

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

*CVPR2023 Highlight*

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# Outline

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- Background
- HairStep
- Experiment
- Conclusion



# Outline

- **Background**

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

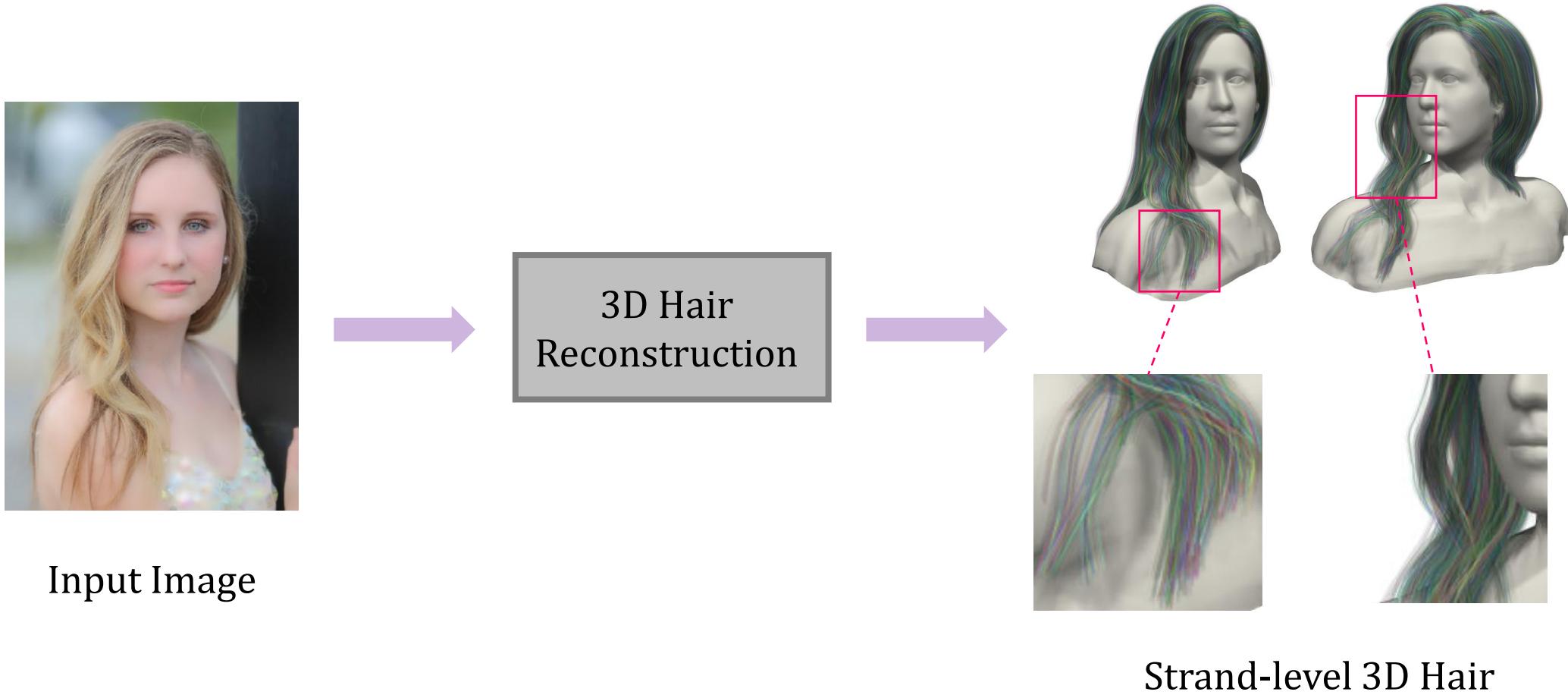
- HairStep

- Experiment

- Conclusion



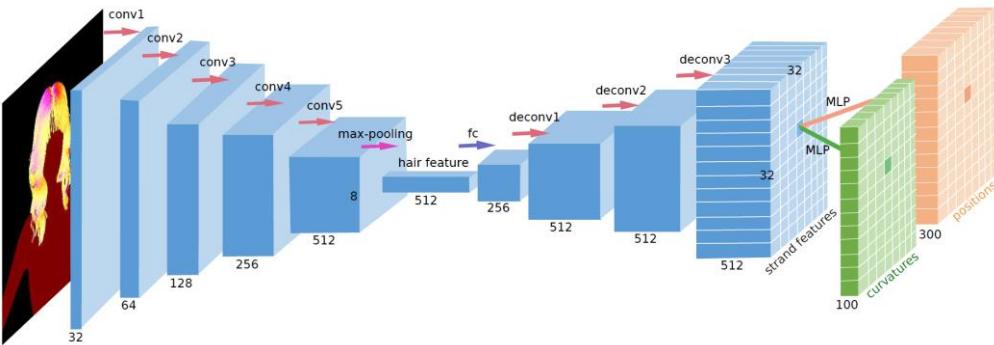
# Single-view 3D Hair Modeling



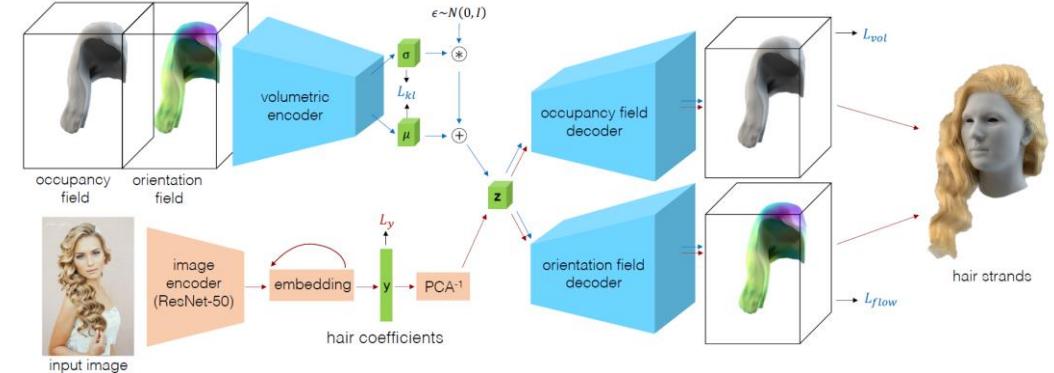
*Chai et al. 2016*



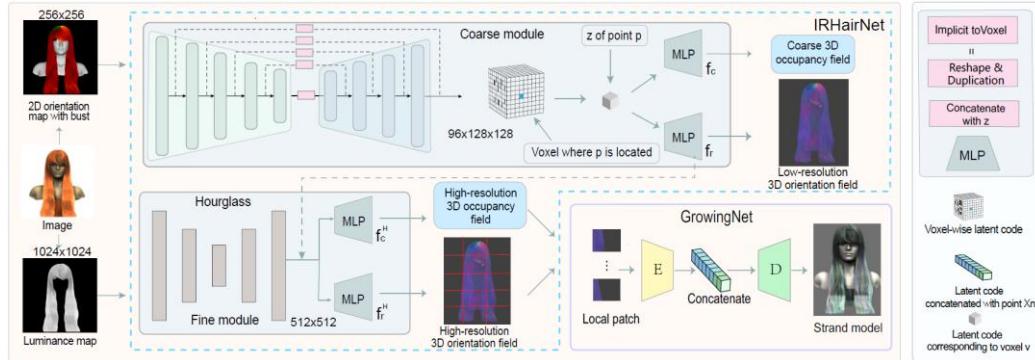
# Previous Approaches



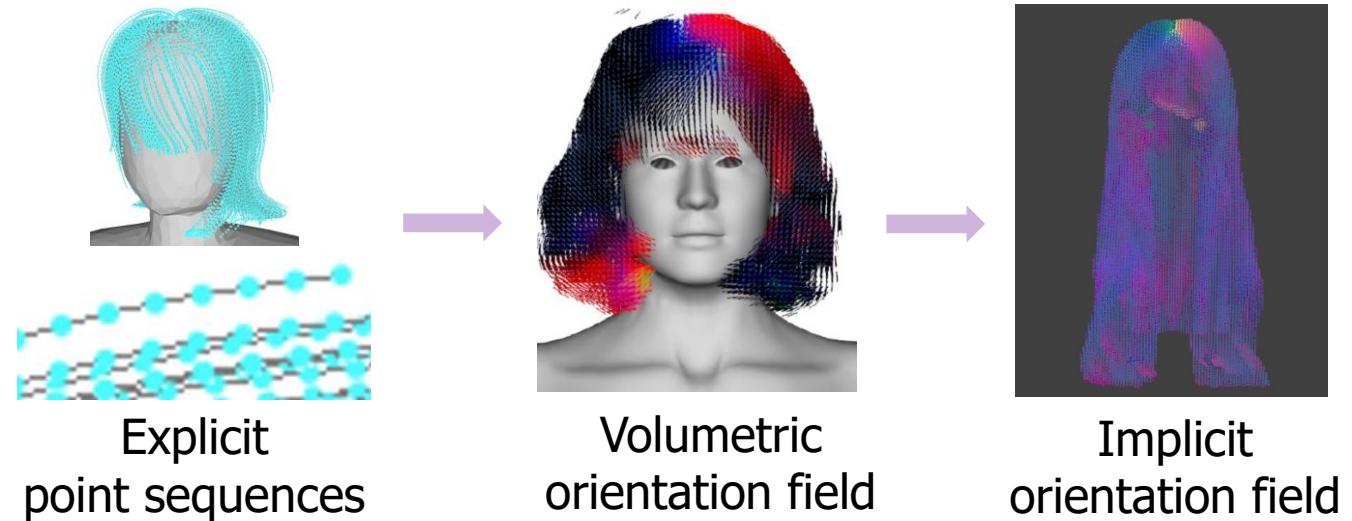
Zhou et al. 2018



Saito et al. 2018



Wu et al. 2022



Explicit  
point sequences

Volumetric  
orientation field

