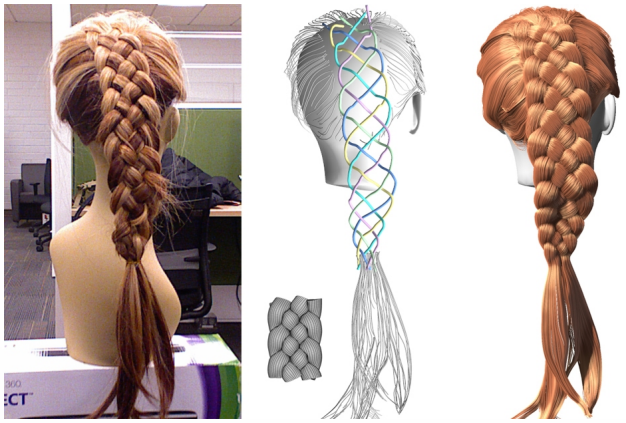
12.2 Data-Driven Shape Analysis & Synthesis



Chongyang Ma

http://cs599.hao-li.com

Outline

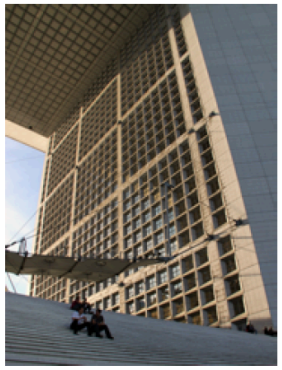
- Structure-aware shape processing
- Data-driven shape analysis
- Data-driven shape synthesis
- *Data-driven hair capture*

Outline

- Structure-aware shape processing
- Data-driven shape analysis
- Data-driven shape synthesis
- *Data-driven hair capture*

Man-made Objects

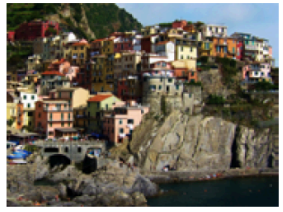












Definition of “Structure”

“The arrangement of and relations between the parts or elements of something complex.”

The Oxford dictionary

Structure of Shapes

- Parts and their relations

Historical Perspective

- *Low-level* shape processing
  - Up until the mid-2000's
  - Entities: points, edges, triangles
  - Criteria: smoothness, detail preservation…
  - Operations: smoothing, decimation, remeshing…

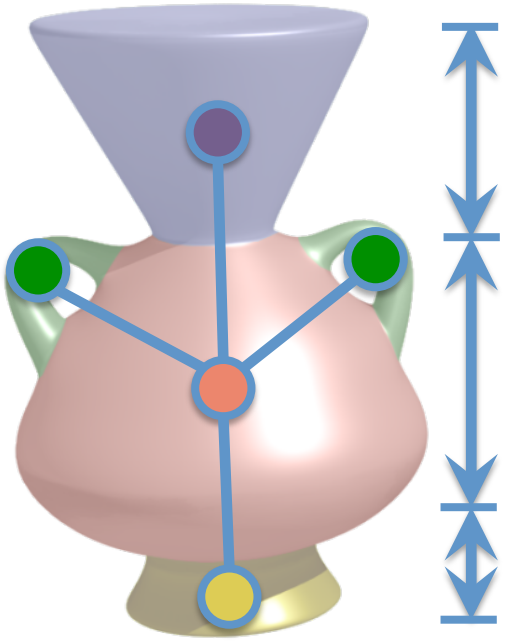
Historical Perspective

- *Low-level* shape processing
  - Up until the mid-2000's
  - Entities: points, edges, triangles
  - Criteria: smoothness, detail preservation…
  - Operations: smoothing, decimation, remeshing…
- *High-level* shape processing
  - Structure-aware
  - [Funkhouser et al. 2004]

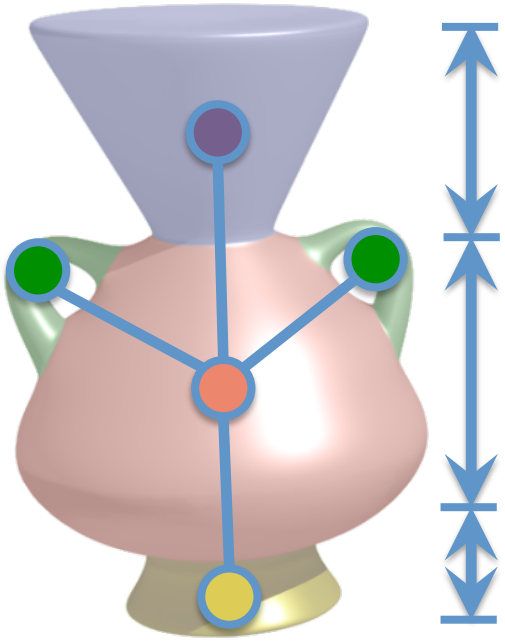
Discover structure: problems

Discover structure: problems

- Identify *parts*
  - Meaningful segmentation
- Extract part *parameters*
  - Quantitative representations
- Extract part *relations*
  - Encoded as constraints

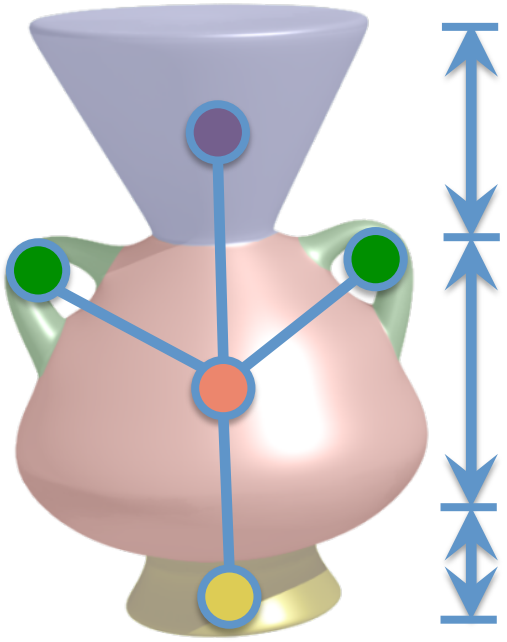


Discover structure: methodologies

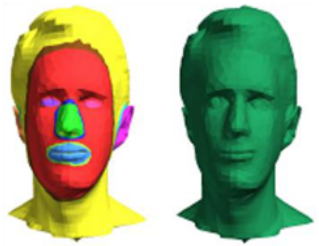
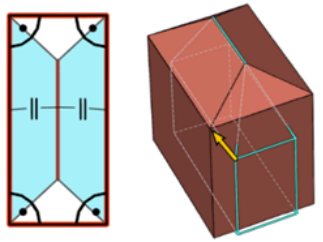
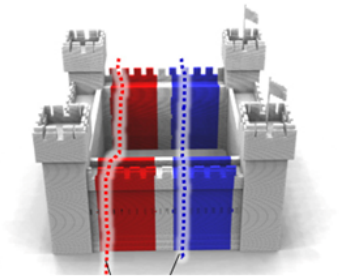
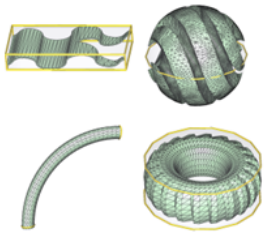
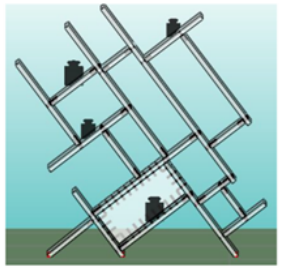
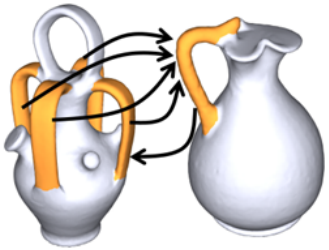
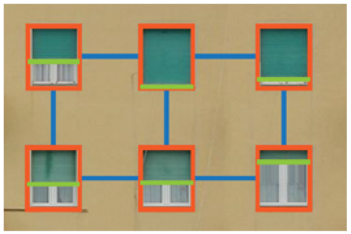


Discover structure: methodologies

- User-specified
  - Interactive interface
- From a fixed/priori model
  - Template fitting, physical laws
- Data-driven
  - Machine-learning approaches



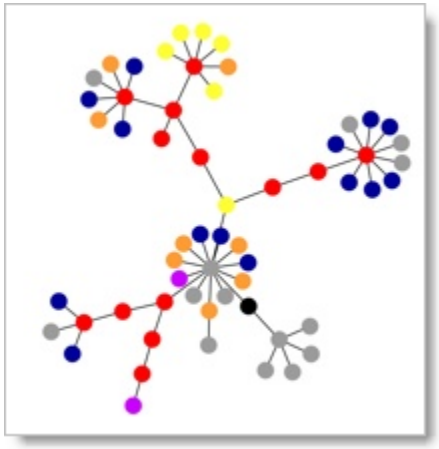
Discover structure: classification

	Parts	Parameters	Relations
User defined	 [Funkhouser et al. 2004]	 [Lin et al. 2011]	 [Habbecke et al. 2012]
Fixed model	 [Bokeloh et al. 2010]	 [Zheng et al. 2011]	 [Umetani et al. 2012]
Learned	 [Huang et al. 2011]	 [AlHalawani et al. 2013]	 [Kalogerakis et al. 2012]

Structure-aware Shape Processing

- Data-driven pipeline

Input data



Analysis

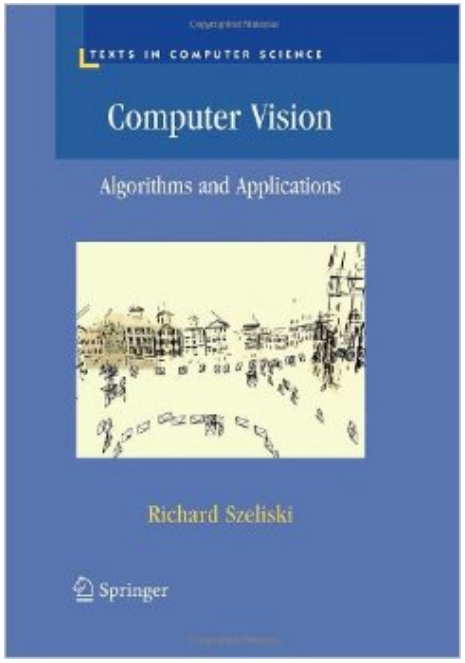
Synthesis

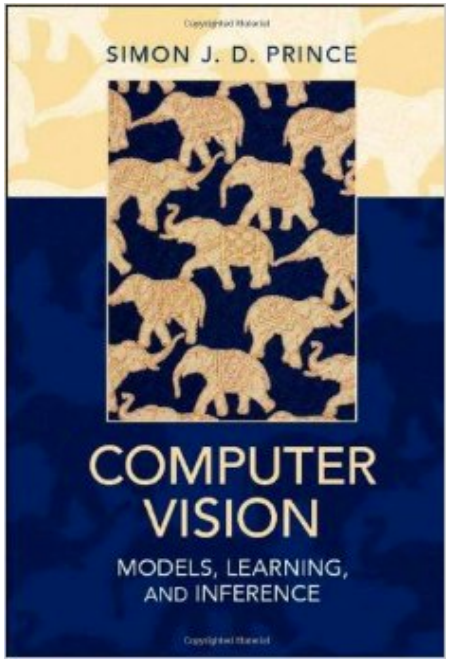
Why structure-aware?

- *Semantic* considerations
  - Table-tops are horizontal
- *Functional* considerations
  - Chair legs support the seat
- *Economic* considerations
  - Repeated parts are cheaper to replicate

Why structure-aware?

- Better understanding
  - Analogous to computer vision for images/videos





Why structure-aware?

- Better understanding
  - Analogous to computer vision for images/videos
- Better content creation
  - Creation & modeling of 3D shapes remains as bottleneck

Why data-driven?

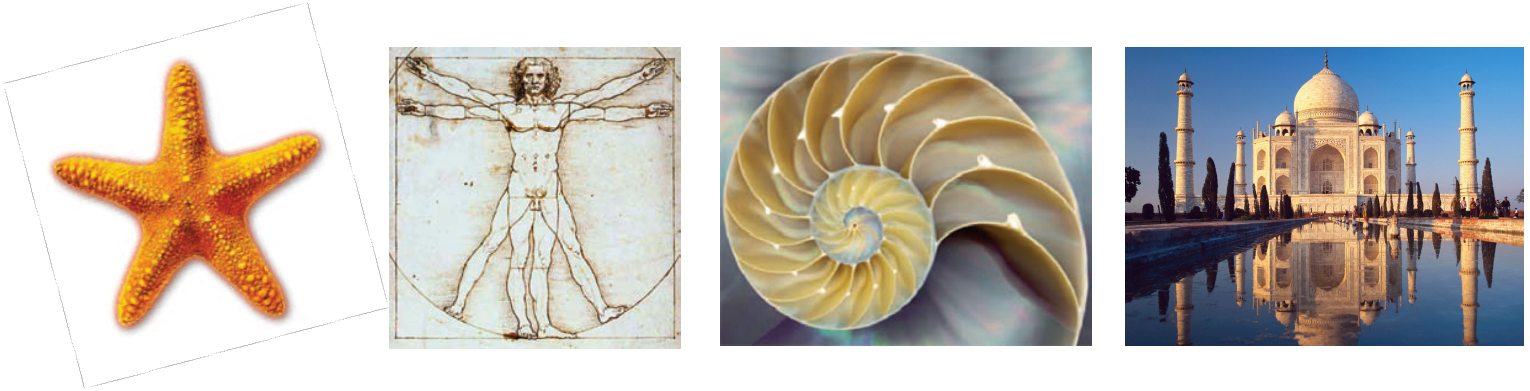
- Manual work is too tedious
- Prior knowledge is limited
- More and more useful data are available

Outline

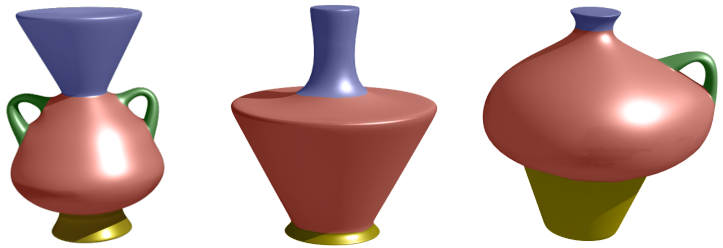
- Structure-aware shape processing
- Data-driven shape analysis
- Data-driven shape synthesis
- *Data-driven hair capture*

