Modeling, Rendering, and Animating Human Hair

Presented by

Tae-Yong Kim

Computer Graphics and Immersive Technologies Laboratory

Integrated Media Systems Center

University of Southern California

Introduction and Presentation Outline

Introduction

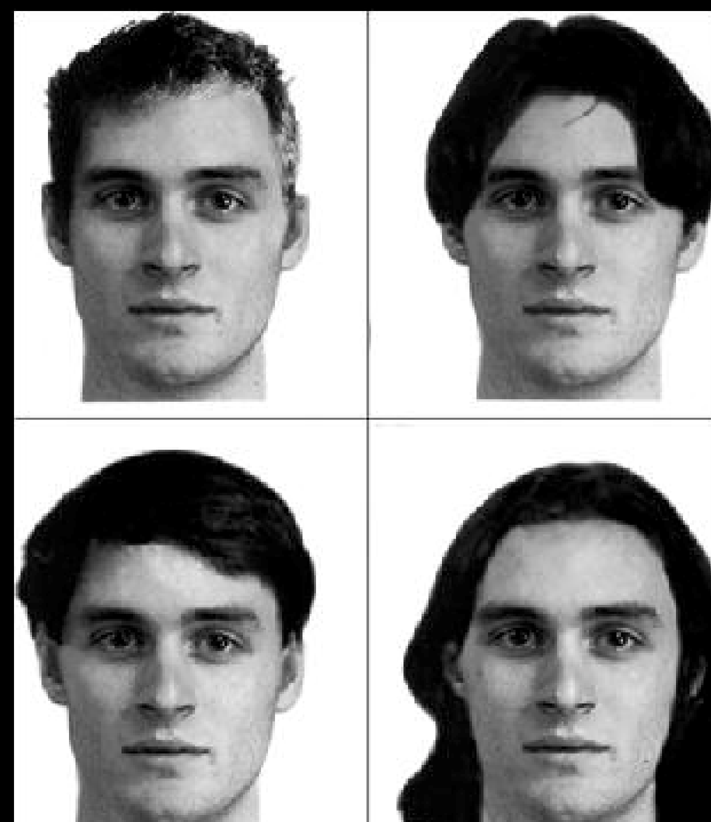
- Importance of hair
- Difficulty of hair

Presentation Outline

- Brief overview over current methods
- Thin Shell Volume Modeling
- Multi-Resolution hair modeling
- Hair Rendering
- Current issues and future work

Hair is important

- Ubiquitous virtual humans (Teleconferencing,game,film..)
- Virtual humans need hair
- Determining factor on first impression



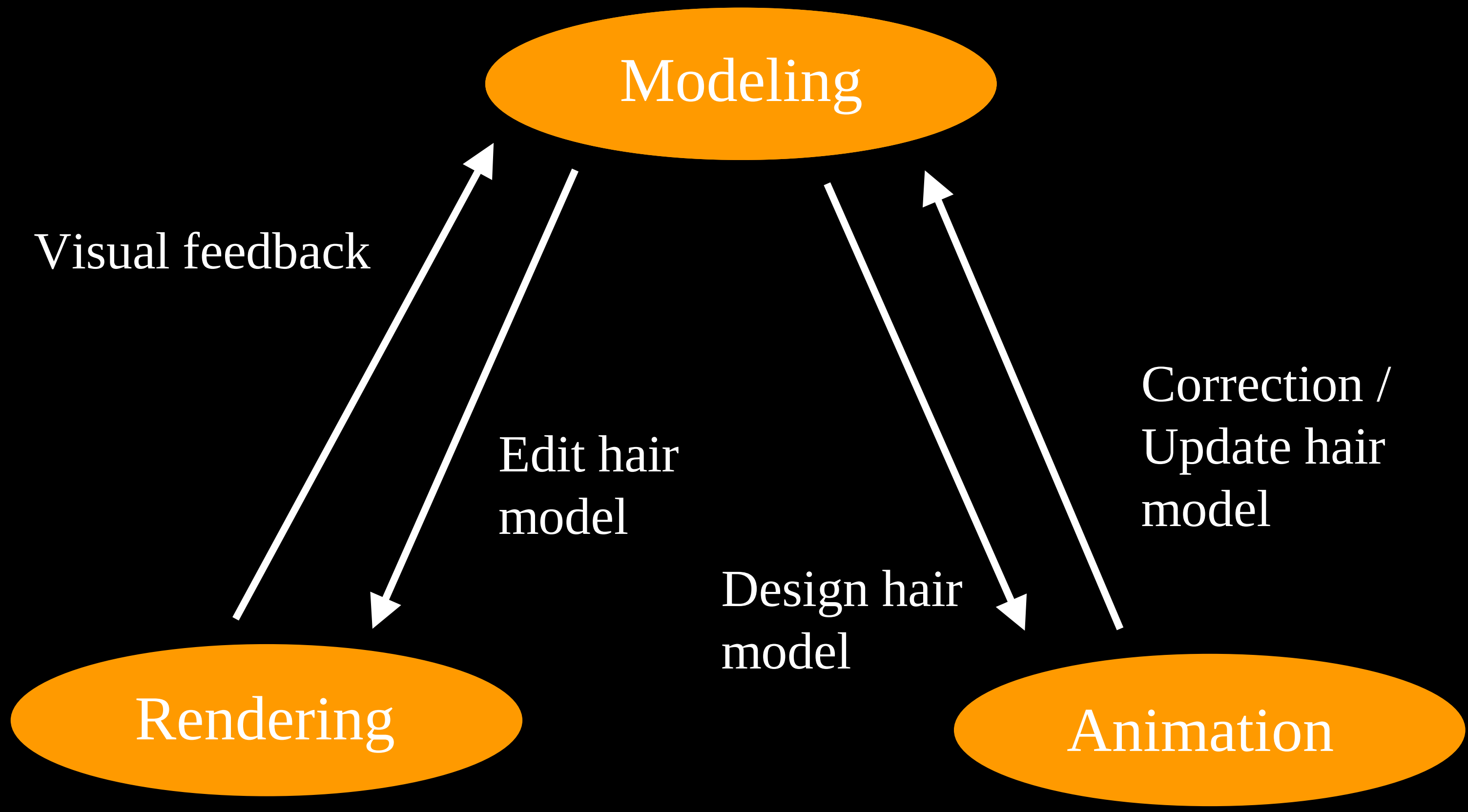
Hair is difficult

- Average number of hair -> 100,000 to 150,000 strands
- Challenge in every aspect of computer graphics
- A hair strand is a very deformable object
- Interaction between hair strands
- Rendering hair take vast amount of computing resource

  (1 to 20 hrs in Final fantasy)

→Hair is still an open problem in computer graphics

Relationships between components



Current approaches

Polygons

Volumetric texture

Surface with texture

Strand Based Model

Cluster model

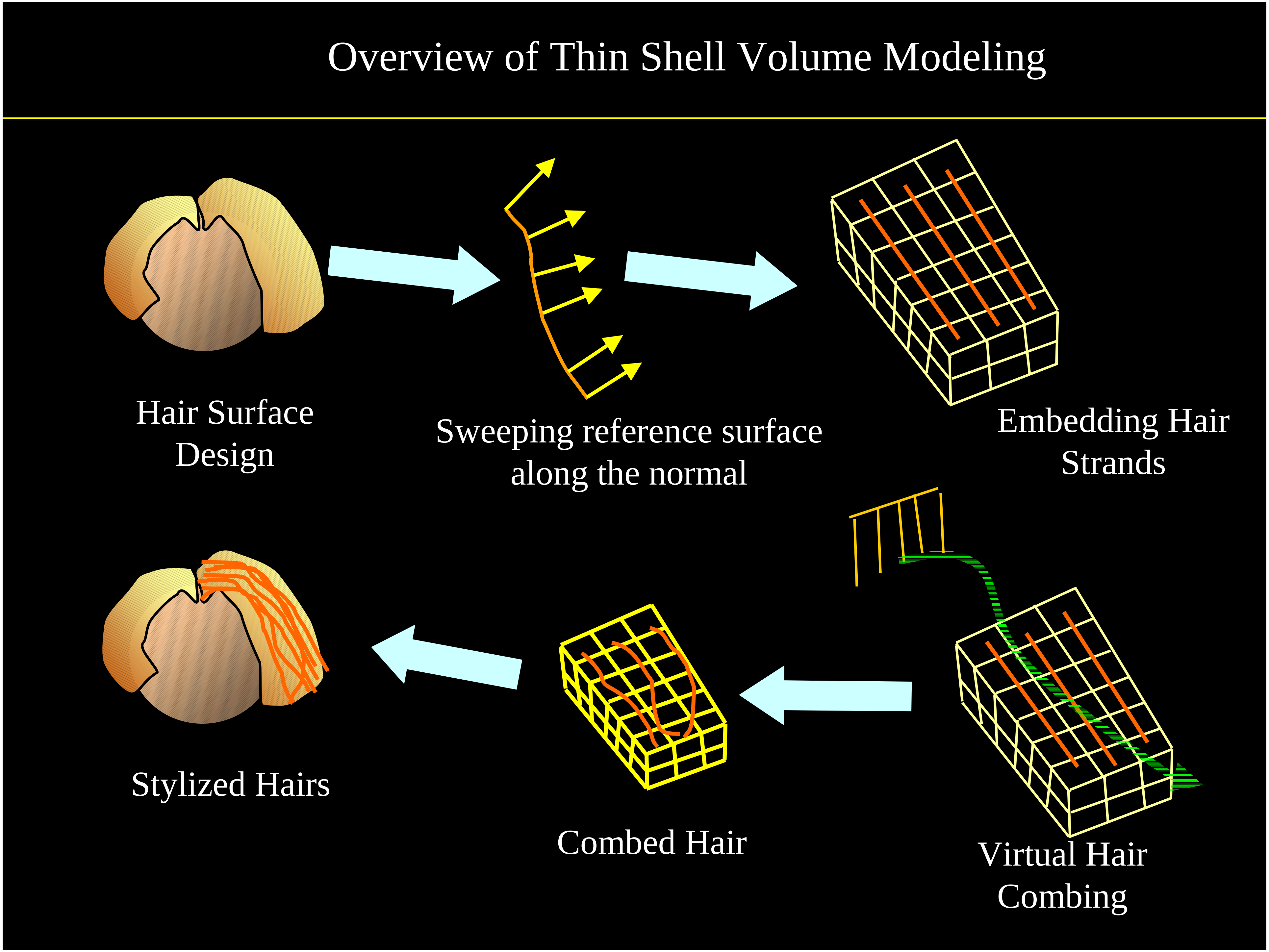
(Wisp-based model)

Overall shape vs Detail

Strand-based model	Wisp-based model
Precise control	Easy control
Tedious without computationally expensive dynamics	Limited level of detail (Too coarse)