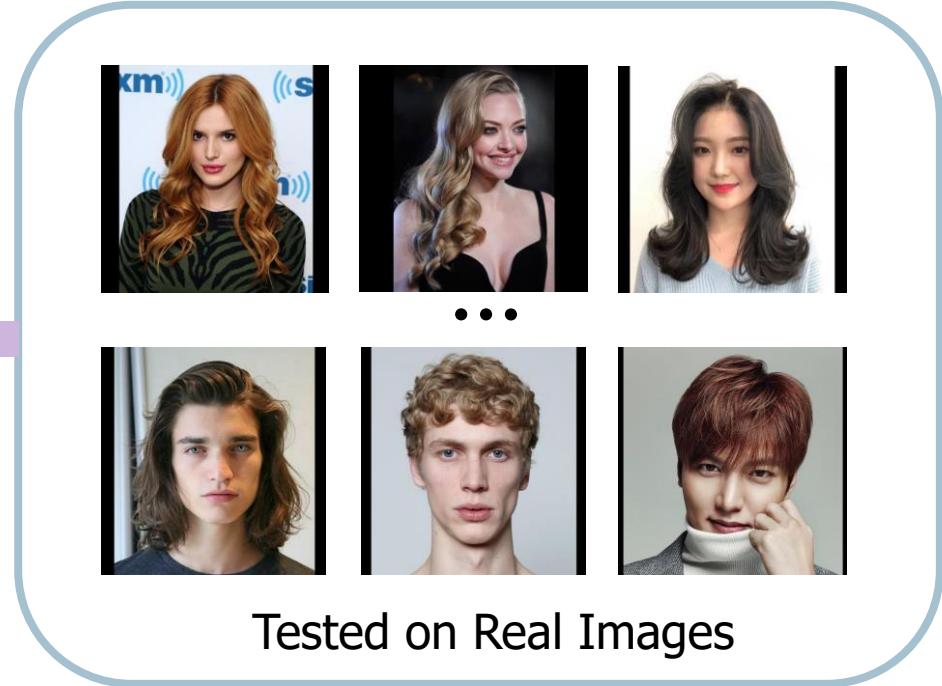
Implicit  
orientation field



# Domain Gap



**Domain Gap**



Failure Cases



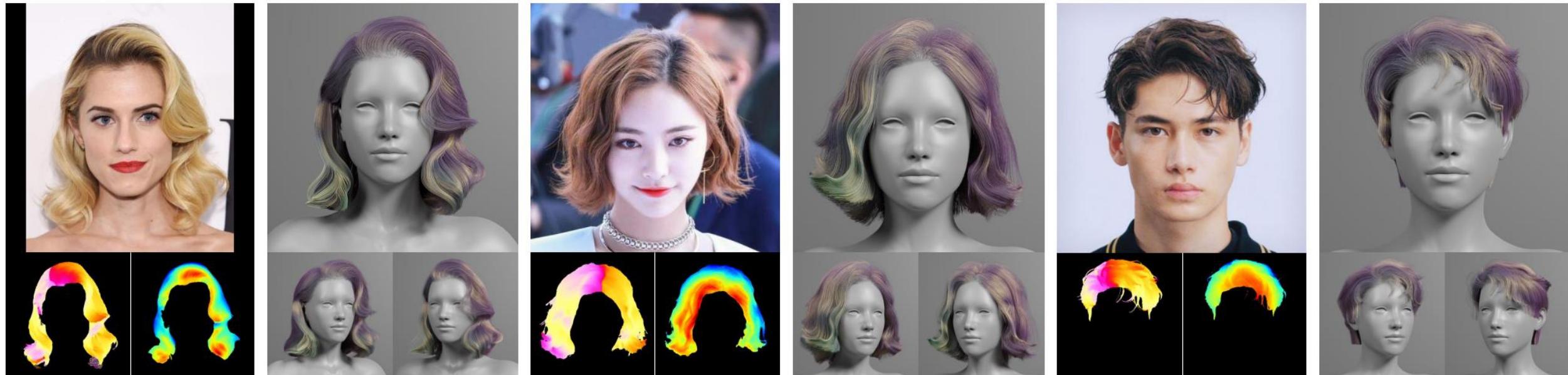
# Outline

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

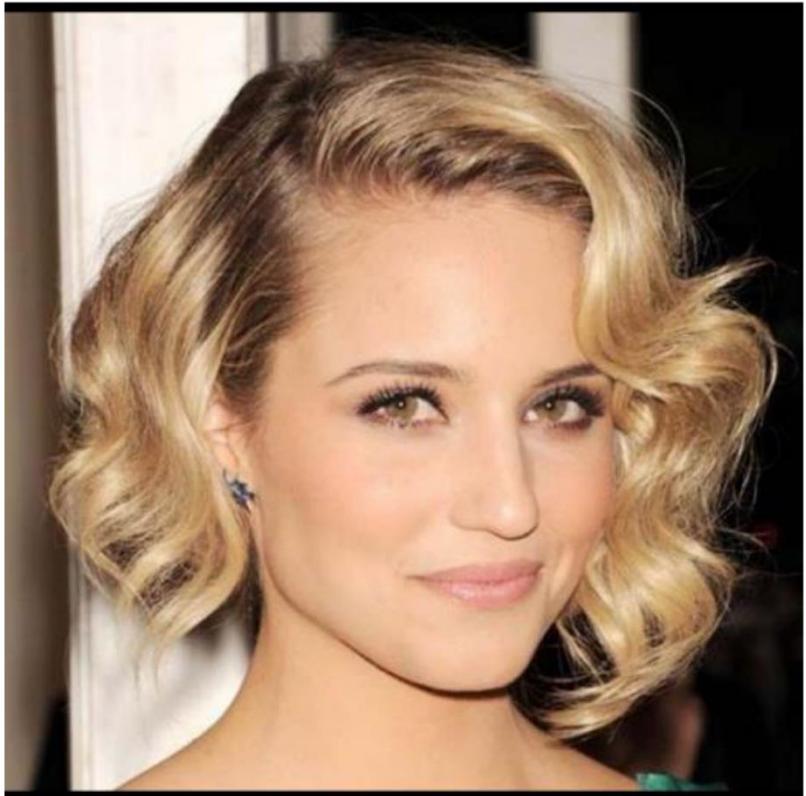


# HairStep

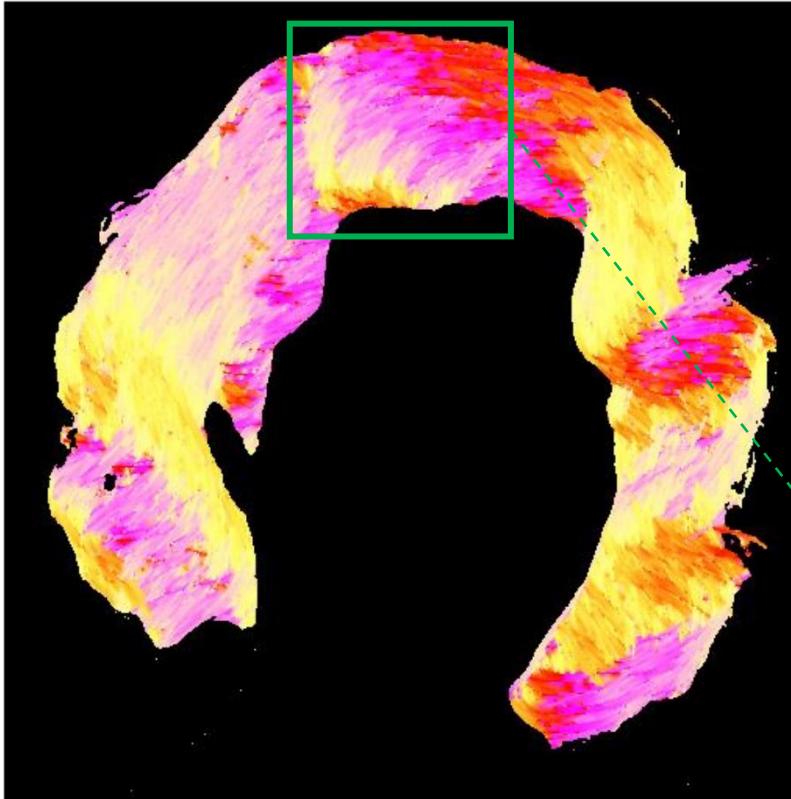
## *HairStep: Transfer Synthetic to Real Using Strand and Depth Maps for Single-View 3D Hair Modeling*



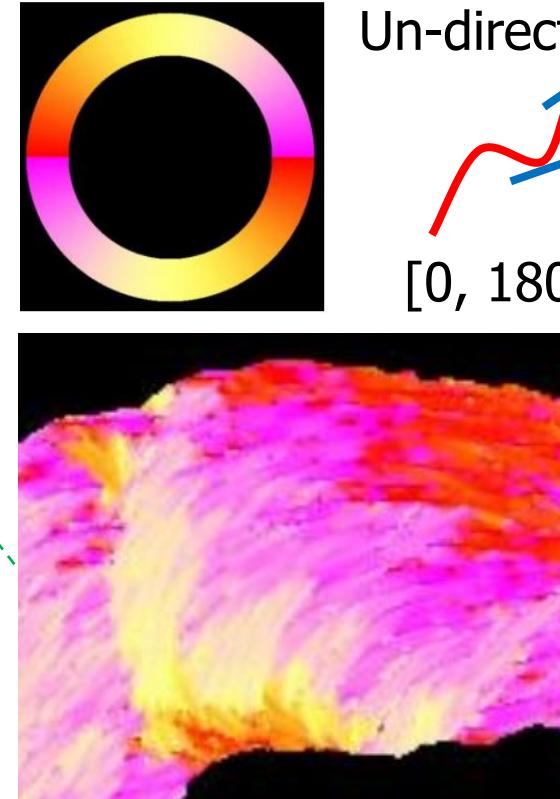
# Motivation



Image

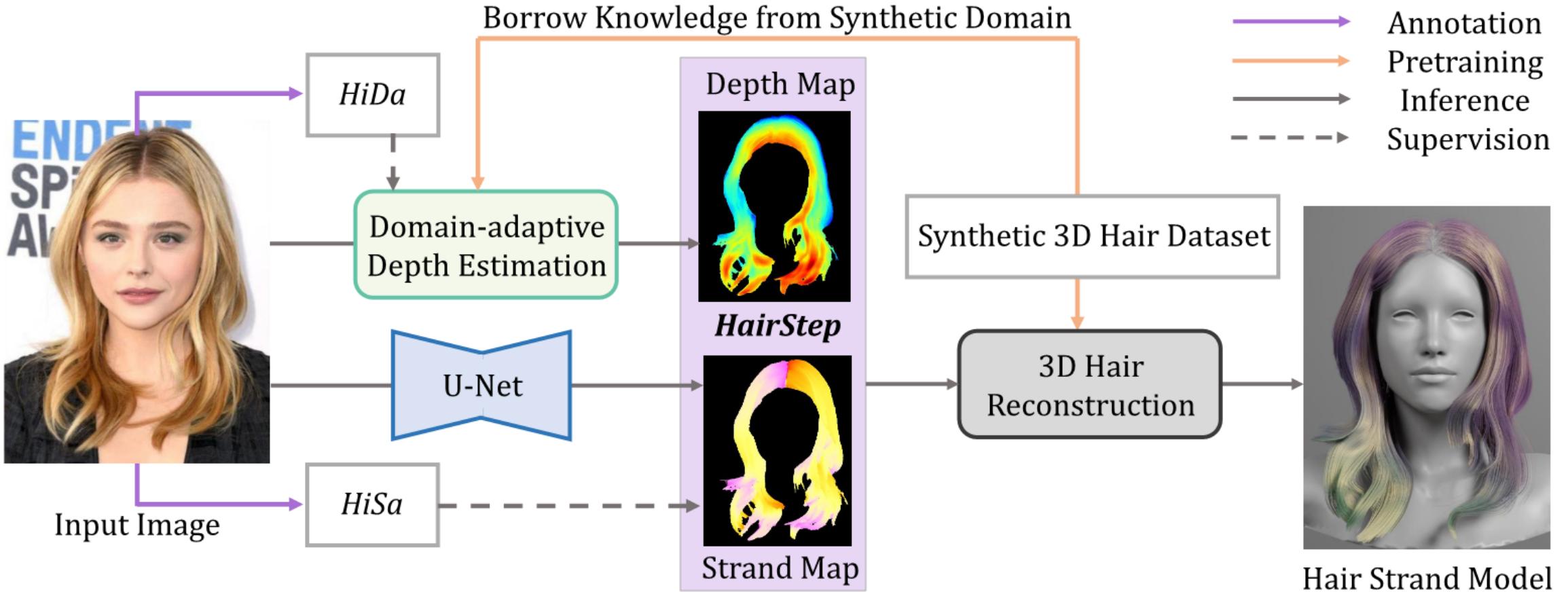


Orientation Map  
from Gabor Filters



**Ambiguous & Noisy!**

# Overview



# HiSa Dataset & Strand Map



Image



Strokes



Stroke Map



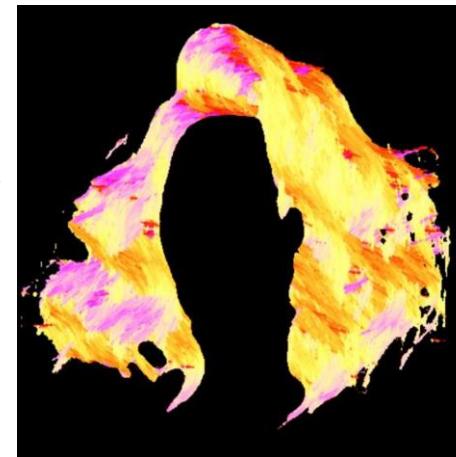
Strand Map



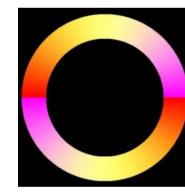
[0, 360]



