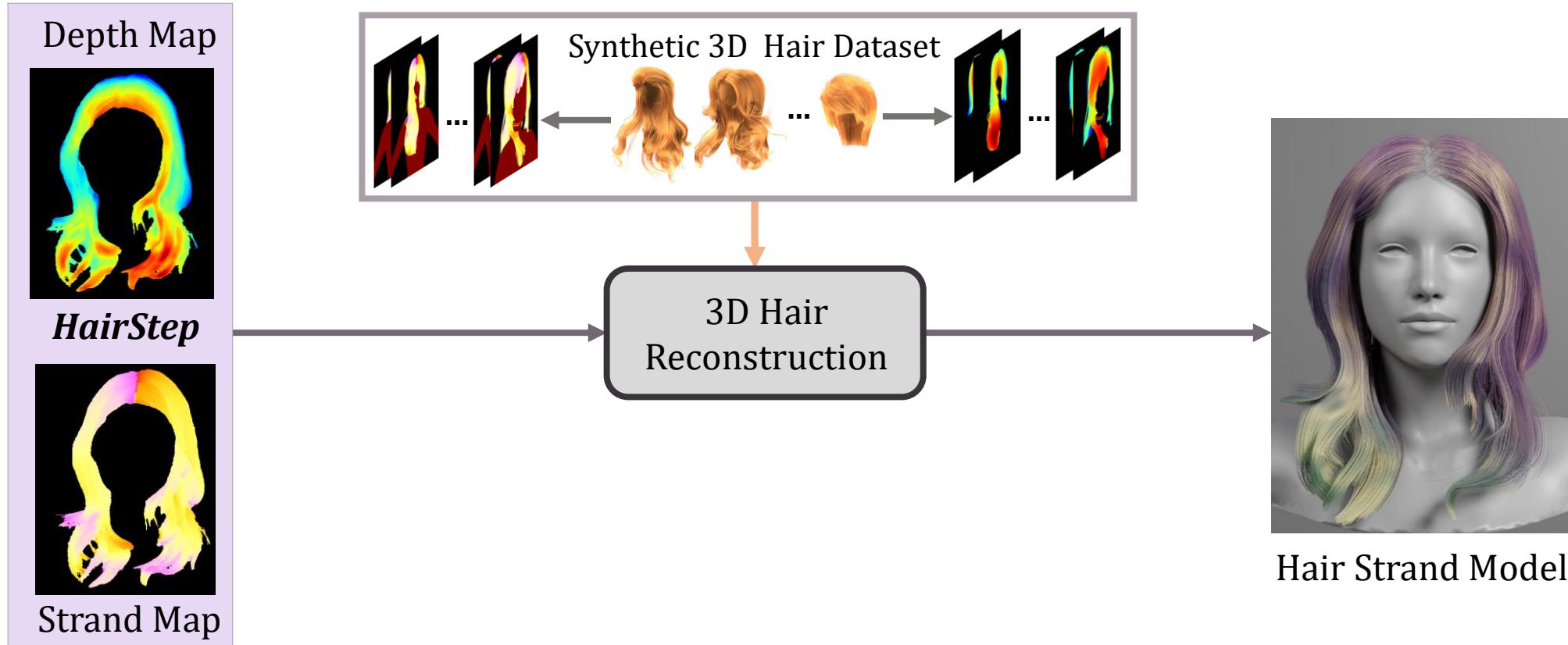


$$L_{rank} = \frac{1}{N} \sum_{i=1}^N \max(0, -(\mathbf{D}_r(p_1^i) - \mathbf{D}_r(p_2^i)) \cdot r^i + \varepsilon)$$

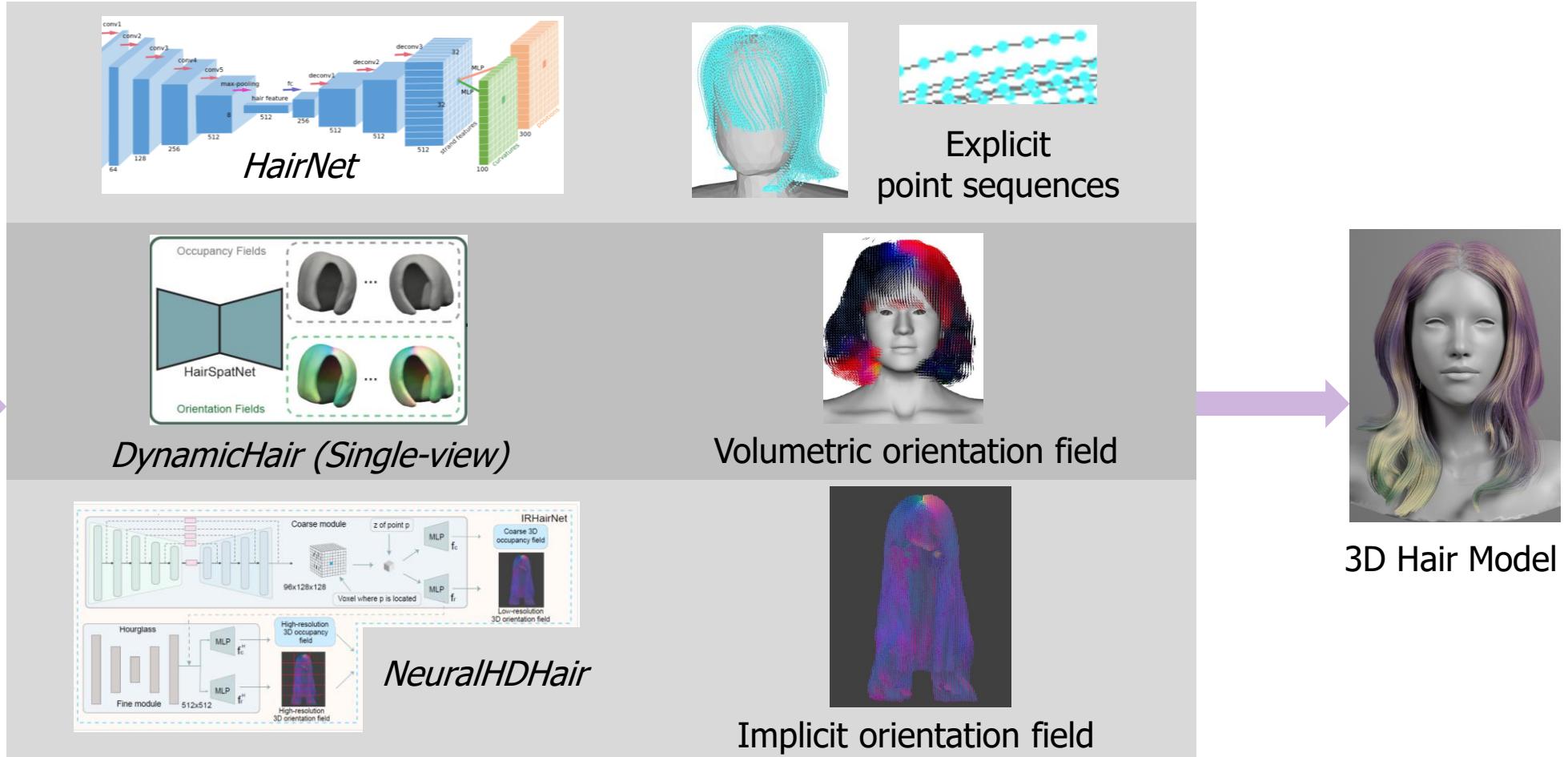
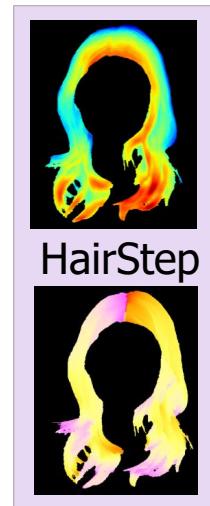
$$L_{depth} = \beta \cdot \|\mathbf{D}_r - \bar{\mathbf{D}}\|_1 + L_{rank}$$



