Non-Rigid Registration

Hao Li

Correspondence Problem Classification

How many meshes?

Two: Pairwise registration

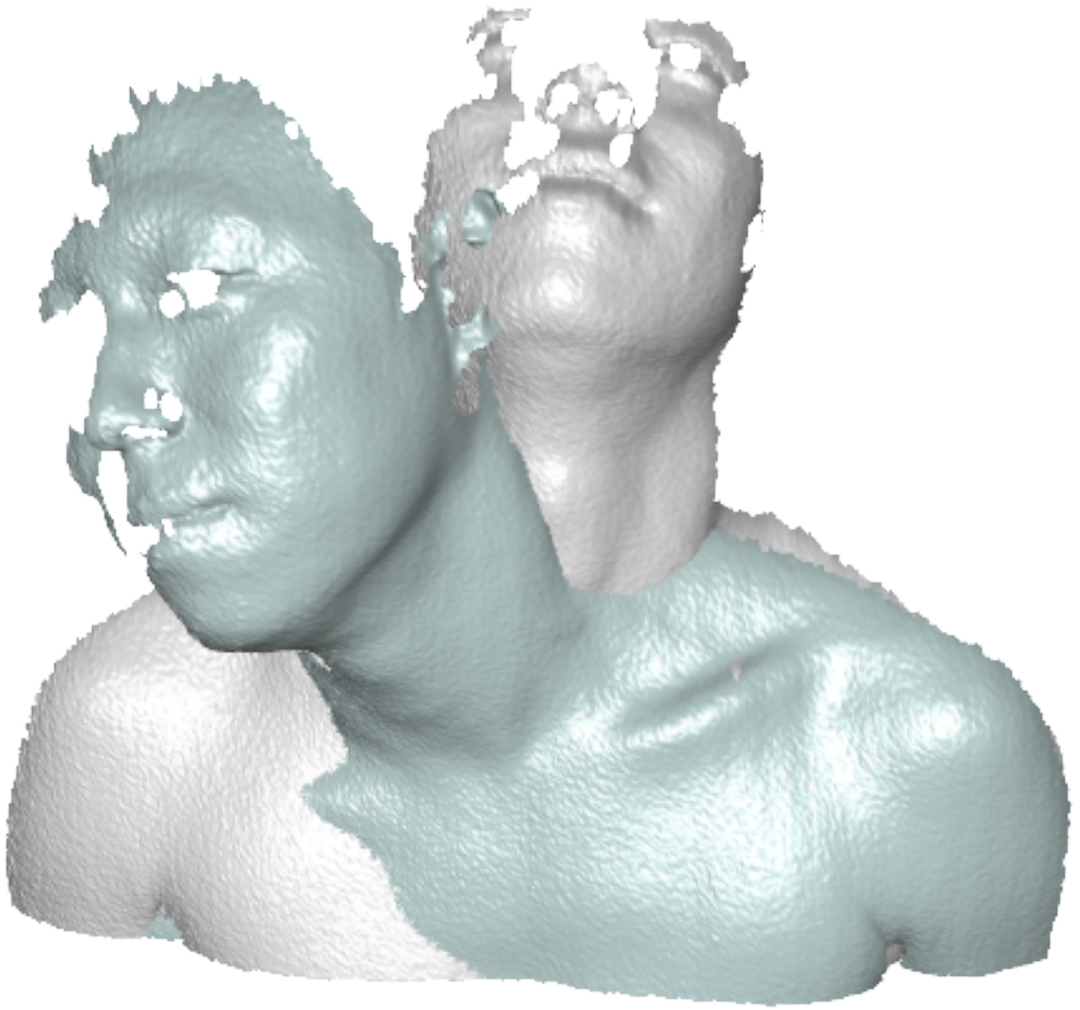
Initial registration available?

Yes: Local optimization methods

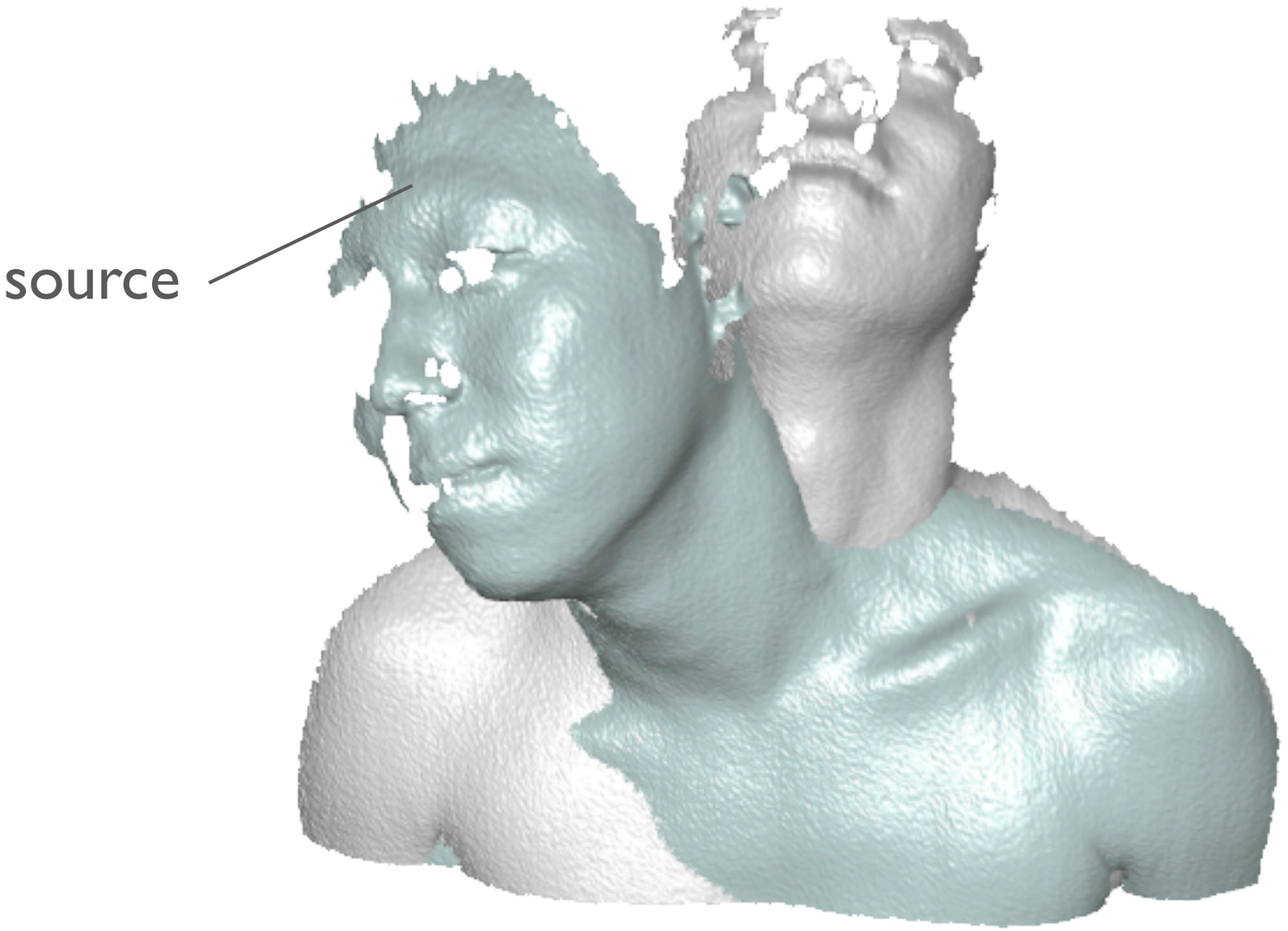
Class of transformations?