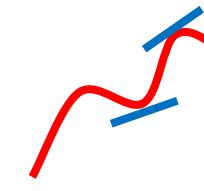
Directed  
Lines



Orientation Map



[0, 180]

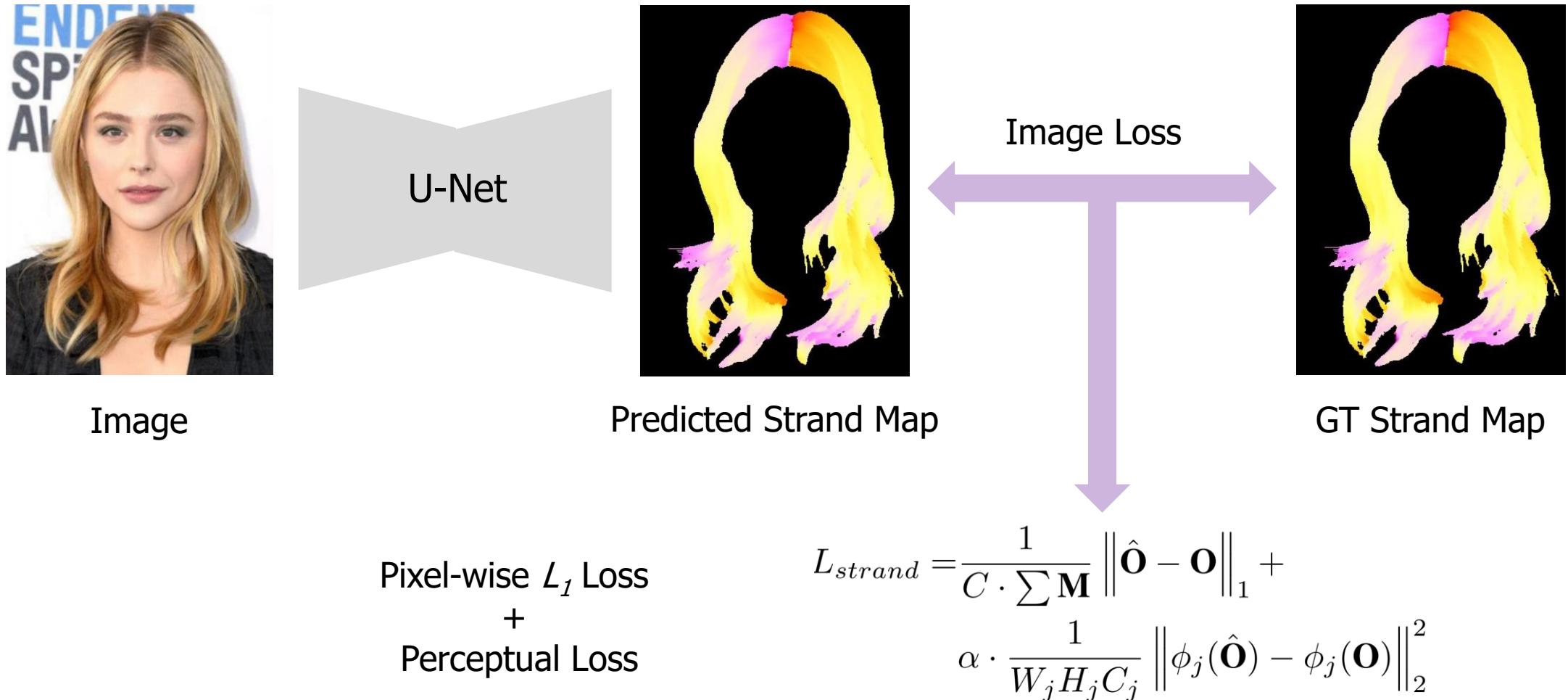


Un-directed  
Lines

300 vector curves  
from hair roots to hair ends



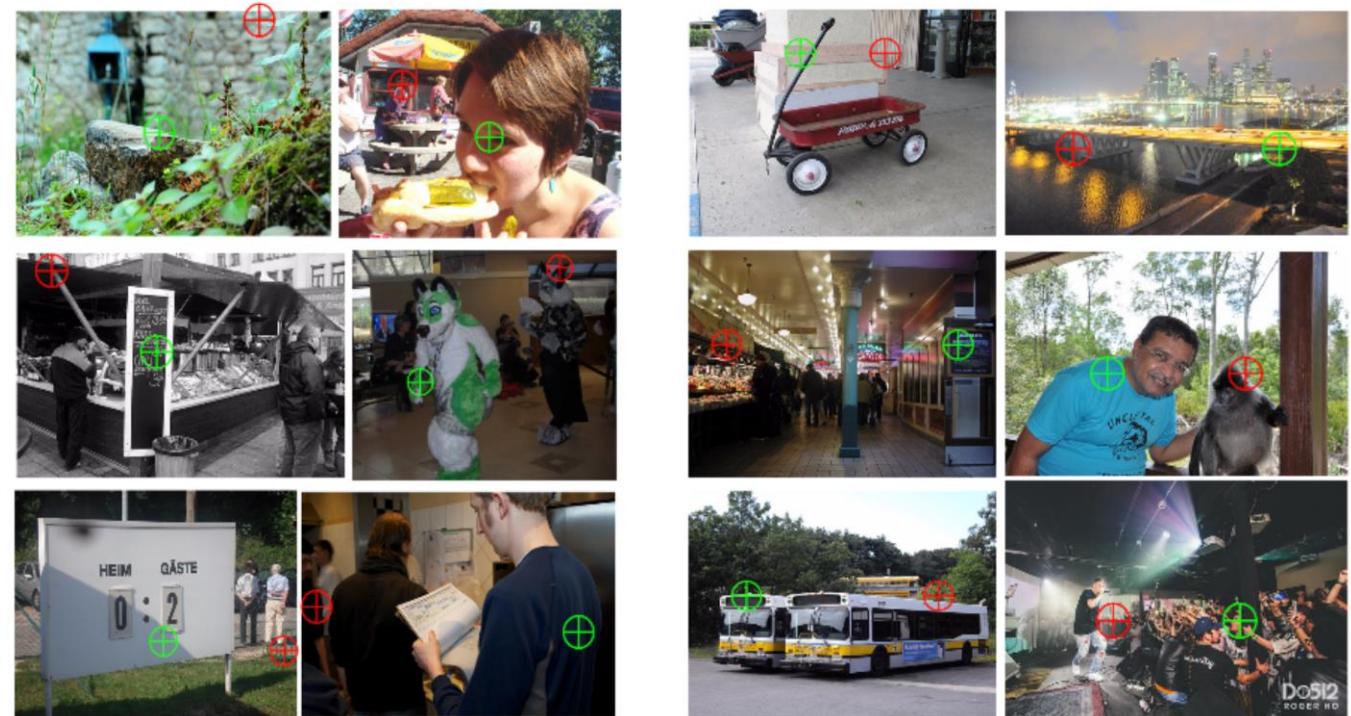
# Extraction of Strand Map



# HiDa Dataset & Relative Depth



How to **annotate depth** of hair?



*Depth-in-the-wild  
Relative depth*



# HiDa Dataset & Relative Depth



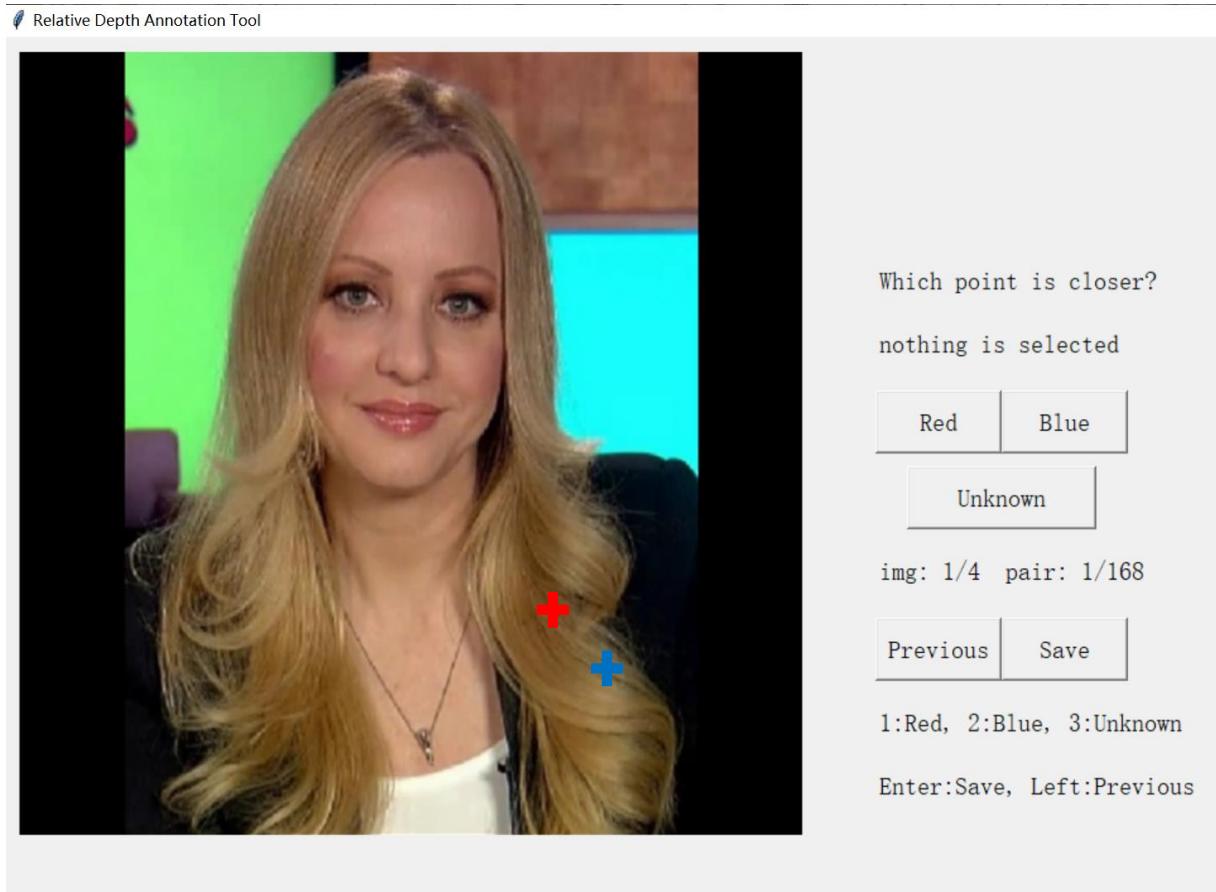
Sample Pairs in Neighbors of Super-pixels

