Real-time Facial Animation

Hao Li
ILM

Mark Pauly
EPFL

High-End 3D Scanning

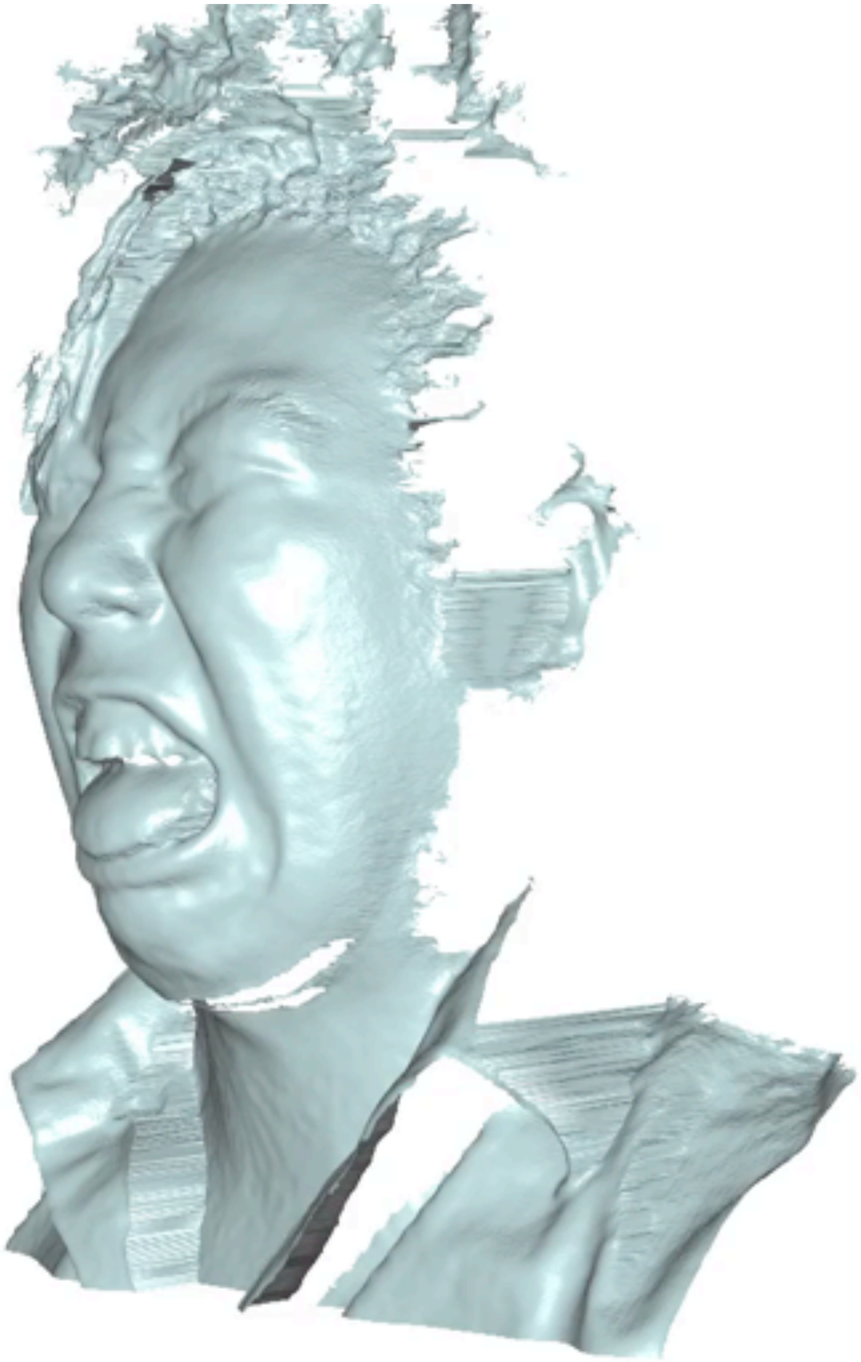
High-End 3D Scanning

Low-Cost Passive Scanning (AGI soft)

stereo pair

Low-Cost Passive Scanning (AGI soft)

stereo pair



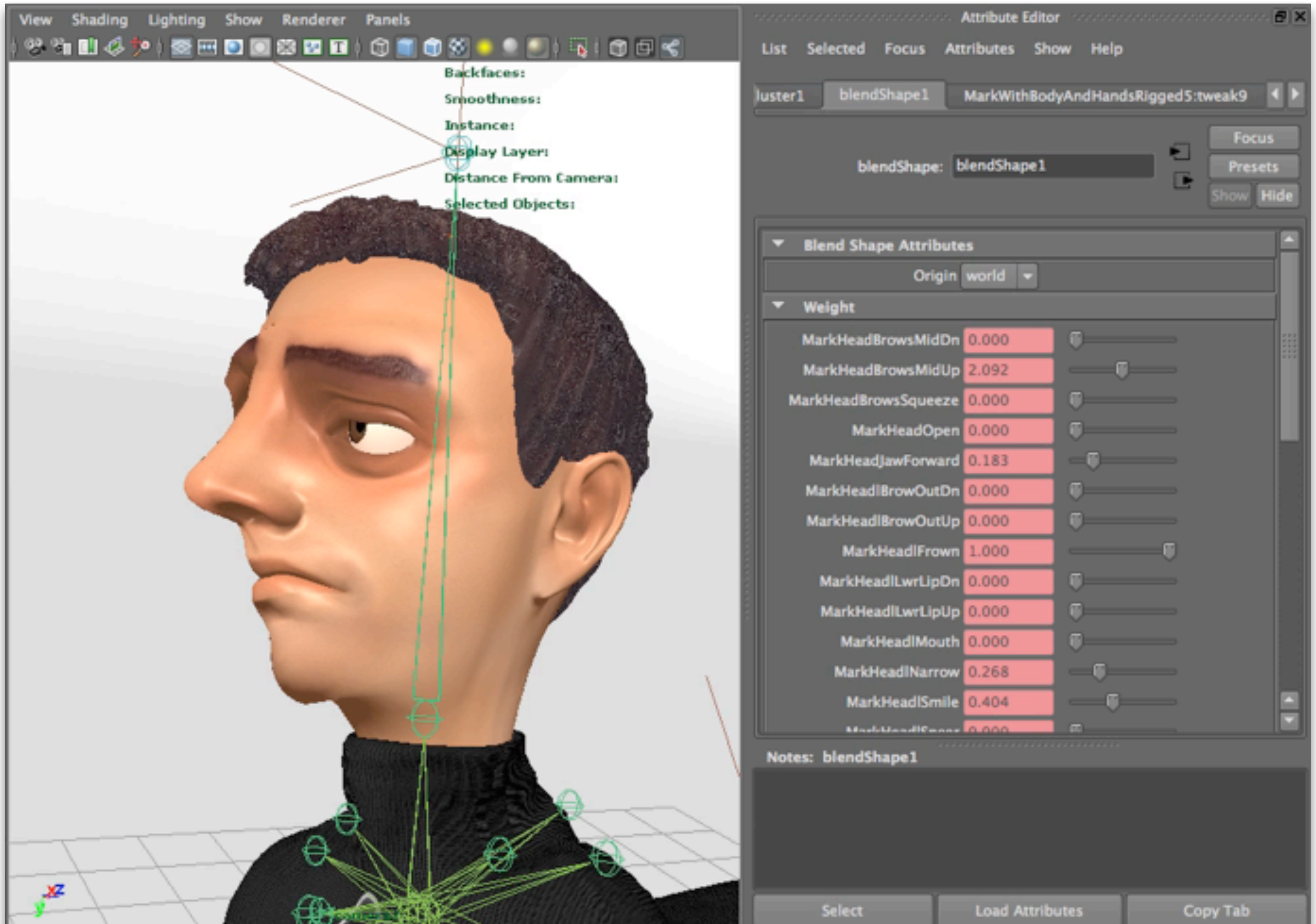
3D scan

Low-Cost Active Scanning + Temporal Upsampling

Microsoft Kinect & Kinect Fusion

Rigging & Animation

Rigging & Animation



Typical Facial Animation Workflow in Industry

Typical Facial Animation Workflow in Industry

3D Scanning

Typical Facial Animation Workflow in Industry

3D Scanning → Modeling + Fitting

Typical Facial Animation Workflow in Industry

3D Scanning → Modeling + Fitting → Light-weight Rigging

Typical Facial Animation Workflow in Industry

3D Scanning → Modeling + Fitting → Light-weight Rigging → Motion Capture

Typical Facial Animation Workflow in Industry

3D Scanning → Modeling + Fitting → Light-weight Rigging → Motion Capture → Cleanup & Key-Framing

Typical Facial Animation Workflow in Industry

3D Scanning → Modeling + Fitting → Light-weight Rigging → Motion Capture → Cleanup & Key-Framing

Modeling

Typical Facial Animation Workflow in Industry

3D Scanning → Modeling + Fitting → Light-weight Rigging → Motion Capture → Cleanup & Key-Framing

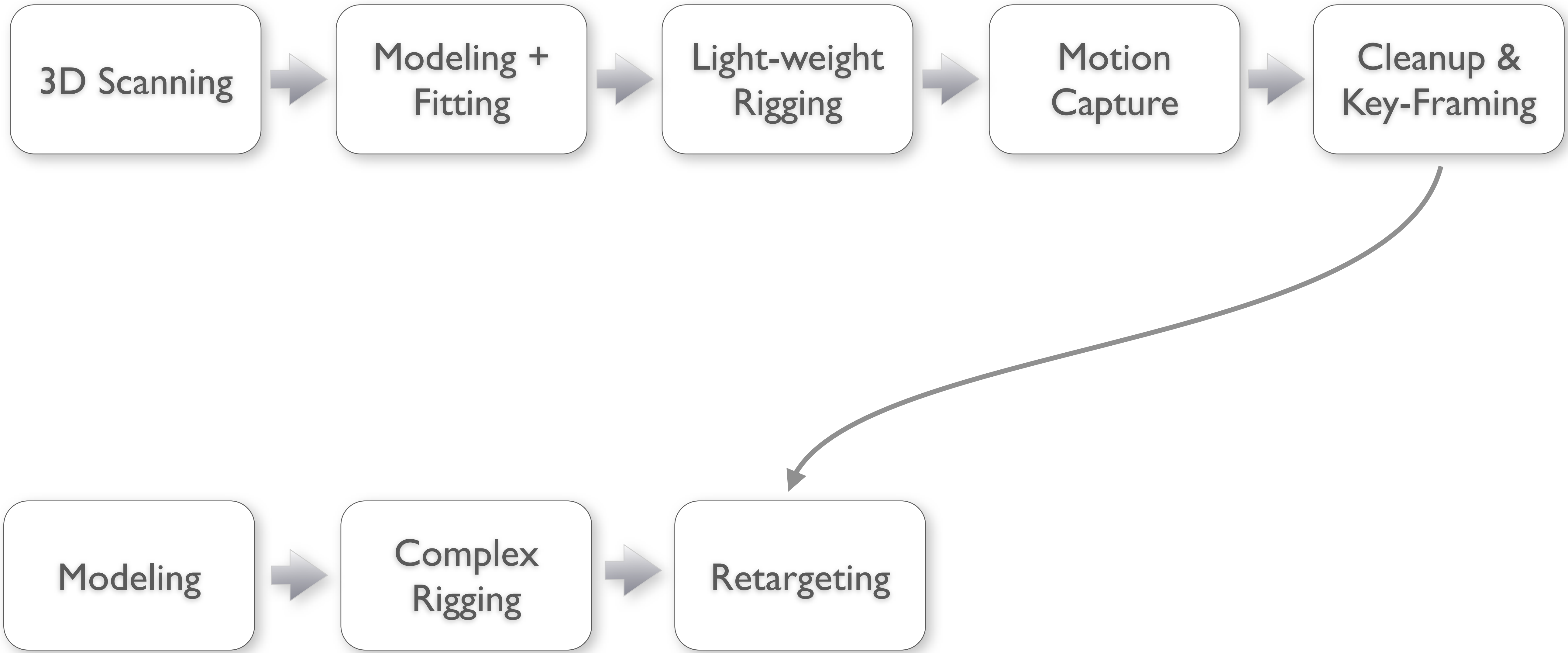
Modeling → Complex Rigging

Typical Facial Animation Workflow in Industry

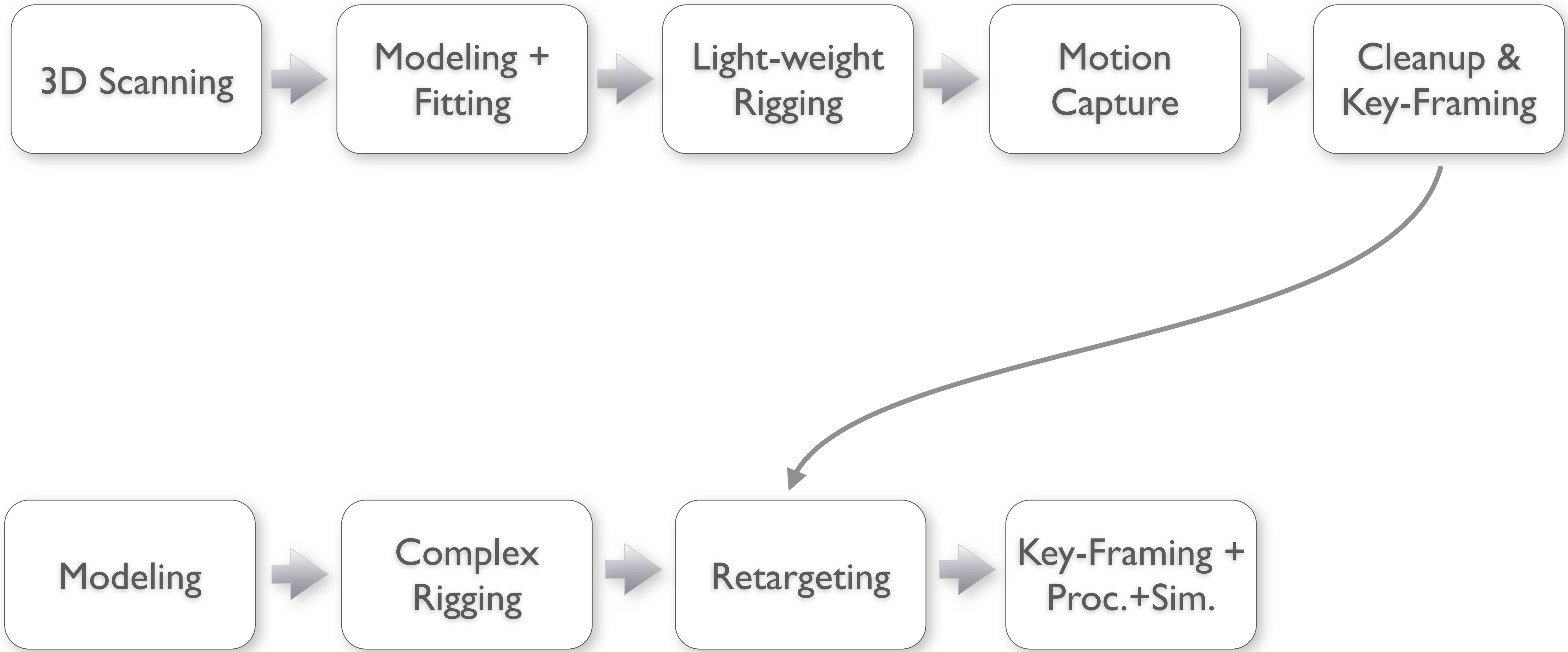
3D Scanning → Modeling + Fitting → Light-weight Rigging → Motion Capture → Cleanup & Key-Framing

Modeling → Complex Rigging → Retargeting

Typical Facial Animation Workflow in Industry



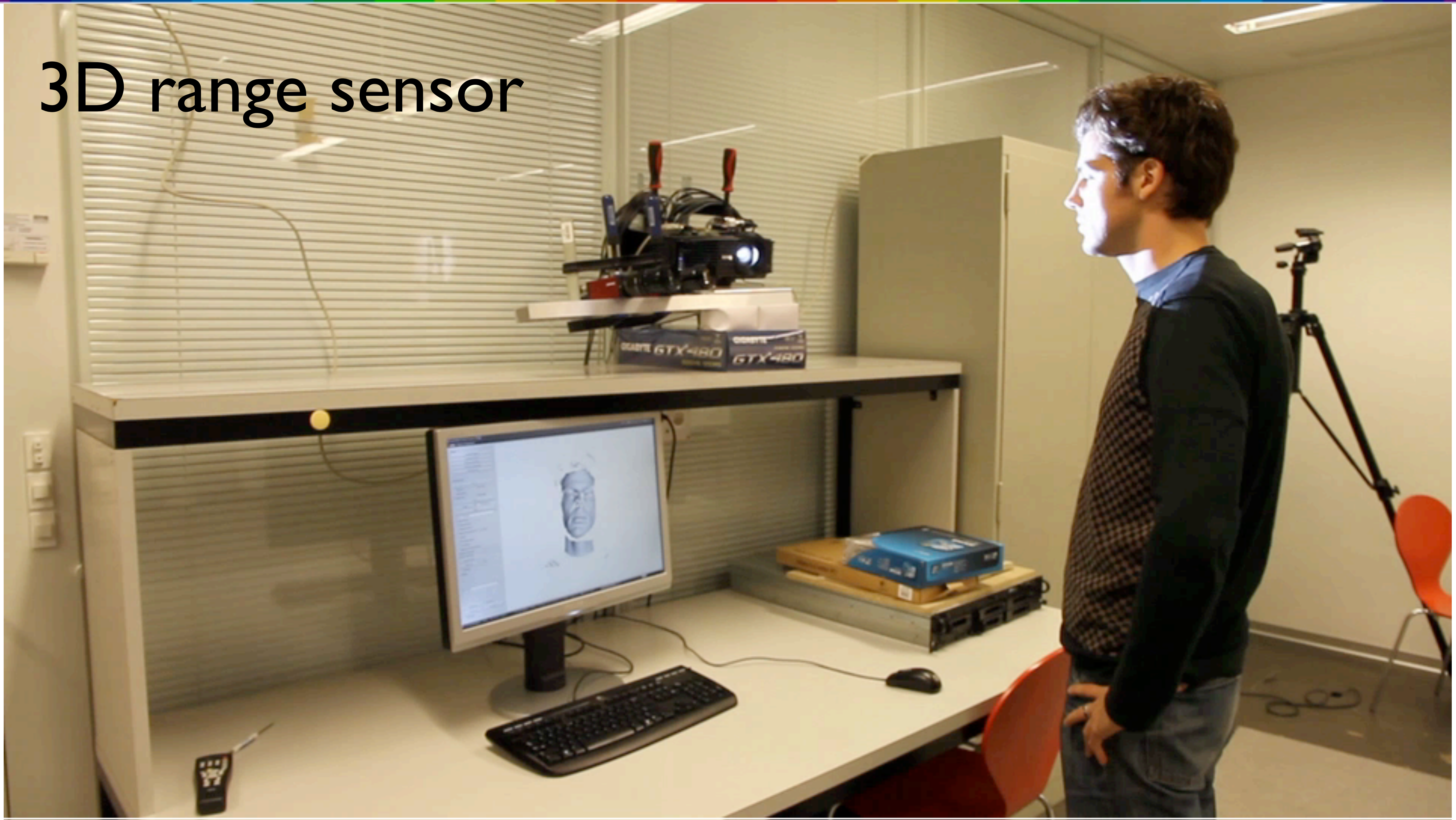
Typical Facial Animation Workflow in Industry



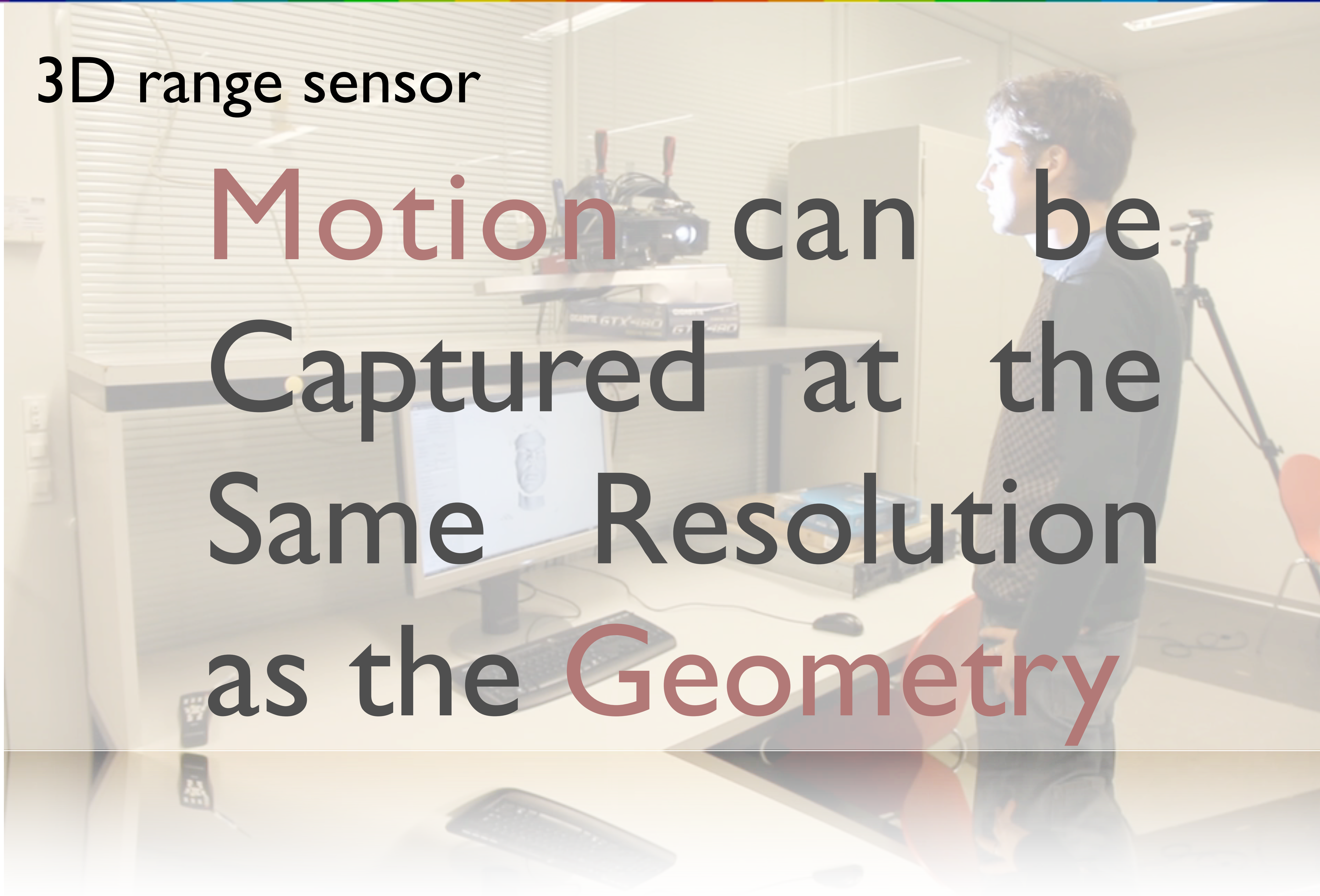
Markerless Facial Capture

3D range sensor

3D range sensor

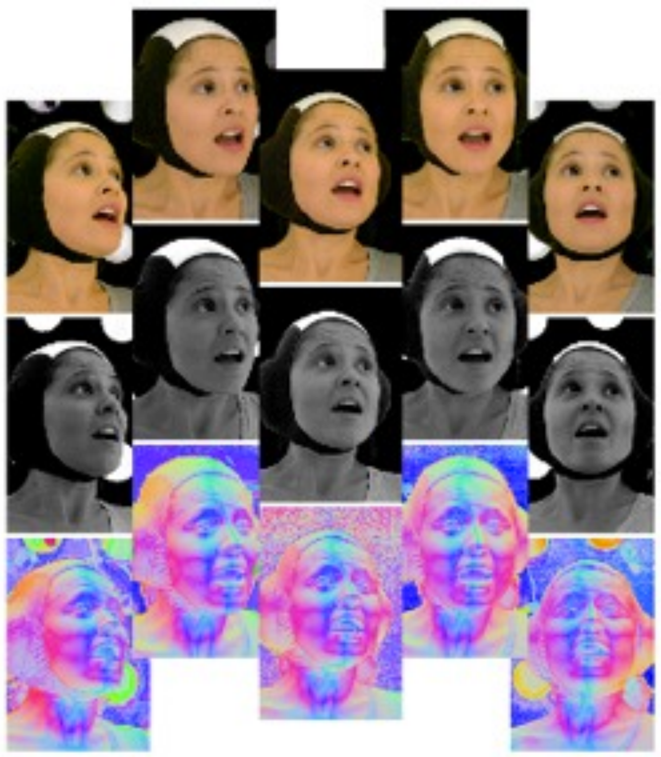


3D range sensor

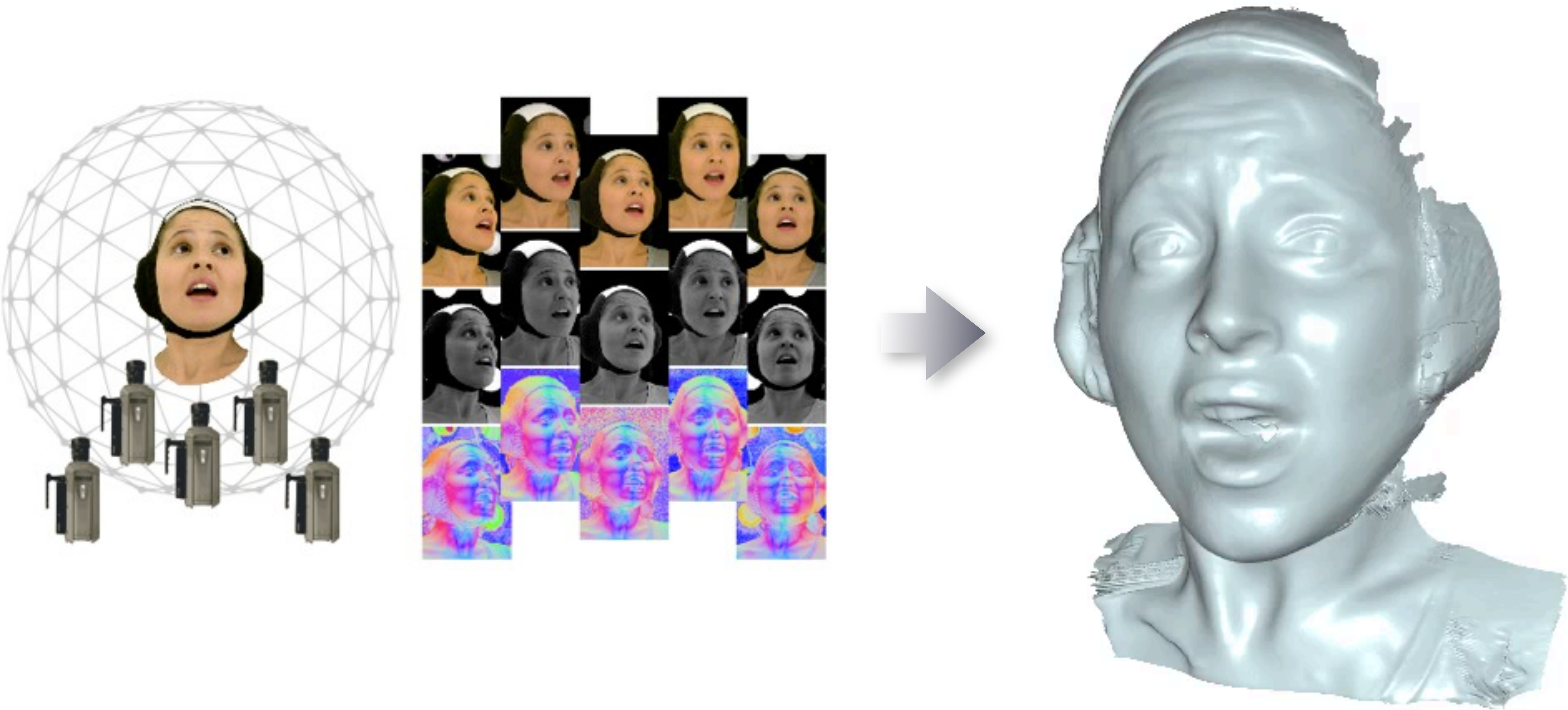


Motion can be Captured at the Same Resolution as the Geometry

USC ICT Light Stage 5

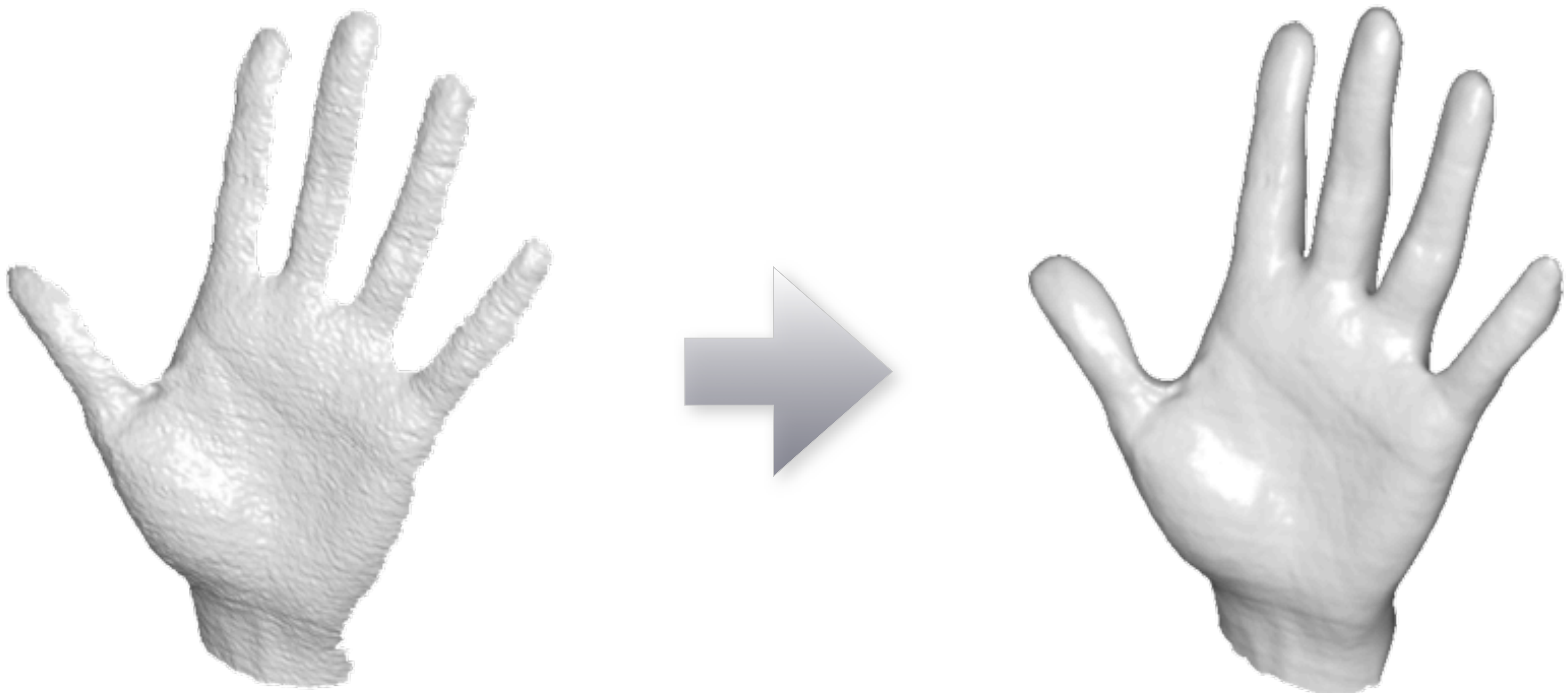


USC ICT Light Stage 5



Goal

Goal



Template-Based Tracking

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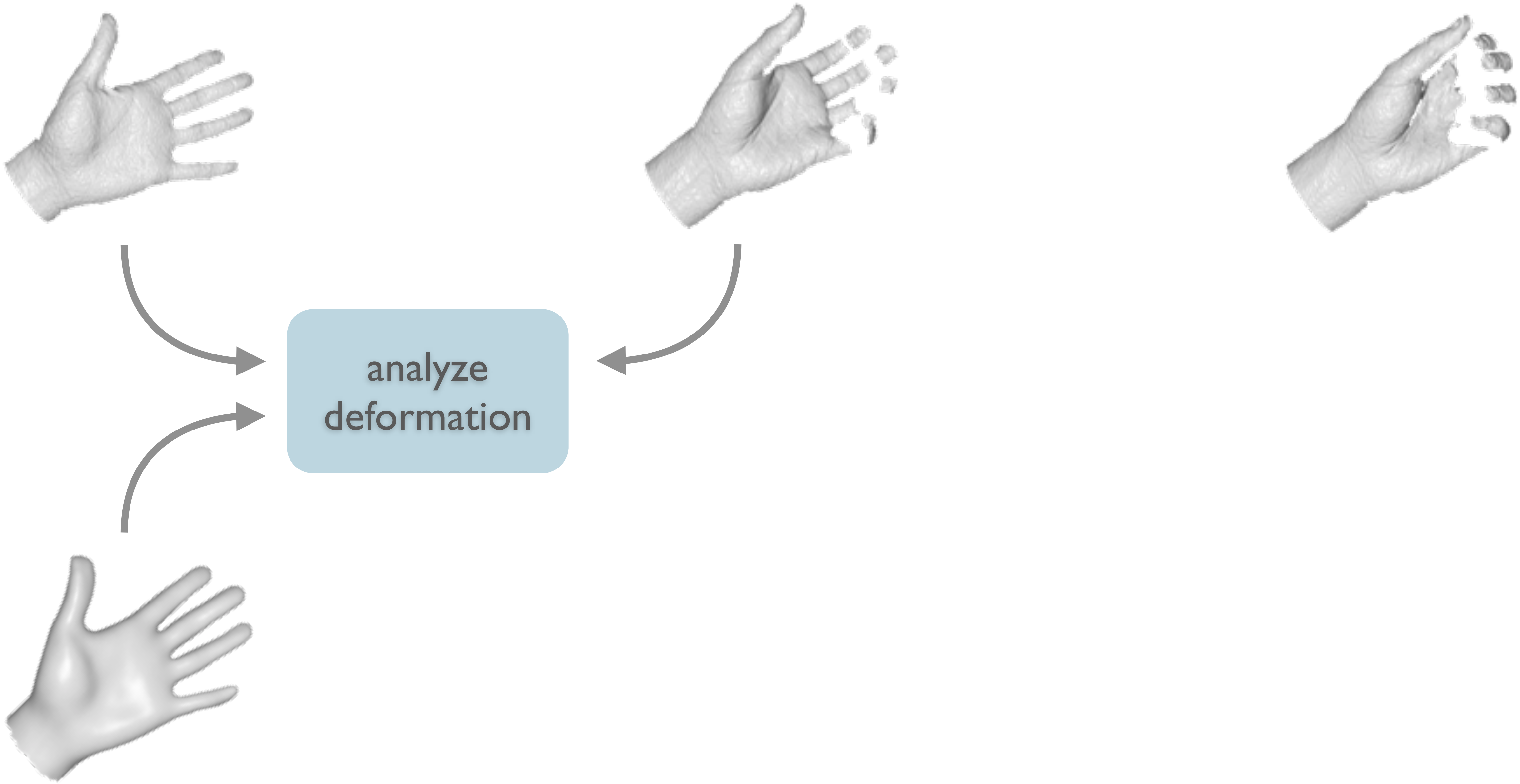

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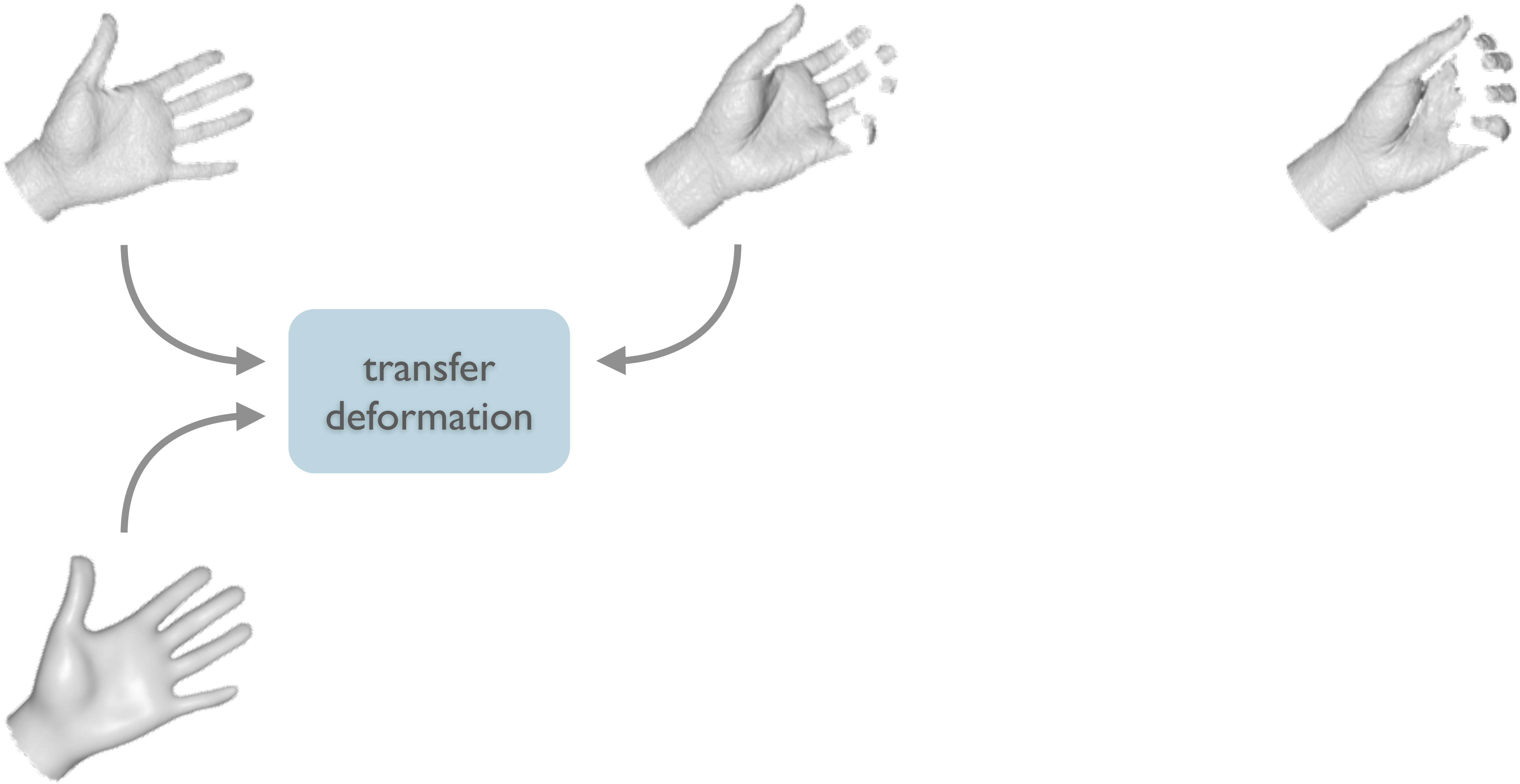

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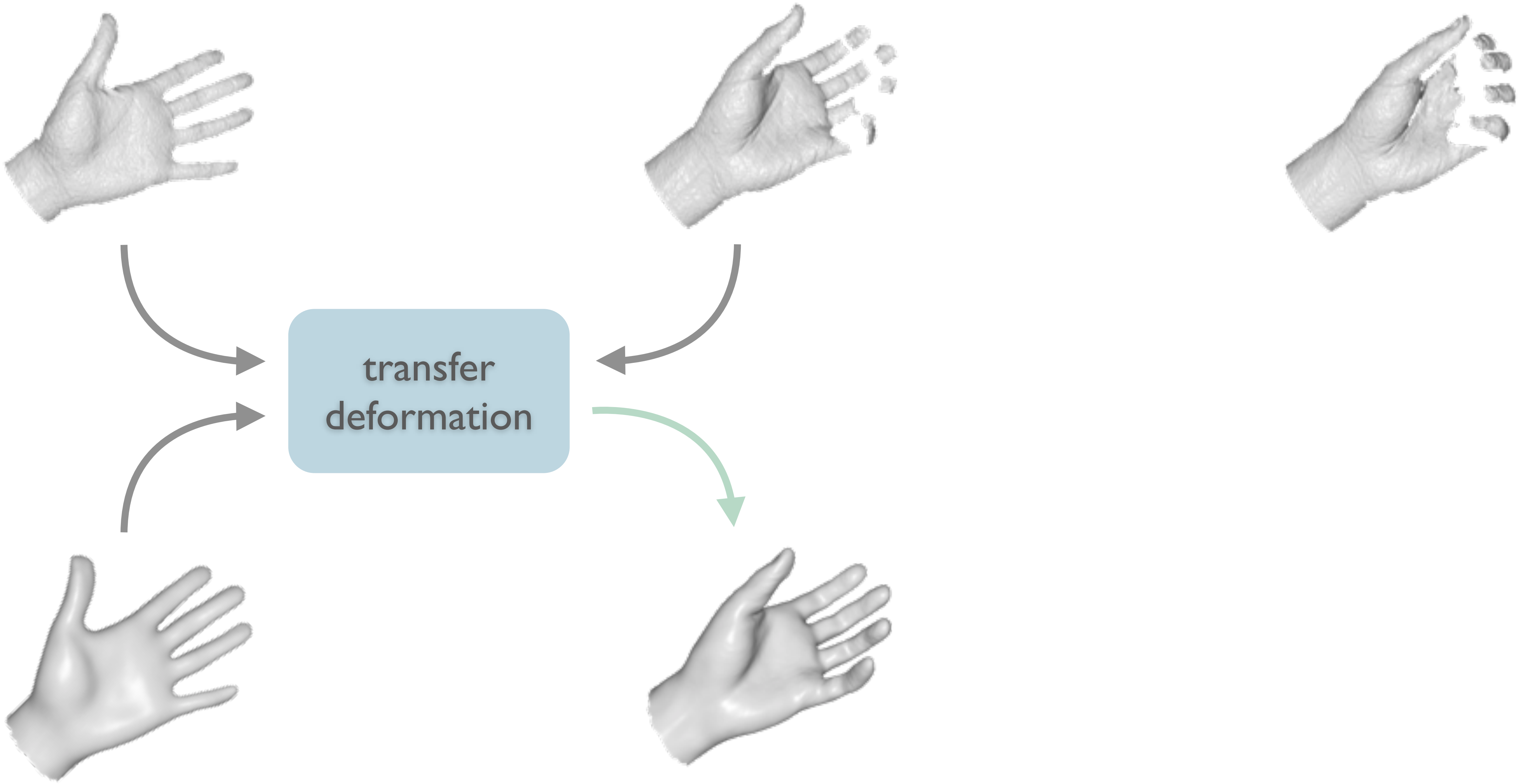