Non-rigid deformations

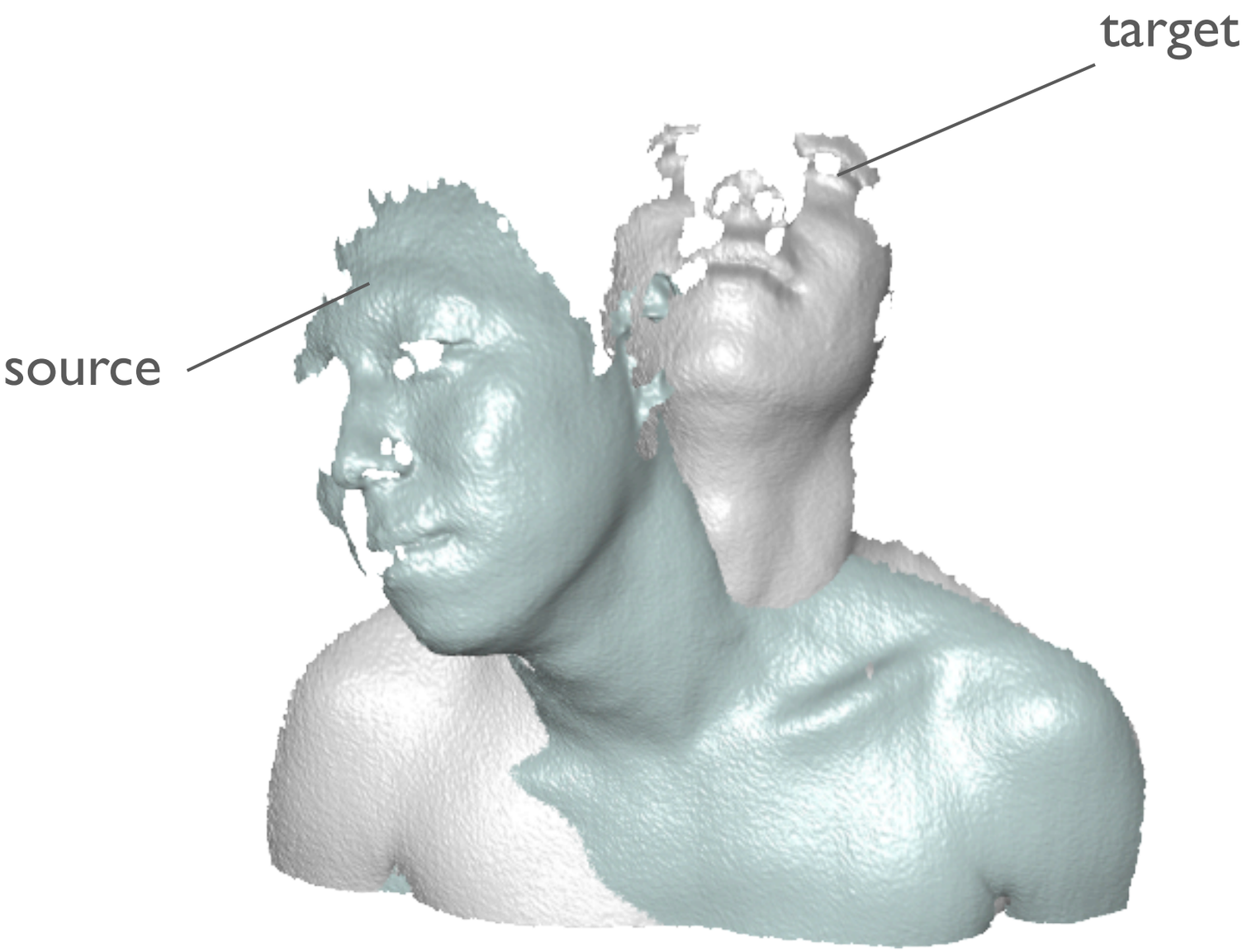
Pair of Scans



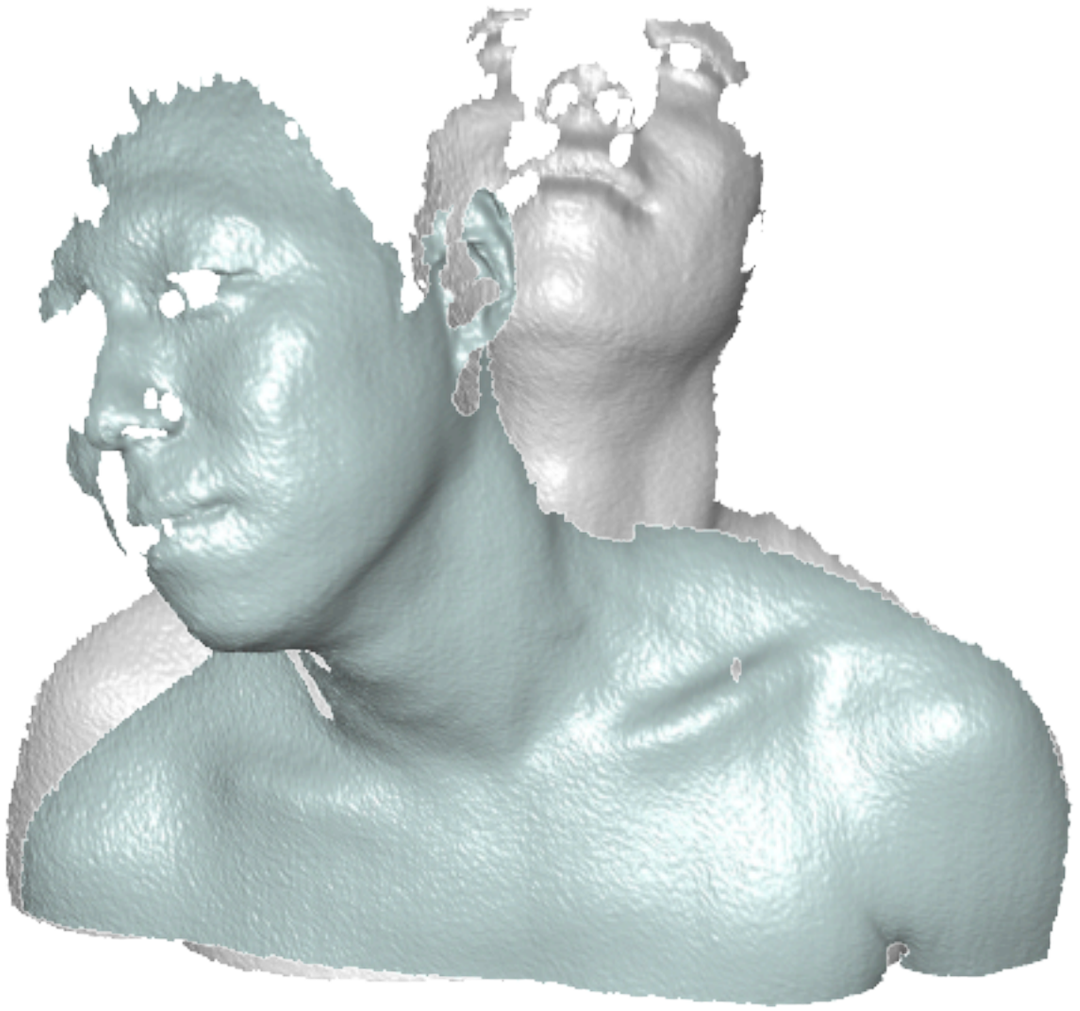
Pair of Scans



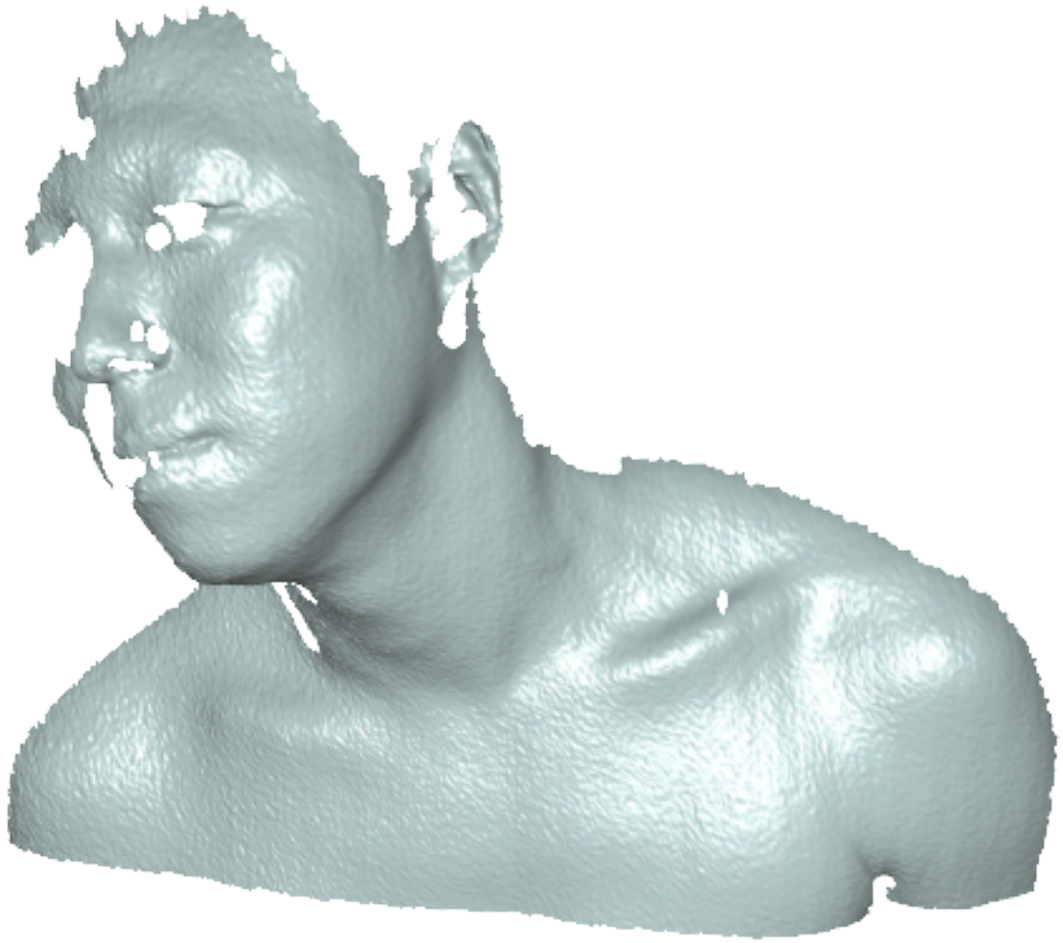
Pair of Scans

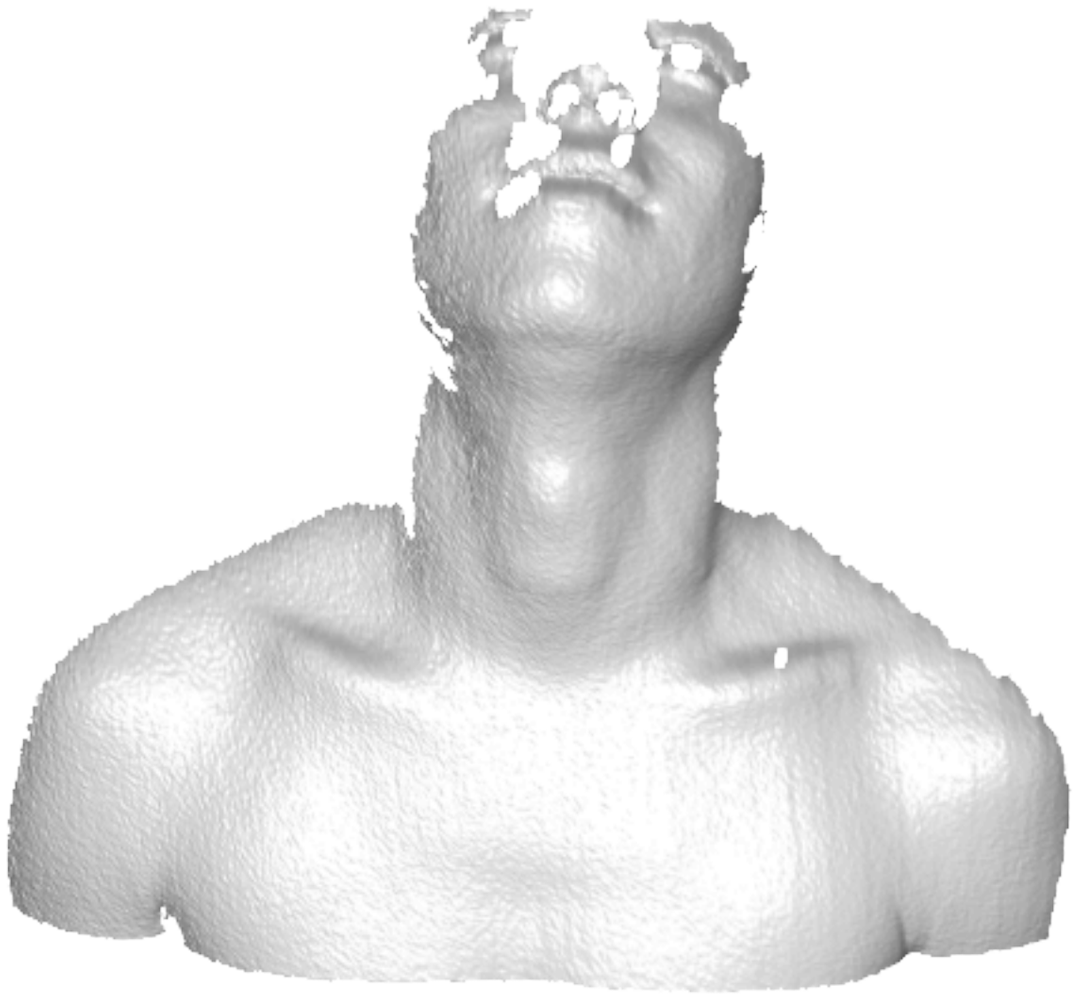


Correspondences are lost



Correspondences are lost





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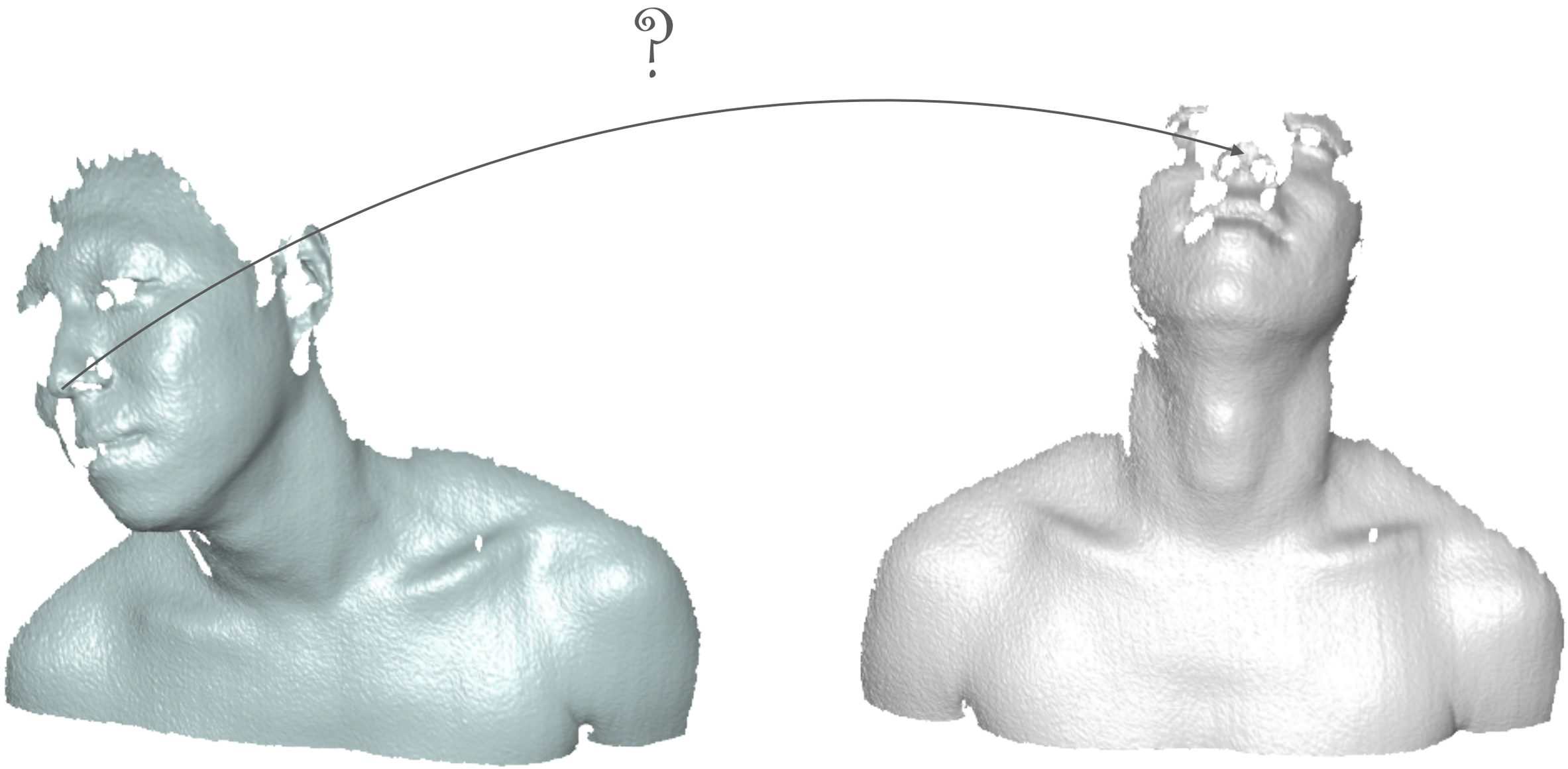
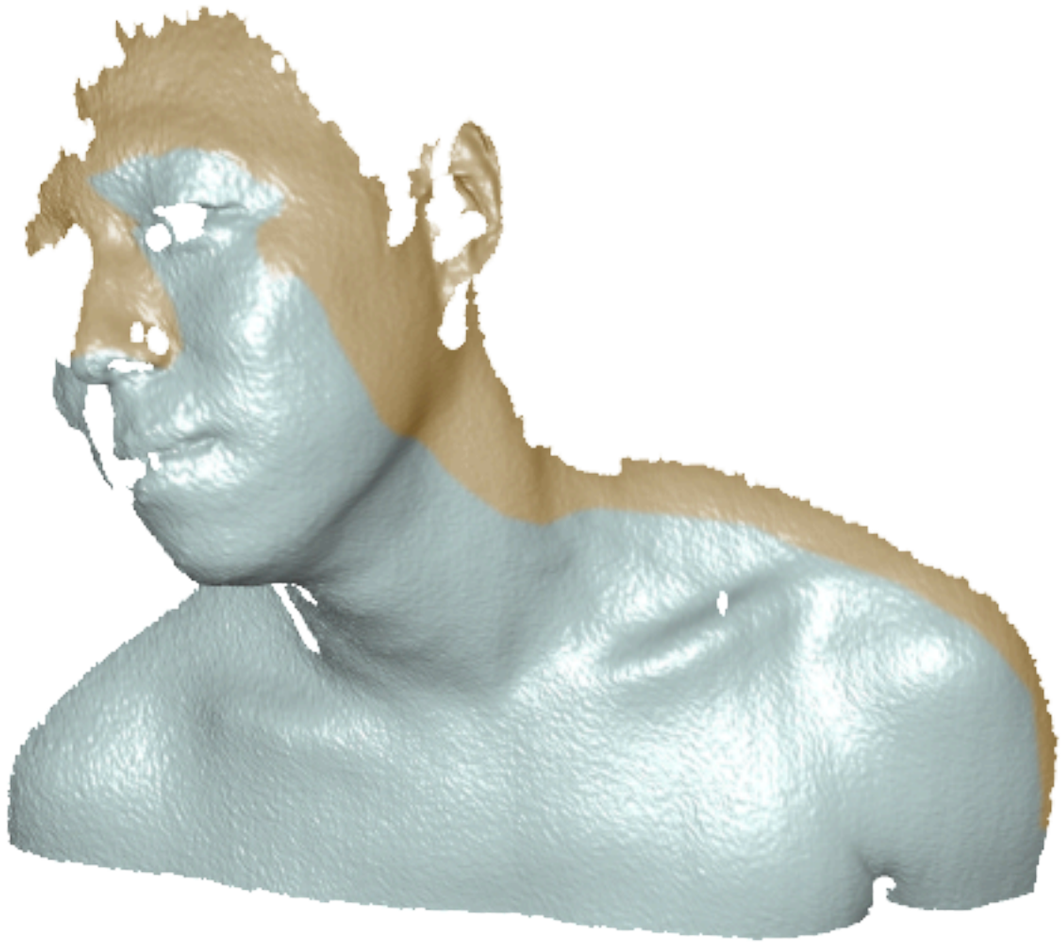