1250 Images

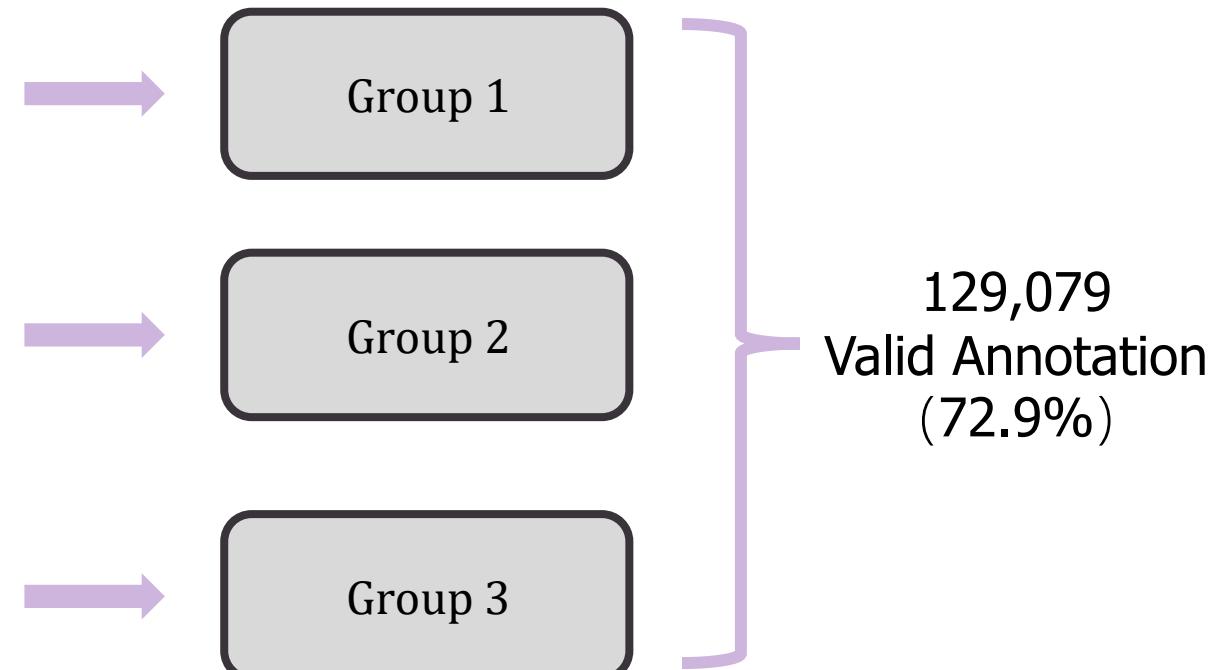
177,074 Pixel Pairs



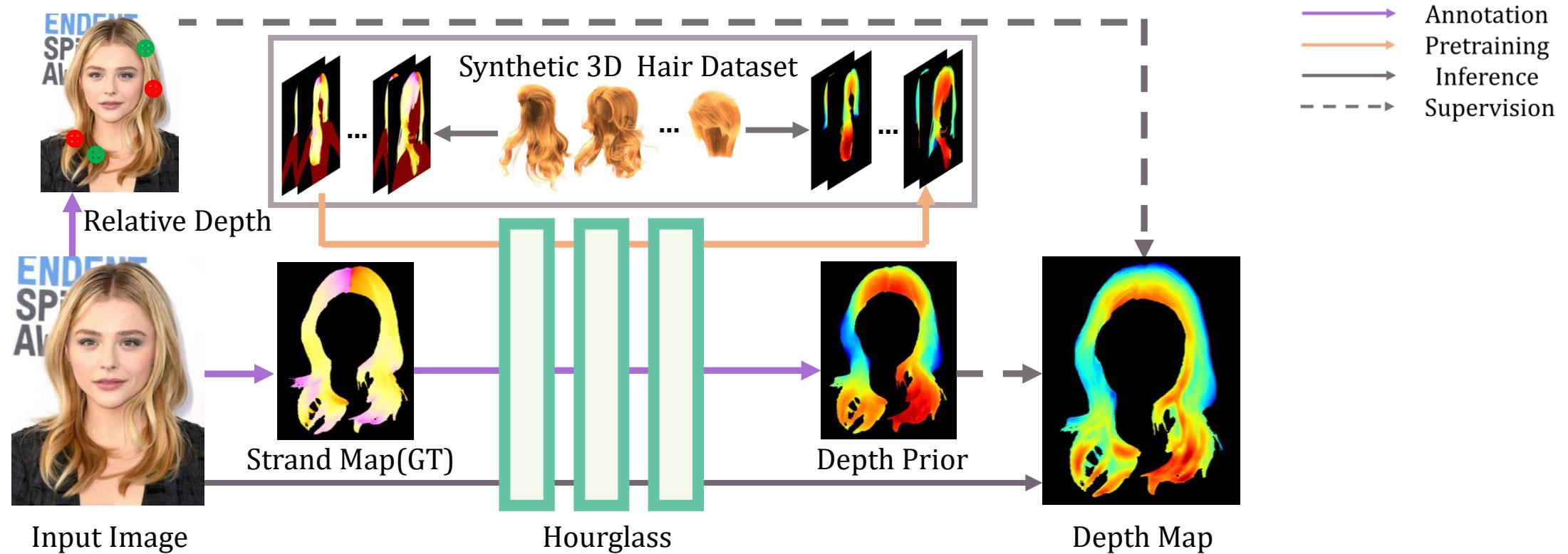
# HiDa Dataset & Relative Depth



Annotation Tool



# Domain-Adaptive Depth Estimation

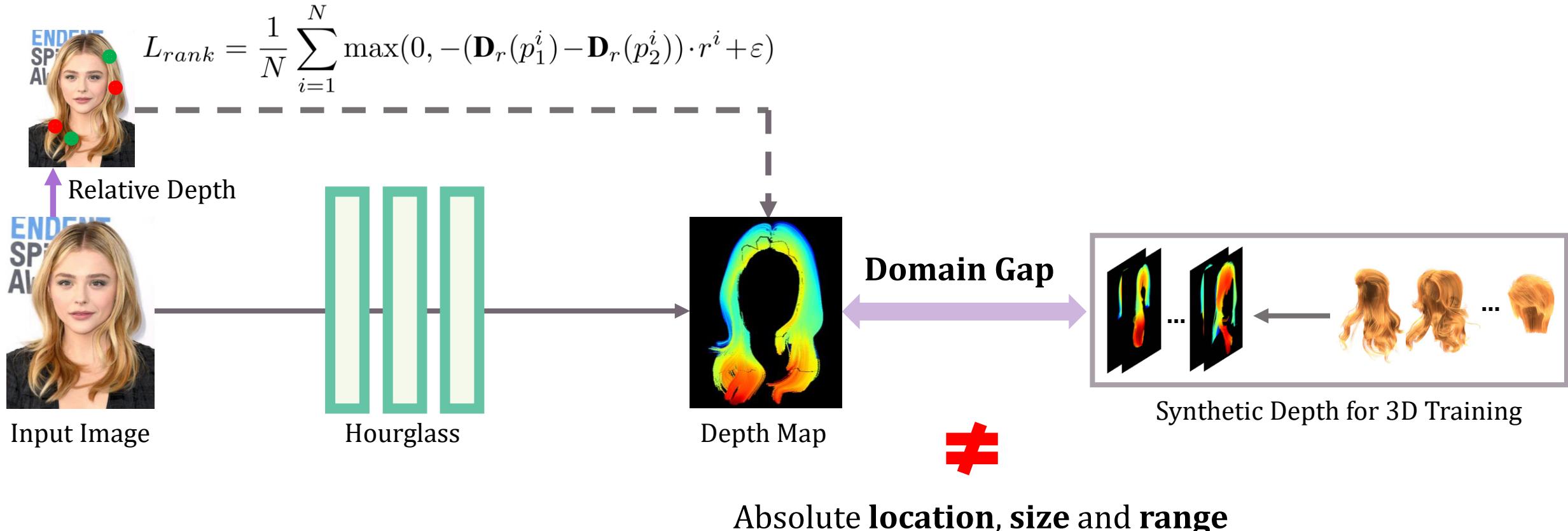


$$L_{rank} = \frac{1}{N} \sum_{i=1}^N \max(0, -(\mathbf{D}_r(p_1^i) - \mathbf{D}_r(p_2^i)) \cdot r^i + \varepsilon)$$

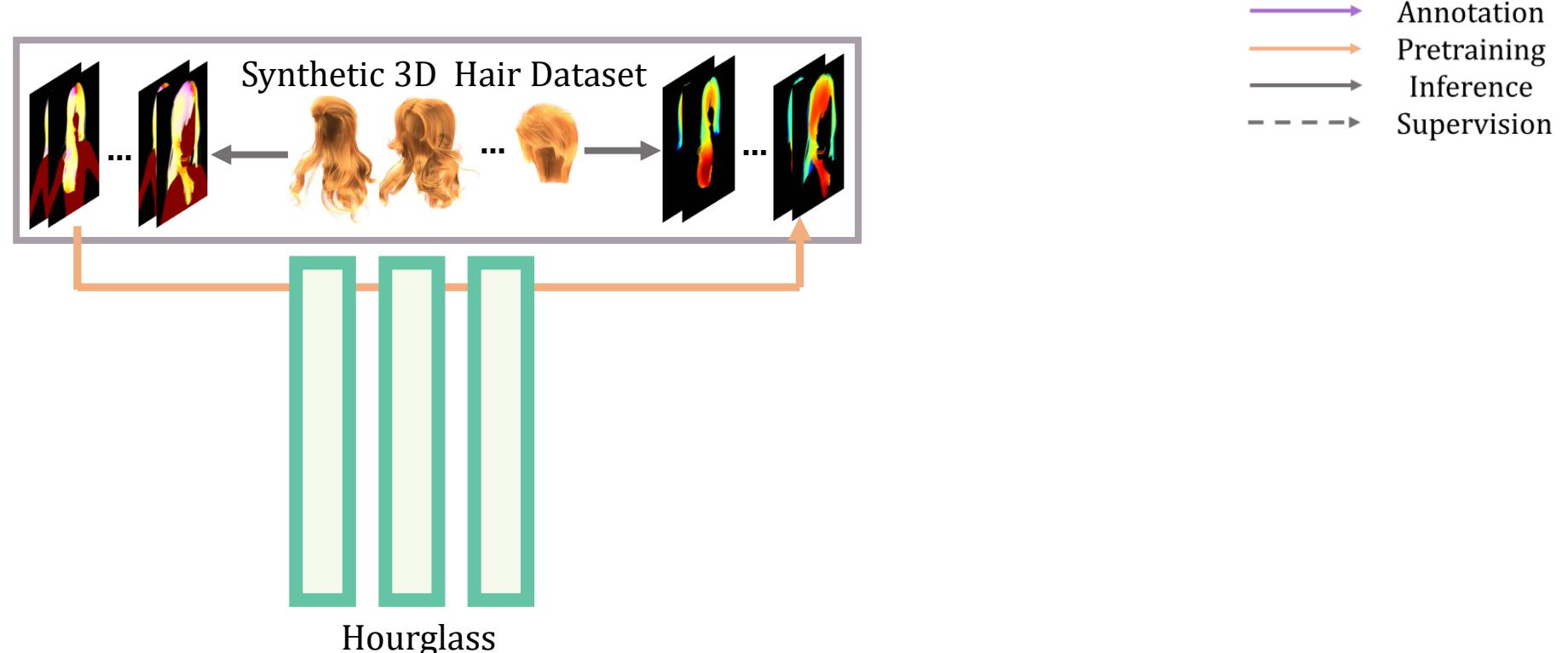
$$L_{depth} = \beta \cdot \|\mathbf{D}_r - \bar{\mathbf{D}}\|_1 + L_{rank}$$



