

SAN ANTONIO
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#2002#

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**Interactive Multiresolution Hair
Modeling and Editing**

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Problem statement



Photograph courtesy by
www.hairboutique.com

- Modeling human hair**
- Complex discontinuous volume
 - Clusters and curliness
 - Virtually any shape is possible
 - Number of hair strands (100K to 200K)

Interactive Multiresolution Hair Modeling and Editing

Our Goal

Interactive system for modeling complex human hair in a reasonable amount of time (< 1 hour)

- Efficient sculpting of volumetric hair model
- Interactive rendering of arbitrary explicit hair models

Interactive Multiresolution Hair Modeling and Editing

Our Goal



Our model

Photograph courtesy by
www.hairboutique.com

Interactive Multiresolution Hair Modeling and Editing

Presentation Overview

- Related work
- Multiresolution hair representation
- Hair editing operations
- Interactive hair rendering
- Results
- Discussion and conclusion

Interactive Multiresolution Hair Modeling and Editing

Related Work

- **Strand based approach**
[Anjyo et al., SIGGRAPH 1991; Rosenblum et al., JVCA 1991; Lee and Ko, GM2001; Hadap and Thalmann 2001, EG 2001]
- **Key hair (interpolation)**
[Watanabe and Suenaga CG&A 1992; Daldegan et al., EG 1993; Chen et al., VC1999; Chang et al., SCA2002]

Interactive Multiresolution Hair Modeling and Editing

Related Work

- **Fluid flow and vector field**
[Hadap and Thalmann, EGCAS 2000; Yu, PG 2001]
- **Short hair/fur**
[Kajiya and Kay, SIGGRAPH 1989; Lengyel et al., I3D 2001]
- **Discontinuous wisp**
[Xu and Yang, CG&A 2001; Plante et al., EGCAS 2001; 'Shrek']
- **Automatic reconstruction**
[Grabli et al., GI 2002]

Interactive Multiresolution Hair Modeling and Editing

Common Problems



Long hairs cluster, split, and curl away

→Complex hairstyles with extreme discontinuity are difficult to model

Interactive Multiresolution Hair Modeling and Editing

Observation



Clustering effects occur at multiple scales

Interactive Multiresolution Hair Modeling and Editing

Observation



Clustering effects occur at multiple scales

→Multiresolution approach for hair modeling

Interactive Multiresolution Hair Modeling and Editing

Our Approach

- **Hair cluster shape modeling with generalized cylinders (GC)**
- **Subdivision and hierarchical hair structure**
- **Multiresolution editing tools**
- **Copy and paste operations**
- **Capture structural aspects of volumetric hairstyles**

Interactive Multiresolution Hair Modeling and Editing

Scalp Surface



Interactive Multiresolution Hair Modeling and Editing

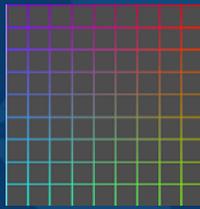
Scalp Surface



- Parametric surface
 $S = P(u,v)$
- Defines the region of hair growth

Interactive Multiresolution Hair Modeling and Editing

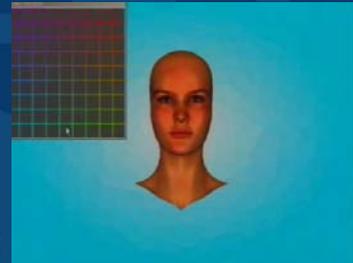
Scalp Surface



Scalp space editor

Interactive Multiresolution Hair Modeling and Editing

Scalp Surface



Atlas for hair cluster positioning

Interactive Multiresolution Hair Modeling and Editing

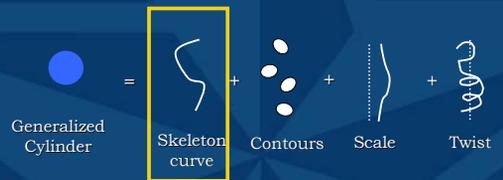
Generalized Cylinder (GC)



$$V(r, \theta, t) = C(t) + rR(\theta, t) \left\{ \cos(\hat{\theta}) S_N(t) \vec{N}(t) + \sin(\hat{\theta}) S_B(t) \vec{B}(t) \right\}$$

Interactive Multiresolution Hair Modeling and Editing

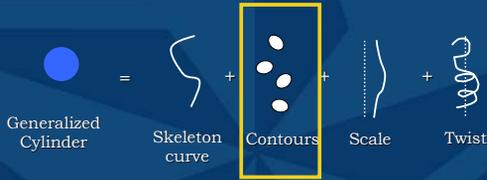
Generalized Cylinder (GC)



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Interactive Multiresolution Hair Modeling and Editing

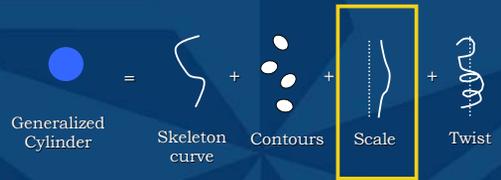
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Interactive Multiresolution Hair Modeling and Editing