What are the regions of overlap?



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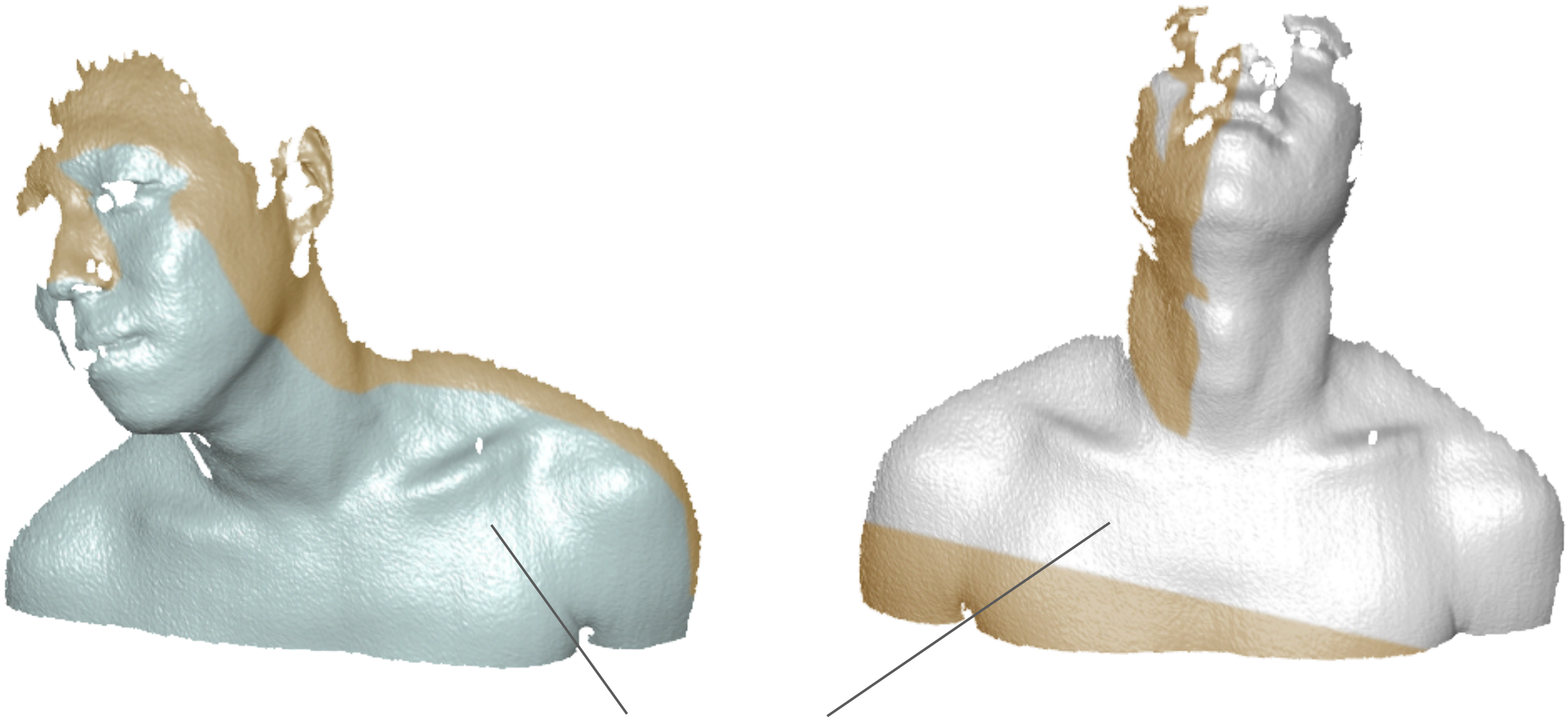
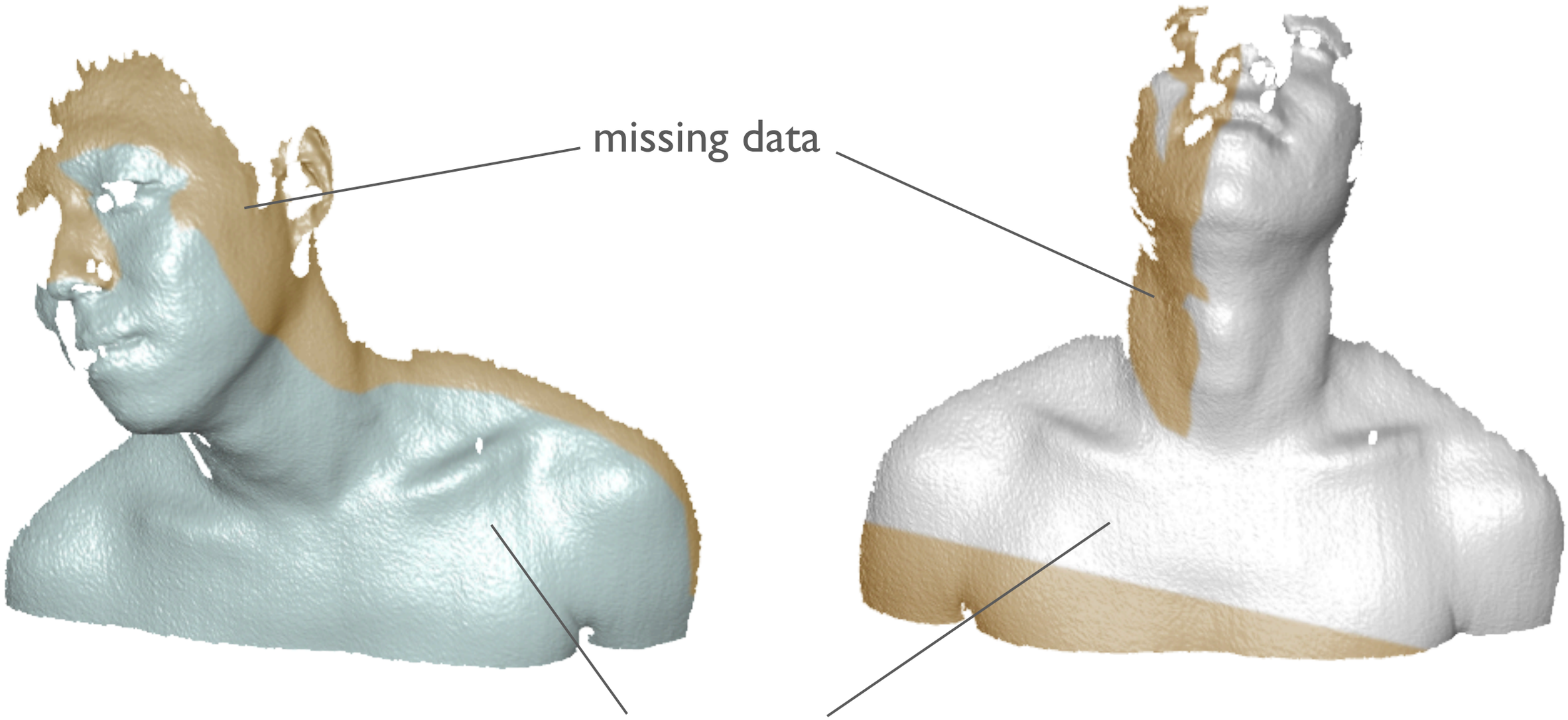
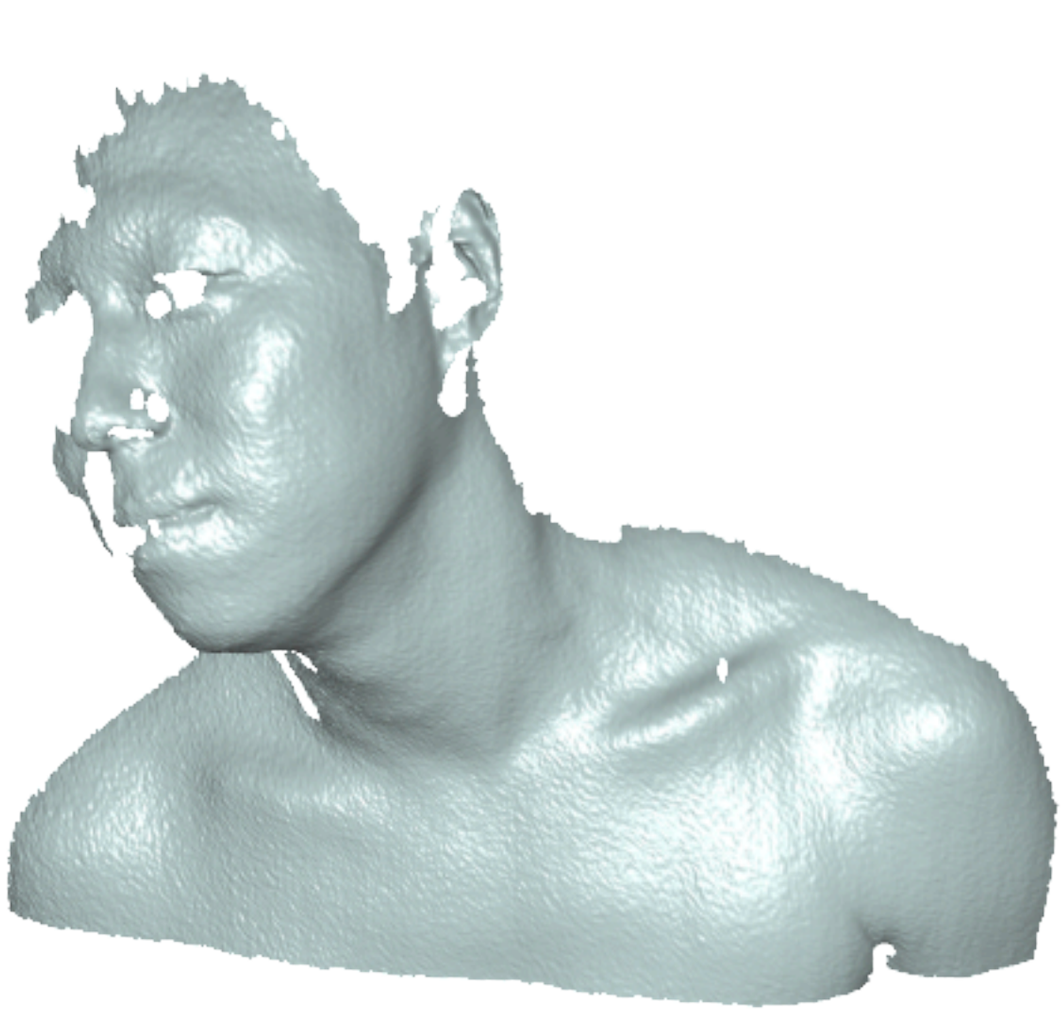