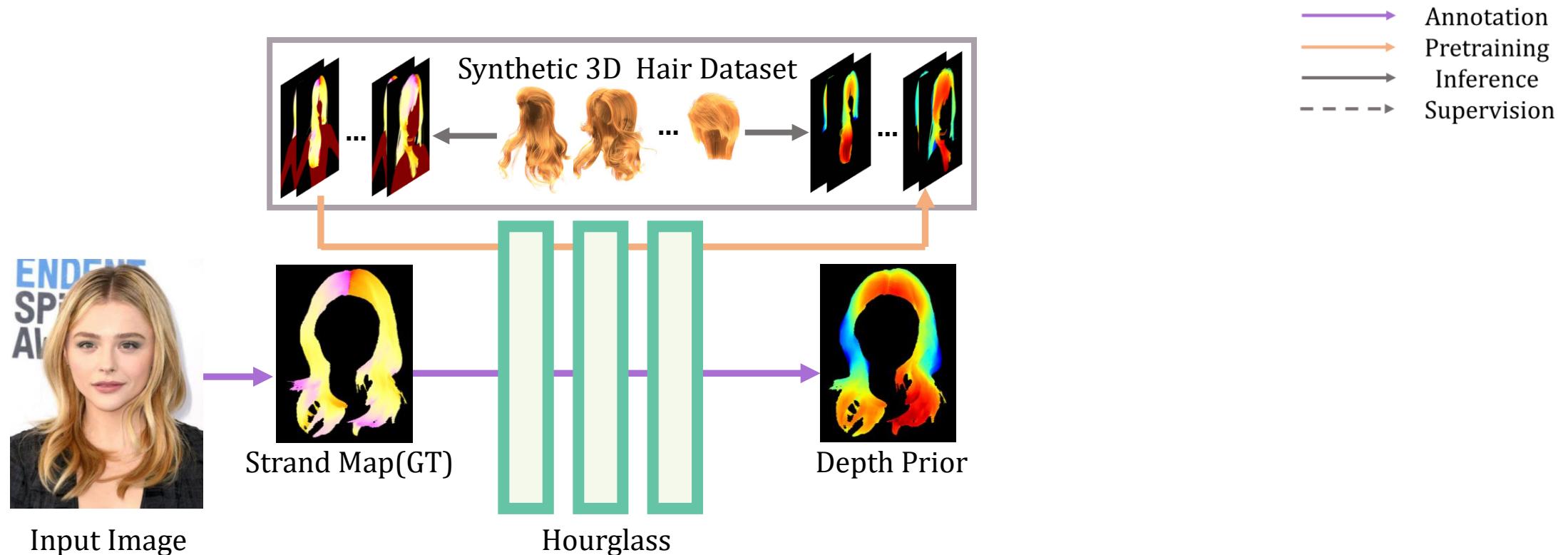
# Domain-Adaptive Depth Estimation



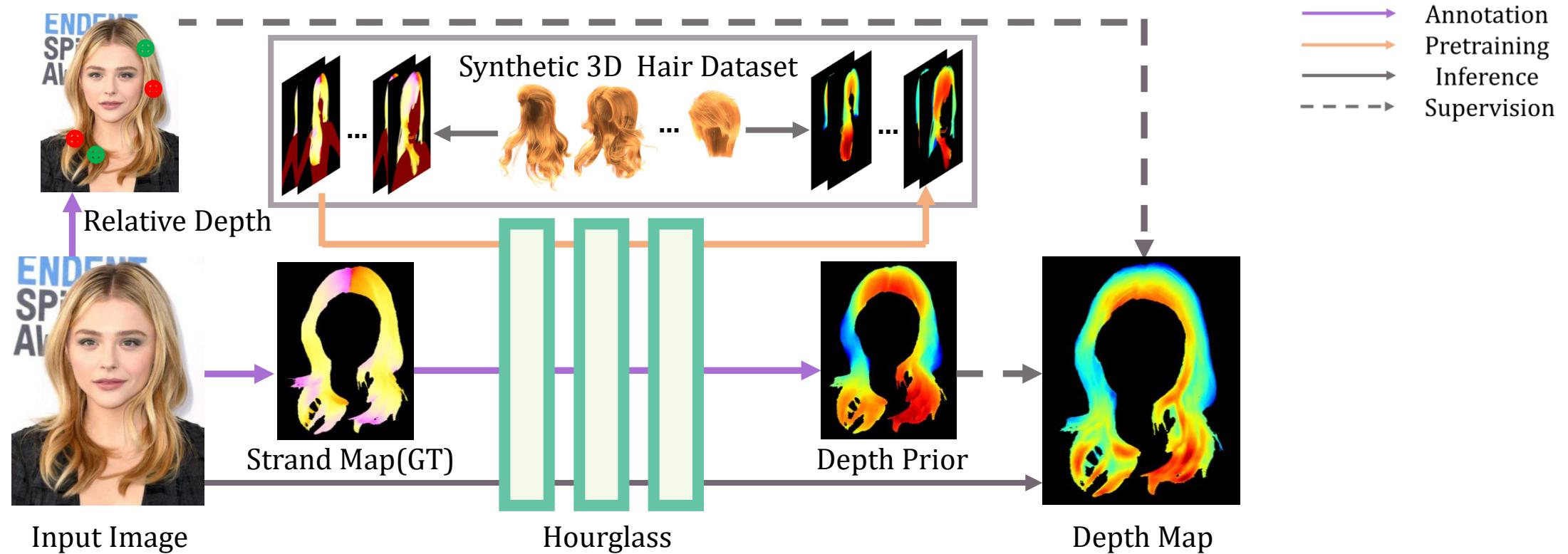
# Domain-Adaptive Depth Estimation



# Domain-Adaptive Depth Estimation



# Domain-Adaptive Depth Estimation

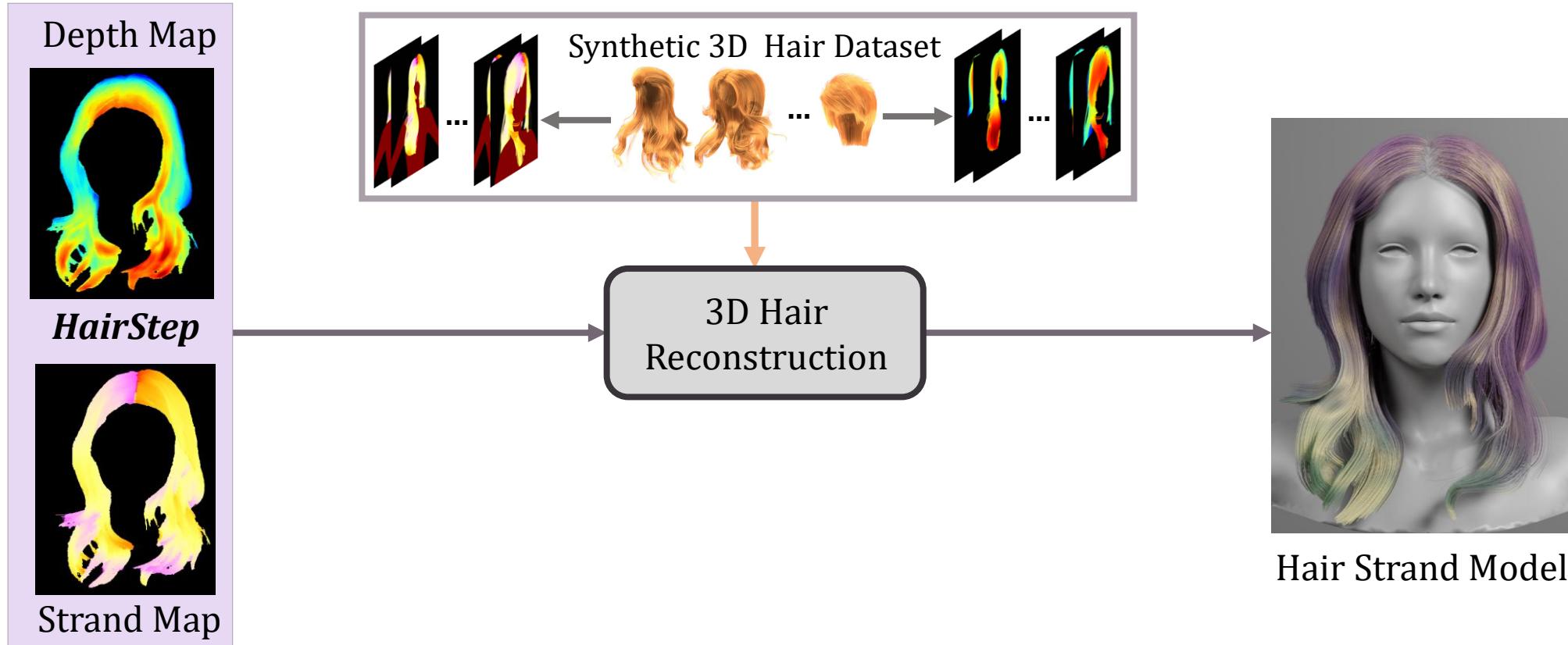


$$L_{rank} = \frac{1}{N} \sum_{i=1}^N \max(0, -(\mathbf{D}_r(p_1^i) - \mathbf{D}_r(p_2^i)) \cdot r^i + \varepsilon)$$

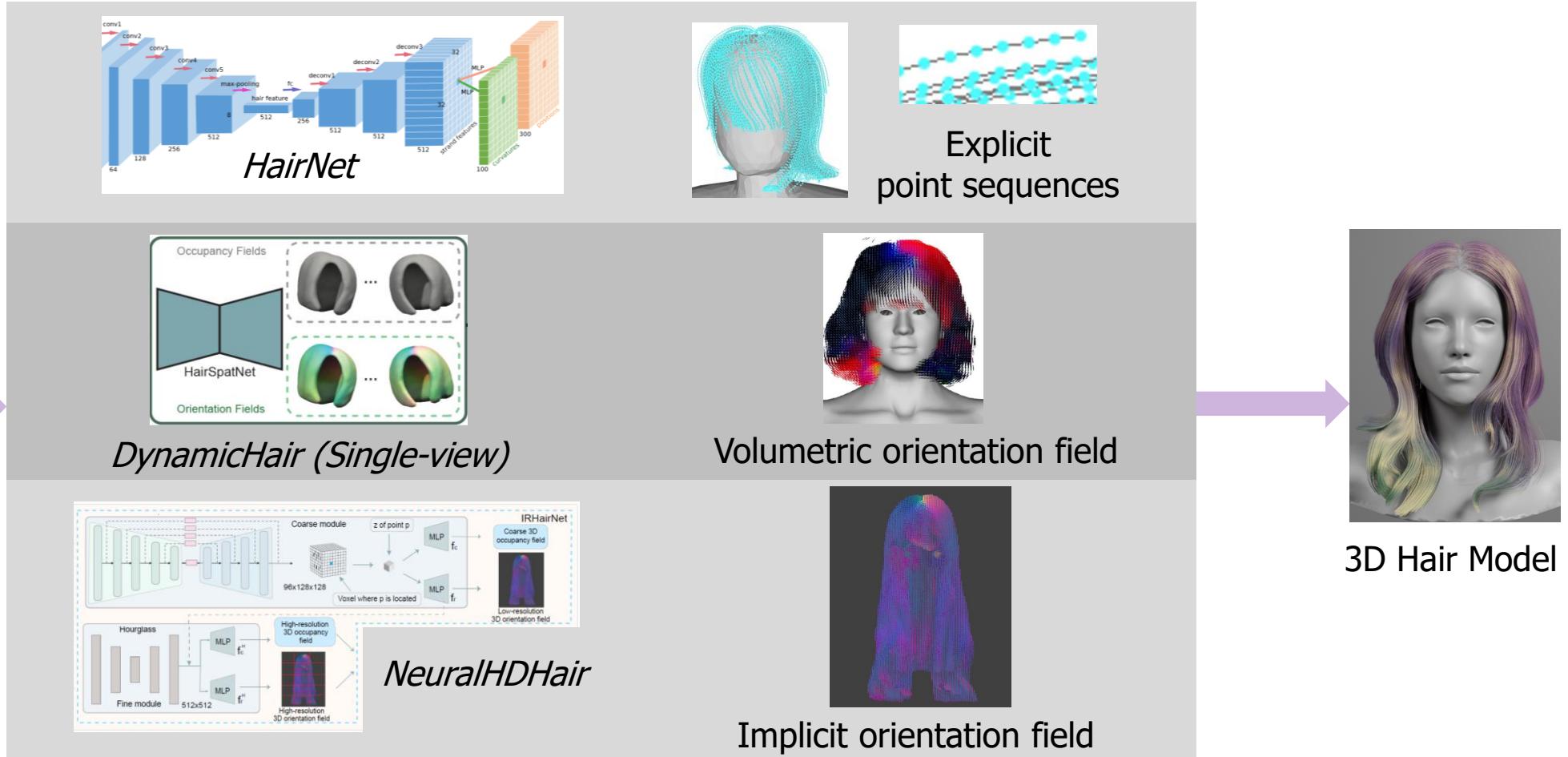
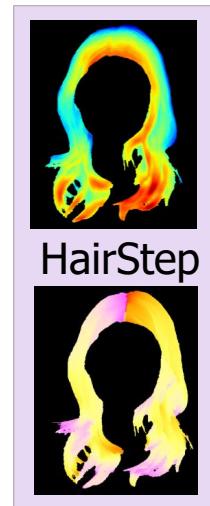
$$L_{depth} = \beta \cdot \|\mathbf{D}_r - \bar{\mathbf{D}}\|_1 + L_{rank}$$



