Capturing Braided Hairstyles

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Braids in Real Life
Braids in Animation

Disney
Braids in VFX
Challenges

Reference photo

Geometric heuristics [Luo et al. 2013]

Strand-based examples [Hu et al. 2014]
Key Idea

- Data-driven reconstruction
- Procedurally generated examples

Captured input  Database  Extracted structure  Output strands
Related Work: Braid Theory [Artin 1947]

4-strand basic braid

4-strand fishtail
Related Work: Hair Modeling

[Choe and Ko 2005]  [Wither et al. 2007]

[Fu et al. 2007]  [Yuksel et al. 2009]
Related Work: Hair Capture

[Wei et al. 2005]

[Paris et al. 2008]

[Jakob et al. 2009]

[Herrera et al. 2012]

[Chai et al. 2013]

[Luo et al. 2013]

[Echevarria et al. 2014]

[Hu et al. 2014]

[Xu et al. 2014]
Related Work: Structure-aware shape processing

[Nan et al. 2012]

[Shao et al. 2012]

[Shen et al. 2012]

[Bradley et al. 2013]

[Kim et al. 2012]

[Li et al. 2010]

[Li et al. 2011]

[Huang et al. 2013]
Overview

Input photos → 2D orientation maps → Database → Fitting result

Input mesh → 3D orientation field → Cleaned mesh → Fitting result
Capture Setup

Multi-view stereo

Hand-held Kinect
Pre-processing

Input photos → 2D orientation maps → Database → Fitting result

Input mesh → 3D orientation field → Cleaned mesh
Pre-processing

Kinect Fusion [Newcombe et al. 2011]
Detect dominant local orientation [Pair et al. 2004]
Pre-processing
Procedural Model

Input photos → 2D orientation maps → Database → Cleaned mesh → Fitting result

Input mesh → 3D orientation field
Procedural Model

- Basic braid
- Four-strand braid
- Five-strand Dutch braid
- Fishtail braid
Basic braid:

\[ L_0 : x = a \sin (t) , \quad y = t , \quad z = b \sin (2t) \]
\[ L_1 : x = a \sin (t + 2\pi /3) , \quad y = t , \quad z = b \sin (2 (t + 2\pi /3)) \]
\[ L_2 : x = a \sin (t + 4\pi /3) , \quad y = t , \quad z = b \sin (2 (t + 4\pi /3)) \]
Procedural Model

Expand
Procedural Model

Four-strand braid

Five-strand Dutch braid

Fishtail braid
Procedural Model

Four-strand braid

Five-strand Dutch braid

Fishtail braid
Procedural Model

Four-strand braid

Five-strand Dutch braid

Fishtail braid
Procedural Model

tail patch
Patch Fitting

Input photos

2D orientation maps

Database

Cleaned mesh

Fitting result
Patch Fitting

Input mesh $C$
Patch $P_f$
Rigid ICP
Non-rigid ICP [Li et al. 2009]
Structure Analysis

Database

Cleaned mesh

Fitting result

Labeling result

Extracted structure
Structure Analysis

Input mesh

Candidate patches
Structure Analysis

Multi-label optimization

Input mesh  Candidate patches

or

...?
Structure Analysis

Multi-label optimization

Input mesh  Candidate patches
Structure Analysis

Multi-label optimization

Input mesh

Candidate patches
Structure Analysis

Multi-label optimization: Graph-cut [Delong et al. 2012]

- Input mesh
- Candidate patches
- Labeling result
- Selected patches
Structure Analysis

Selected patches

Extracted centerlines

Connected centerlines

Expanded mesh

Refined result
Perlin Noise for strand variation [Choe and Ko 2005]

Without fuzziness  With fuzziness
Results: Five-strand Dutch Braid

Reference photos  Extracted structure  Output strands
Results: Basic Braid

Reference photos  Extracted structure  Output strands
Results: French Braid

Reference photos

Extracted structure

Output strands
Results: Two Basic Braids

Reference photos  Extracted structure  Output strands
Results: Princess Anne Braid

Reference photos  Extracted structure  Output strands
Evaluation

Different example patches

Reference photo

Fishtail E = 66.86

3-strand E = 87.09

4-strand E = 98.52
Evaluation

Different example patches

Reference photo

Fishtail
$E = 66.86$

3-strand
$E = 87.09$

Fishtail & 3-strand
$E = 68.36$
Convergence on different initial scales of example patch

Reference photo

- $s = 0.8$
  - $E = 54.86$

- $s = 1.0$
  - $E = 55.98$

- $s = 1.2$
  - $E = 58.92$

- $s = 1.3$
  - $E = 62.80$
Limitations

Reference photo

With tapering

Without tapering
Summary

Data-driven framework

Procedural braid models

Patch-based analysis algorithm
Future work

- Hair segmentation
- Scale extraction [Huang et al. 2014]
- More complex structures
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