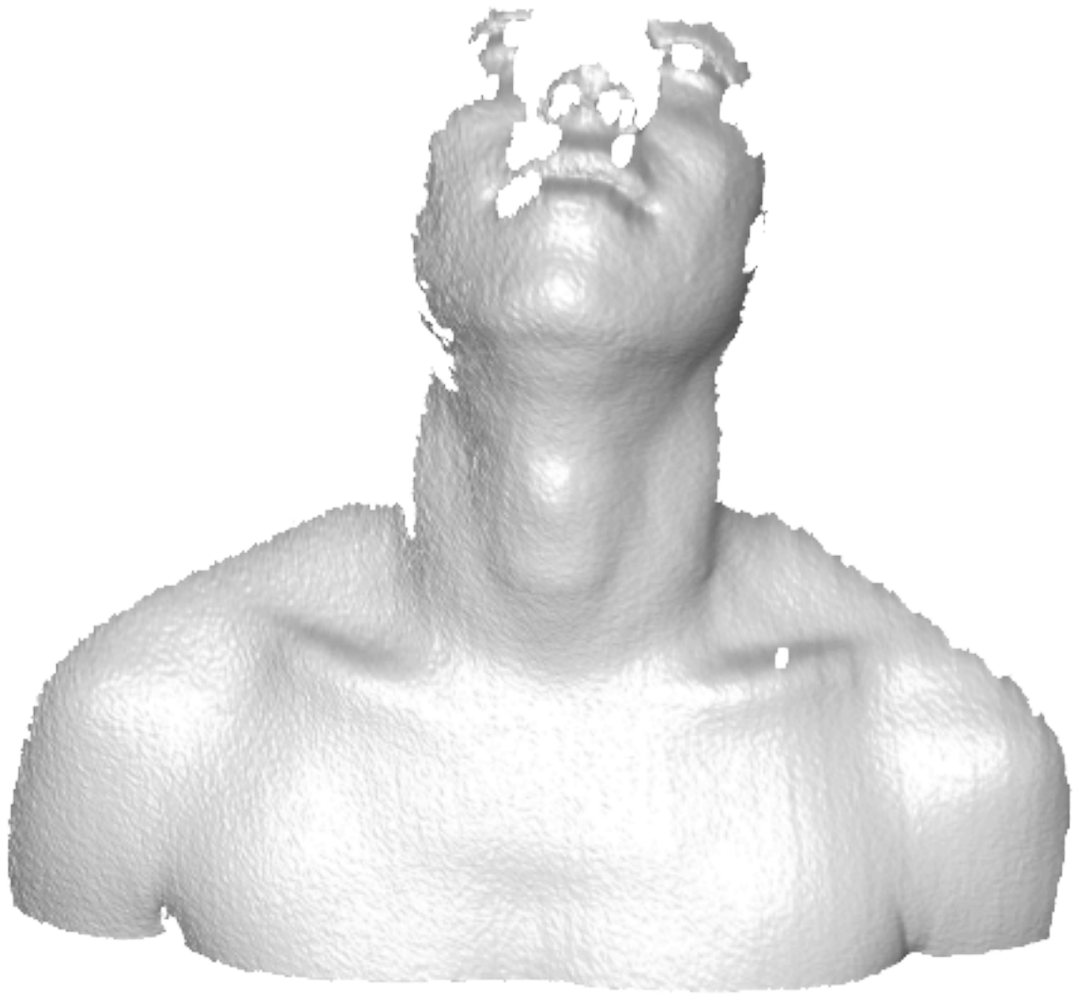
overlapping regions

What are the regions of overlap?



What are the regions of overlap?





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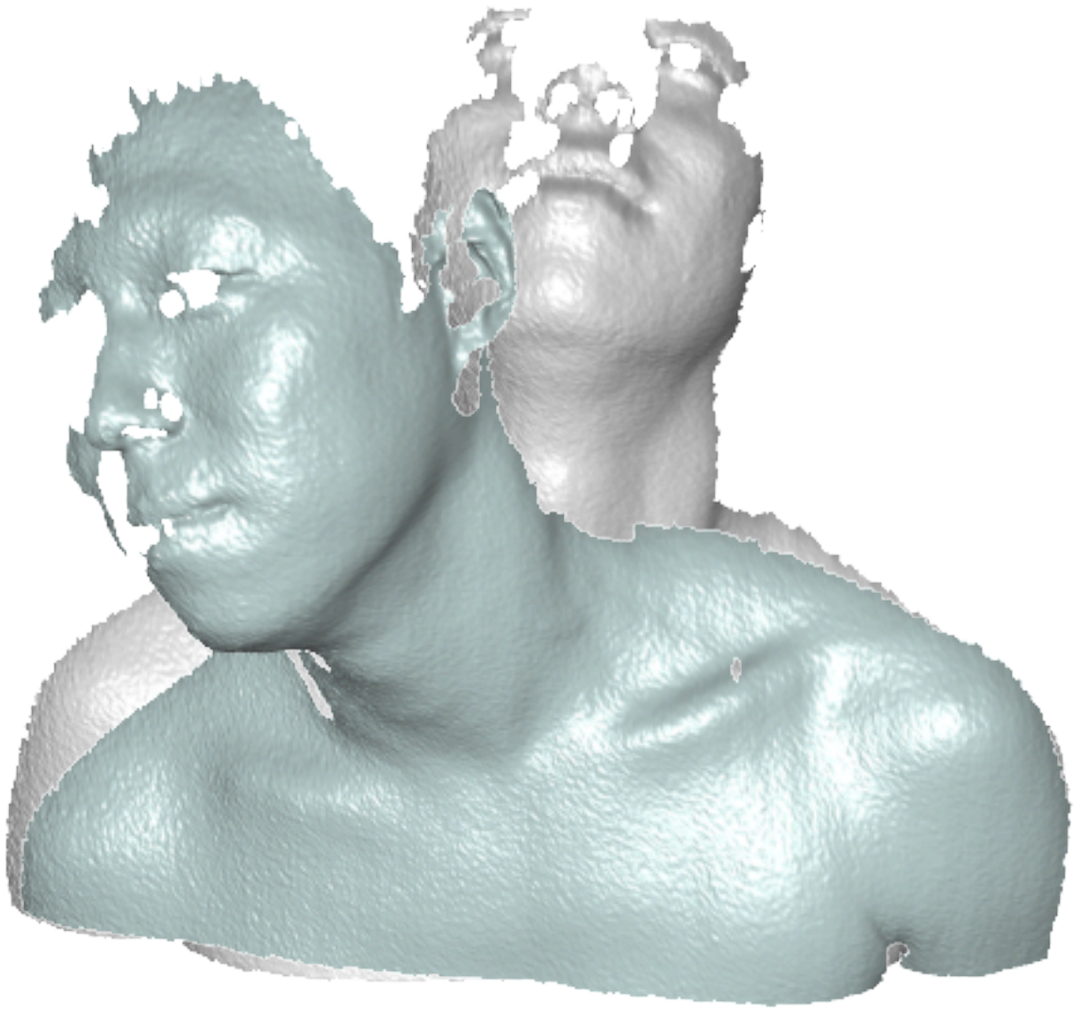
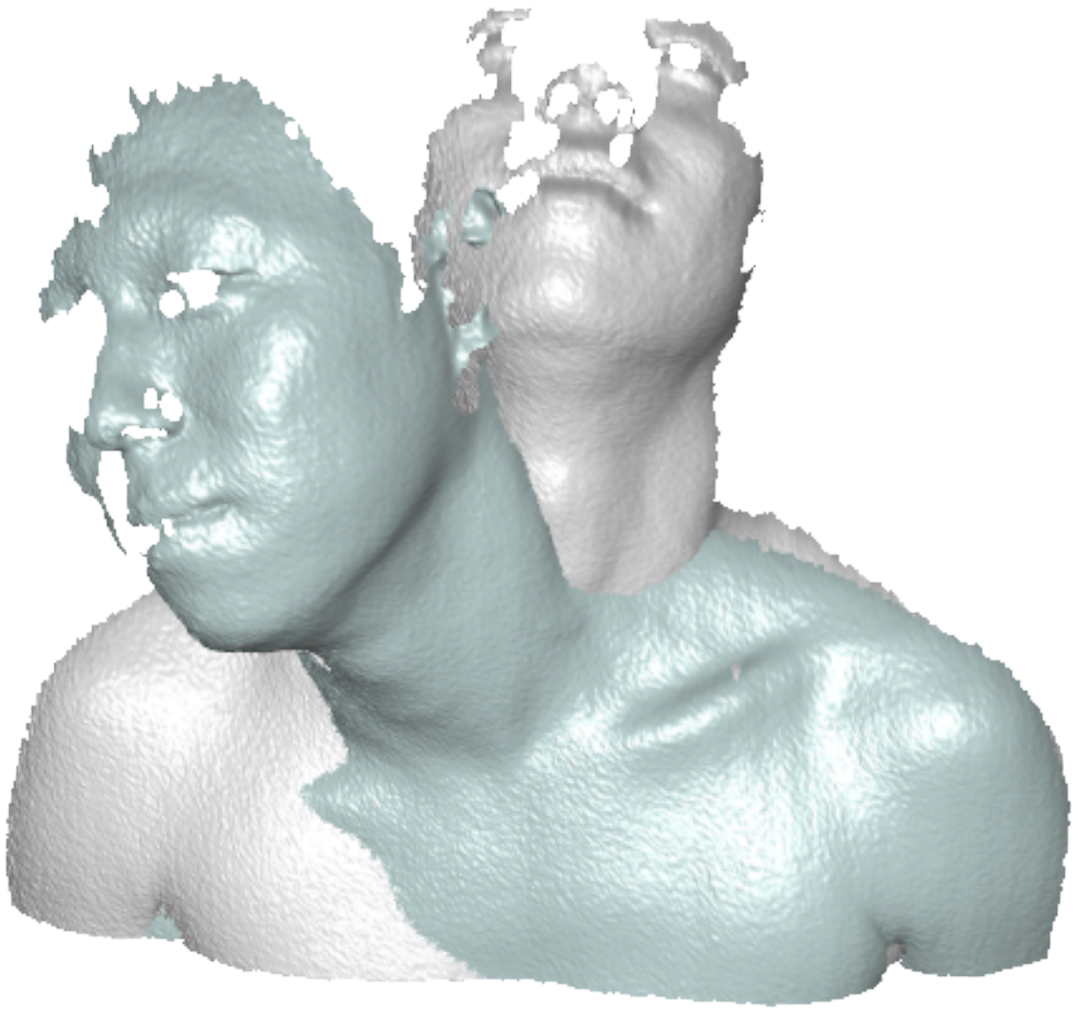