# Single-View 3D Hair Modeling



# Single-View 3D Hair Modeling

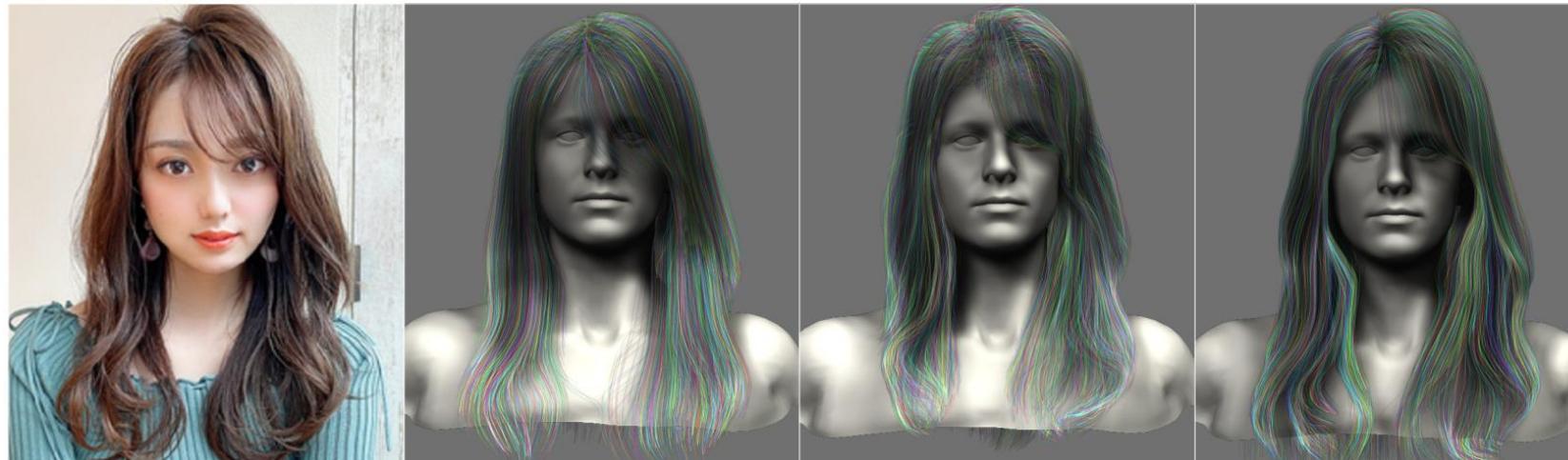


# Outline

- Background
- HairStep
- 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

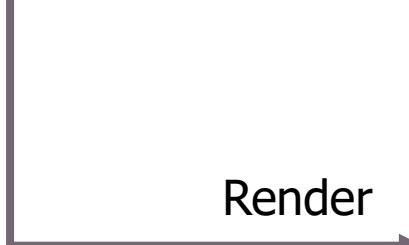


Render

GT Annotation



HairSale

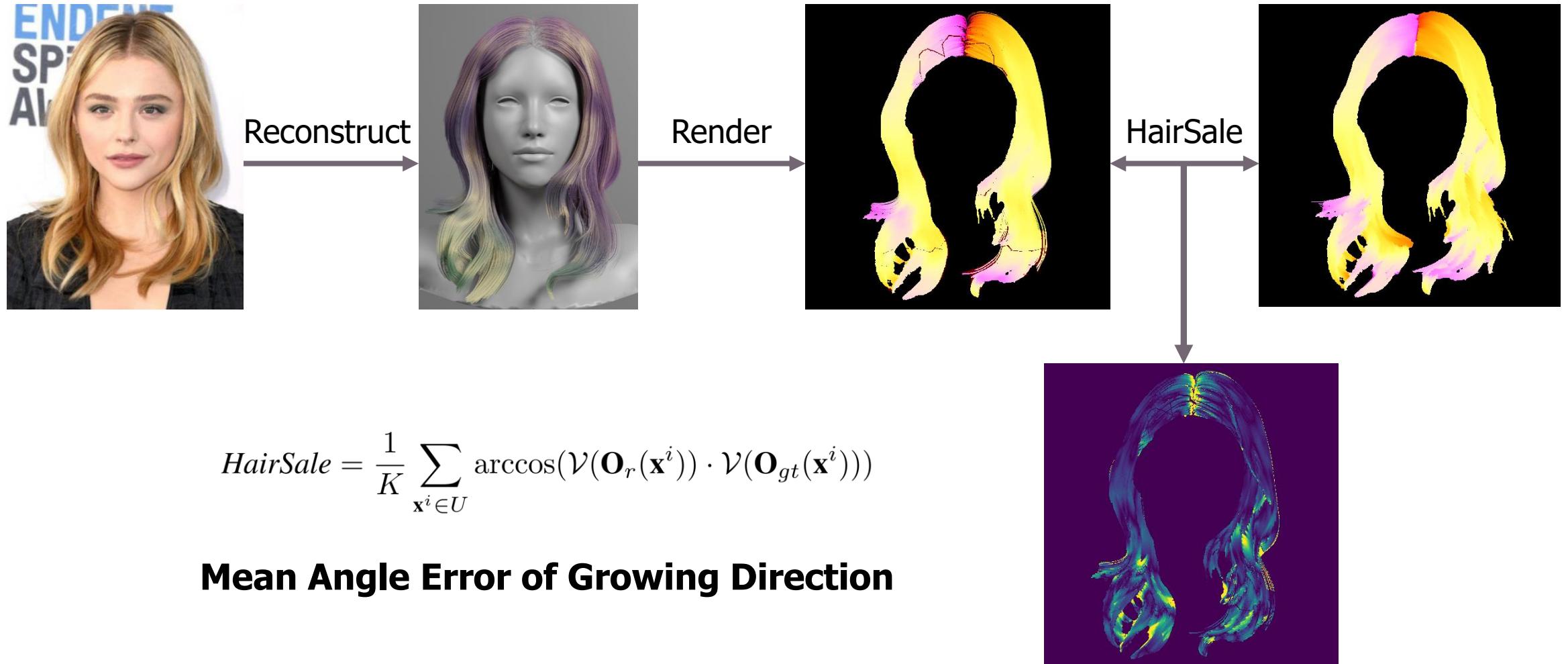


Render

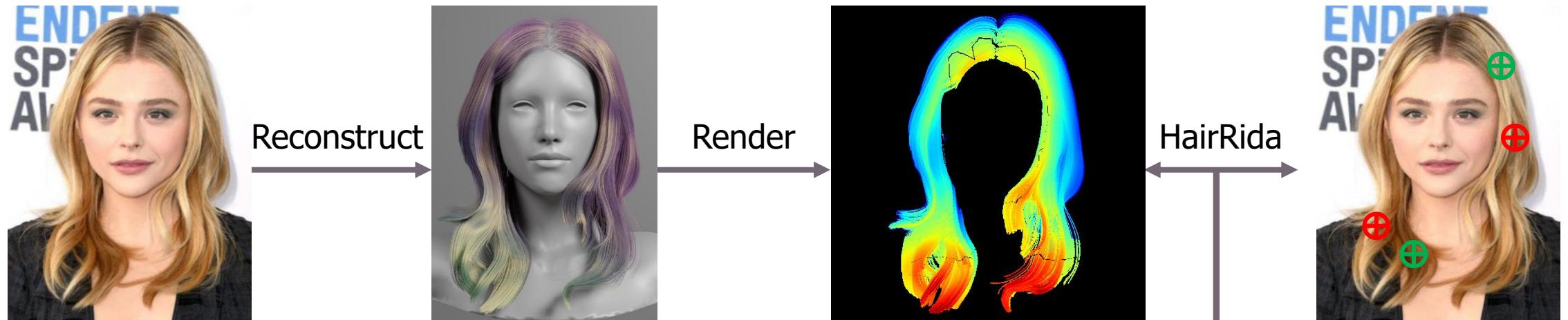
HairRida



# HairSale



# HairRida

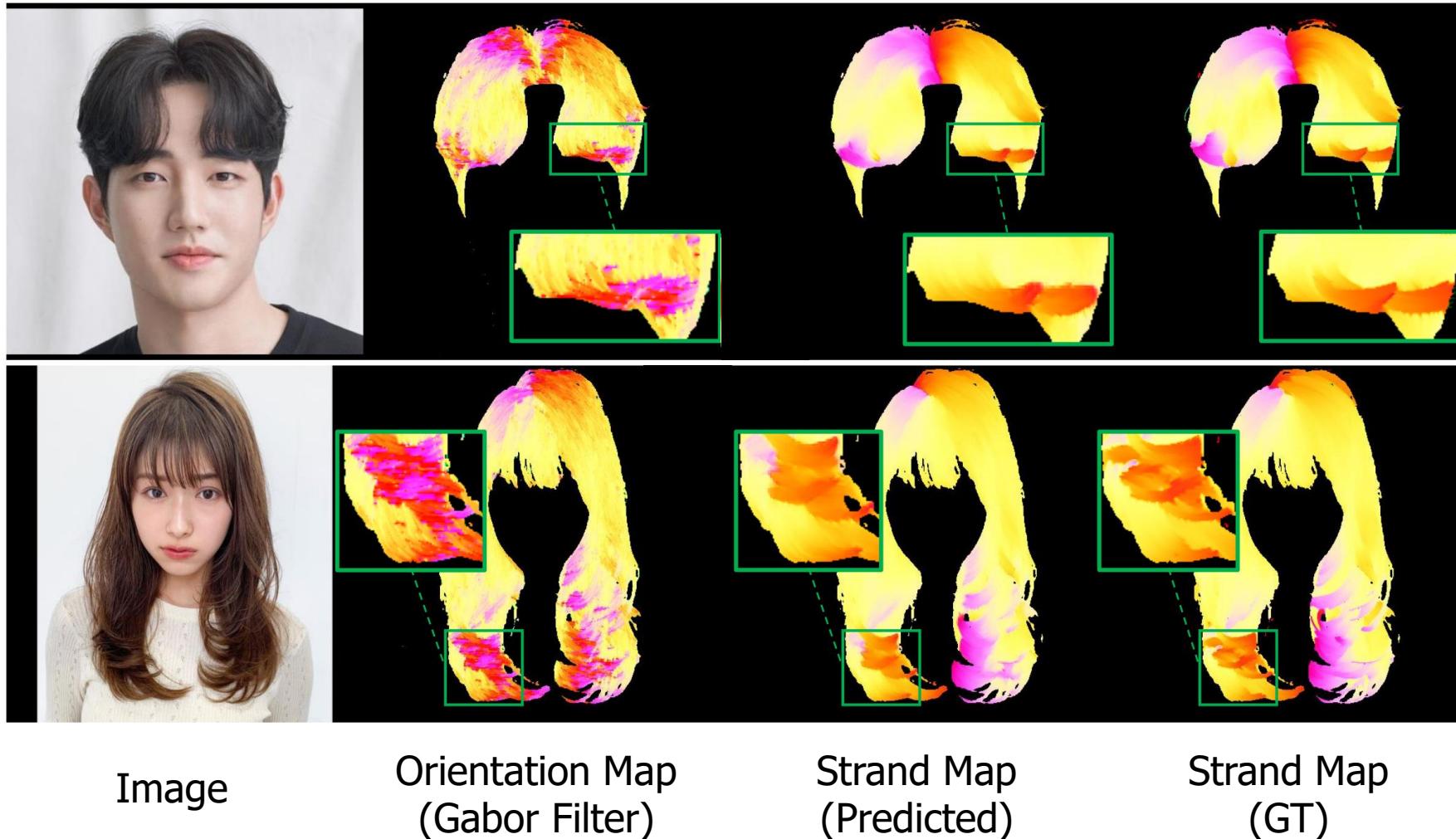


$$HairRida = \frac{1}{Q} \sum_{i=1}^Q \max(0, r^i \cdot \text{sign}(\mathbf{D}_r(p_1^i) - \mathbf{D}_r(p_2^i)))$$