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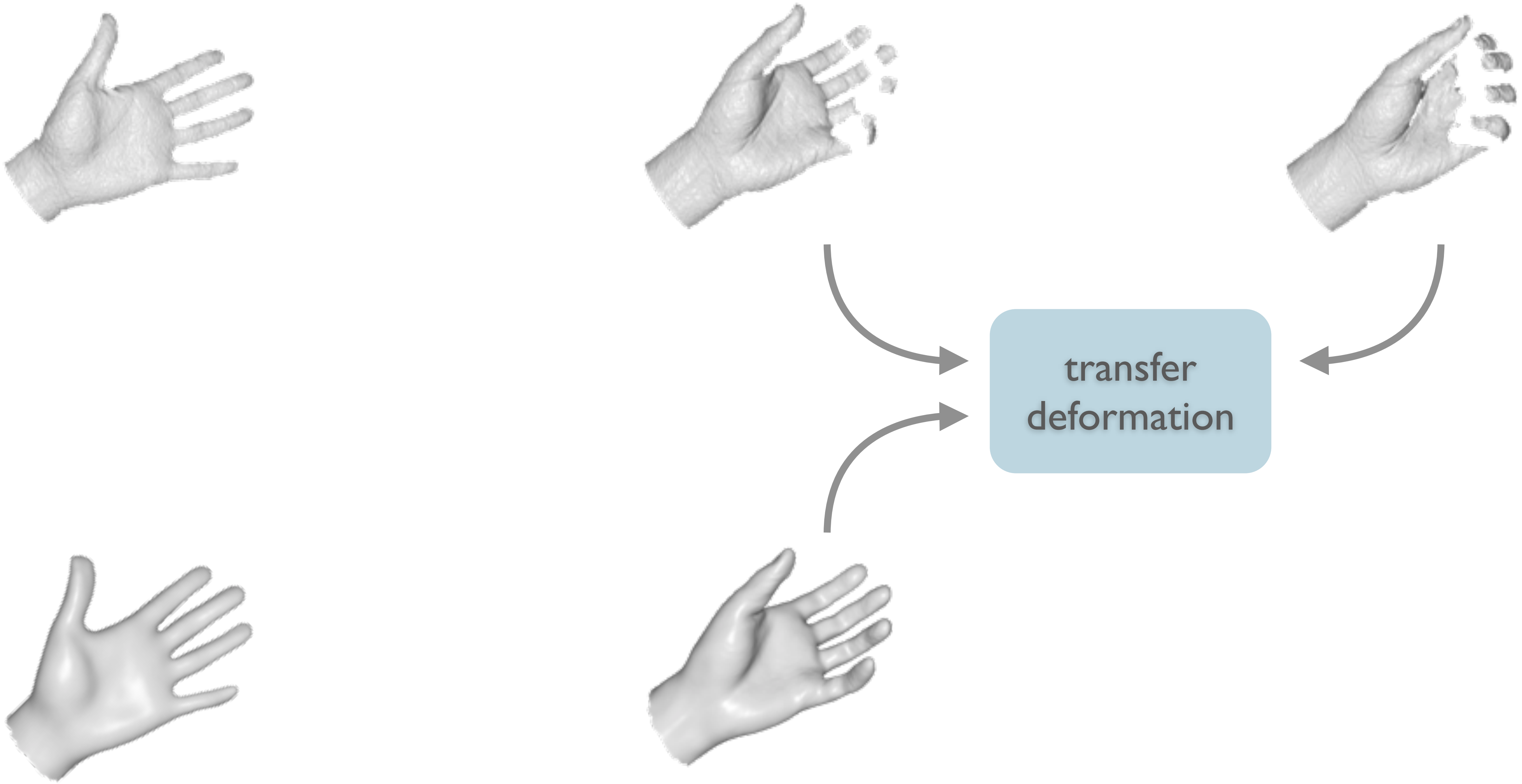

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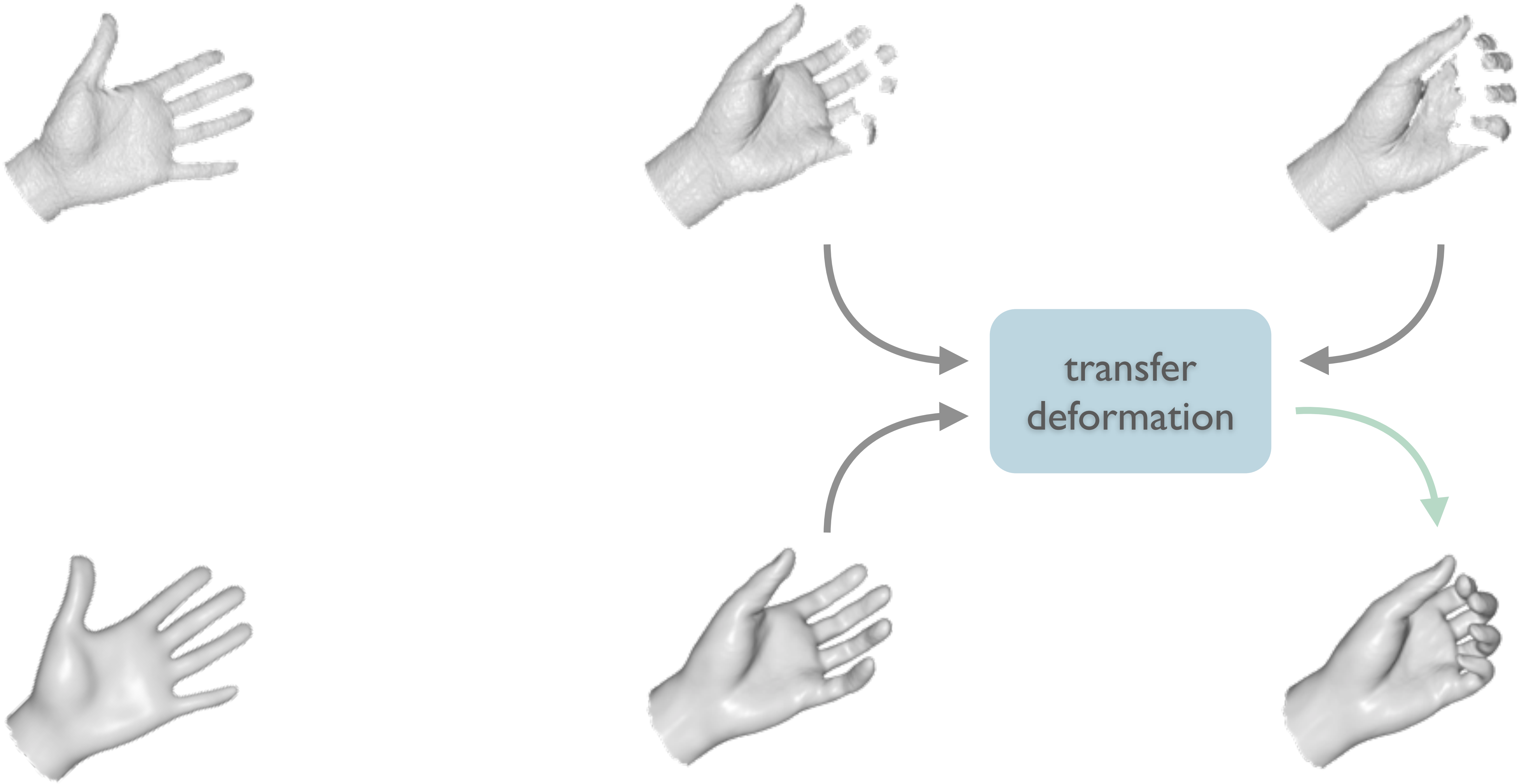

Correspondences Problem

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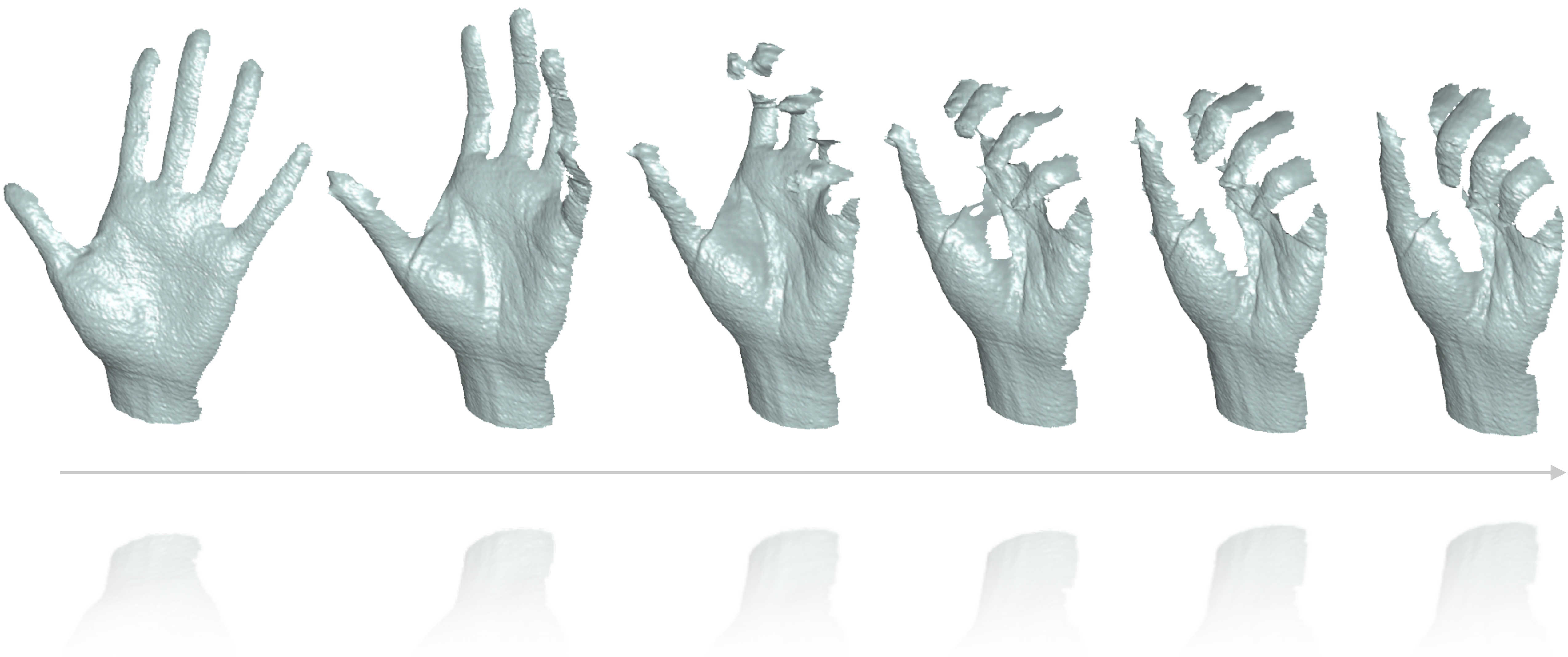

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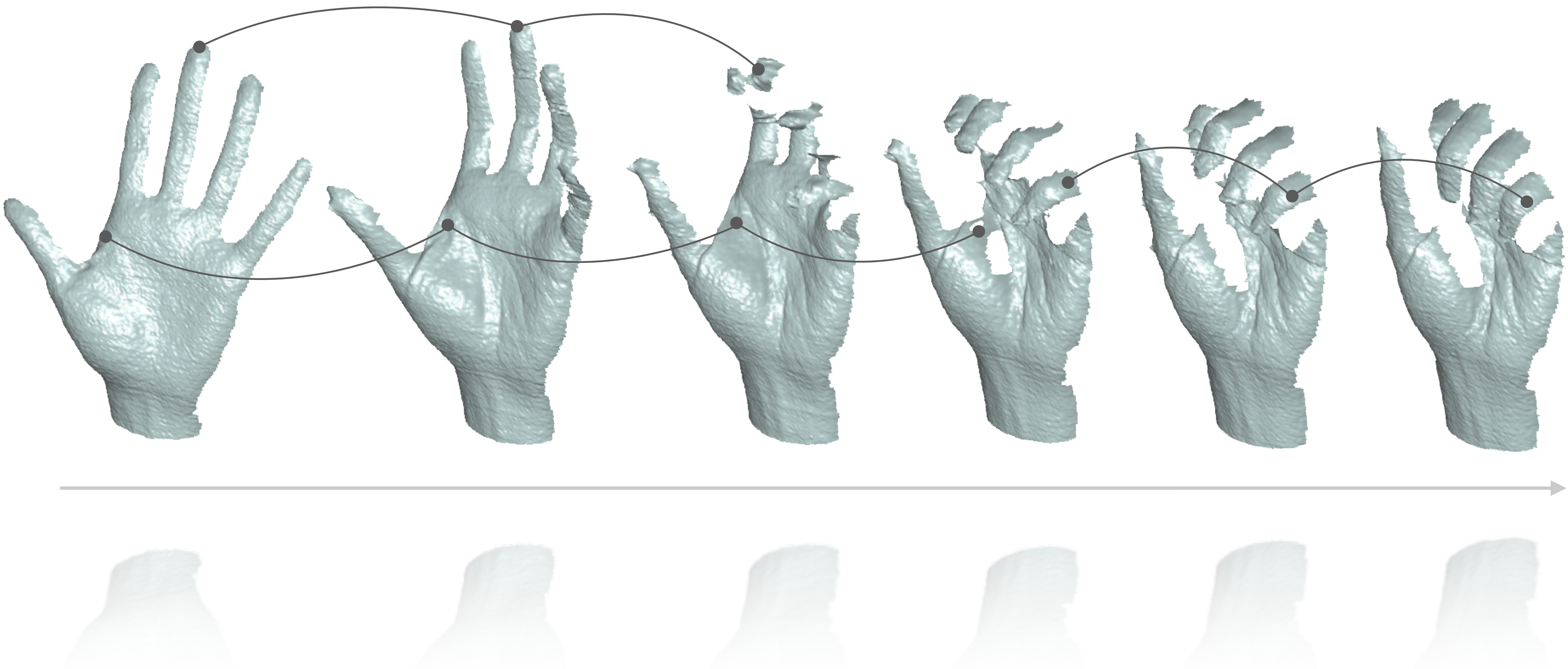

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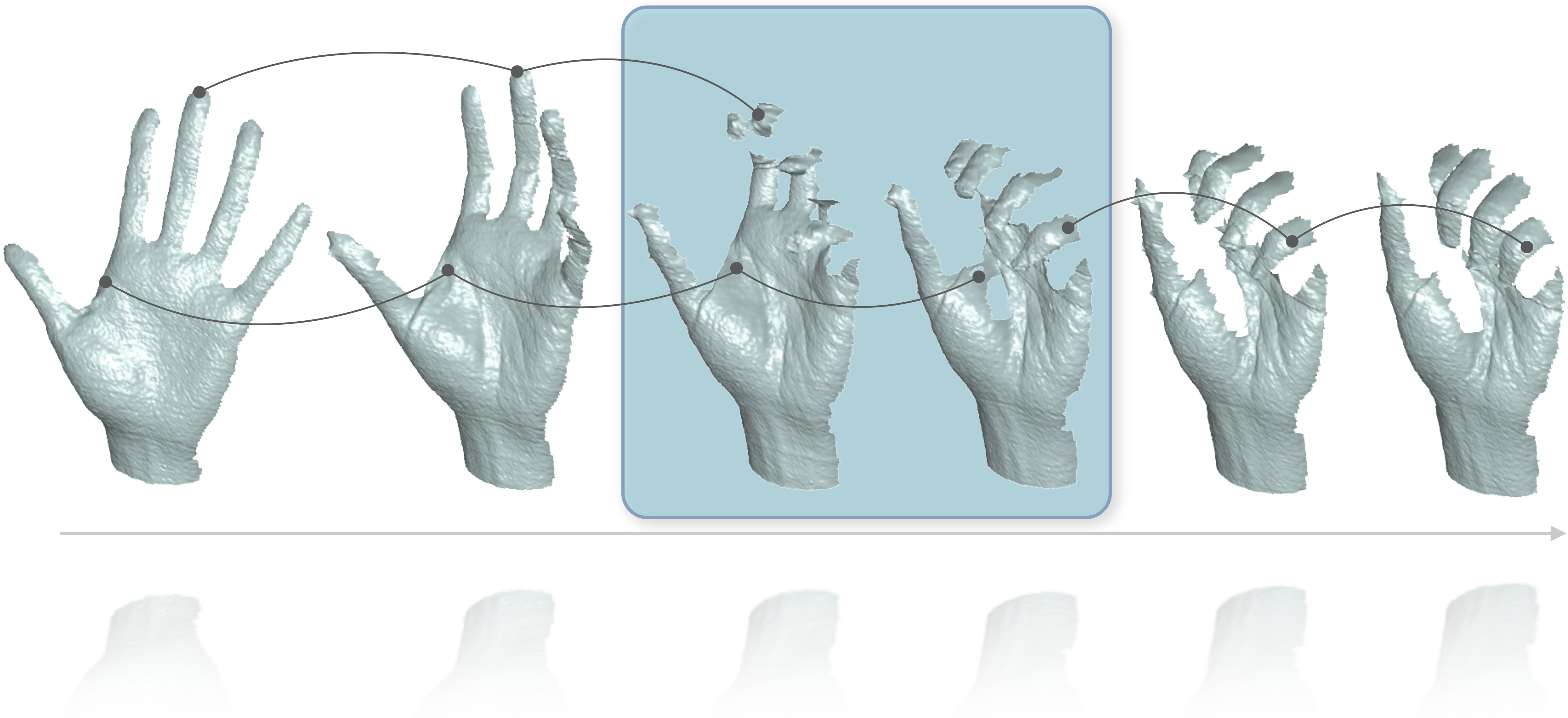
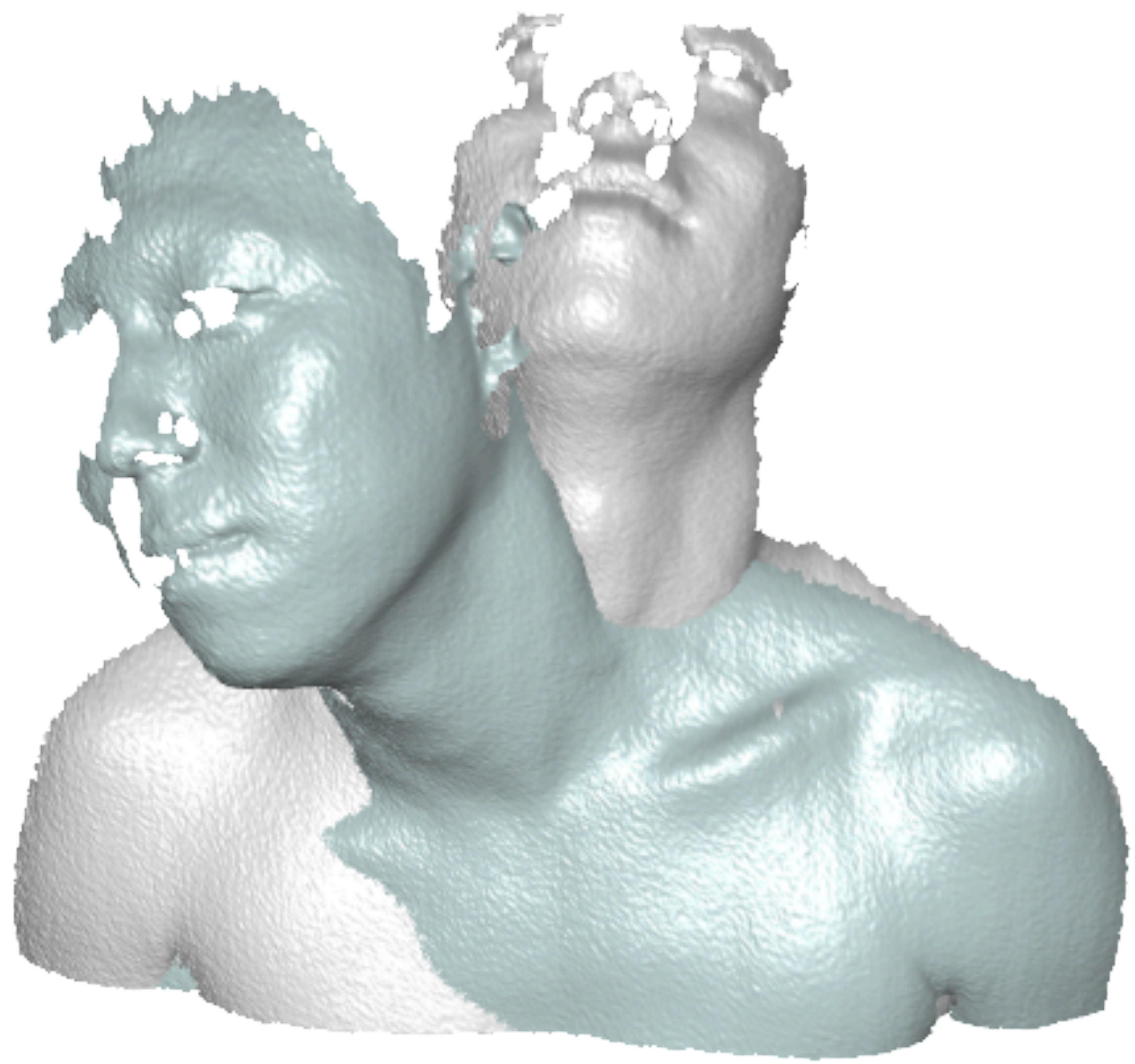


Non-Rigid Registration

Pair of 3D Scans



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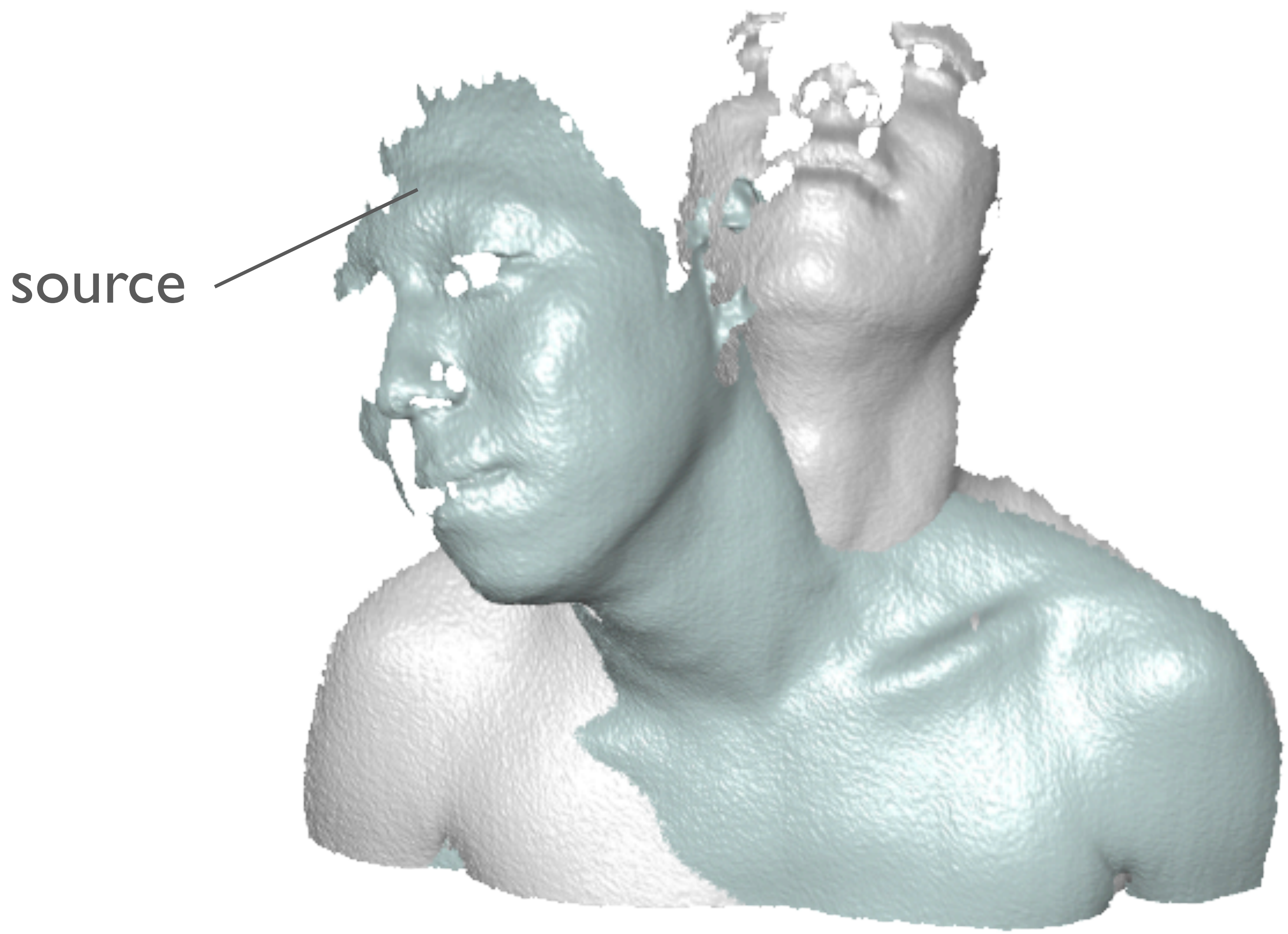
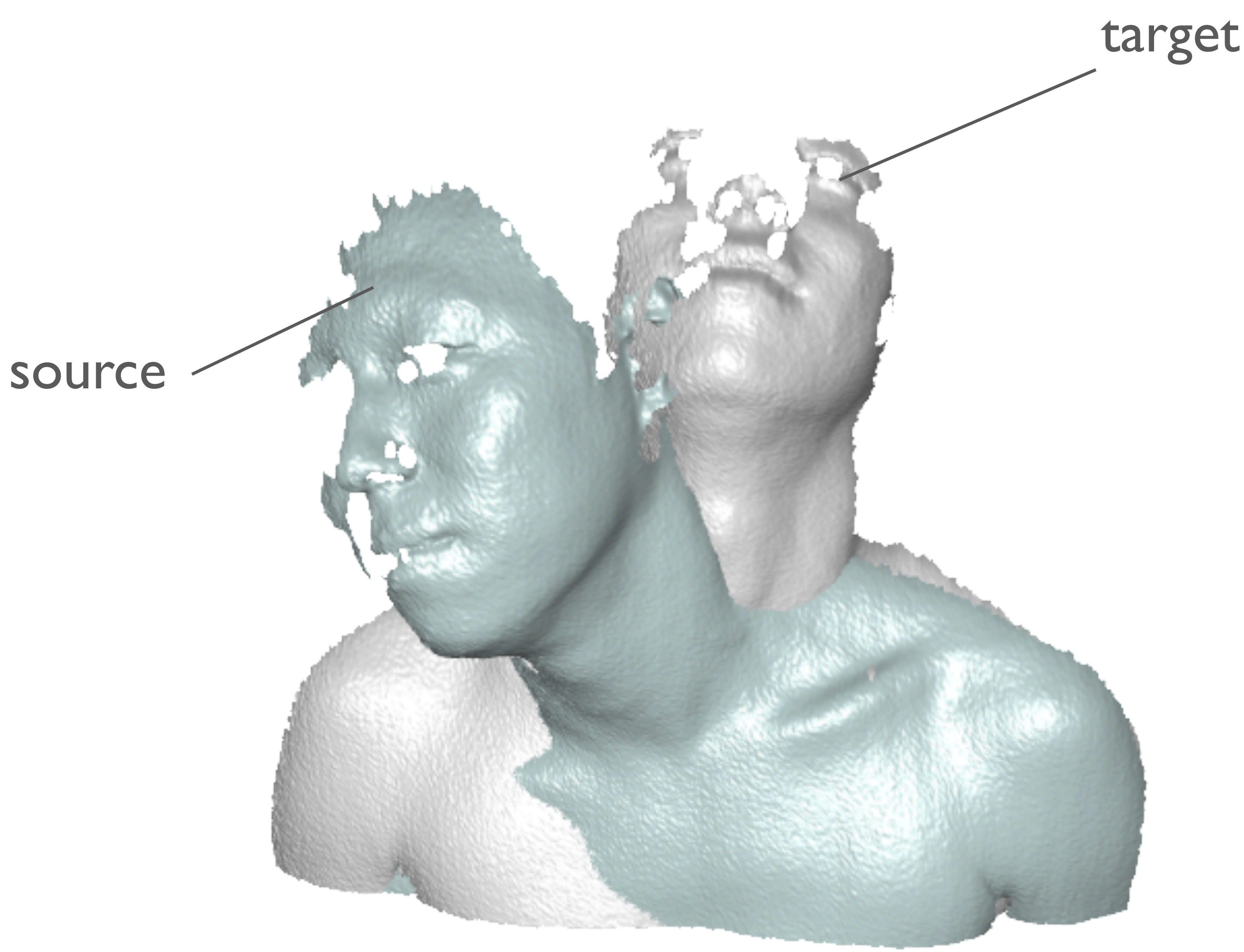
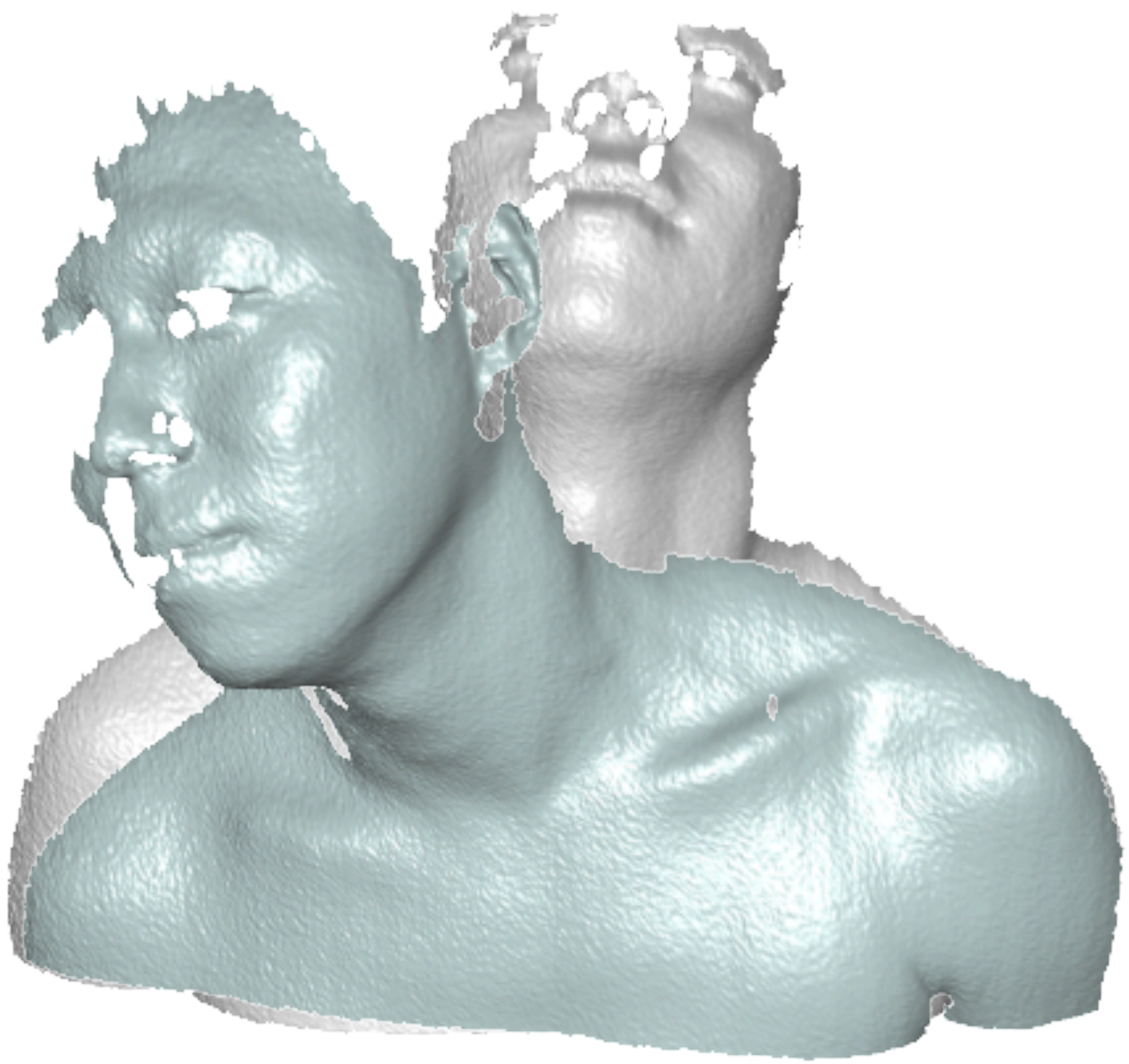


Pair of 3D Scans



Correspondences are Lost



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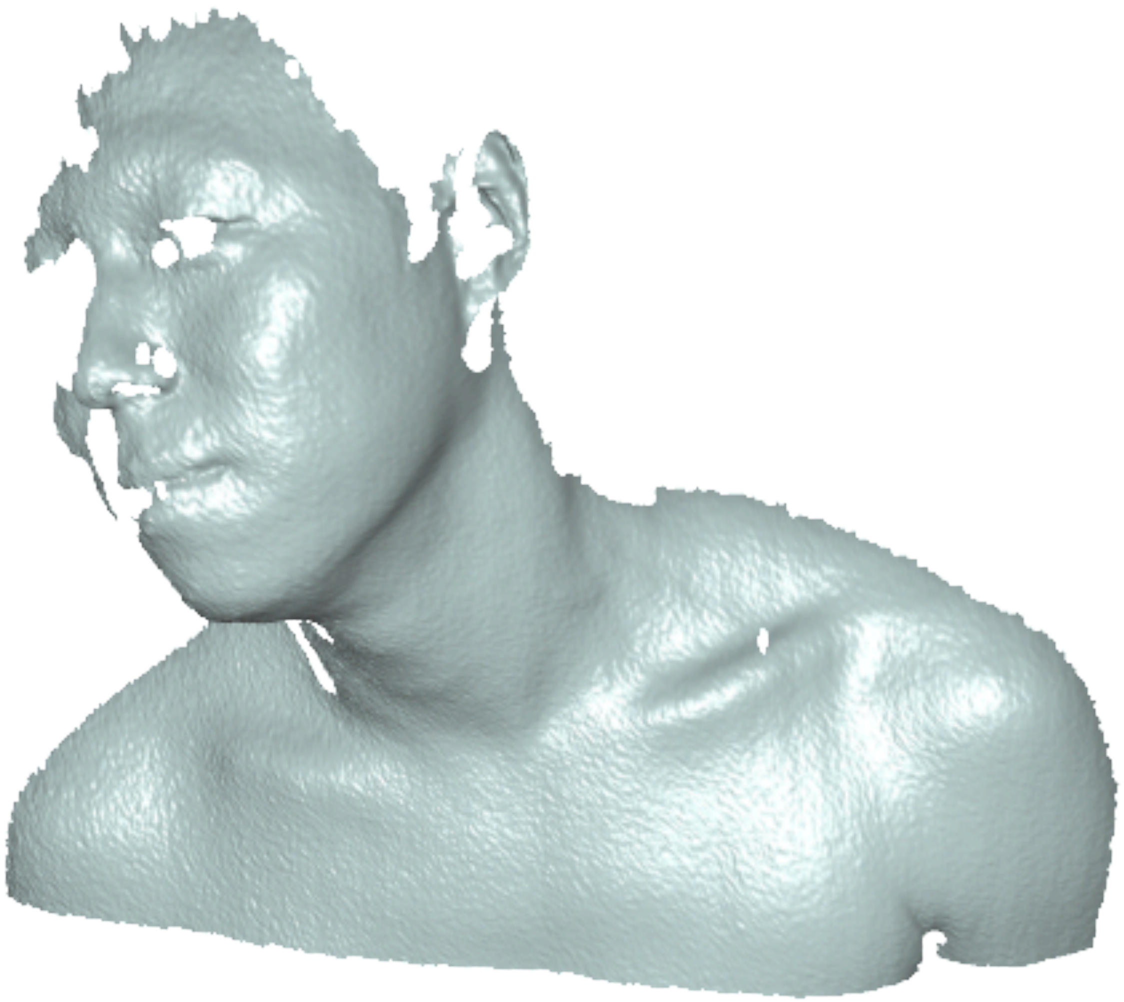