Non-Rigid Registration

Non-Rigid Registration



Ingredients

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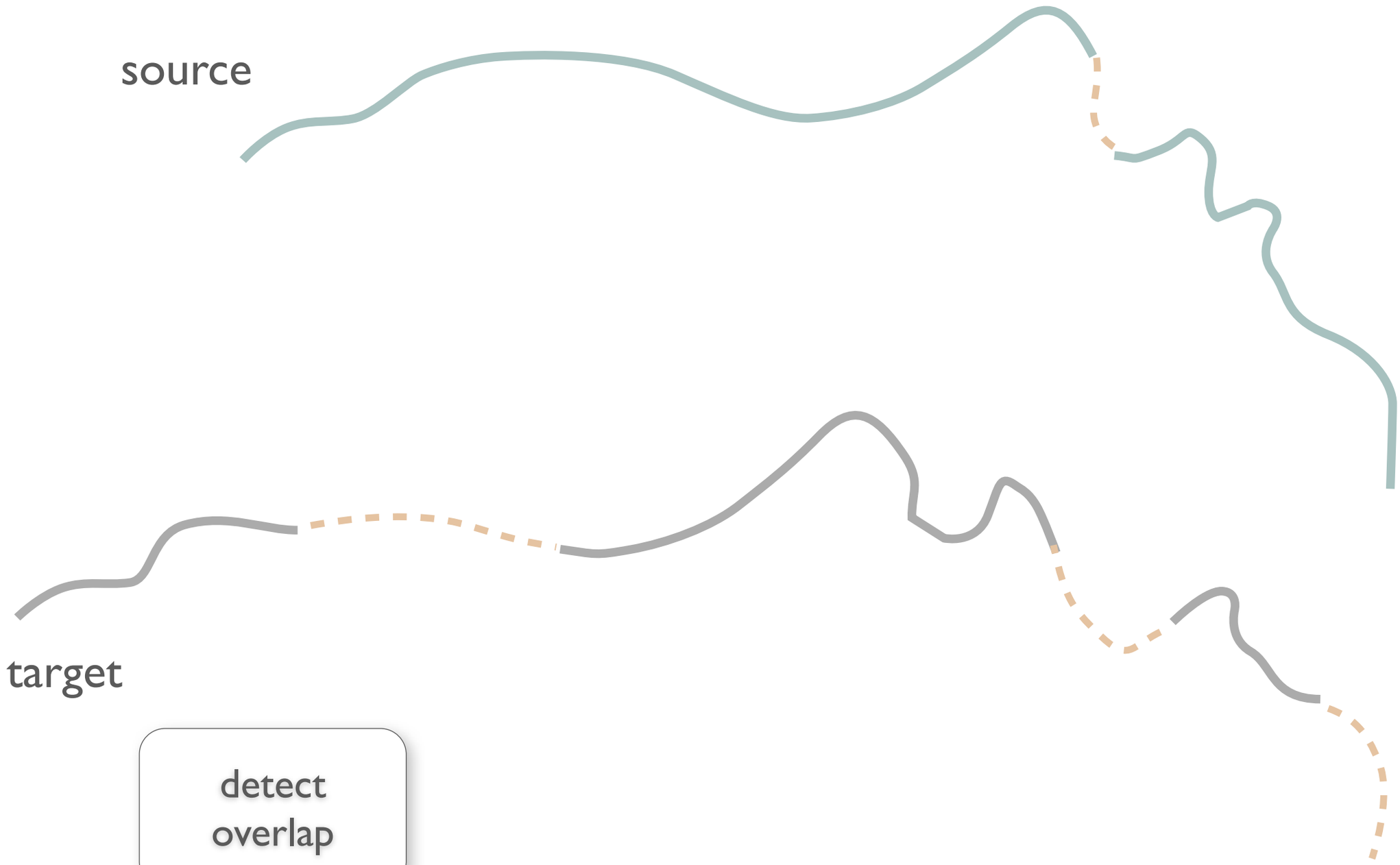
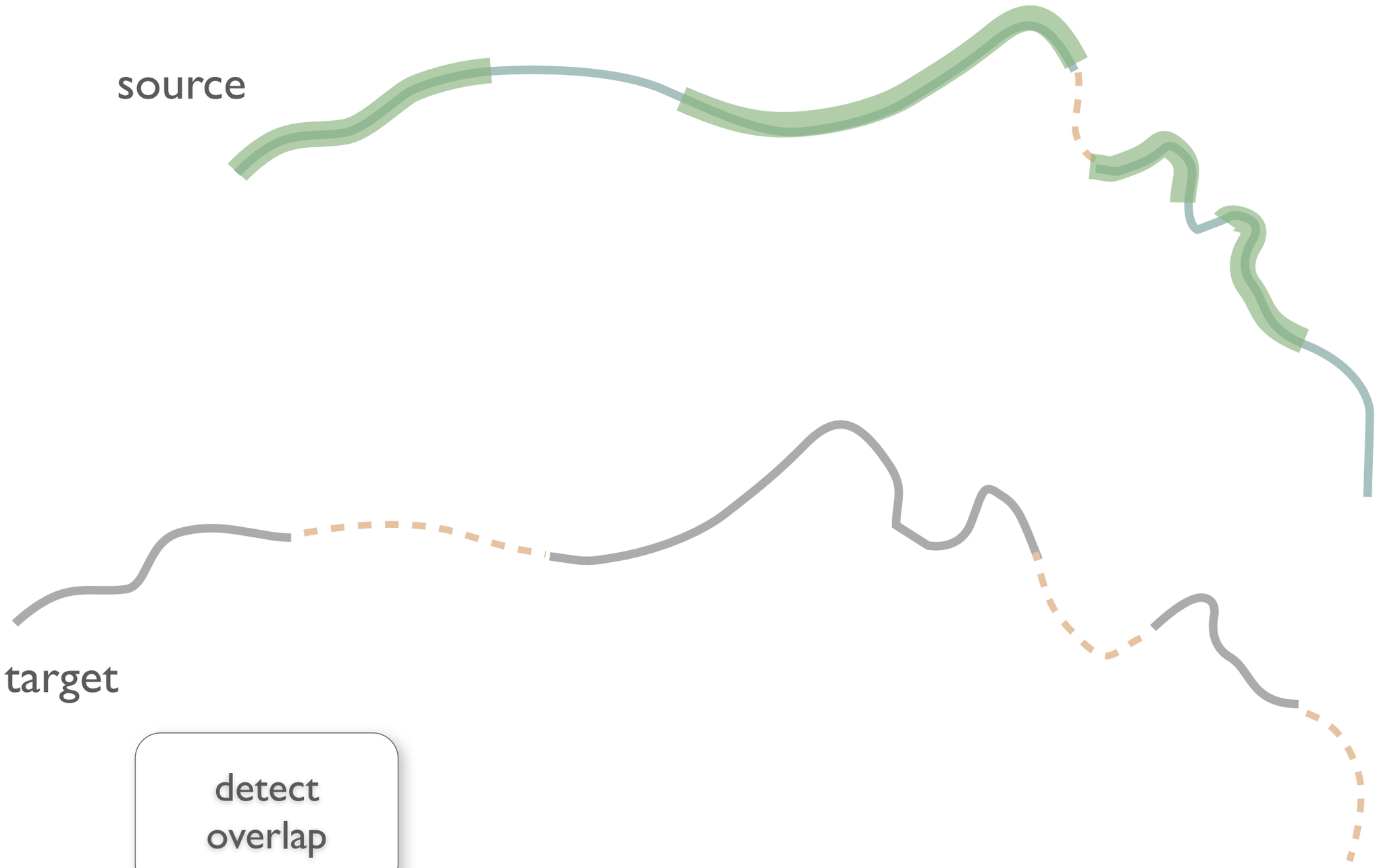
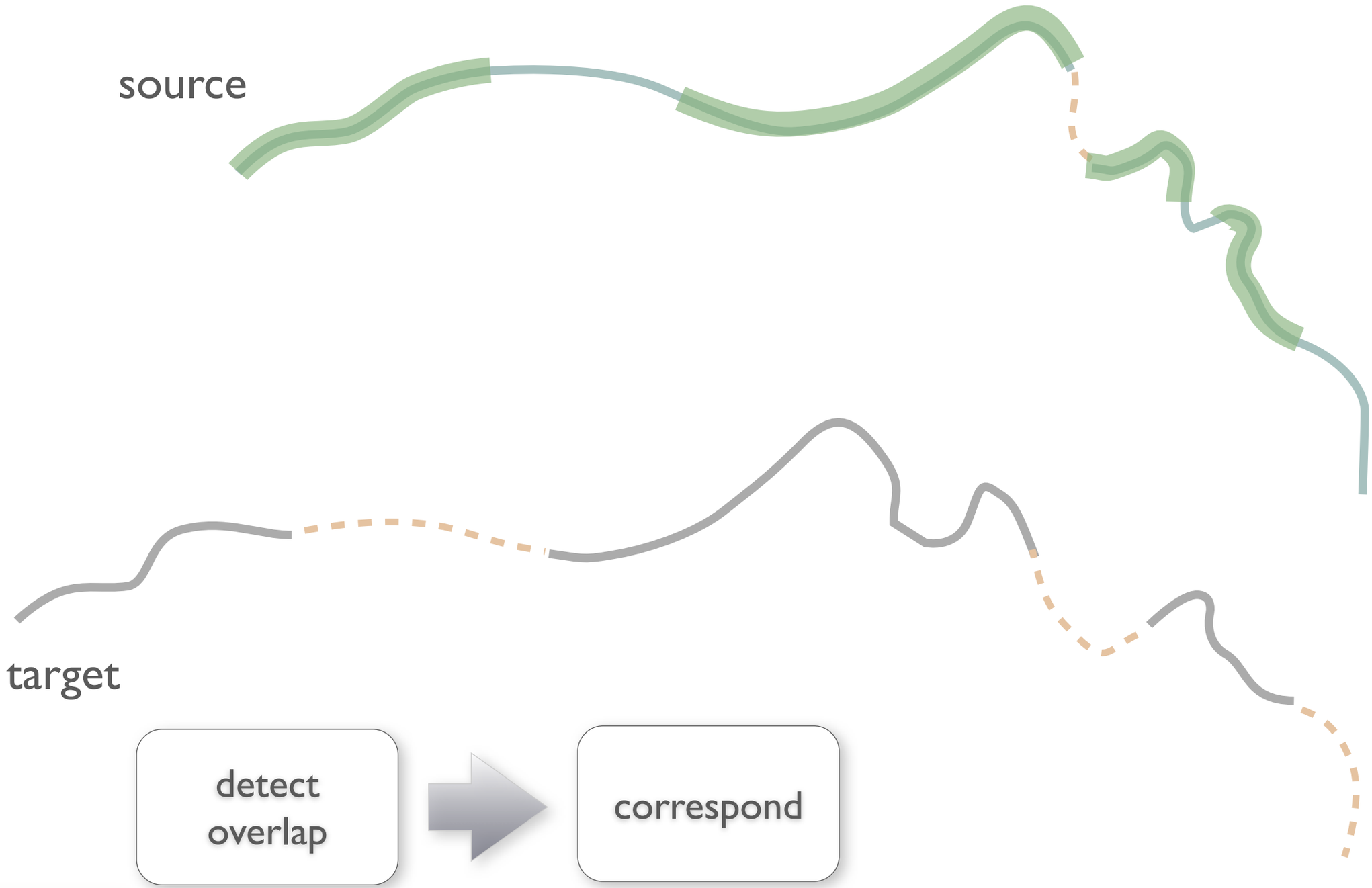