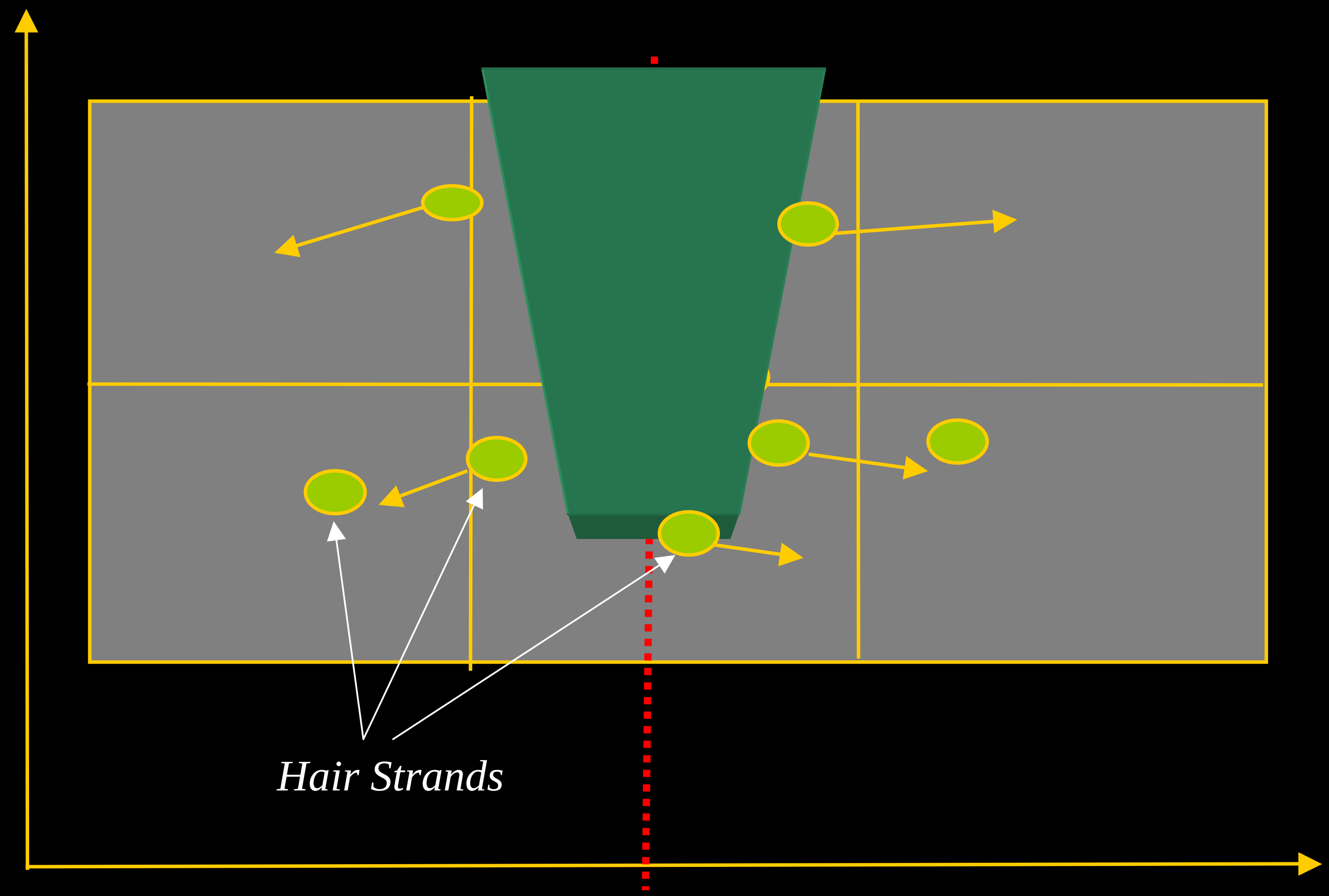
- Importance of structural detail
- Thin-shell volume modeling – phase1
- Multi-resolution hair modeling – phase2

Modeling – phase 1
Thin shell volume modeling
(IEEE computer animation 2000)



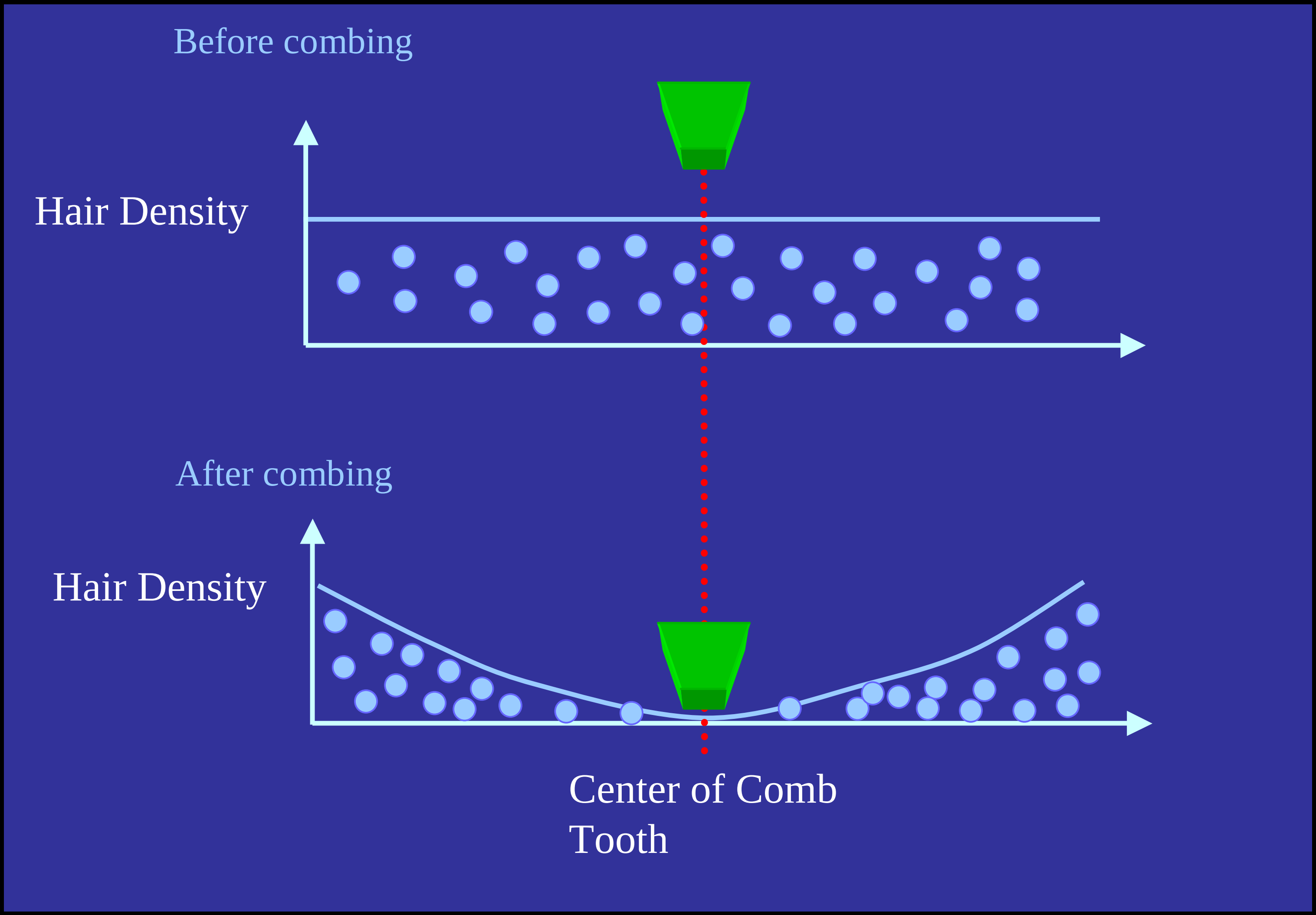
Overview of Thin Shell Volume Modeling
Hair Surface Design
Sweeping reference surface along the normal
Embedding Hair Strands
Virtual Hair Combing
Combed Hair
Stylized Hairs