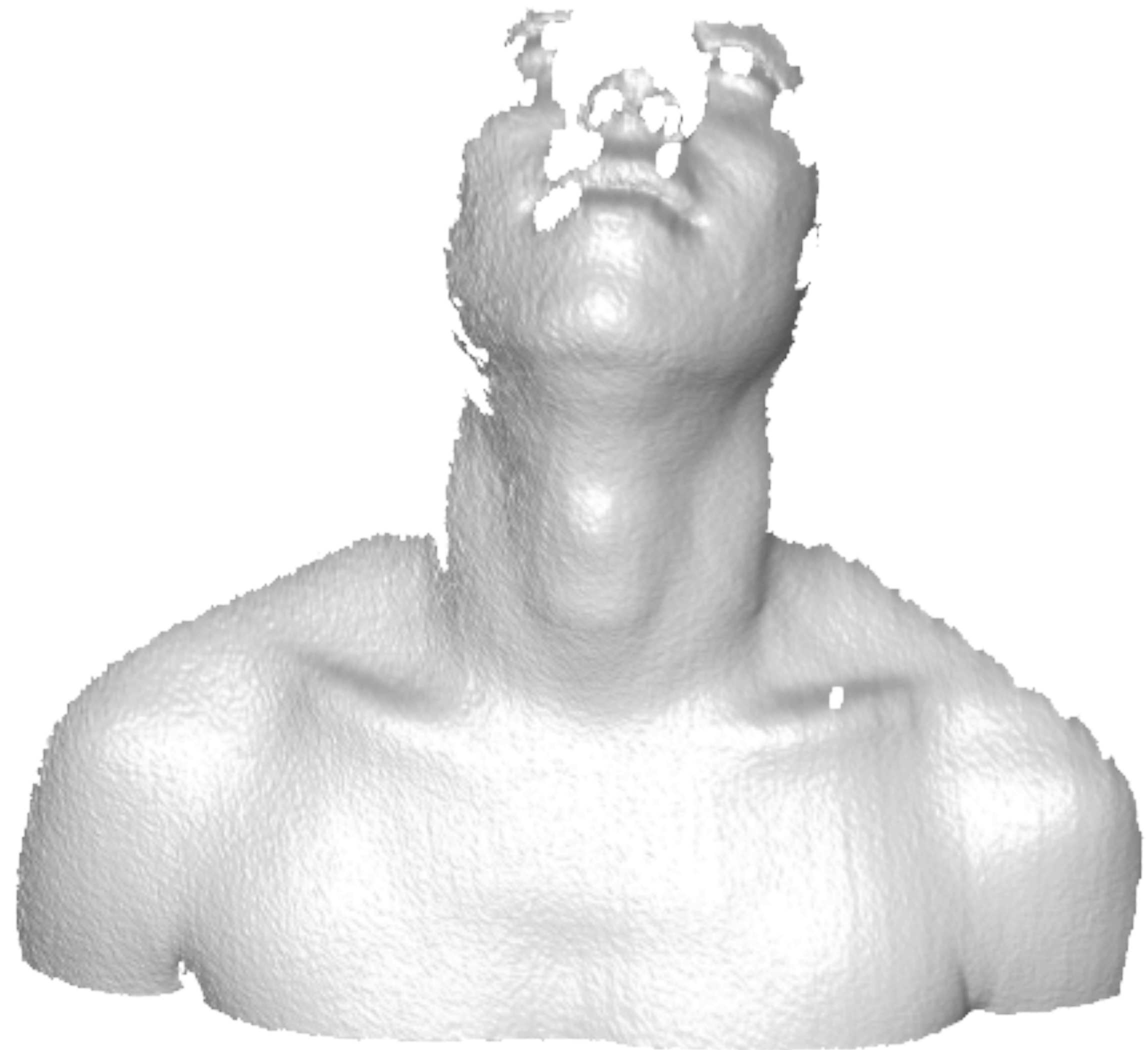

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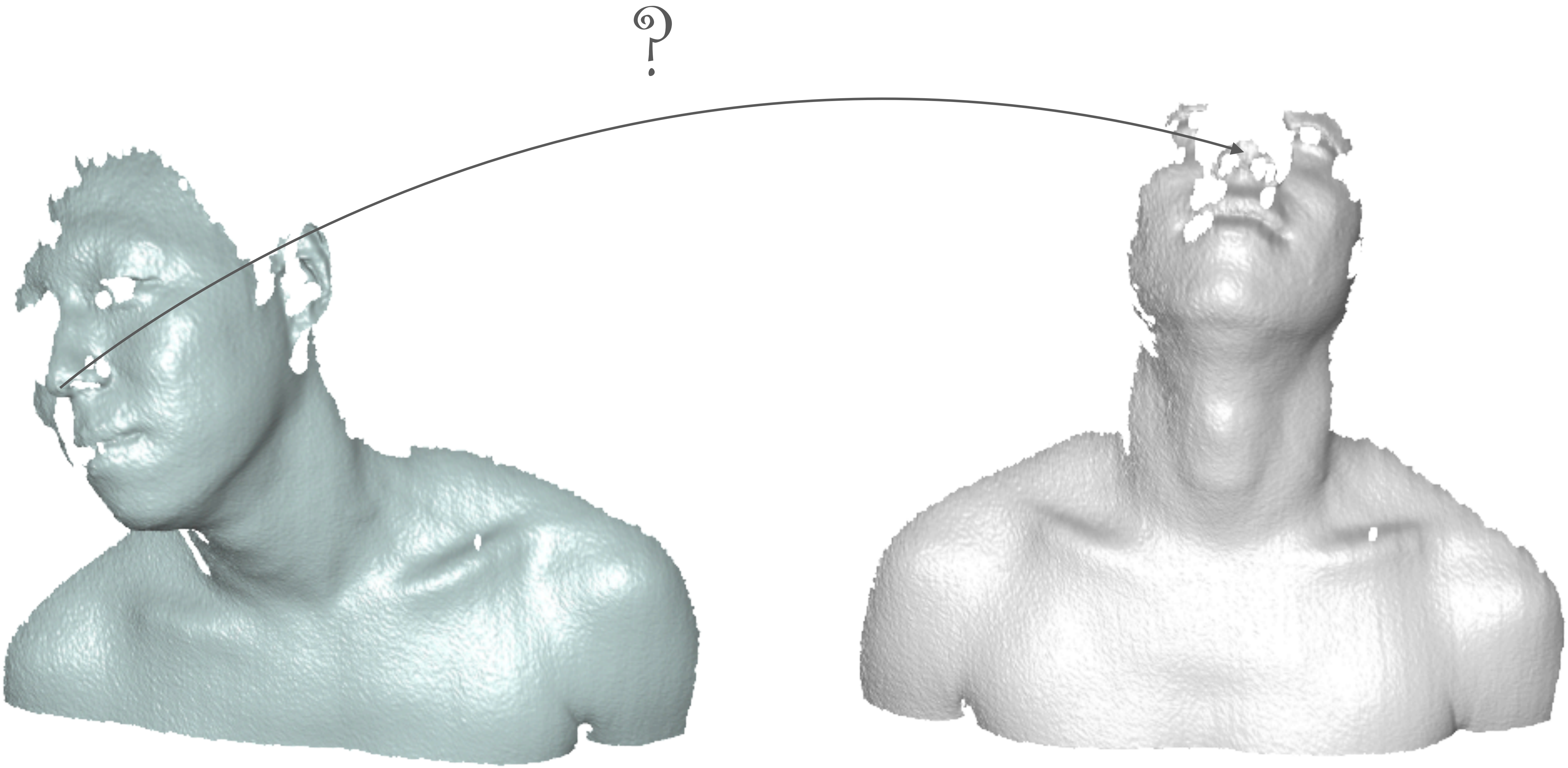
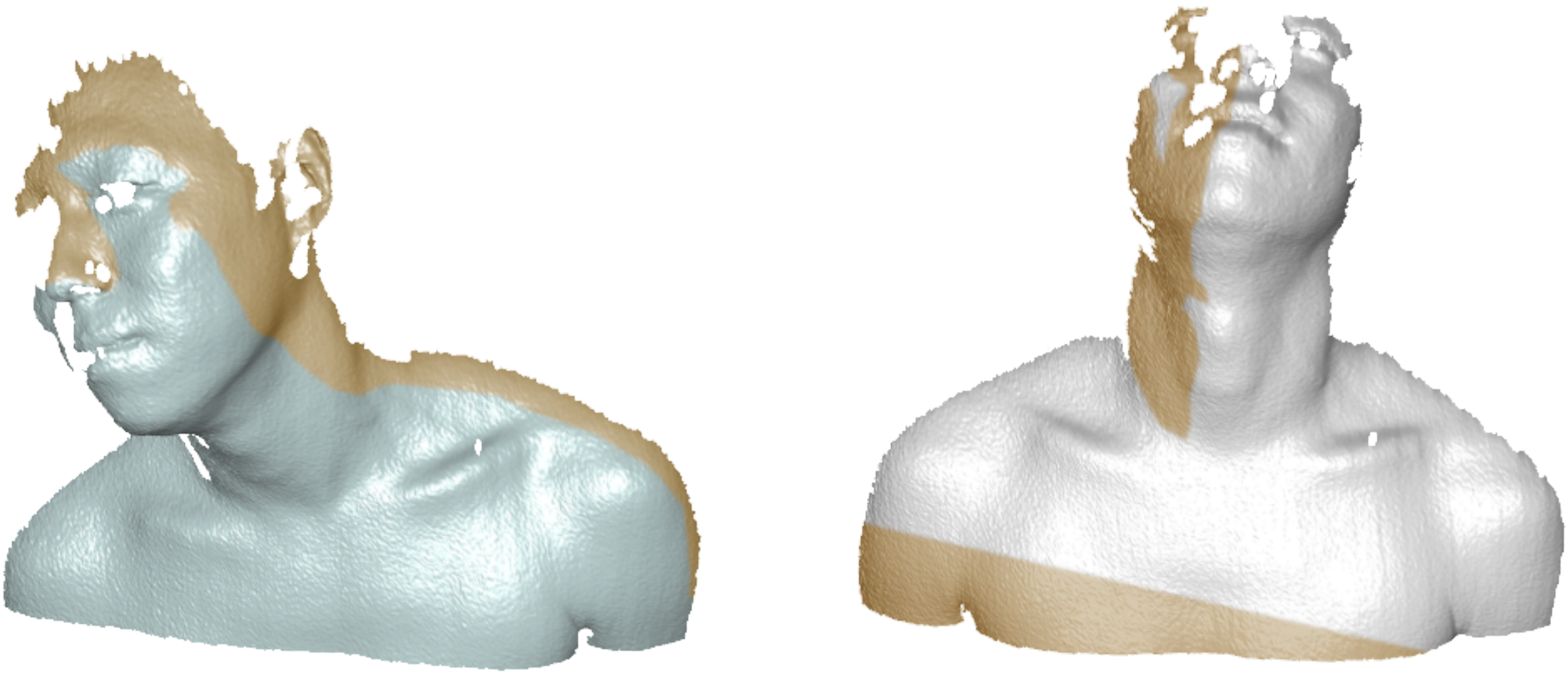


Overlapping Regions are Lost



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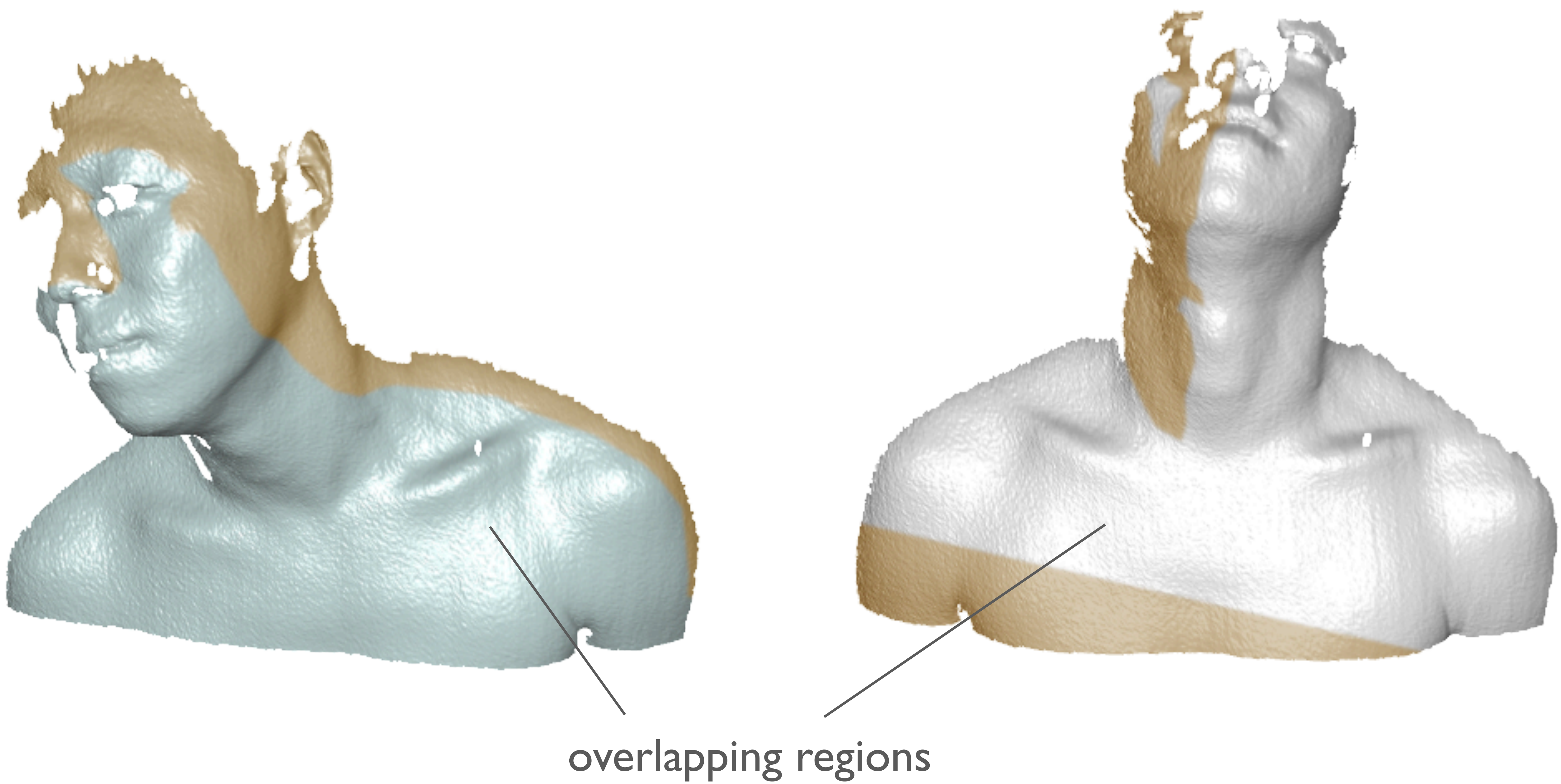

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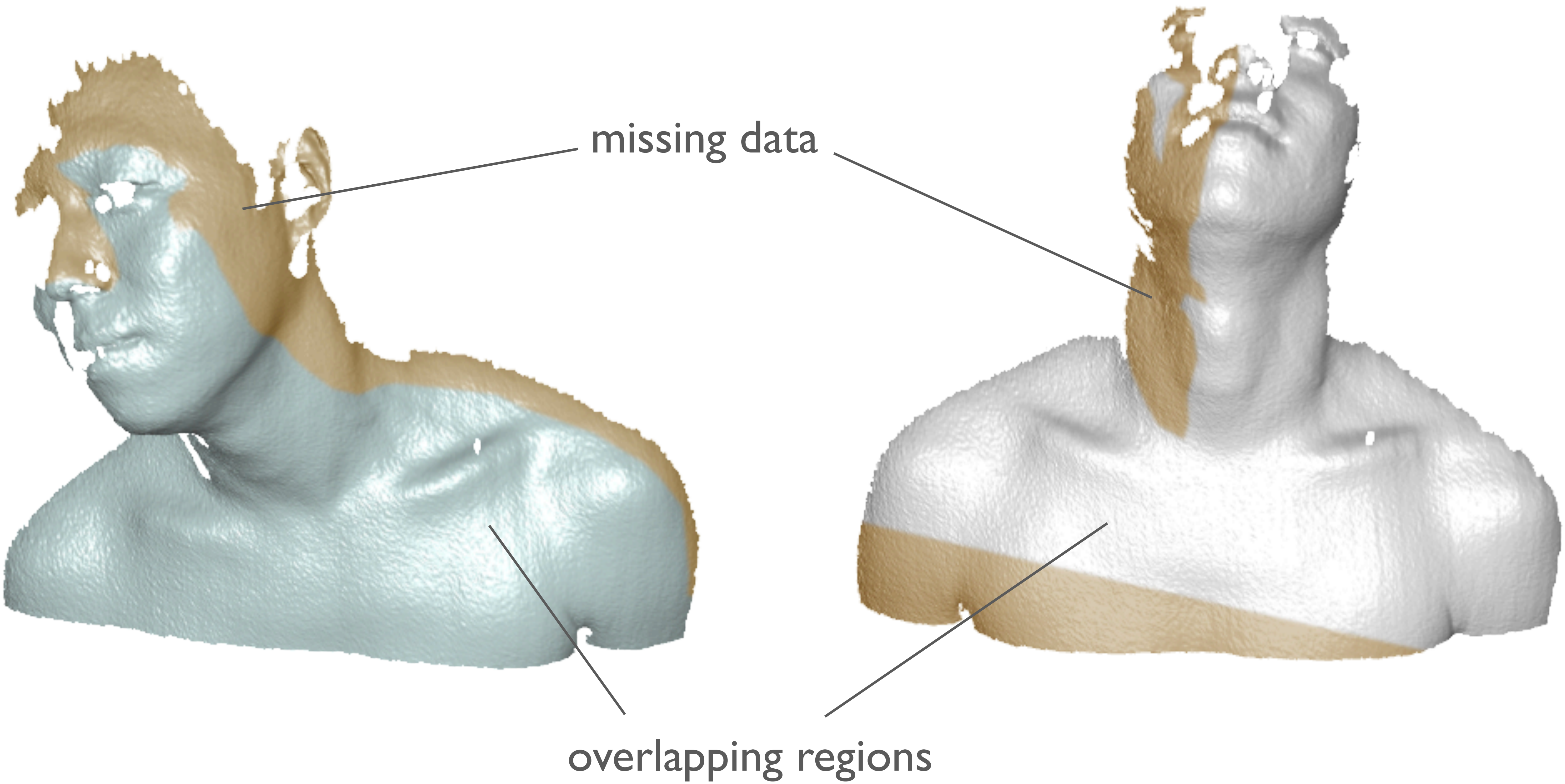

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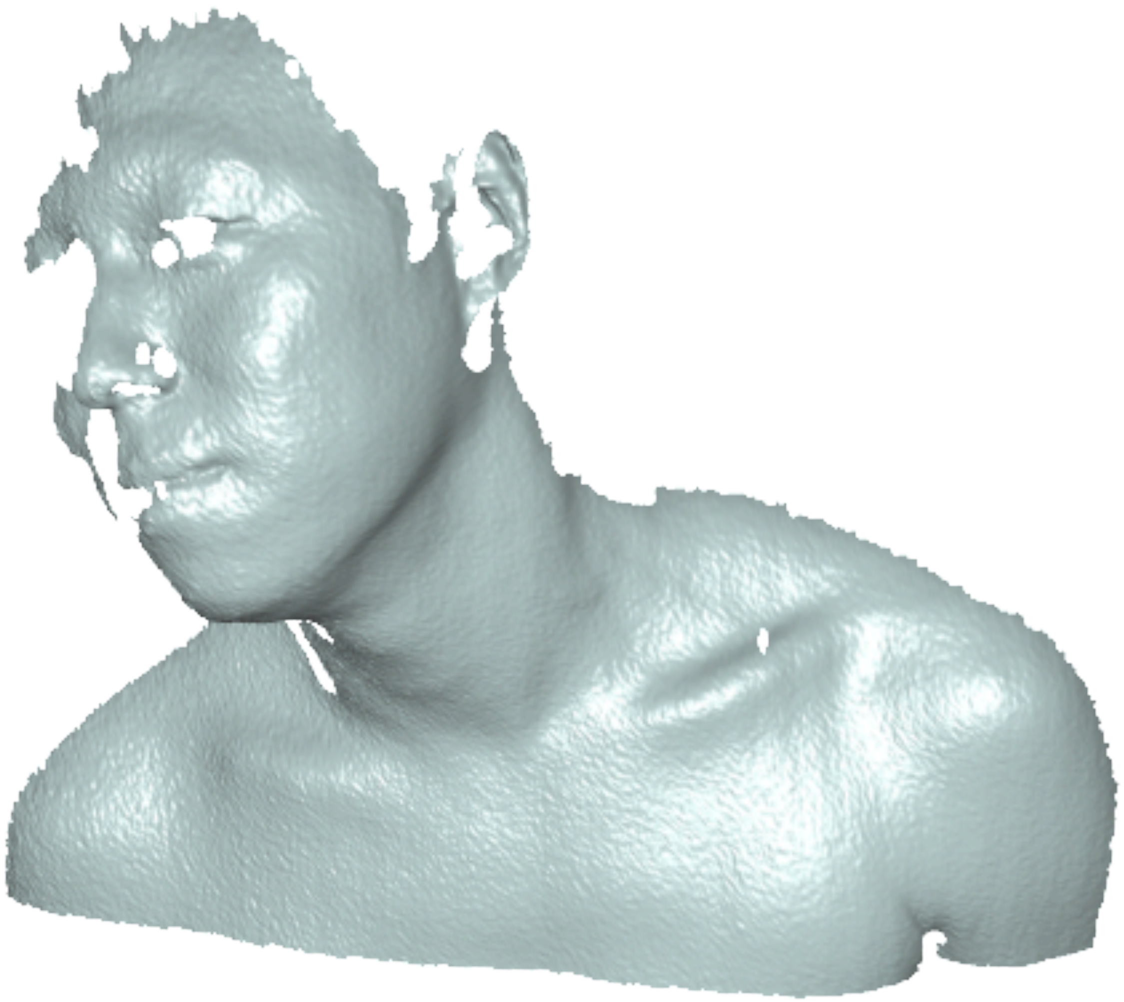

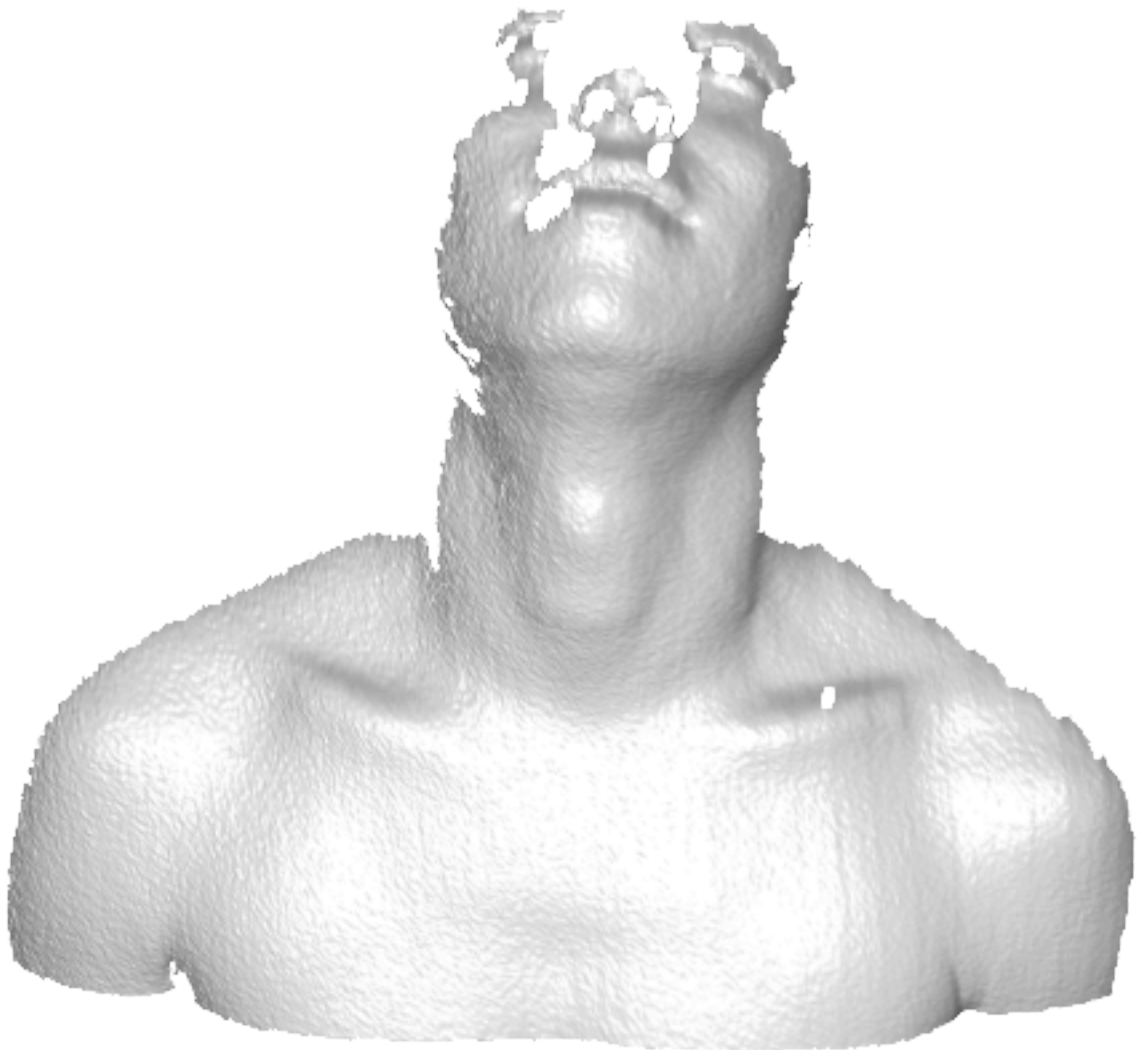

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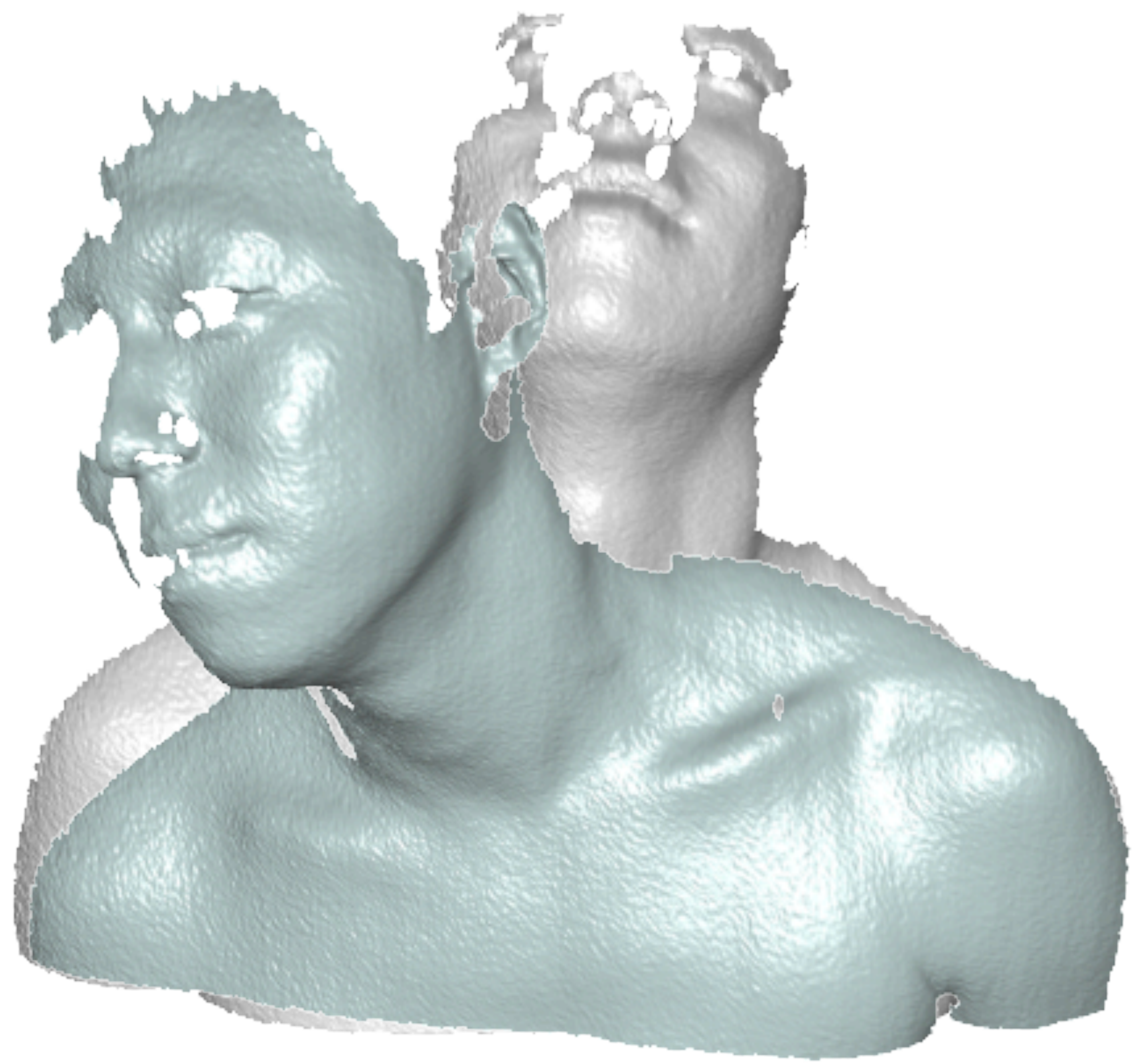

Non-Rigid Registration

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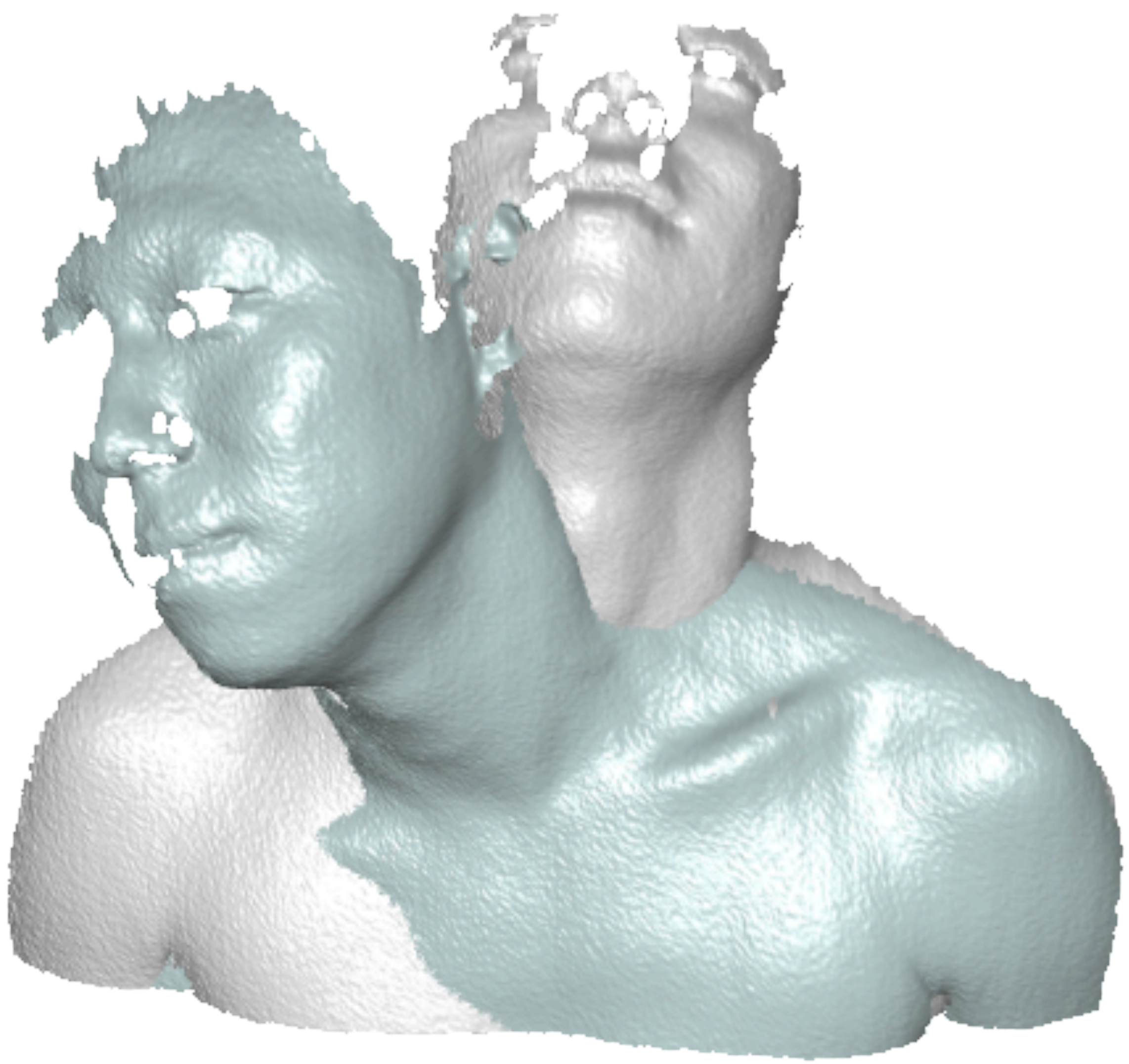

Three Ingredients

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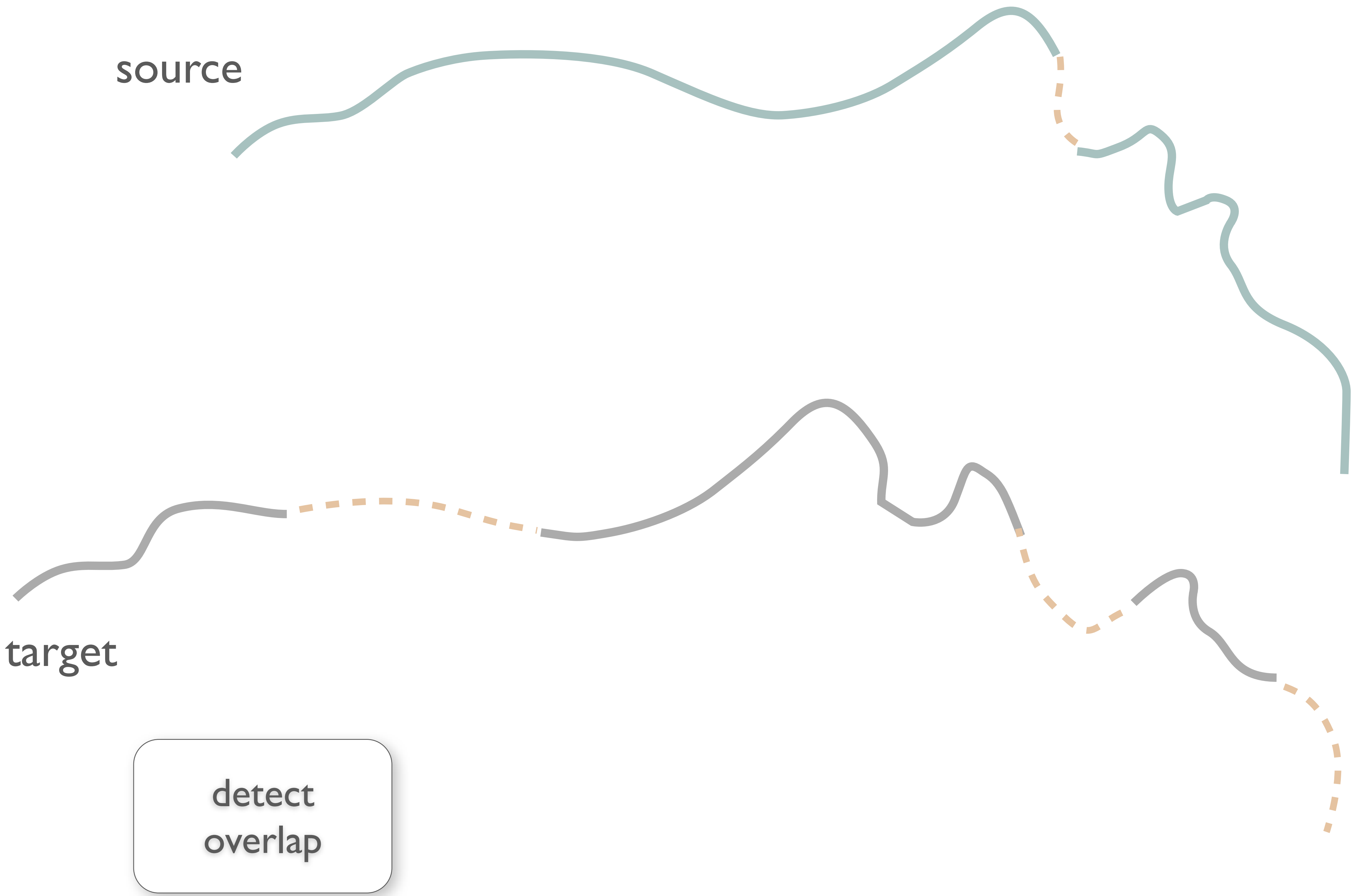
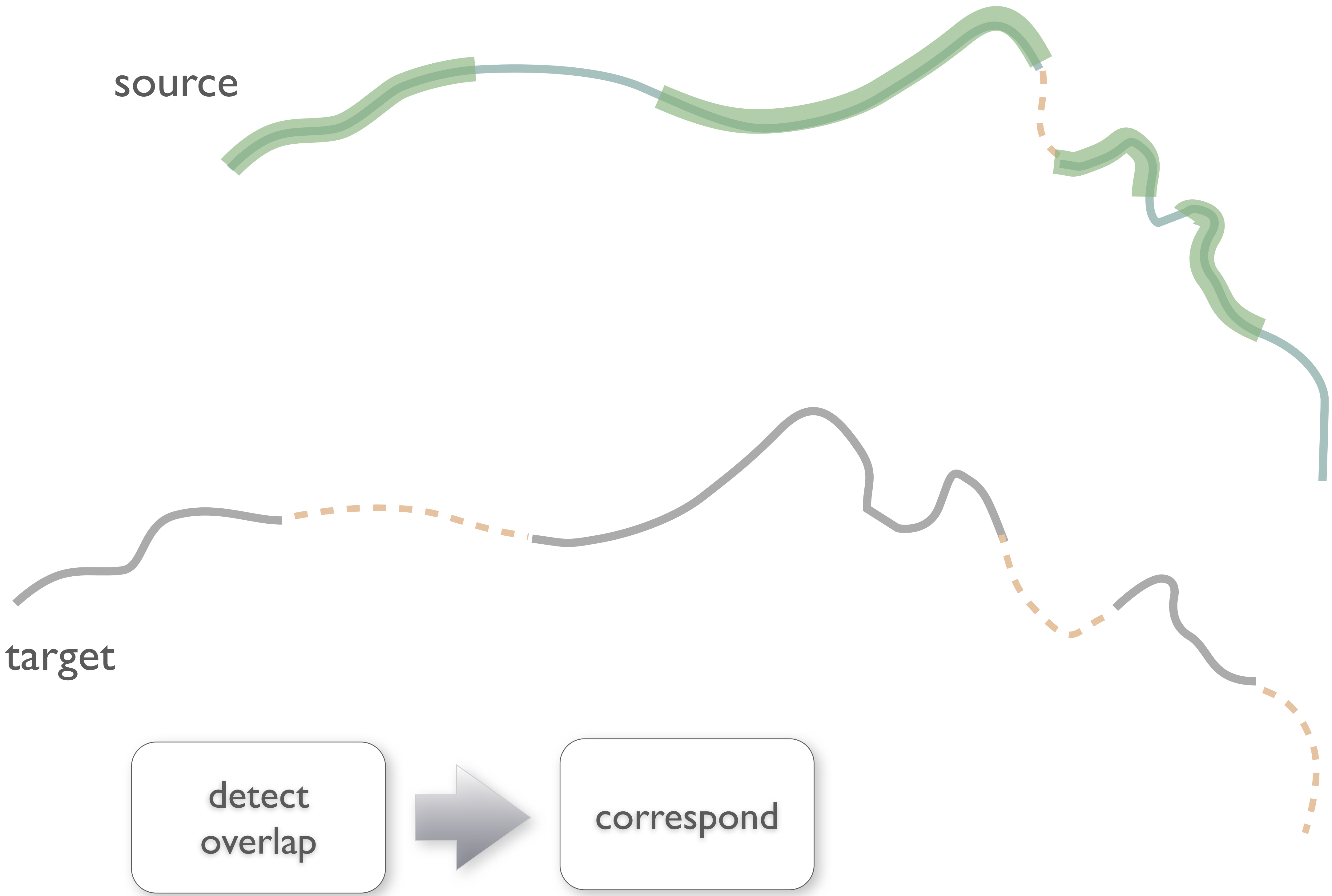


Three Ingredients

detect
overlap

Three Ingredients



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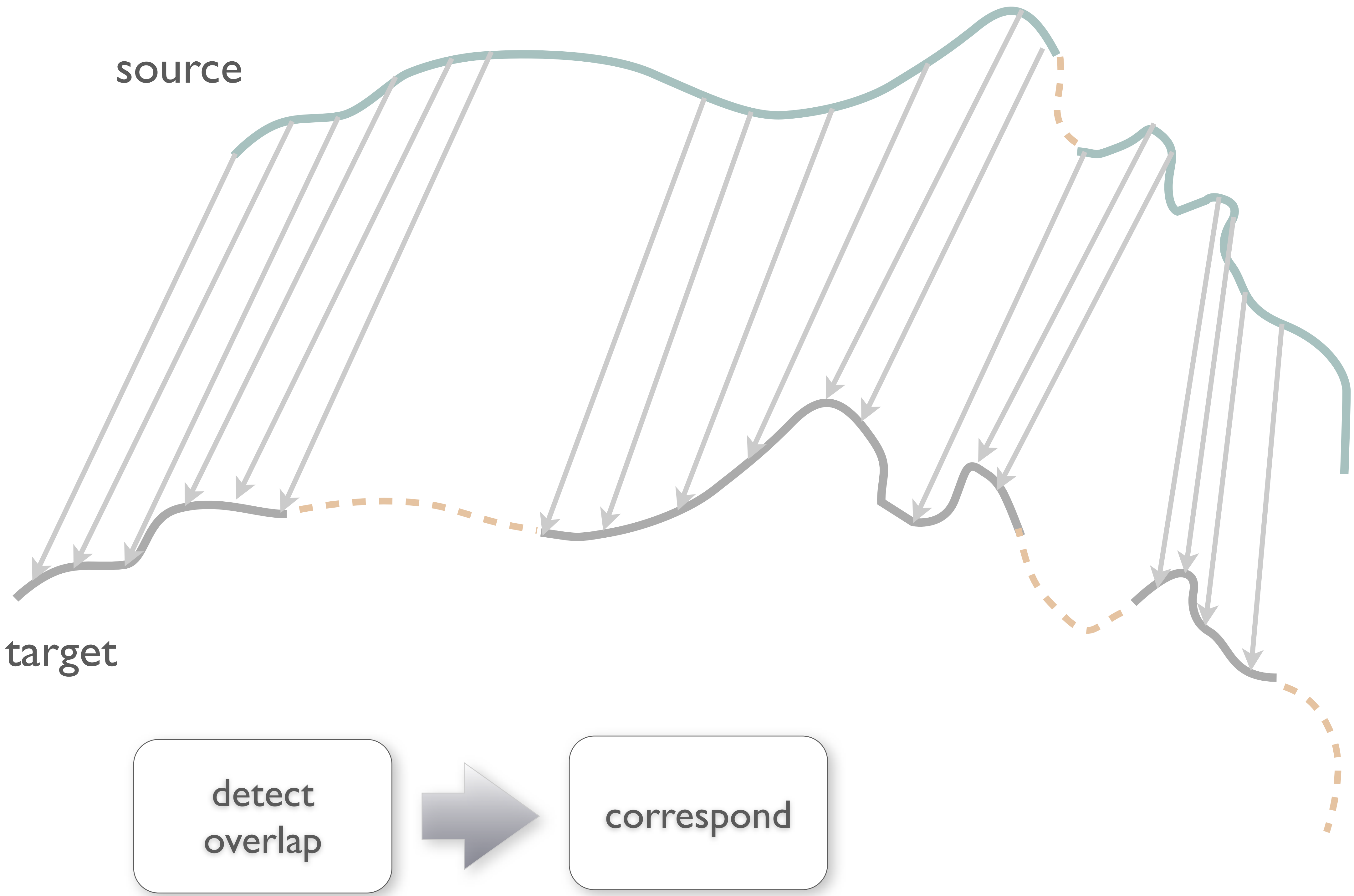