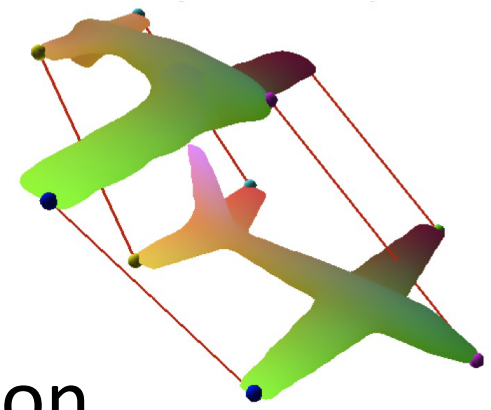
Data-Driven Shape Analysis

- Symmetry detection



- Segmentation

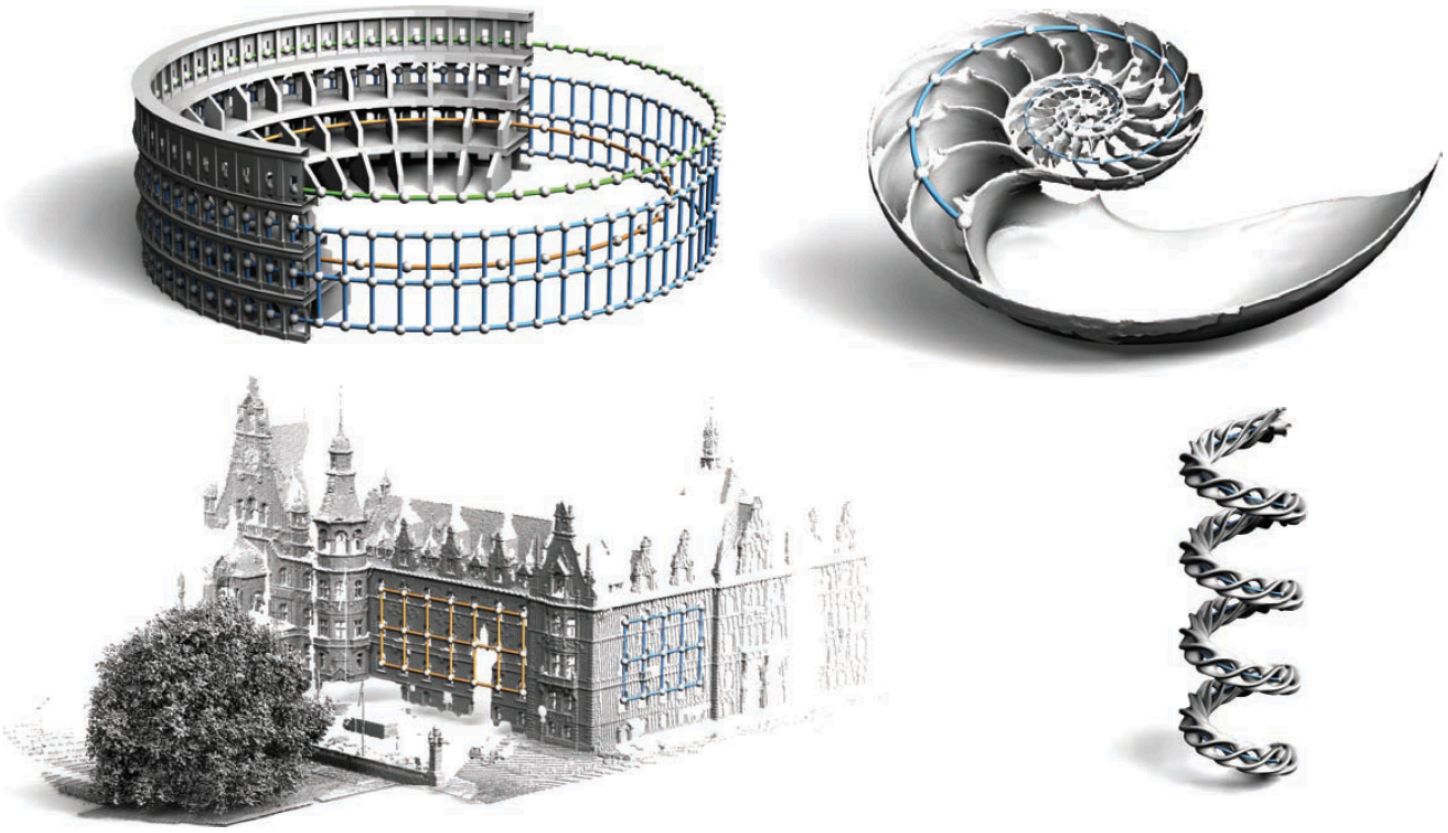




- Correspondence computation

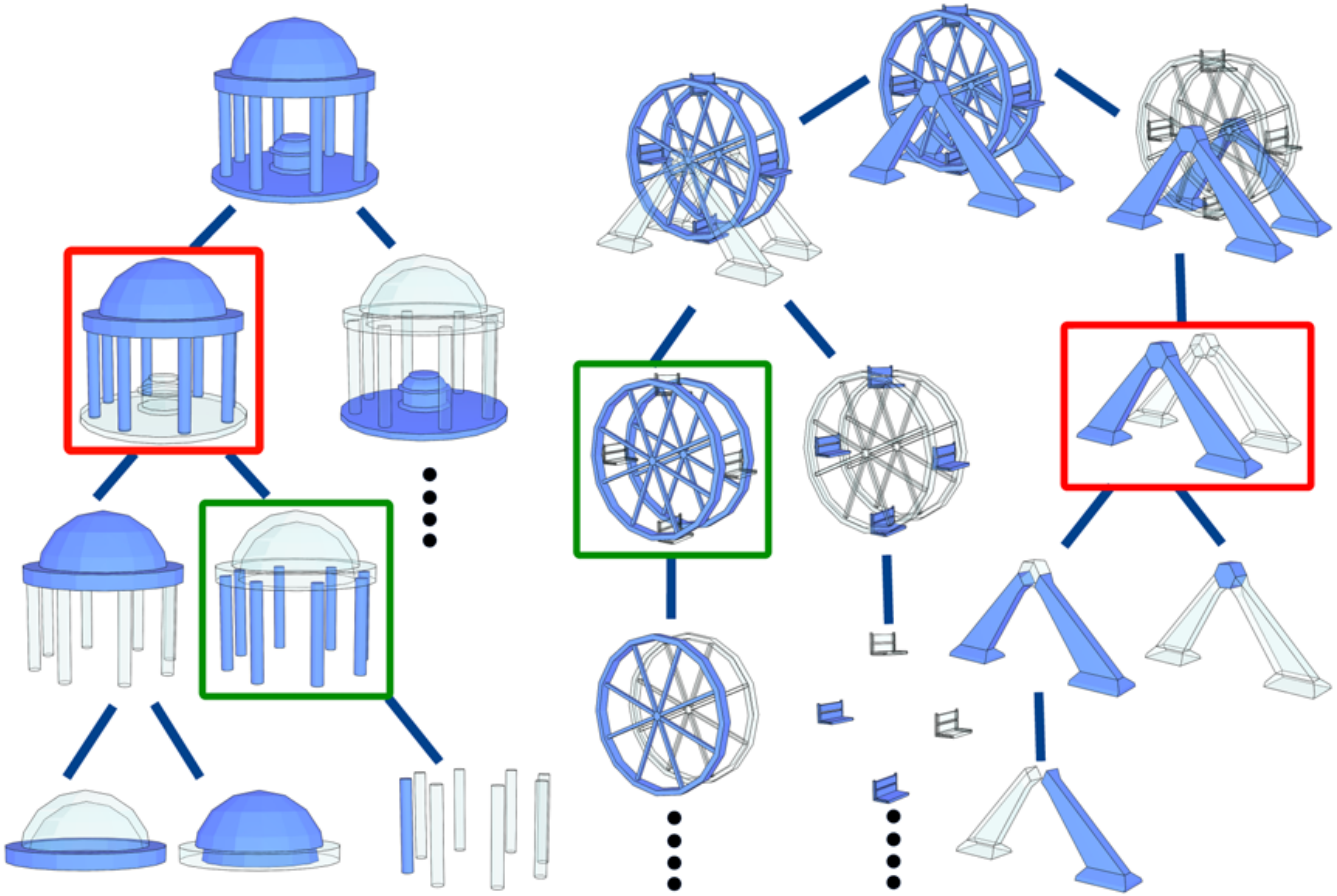
Discover Structural Regularity

- [Pauly et al. SIGGRAPH 2008]



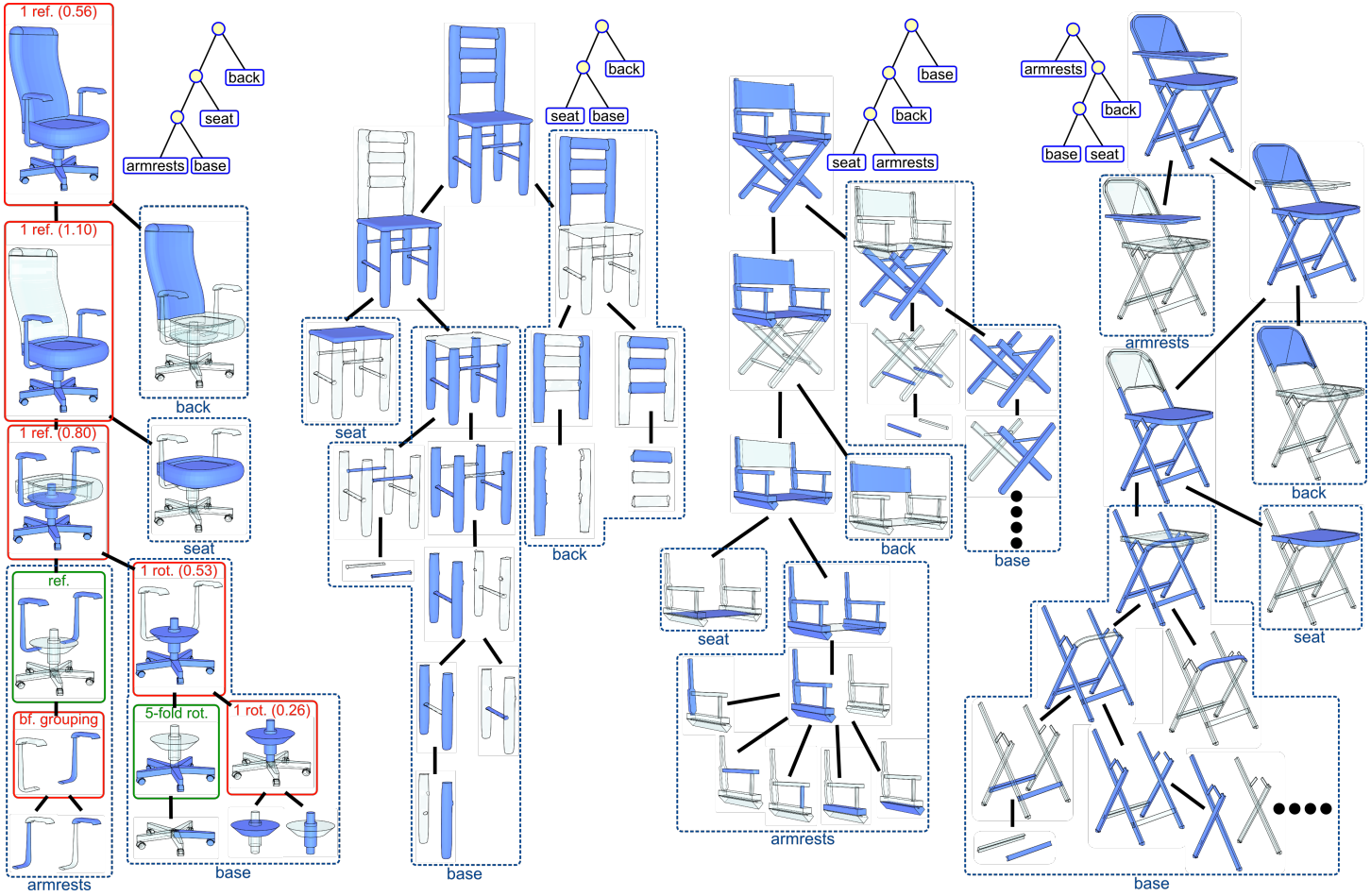
Symmetry Hierarchy

- [Wang et al. Eurographics 2011]



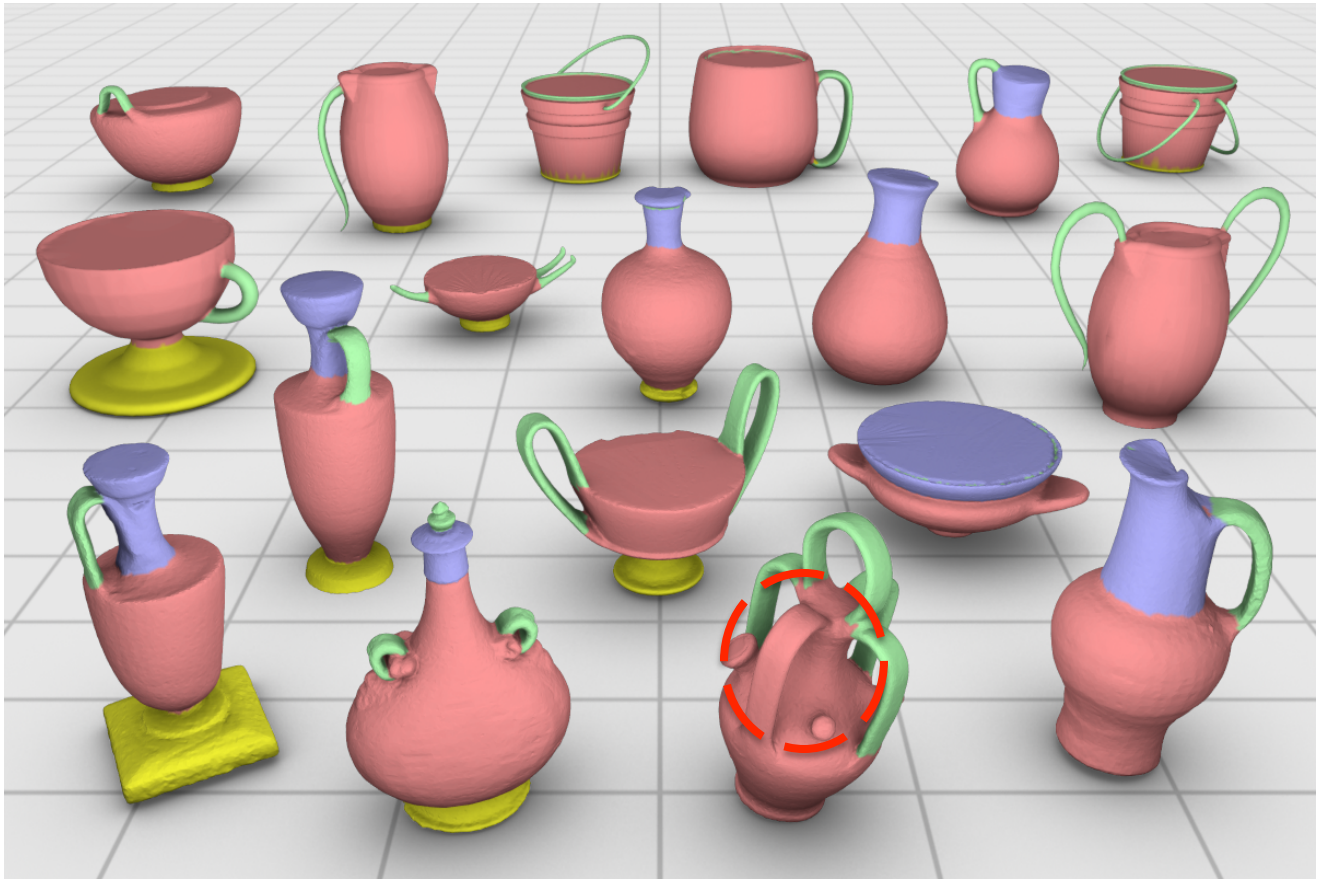
Symmetry Hierarchy

- [Wang et al. Eurographics 2011]



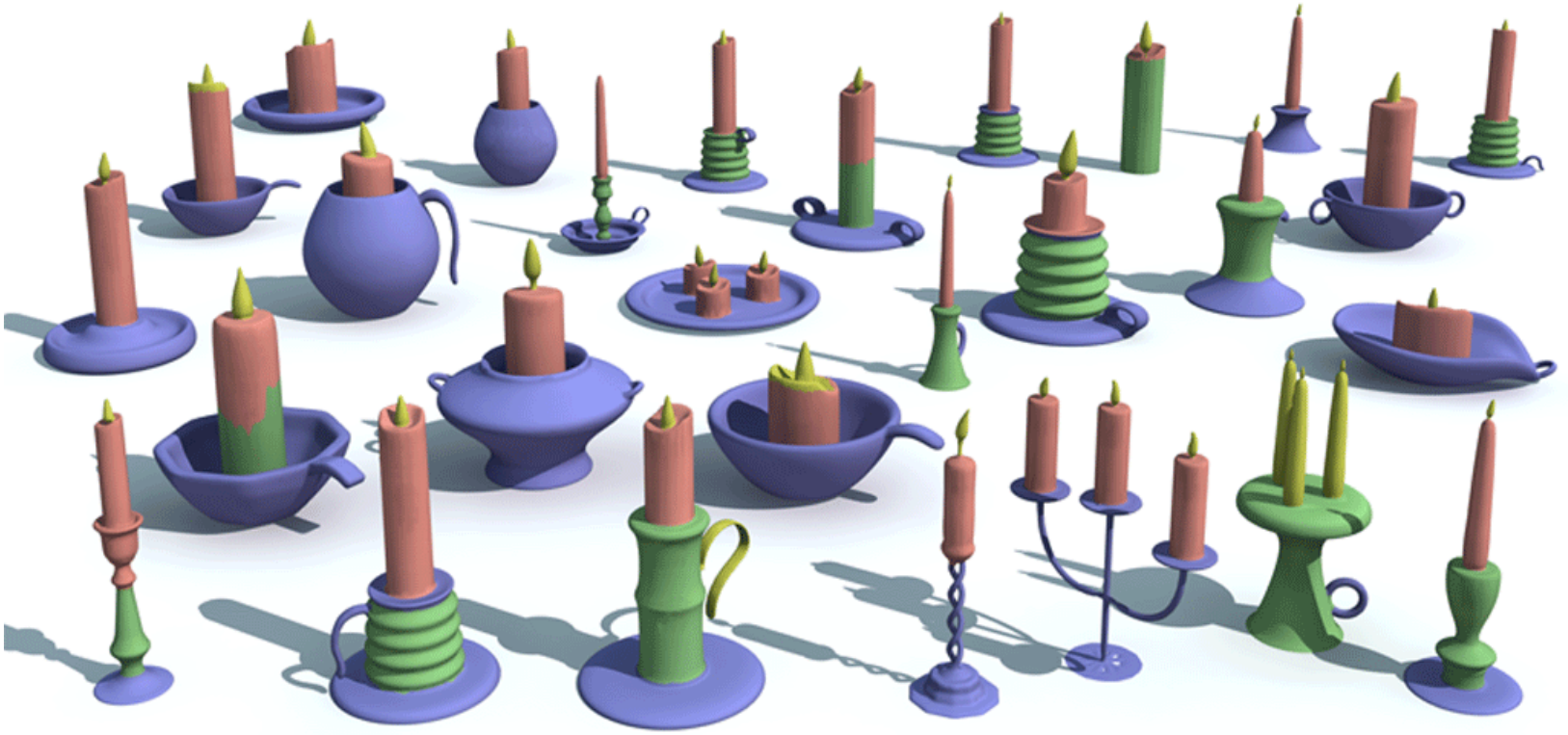
Unsupervised Co-Segmentation

- [Sidi et al. SIGGRAPH Asia 2011]