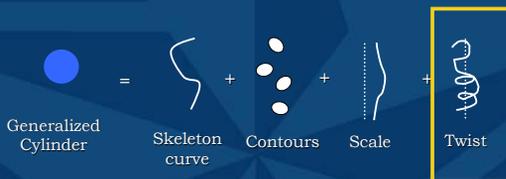
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Interactive Multiresolution Hair Modeling and Editing

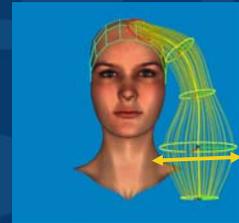
Generalized Cylinder (GC)



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Interactive Multiresolution Hair Modeling and Editing

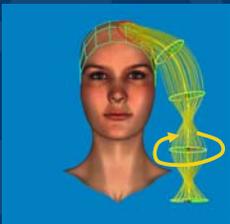
Scale Change



$$V(r, \theta, t) = C(t) + rR(\theta, t) \left\{ \cos(\hat{\theta}) S_N(t) \vec{N}(t) + \sin(\hat{\theta}) S_B(t) \vec{B}(t) \right\}$$

Interactive Multiresolution Hair Modeling and Editing

Twist Change



$$V(r, \theta, t) = C(t) + rR(\theta, t) \left\{ \cos(\hat{\theta}) S_N(t) \vec{N}(t) + \sin(\hat{\theta}) S_B(t) \vec{B}(t) \right\}$$

Interactive Multiresolution Hair Modeling and Editing

Adding Details

- A single generalized cylinder (GC) is limited by a few parameters
- Simply adding more GCs results in too many controls

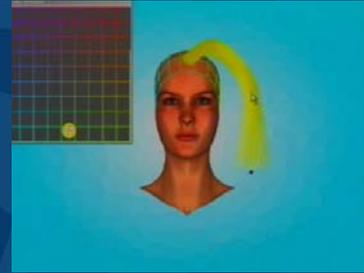
Interactive Multiresolution Hair Modeling and Editing

Subdivision

- Subdivide a parent GC into several smaller child GCs
- Hierarchical control over the hair model
- Editing a child GC changes the shape of hair strands
- Editing a parent GC affects child GCs as well as hair strands

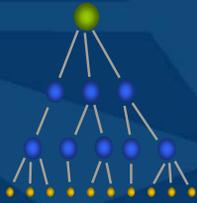
Interactive Multiresolution Hair Modeling and Editing

Subdivision



Interactive Multiresolution Hair Modeling and Editing

Hair Tree



- A hair model
- Generalized cylinder
- Hair strand

- Subdivision allows more refined controls to the hair model → down to a hair strand

Interactive Multiresolution Hair Modeling and Editing

Subdivision

- Skeleton curves
- Contour functions
- Hair strand generation

Interactive Multiresolution Hair Modeling and Editing

Subdivision

- Skeleton curves
- Contour functions
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$$V(r, \theta, t) = C(t) + rR(\theta, t) \left\{ \cos(\hat{\theta}) S_N(t) \vec{N}(t) + \sin(\hat{\theta}) S_B(t) \vec{B}(t) \right\}$$

Interactive Multiresolution Hair Modeling and Editing

Subdivision

- Skeleton curves
- Contour functions
- Hair strand generation



Random Positioning

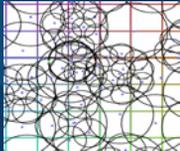


Position Relaxation

Interactive Multiresolution Hair Modeling and Editing

Subdivision

- Skeleton curves
- Contour functions
- Hair strand generation



Overlaps and holes

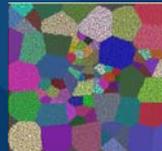


Uneven hair density

Interactive Multiresolution Hair Modeling and Editing

Subdivision

- Skeleton curves
- Contour functions
- Hair strand generation



Hair assignment



Consistent hair density

Interactive Multiresolution Hair Modeling and Editing

Multiresolution Editing



Interactive Multiresolution Hair Modeling and Editing

Multiresolution Editing

- Bind
When a GC is selected for edit, its descendants are attached to the GC
- Update
During editing, the children GCs are updated using GC equation of the parent

Interactive Multiresolution Hair Modeling and Editing

Multiresolution Editing

- Bind: $\mathbf{P} = \mathbf{V}(\mathbf{r}, \theta, \mathbf{t})$
 $(\mathbf{r}, \theta, \mathbf{t}) = \mathbf{V}^{-1}(\mathbf{P})$
- $\mathbf{V}(\mathbf{r}, \theta, \mathbf{t}) \rightarrow \mathbf{V}'(\mathbf{r}, \theta, \mathbf{t})$
- Update: $\mathbf{P}' = \mathbf{V}'(\mathbf{r}, \theta, \mathbf{t})$

$$V(r, \theta, t) = C(t) + rR(\theta, t) \left\{ \cos(\hat{\theta}) S_N(t) \vec{N}(t) + \sin(\hat{\theta}) S_B(t) \vec{B}(t) \right\}$$