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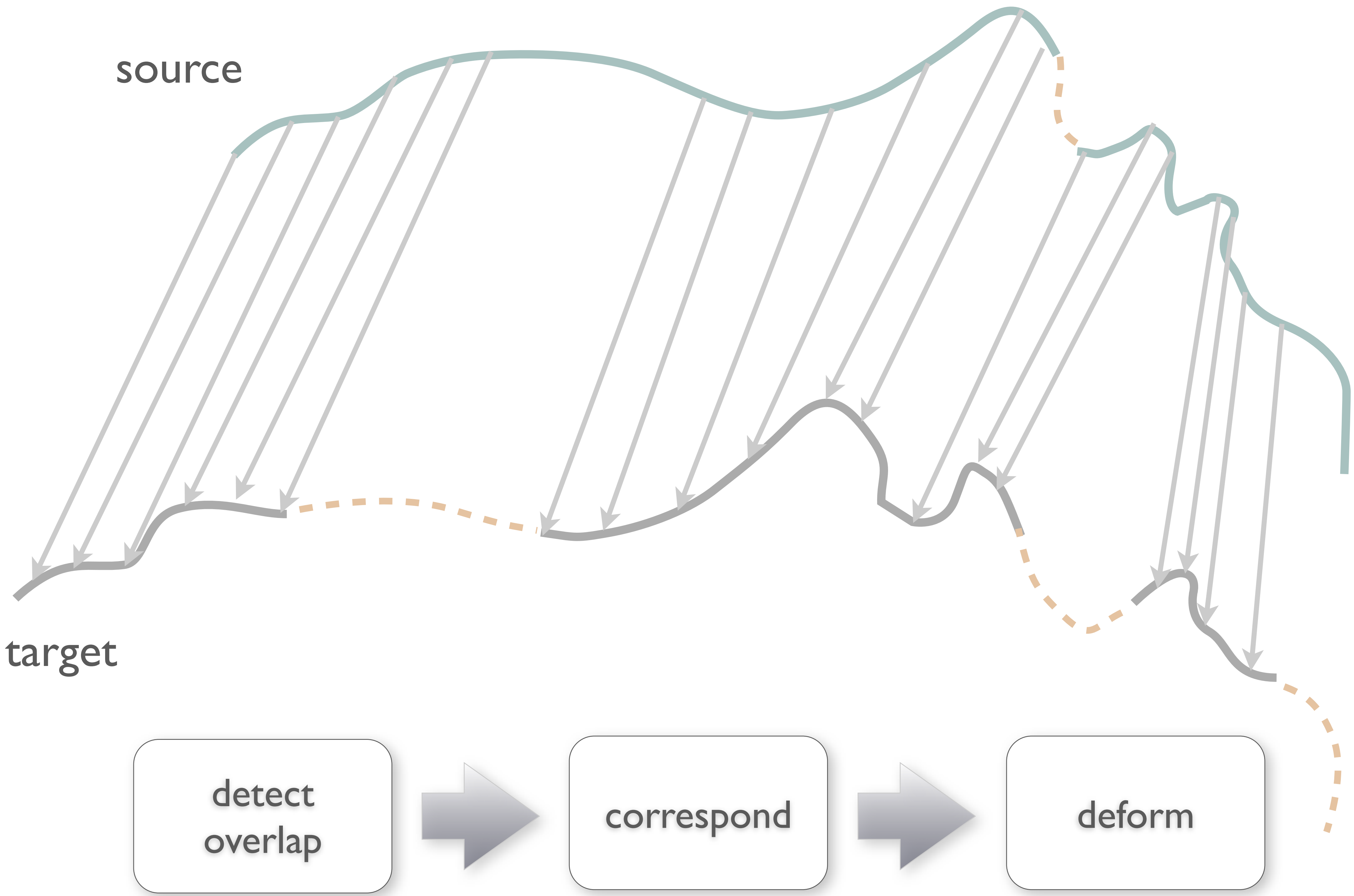

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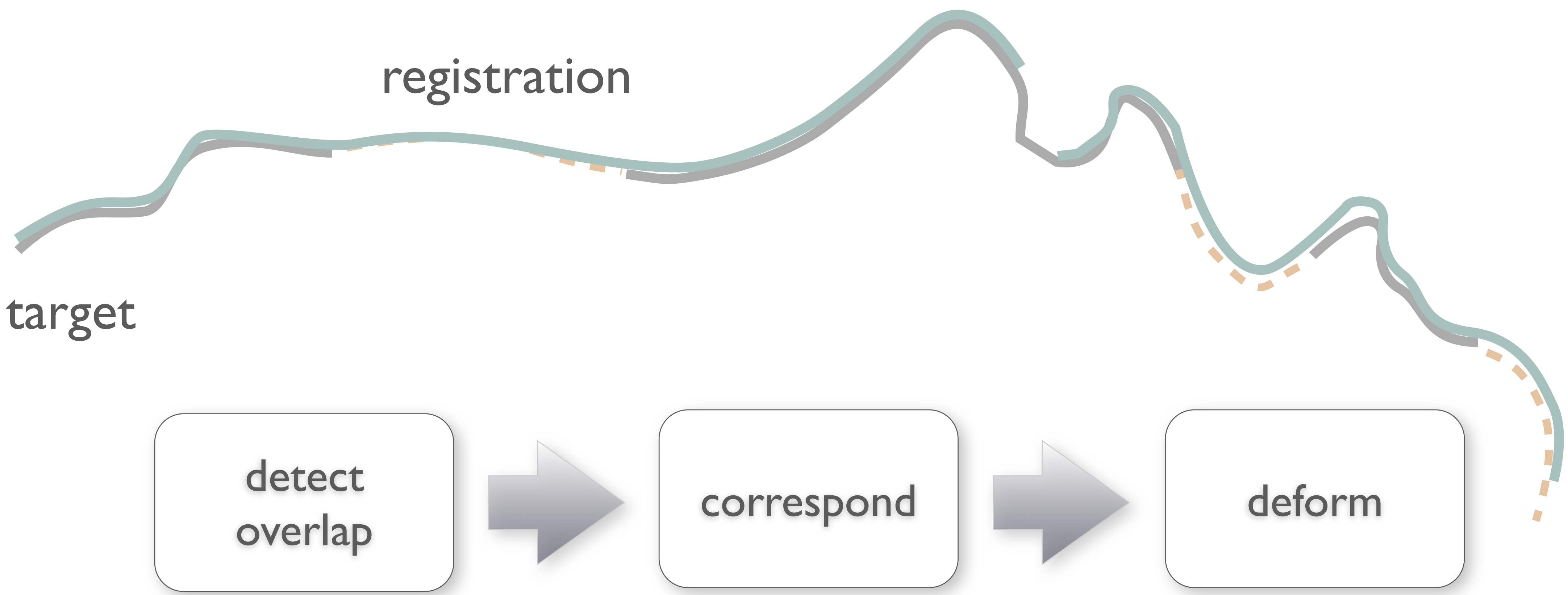
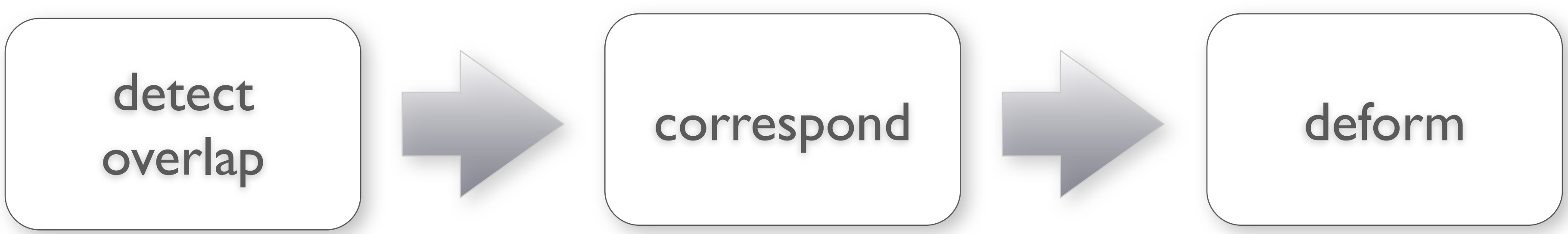


Challenges

detect overlap → correspond → deform

Challenges



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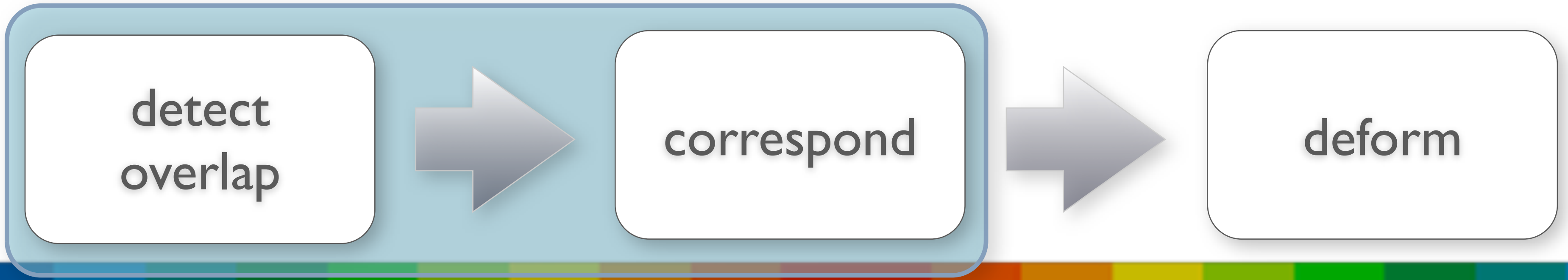

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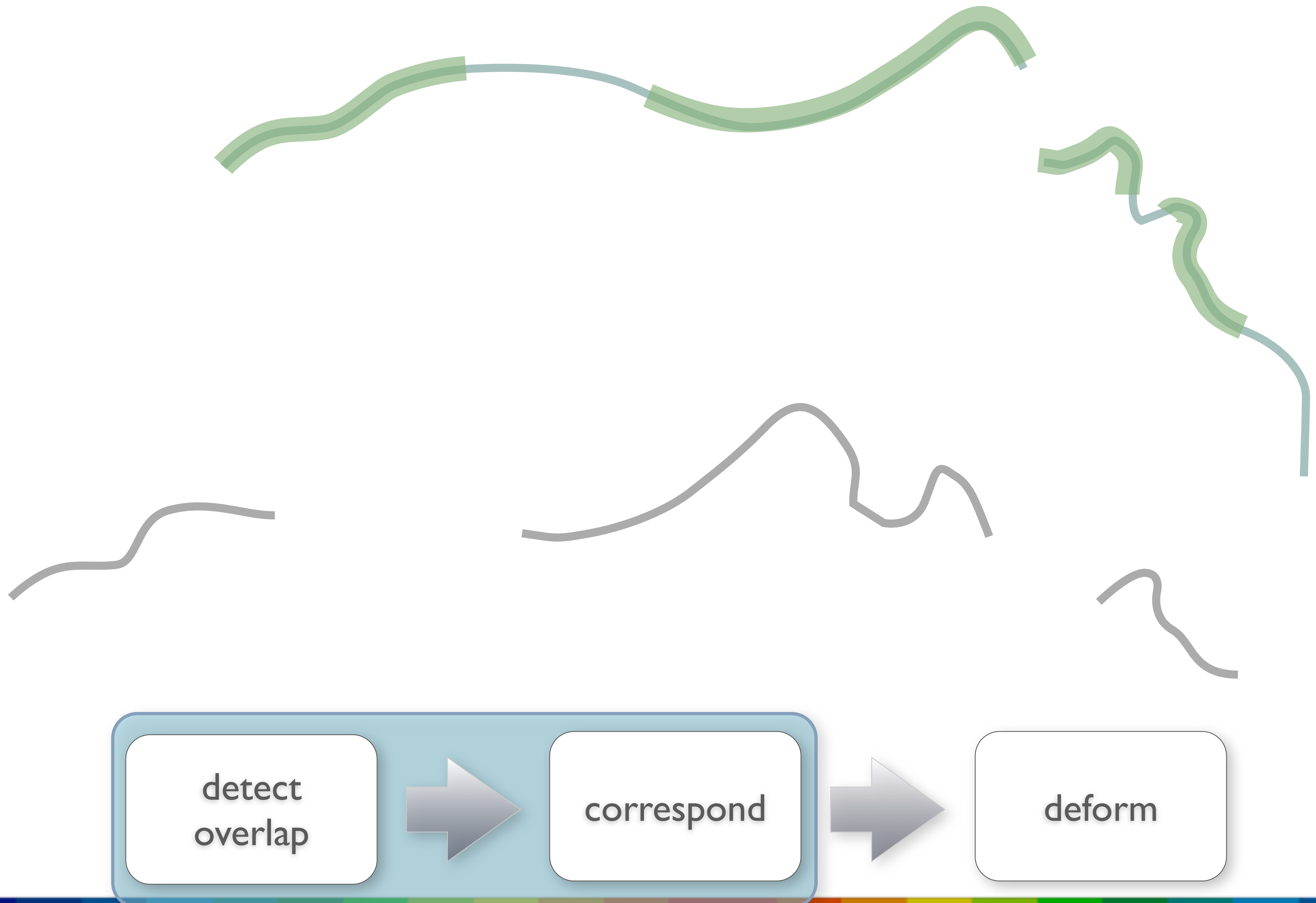

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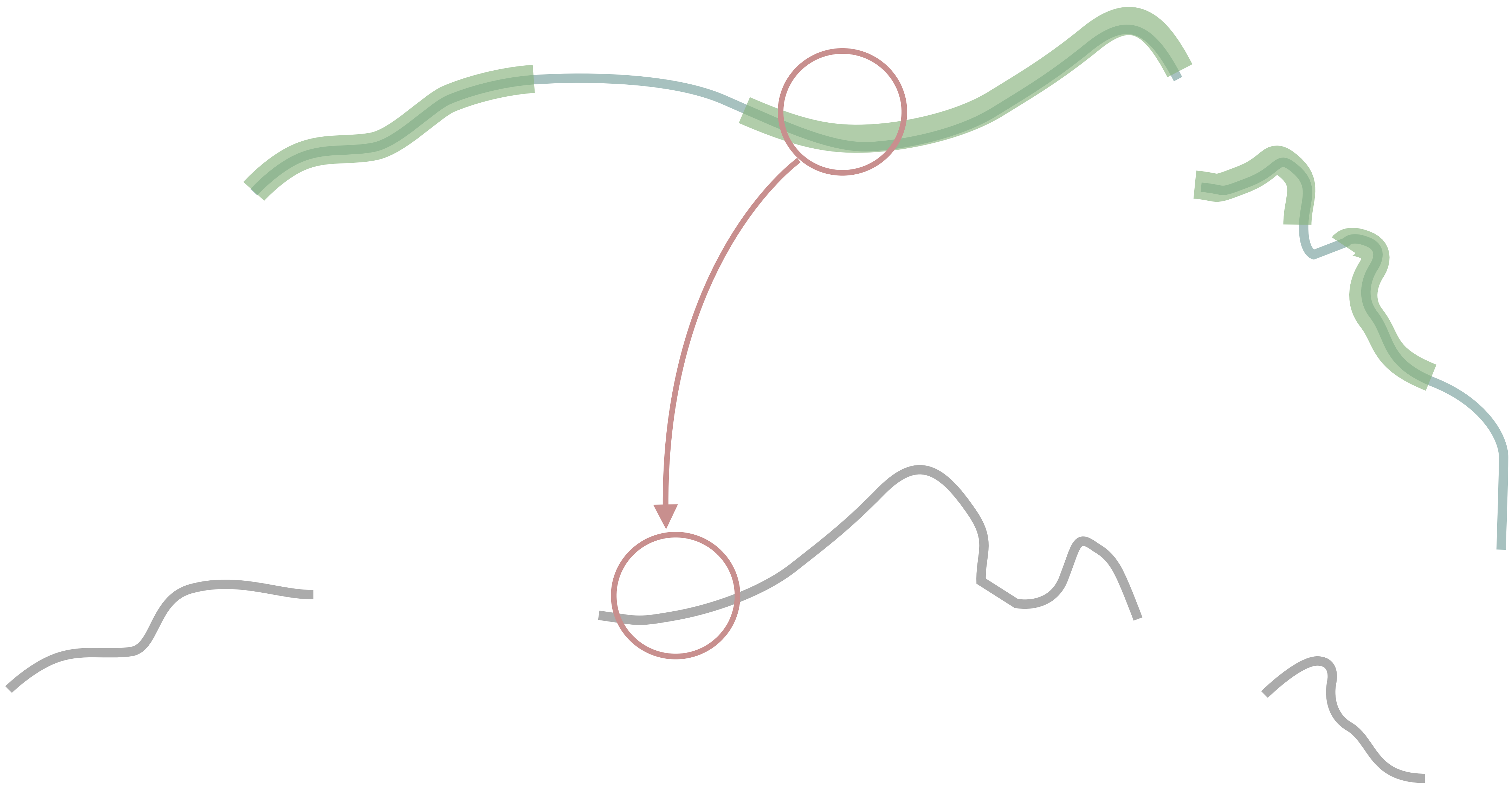

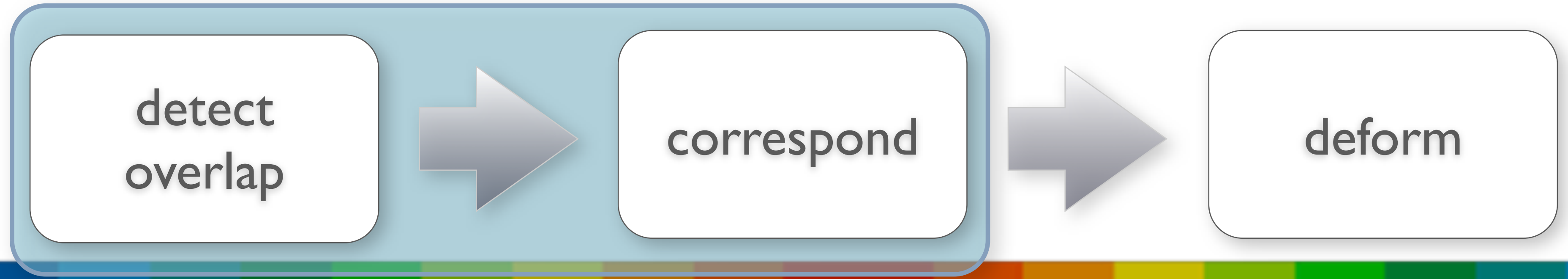

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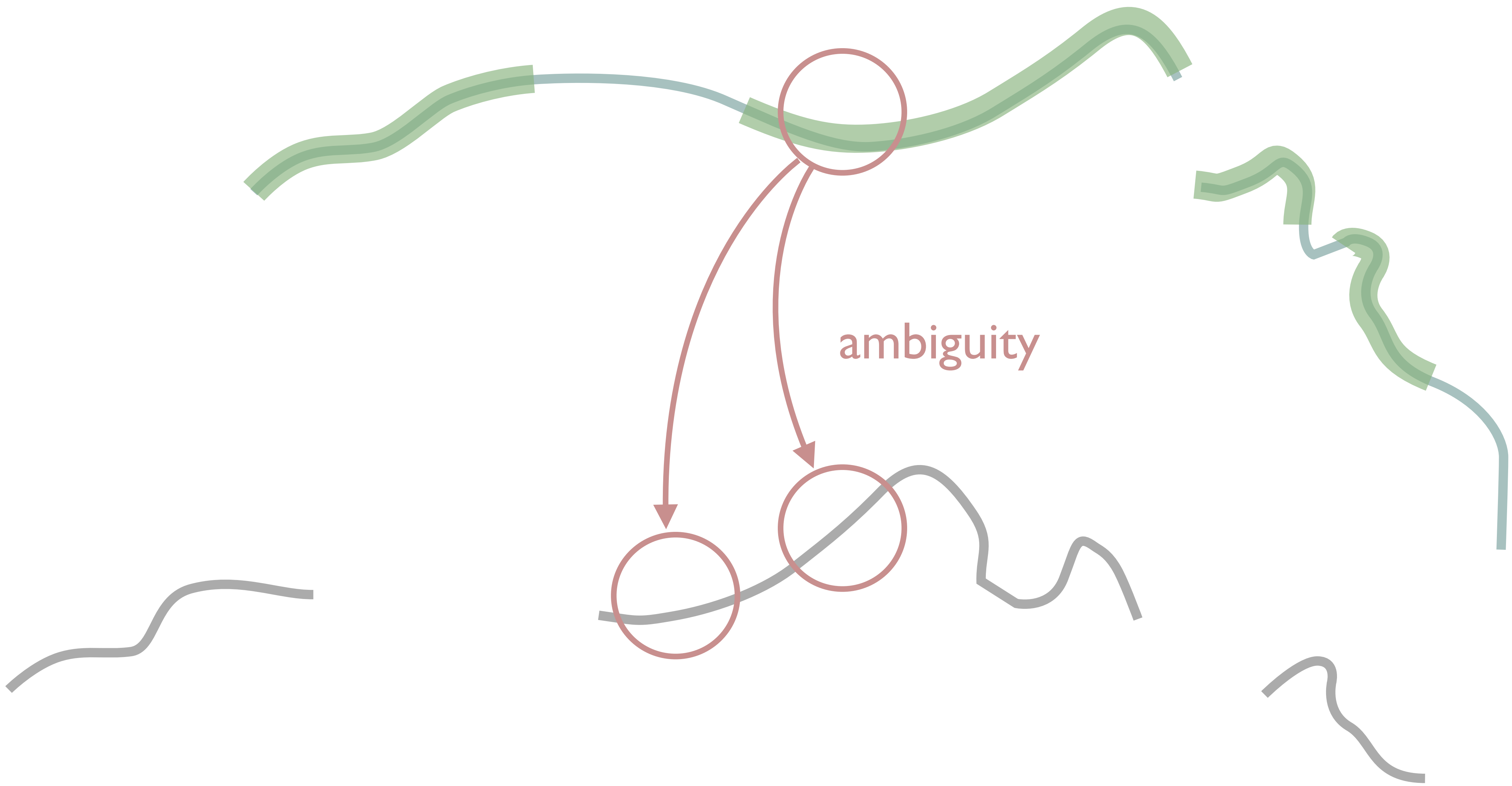

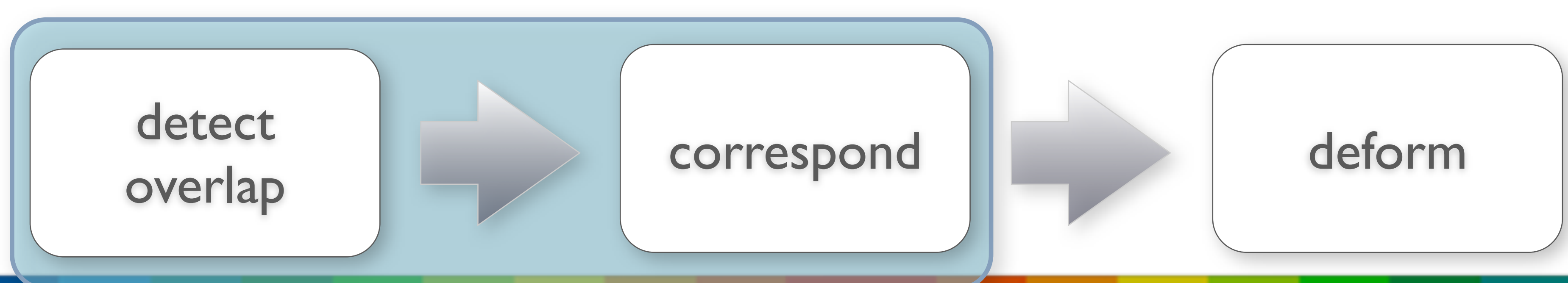

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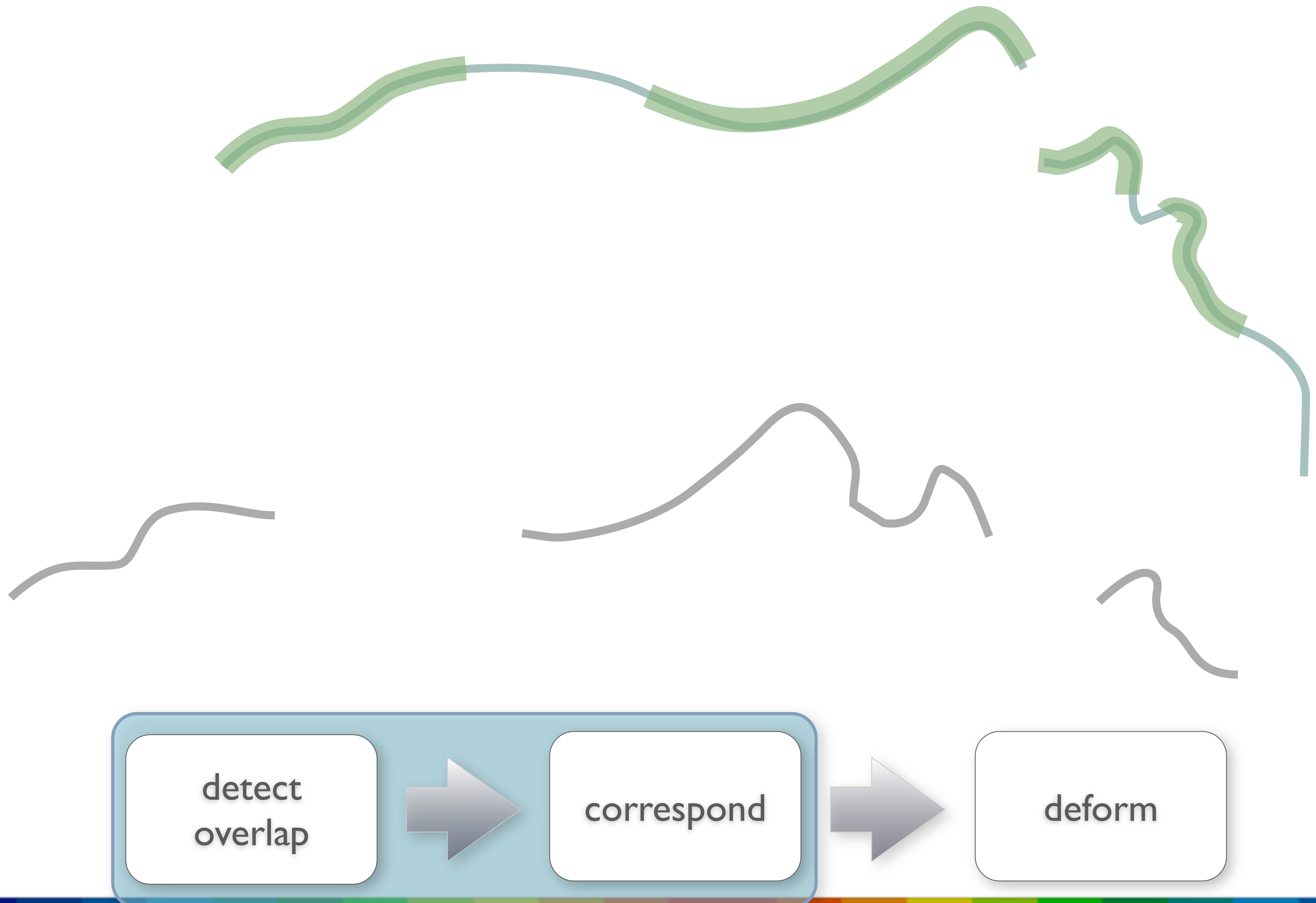

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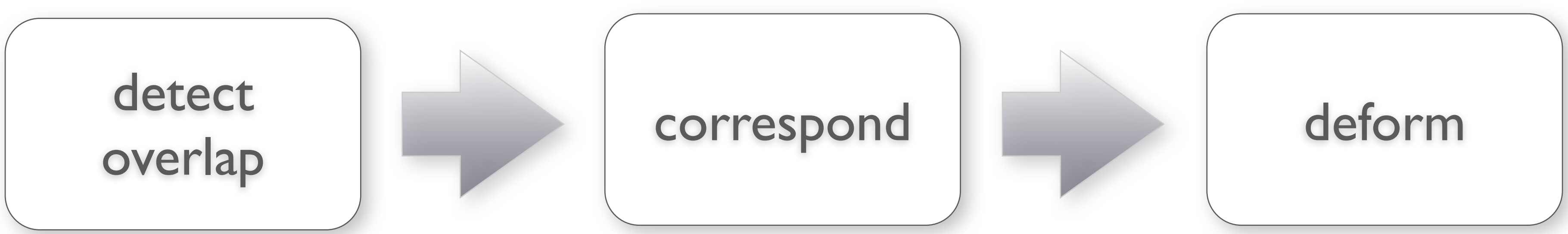

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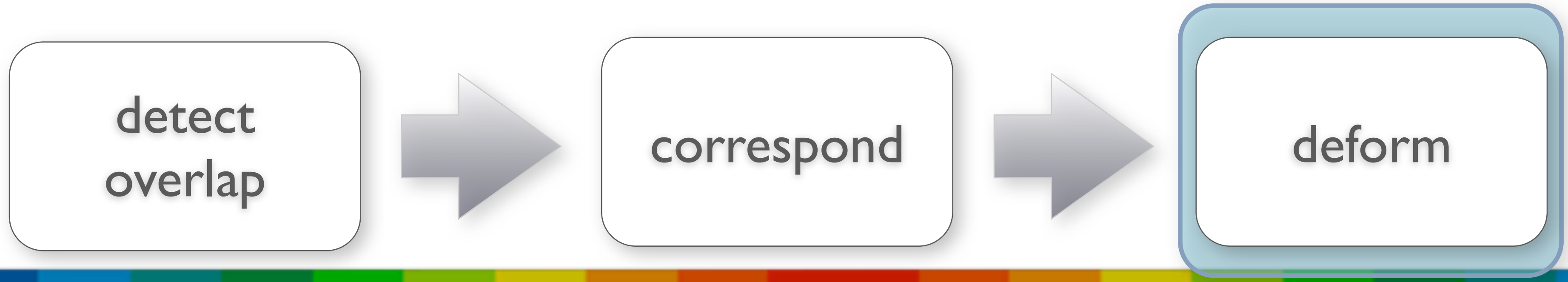

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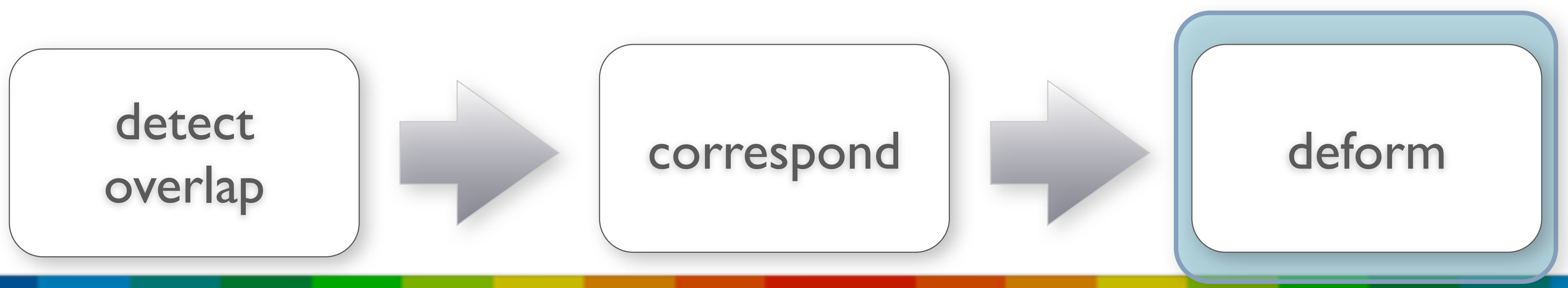
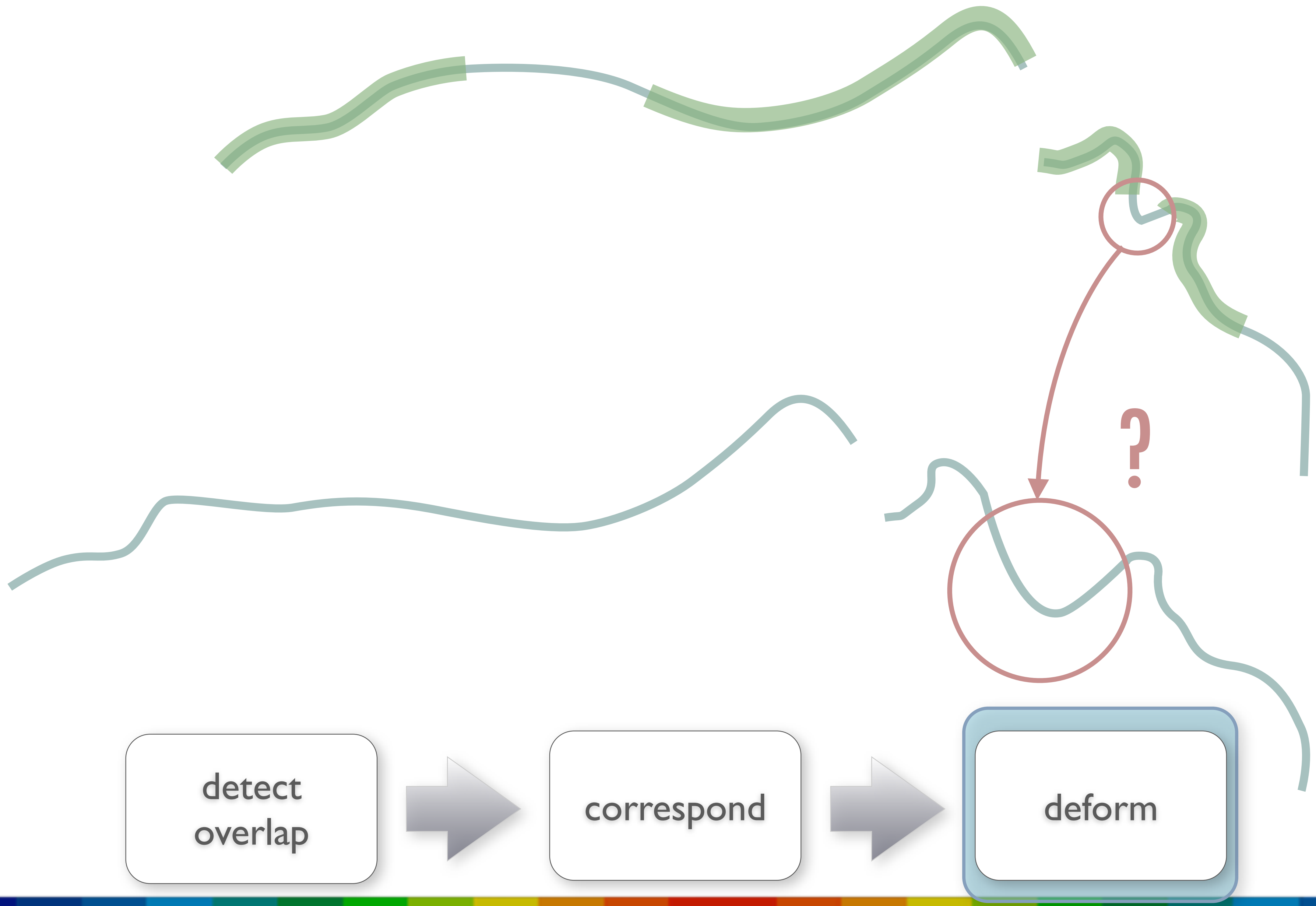


Challenges



Challenges

detect
overlap

correspond

deform

Challenges

correspond

detect overlap

deform

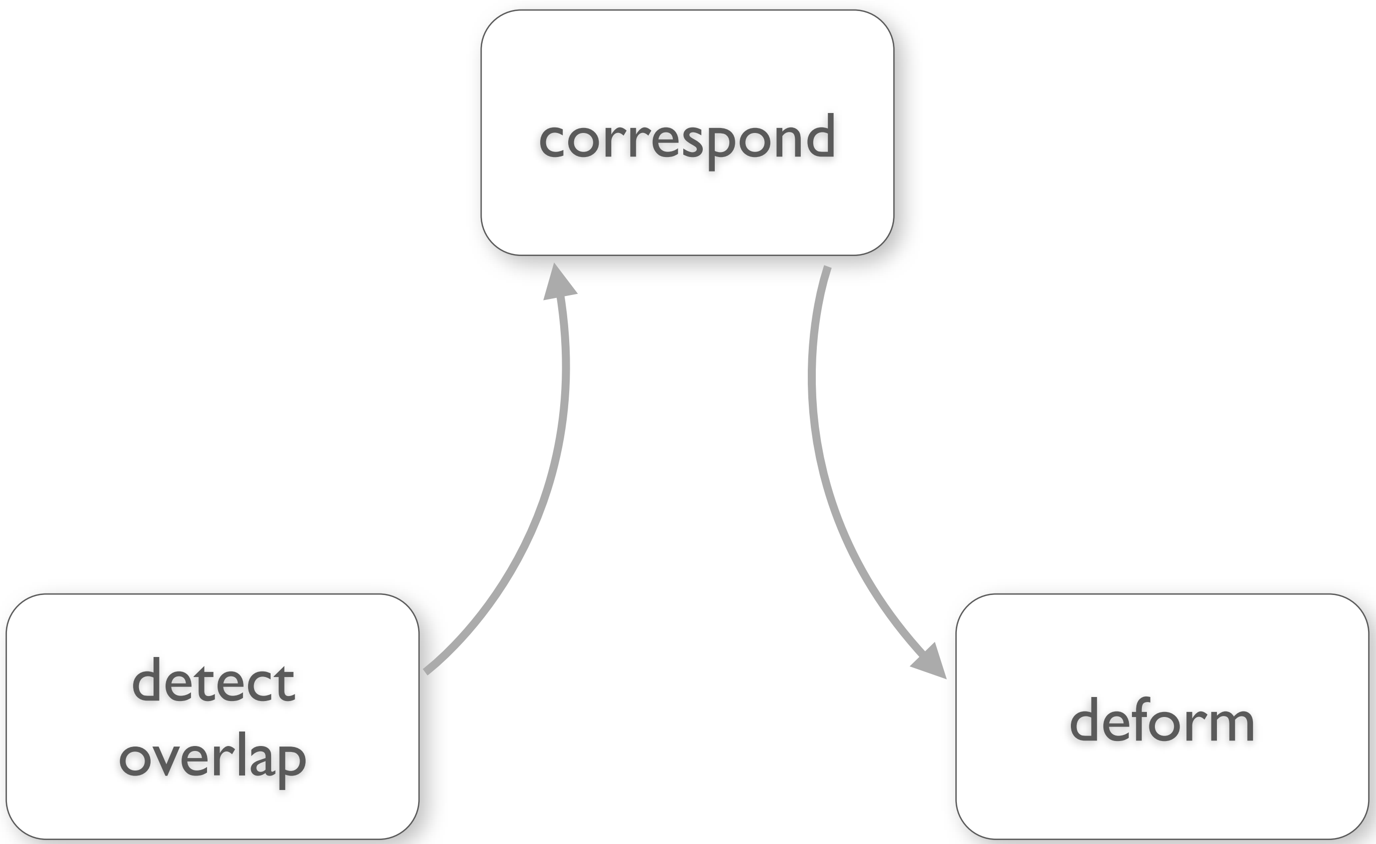
Observation

correspond

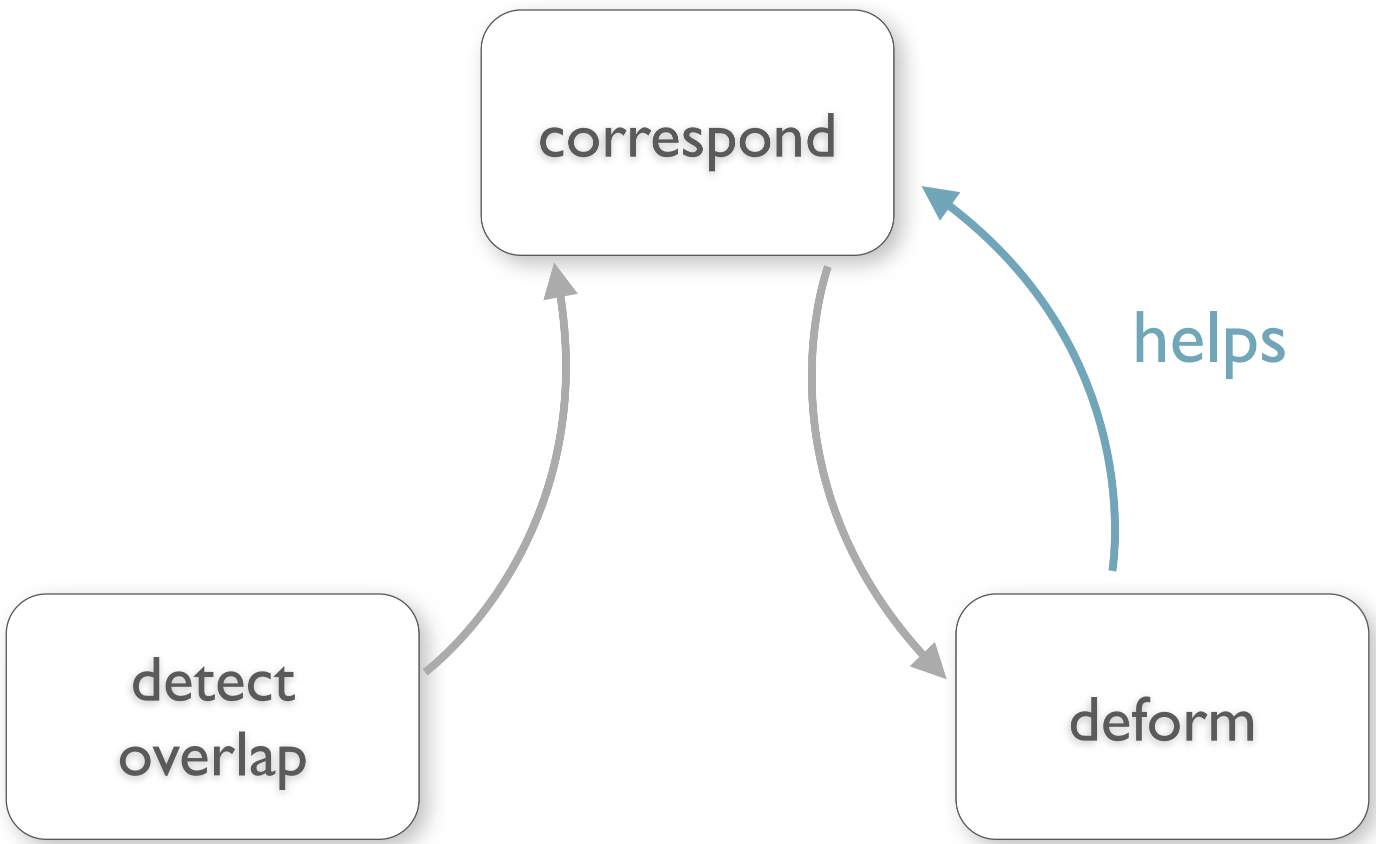
detect overlap

deform

Observation



Observation



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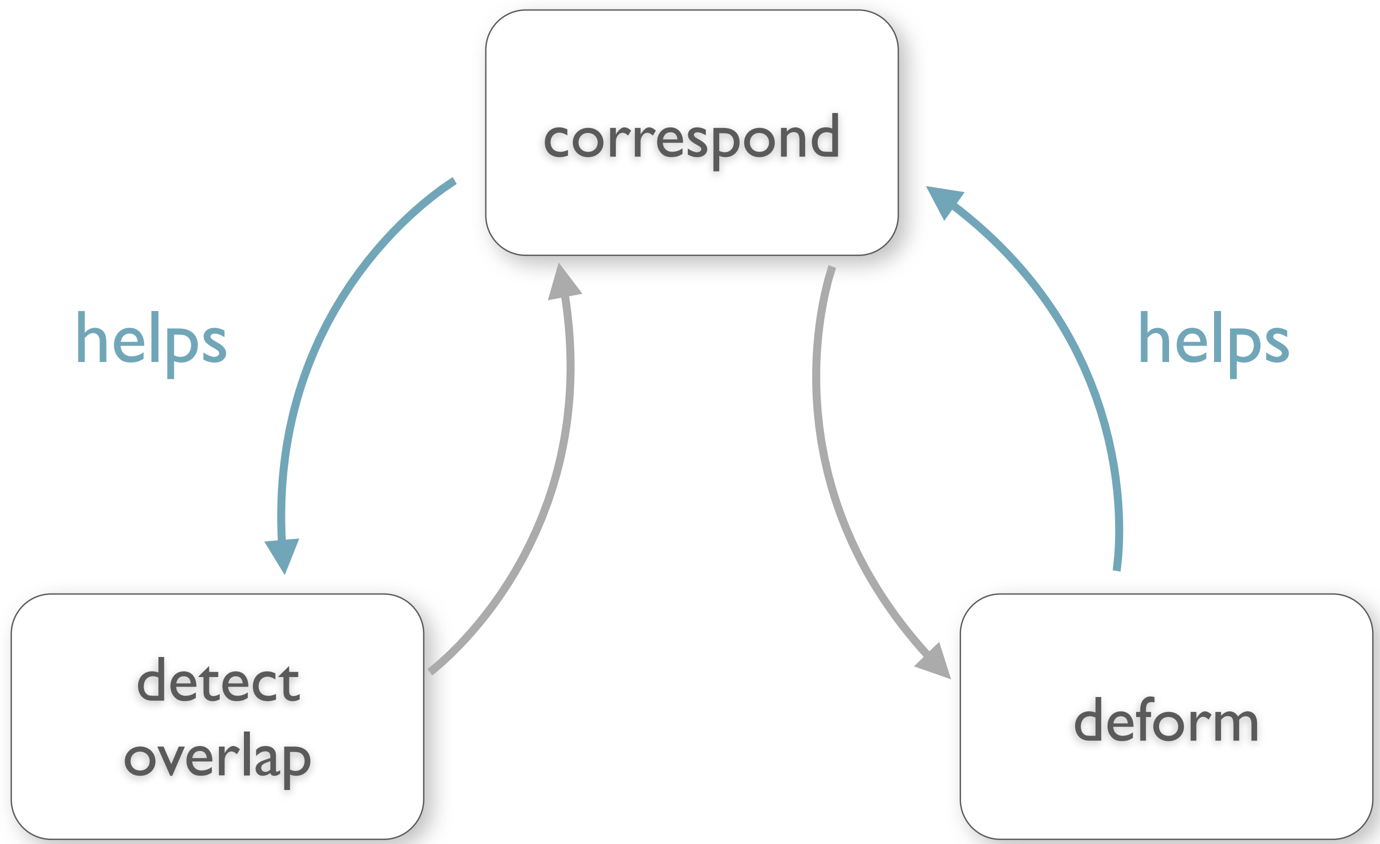