Single-View 3D Hair Modeling



Single-View 3D Hair Modeling

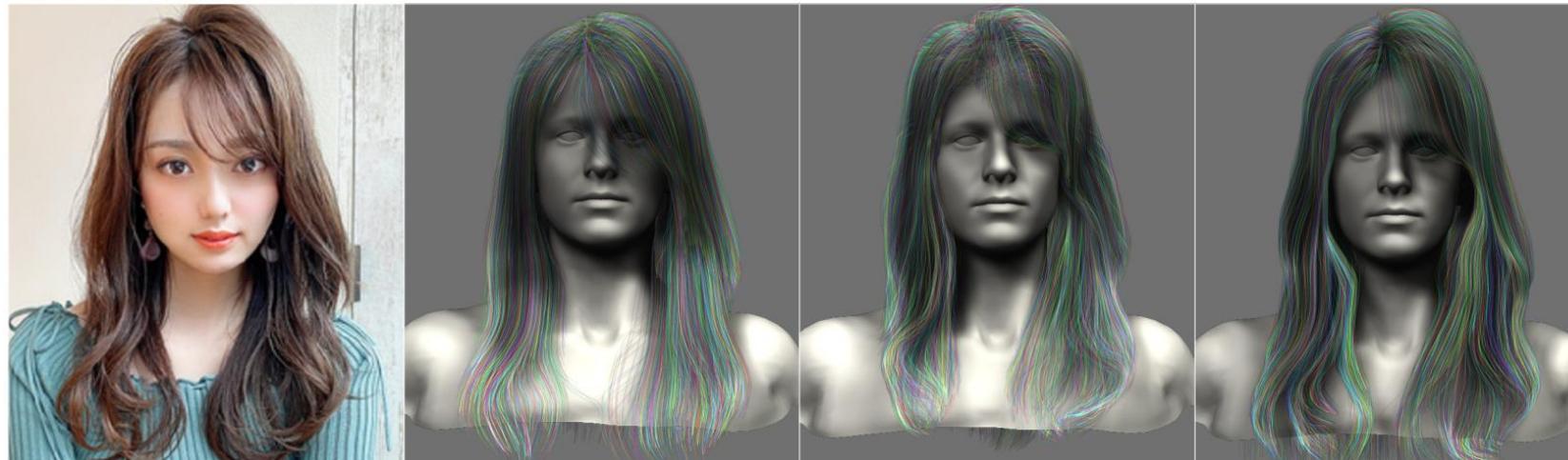


Outline

- Background
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- Experiment
 - Fair Metrics
 - Evaluation on HairStep Extraction
 - Comparisons of 3D Reconstruction
 - Ablation Study
- Conclusion