Interactive Multiresolution Hair Modeling and Editing

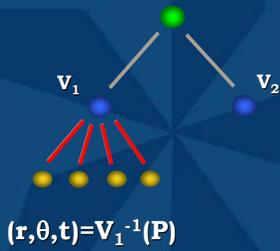
Copy and Paste



Transfer a *style* from one cluster to another

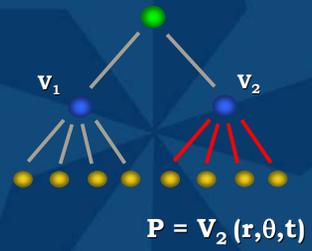
Interactive Multiresolution Hair Modeling and Editing

Copy and Paste



Interactive Multiresolution Hair Modeling and Editing

Copy and Paste



Interactive Multiresolution Hair Modeling and Editing

Copy and Paste



Interactive Multiresolution Hair Modeling and Editing

Example



Global hair shape modeling with GCs

Interactive Multiresolution Hair Modeling and Editing

Example



Subdivision and local editing

Interactive Multiresolution Hair Modeling and Editing

Example



Copy and paste

Interactive Multiresolution Hair Modeling and Editing

Example



Multiresolution editing and refinement

Interactive Multiresolution Hair Modeling and Editing

Example



Interactive Multiresolution Hair Modeling and Editing

Example



Top level
(30 GCs)

2nd level
(177 GCs)

3rd level
(840 GCs)

Interactive Multiresolution Hair Modeling and Editing

Interactive Rendering

- Explicit geometry
- Any hair renderer that handles arbitrary explicit hair models could be used
- Instant feedback for WYSIWYG hair modeling
- Integrated rendering system with OpenGL hardware
- Each hair strand drawn as polyline

Interactive Multiresolution Hair Modeling and Editing

Interactive Rendering

- Self-shadows
- Anti-aliasing

→ Interactive visualization of complex hair geometry

Interactive Multiresolution Hair Modeling and Editing

Self-shadows

- Crucial for volumetric hair



No shadows



With shadows

Interactive Multiresolution Hair Modeling and Editing

Self-shadows

- Crucial for volumetric hair



Interactive Multiresolution Hair Modeling and Editing

Self-shadows

- Opacity shadow maps [Kim and Neumann, EGRW 2001]
- Scalable approximation for volumetric shadows
- Cached shadows for interactive visualization

Interactive Multiresolution Hair Modeling and Editing

Antialiasing

Without Antialiasing



With Antialiasing



Interactive Multiresolution Hair Modeling and Editing

Antialiasing



Interactive Multiresolution Hair Modeling and Editing

Results



Interactive Multiresolution Hair Modeling and Editing

Results



Interactive Multiresolution Hair Modeling and Editing

Results



Interactive Multiresolution Hair Modeling and Editing

Results



Interactive Multiresolution Hair Modeling and Editing

Results



Interactive Multiresolution Hair Modeling and Editing

Results



Interactive Multiresolution Hair Modeling and Editing

Conclusion

- Multiresolution hair modeling framework
- Interactive hair rendering

Interactive Multiresolution Hair Modeling and Editing

Extensions

- High level tools for global shape modeling
- Hairstyle database
- Use other modeling systems as front-end and ours as back-end
- Fitting and stitching of GCs
- Model transfer between different head meshes

Interactive Multiresolution Hair Modeling and Editing

How to animate it?

- Kinematic control for top-level clusters
- Strand-based animation techniques
- Fitting GCs for key hair approach
- Multiresolution framework for hair animation (dynamic hair tree)
- Hair-hair interaction algorithms for complex hair models

Interactive Multiresolution Hair Modeling and Editing

Acknowledgements

- USC Annenberg Center
- NSF foundation
- Junyong Noh, Doug Fidaleo, Clint Chua
- J.P. Lewis, Hiroki Itokazu, Bret StClair
- Marianne LaFrance
- Sean Mausuch, Laehyun Kim
- All the colleagues at USC CGIT laboratory

Interactive Multiresolution Hair Modeling and Editing

Level of Detail



High complexity model
1.2M lines
20000 strands, 60 lines /
strand, $a = 0.3$



Low complexity model
(100K lines)
5000 strands, 20 lines /
strand, $a = 1.0$

Interactive Multiresolution Hair Modeling and Editing

Level of Detail



High complexity model
(1.2M lines)



Low complexity model
(100K lines)

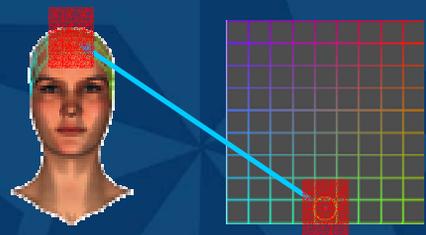
Interactive Multiresolution Hair Modeling and Editing

Results (video)



Interactive Multiresolution Hair Modeling and Editing

Scalp Surface



Atlas for hair cluster positioning

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