Vertical Shape of a Comb Tooth

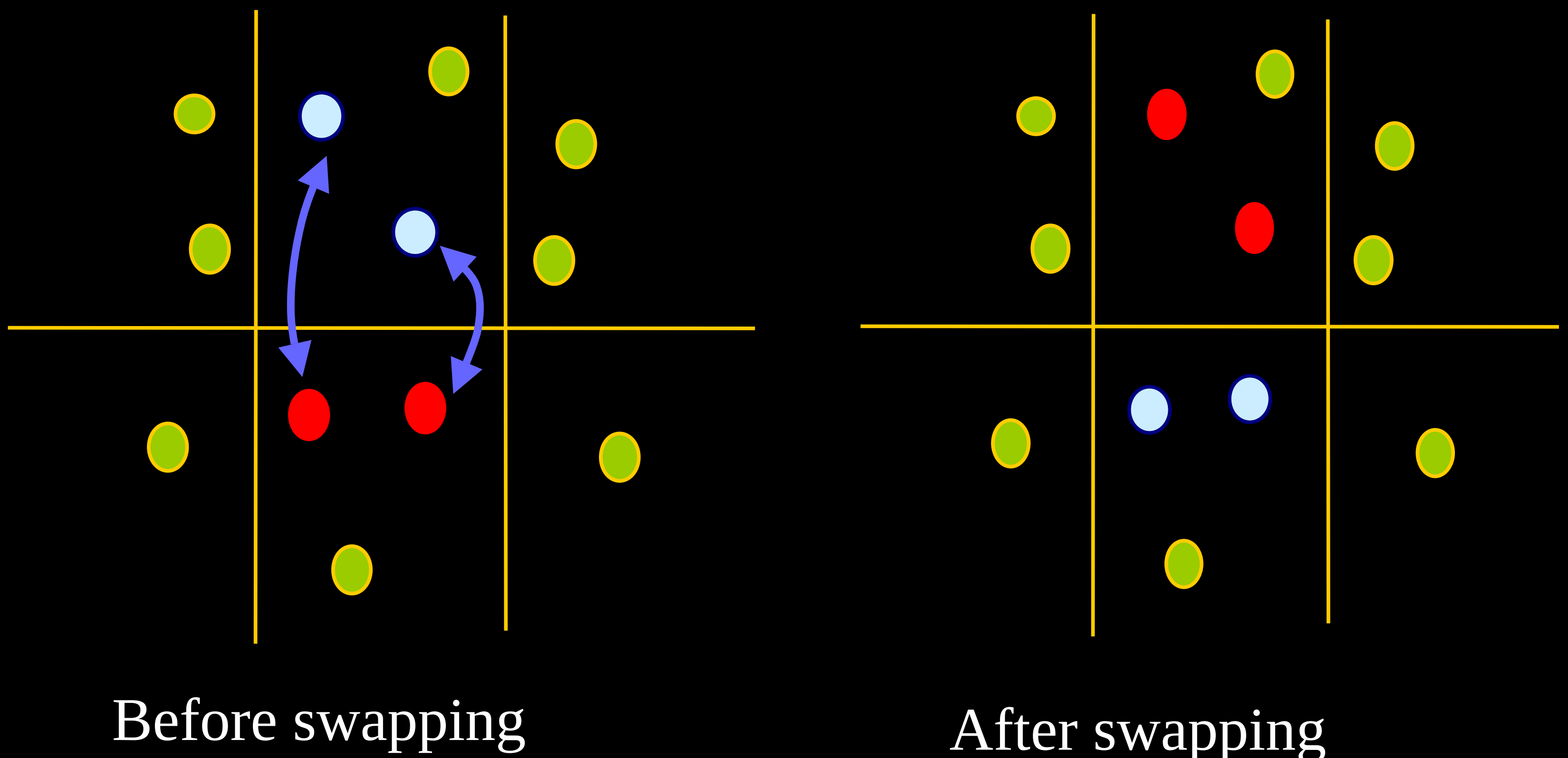


Center of a tooth

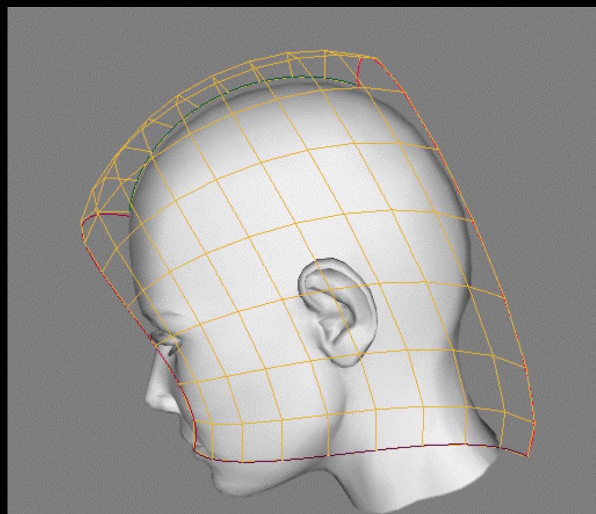
Hair Density Change Due to Combing



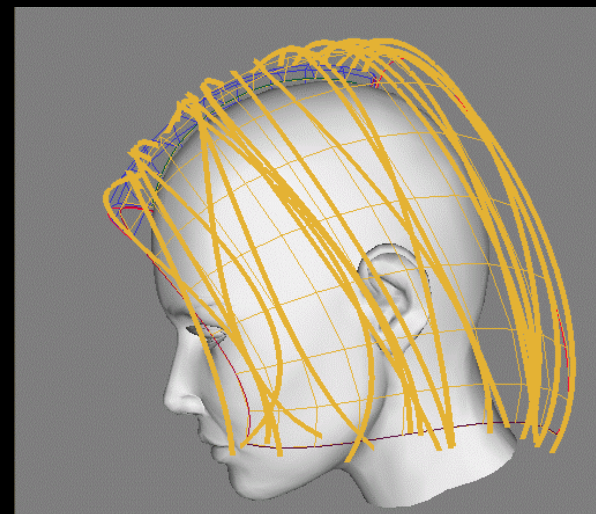
Vertical Motion



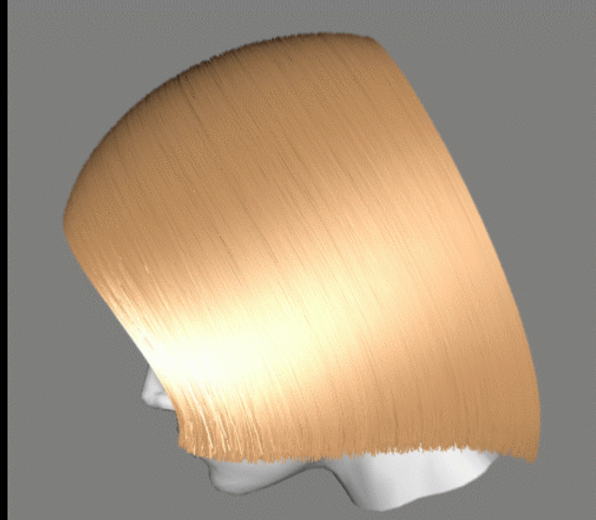
Example



Hair Surface Design



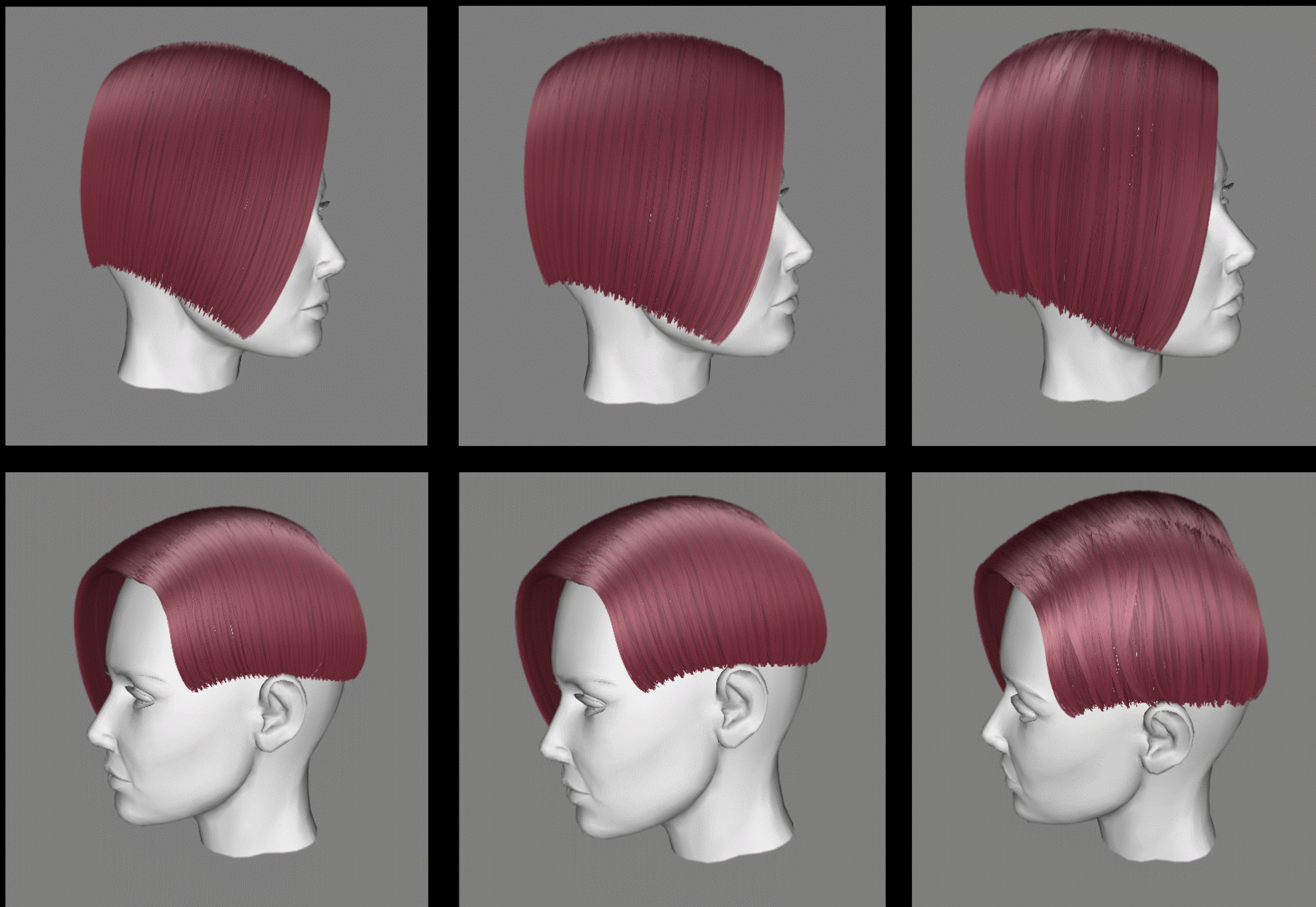
Combing Function



Reconstructed Hair

Combed Hair

More Results



40 teeth 20 teeth 12 teeth

Modeling – phase 2
Multi-Resolution Hair Modeling

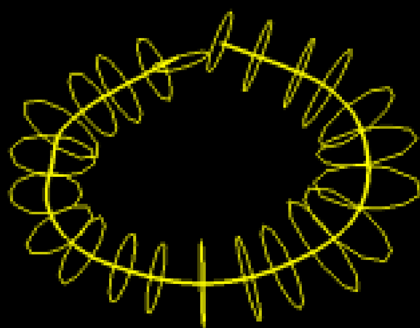
Strand-based model	Wisp-based model
Precise control	Easy control
Tedious manual process	Limited level of detail (Too coarse)

Multi-resolution hair modeling(MRHM)

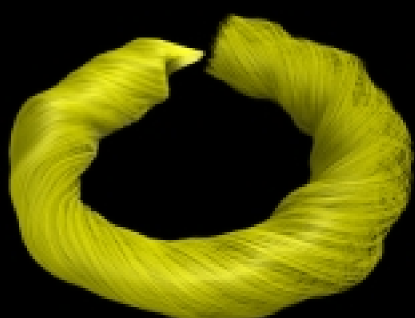
- Multiple level of details
- Smooth transition from wisp-level to strand-level
- Rough design at wisp-level, while allowing strand-level manipulation

Multi-resolution hair modeling

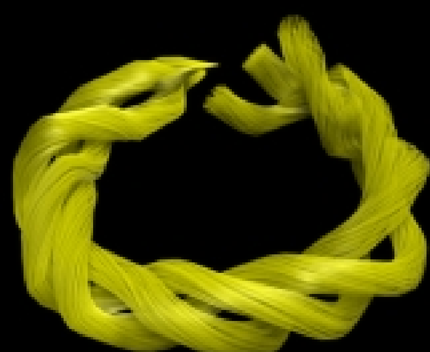
Idea1 : Generalized cylinder



Idea2 : Level of detail in hair modeling



Level = 1



Level = 2

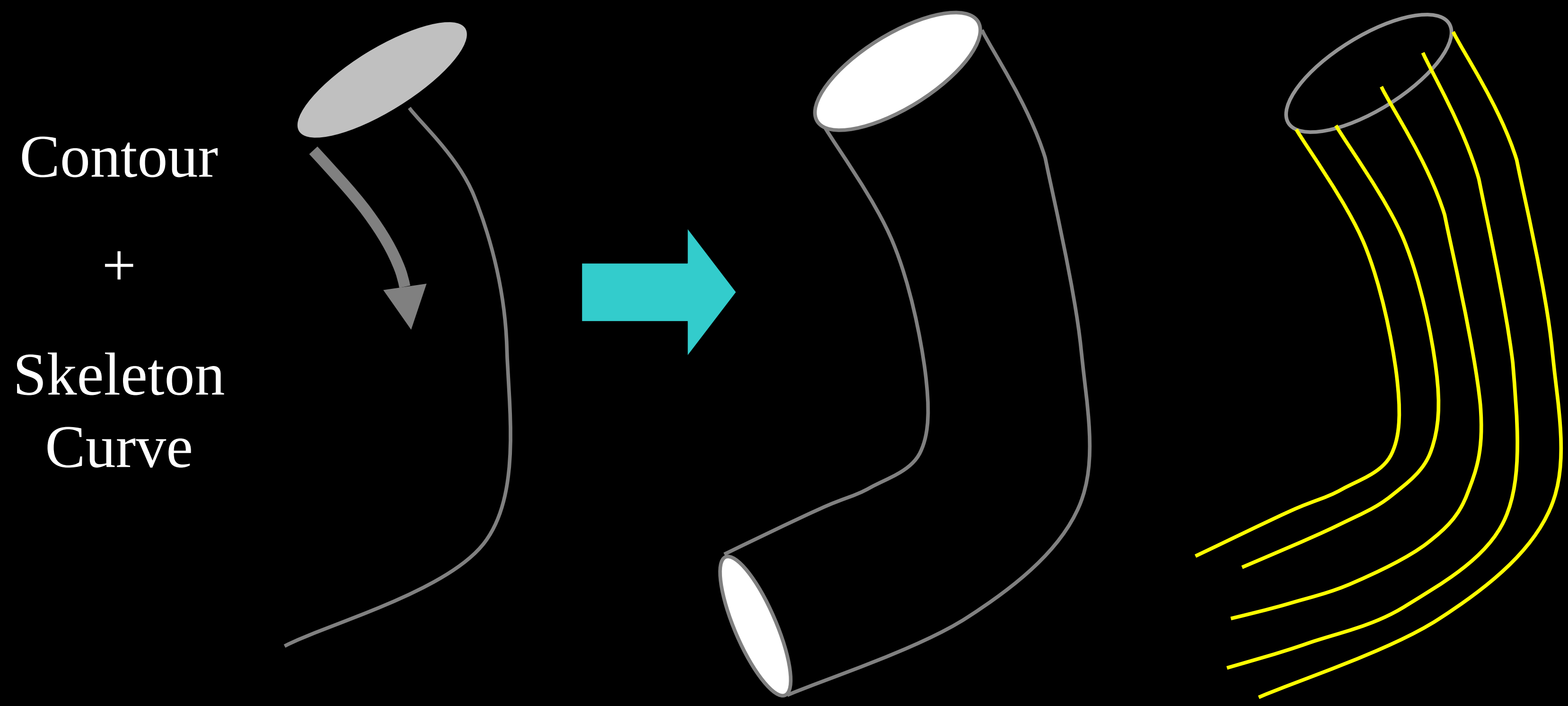
Level = 3

....

Generalized cylinder

Hair cluster : a group of neighboring hairs

Generalized cylinder as a tool for modeling hair



Parameters for a hair cluster

•Scale variation

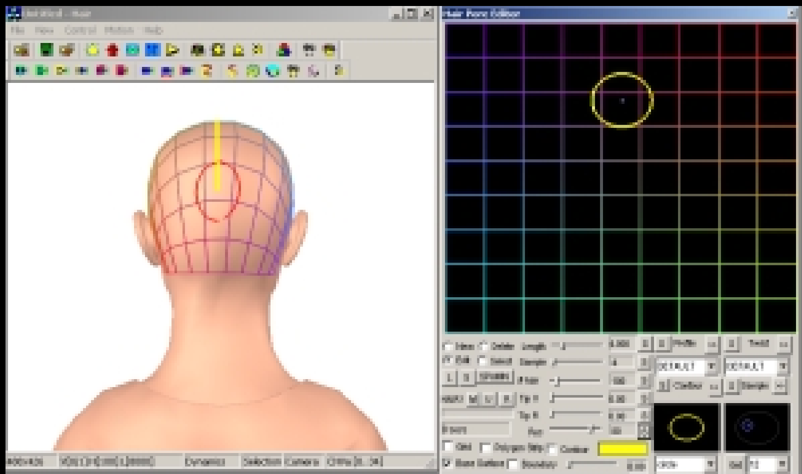
•Orientation (curliness) variation

•Tip variation

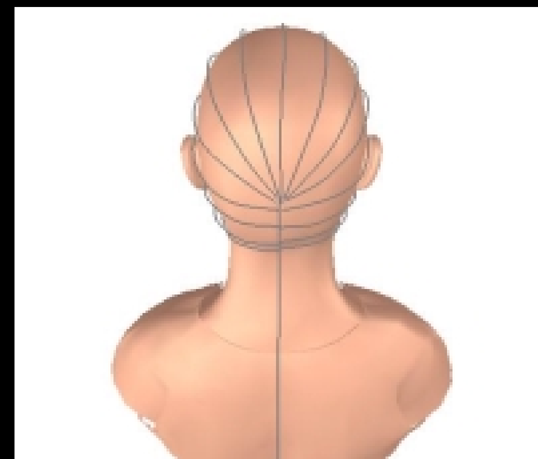
•Number of hairs

•Color ……….