Fair Metrics



Wu et al. 2022



Saito et al. 2018

Only Comparisons of
the **Visual Quality**
in Existing Methods



Fair Metrics

Input Image



3D Strands



Reconstruct

Rendered Map

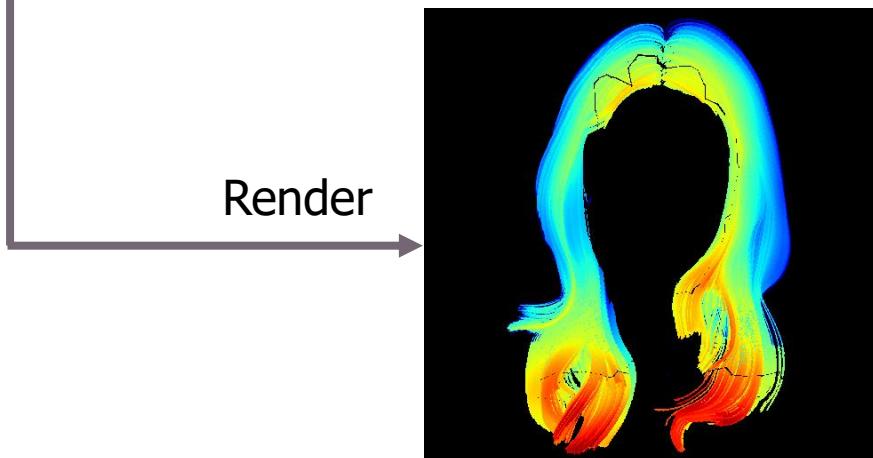


Render

GT Annotation



HairSale

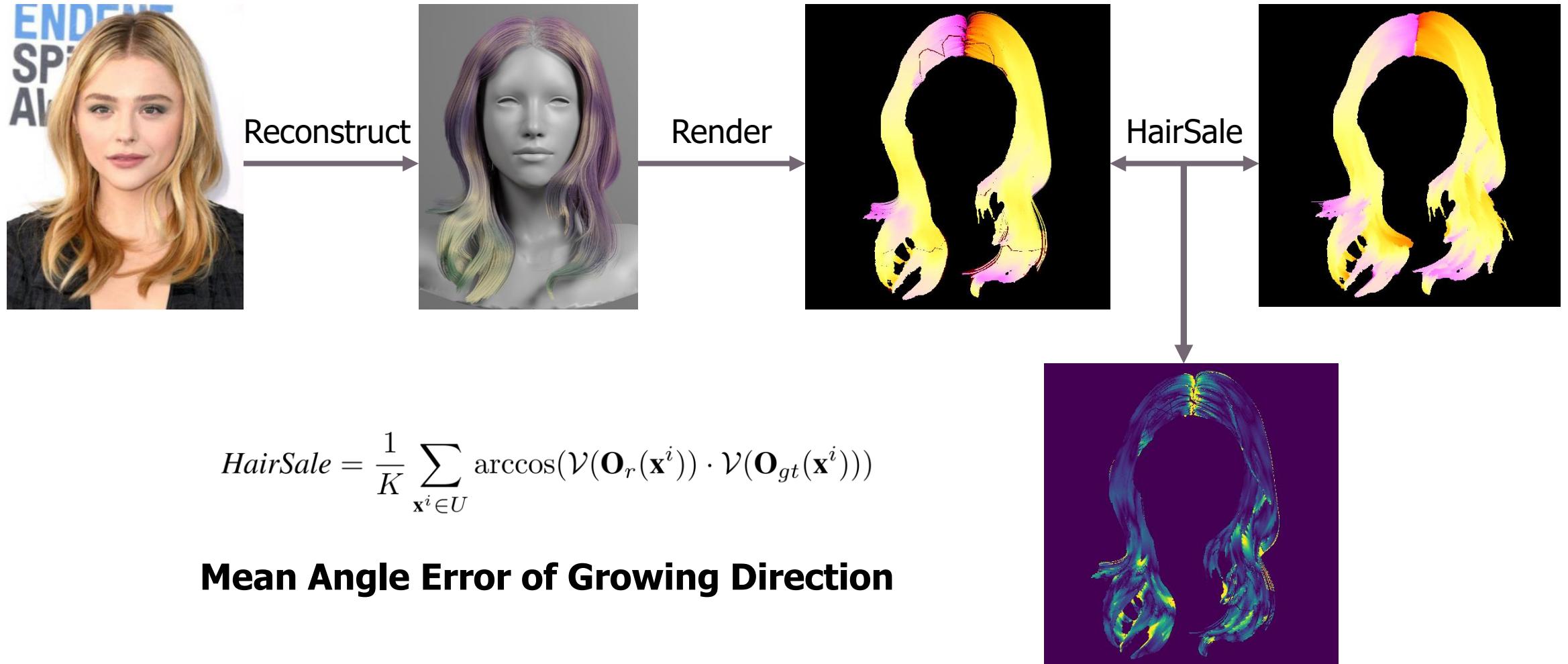


Render

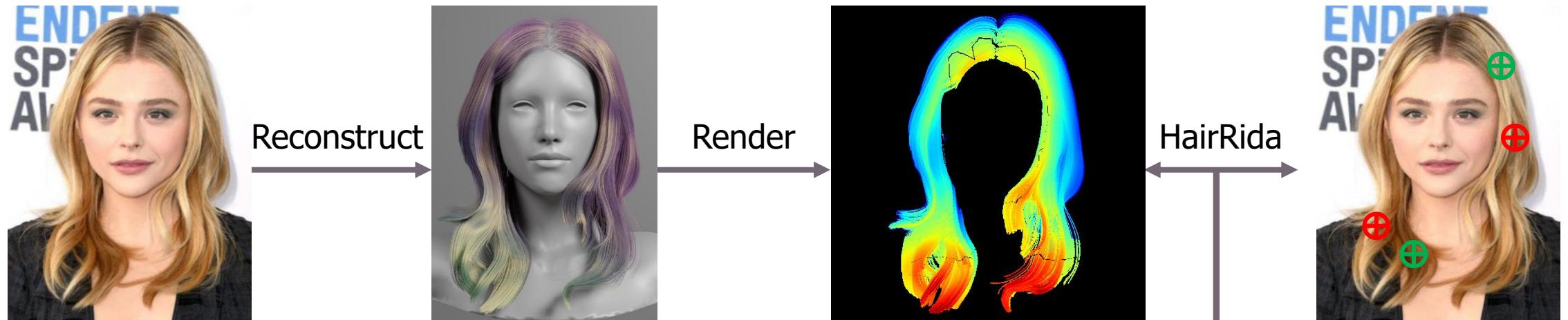