Observation

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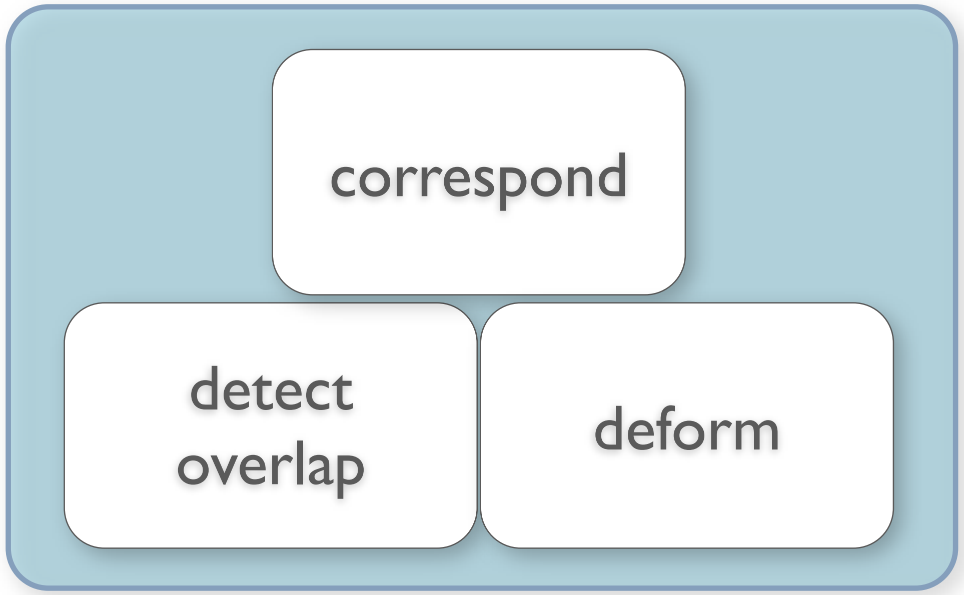
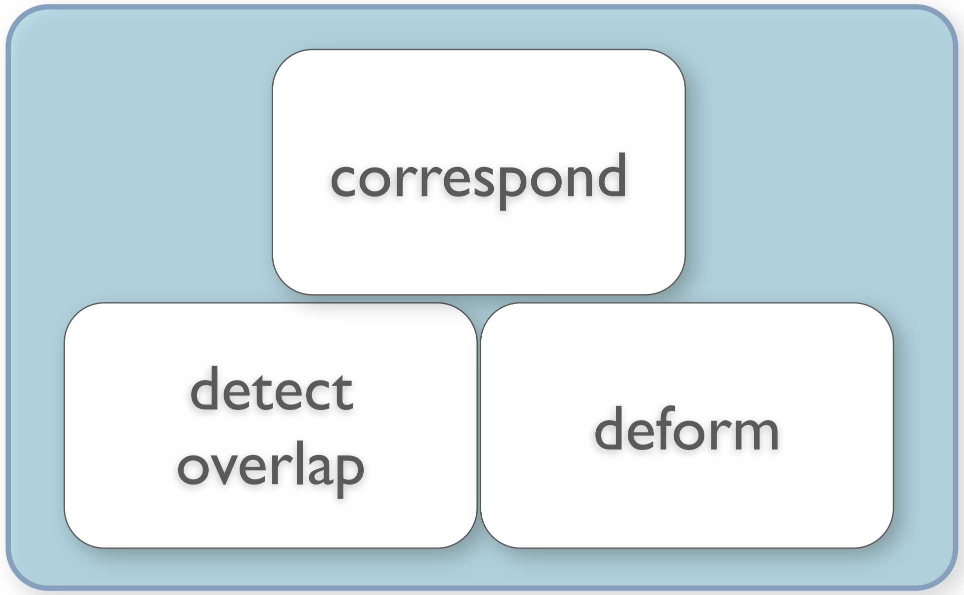
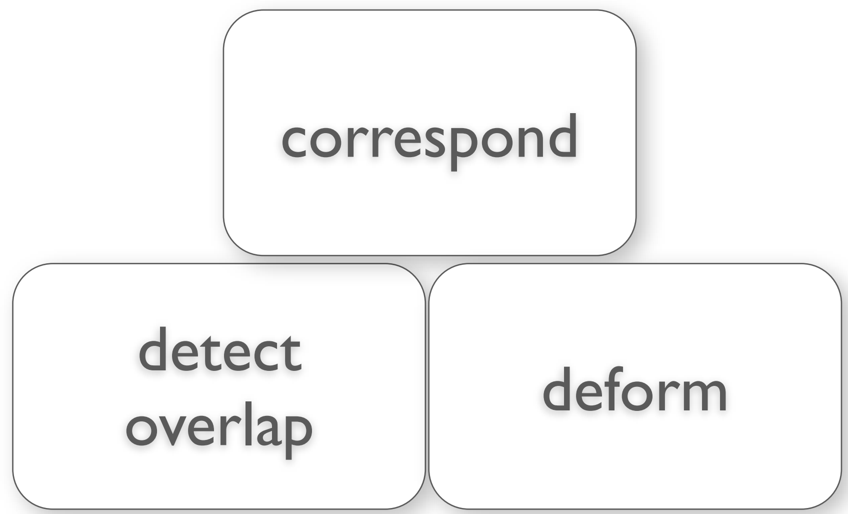


Observation



global optimization via local refinement

Iterative Global Optimization



Iterative Global Optimization

correspond

detect overlap

deform

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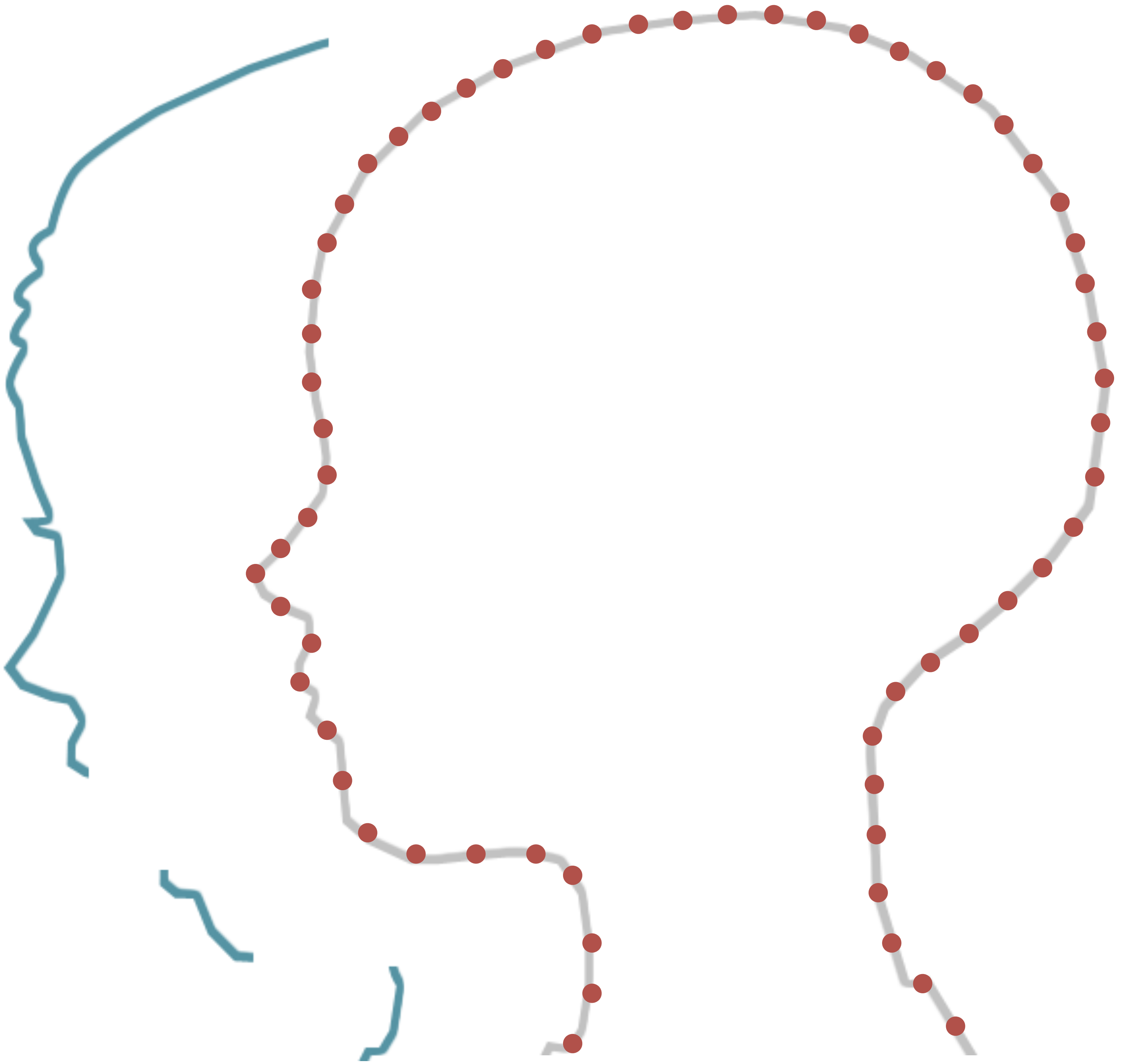
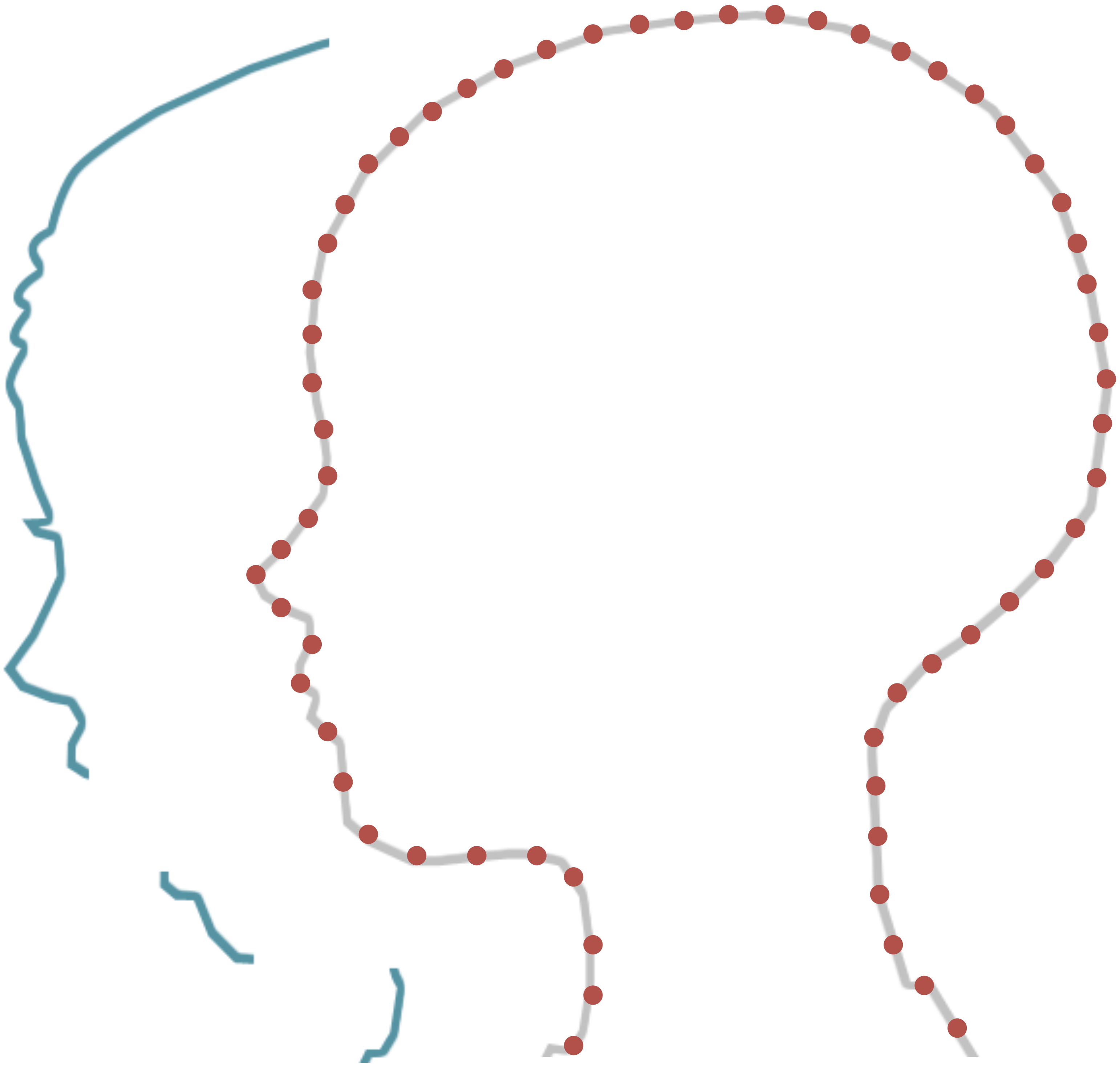