Semi-supervised Co-Segmentation

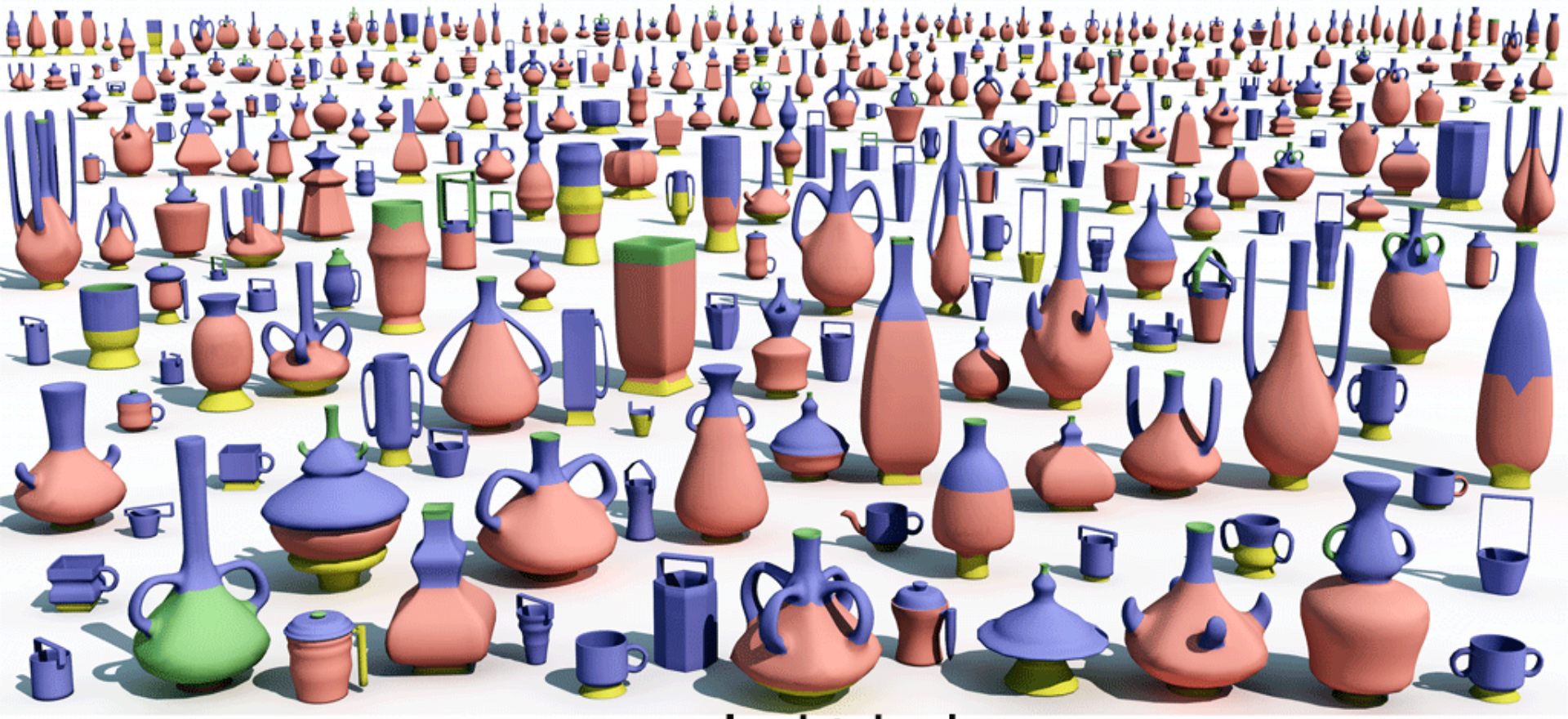
- [Wang et al. SIGGRAPH Asia 2012]



Initial

Semi-supervised Co-Segmentation

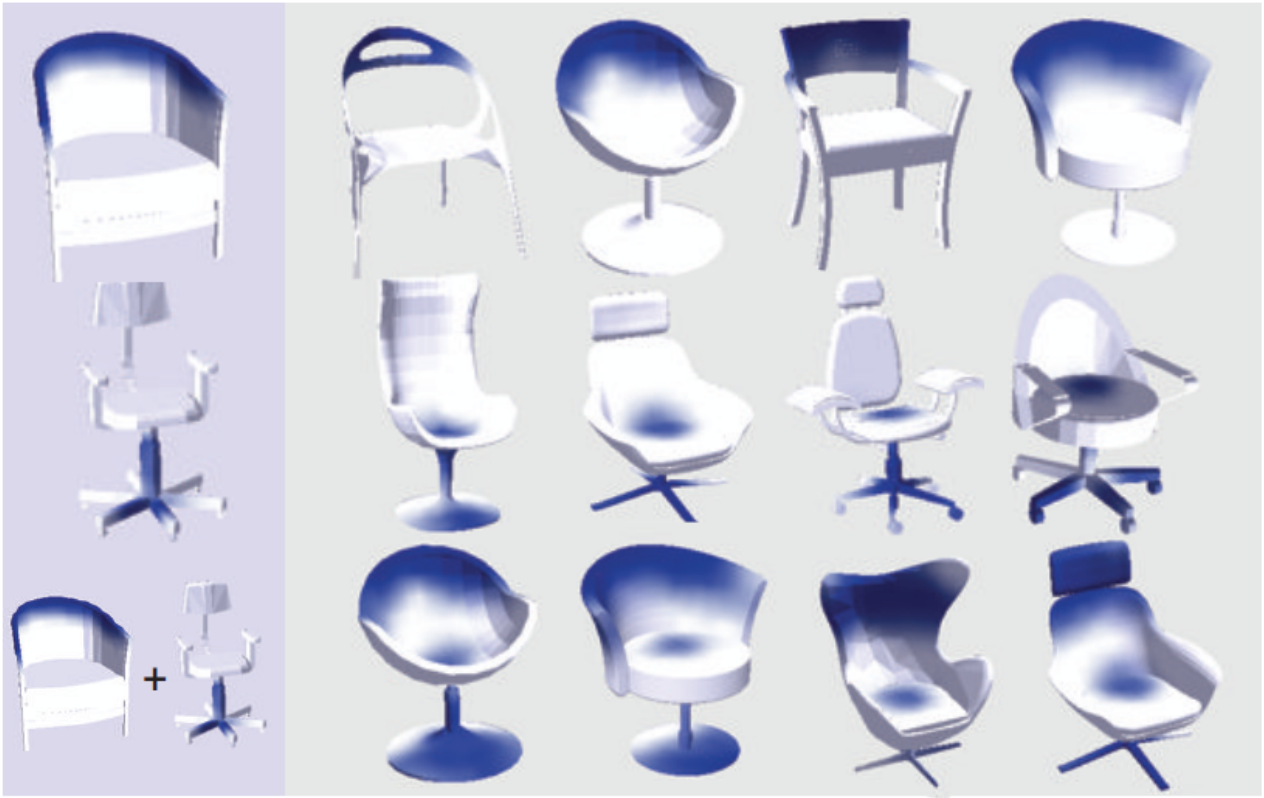
- [Wang et al. SIGGRAPH Asia 2012]



Initial

Fuzzy Correspondence

- [Kim et al. SIGGRAPH 2012]



Exploring Collections of 3D Models using Fuzzy Correspondences

Vladimir G. Kim
Princeton University

Wilmot Li
Adobe Systems

Niloy J. Mitra
UCL

Steve DiVerdi
Adobe Systems

Thomas Funkhouser
Princeton University

Outline

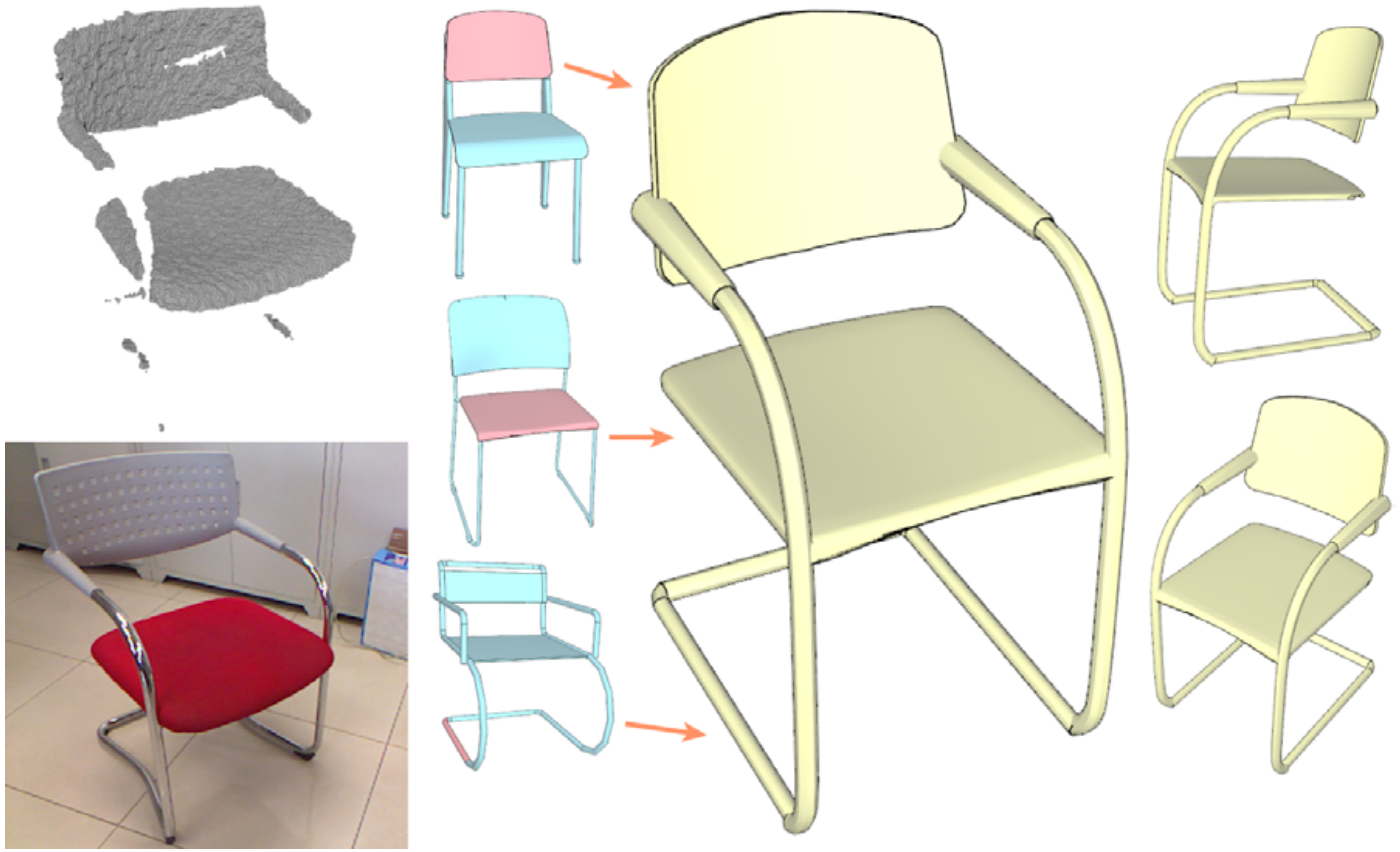
- Structure-aware shape processing
- Data-driven shape analysis
- Data-driven shape synthesis
- *Data-driven hair capture*

Photo-Inspired Deformation

- [Xu et al. SIGGRAPH 2011]

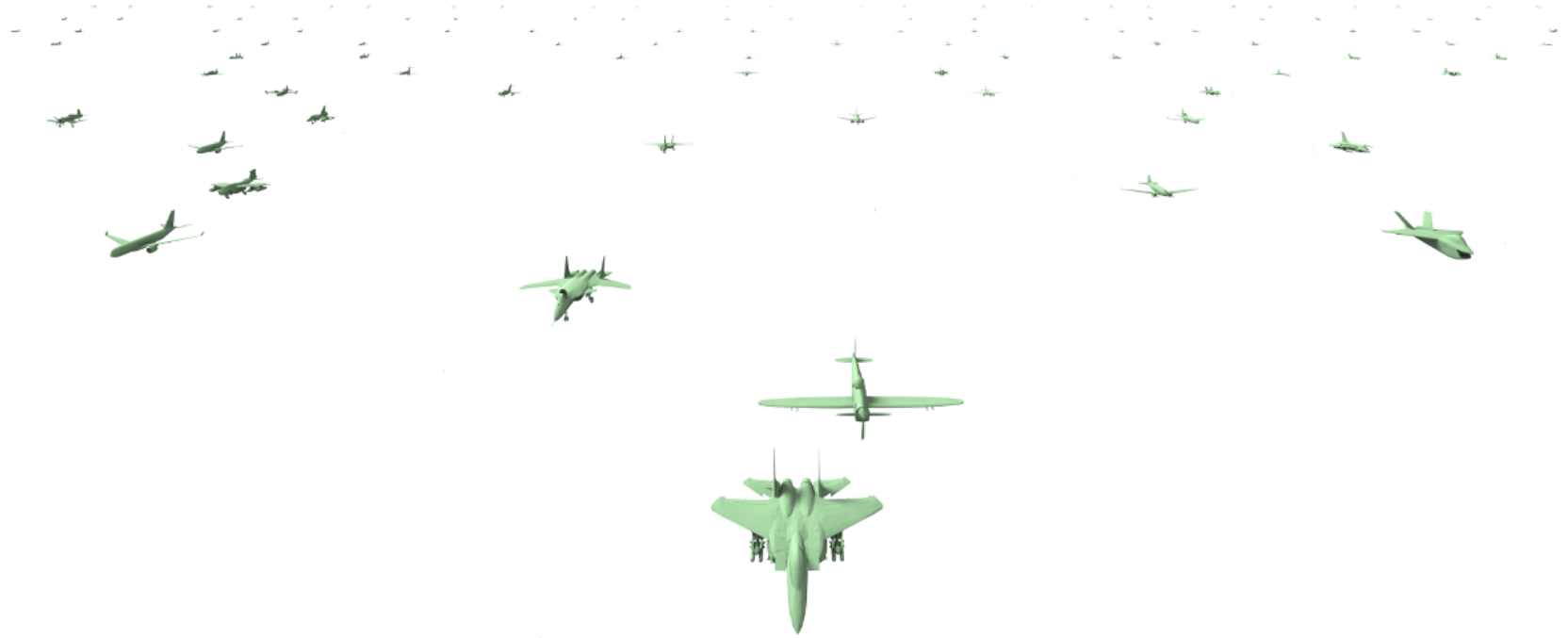
Capture-Inspired Part Assembly

- [Shen et al. SIGGRAPH Asia 2012]



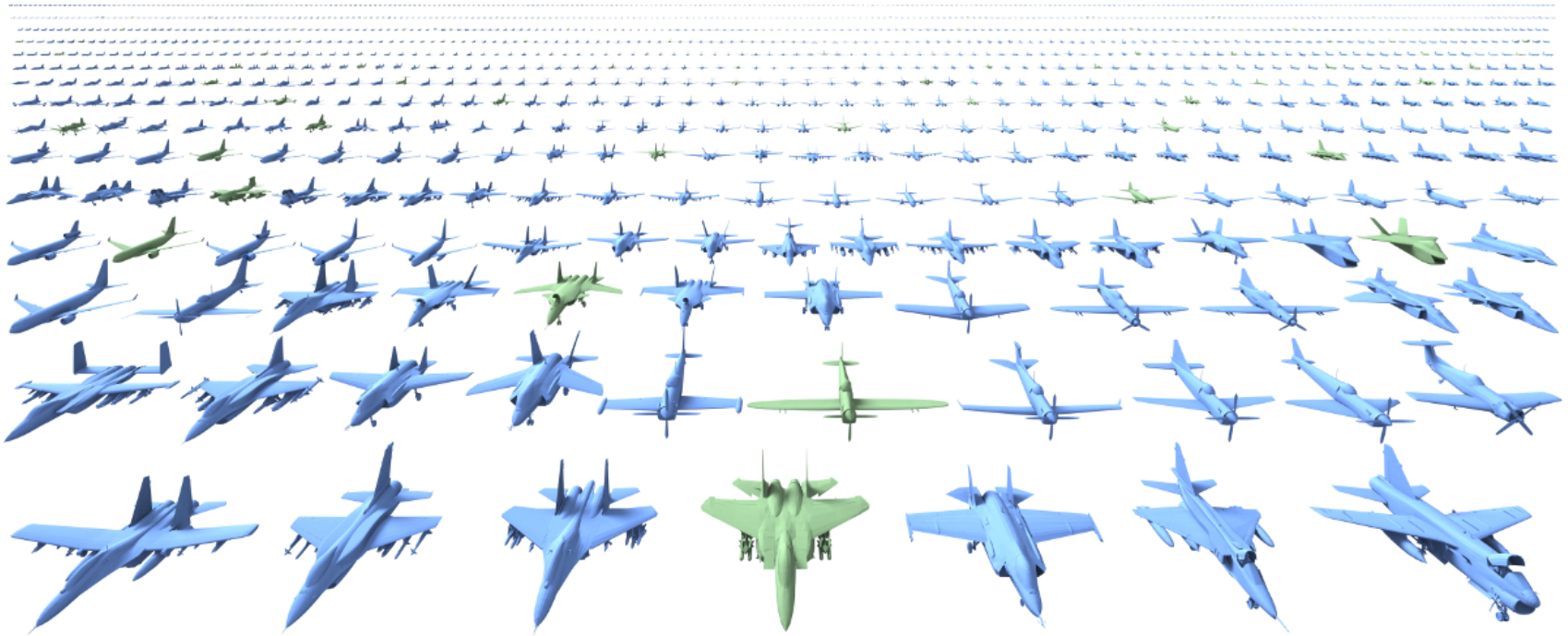
Probability-based Part Assembly

- [Kalogerakis et al. SIGGRAPH 2012]