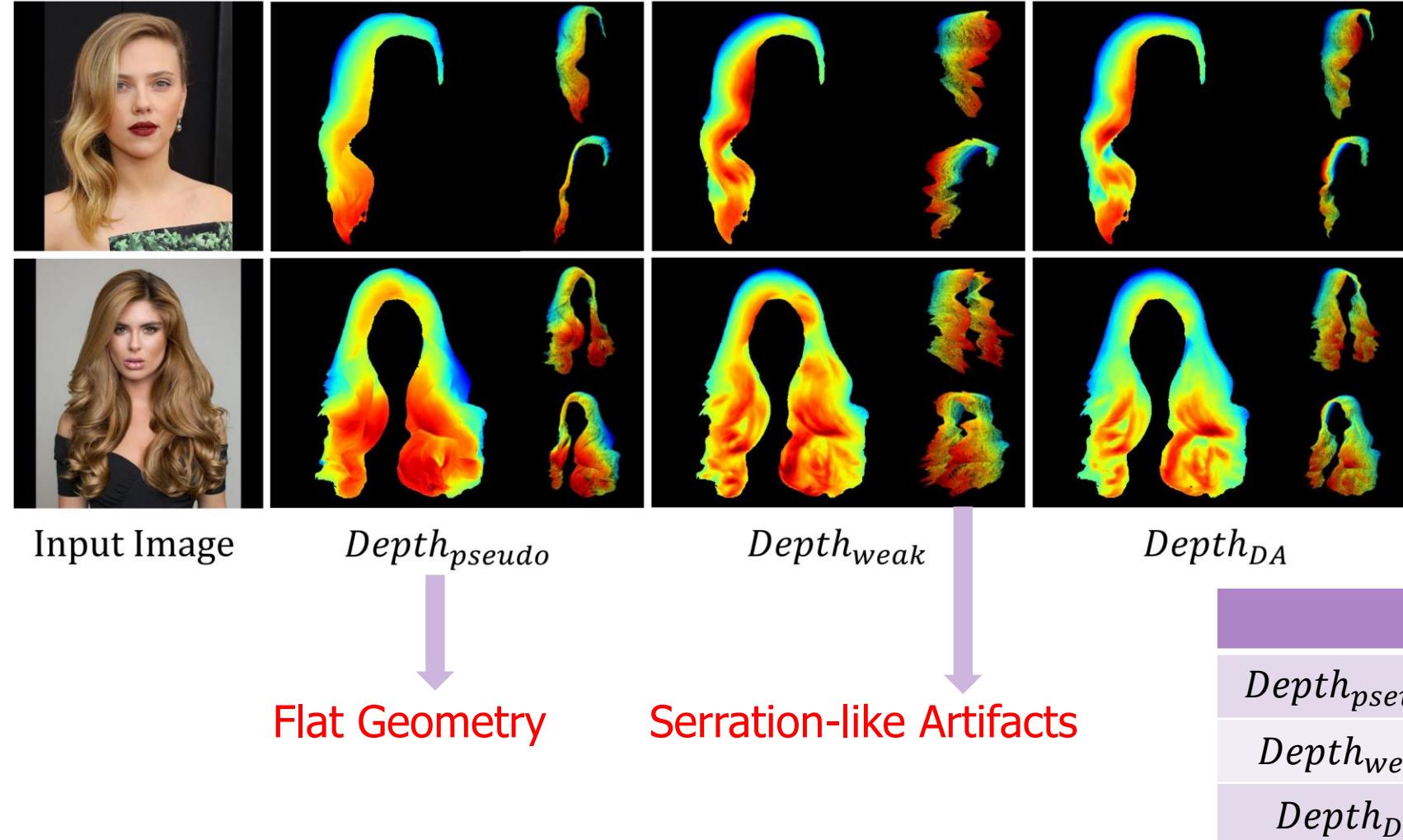
**The Relative Depth Accuracy**



# Evaluation on the Extraction of Strand Map



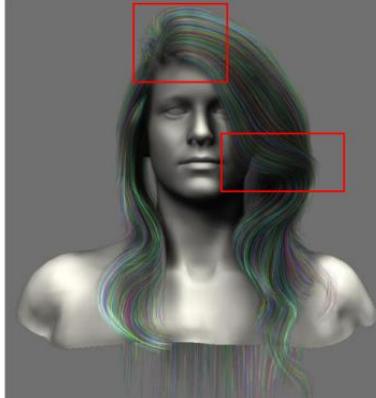
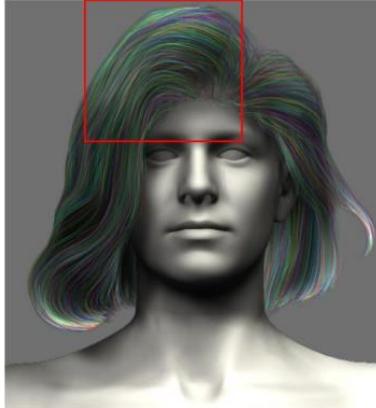
# Evaluation on Depth Estimation



	HairRida↑	L1↓
$Depth_{pseudo}$	80.47%	/
$Depth_{weak}$	85.17%	0.2470
$Depth_{DA}$	<b>85.20%</b>	<b>0.1768</b>



# Visual Comparisons with Existing Methods



Input Image

NeuralHDHair

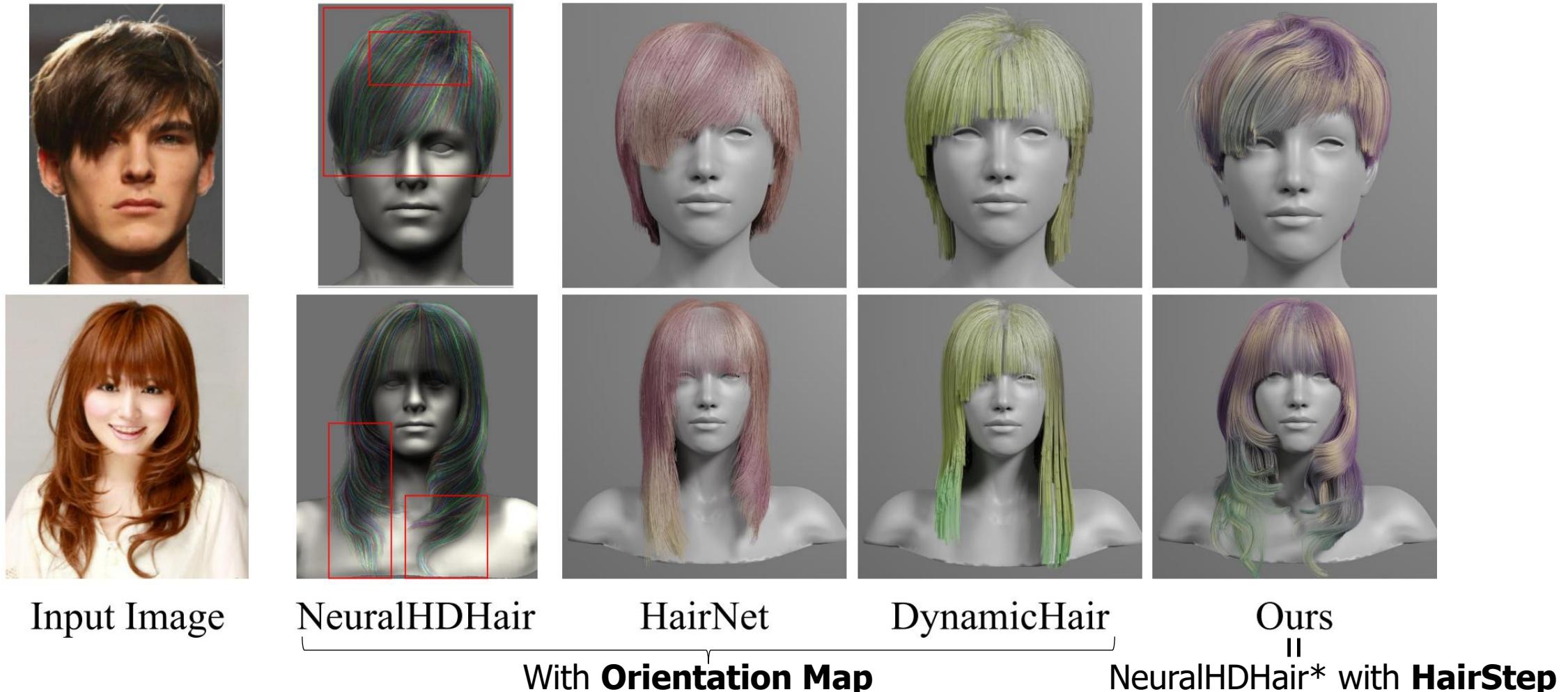
HairNet

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%	<b>16</b> (-18.4%)	72.37%
NeuralHDHair* (HairStep)	77.22%	16.36 (-16.5%)	<b>76.79%</b>
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

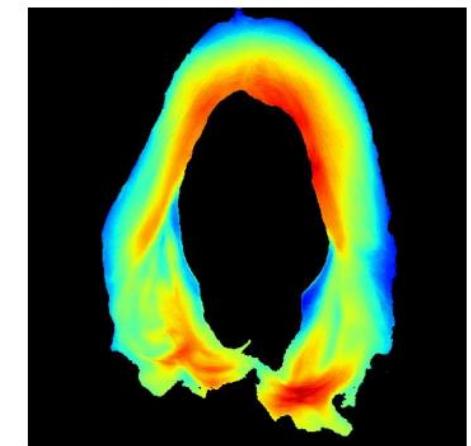
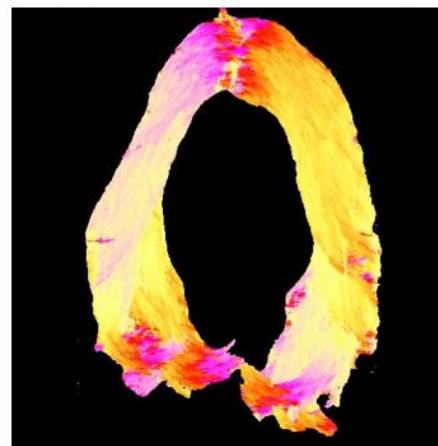