HairRida



HairSale



HairRida

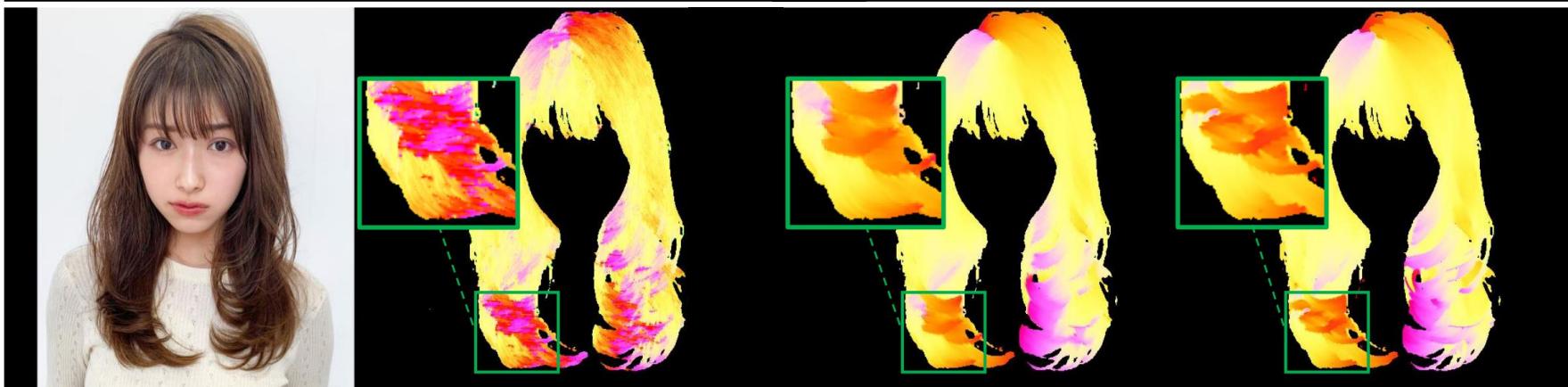
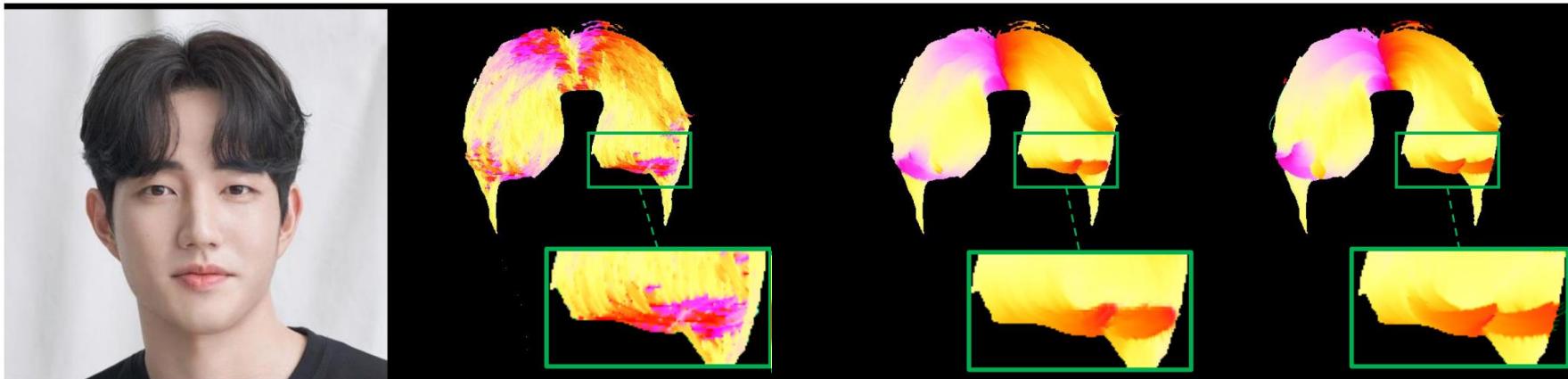


$$HairRida = \frac{1}{Q} \sum_{i=1}^Q \max(0, r^i \cdot \text{sign}(\mathbf{D}_r(p_1^i) - \mathbf{D}_r(p_2^i)))$$

The Relative Depth Accuracy



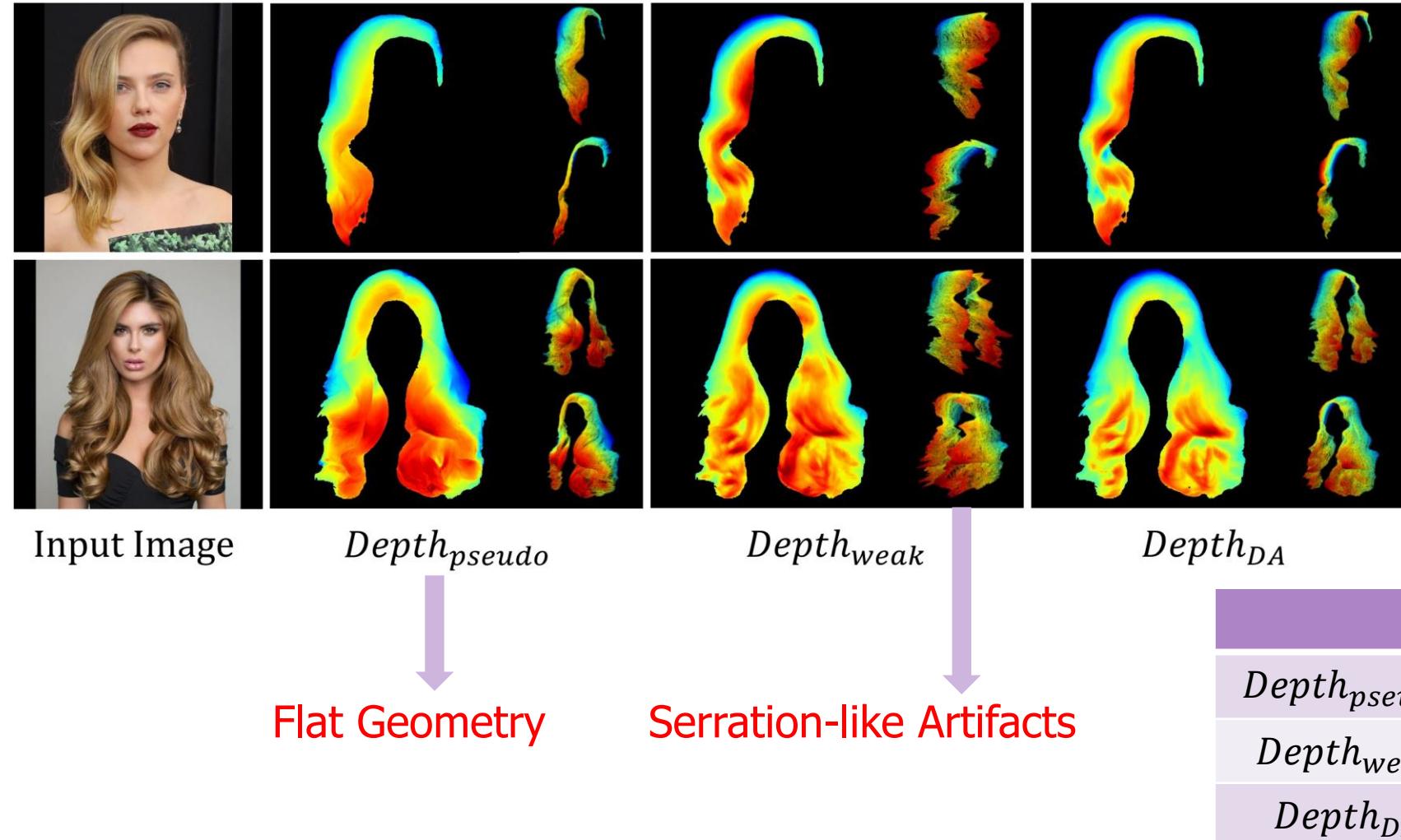
Evaluation on the Extraction of Strand Map