correspond

detect overlap

deform

Iterative Global Optimization

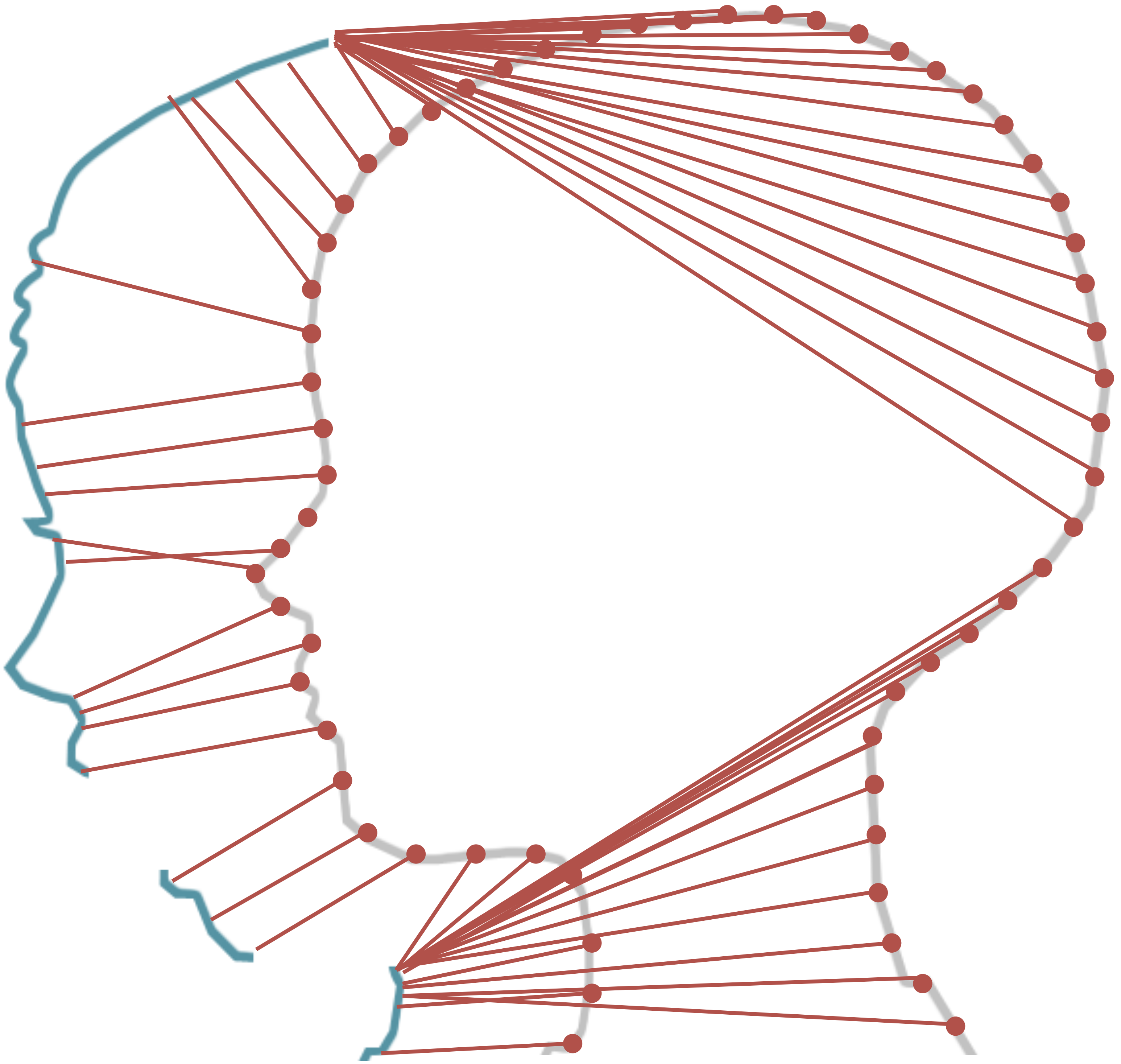


closest point

detect overlap

deform

Iterative Global Optimization

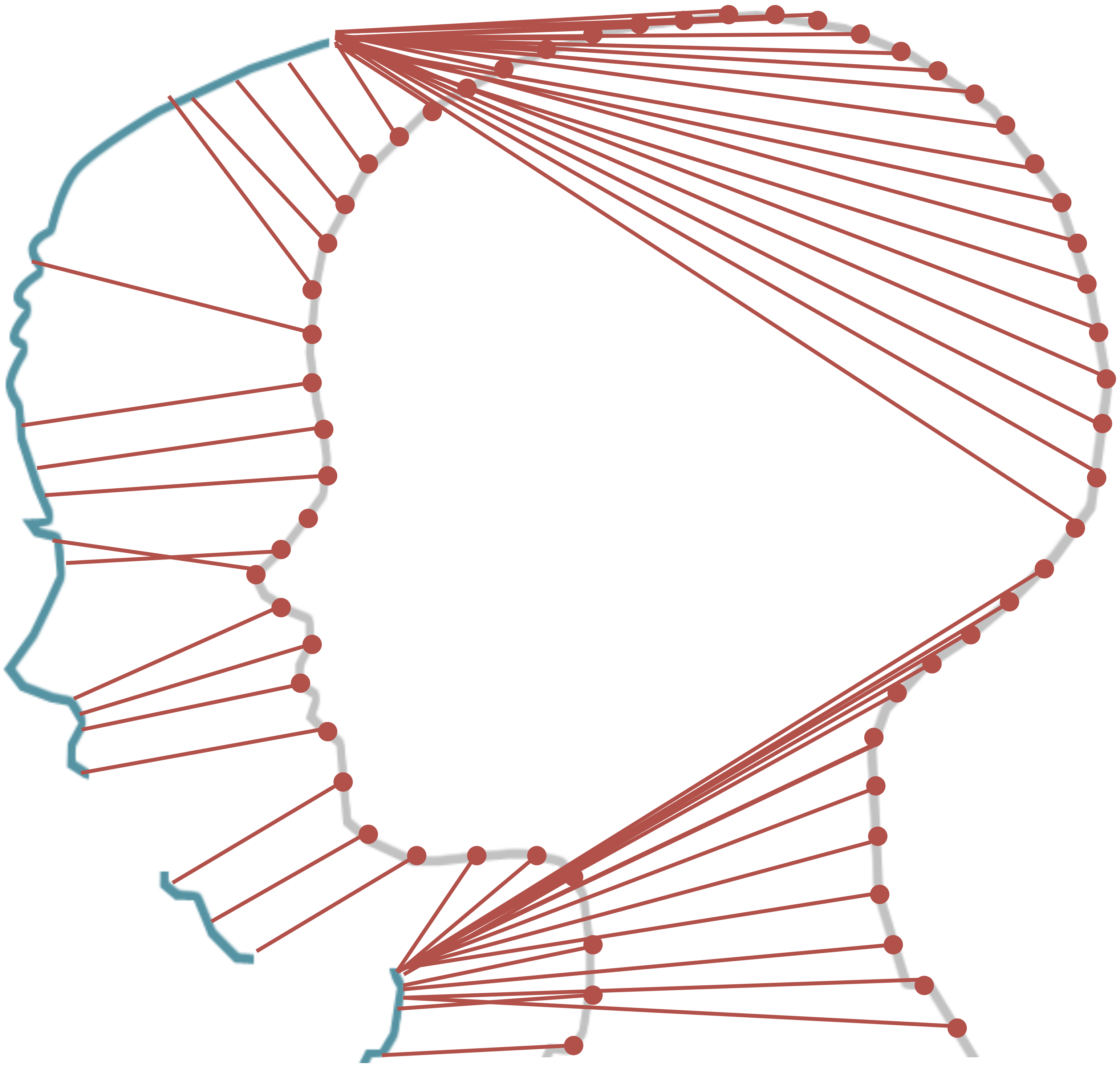


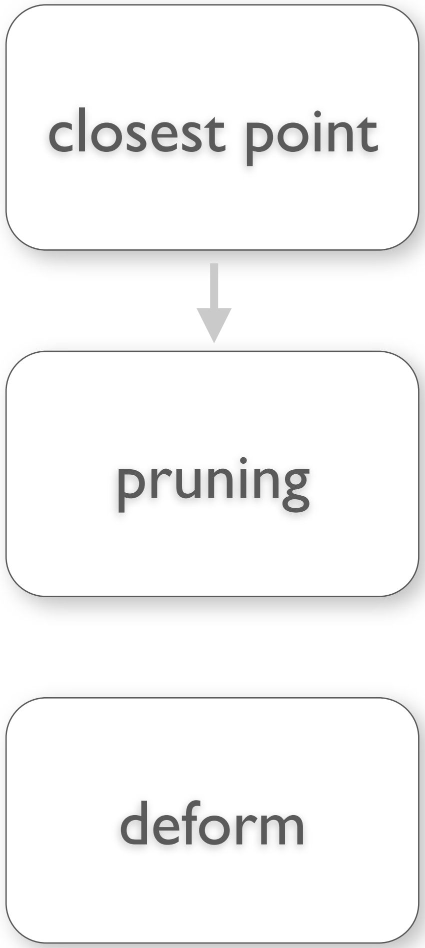
closest point

detect overlap

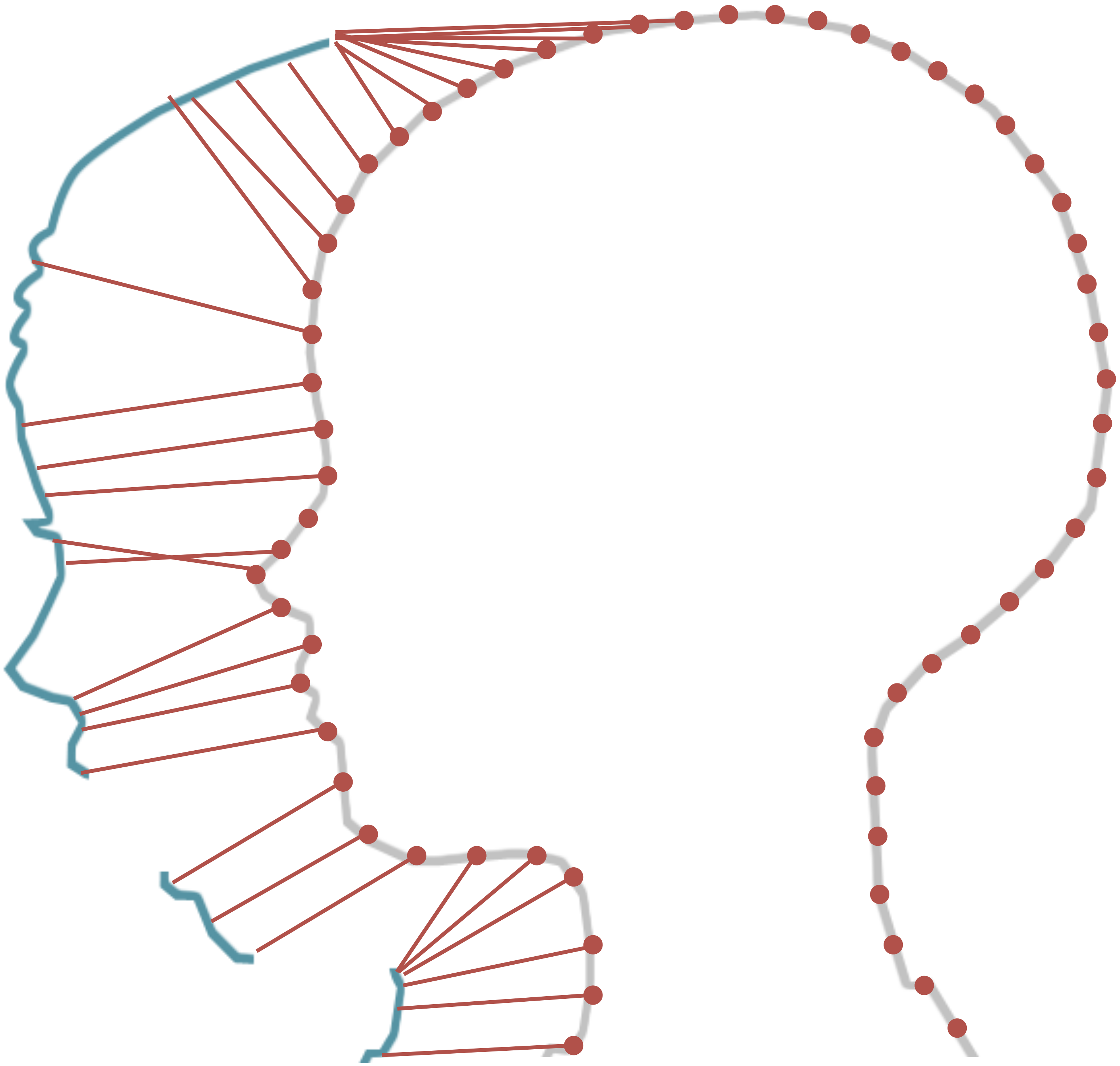
deform

Iterative Global Optimization





Iterative Global Optimization

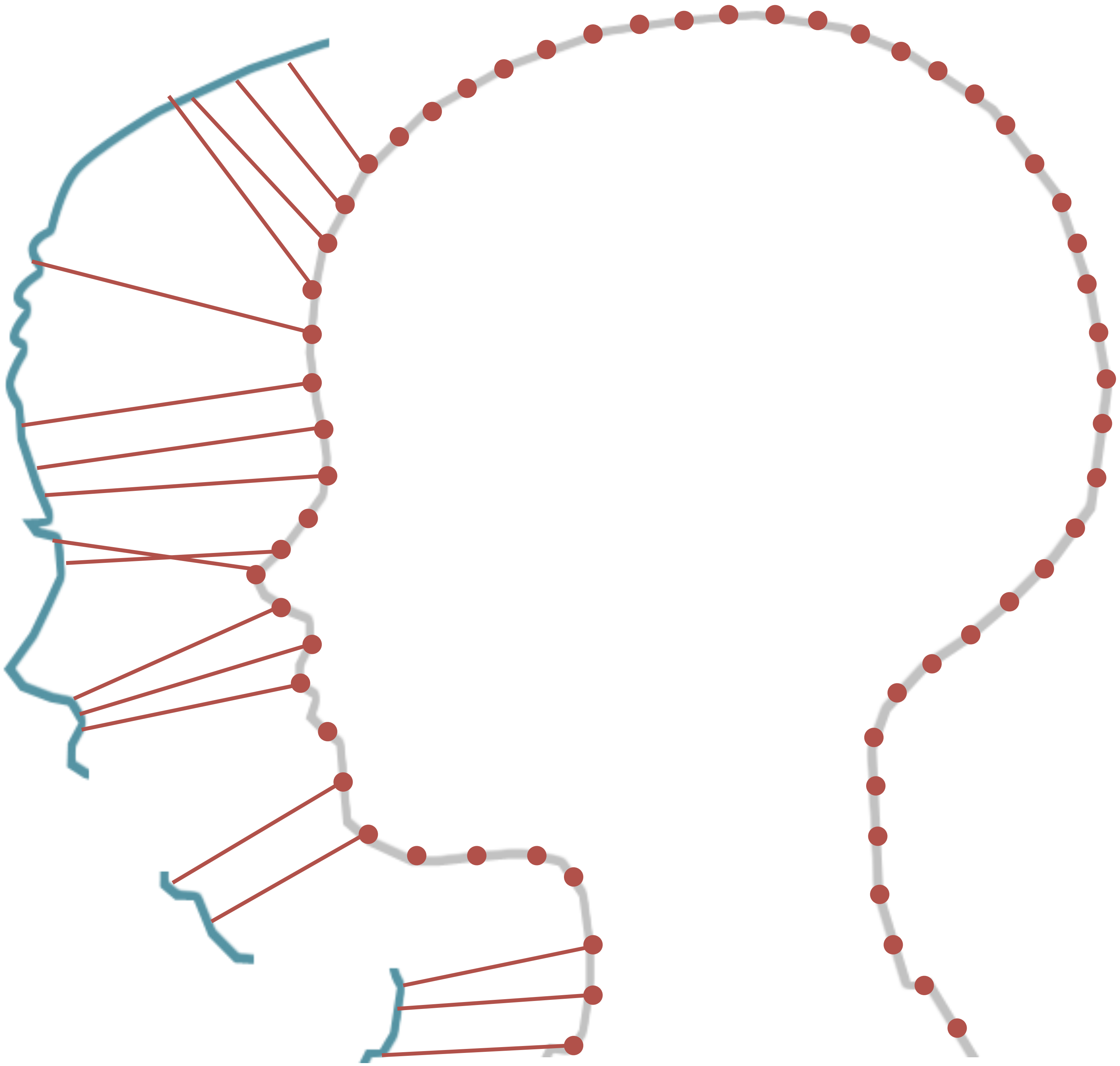


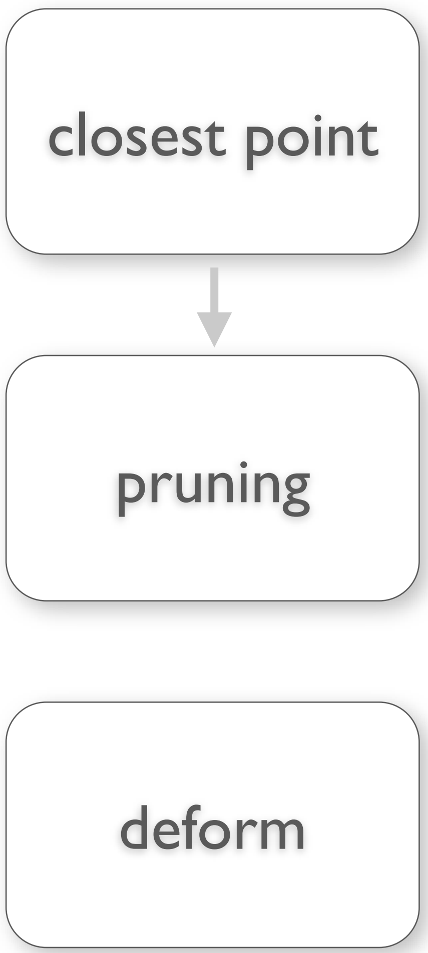
closest point

pruning

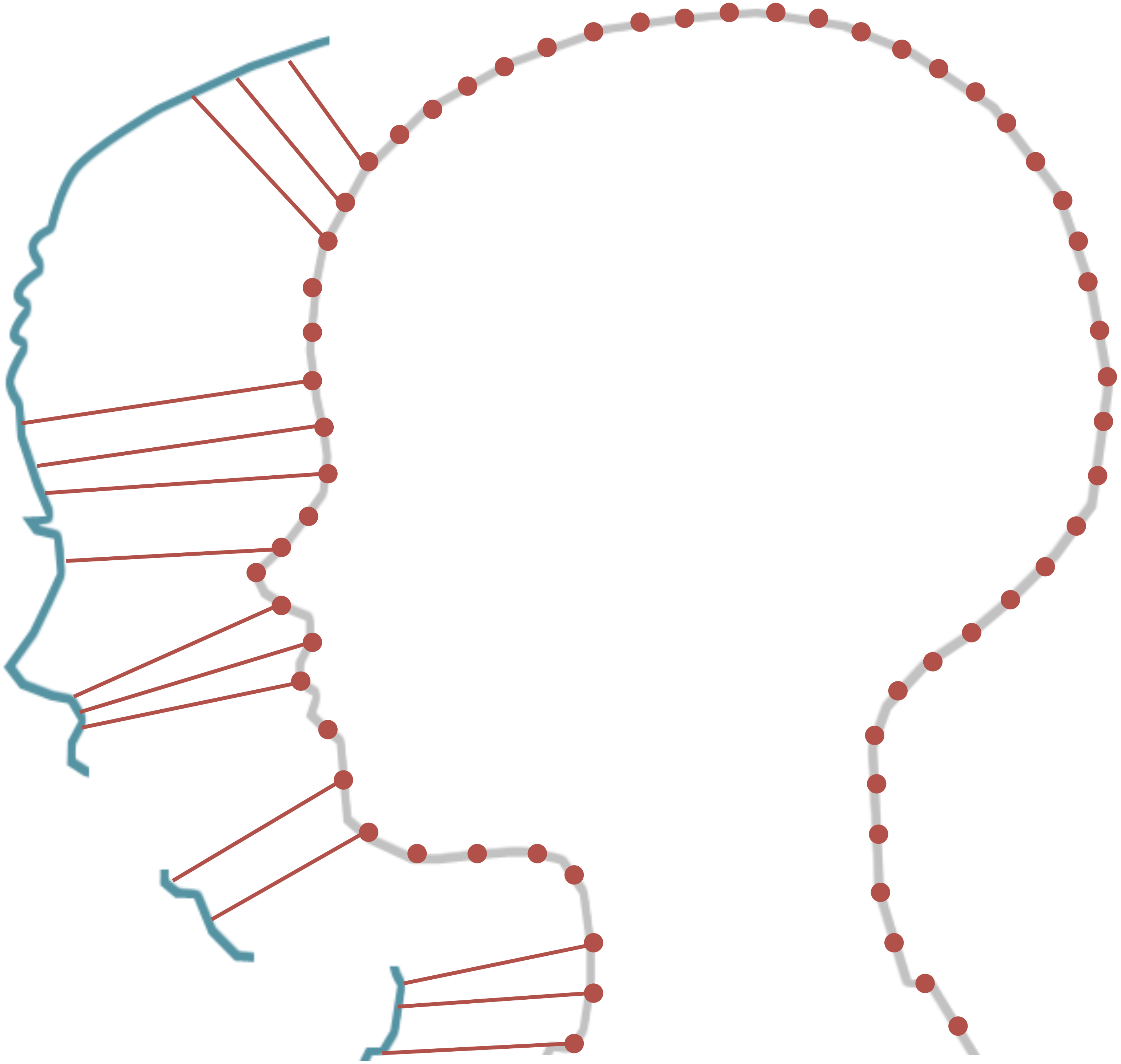
deform

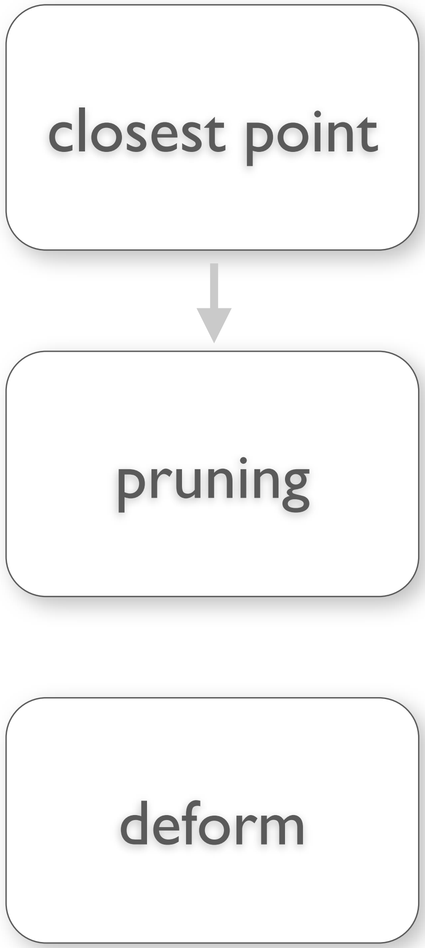
Iterative Global Optimization



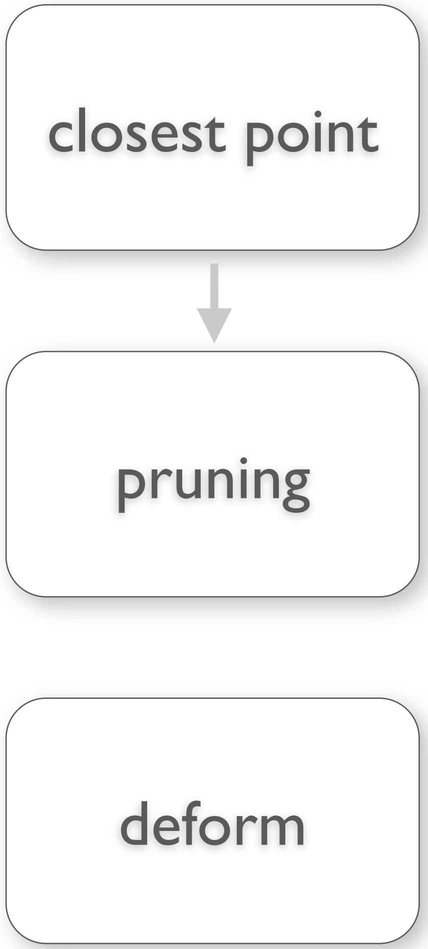


Iterative Global Optimization





Iterative Global Optimization



Iterative Global Optimization

closest point

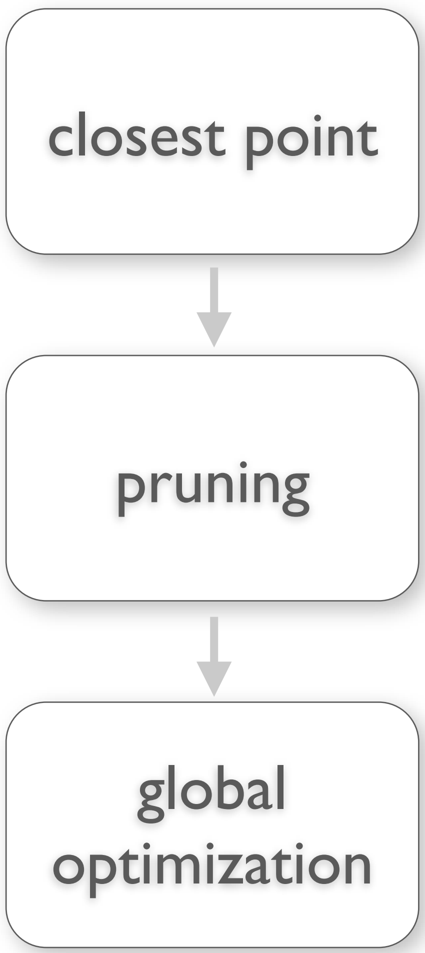
↓

pruning

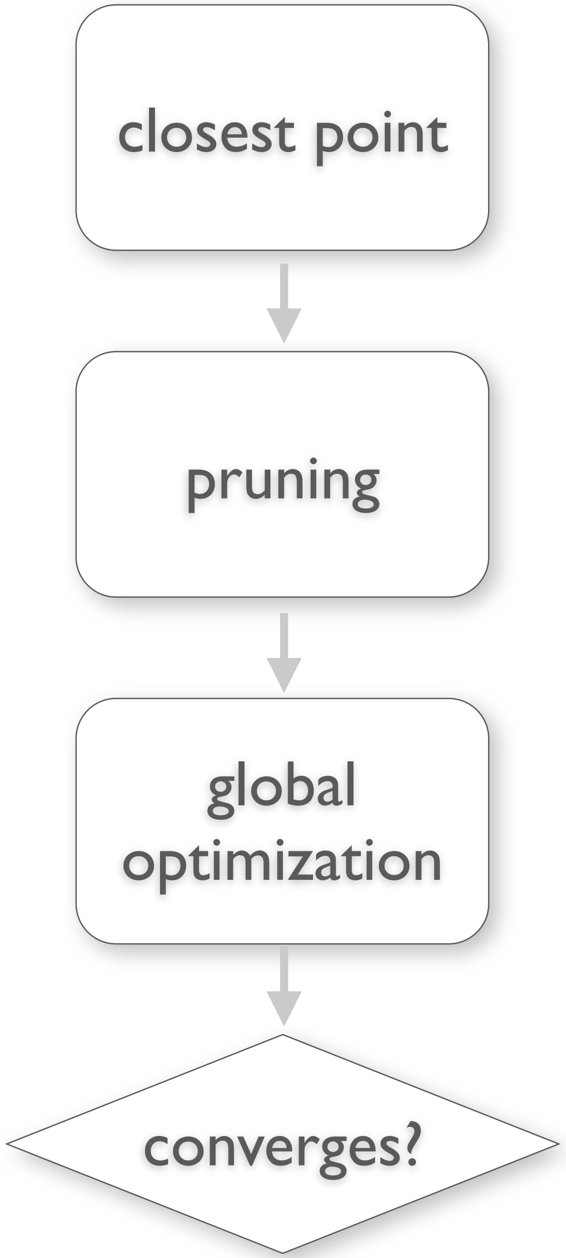
↓

global optimization

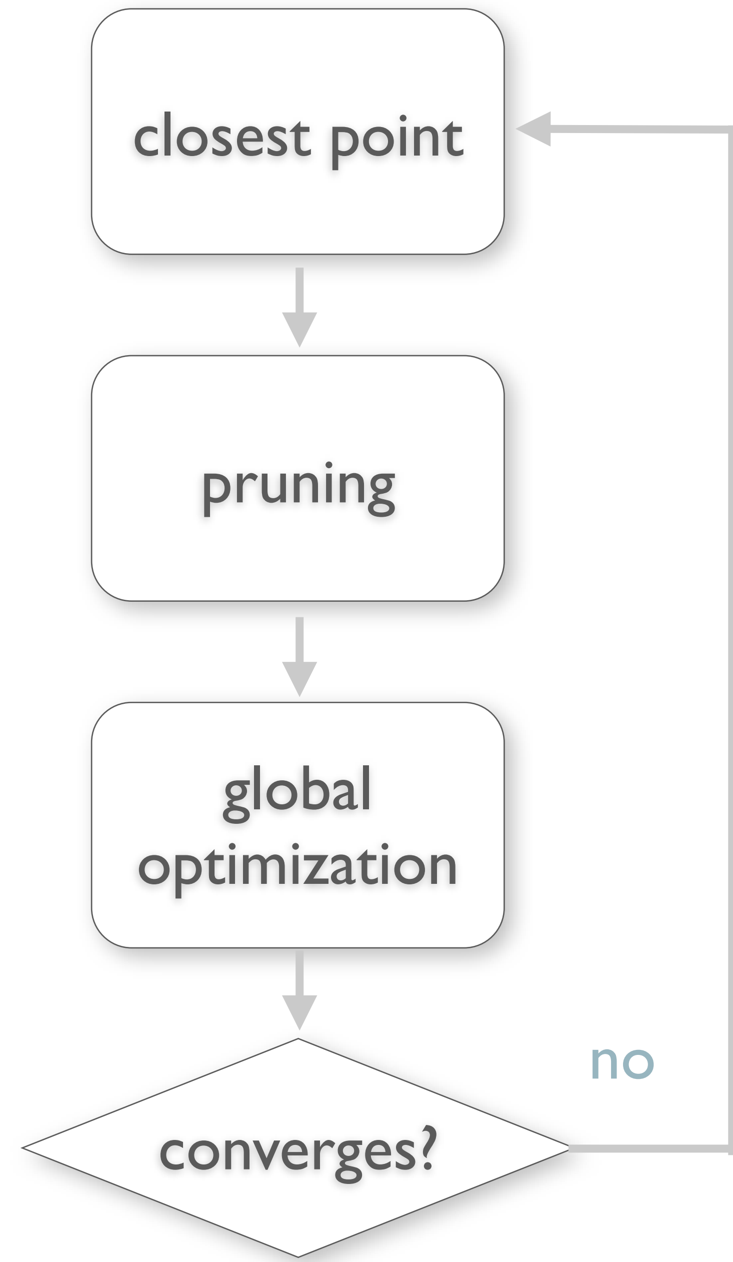
Iterative Global Optimization



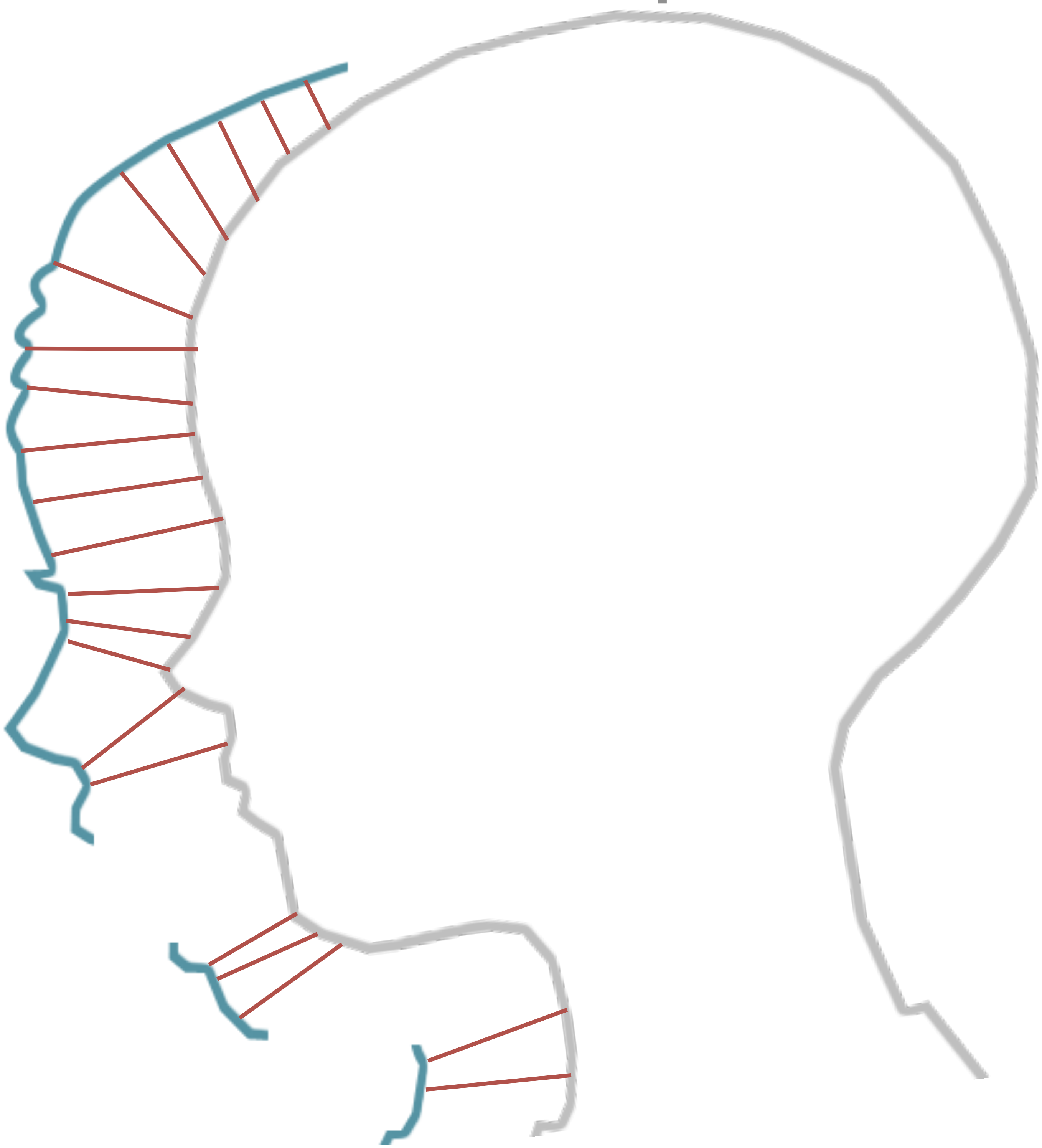
Iterative Global Optimization

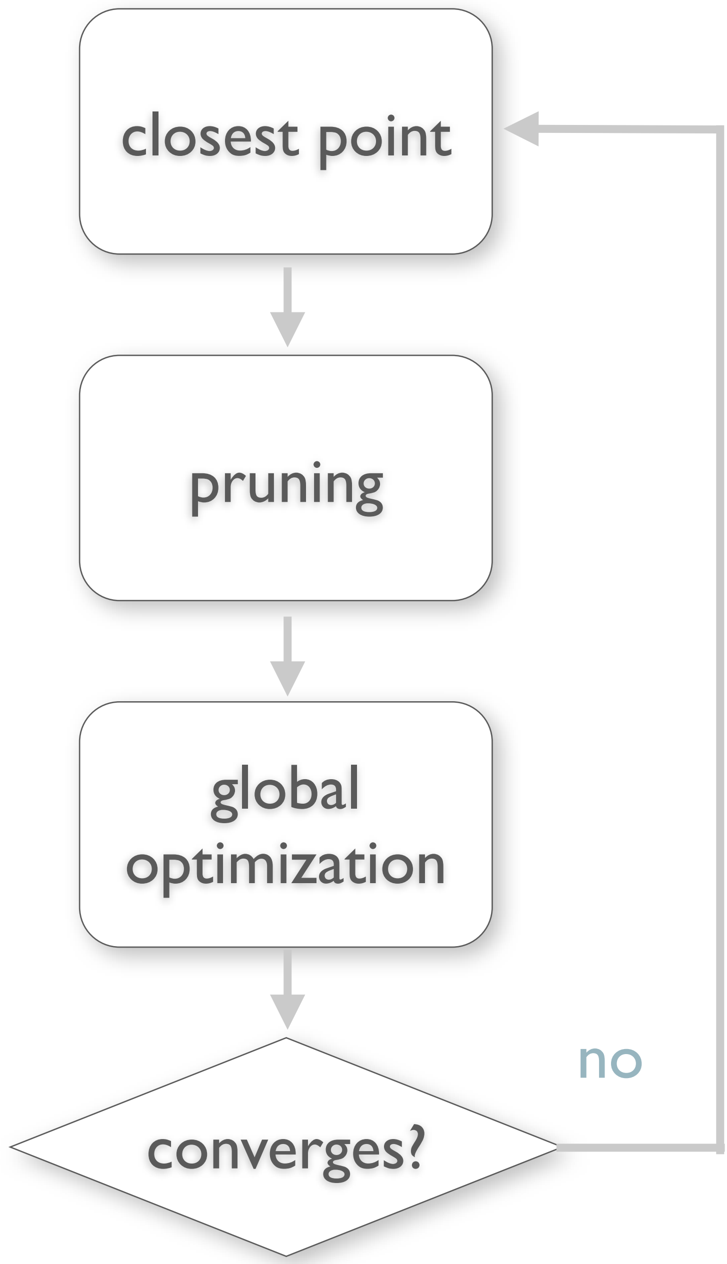


Iterative Global Optimization

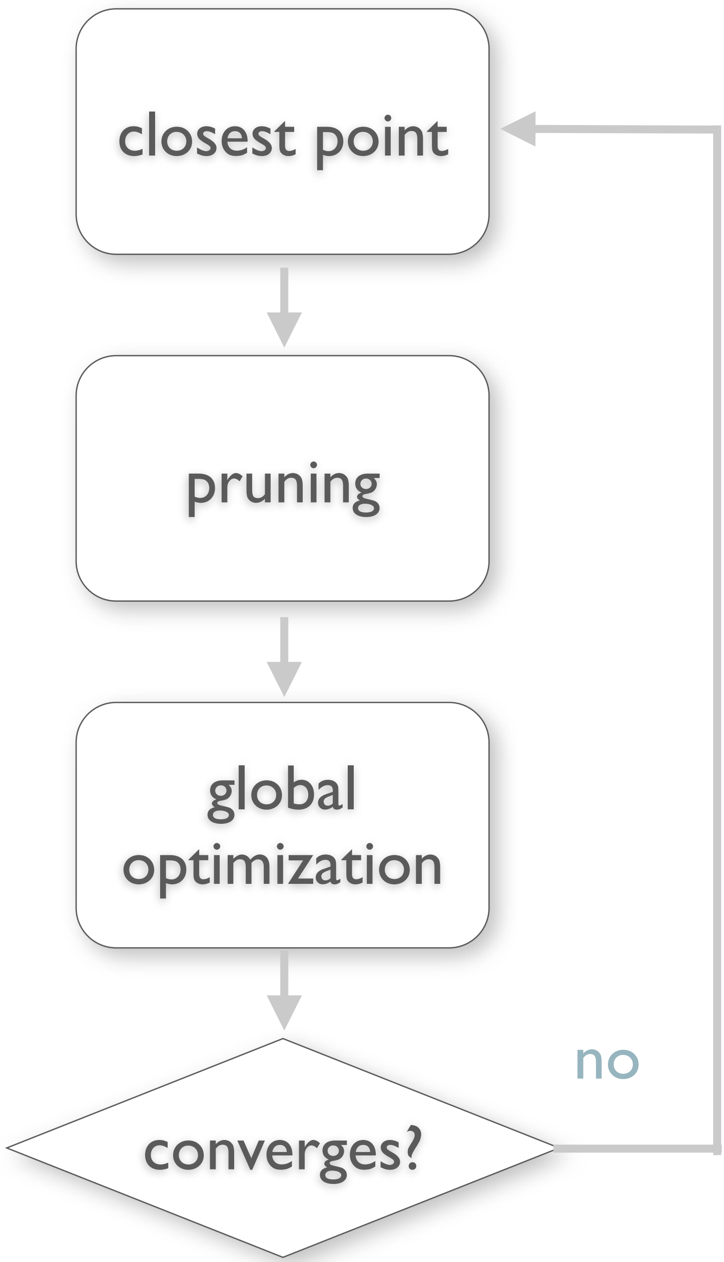


Iterative Global Optimization

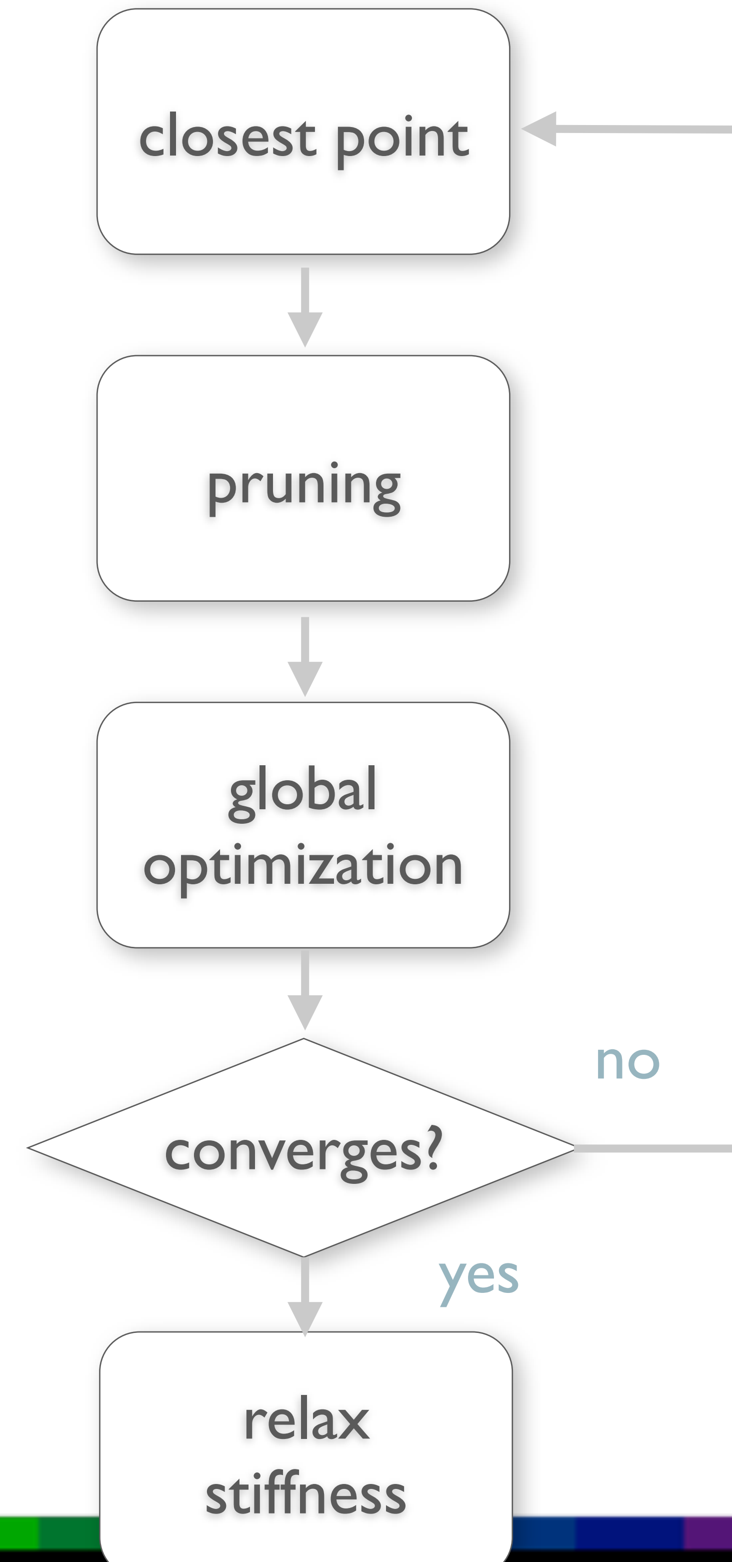




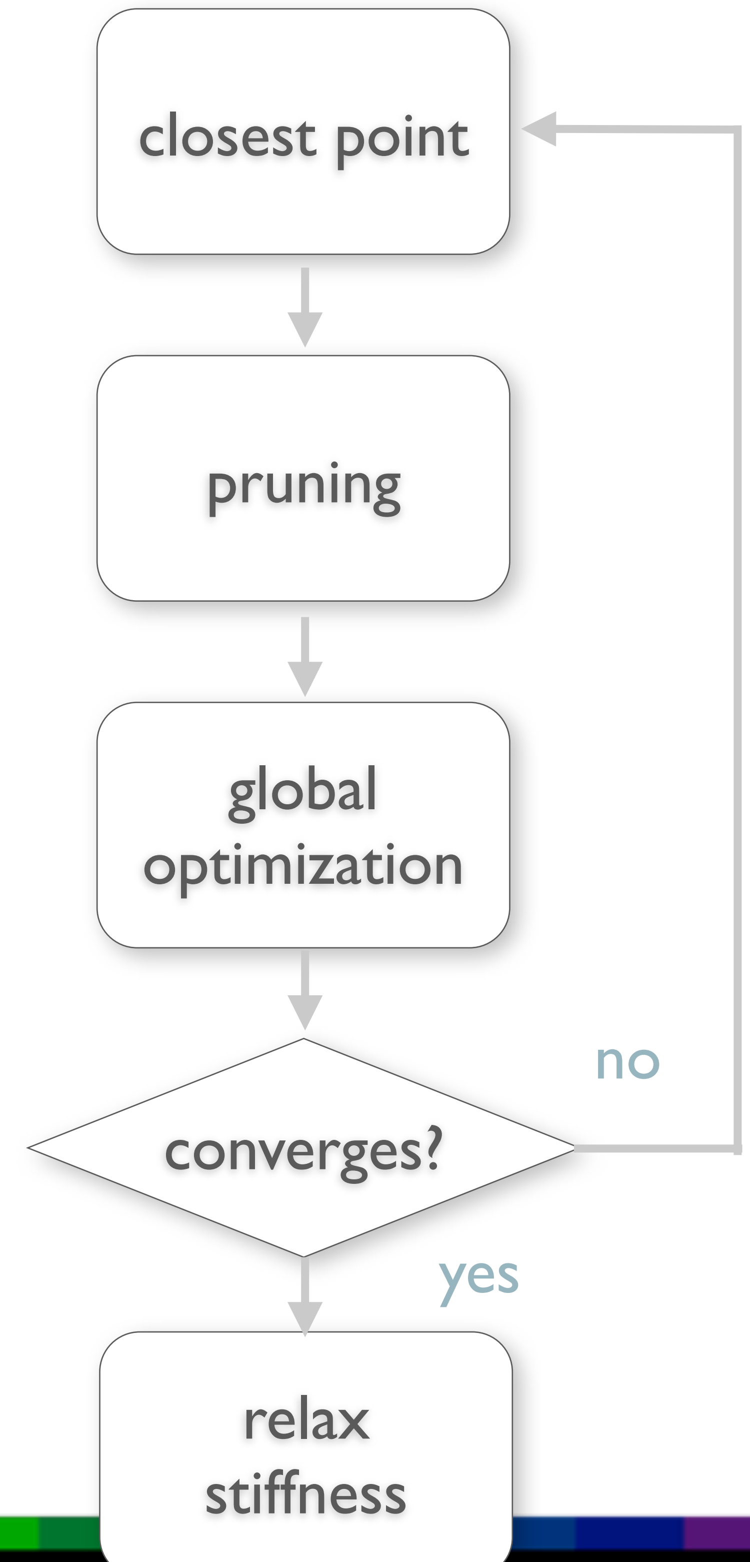
Iterative Global Optimization



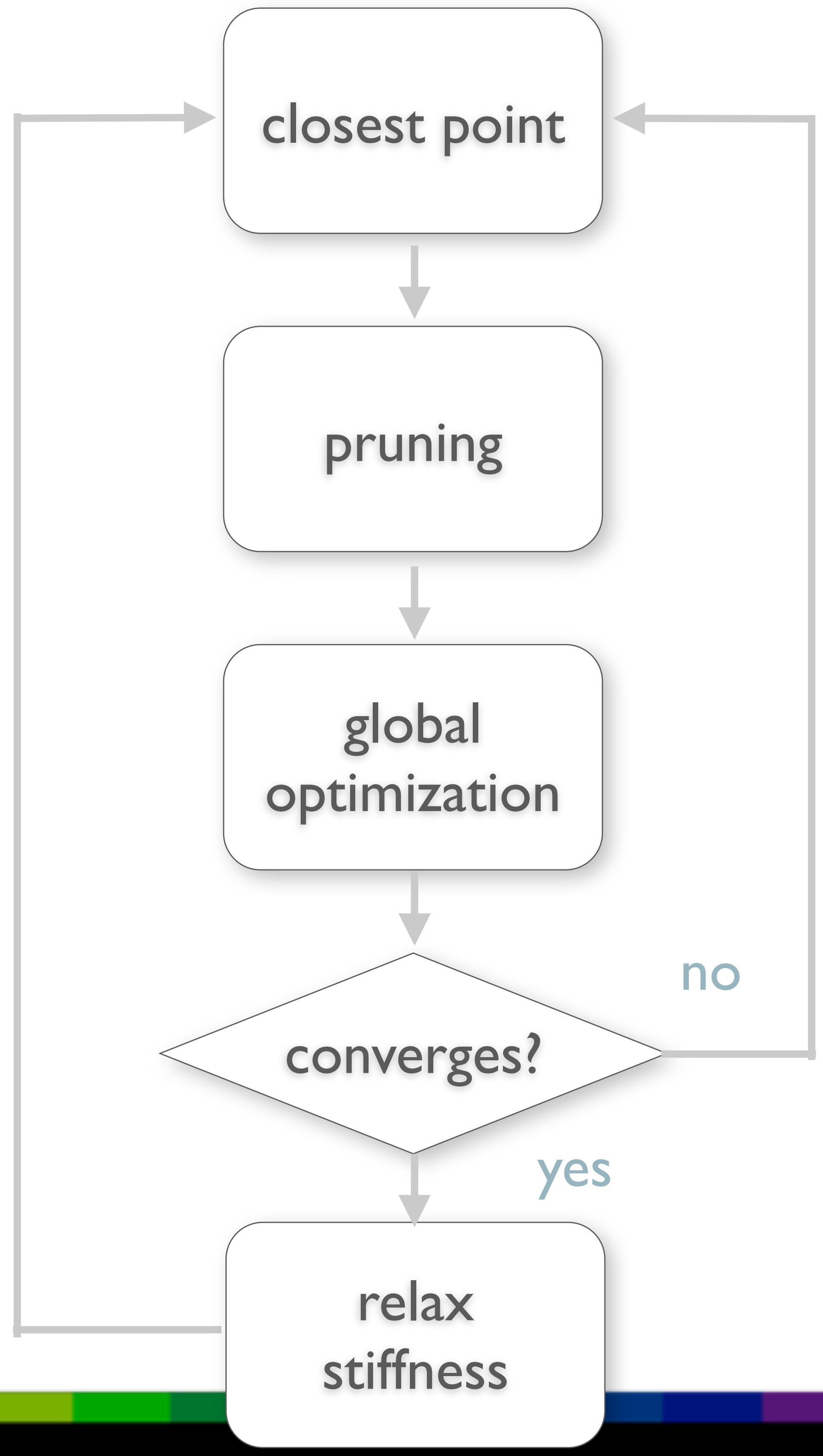
Iterative Global Optimization



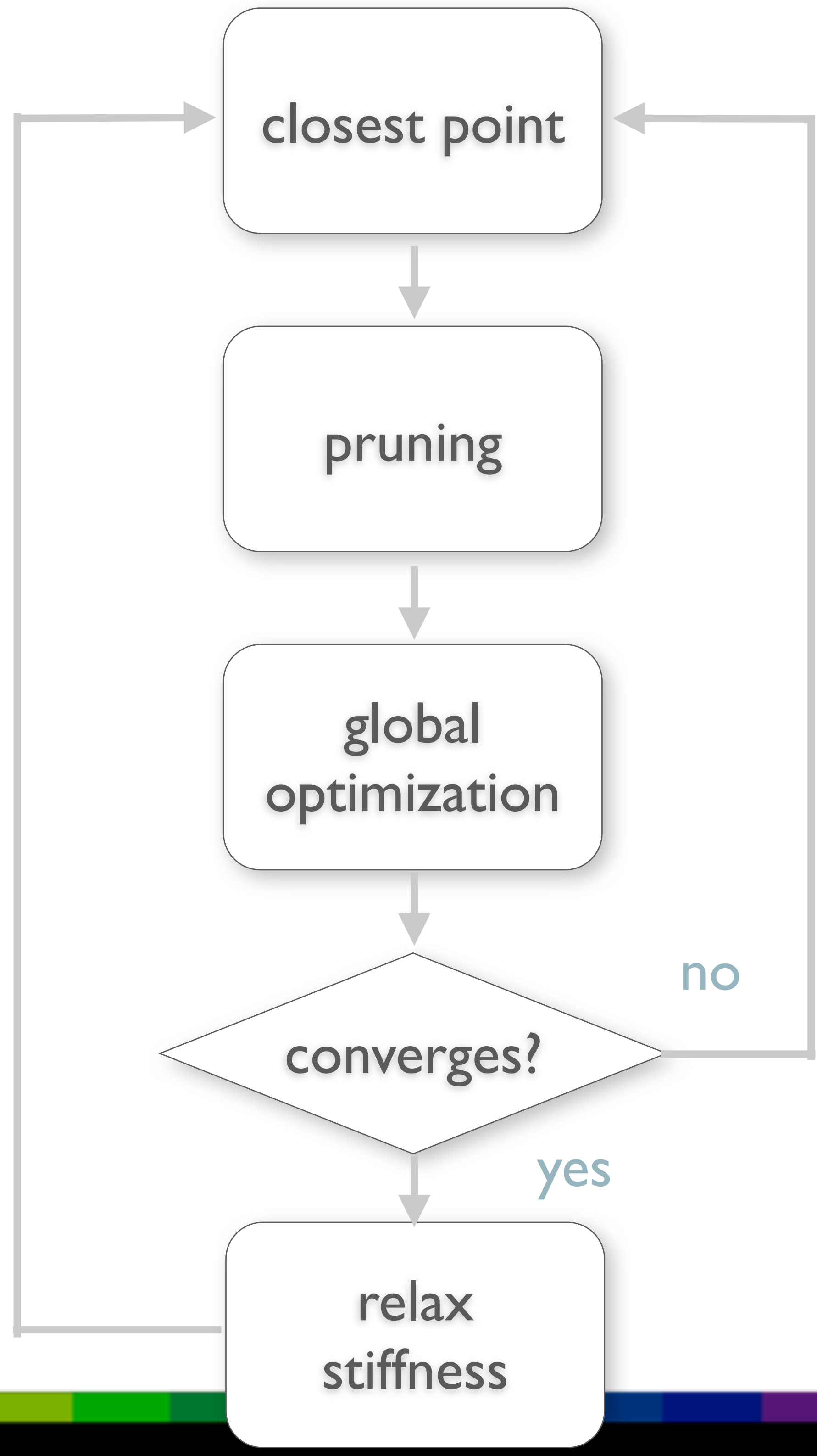
Iterative Global Optimization



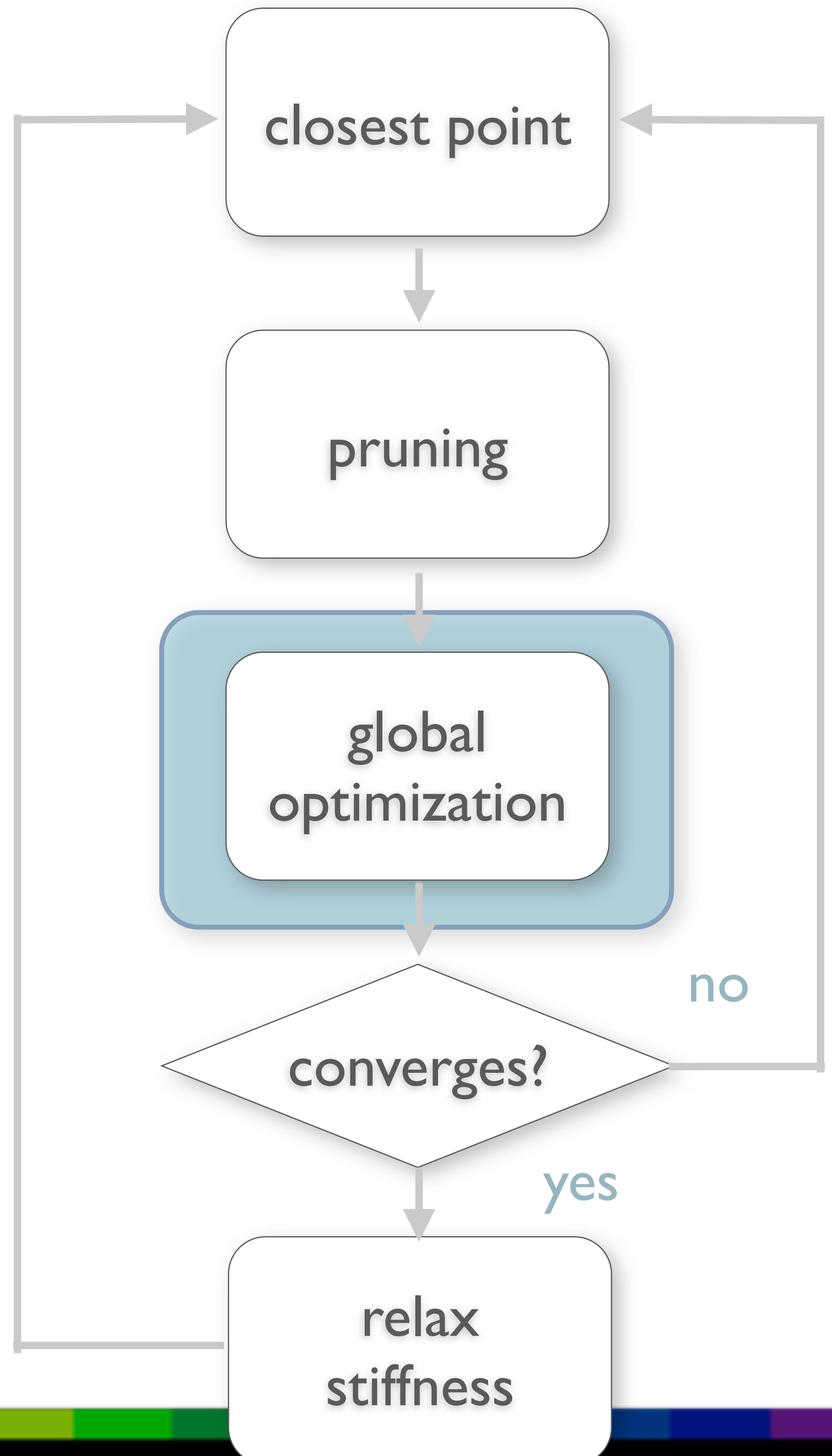
Iterative Global Optimization



Iterative Global Optimization



Iterative Global Optimization

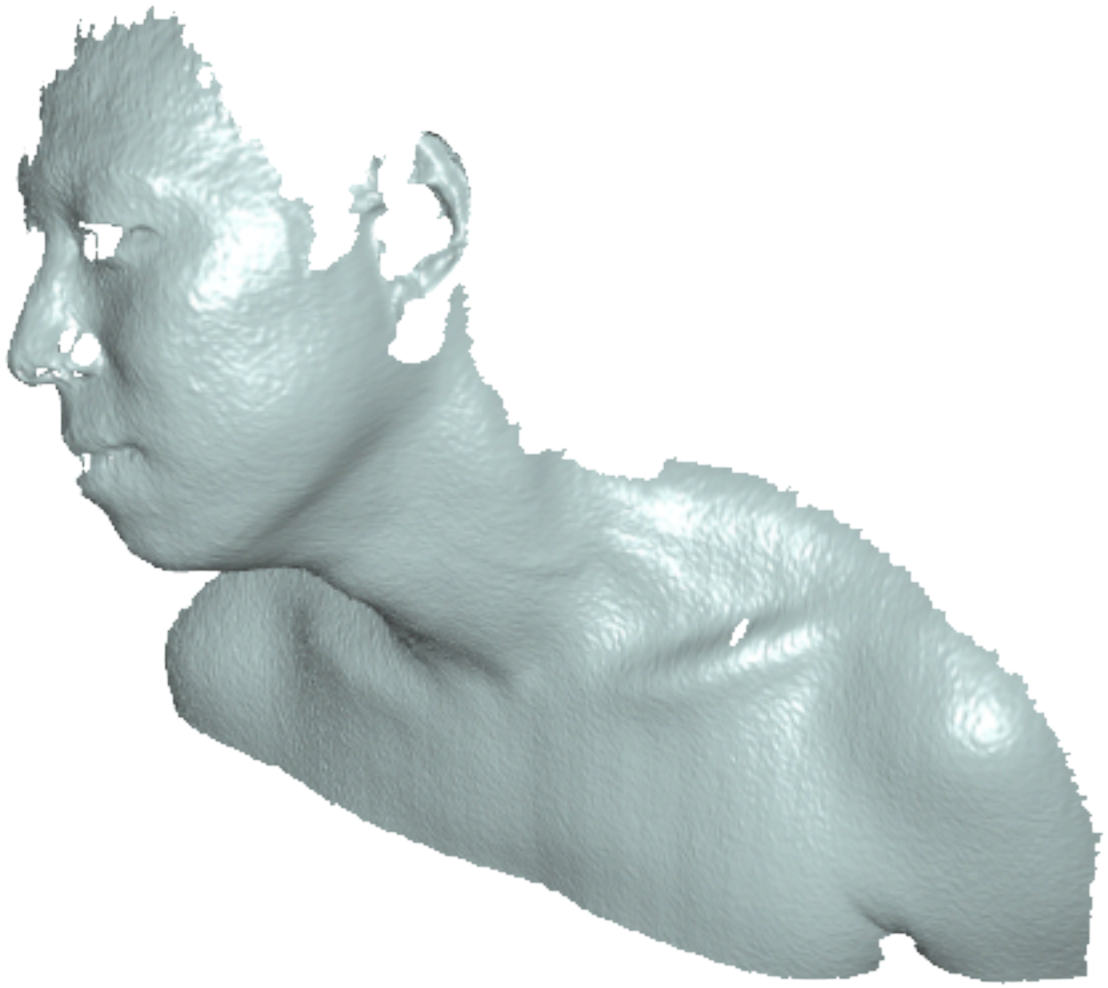


Embedded Deformation Model

detail preservation

global consistency

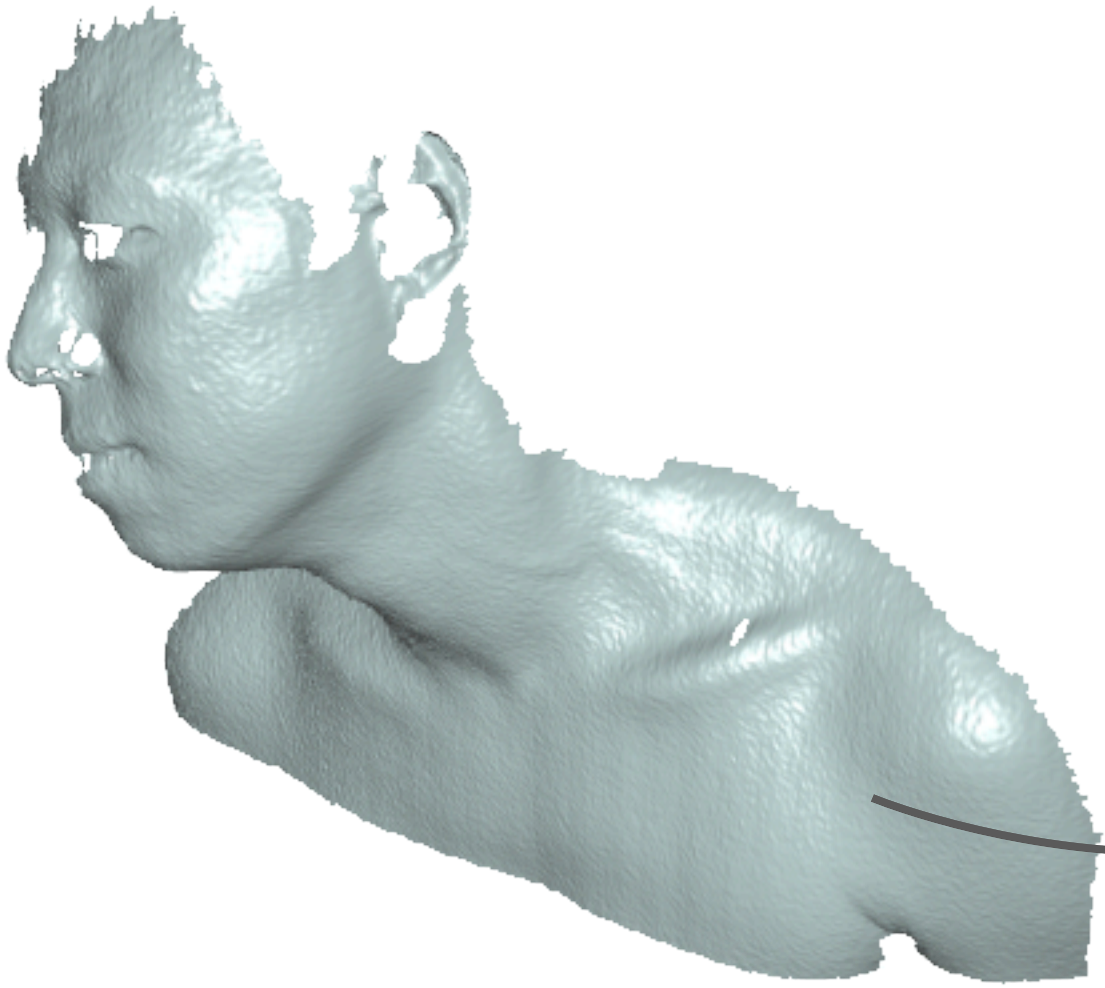
Embedded Deformation Model



detail preservation

global consistency

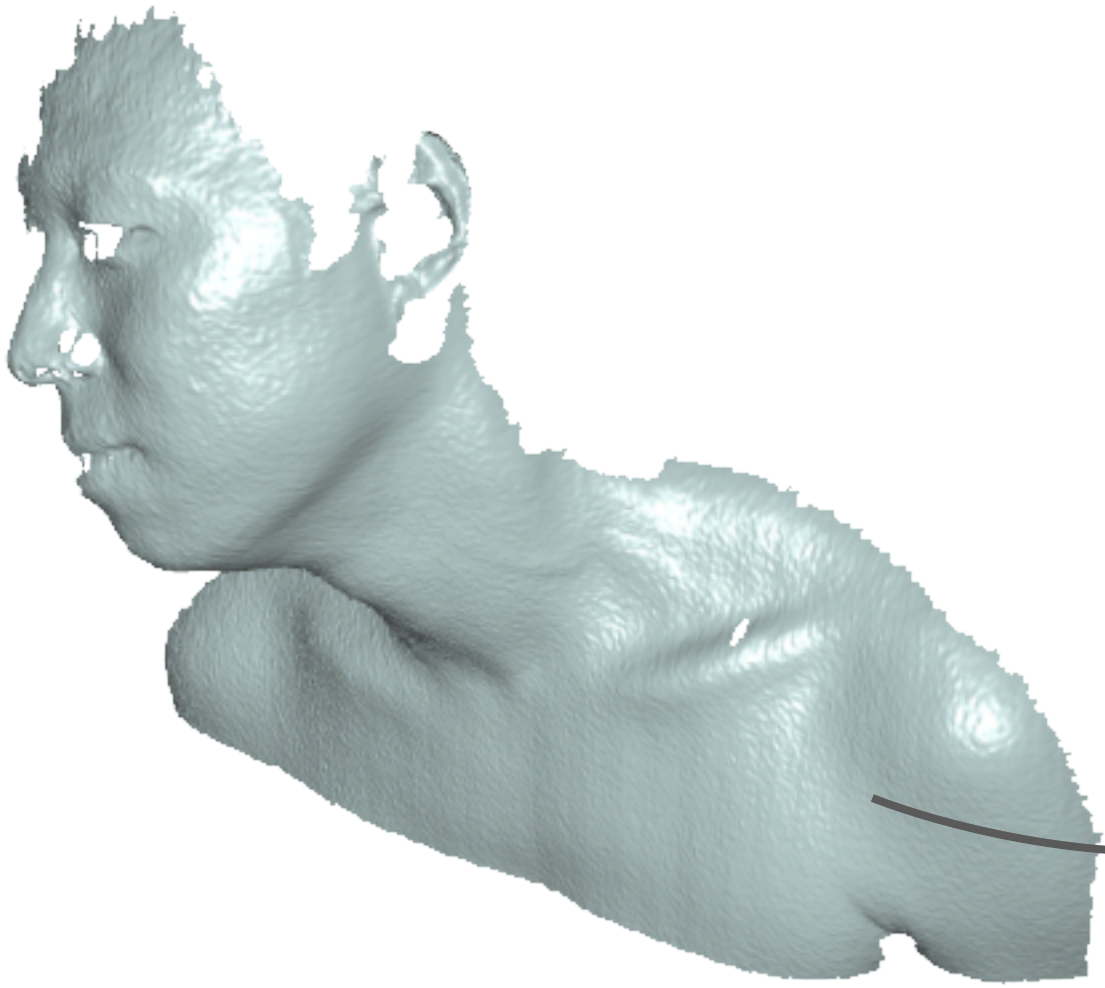
Embedded Deformation Model