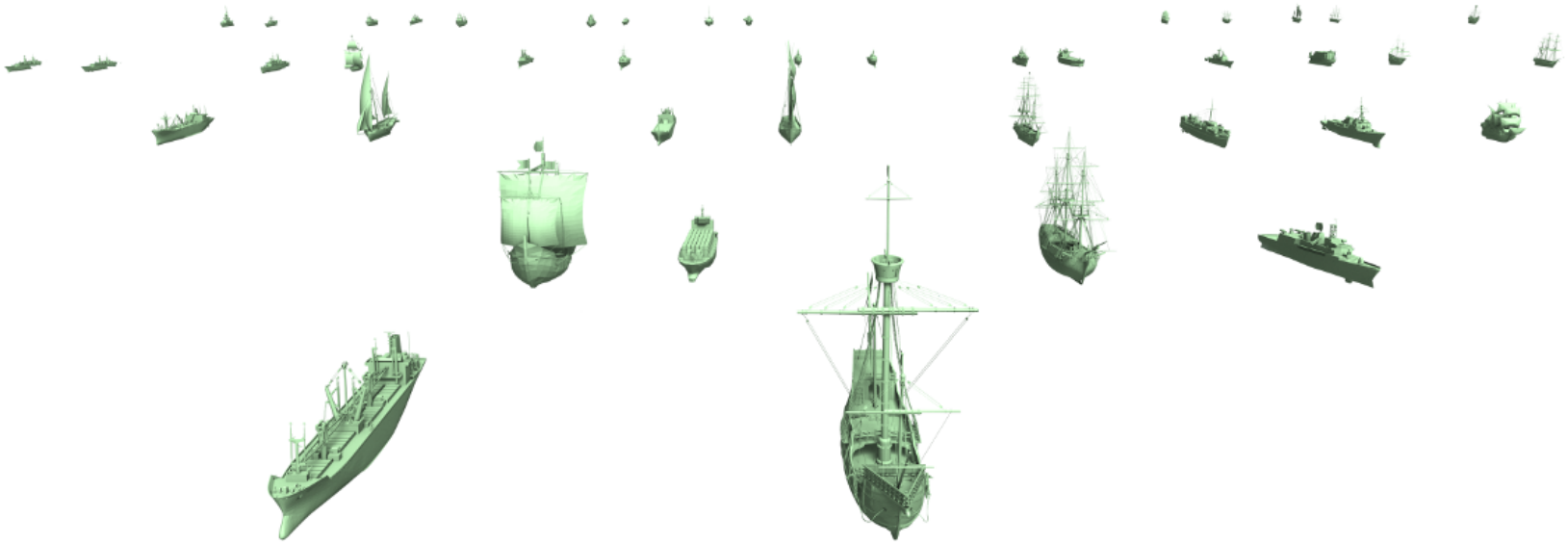
Probability-based Part Assembly

- [Kalogerakis et al. SIGGRAPH 2012]



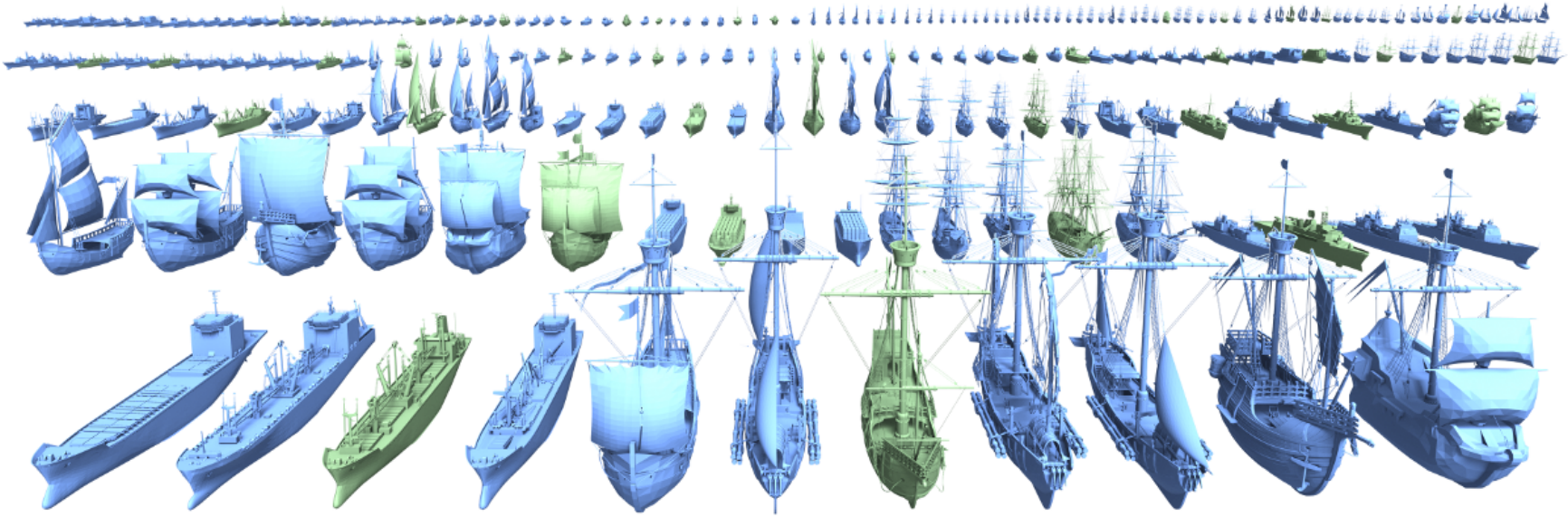
Probability-based Part Assembly

- [Kalogerakis et al. SIGGRAPH 2012]



Probability-based Part Assembly

- [Kalogerakis et al. SIGGRAPH 2012]



Probability-based Part Assembly

- [Kalogerakis et al. SIGGRAPH 2012]

Probability-based Part Assembly

- [Kalogerakis et al. SIGGRAPH 2012]

Probability-based Part Assembly

- [Kalogerakis et al. SIGGRAPH 2012]

Set Evolution

- [Xu et al. SIGGRAPH 2012]

Set Evolution

- [Xu et al. SIGGRAPH 2012]

Candelabra set

Input set

Set Evolution

- [Xu et al. SIGGRAPH 2012]

The 5th generation

Set Evolution

- [Xu et al. SIGGRAPH 2012]

The 10th generation

Set Evolution

- [Xu et al. SIGGRAPH 2012]

The 15th generation

Evolving a teapot set

Outline

- Structure-aware shape processing
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- Data-driven shape synthesis
- *Data-driven hair capture*

SIGGRAPH ASIA 2014 SHENZHEN

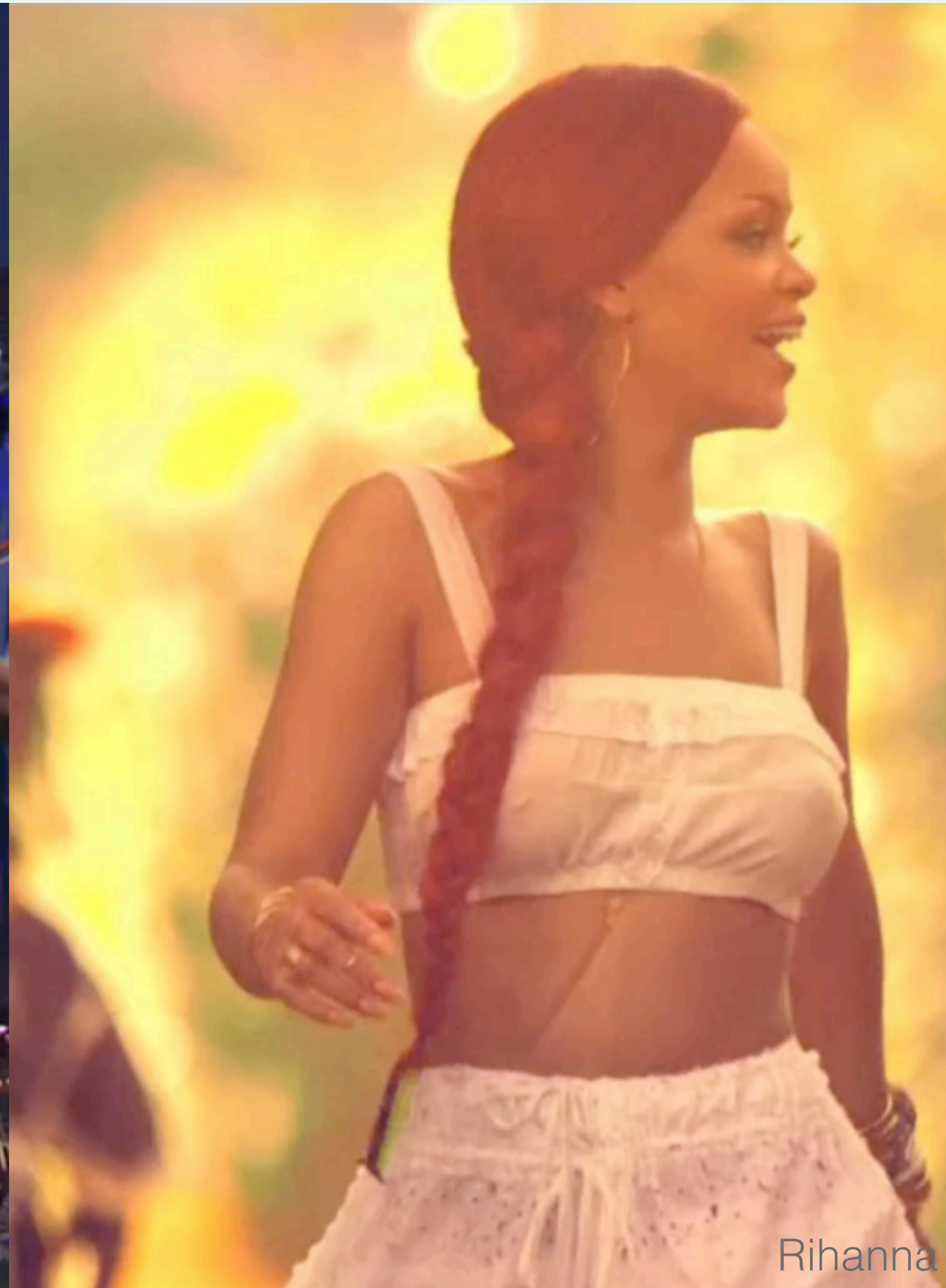
Capturing Braided Hairstyles

Liwen Hu[1] Chongyang Ma[1] Linjie Luo[2] Li-Yi Wei[3] Hao Li[1]

[1]University of Southern California
[2]Adobe Research
[3]The University of Hong Kong

Braids in Real Life

Taylor Swift



Rihanna

Braids in Animation

Braids in VFX

Lionsgate

Warner Bros. Pictures

Challenges

Reference photo

Geometric heuristics
[Luo et al. 2013]

Strand-based examples
[Hu et al. 2014]