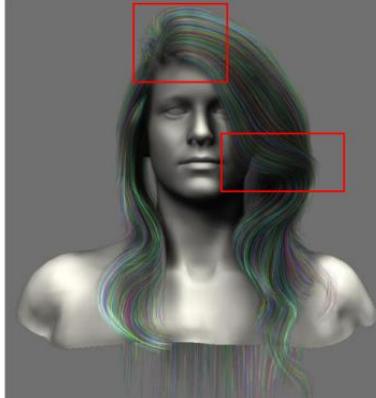
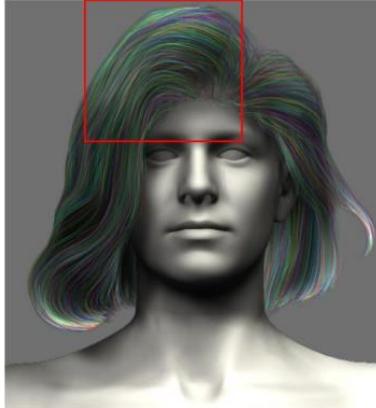
	HairSale↑ (Undirected)
Gabor Filters	18.4
Ours	14.2

22.8% Better

Evaluation on Depth Estimation



Visual Comparisons with Existing Methods



Input Image

NeuralHDHair

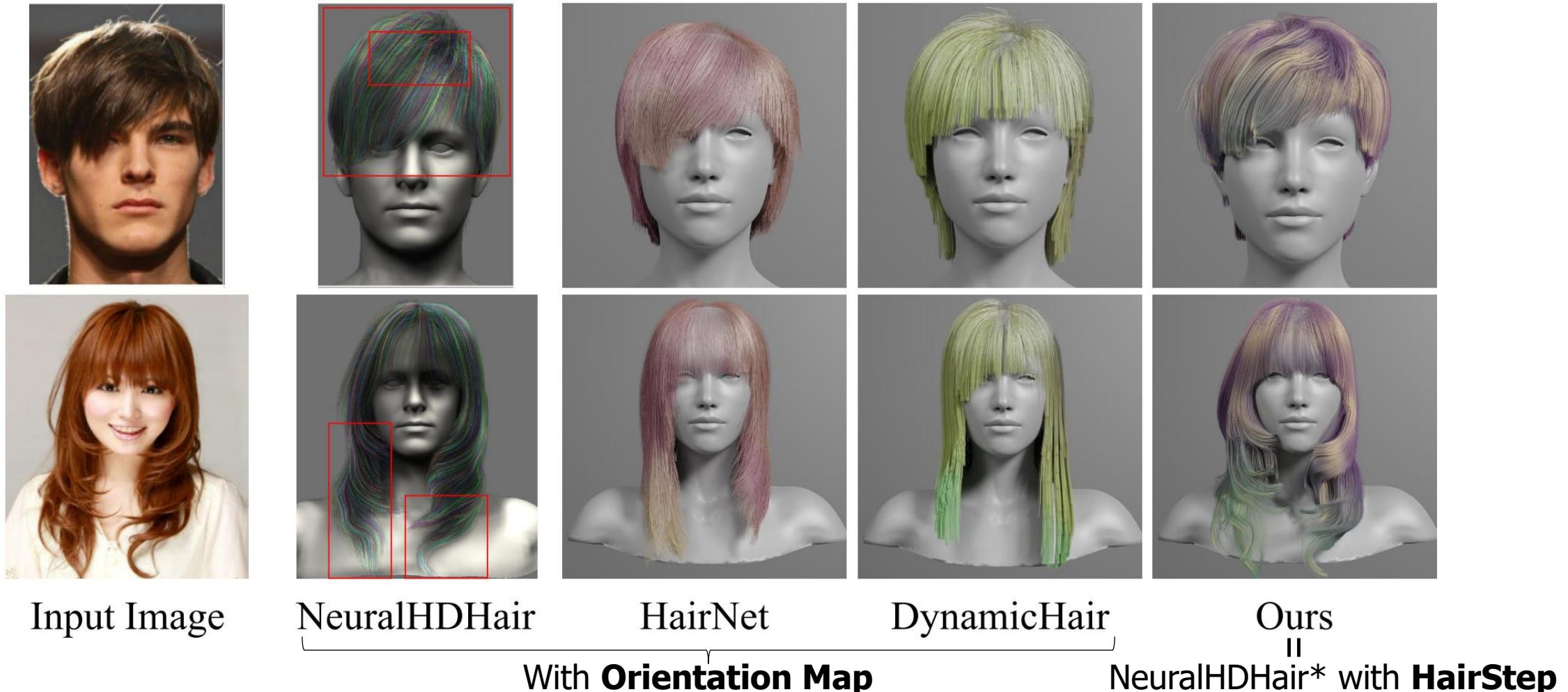
HairNet

DynamicHair

With **Orientation Map**

Ours
^{II}
NeuralHDHair* with **HairStep**

Visual Comparisons with Existing Methods



Quantitative Comparisons on Representation

On Synthetic Data

Method	Orien. err. ↓	Occ. acc. ↑
NeuralHDHair* (Orientation map)	0.1324	82.59%
NeuralHDHair* (Strand map)	0.0722 (-41.7%)	84.18%
NeuralHDHair* (HairStep)	0.0658 (-50.3%)	86.77%
DynamicHair (Orientation map)	0.1352	78.19%
DynamicHair (Strand map)	0.1185 (-12.4%)	79.62%
DynamicHair (HairStep)	0.1174 (-13.2%)	79.78%
HairNet (Orientation map)	0.02349	/
HairNet (Strand map)	0.02206 (-6.1%)	/
HairNet (HairStep)	0.02184 (-7.0%)	/