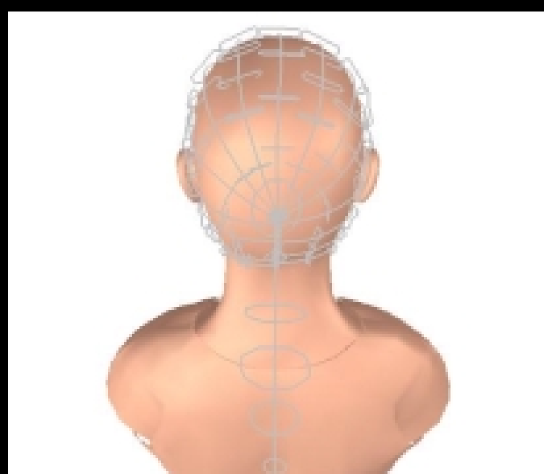
Hair modeling using hair clusters



Step 1



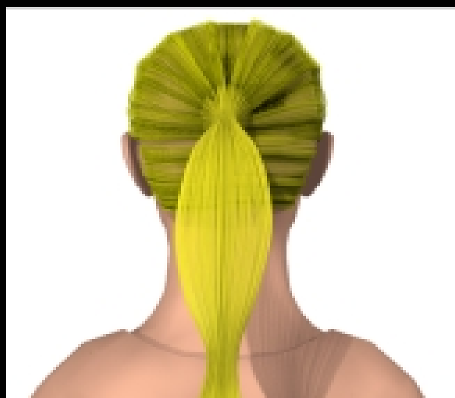
Step 2



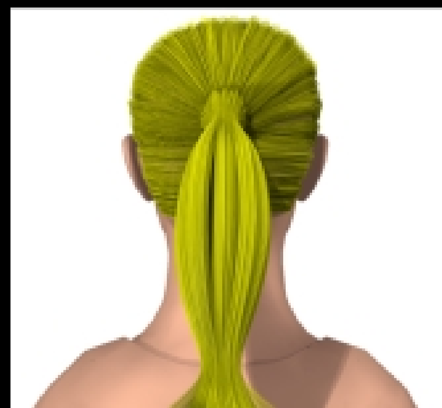
Step 3

Step 4

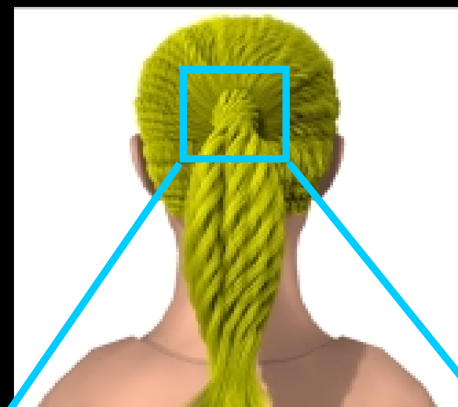
Example



16 clusters



130 clusters

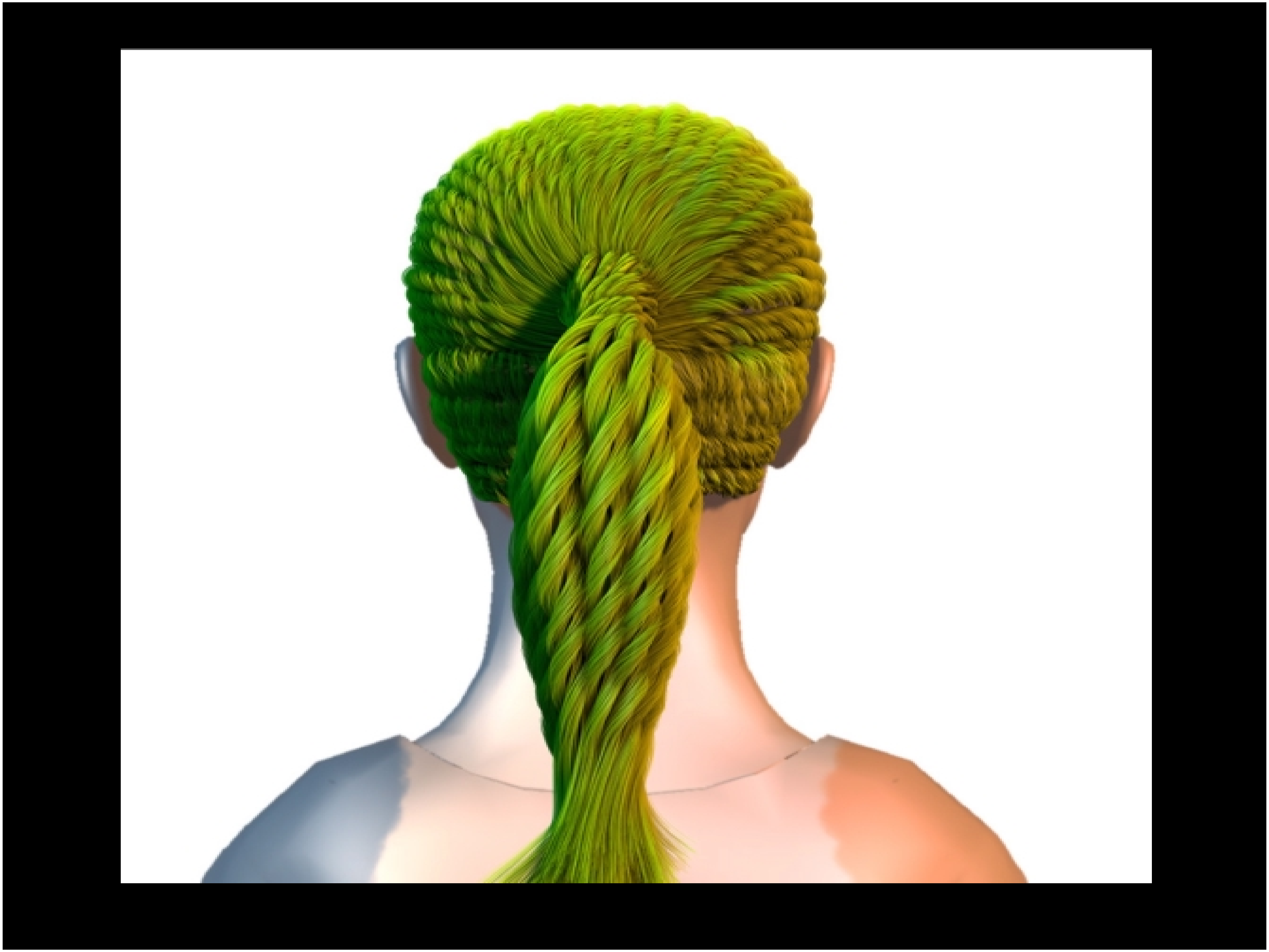


390 clusters

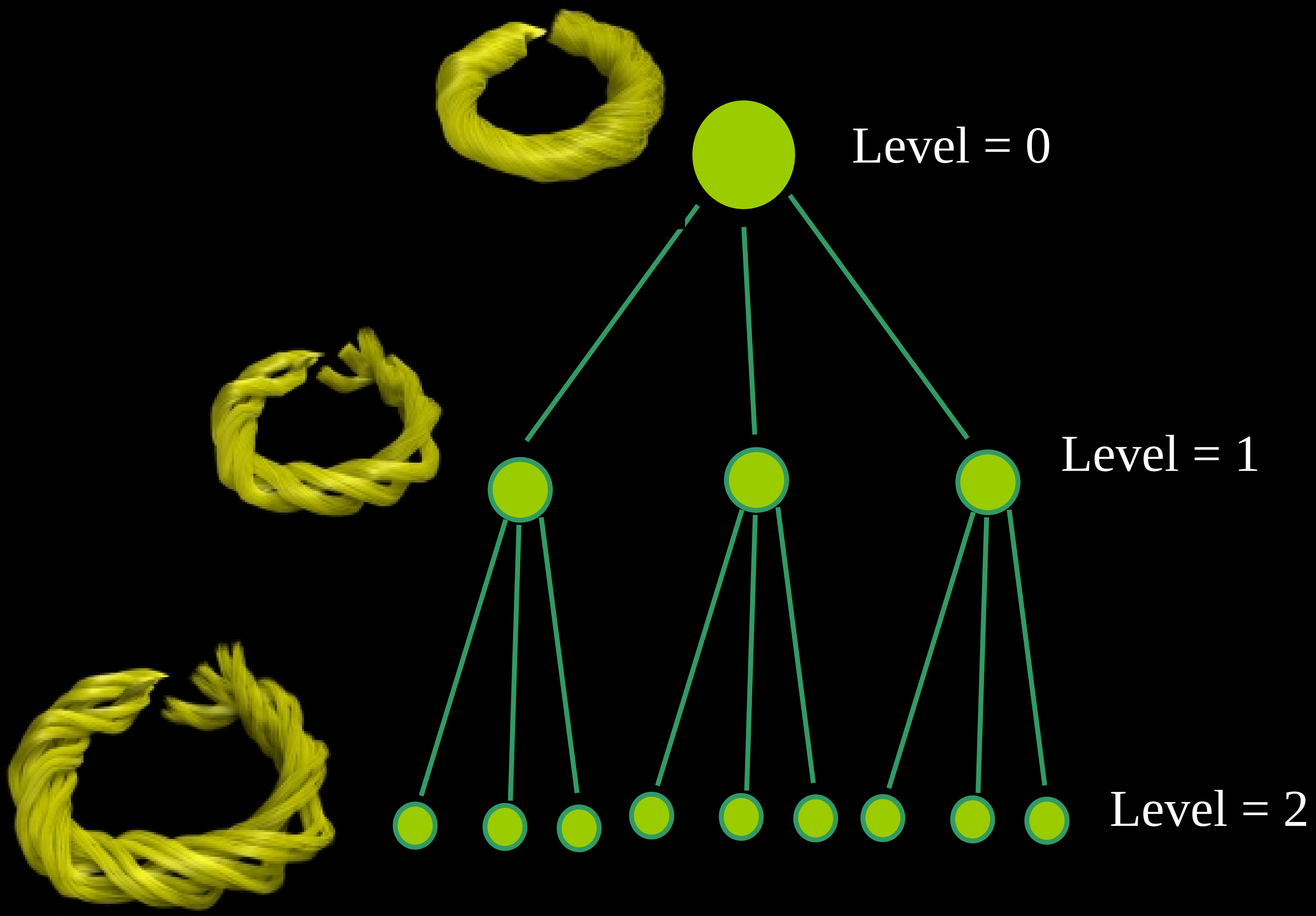
Easy control

Vs

Fine detail

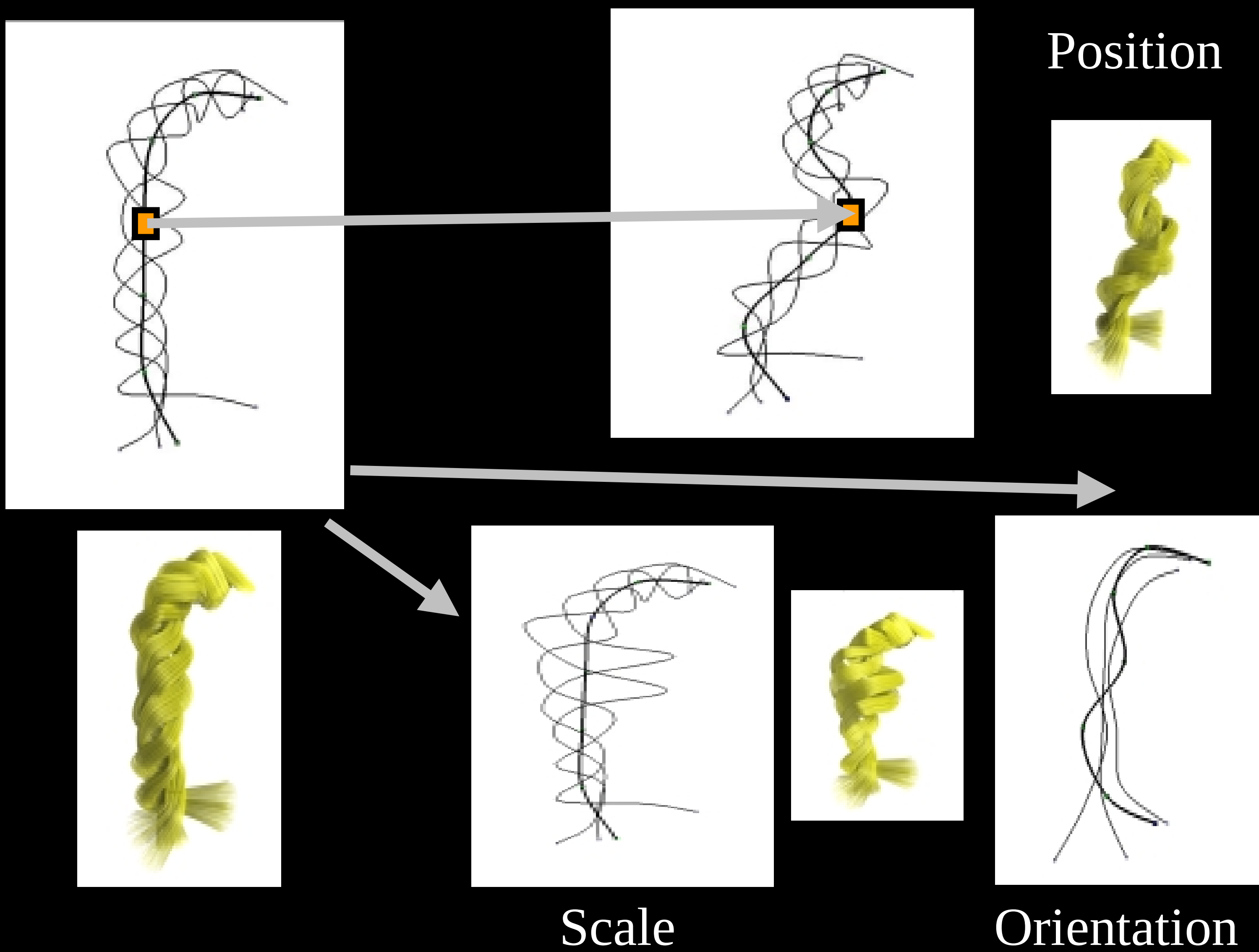


Hair tree

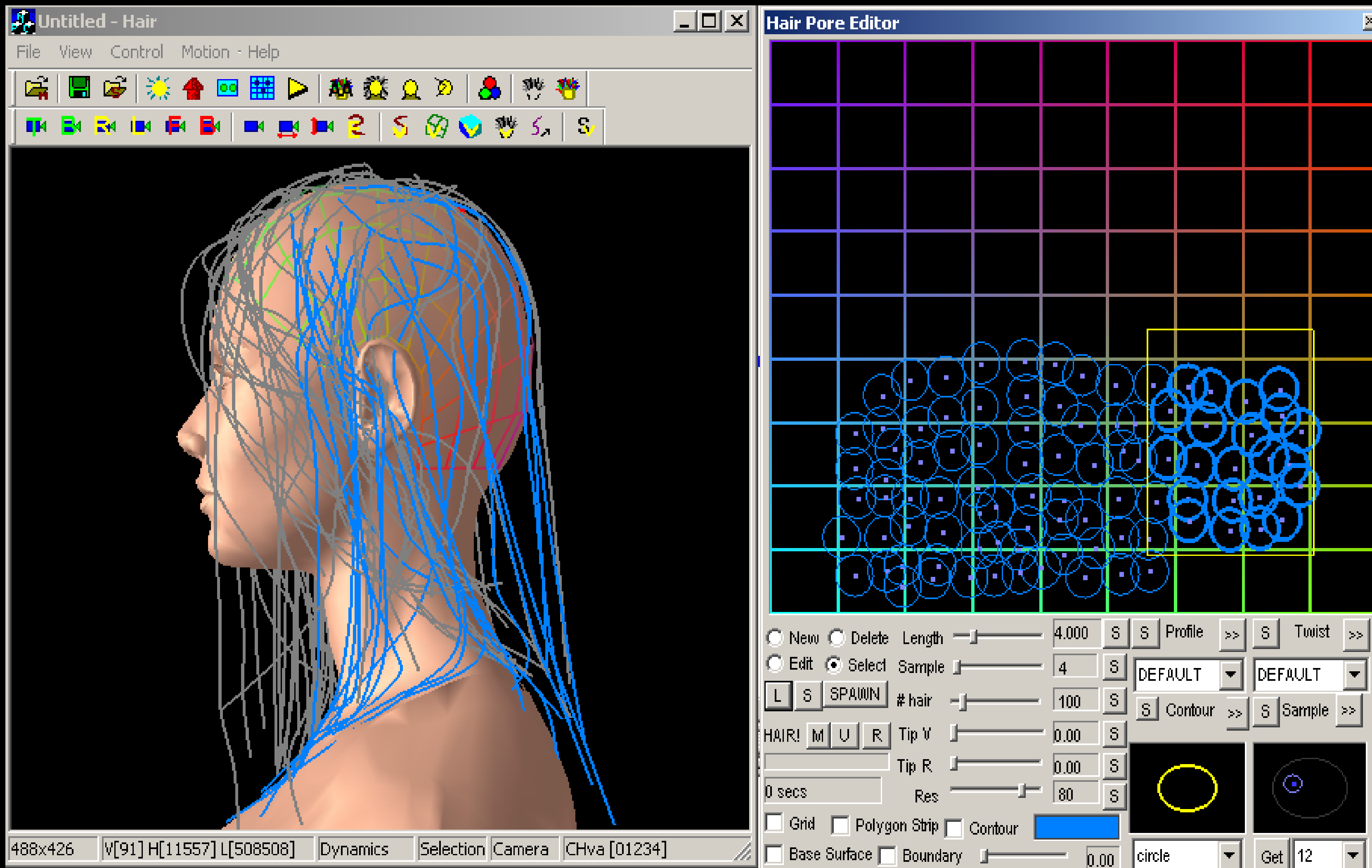


Multi-resolution editing

Editing properties of parent cluster affects its child clusters

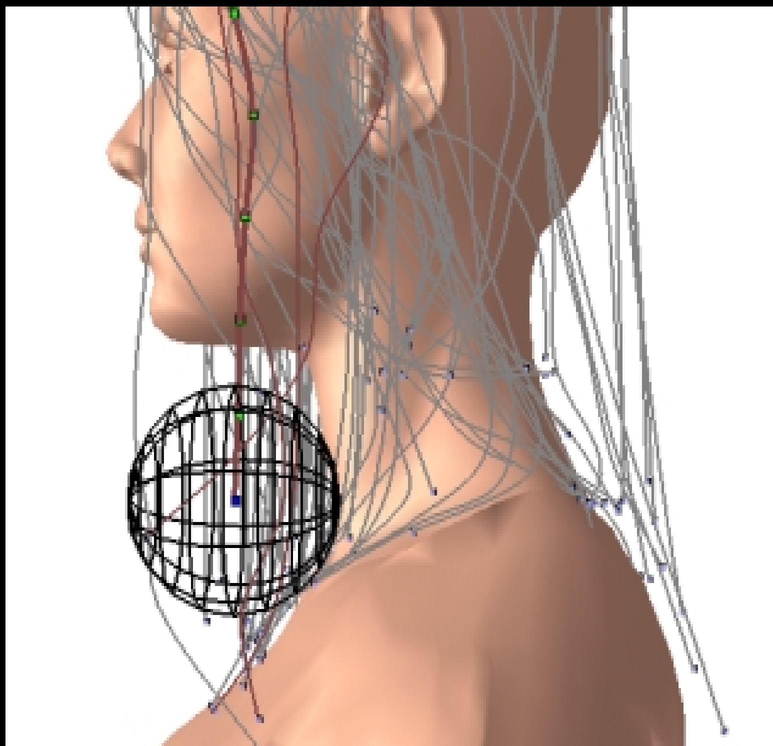


Selection tools

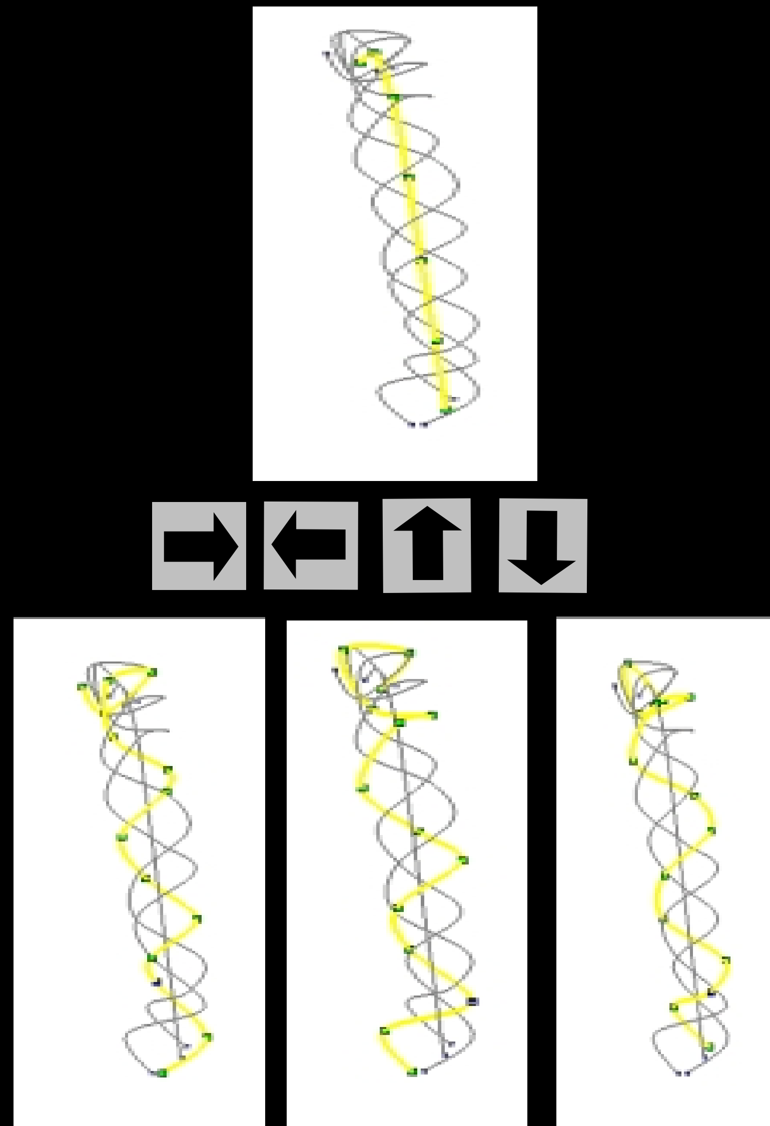


Selection by head surface

Selection tools



Selection by sphere

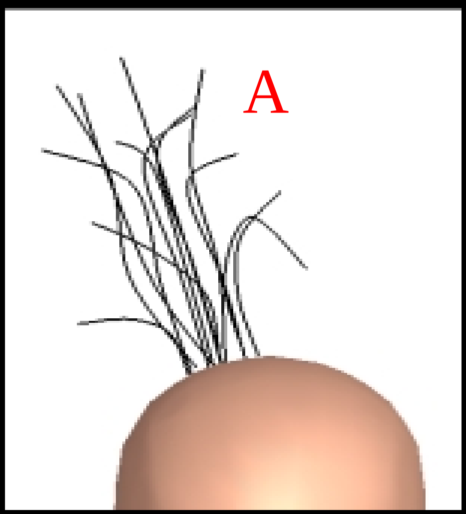


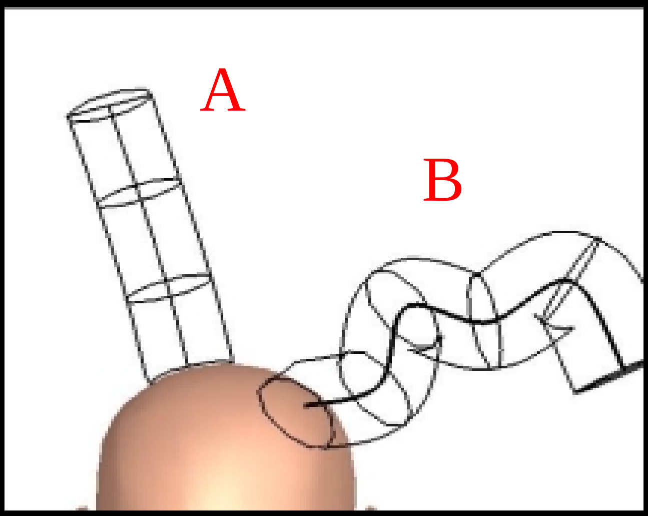
Tree traversal

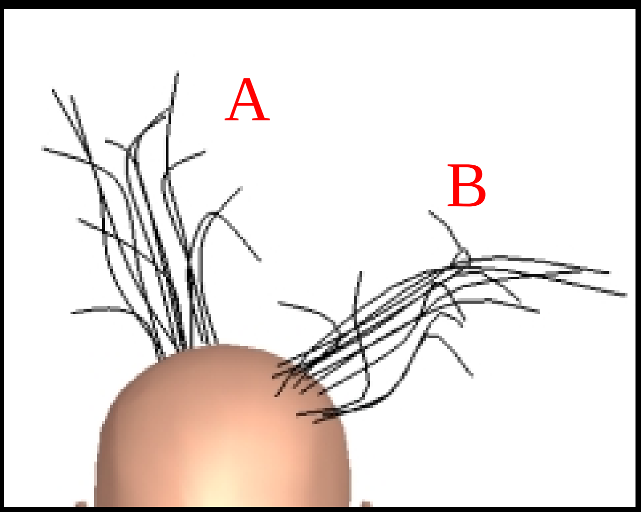
Copy and paste

A sub-tree serves as a style template

→ Can be copied to other clusters

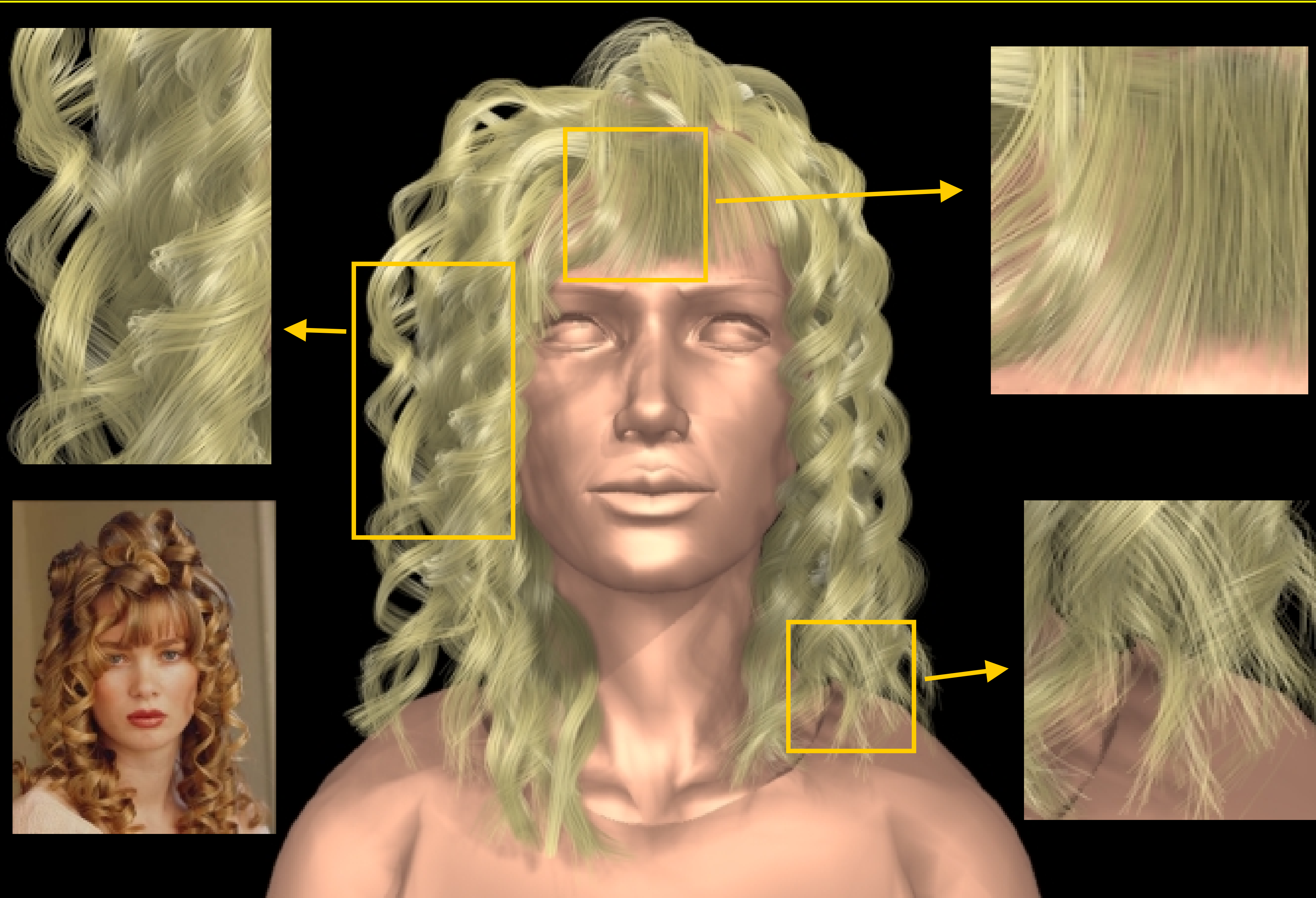






The *style* of cluster A is copied to cluster B

Another example



And more examples

Hair rendering

(Published in part at Eurographics Rendering Workshop 2001)

Difficulty of hair rendering

Hair rendering is hard because of..

- Again, number of hairs
- Thin geometry
- Shadows
- Volumetric nature
- Anistropy, scattering due to layered structure ….

Solution

- Use of existing graphics hardware
- Opacity shadow maps
- Approximate visibility ordering algorithm

Shadow

Essential cues for recognizing volumetric structure

No shadow

With shadows

Existing hair shadow generation methods

Traditional shadow map

- Depth buffer is stored
- Easily accelerated with hardware
- Prone to aliasing
- Inefficient for small objects (for example, *hairs*)
- Binary decision → Cannot handle transparency

Existing hair shadow generation methods

Deep Shadow Maps [Lokovic2000]

- Each pixel stores a visibility function with regard to the light
  - → accurate approximation of light transmittance
- Special data structure
  - → not easily accelerated with hardware
  - → construction cost is high

Opacity Shadow Maps

- Combines benefits of previous shadow algorithms
  - Fast computation with hardware acceleration
  - Smooth and anitialiased shadows
- Orders of magnitude faster than deep shadow maps
- Commodity hardware
- Scalable approximation