detail preservation

global consistency

Embedded Deformation Model



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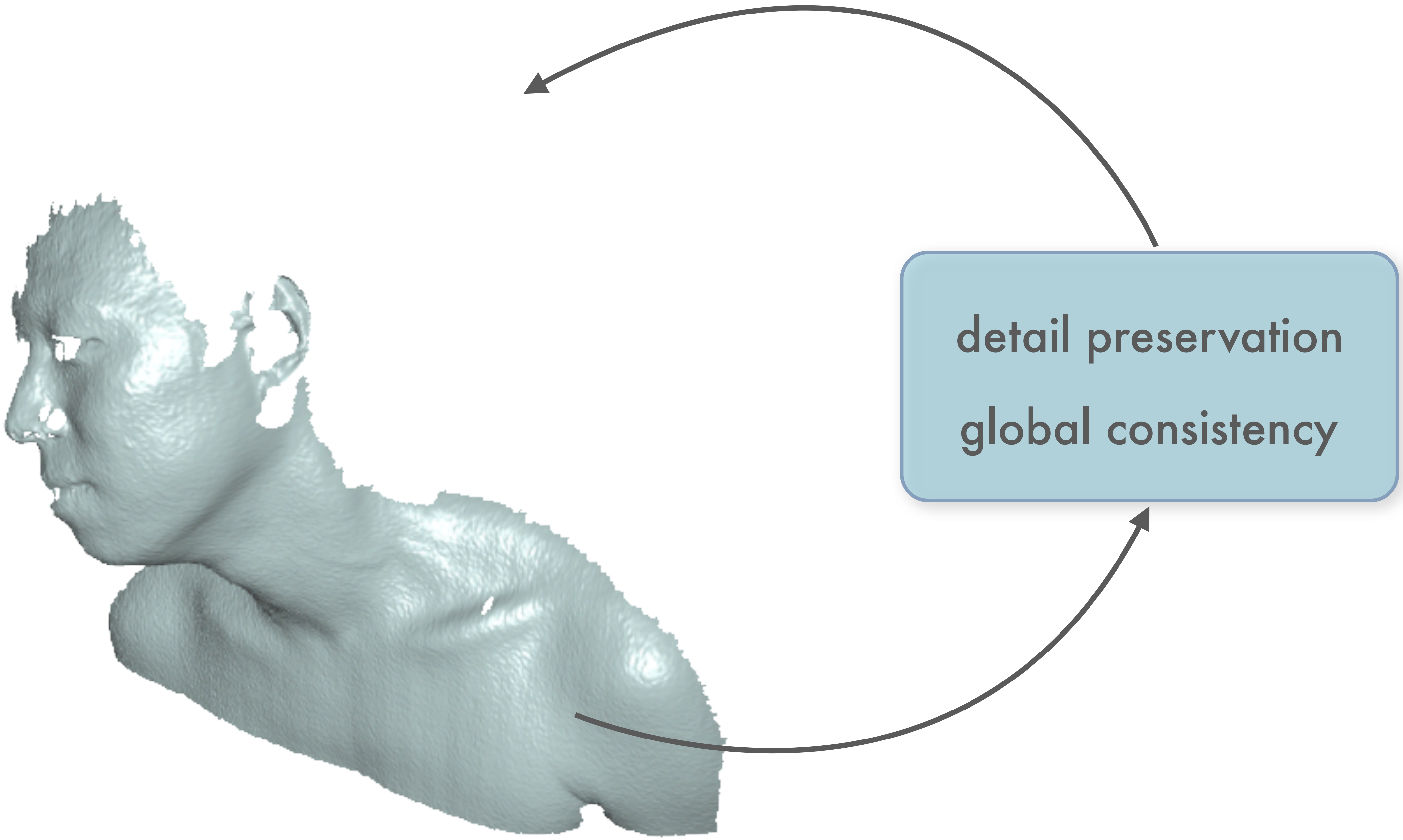

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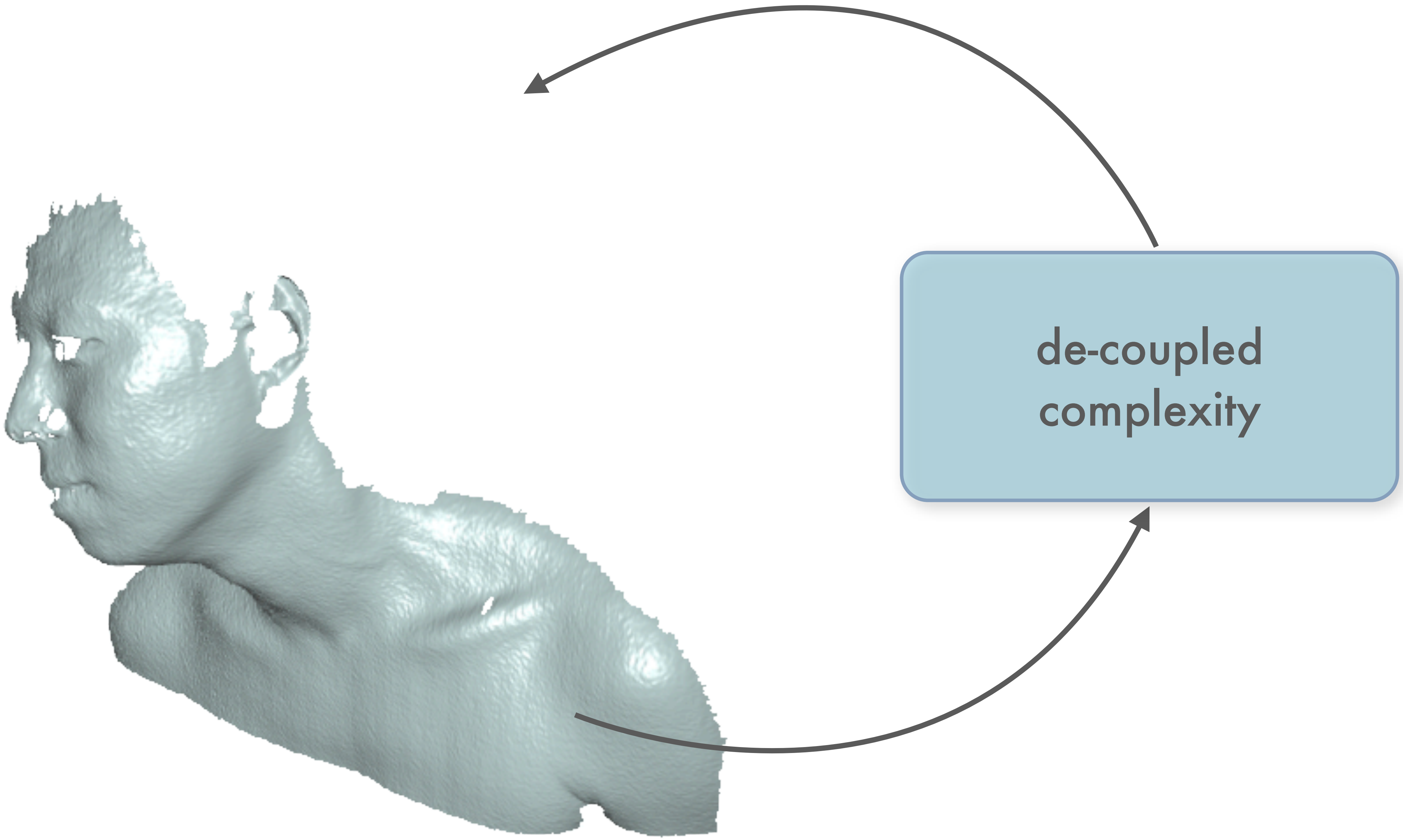
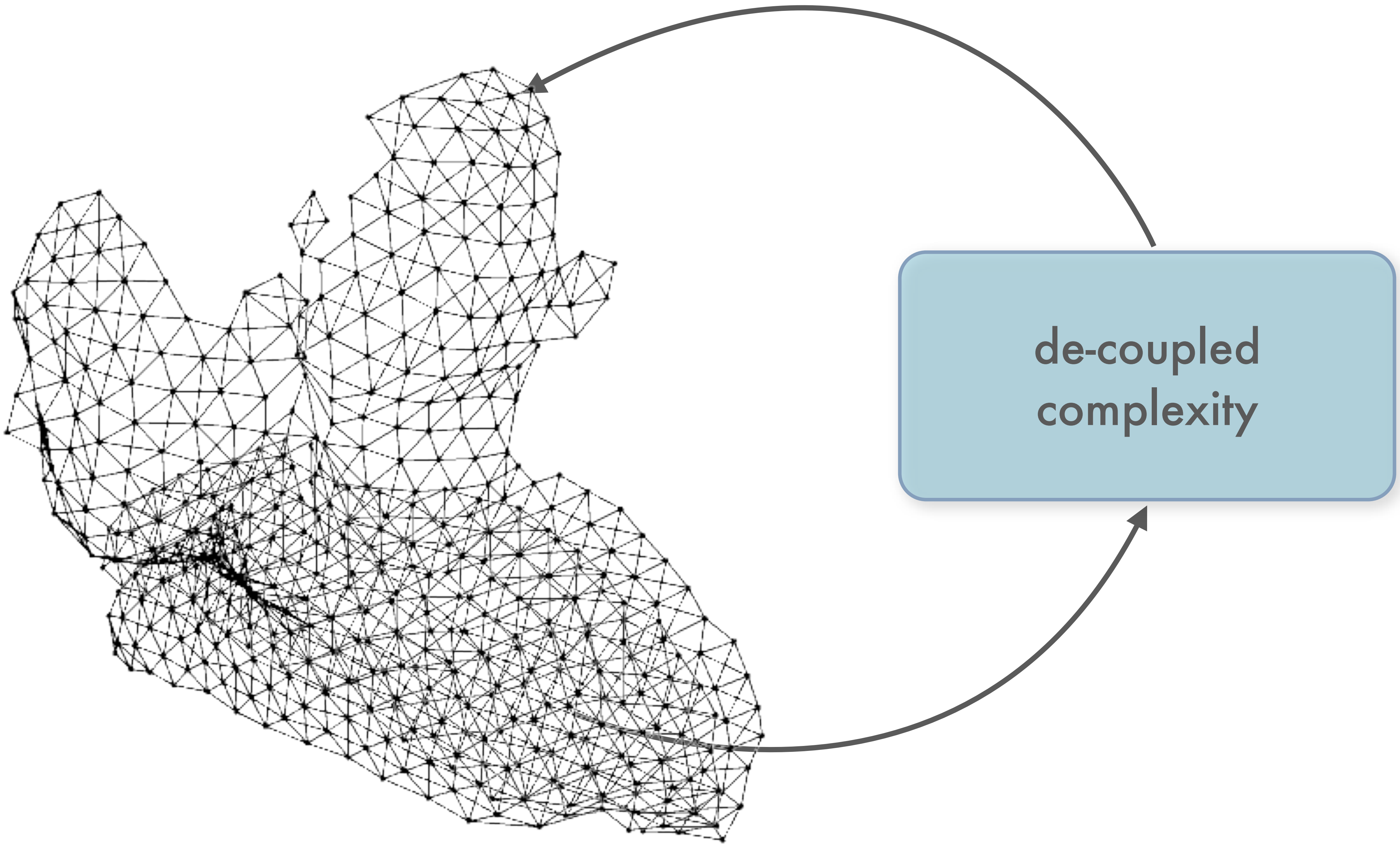
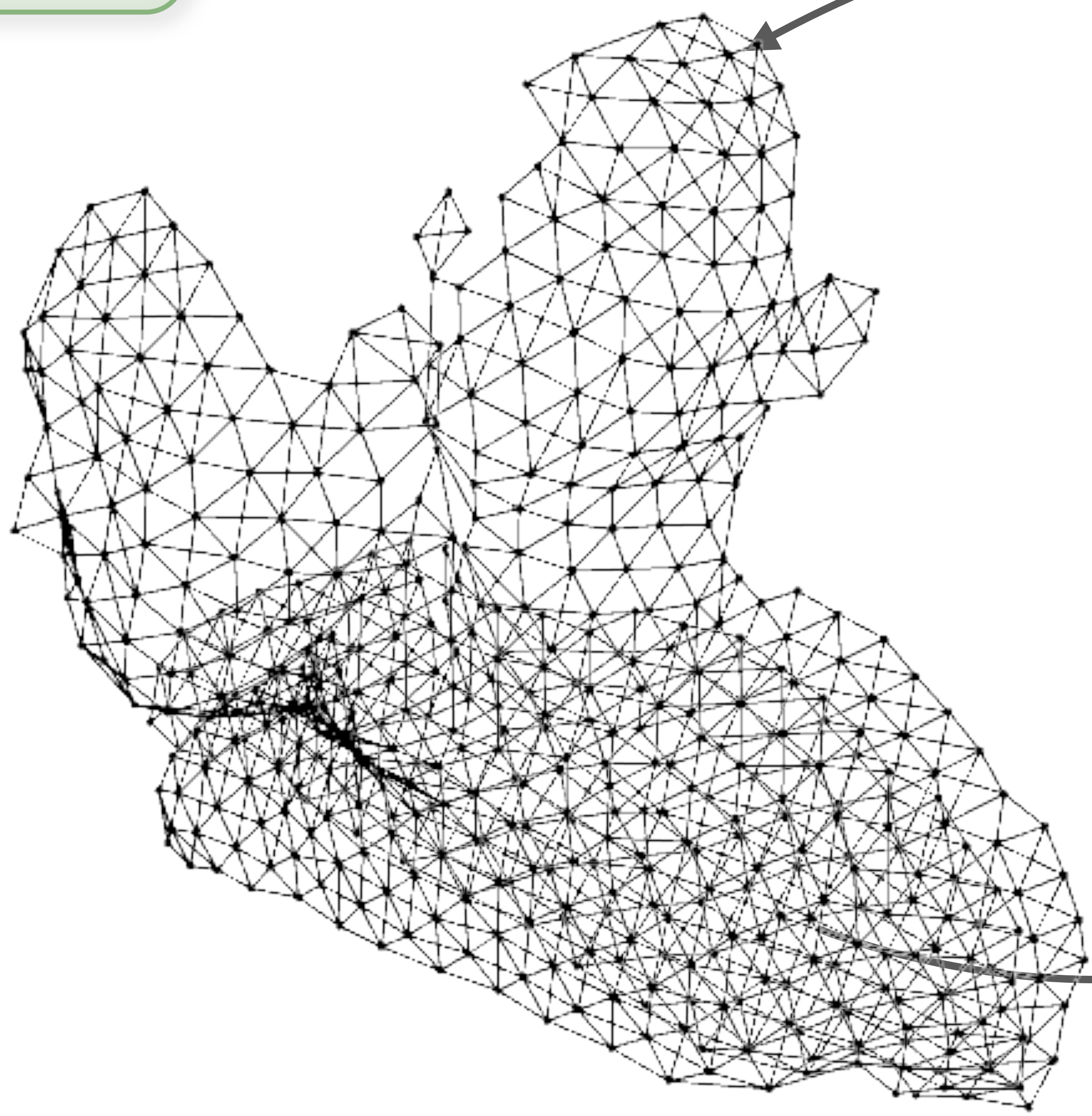


Embedded Deformation Model



Embedded Deformation Model

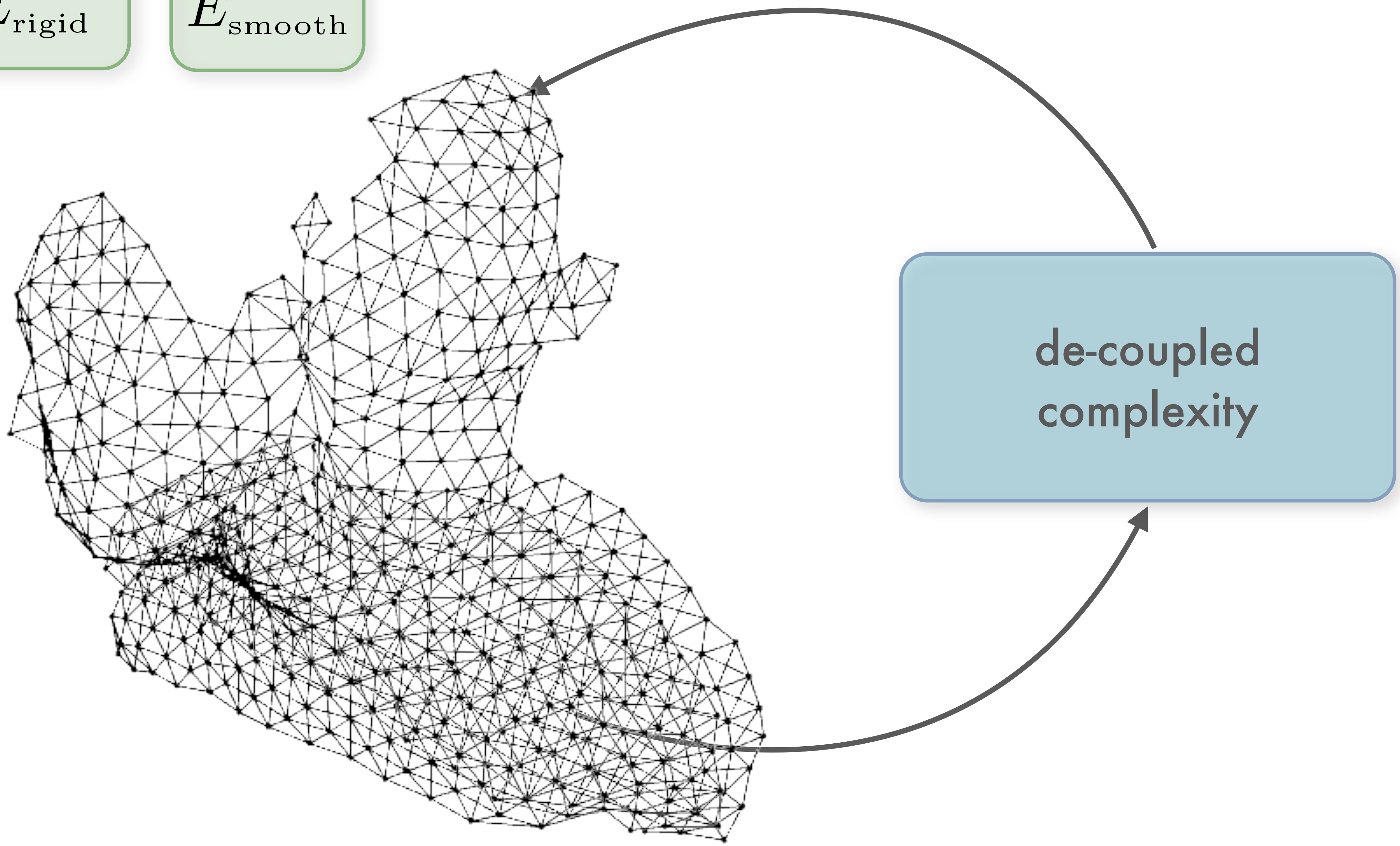
E_{rigid}



de-coupled complexity

Embedded Deformation Model

E_{rigid} E_{smooth}



Non-Linear Energy Minimization

E_{rigid}

E_{smooth}

Non-Linear Energy Minimization

E_{rigid}

E_{smooth}

Non-Linear Energy Minimization

E_{rigid} E_{smooth}

Non-Linear Energy Minimization

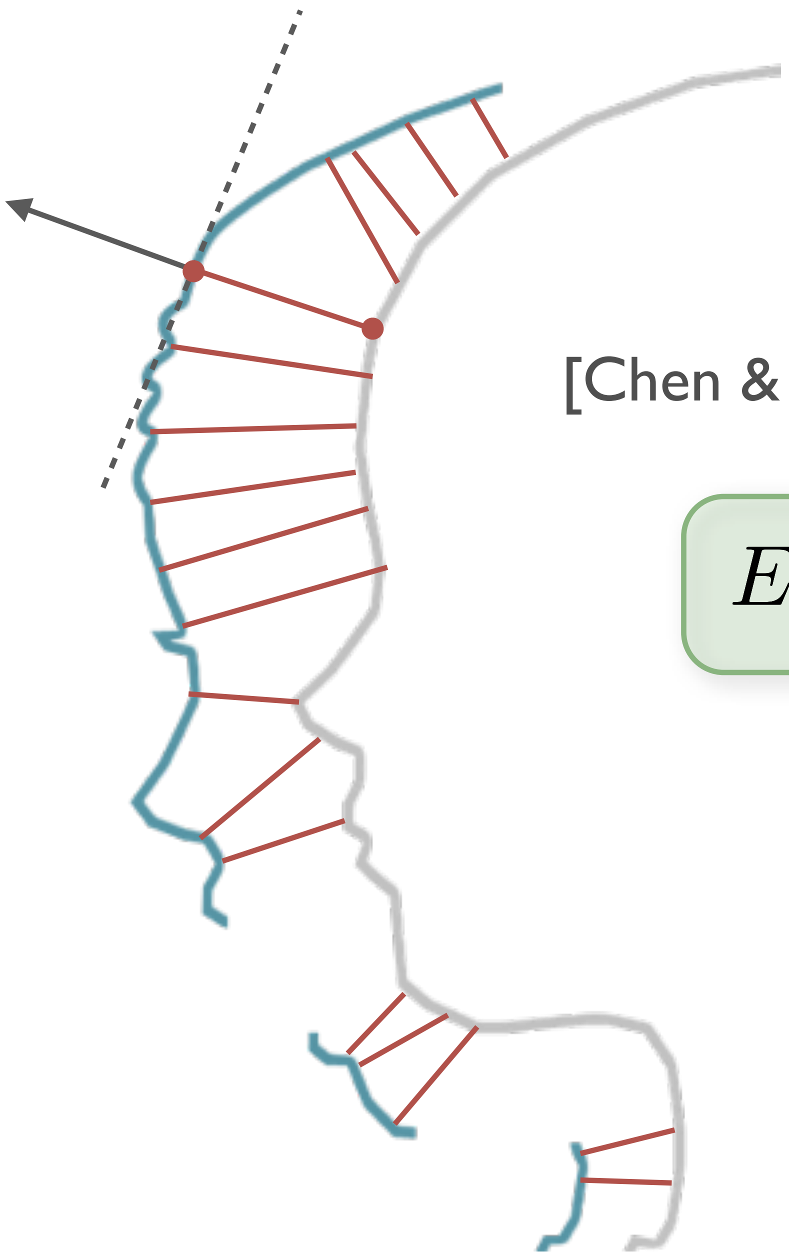
E_{rigid}

E_{smooth}

Non-Linear Energy Minimization

E_{point} E_{rigid} E_{smooth}

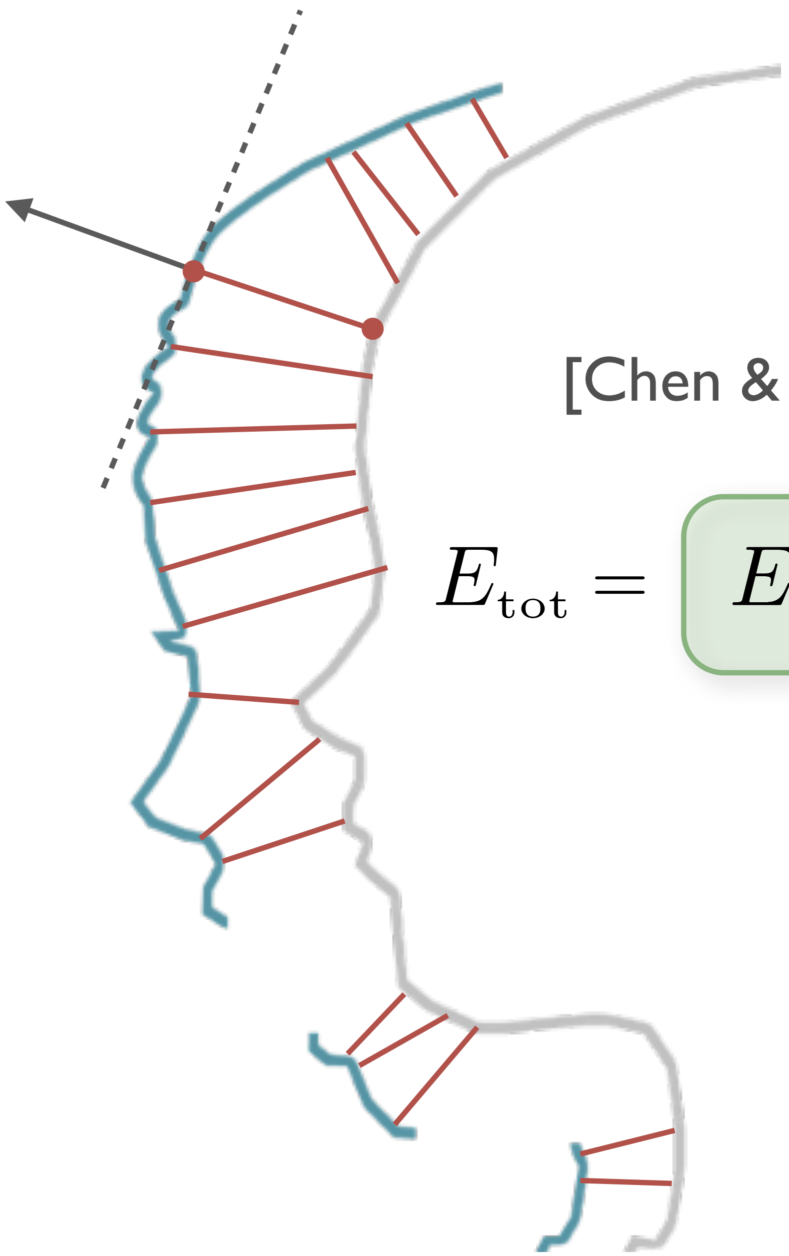
Non-Linear Energy Minimization



[Chen & Medioni '92]

E_{plane} E_{point} E_{rigid} E_{smooth}

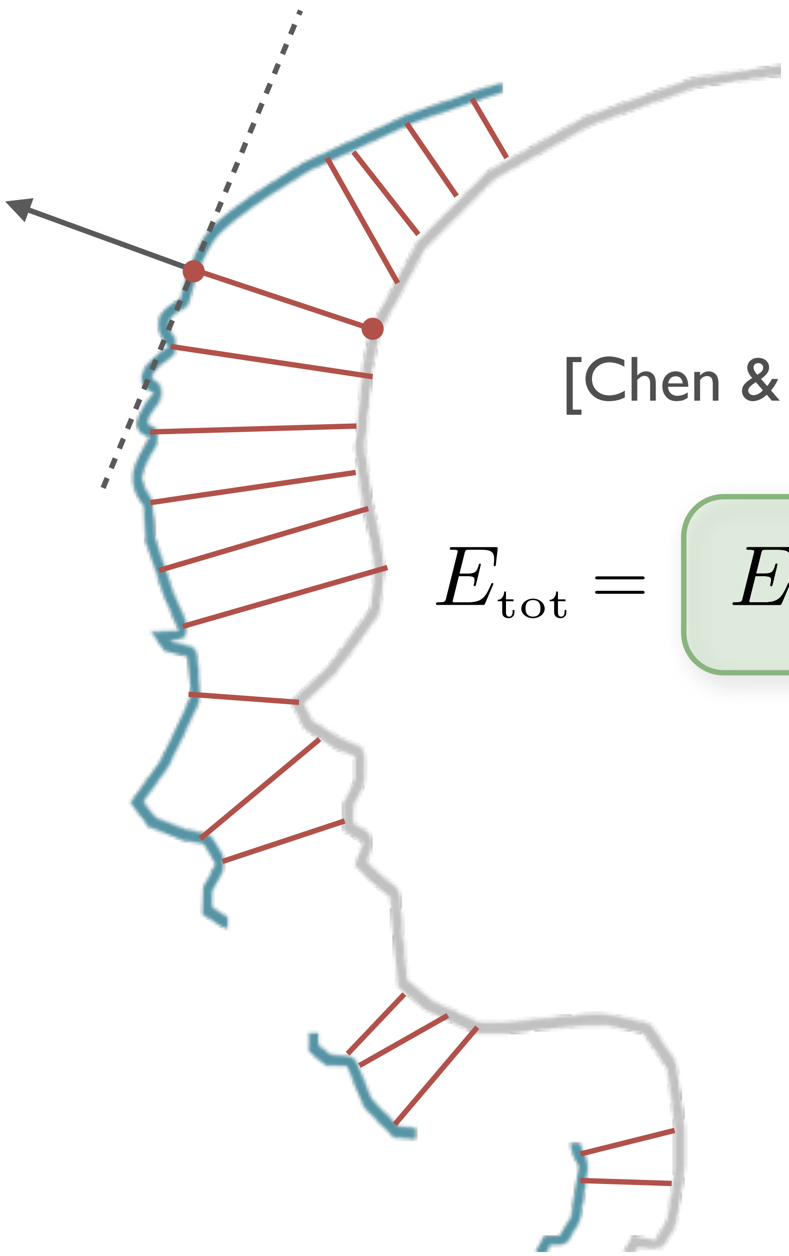
Non-Linear Energy Minimization



[Chen & Medioni '92]

$$E_{\text{tot}} = \boxed{E_{\text{plane}}} + \alpha_{\text{point}} \boxed{E_{\text{point}}} + \alpha_{\text{rigid}} \boxed{E_{\textbf{rigid}}} + \alpha_{\text{smooth}} \boxed{E_{\text{smooth}}}$$

Non-Linear Energy Minimization



[Chen & Medioni '92]

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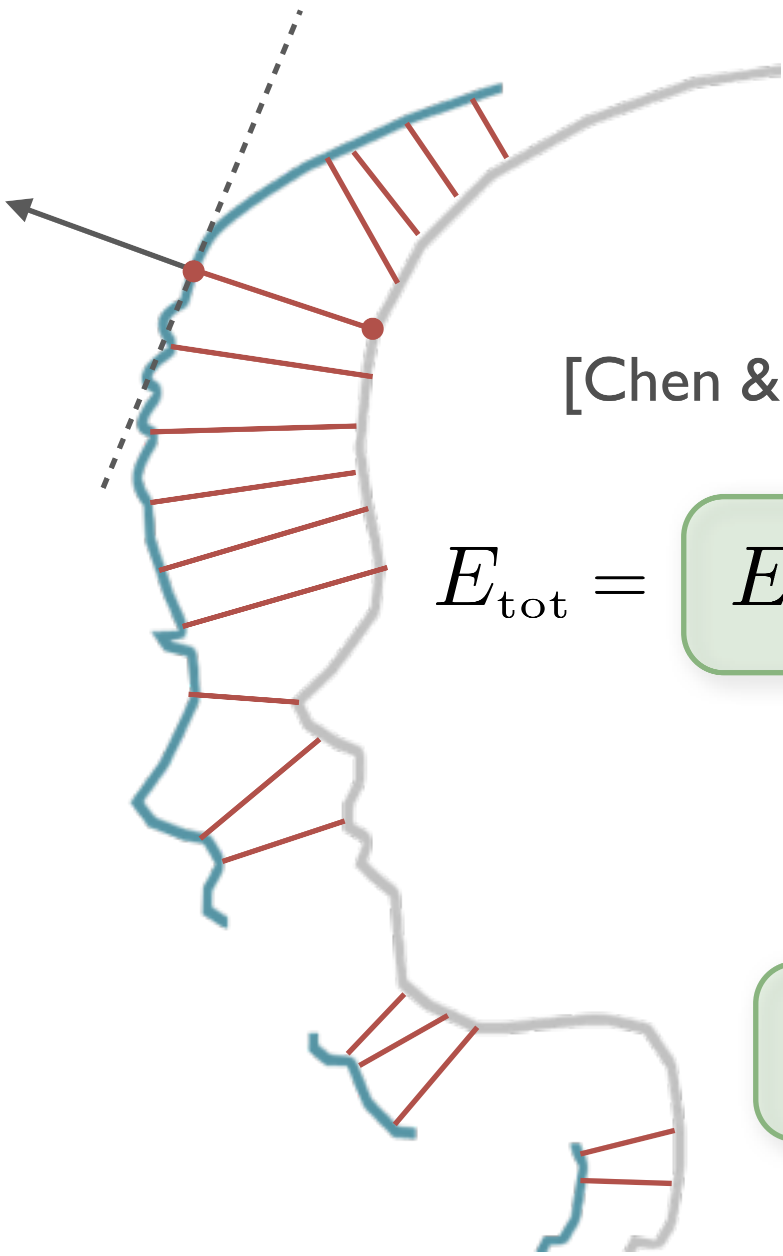
non-linear least squares minimization

Non-Linear Energy Minimization



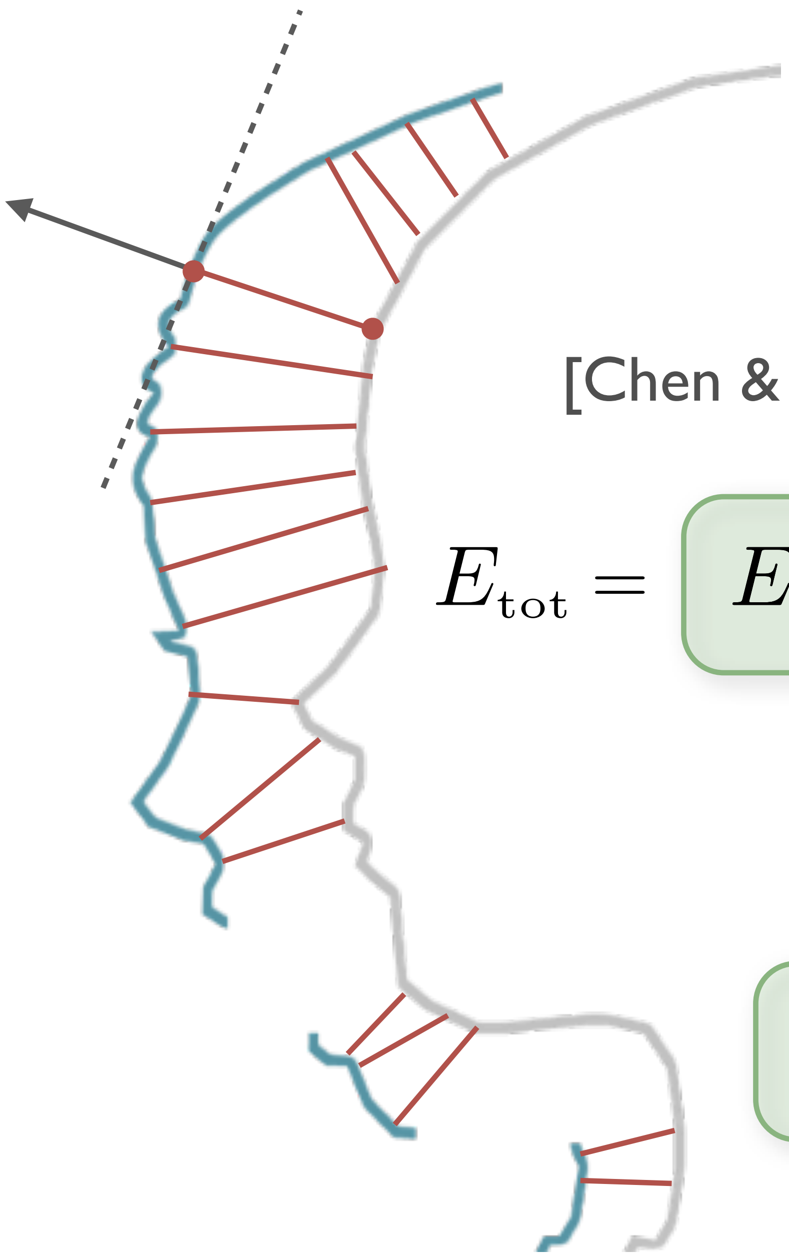
[Chen & Medioni '92]

$$E_{\text{tot}} = \boxed{E_{\text{plane}}} + \alpha_{\text{point}} \boxed{E_{\text{point}}} + \alpha_{\text{rigid}} \boxed{E_{\text{rigid}}} + \alpha_{\text{smooth}} \boxed{E_{\text{smooth}}}$$

non-linear least squares minimization

Gauss-Newton method

Non-Linear Energy Minimization



[Chen & Medioni '92]