On Real Data

Method	IoU ↑	<i>HairSale</i> ↓	<i>HairRida</i> ↑
NeuralHDHair* (Orientation map)	77.56%	19.6	70.67%
NeuralHDHair* (Strand map)	77.6%	16 (-18.4%)	72.37%
NeuralHDHair* (HairStep)	77.22%	16.36 (-16.5%)	76.79%
DynamicHair (Orientation map)	56.39%	32.66	74.08%
DynamicHair (Strand map)	59.51%	26.53 (-18.8%)	73.42%
DynamicHair (HairStep)	59.14%	27.51 (-15.8%)	73.58%
HairNet (Orientation map)	57.15%	31.97	75.65%
HairNet (Strand map)	57.48%	28.6 (-10.5%)	74.81%
HairNet (HairStep)	57.01%	27.68 (-13.4%)	74.97%

HairStep Benefits all Methods
On Both **Synthetic & Real** Data



Visual Comparisons on Representation (NeuralHDHair*)

Image



From Orientation Map



Orientation Map

From Strand Map

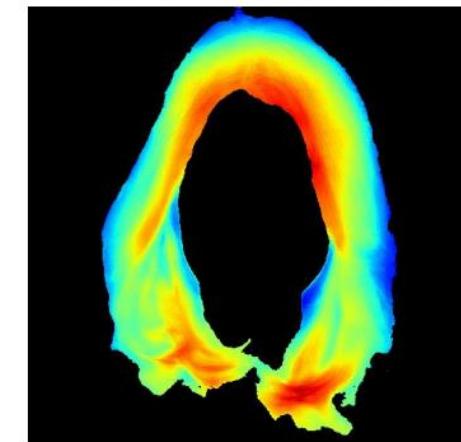
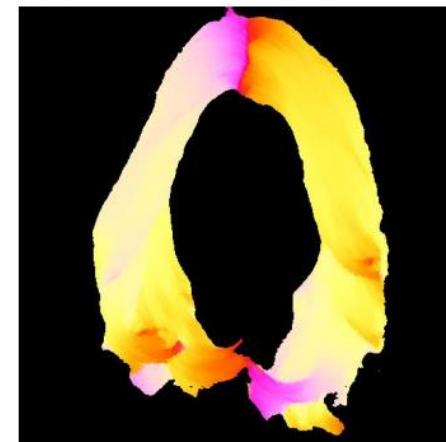
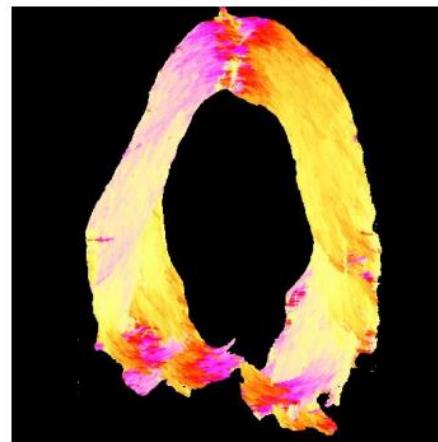


Strand Map

From HairStep



Depth Map



Visual Comparisons on Representation (NeuralHDHair*)

Image



From Orientation Map



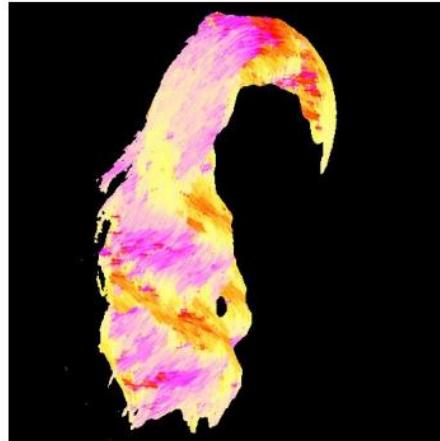
From Strand Map



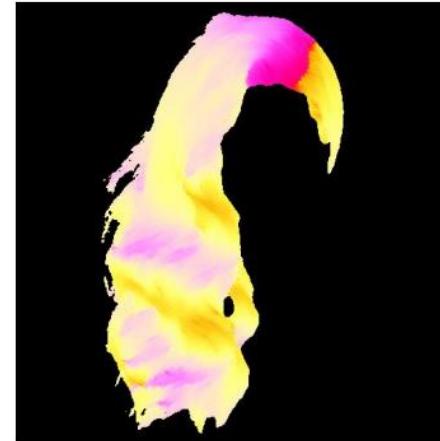
From HairStep



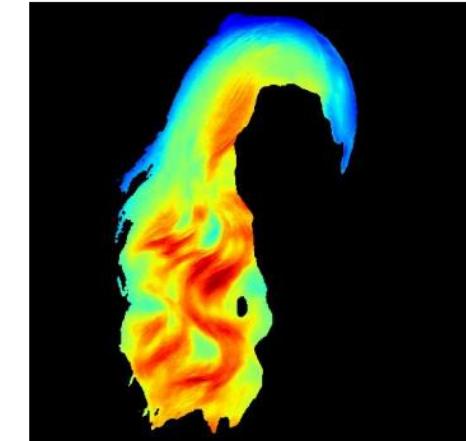
Orientation Map



Strand Map

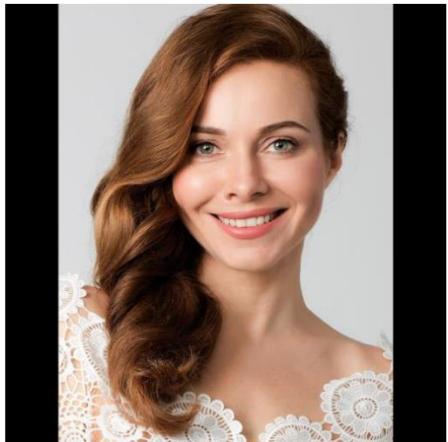


Depth Map



Visual Comparisons on Representation (NeuralHDHair*)