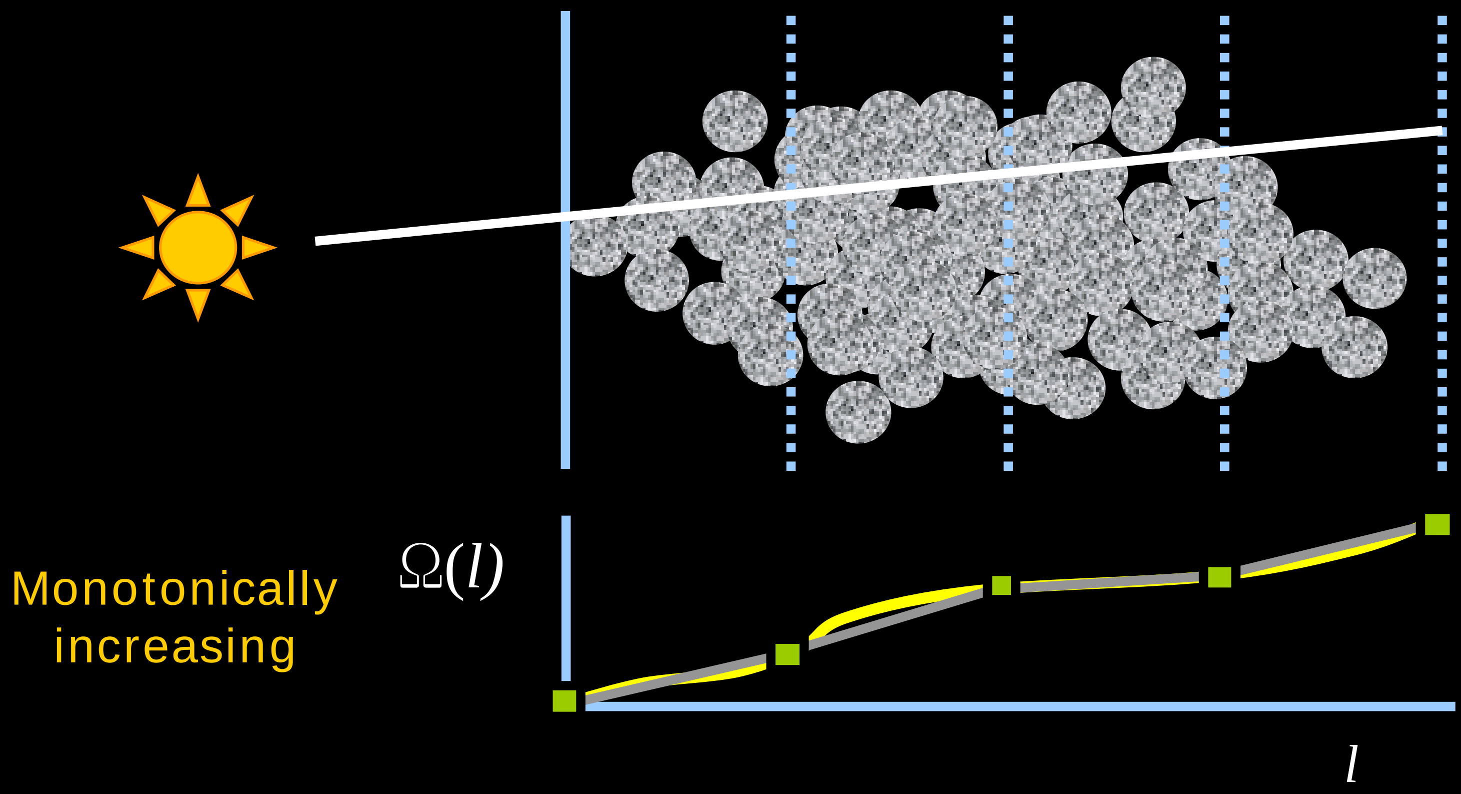
Opacity Shadow Maps

$$\tau(p) = \exp(-\Omega)$$

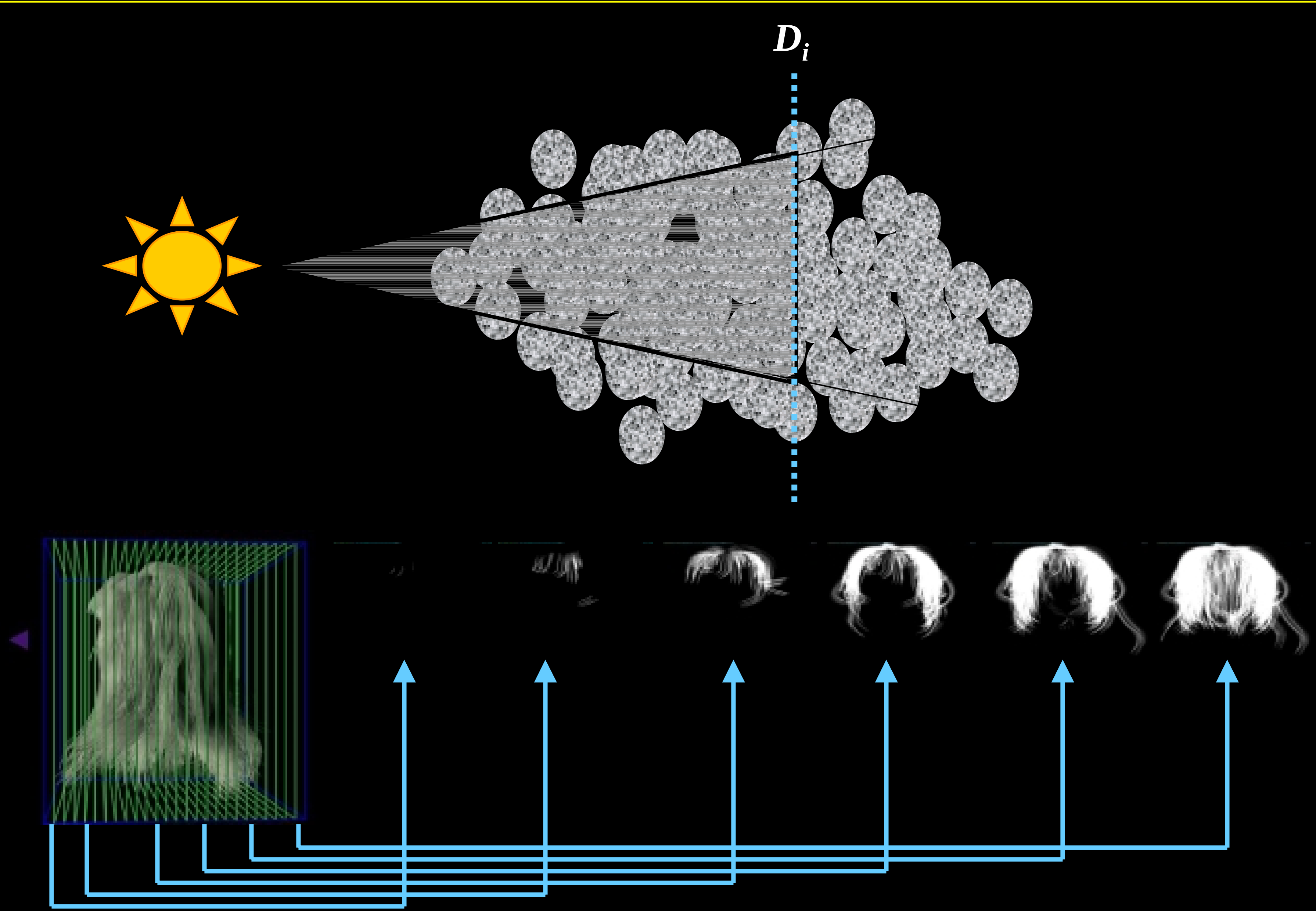
Transmittance

$$\Omega = \int_0^l \rho(l')\,dl'$$

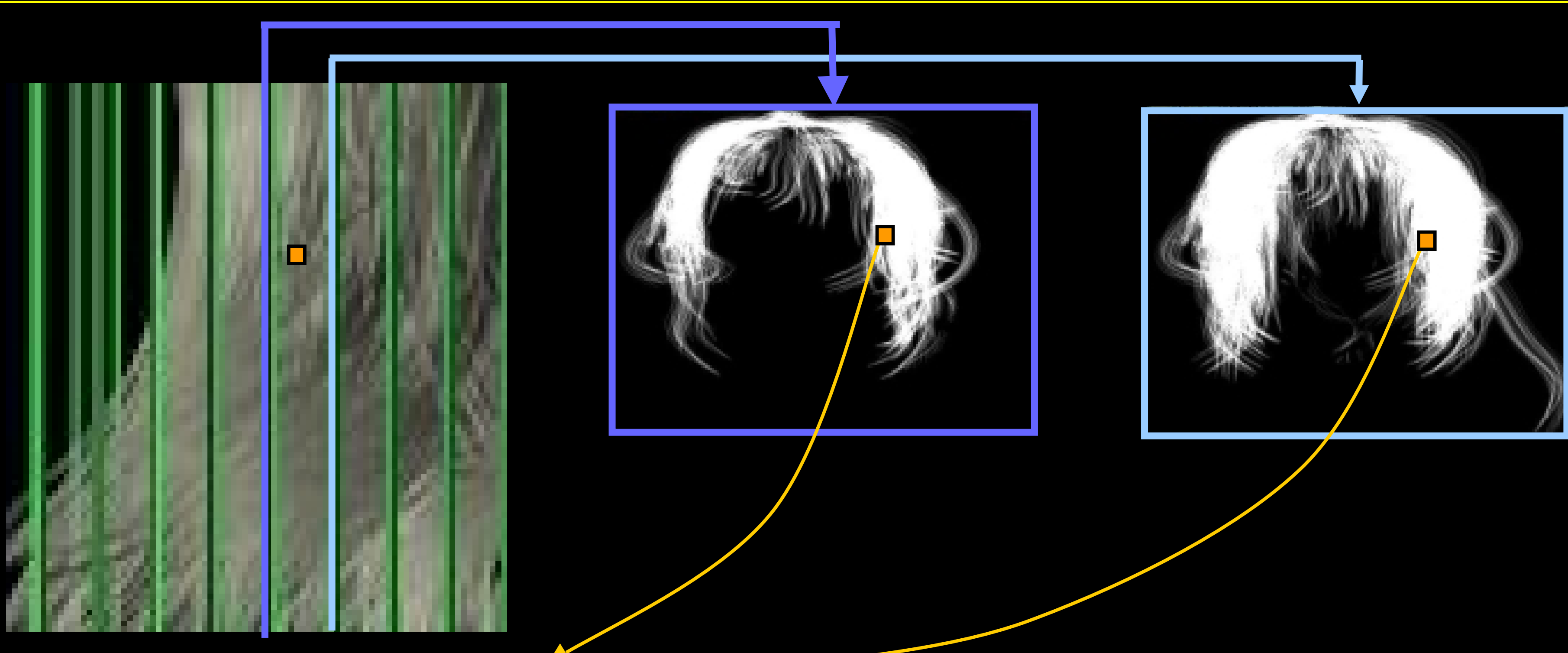
Opacity



Opacity Shadow Maps

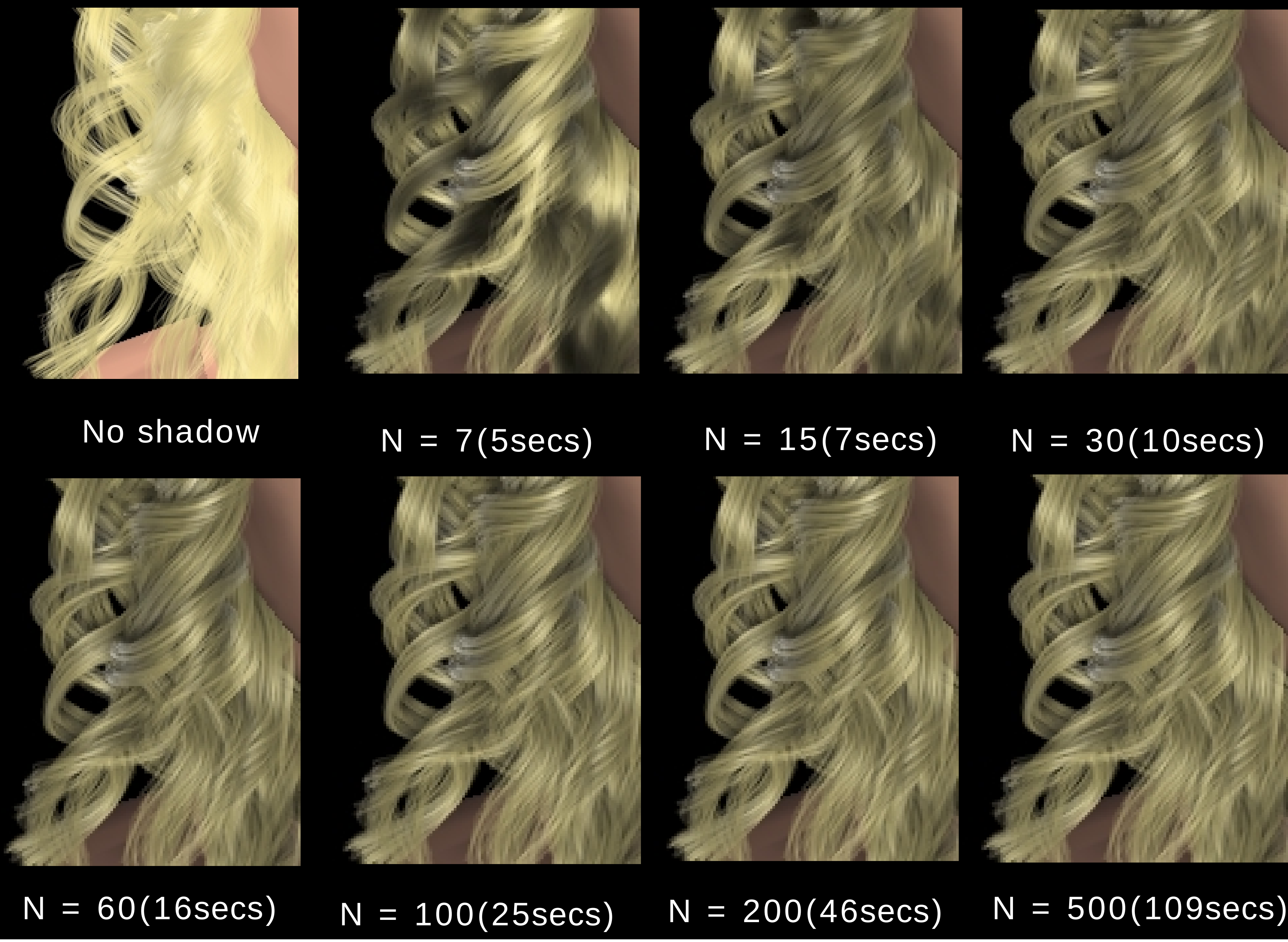


Opacity Shadow Maps

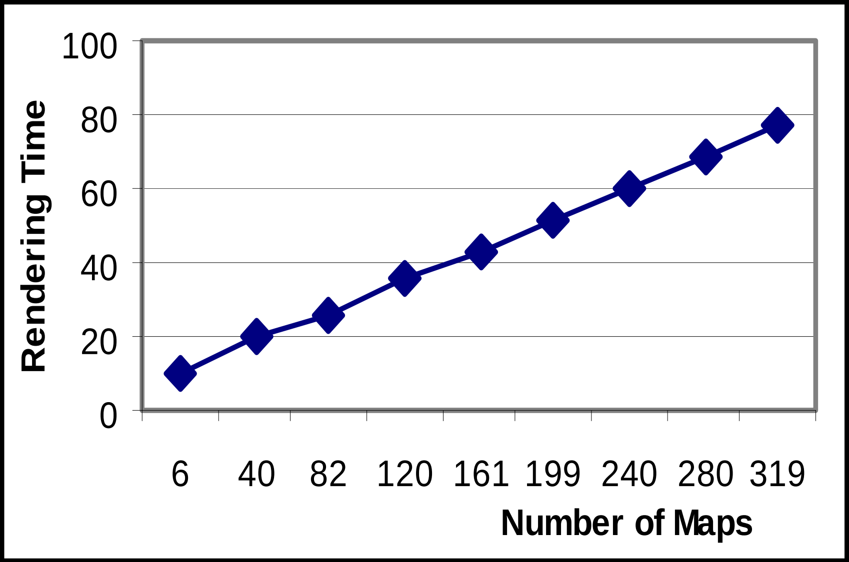


$$\Omega(p_k) = (1.0 - t)\Omega_{prev} + t\Omega_{current}, t = (Depth(p_k) - D_{i-1})/(D_i - D_{i-1})$$

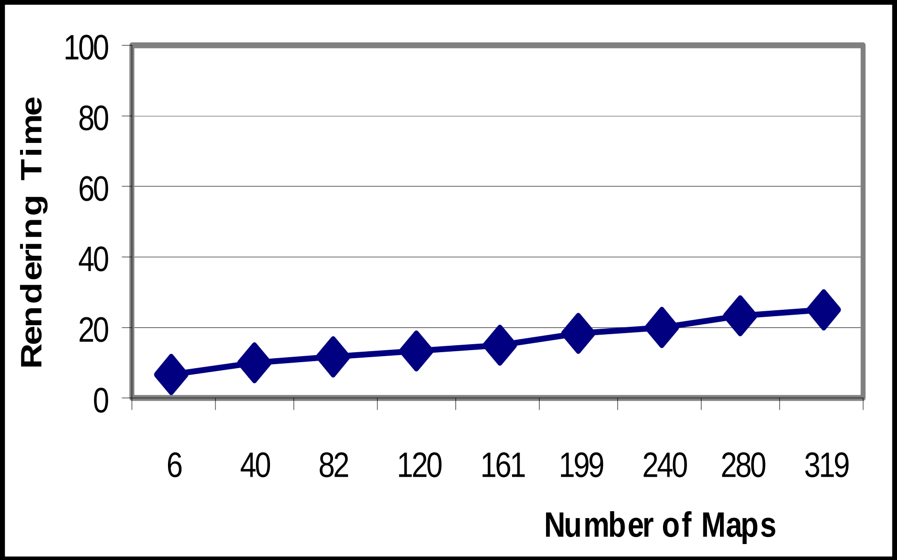
Opacity Shadow Maps
(Effect of Visual Masking)



Performance



P550 with Cobalt graphics
(PCI, 5M triangles/secs)



P700 with nVidia GeForce3
(AGP, 30M triangles/secs)

- The overall complexity is O(NM)
- but O(M) term is small due to hardware acceleration

Antialiasing

Hairs are very thin → High frequency image

Antialiasing

Supersampling

- Use enough pixels (Sampling theory)
  - Problem: needs a lot of pixels for hair rendering (4000x4000 to 10000x10000)

Alpha blending

- Order objects from back to front
- Draw each hair with correct color blending
- Require correct visibility ordering