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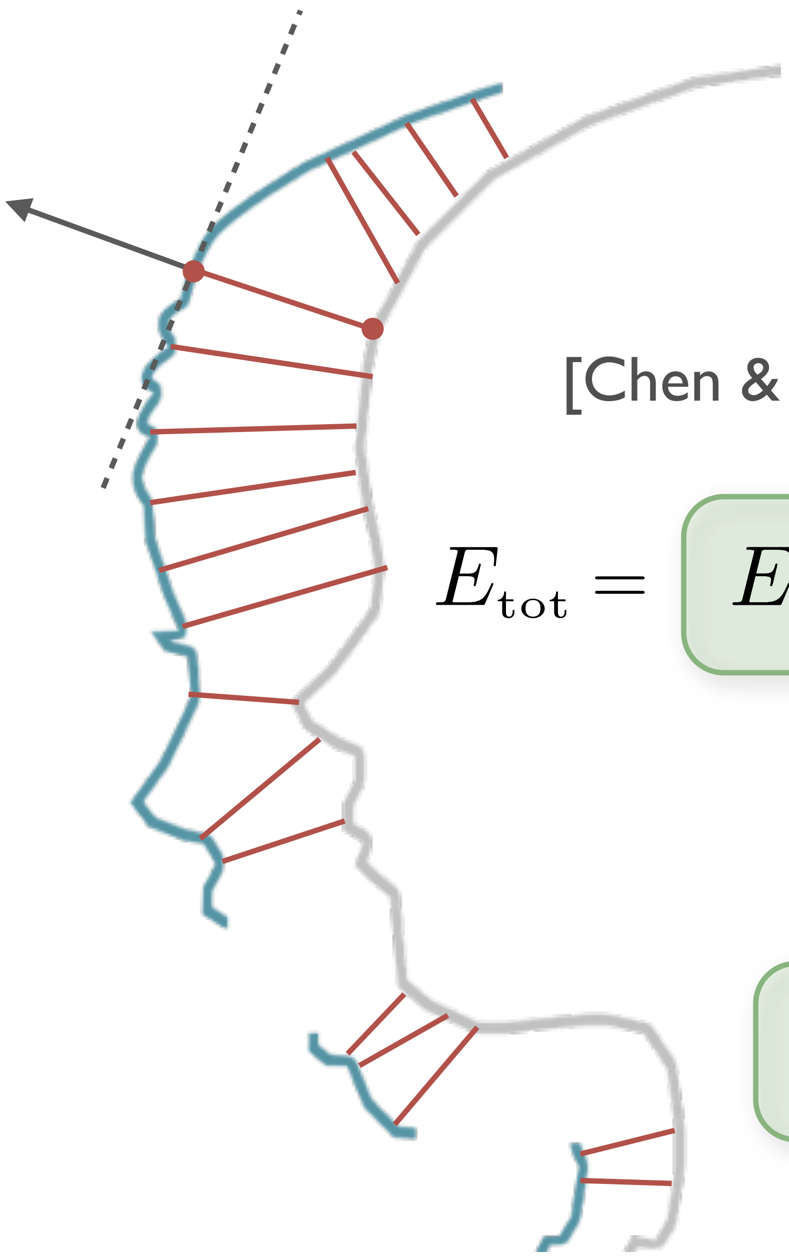
non-linear least squares minimization

Gauss-Newton method

Jacobian is sparse

Non-Linear Energy Minimization



[Chen & Medioni '92]

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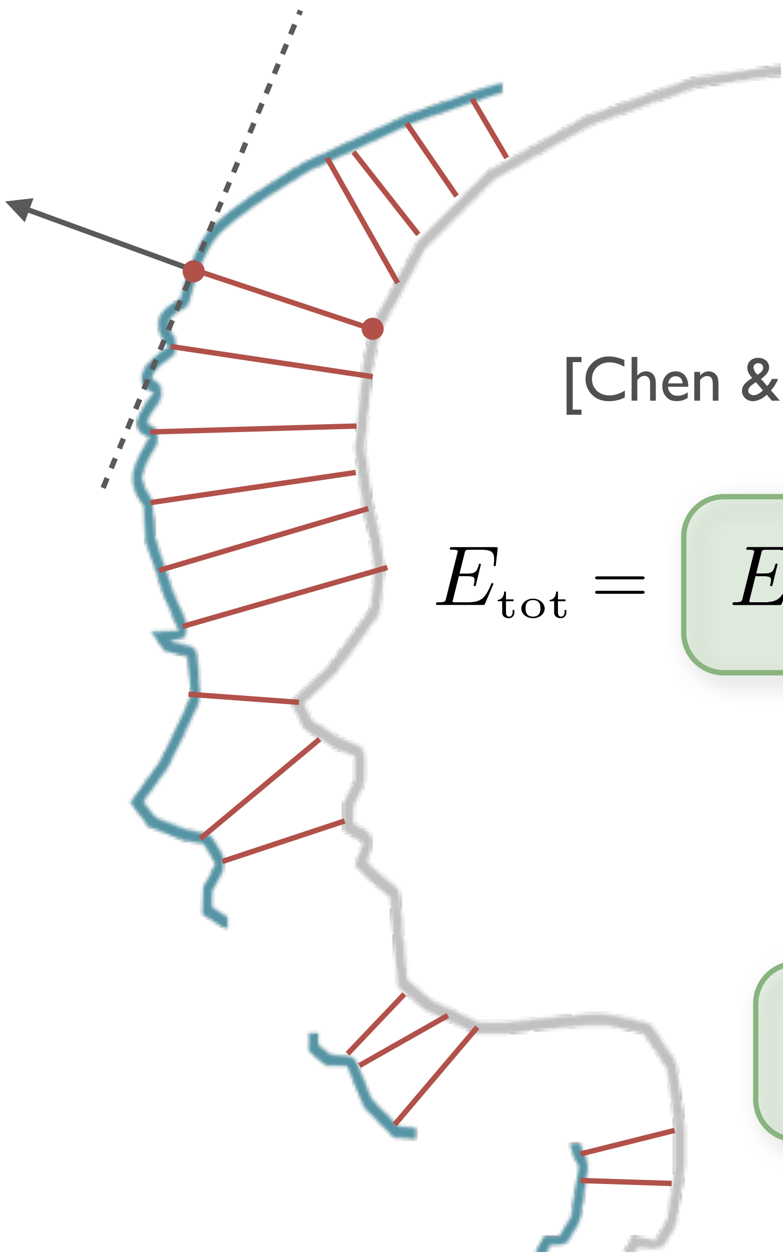
non-linear least squares minimization

Gauss-Newton method

Jacobian is sparse

sparse Cholesky factorization

Non-Linear Energy Minimization



[Chen & Medioni '92]

$$E_{\text{tot}} = \boxed{E_{\text{plane}}} + \alpha_{\text{point}} \boxed{E_{\text{point}}} + \alpha_{\text{rigid}} \boxed{E_{\text{rigid}}} + \alpha_{\text{smooth}} \boxed{E_{\text{smooth}}}$$

non-linear least squares minimization

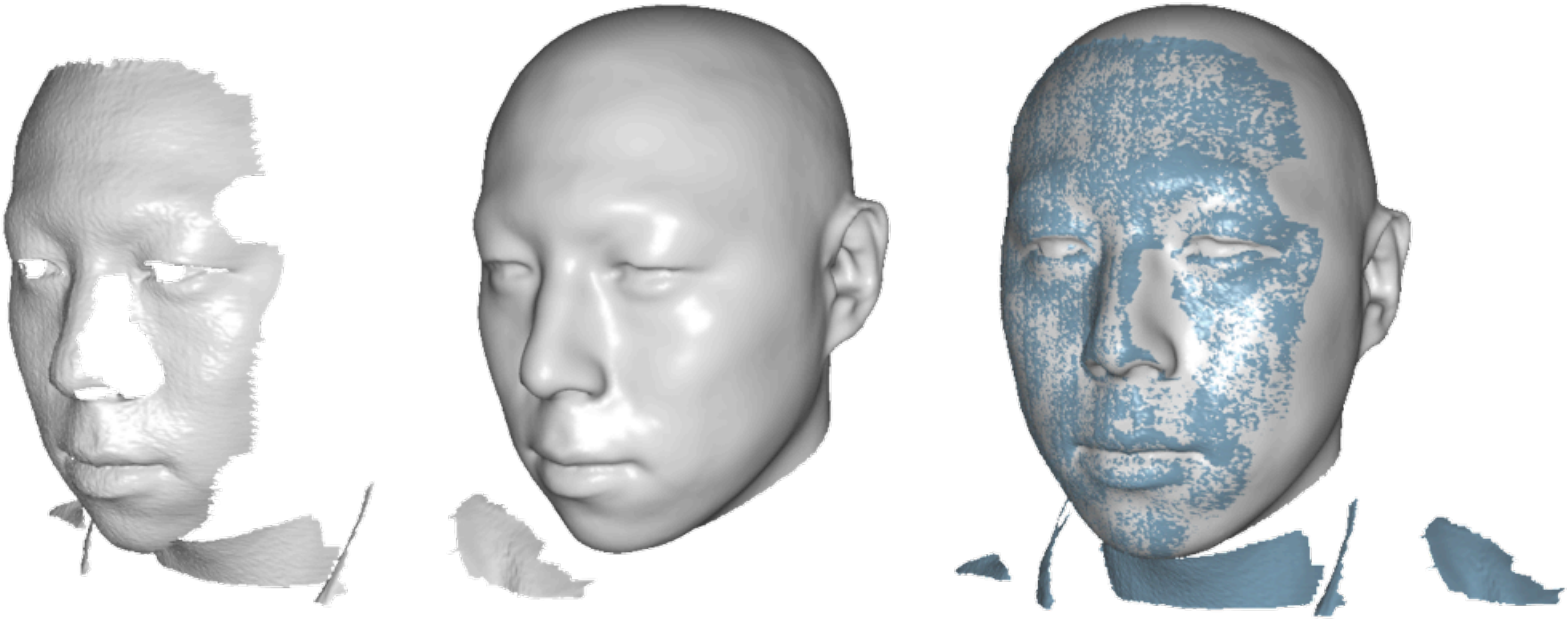
Jacobian is sparse

Gauss-Newton method

sparse Cholesky factorization

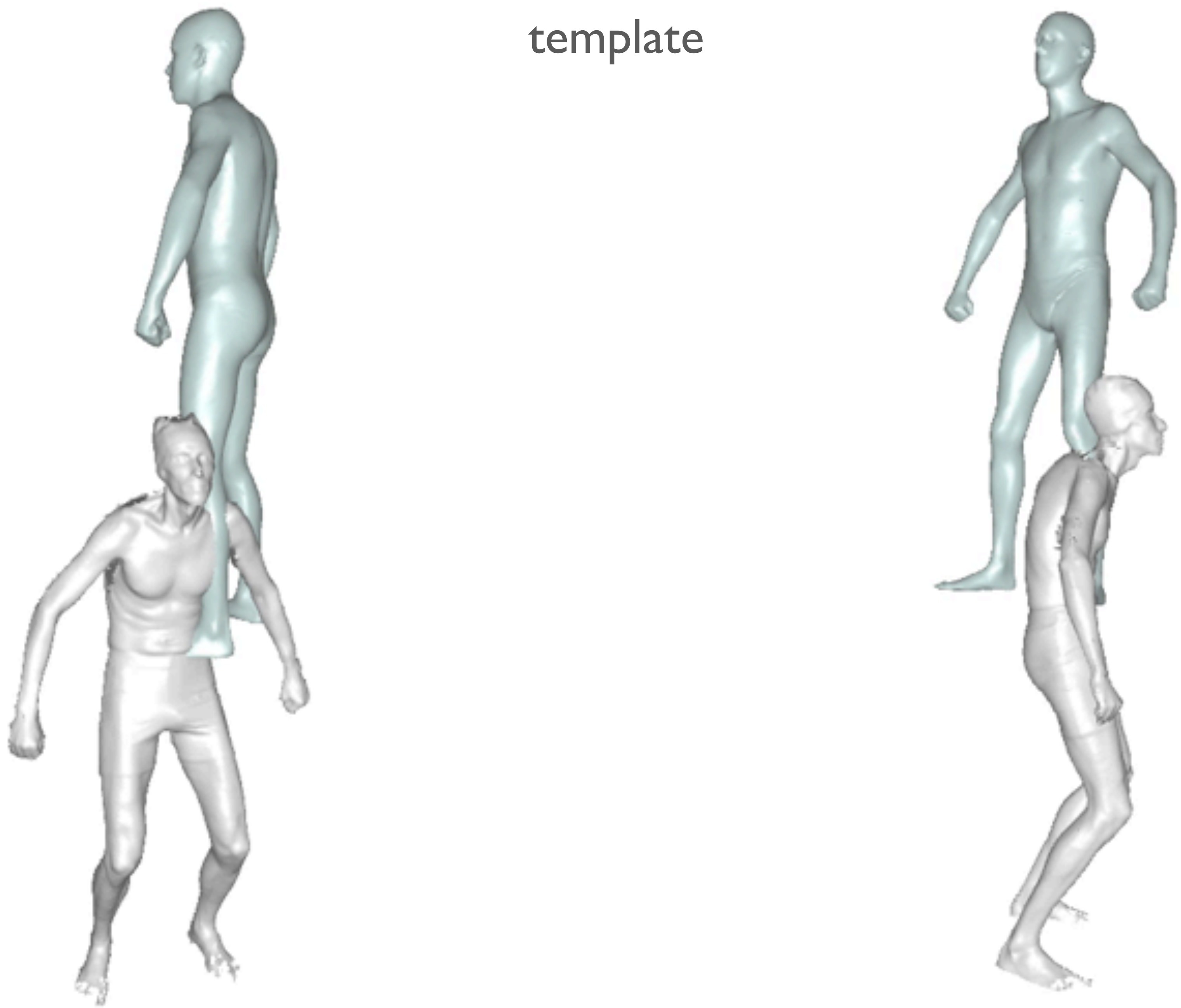
that's it!

Template-Based Tracking

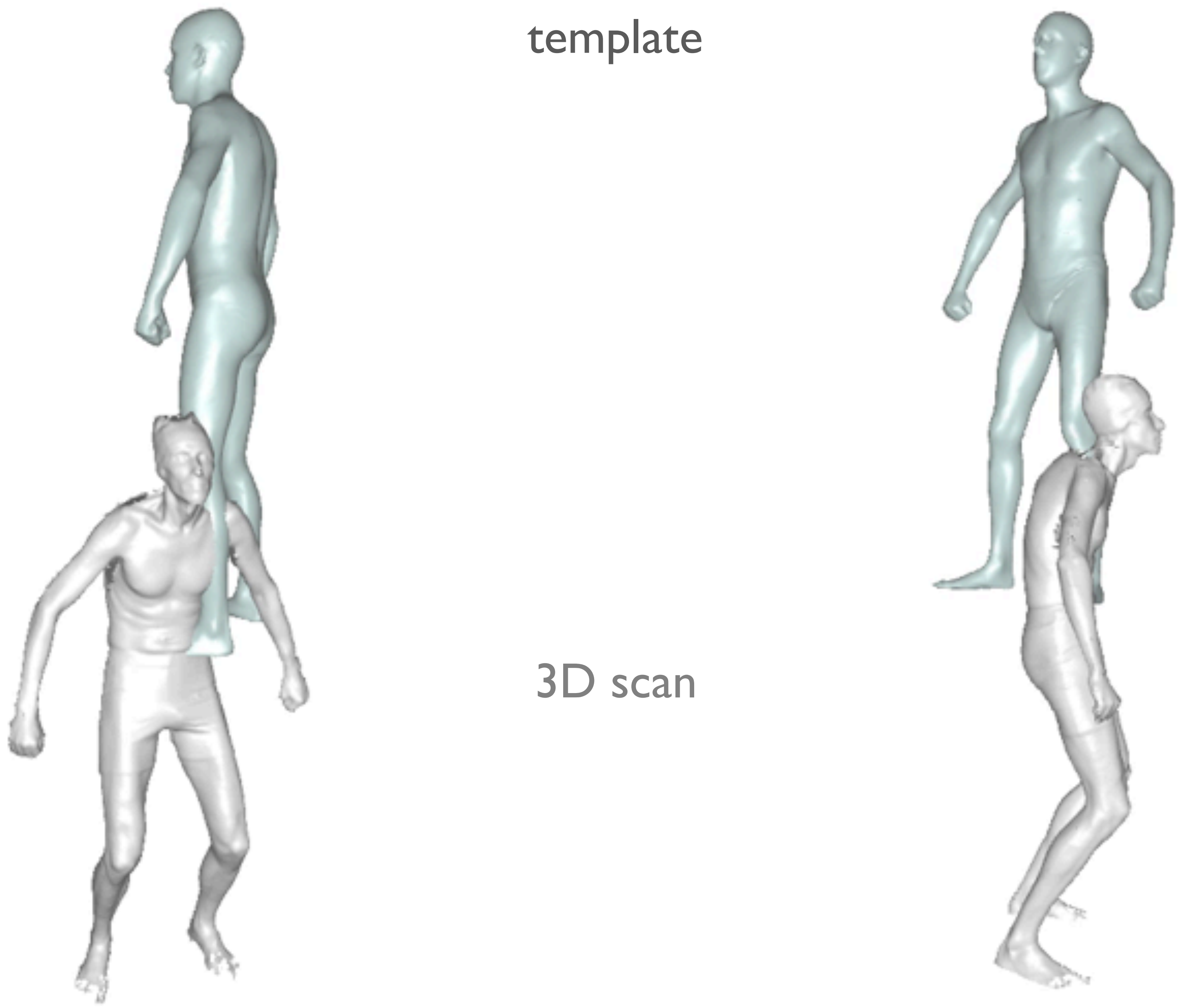


Not only for Faces!

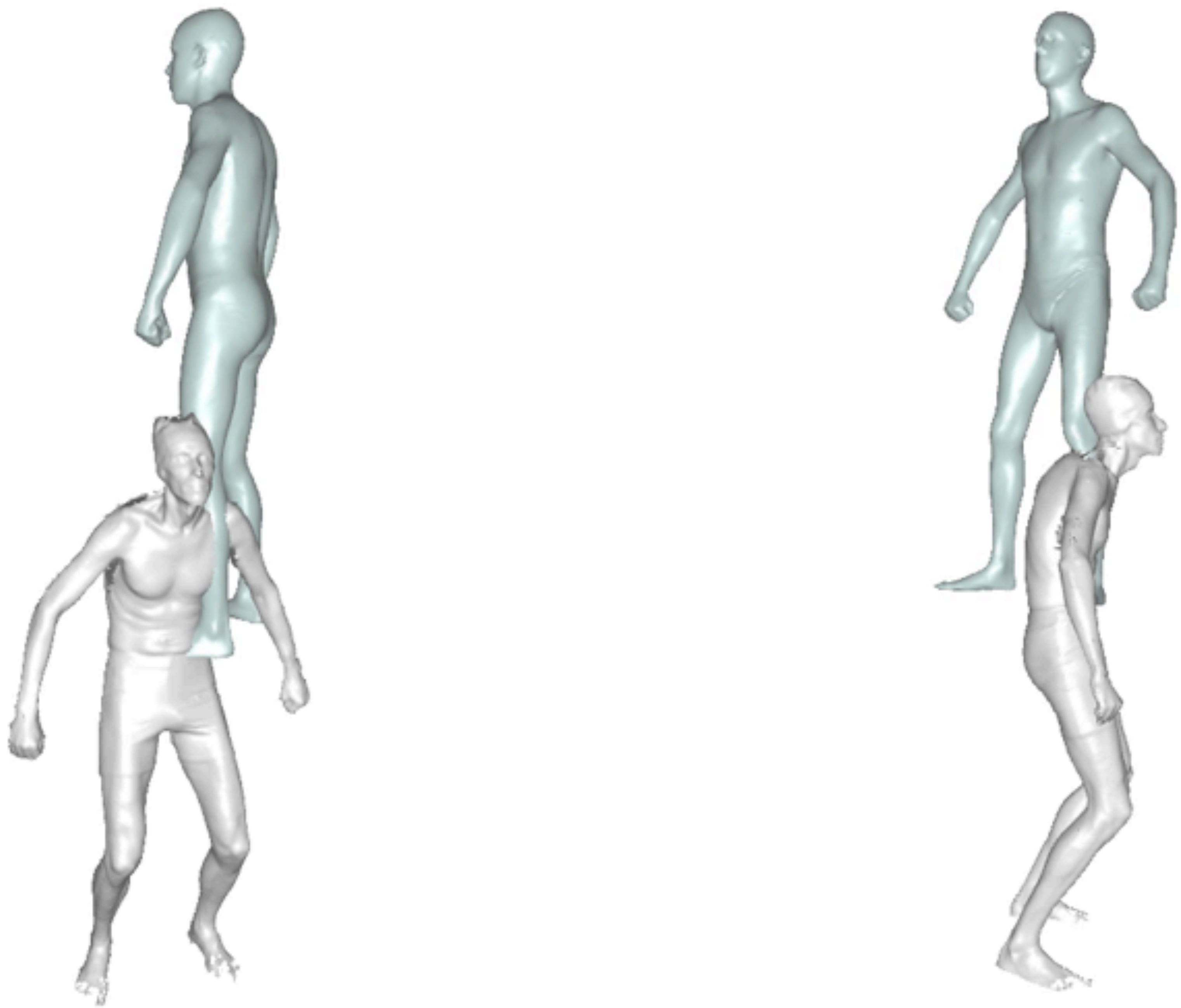
Not only for Faces!



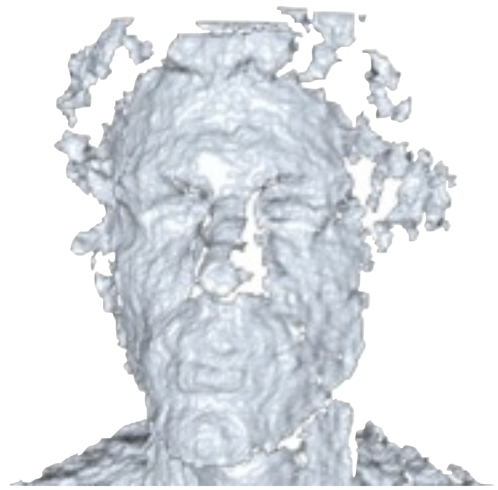
Not only for Faces!

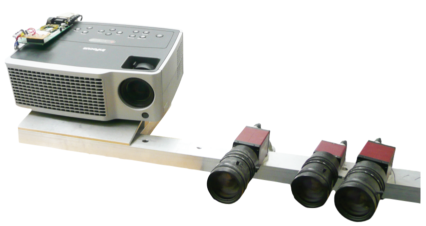


Not only for Faces!

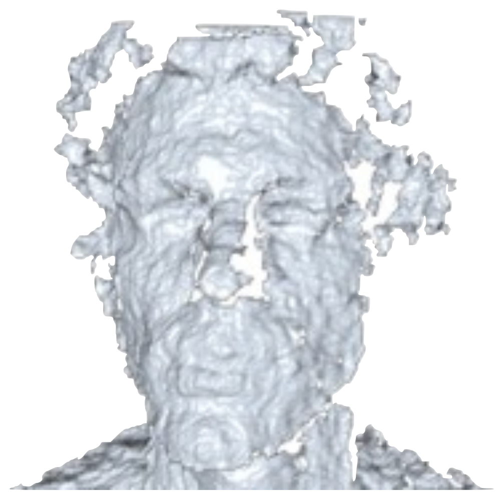
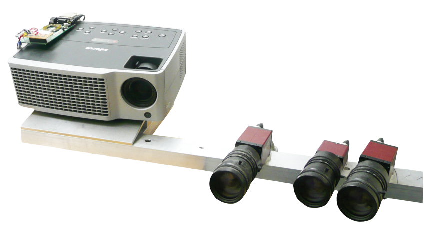


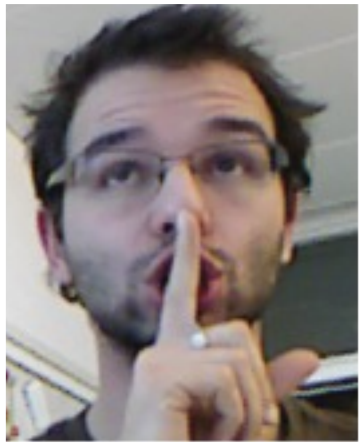
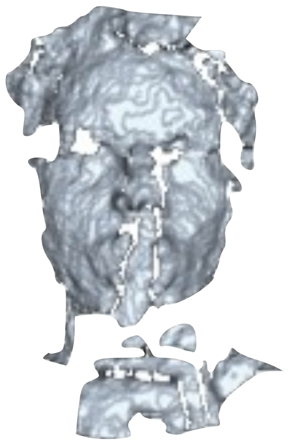
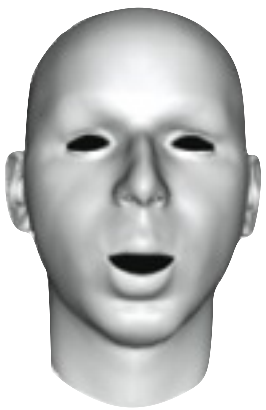
Requirements for a Practical System



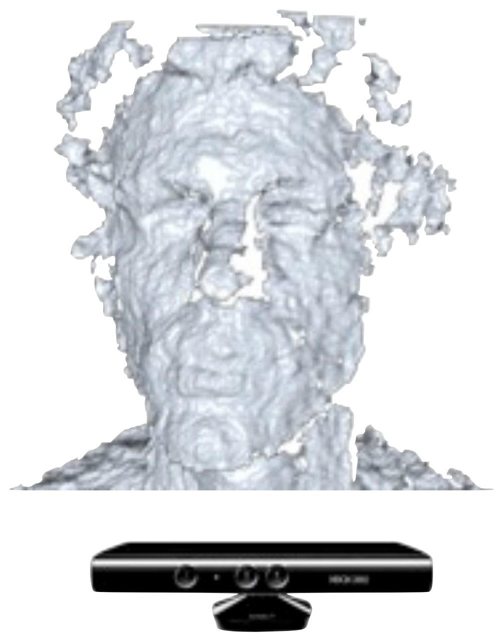


Requirements for a Practical System

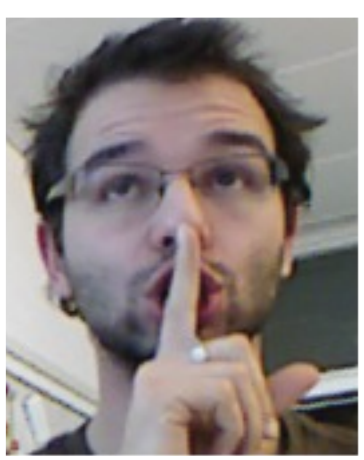




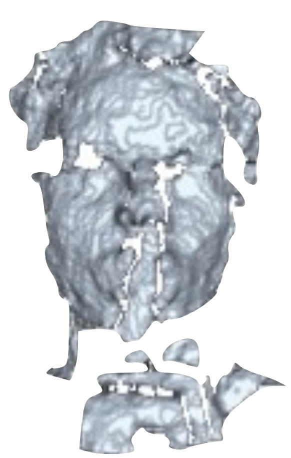




Requirements for a Practical System

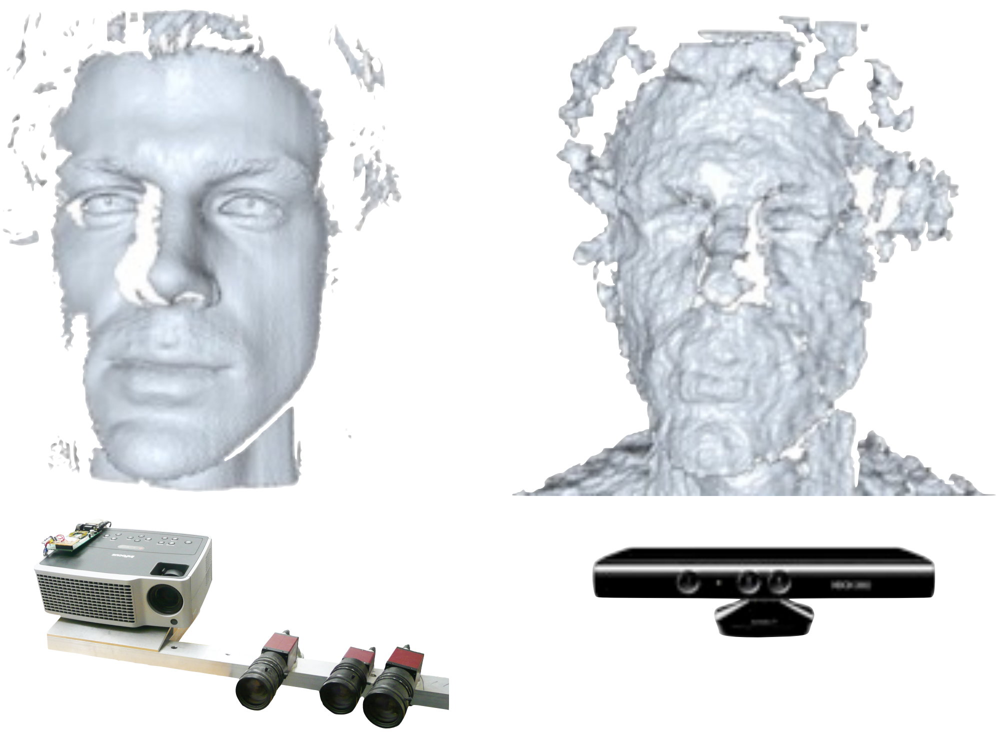


1.Real-time performance



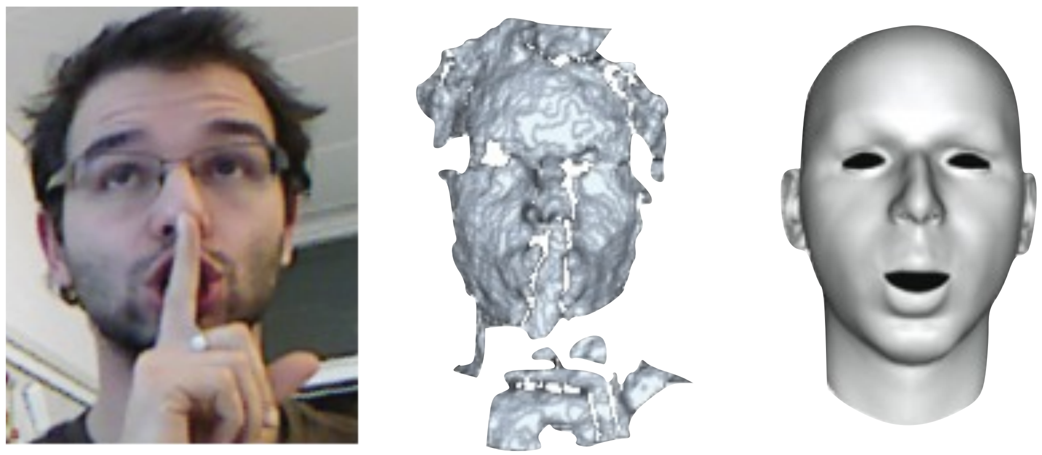


Requirements for a Practical System

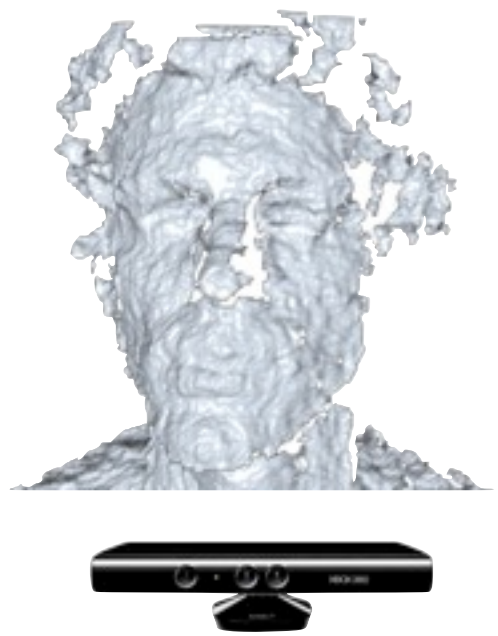


1. Real-time performance

2. Robustness to noise



Requirements for a Practical System



1. Real-time performance
2. Robustness to noise
3. High-level semantics

Real-time Facial Capture

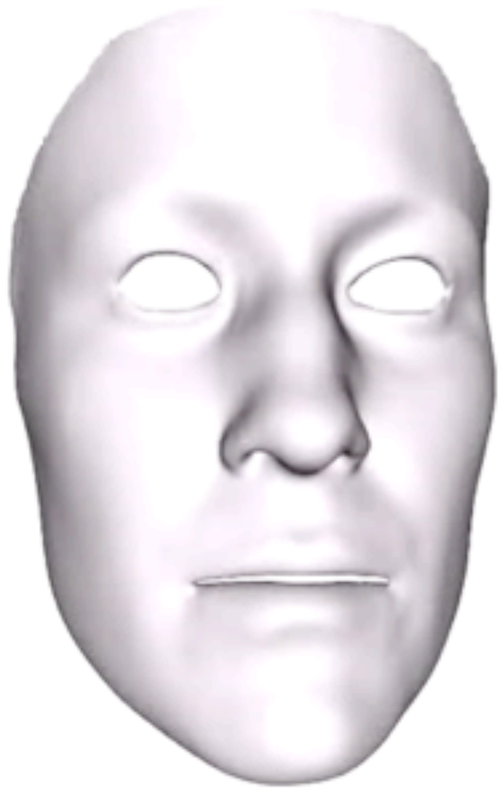
Objective

Building Expression Space

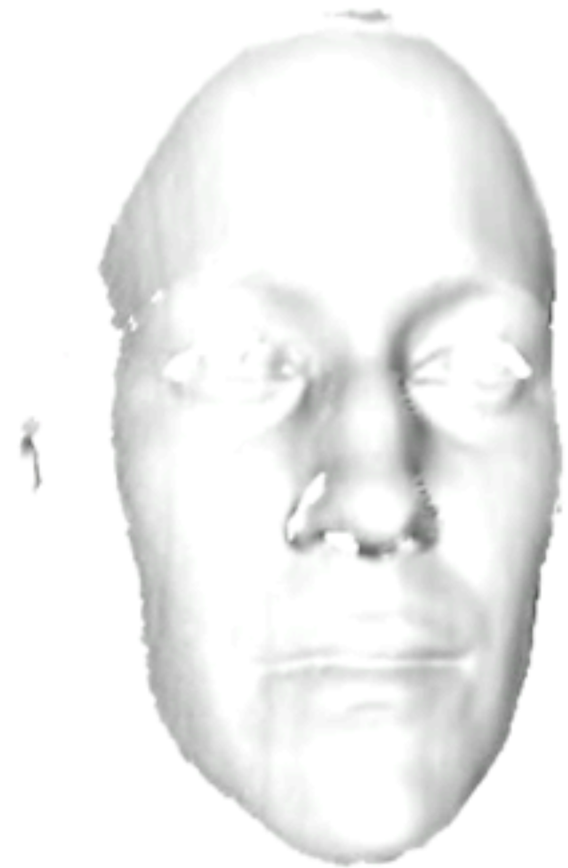
tracked template

input scan

Building Expression Space



tracked template



input scan

Expression PCA for Reduced Dimension

Expression PCA for Reduced Dimension

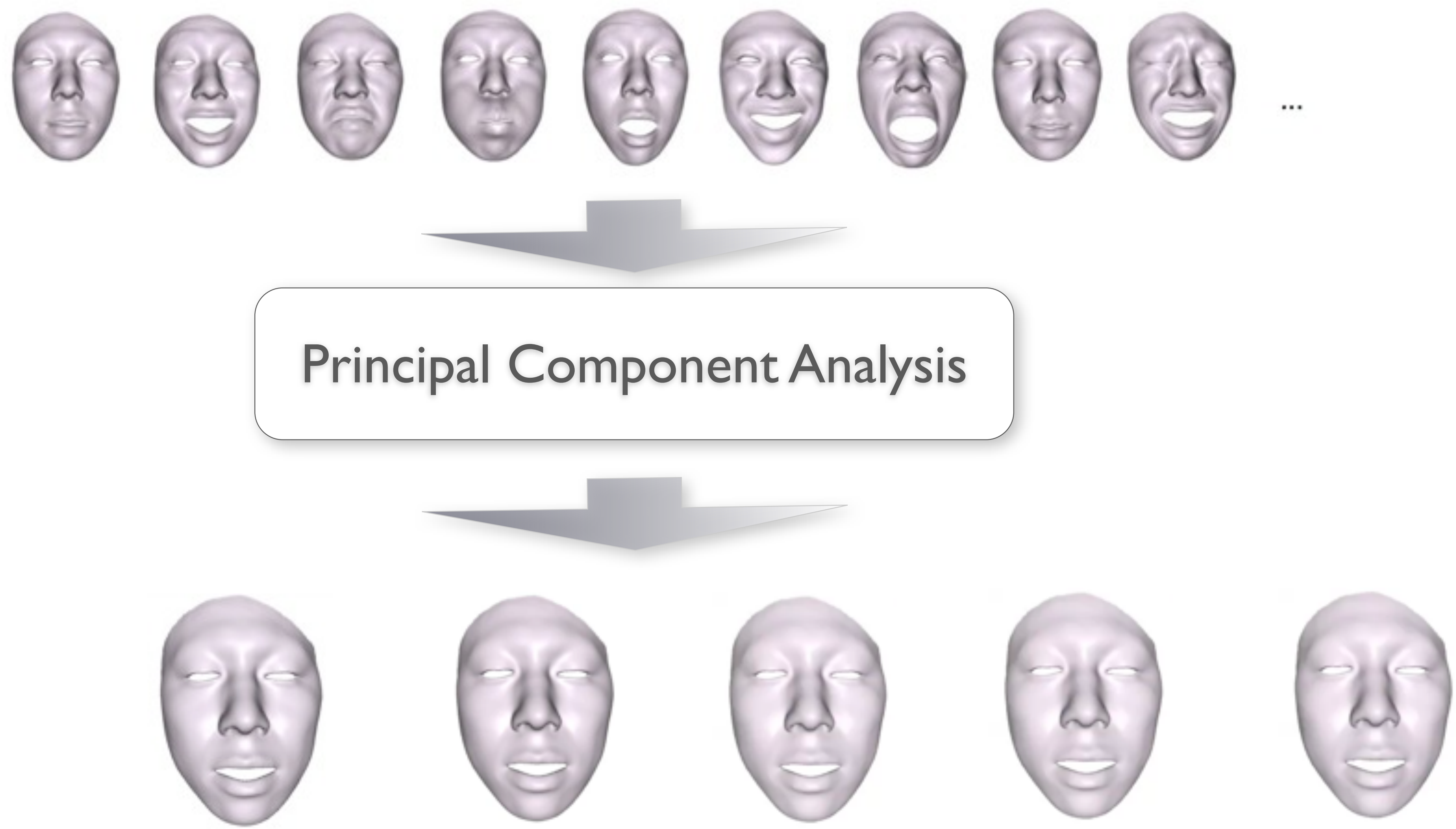
...

Expression PCA for Reduced Dimension

Expression PCA for Reduced Dimension

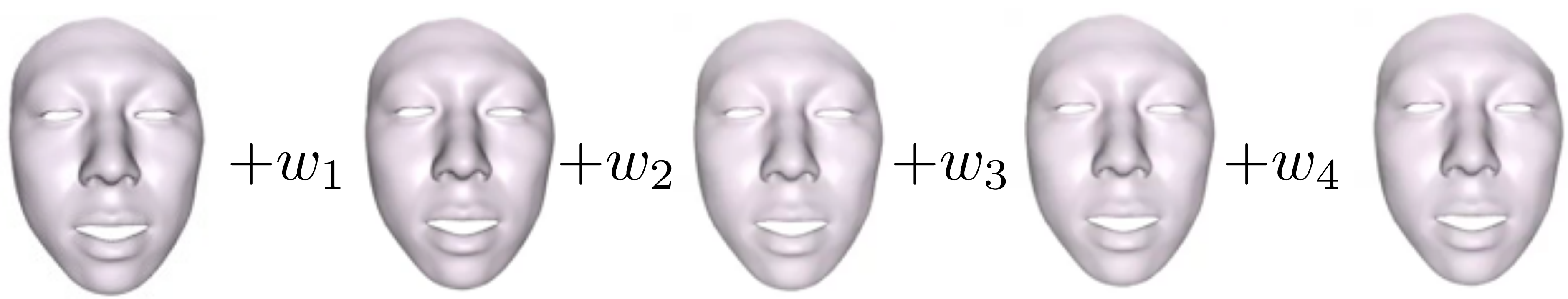
Principal Component Analysis

Expression PCA for Reduced Dimension



Expression PCA for Reduced Dimension

Principal Component Analysis



Expression PCA for Reduced Dimension