Image



From Orientation Map



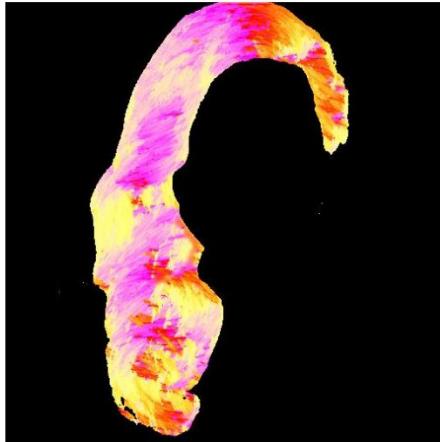
From Strand Map



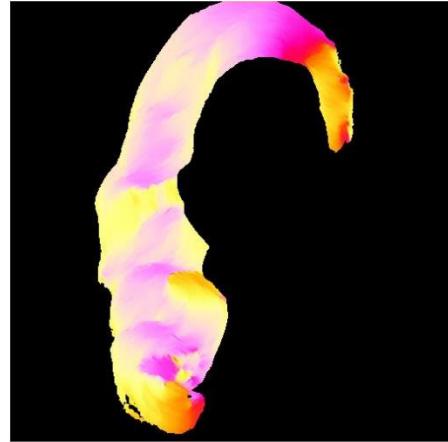
From HairStep



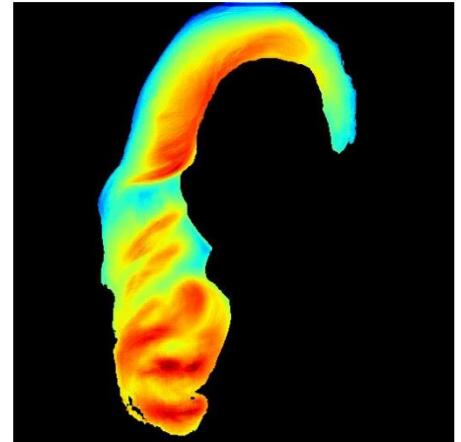
Orientation Map



Strand Map



Depth Map

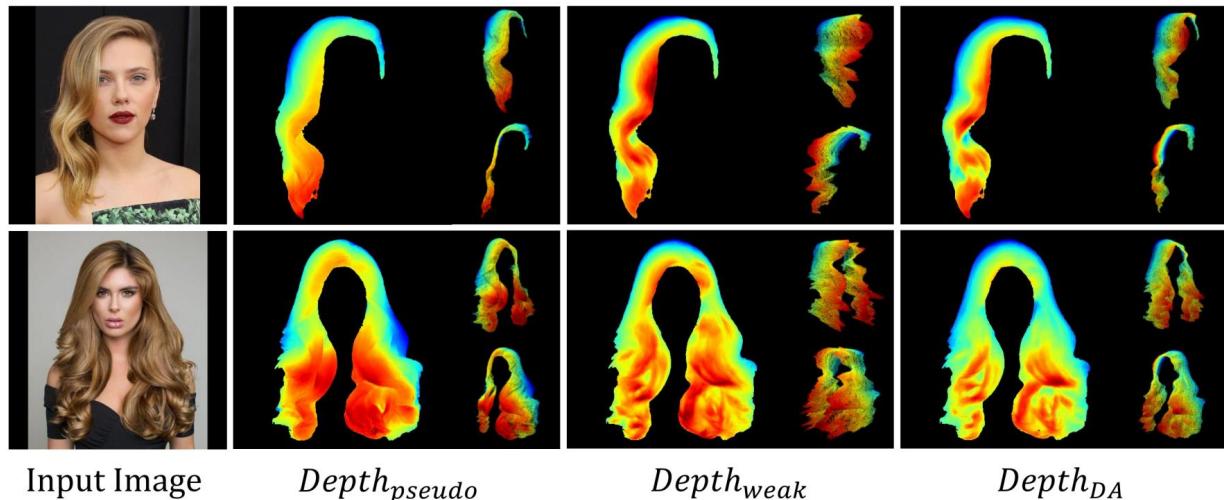


Visual Comparisons on Representation (Multi-view)

Comparisons with Orientation Map



Ablation Study



↓
 C_1 gives worse alignment of hair growth.

↓
 C_0 suffers from the flat geometry of depth.

- C_0 : strand map + $Depth_{pseudo}$.
- C_1 : strand map + $Depth_{weak}$.
- **Full**: strand map + $Depth_{DA}$.

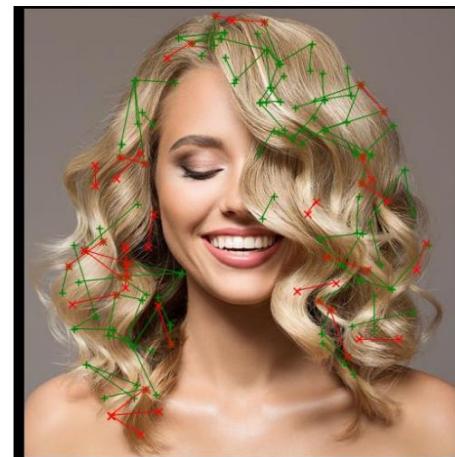
Method	IoU \uparrow	<i>HairSale</i> \downarrow	<i>HairRida</i> \uparrow
C_0	77.75%	16.03 (-18.2%)	73.57%
C_1	77.11%	16.54 (-15.6%)	75.8%
Full	77.22%	16.36 (-16.5%)	76.79%