  -> Develop a visibility ordering algorithm for hairs

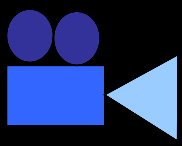
Effects of visibility ordering

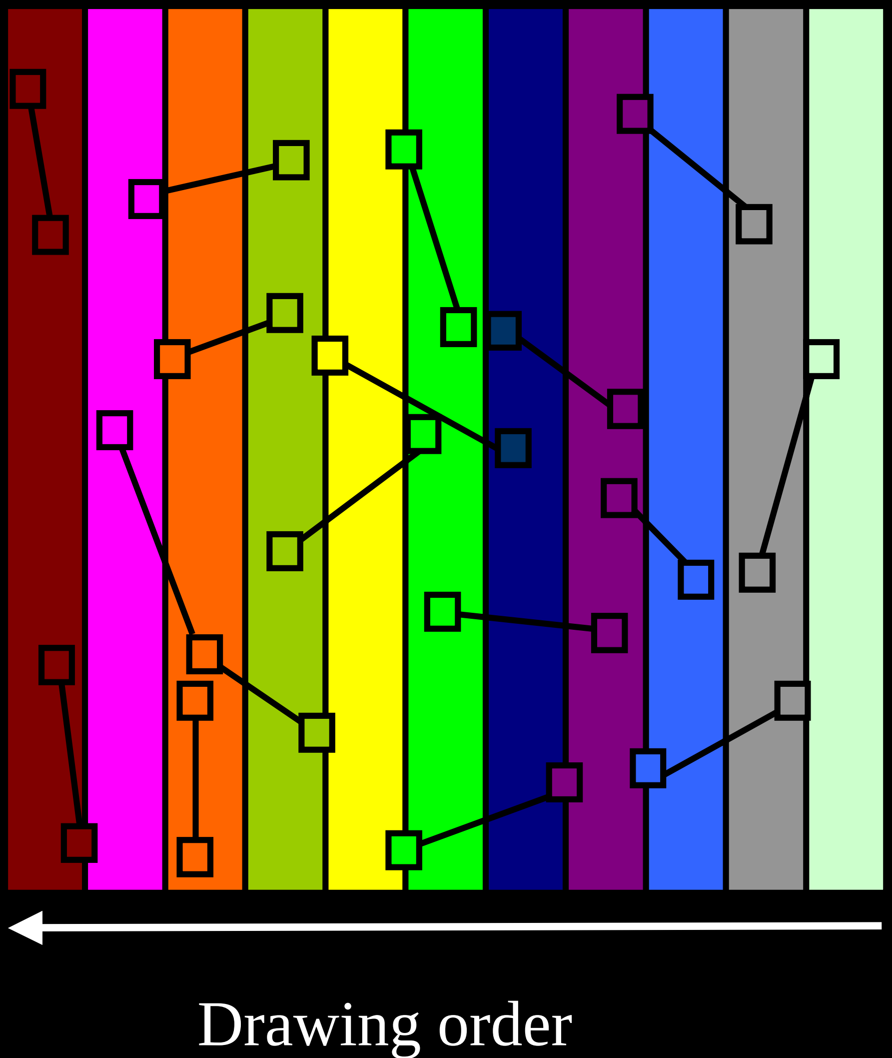
Correct

Wrong

Antialiasing-Visibility ordering

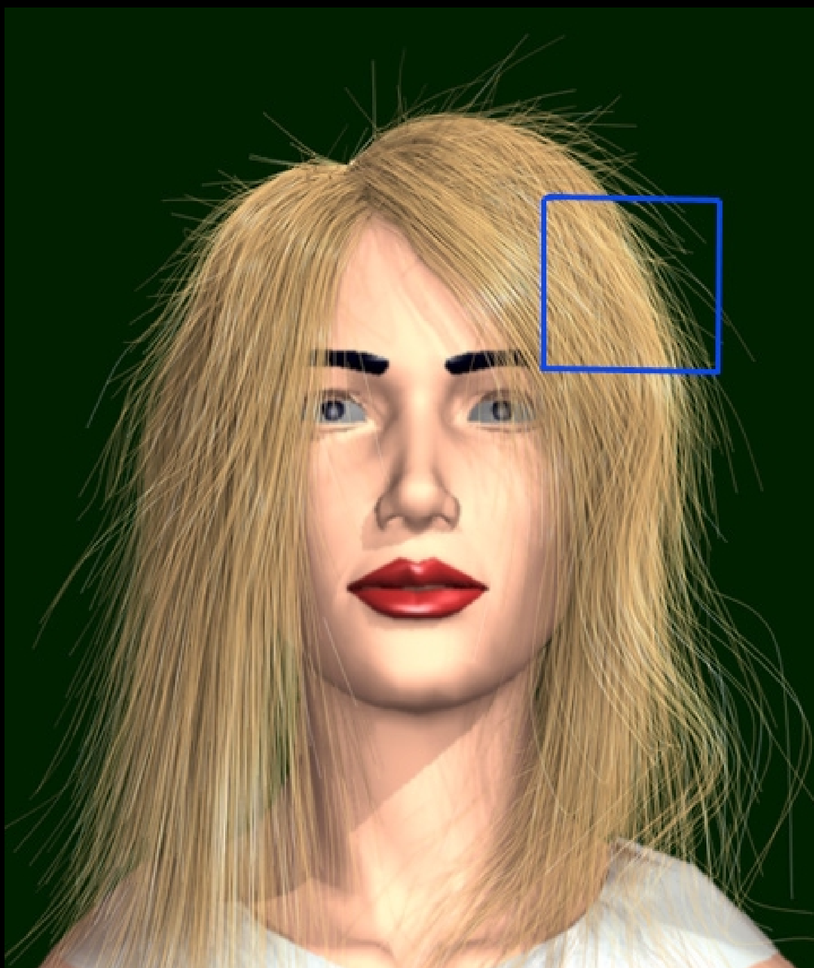
- The hair volume is sliced
- Each slice keeps an index array
- Hairs are drawn from the farthest slice to the closest slice
- Linear algorithm(700k lines/sec)

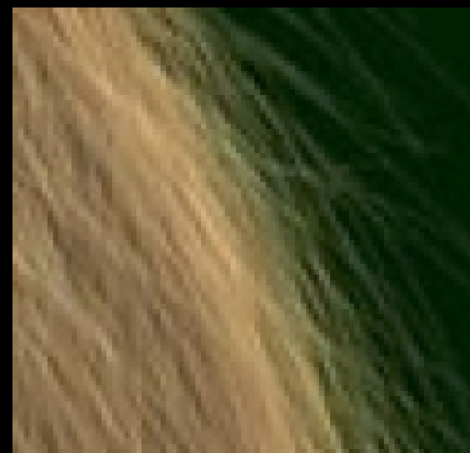




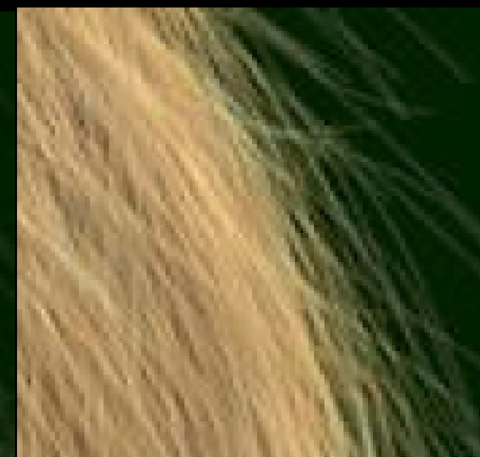
Antialiasing

α controls the thickness of hair strands.

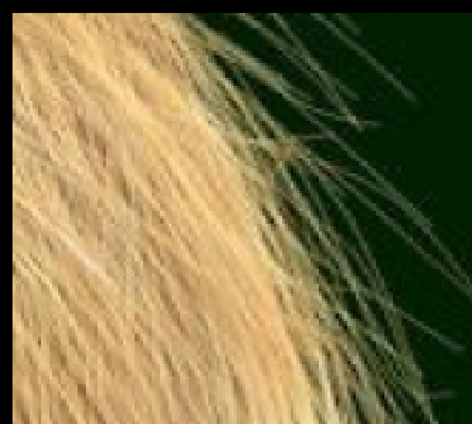




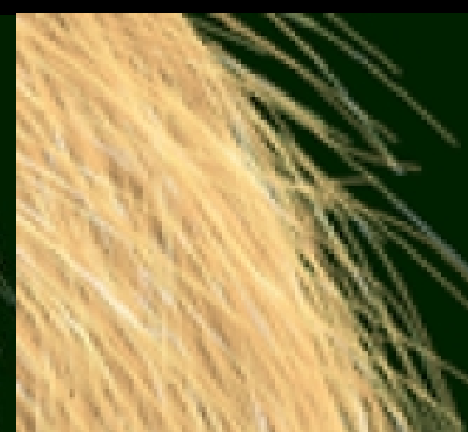
$\alpha=0.2$



$\alpha=0.35$



$\alpha=0.65$



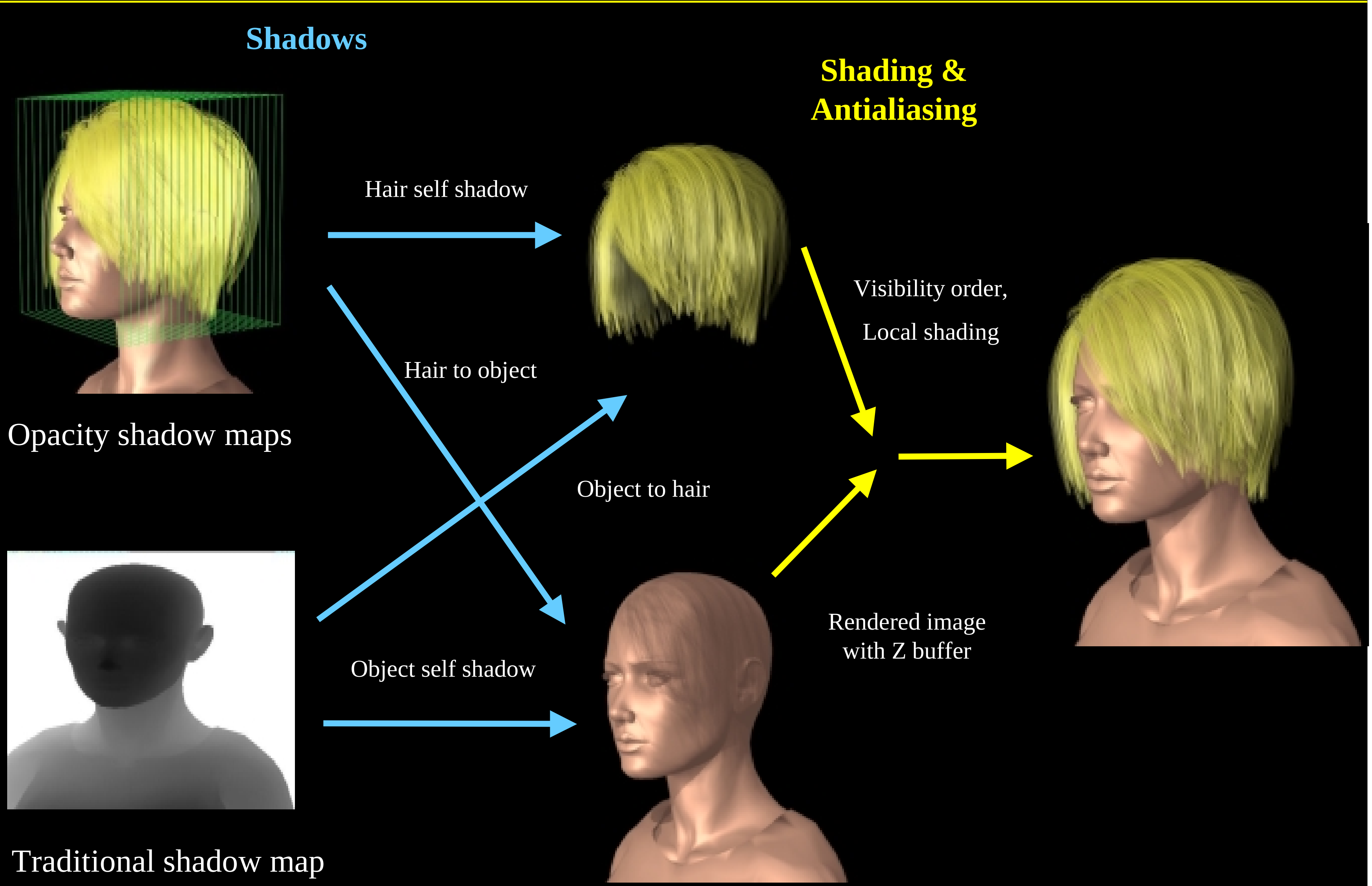
$\alpha=1.0$

Virtual hair vs Real hair

Rendered hair

Real hair

Hair rendering pipeline



Summary of contributions

- Difficulty and importance of hair
- Thin shell volume modeling
- Multi-resolution hair modeling
- Interactive hair modeling system
- Opacity shadow maps
- Visibility ordering for antialasing
- Integrated hair rendering pipeline

Current and future work

Near future - Thesis

Modeling

- Building hairstyle gallery
- Integration with human face and other human body
- Refine MRHM system

Rendering

- More efficient rendering algorithms
- Level-of-detail control

Animation

- Extending MRHM for animation

Long term extensions

Modeling

- Modeling with interactive hair dynamics
- Animal fur modeling

Rendering

- Real-time hair rendering
- Physically based shading model
- Non-photorealistic rendering
- Other volumetric objects (grass, trees, clouds….)

Animation

- Hair/hair interaction model

Progress spiral