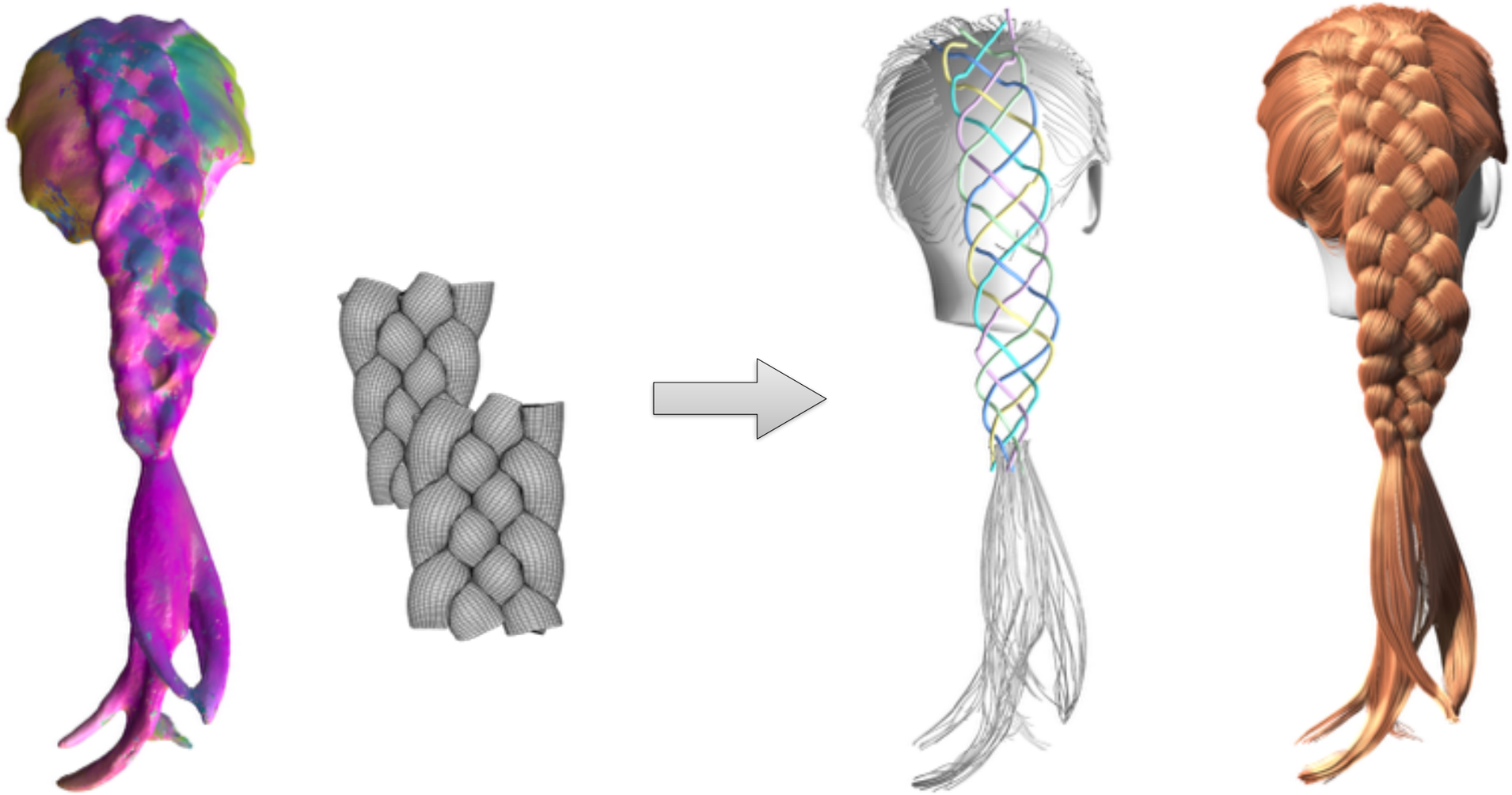
Motivation

Repetition

Procedure

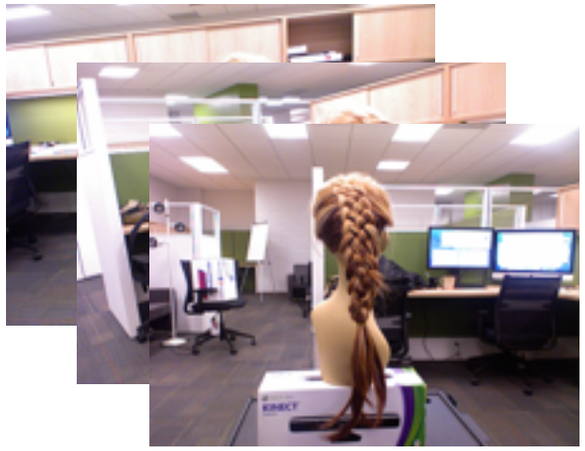
Key Idea

- Data-driven reconstruction
- Procedurally generated examples

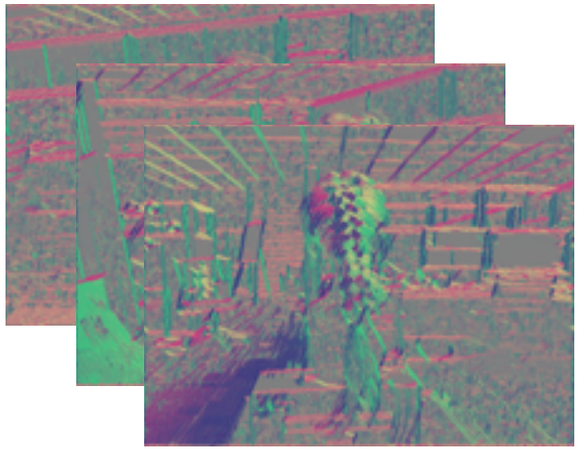


Captured input Database Extracted structure Output strands

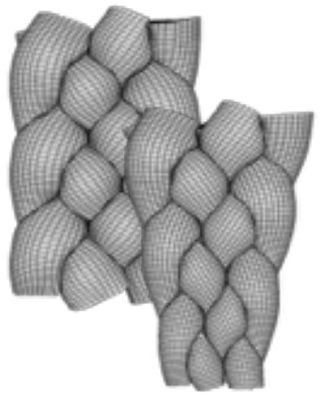
Overview



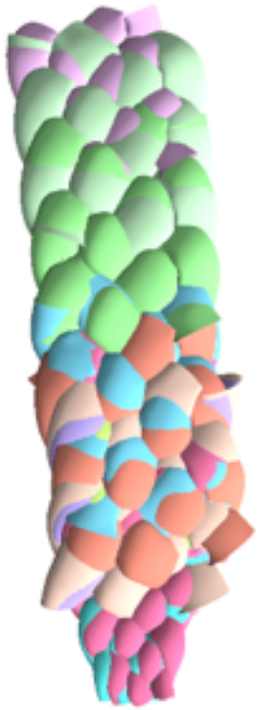
Input photos



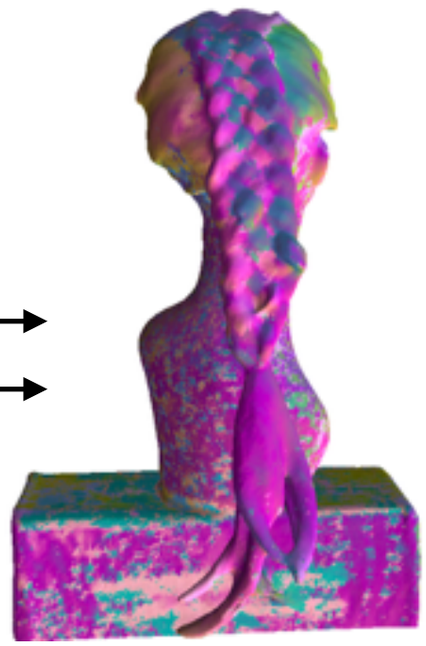
2D orientation maps



Database



Input mesh

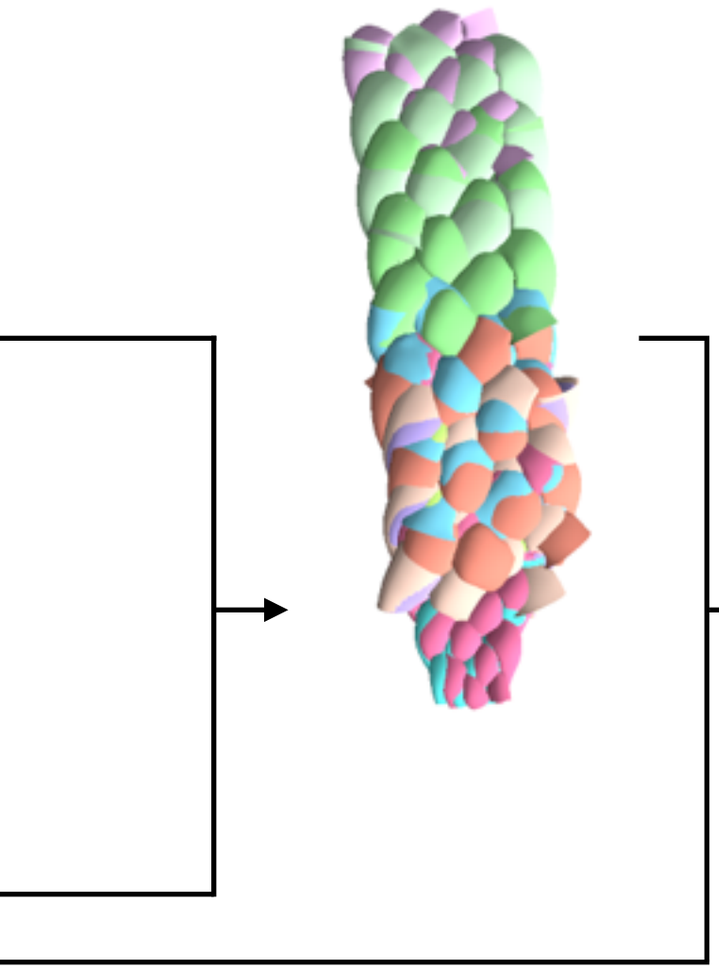


3D orientation field

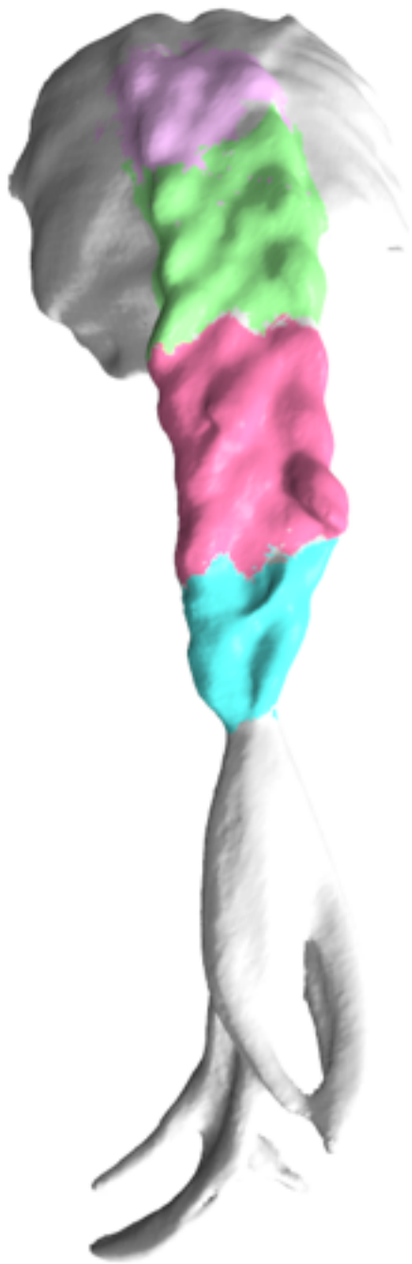
Cleaned mesh

Fitting result

Overview



Fitting result

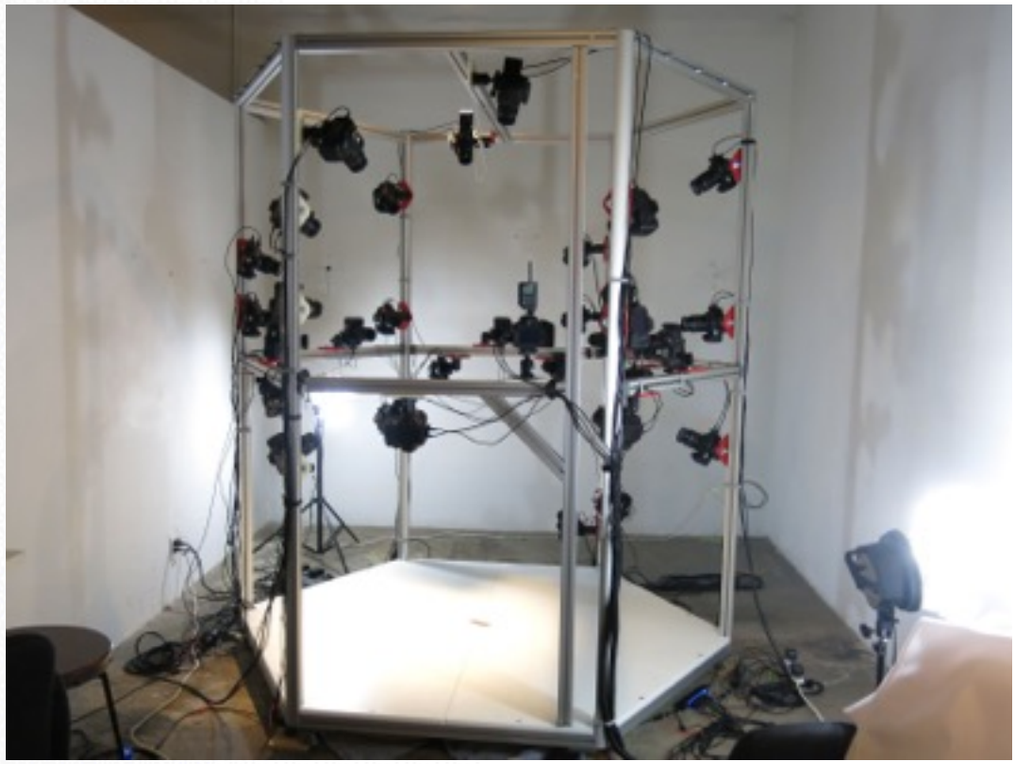


Labeling result

Extracted structure

Output strands

Capture Setup



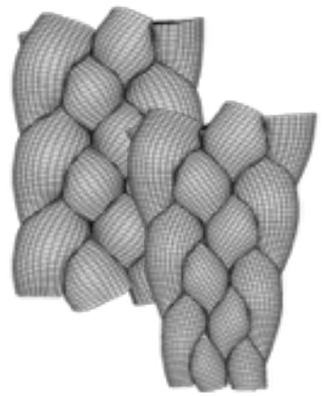
Multi-view stereo

Hand-held Kinect

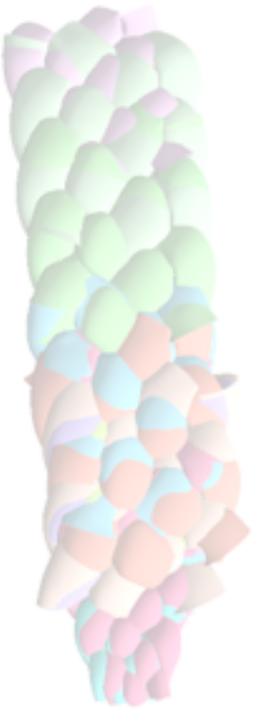
Procedural Model

Input photos

2D orientation maps



Database



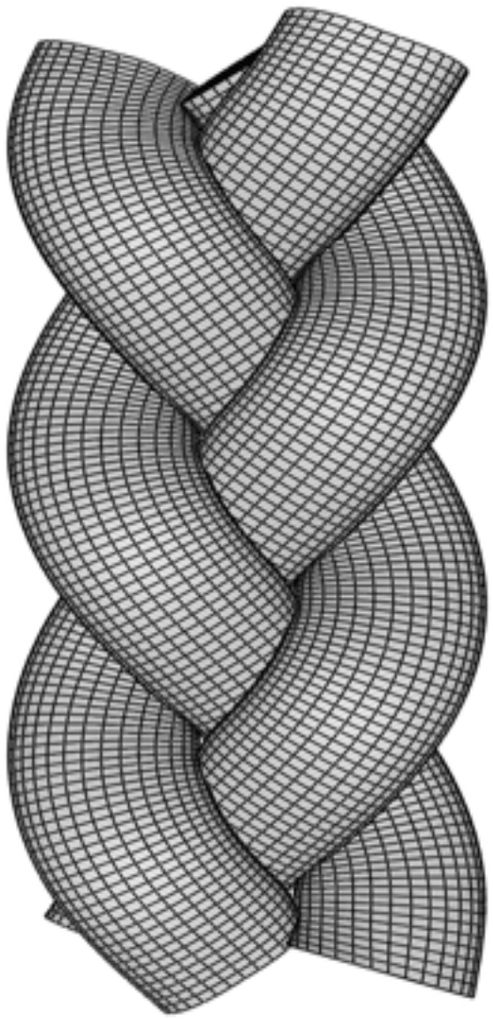
Input mesh

3D orientation field

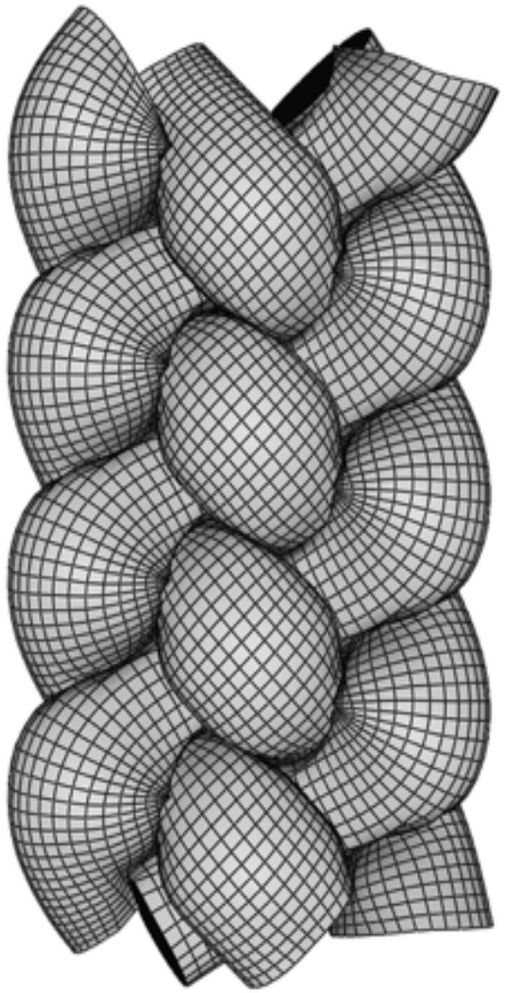
Cleaned mesh

Fitting result

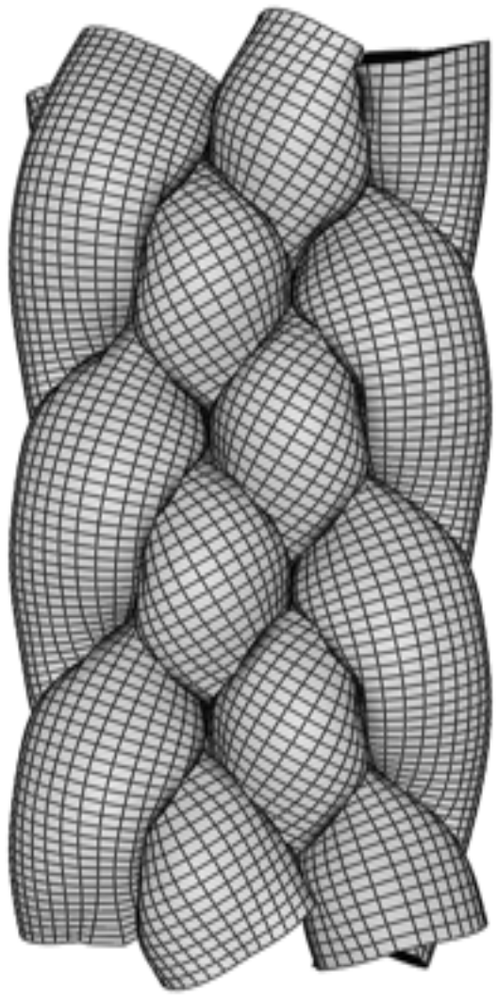
Procedural Model



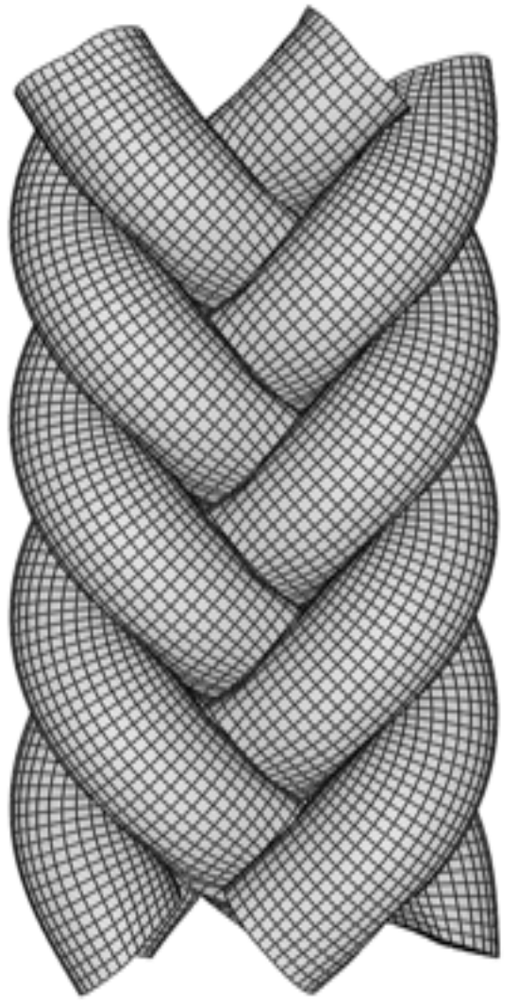
Basic
braid



Four-strand
braid



Five-strand
Dutch braid

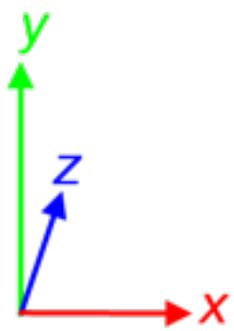


Fishtail
braid

Procedural Model

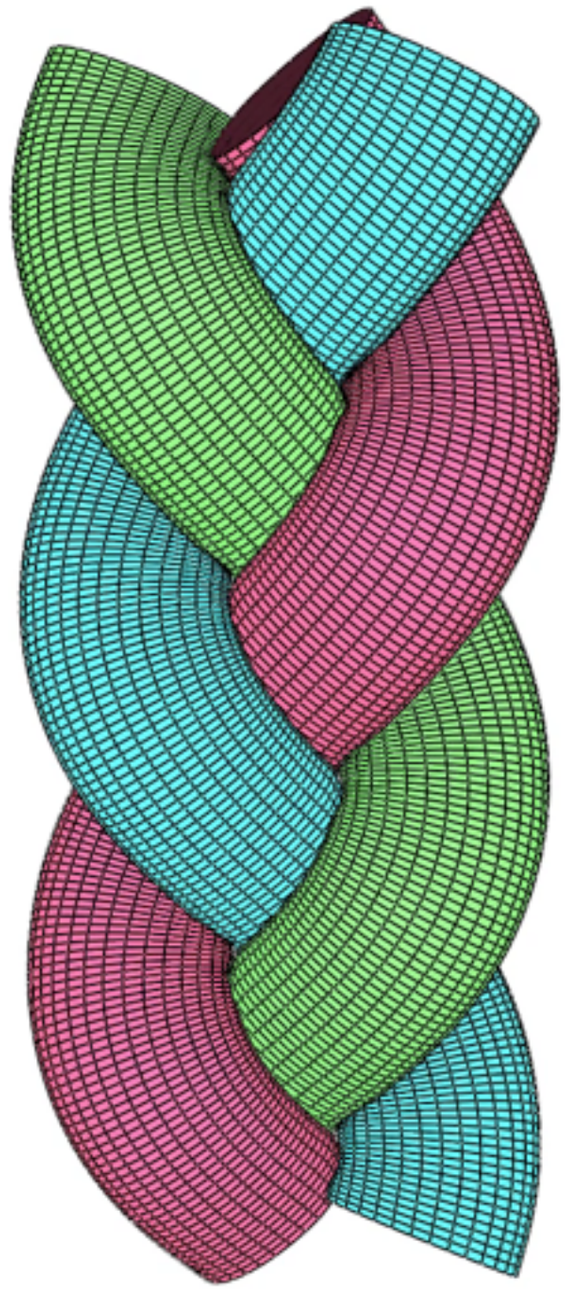
Basic braid:

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

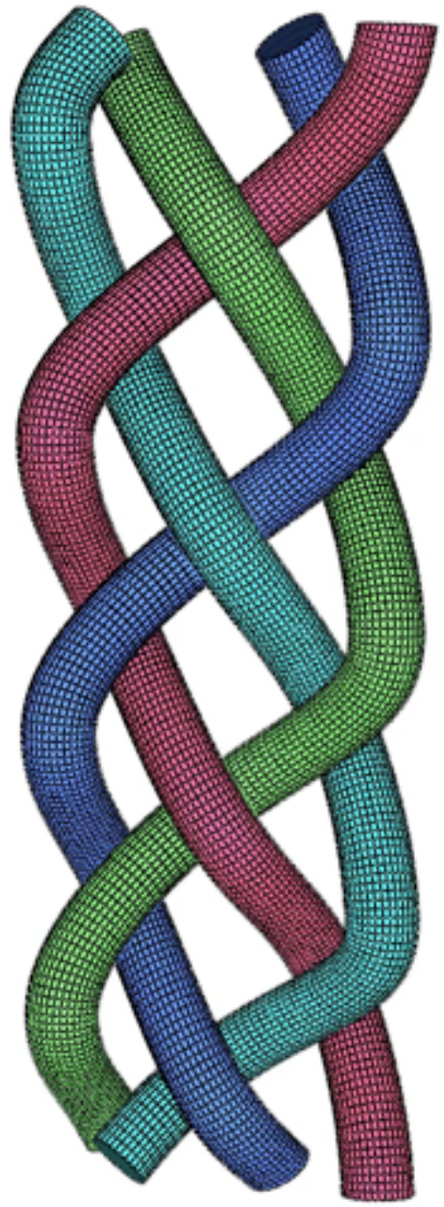


Procedural Model

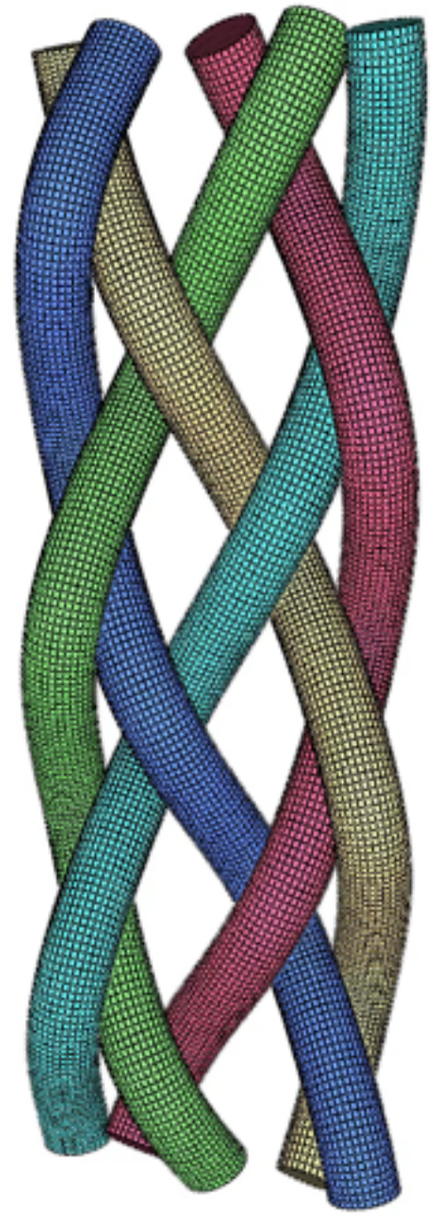
Expand



Procedural Model



Four-strand
braid



Five-strand
Dutch braid

Fishtail
braid

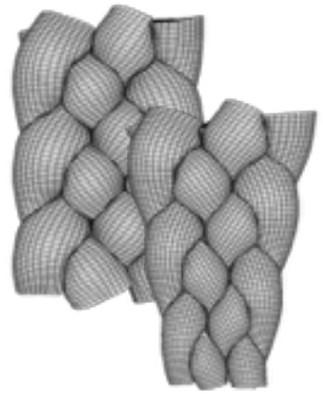
Patch Fitting

Input photos

2D orientation maps

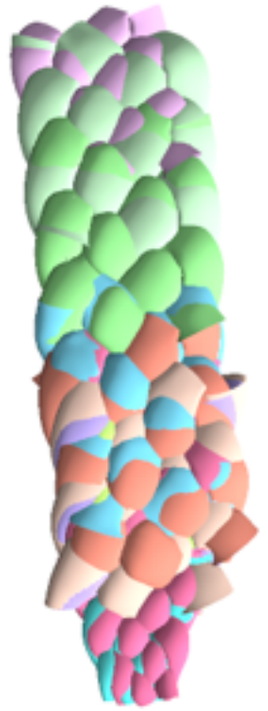
Input mesh

3D orientation field



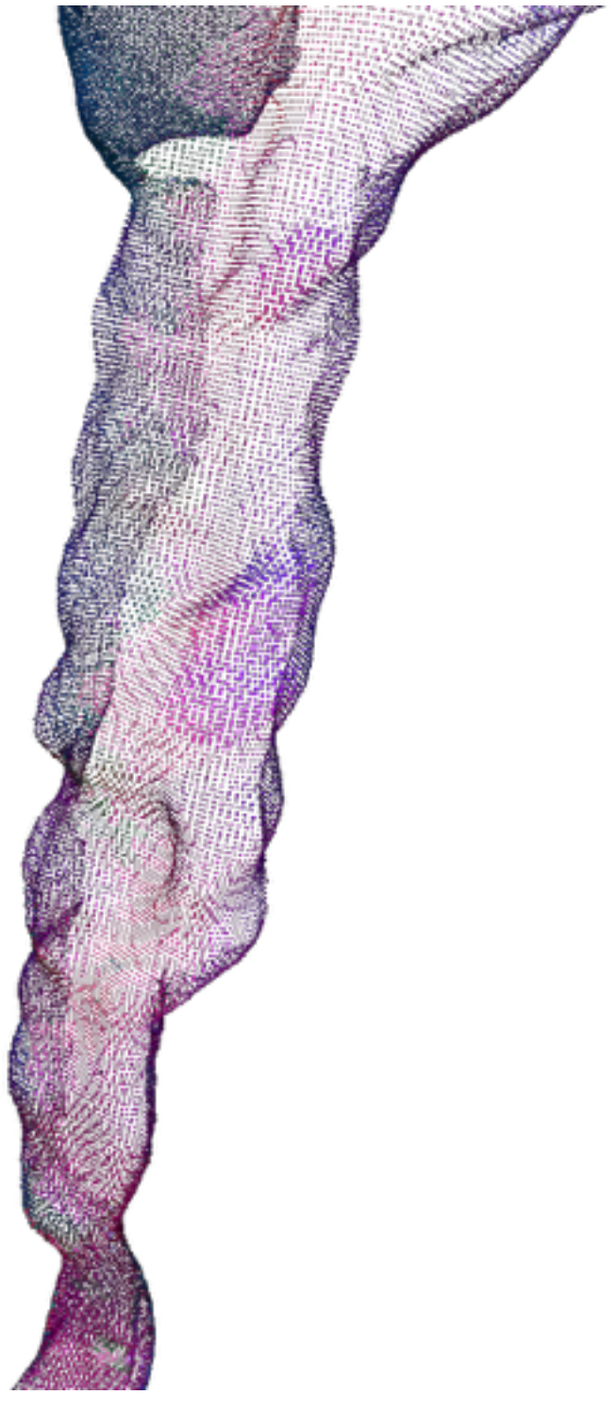
Database

Cleaned mesh

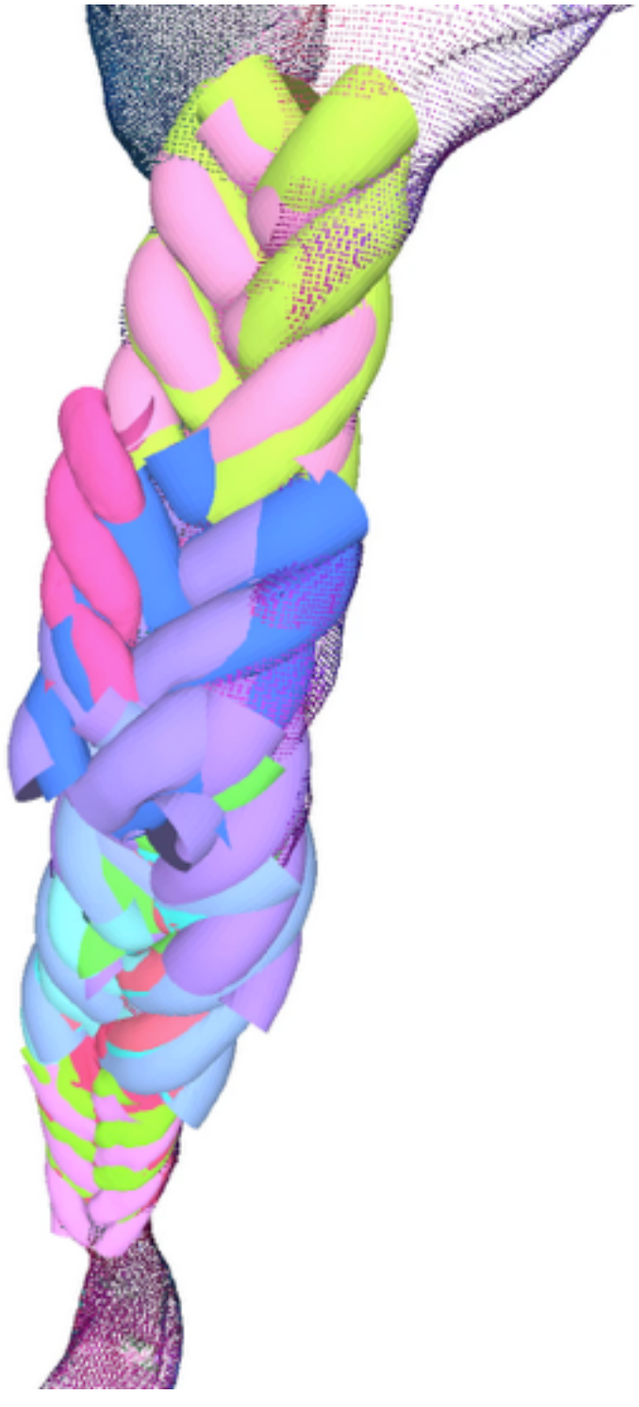


Fitting result

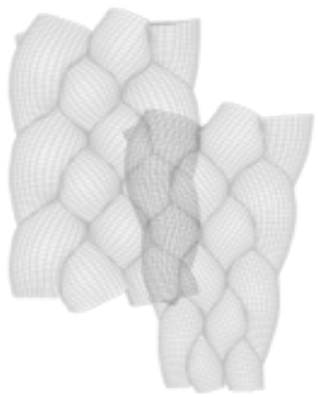
Patch Fitting



Random sampling

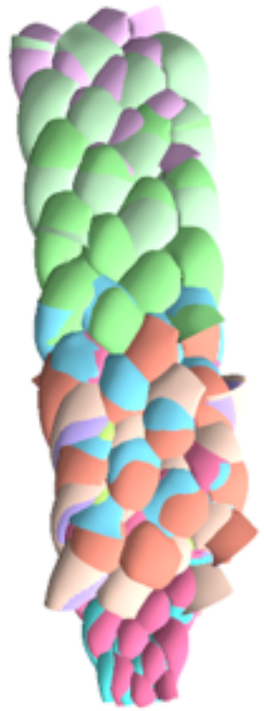


Structure Analysis

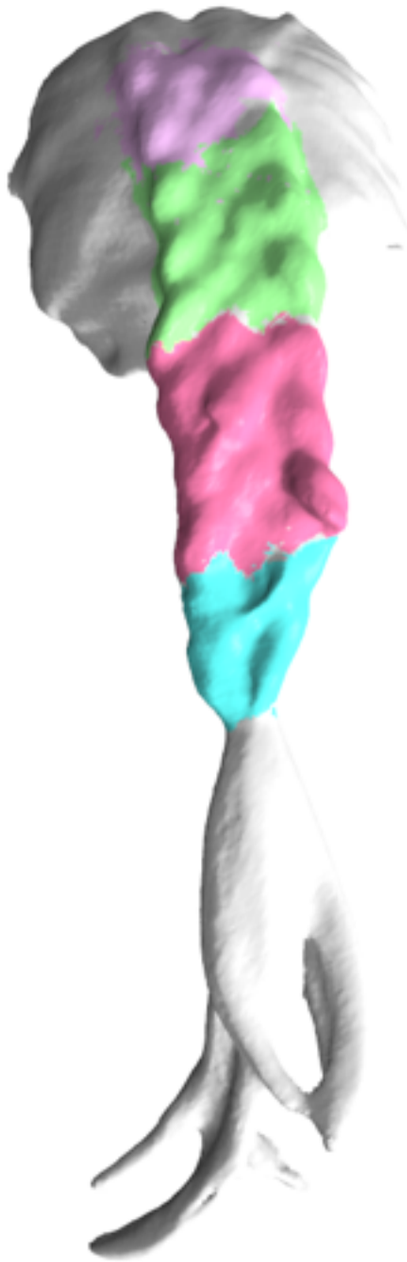


Database

Cleaned mesh



Fitting result

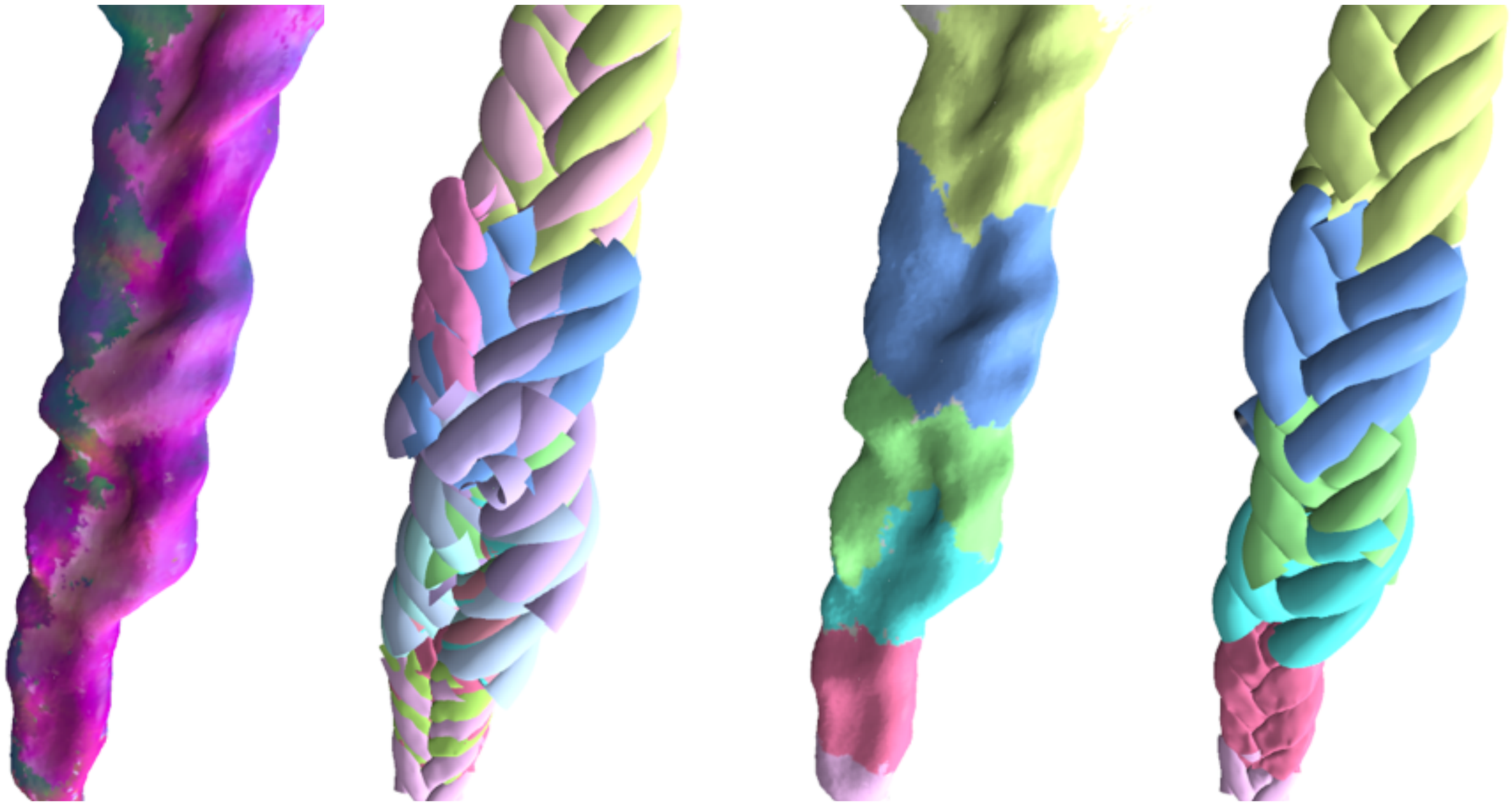


Labeling result

Extracted structure

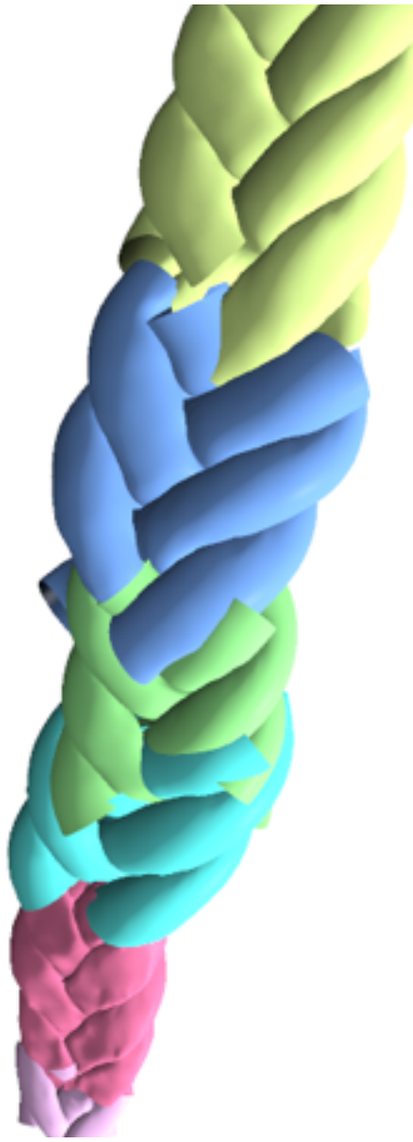
Structure Analysis

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

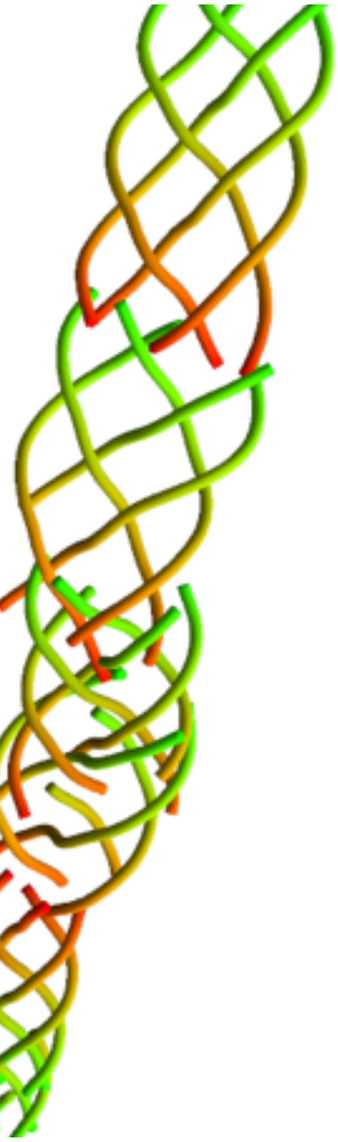