Ablation Study

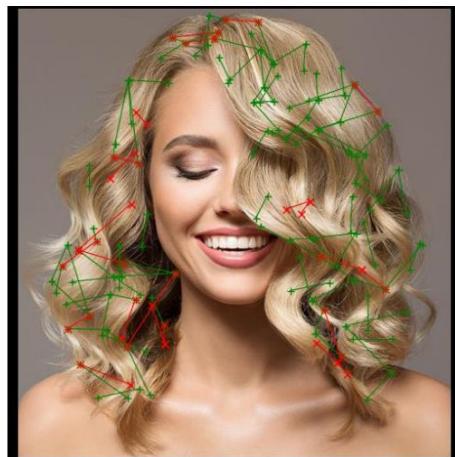


Image

C_0



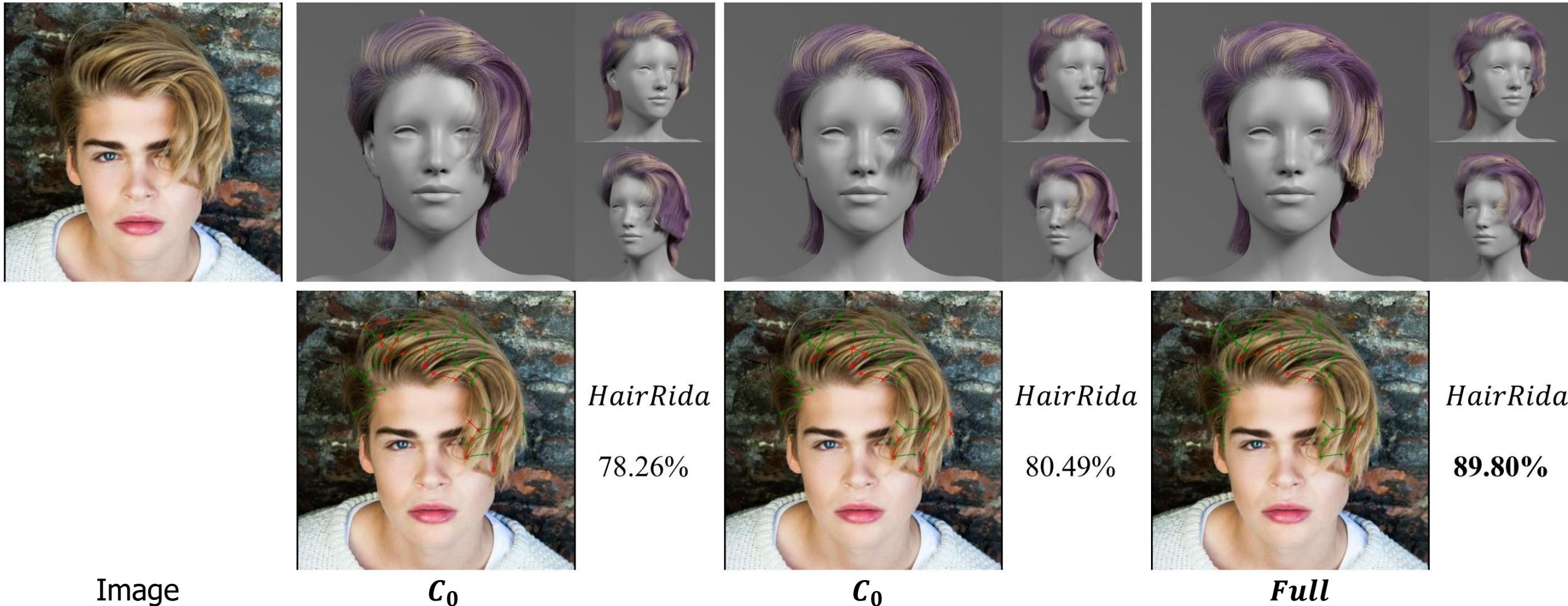
C_0



Full



Ablation Study



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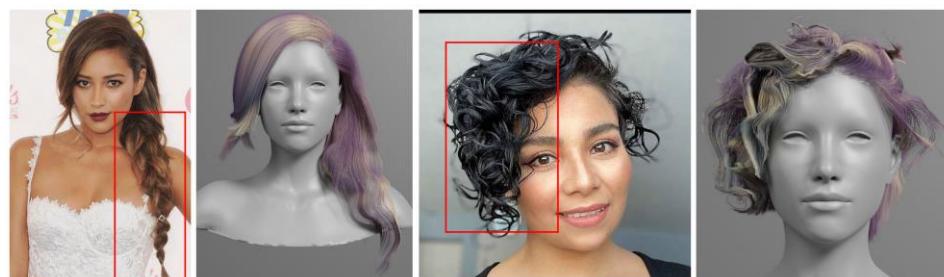


Conclusion

- A novel **representation** HairStep
- Two **datasets** HiSa & HiDa for future research
- Fair **metrics** for single-view 3D hair modeling

Limitation

- No update for current pipeline of 3D hair modeling
- Fails on hairstyles with braid and complex curly pattern



Reference

- [1] Chai, M., Shao, T., Wu, H., Weng, Y., & Zhou, K. (2016). Autohair: Fully automatic hair modeling from a single image. ACM Transactions on Graphics, 35(4).
- [2] Zhou, Y., Hu, L., Xing, J., Chen, W., Kung, H. W., Tong, X., & Li, H. (2018). Hairnet: Single-view hair reconstruction using convolutional neural networks. In Proceedings of the European Conference on Computer Vision (ECCV) (pp. 235-251).
- [3] Saito, S., Hu, L., Ma, C., Ibayashi, H., Luo, L., & Li, H. (2018). 3D hair synthesis using volumetric variational autoencoders. ACM Transactions on Graphics (TOG), 37(6), 1-12.
- [4] Wu, K., Ye, Y., Yang, L., Fu, H., Zhou, K., & Zheng, Y. (2022). NeuralHDHair: Automatic High-fidelity Hair Modeling from a Single Image Using Implicit Neural Representations. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (pp. 1526-1535).
- [5] Paris, S., Briceno, H. M., & Sillion, F. X. (2004). Capture of hair geometry from multiple images. ACM transactions on graphics (TOG), 23(3), 712-719.
- [6] Chen, W., Fu, Z., Yang, D., & Deng, J. (2016). Single-image depth perception in the wild. Advances in neural information processing systems, 29.
- [7] Yang, L., Shi, Z., Zheng, Y., & Zhou, K. (2019). Dynamic hair modeling from monocular videos using deep neural networks. ACM Transactions on Graphics (TOG), 38(6), 1-12.



The End

Thank You!