Strand Map

From HairStep



Depth Map



# Visual Comparisons on Representation (NeuralHDHair\*)

Image



From Orientation Map



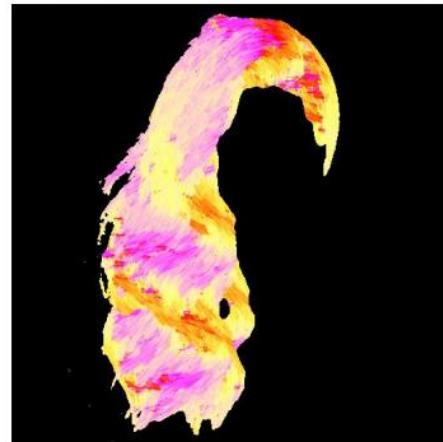
From Strand Map



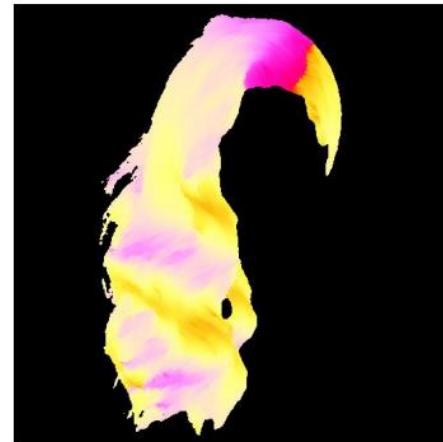
From HairStep



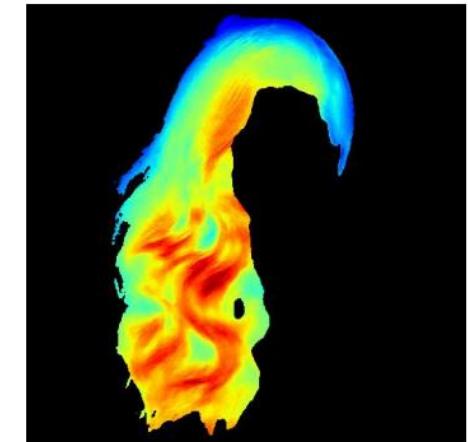
Orientation Map



Strand Map

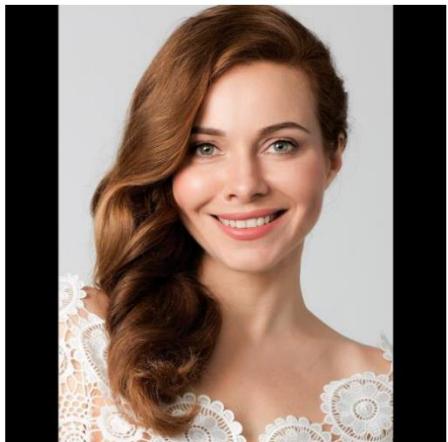


Depth Map



# Visual Comparisons on Representation (NeuralHDHair\*)

Image



From Orientation Map



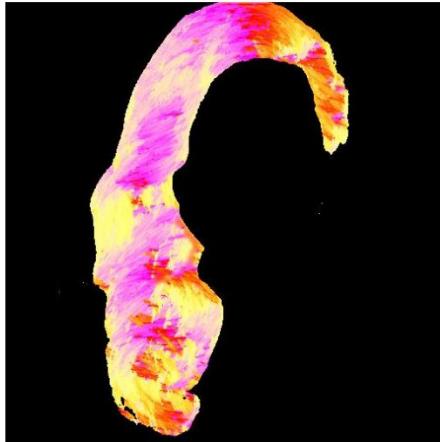
From Strand Map



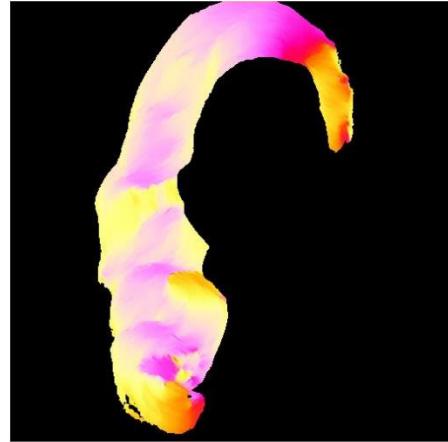
From HairStep



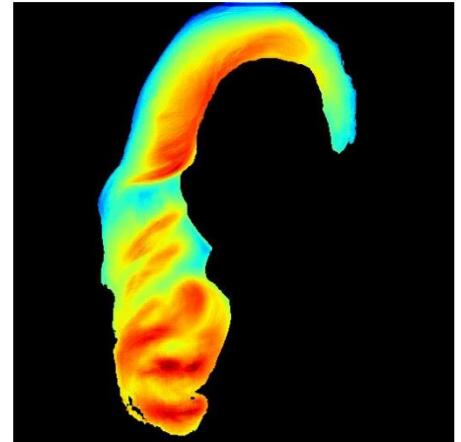
Orientation Map



Strand Map



Depth Map

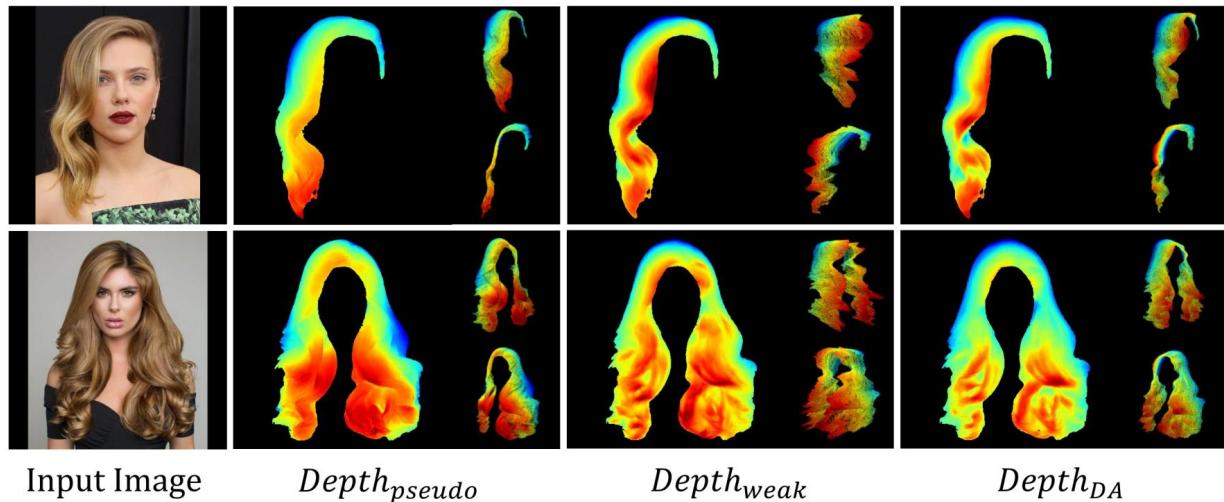


# Visual Comparisons on Representation (Multi-view)

## 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 +  $Depth_{DA}$ .

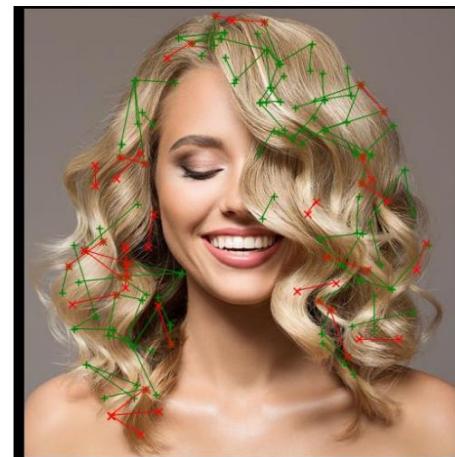
Method	IoU $\uparrow$	<i>HairSale</i> $\downarrow$	<i>HairRida</i> $\uparrow$
$C_0$	77.75%	16.03 (-18.2%)	73.57%
$C_1$	77.11%	16.54 (-15.6%)	75.8%
<b>Full</b>	77.22%	16.36 (-16.5%)	76.79%

# Ablation Study

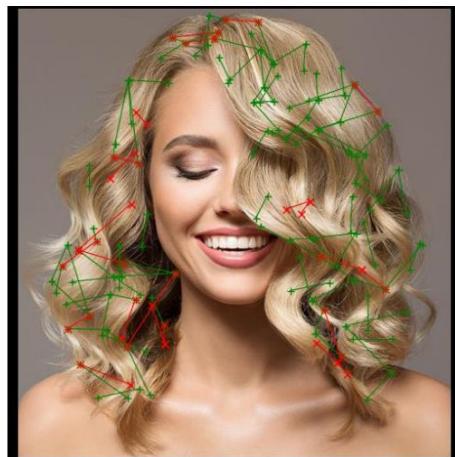


Image

$C_0$



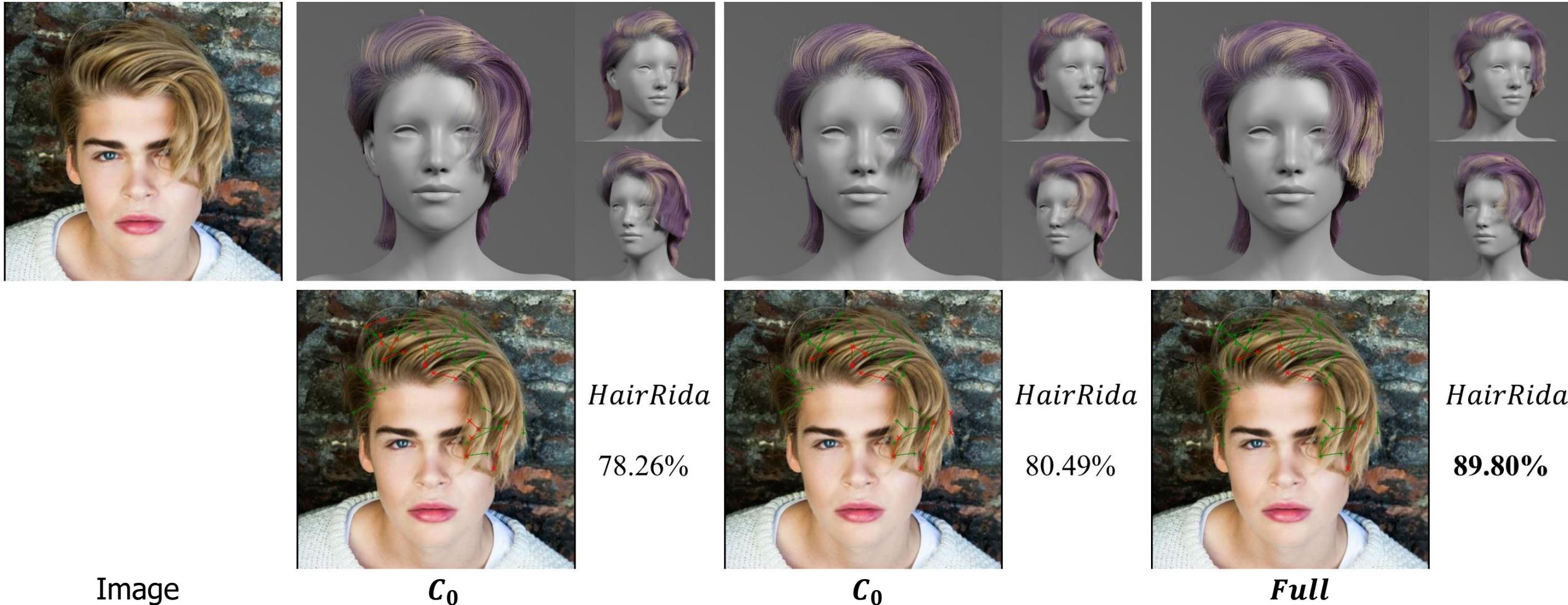
$C_0$



**Full**



# Ablation Study



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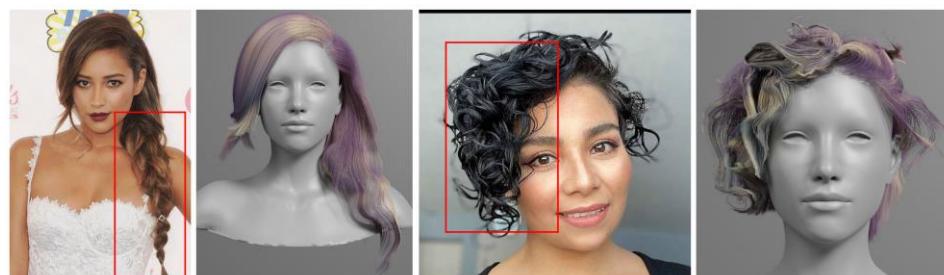


# Conclusion

- 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



# The End

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# Thank You!