Input mesh | Candidate patches | Labeling result | Selected patches

Structure Analysis

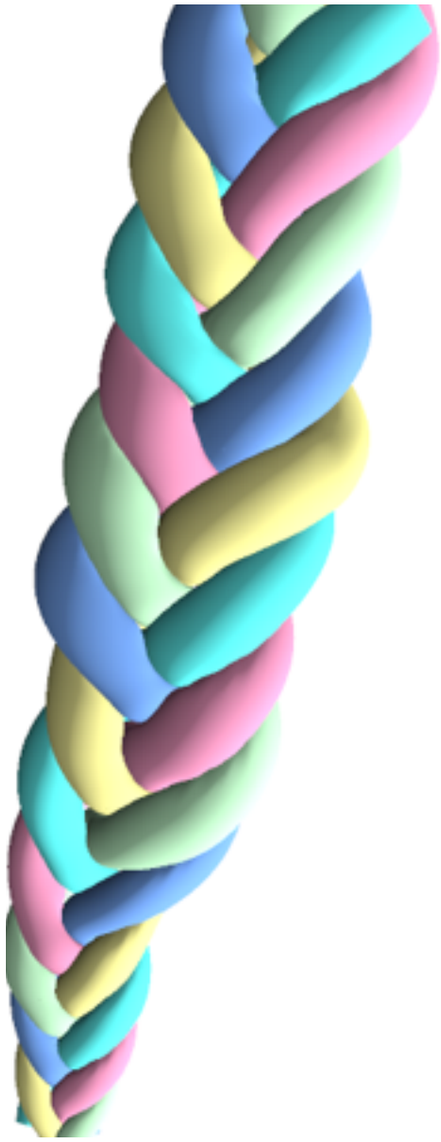


Selected patches

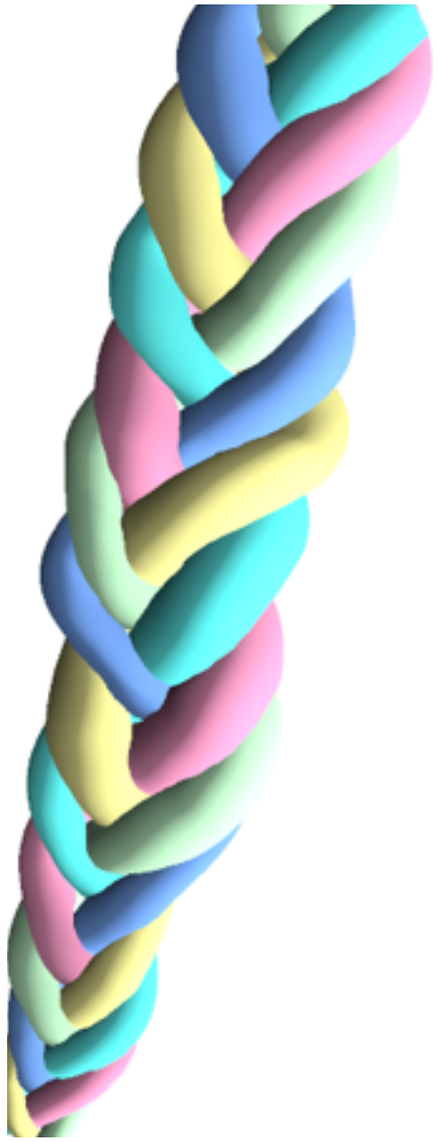


Extracted centerlines

Connected centerlines

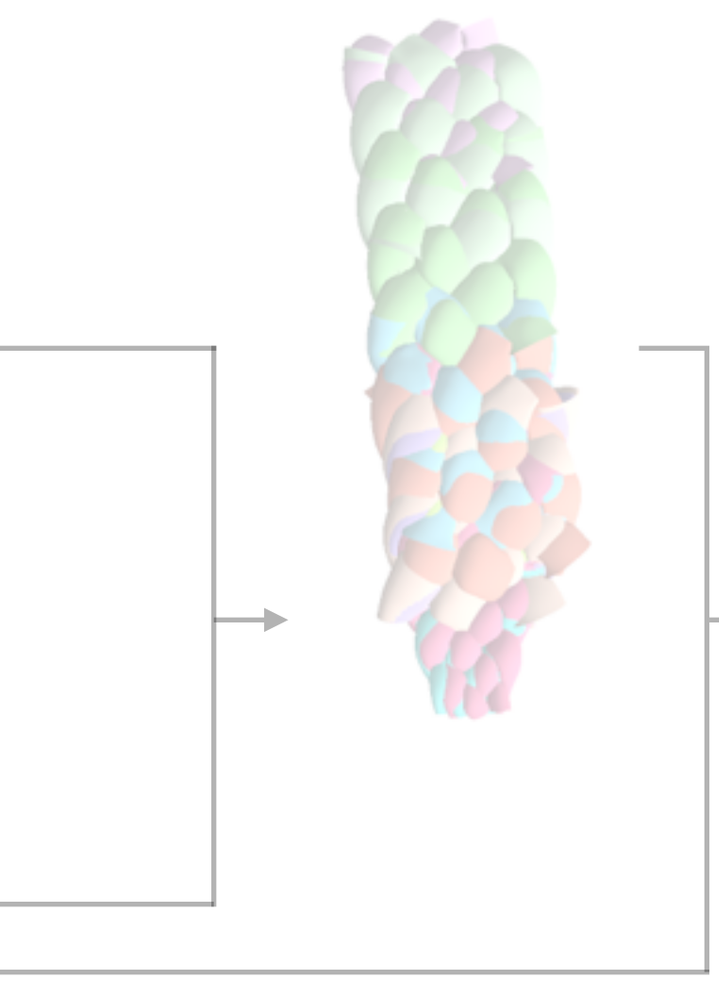


Expanded mesh



Refined result

Strand Synthesis



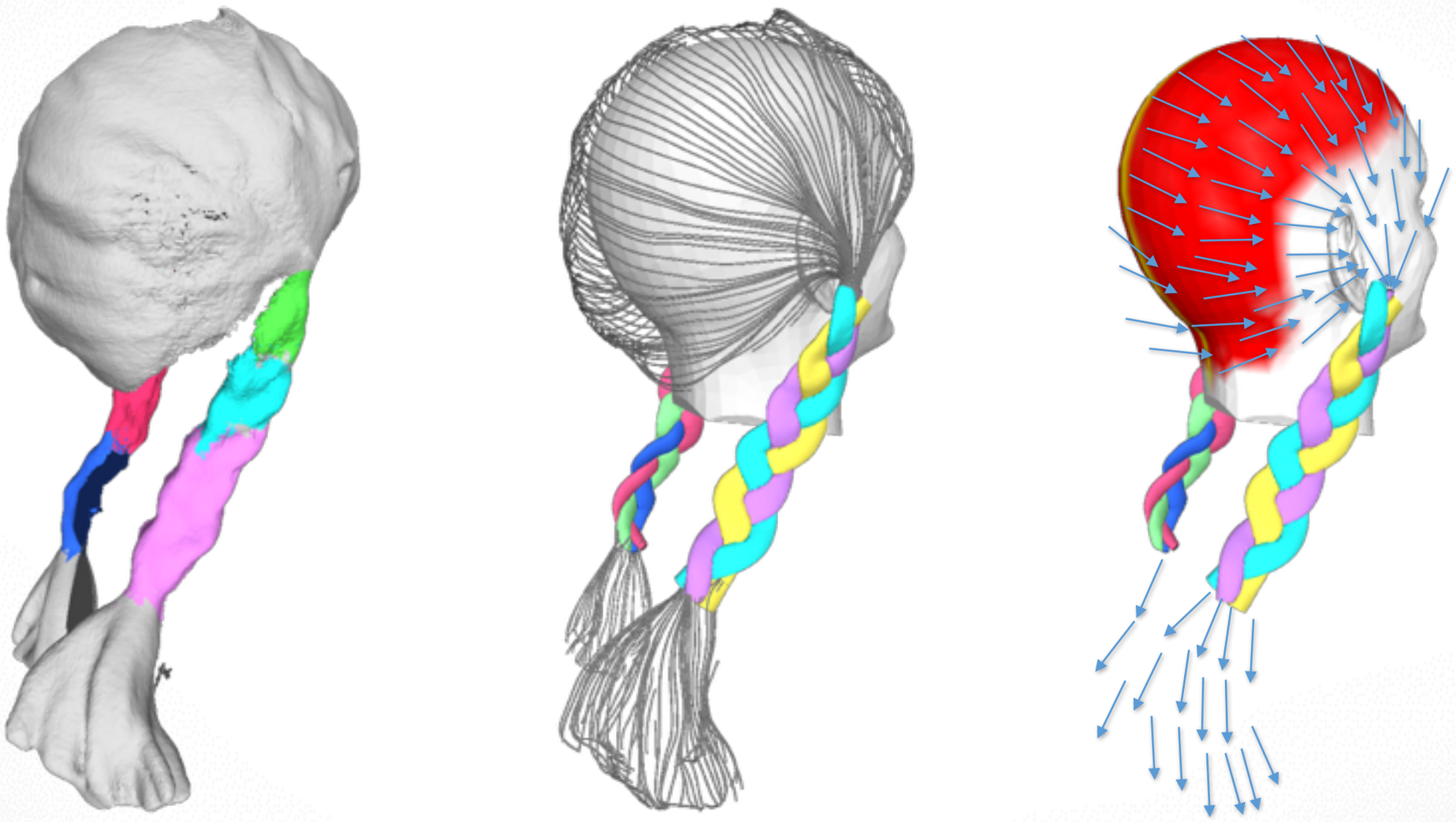
Fitting result

Labeling result

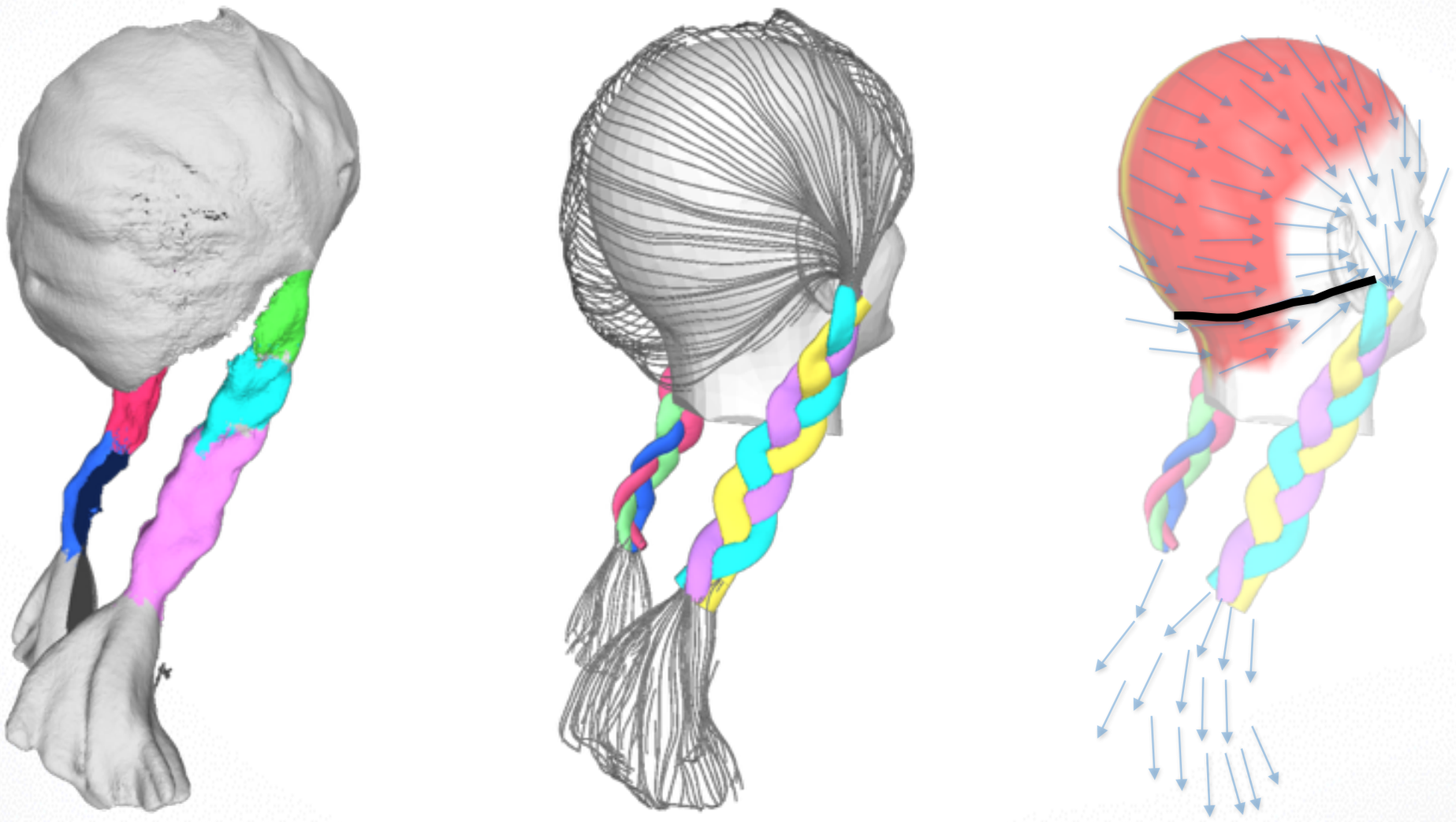
Extracted structure

Output strands

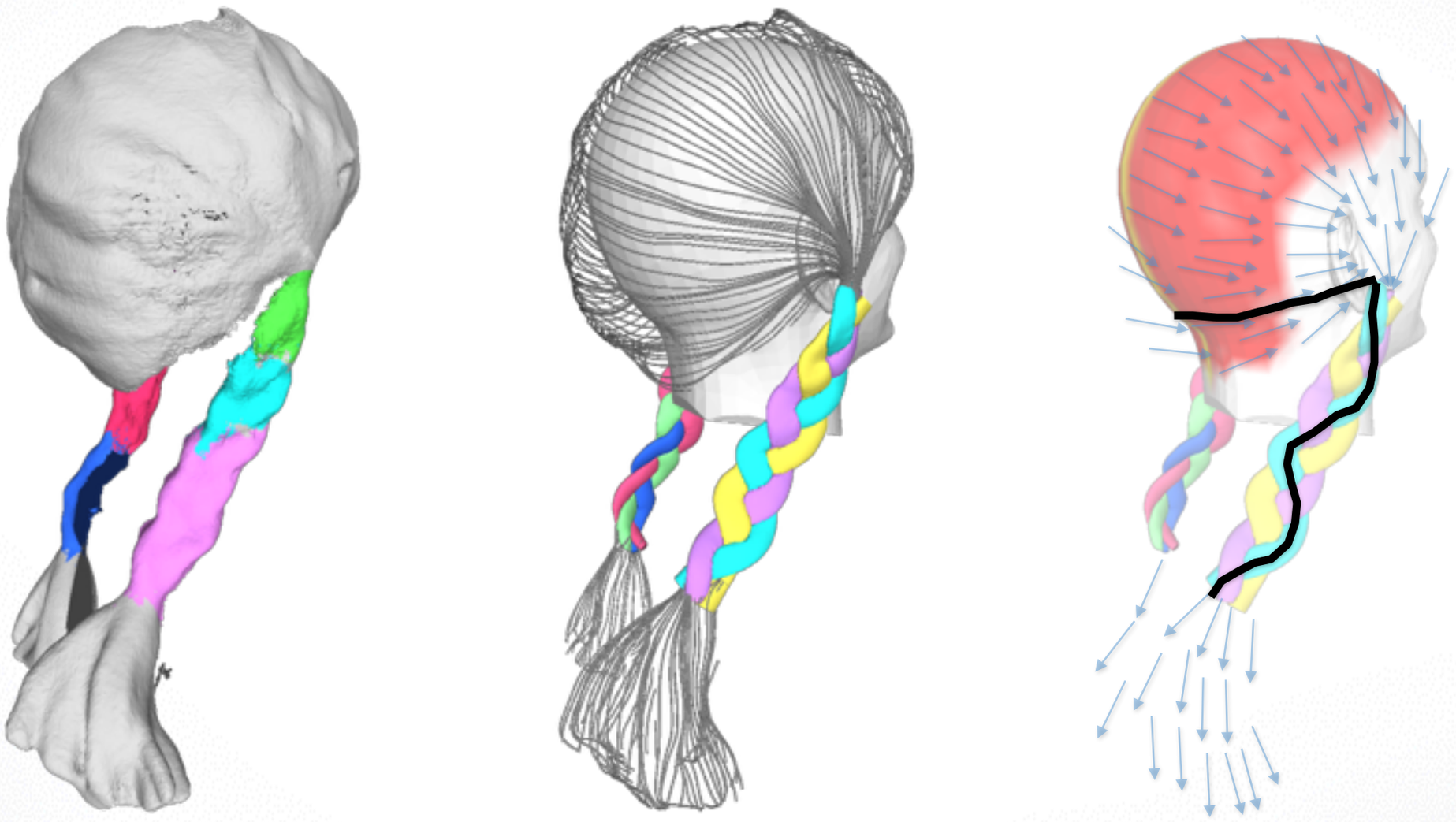
Strand Synthesis



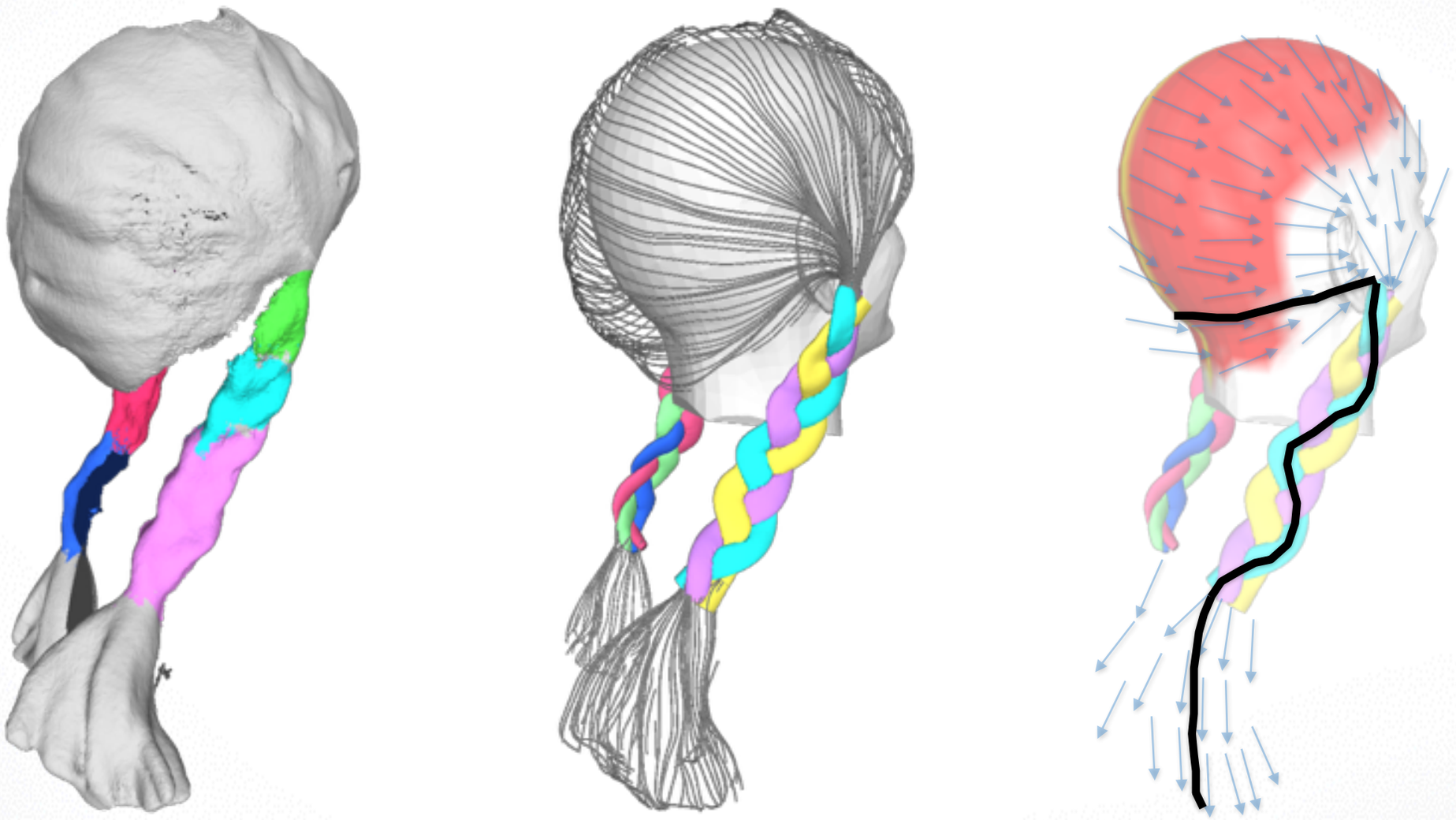
Strand Synthesis



Strand Synthesis



Strand Synthesis



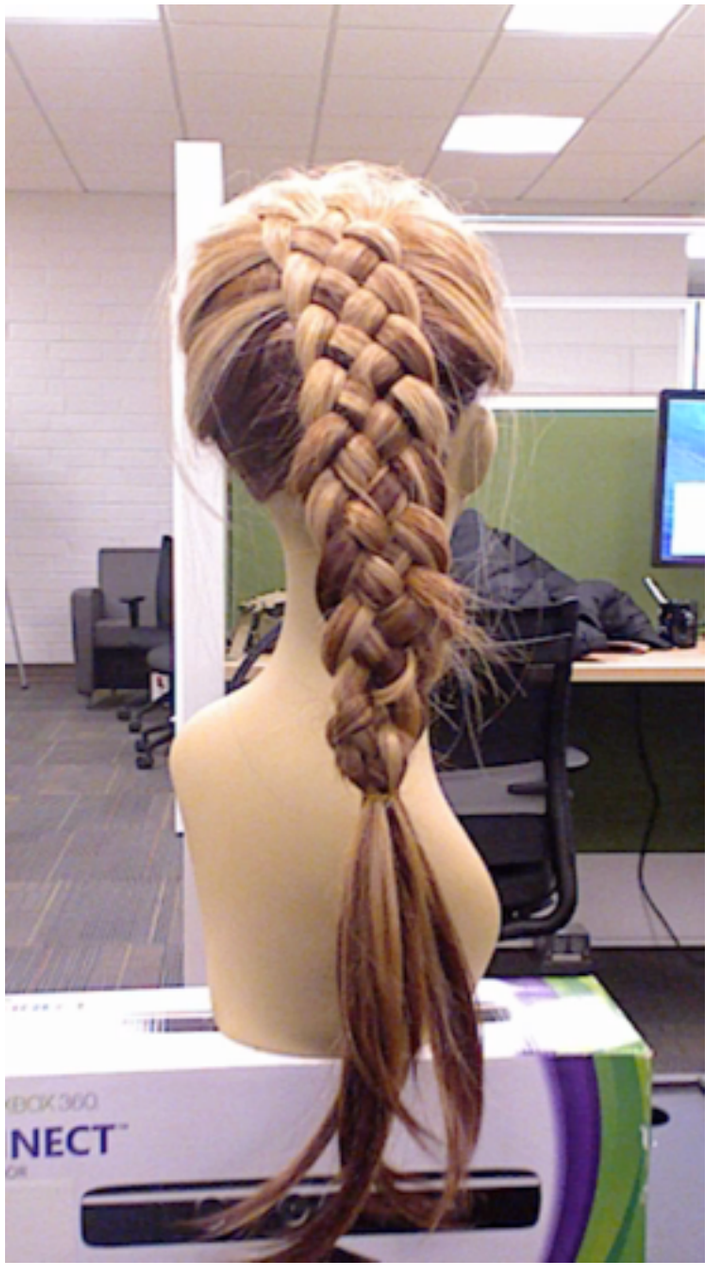
Strand Synthesis

Perlin Noise for strand variation [Choe and Ko 2005]

Without fuzziness

With fuzziness

Results: Five-strand Dutch Braid



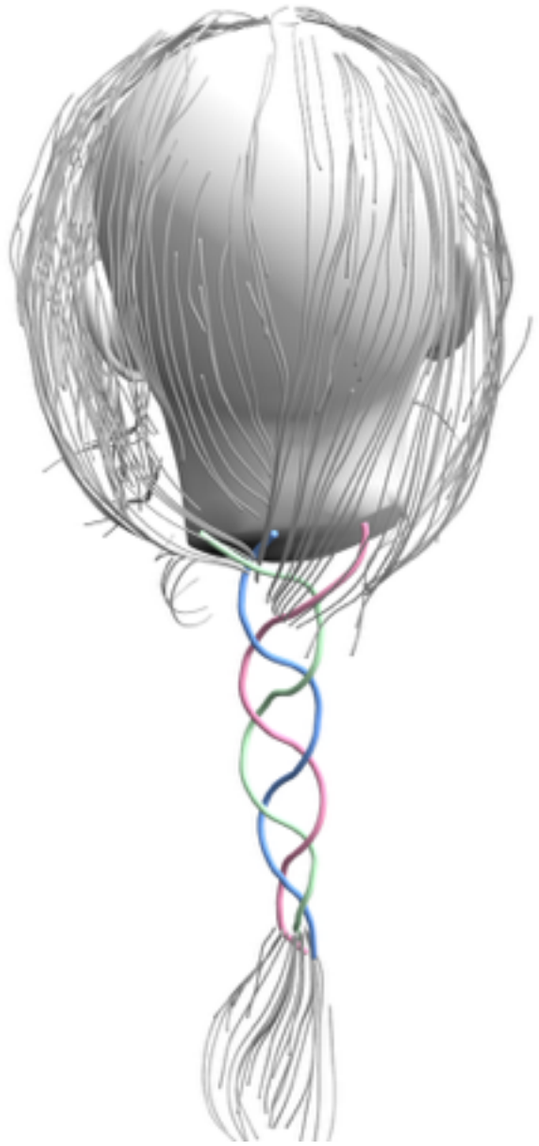
Reference photos

Extracted structure

Output strands

Results: Basic Braid

Reference photos

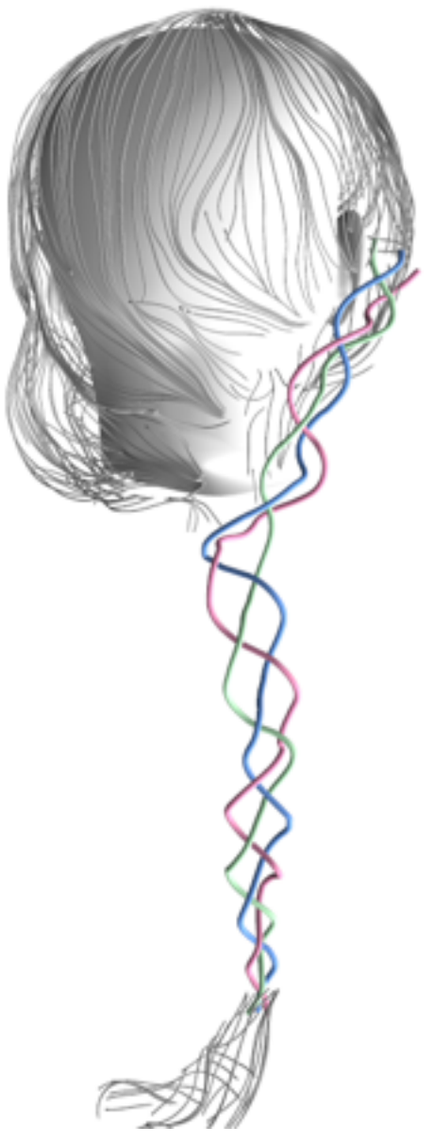