Ingredients

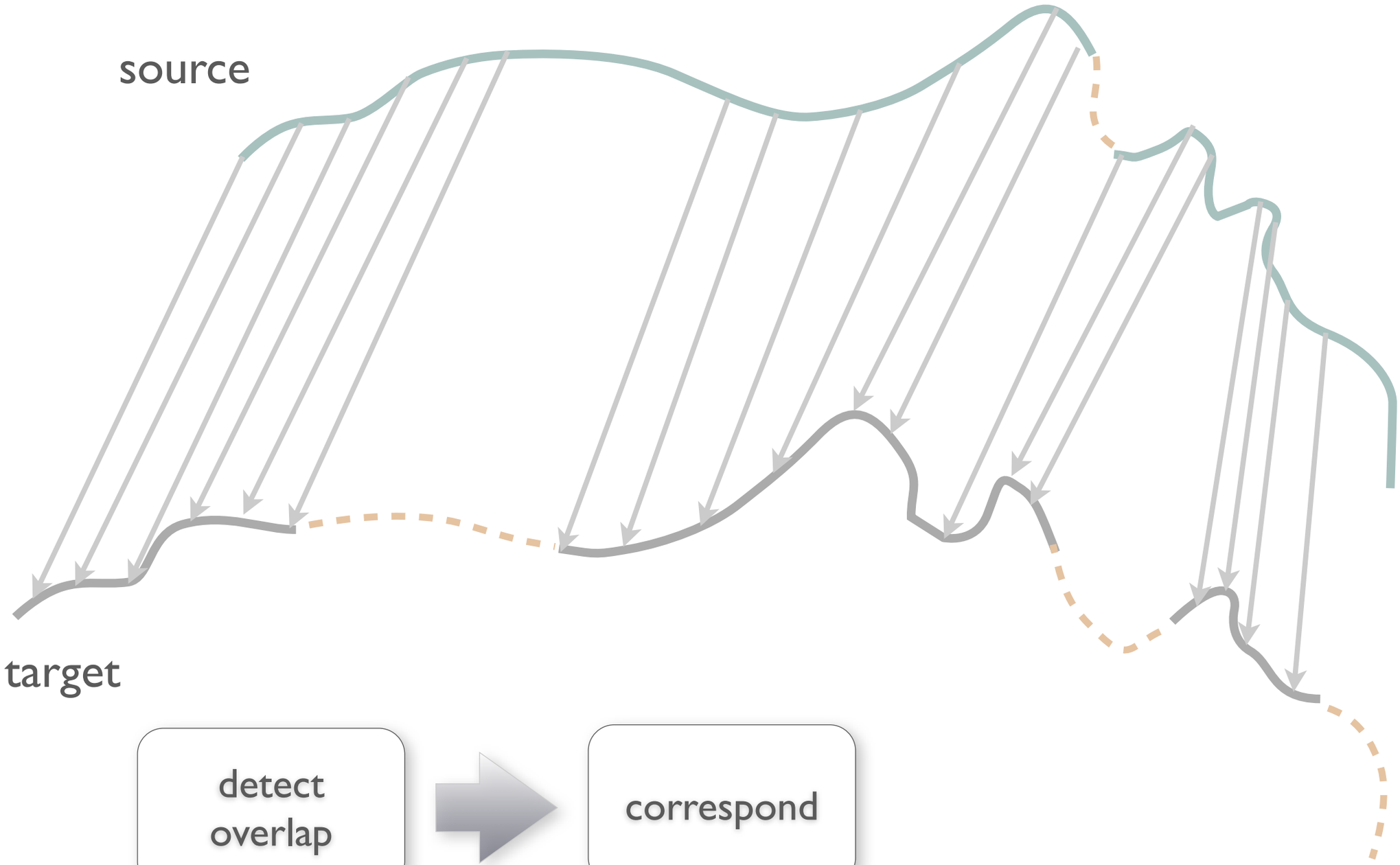


detect
overlap

Ingredients

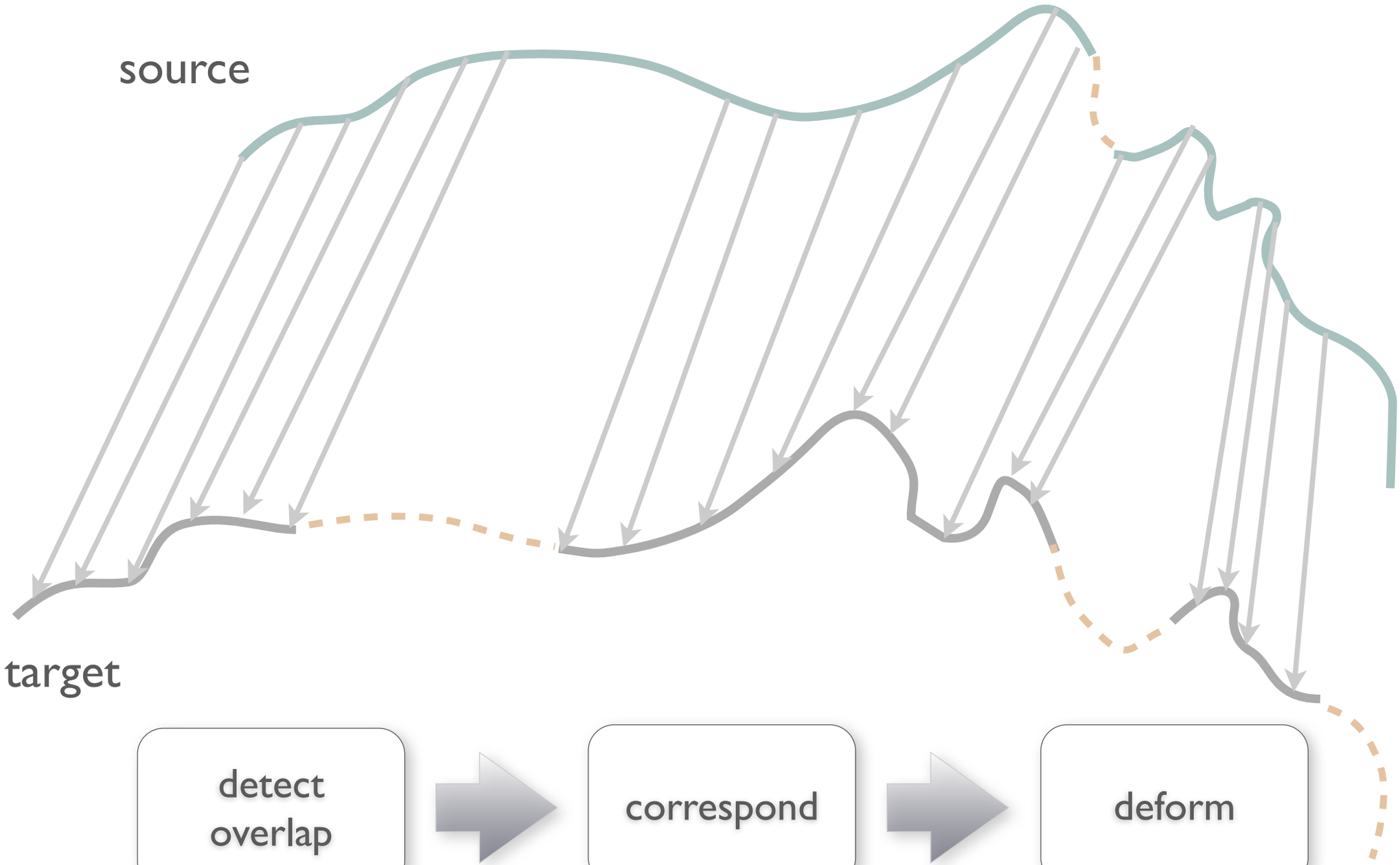


Ingredients



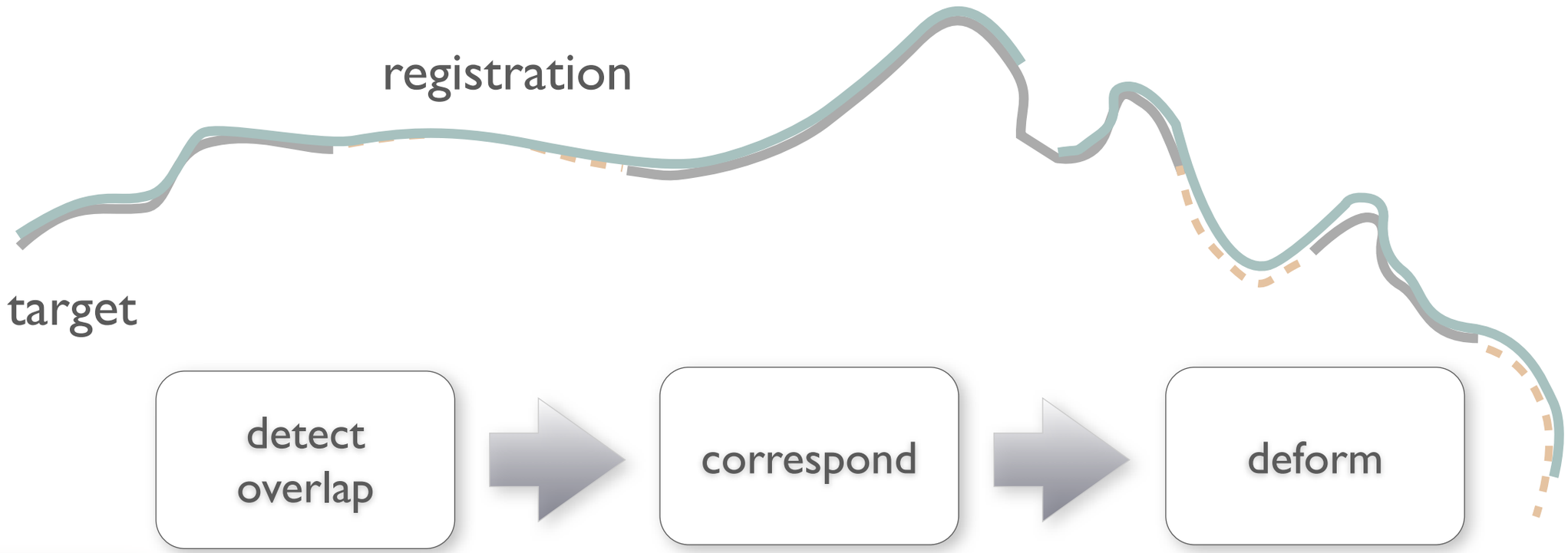
detect overlap → correspond

Ingredients

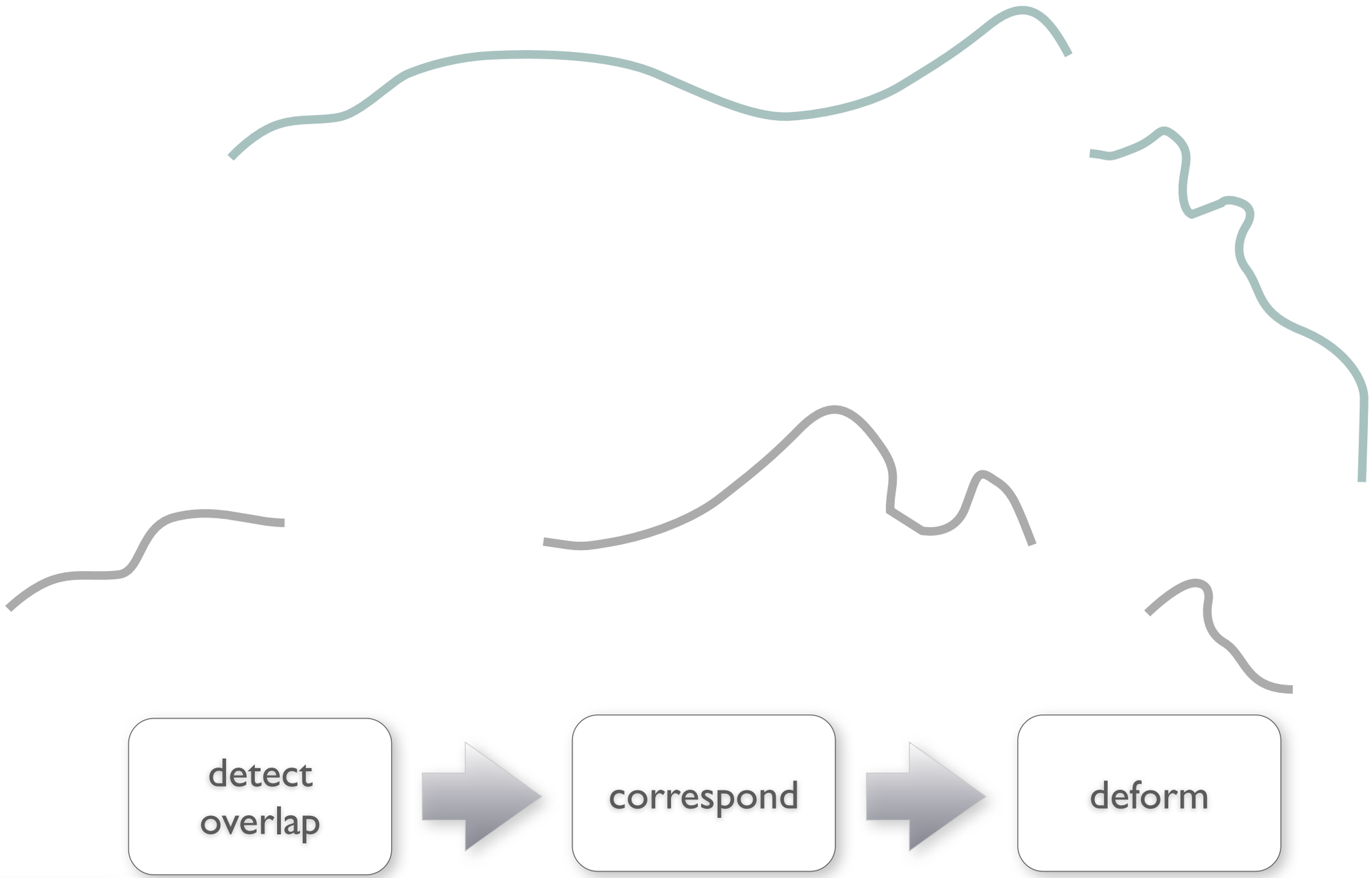


detect overlap → correspond → deform

Ingredients



What's so difficult?



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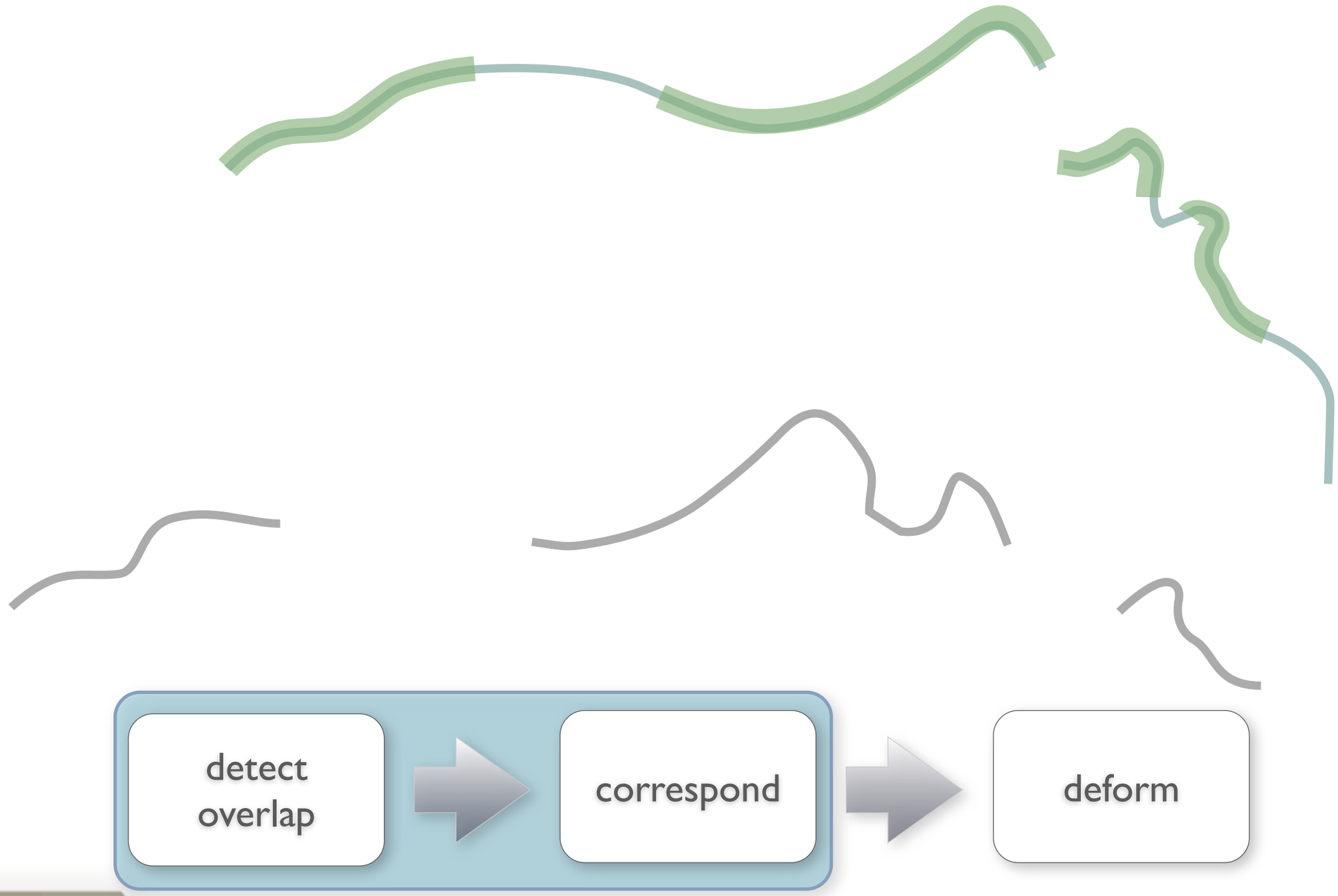