Extracted structure

Output strands

Results: French Braid

Reference photos

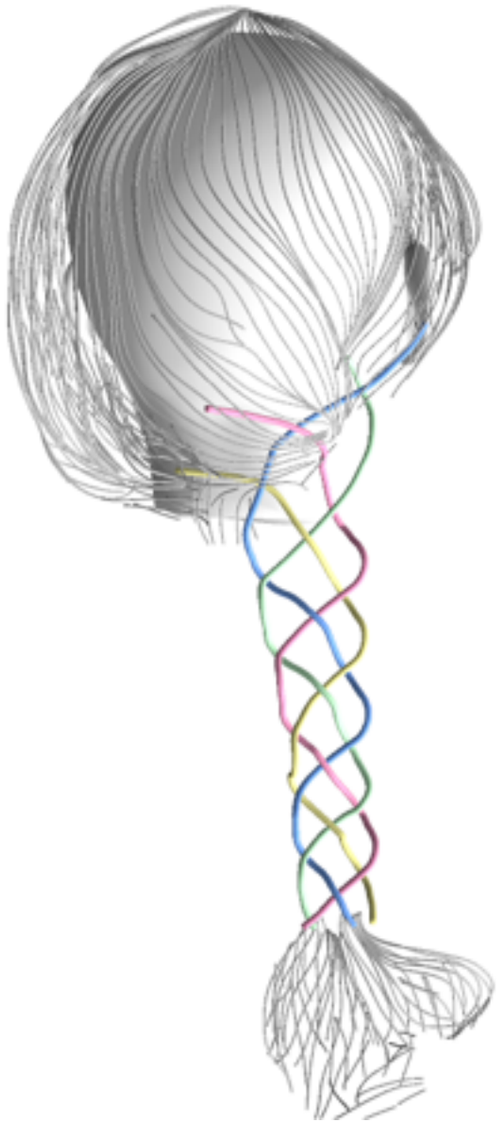


Extracted structure

Output strands

Results: Four-strand Braid

Reference photos

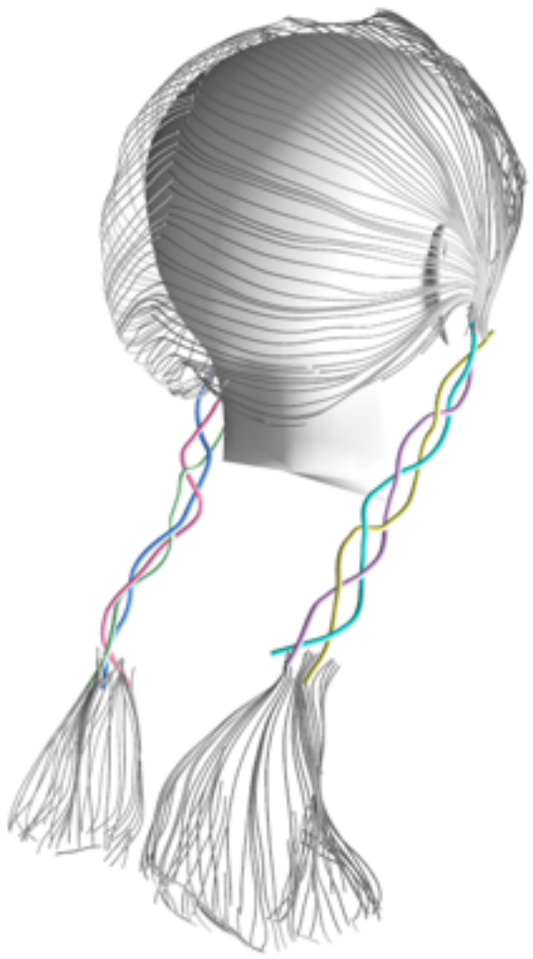


Extracted structure

Output strands

Results: Two Basic Braids

Reference photos

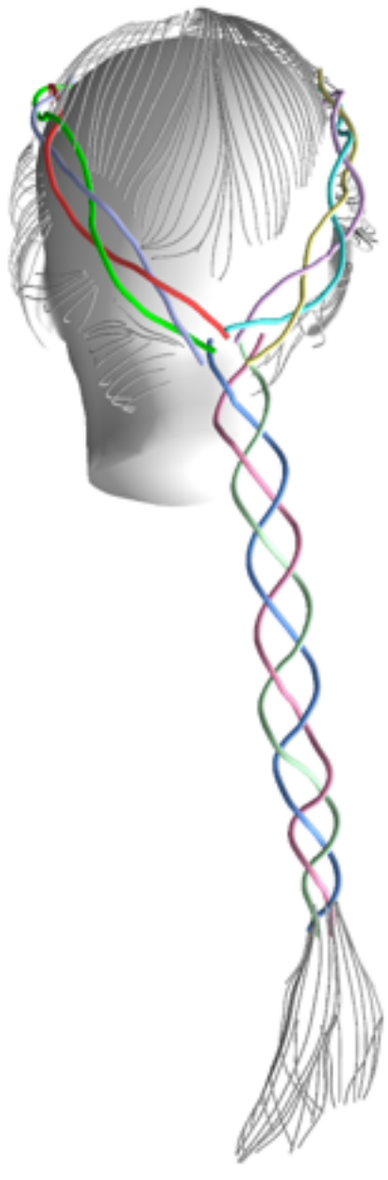


Extracted structure

Output strands

Results: Princess Anne Braid

Reference photos



Extracted structure

Output strands

“It's not who has the best algorithm that wins. It's who has the most data.”

Andrew Ng

Literature

- Mitra et al. “Structure-Aware Shape Processing”, Eurographics State-of-the-Art Report (STAR), 2013.

- Mitra et al. “Symmetry in 3D Geometry: Extraction and Applications”, Eurographics State-of-the-Art Report (STAR), 2012.

- van Kaick et al. “A Survey on Shape Correspondence”, Eurographics State-of-the-Art Report (STAR), 2010.

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Thanks!