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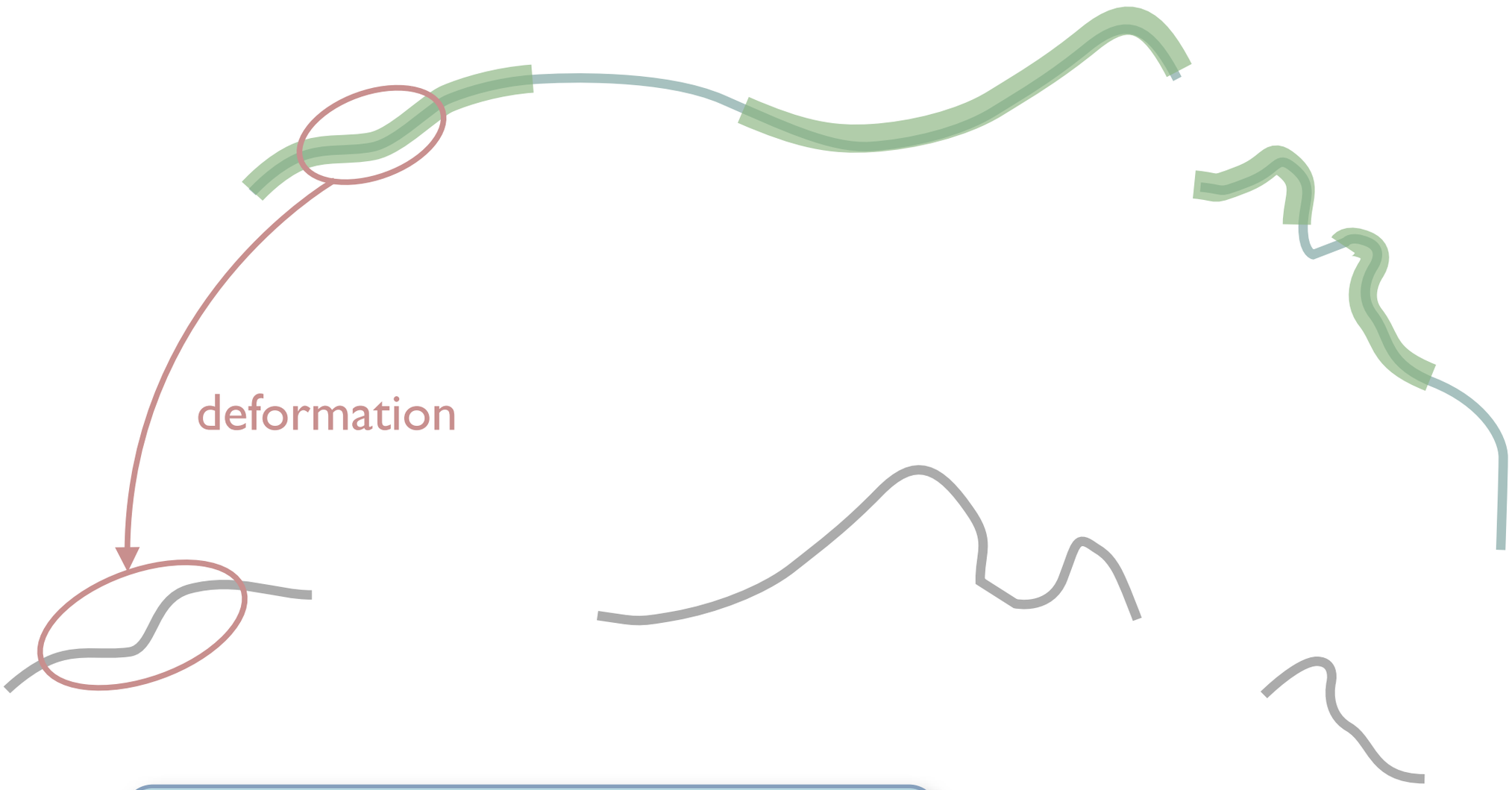

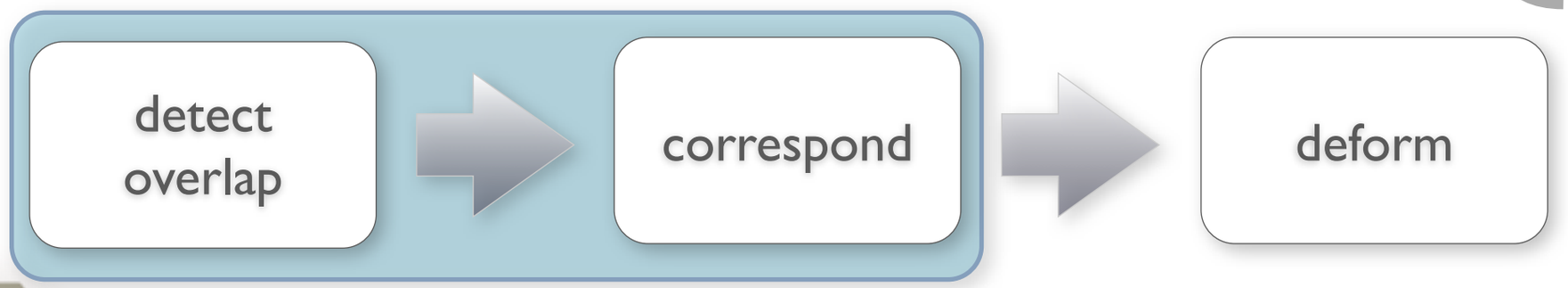

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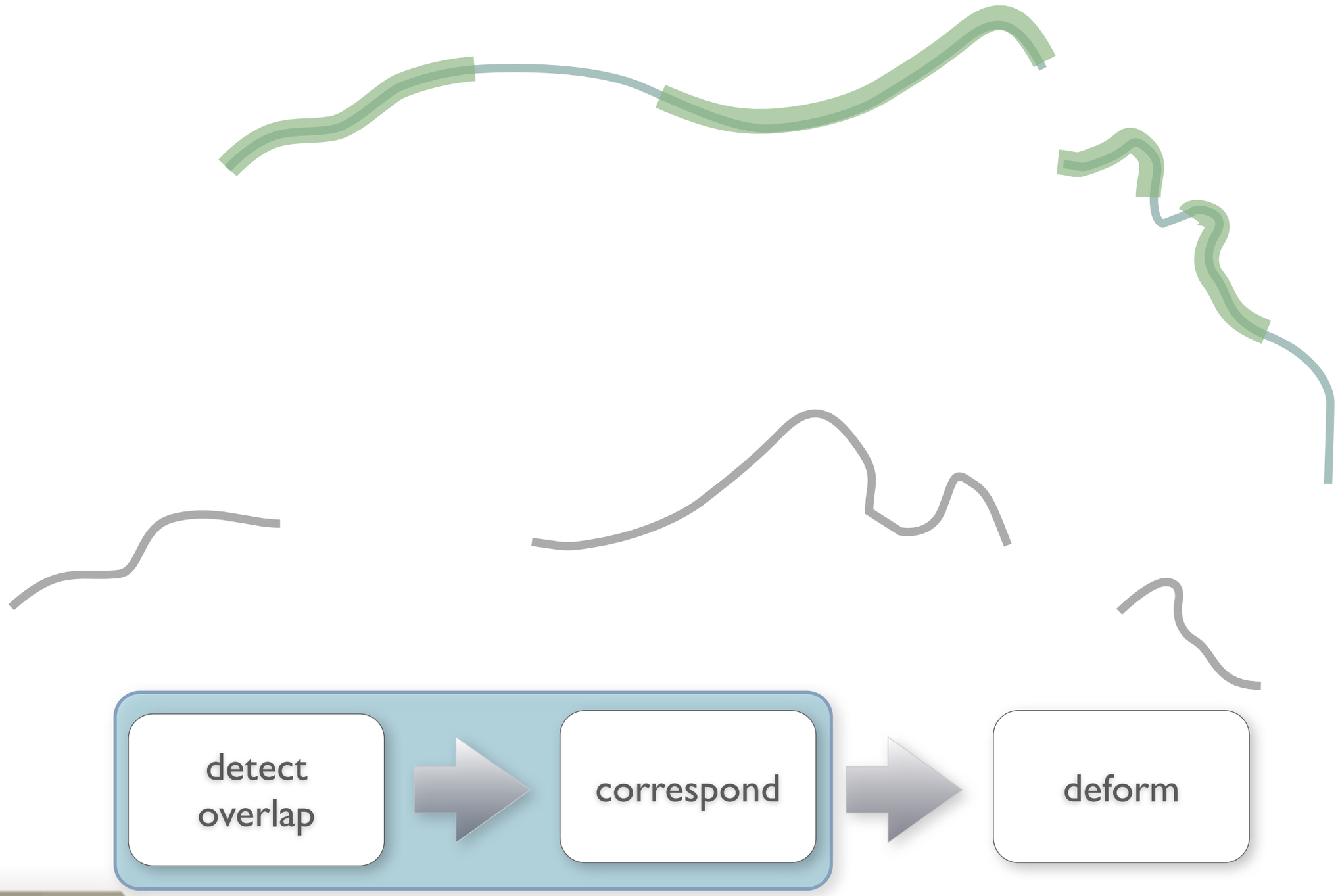

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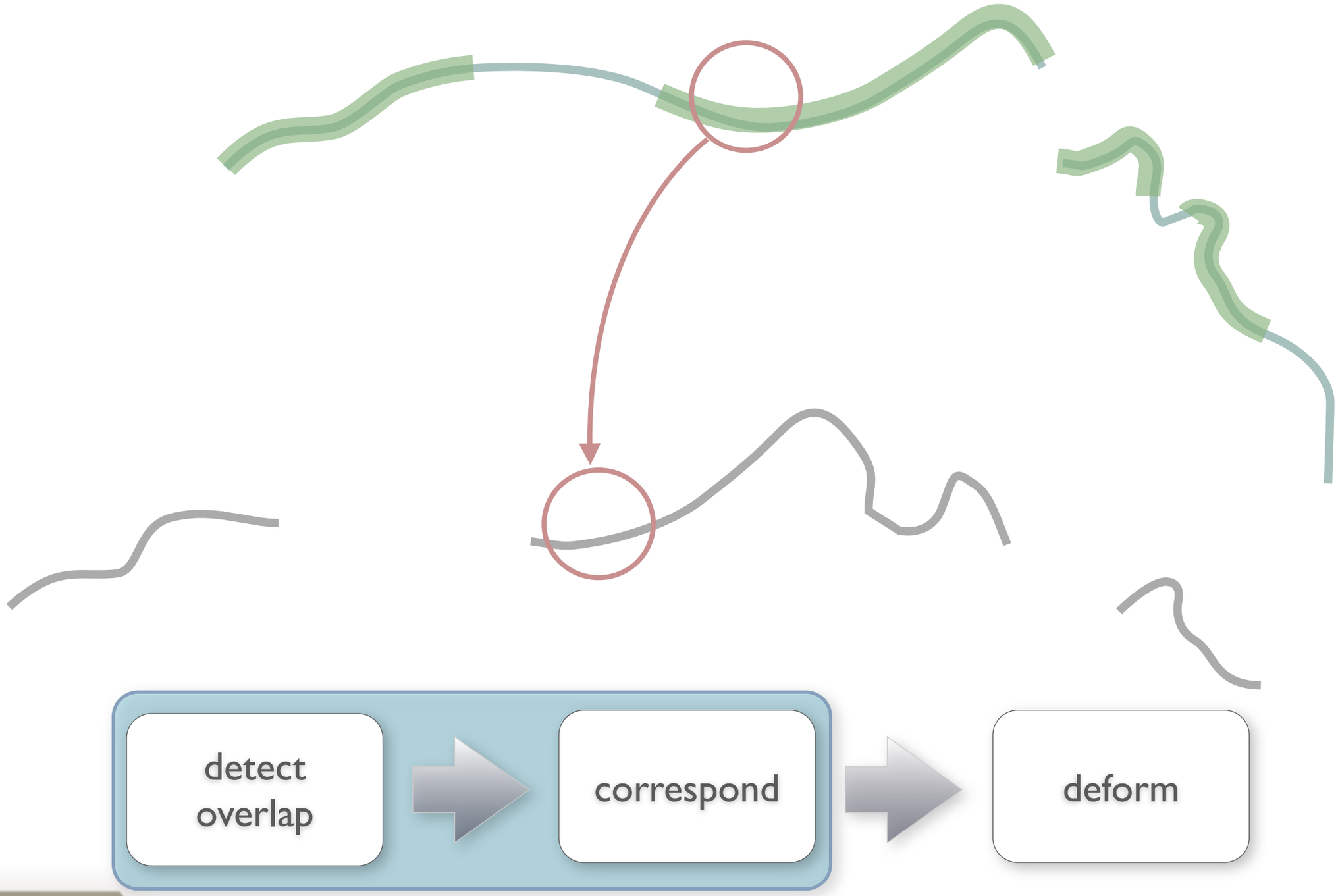

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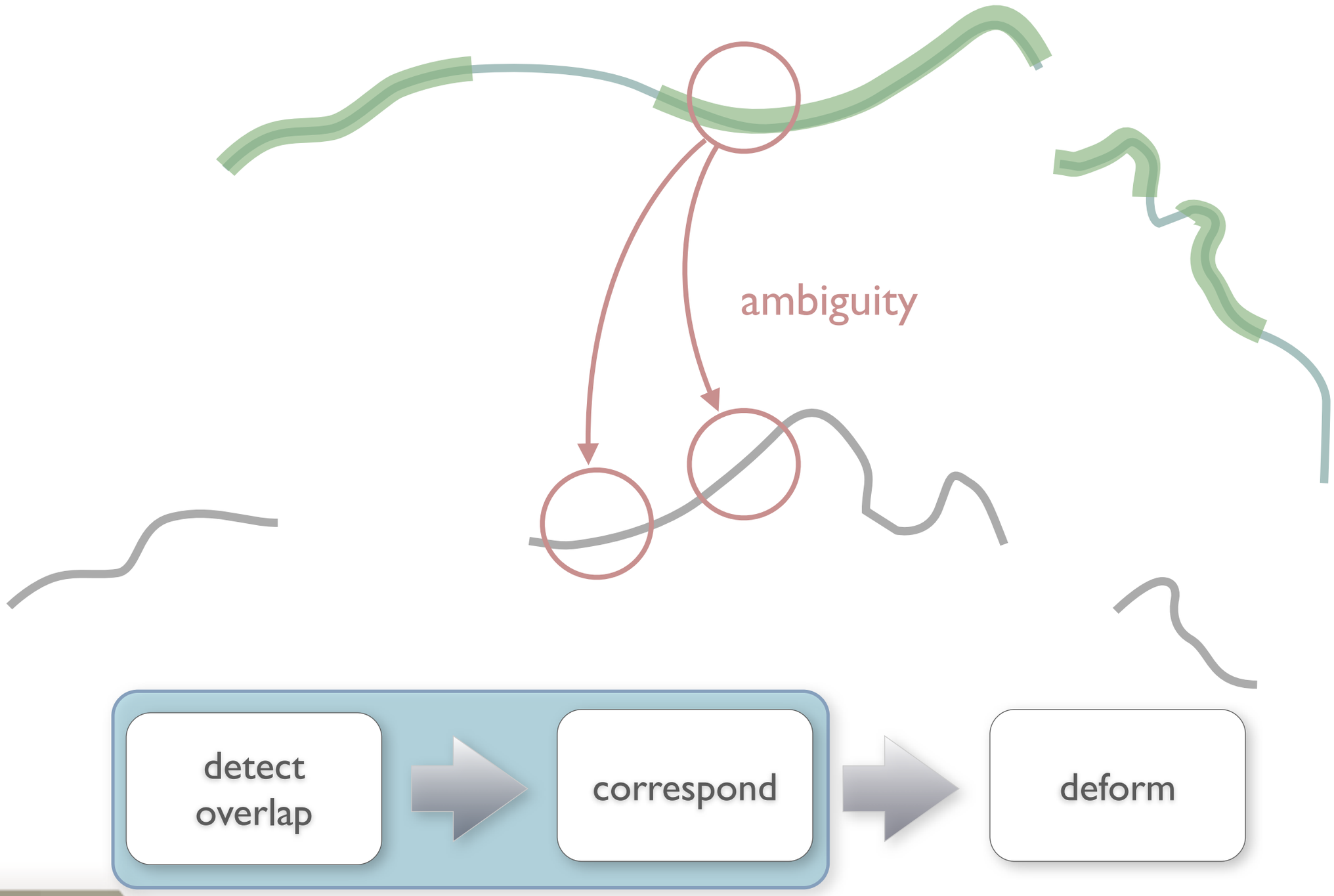

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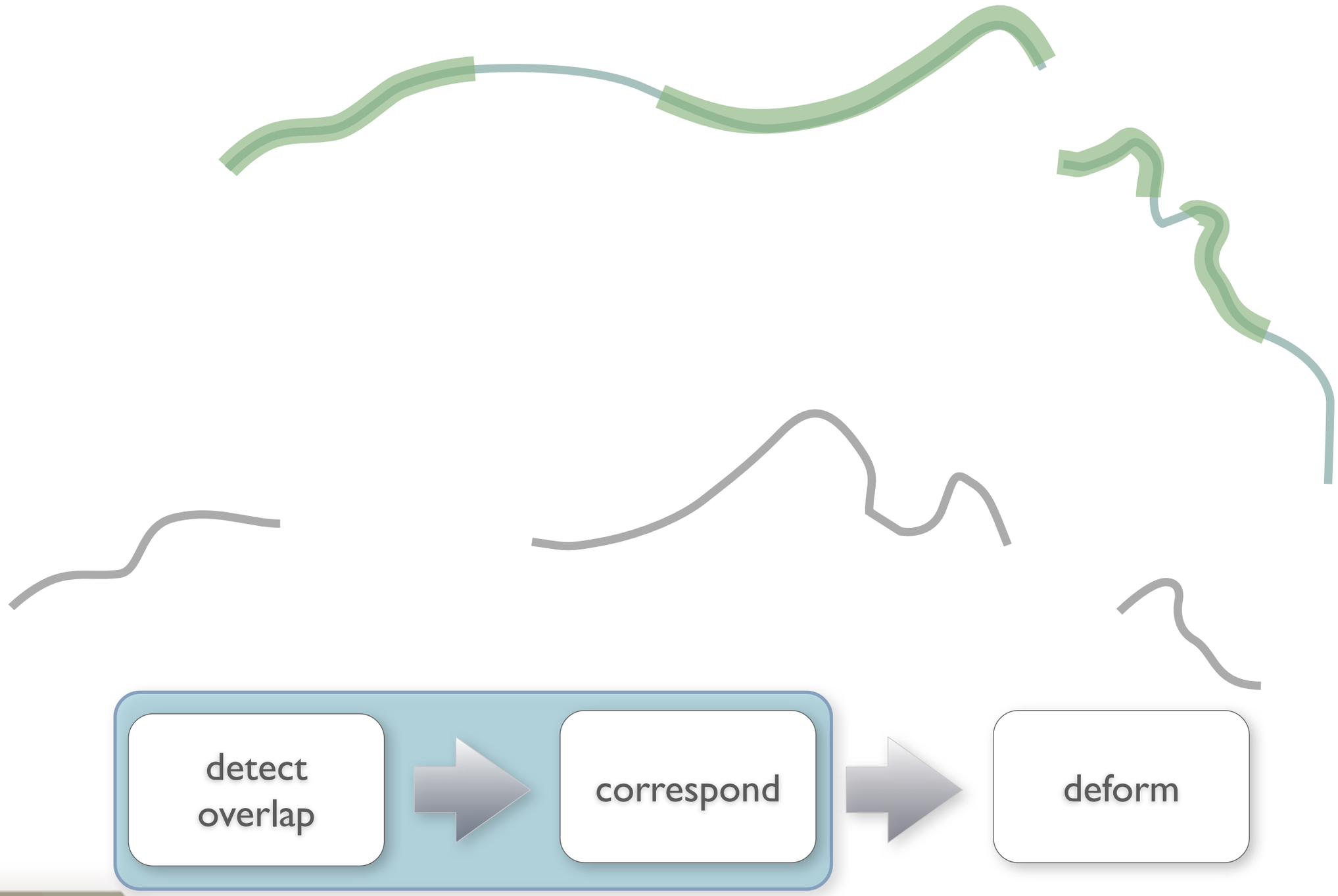

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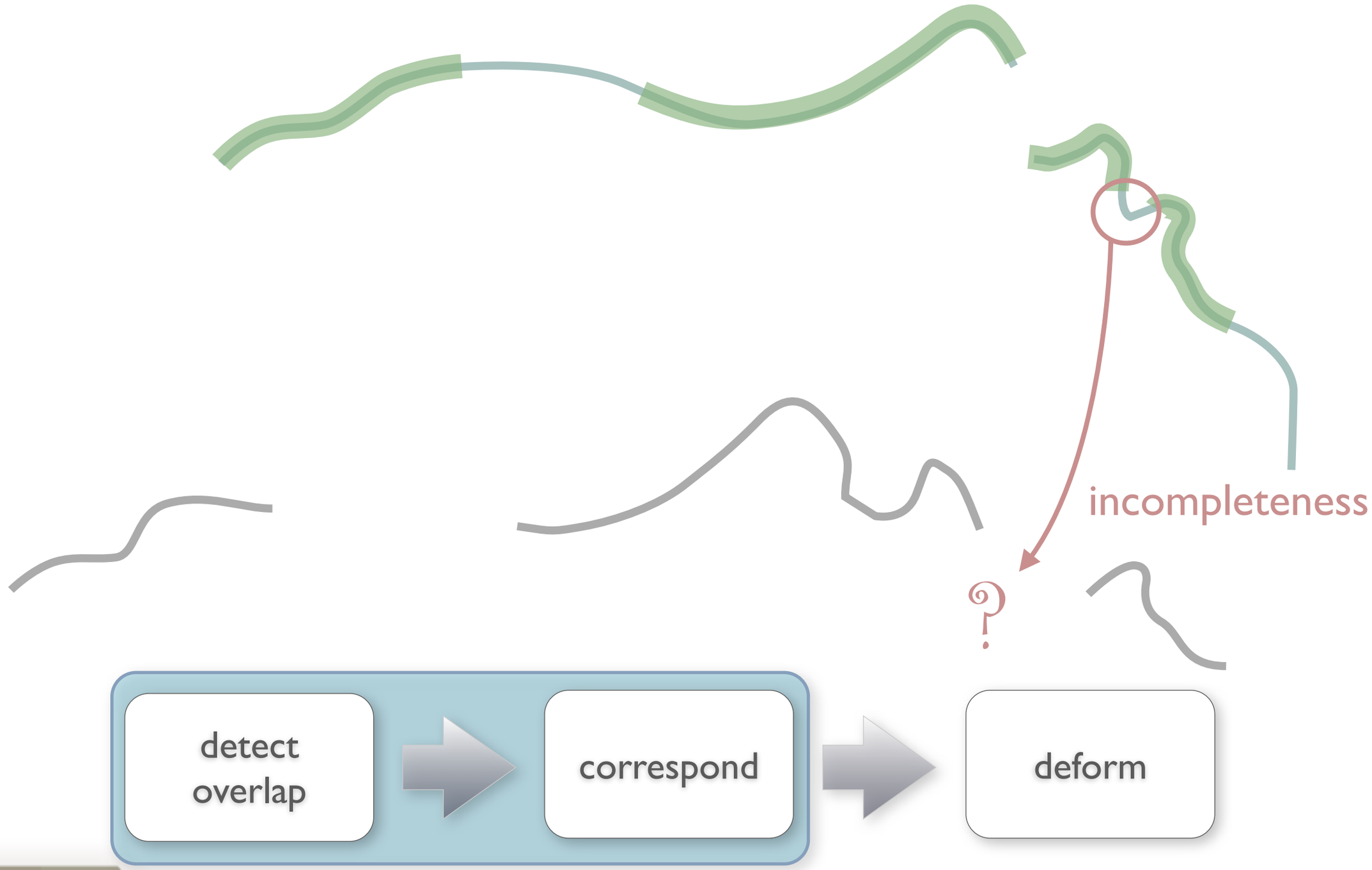

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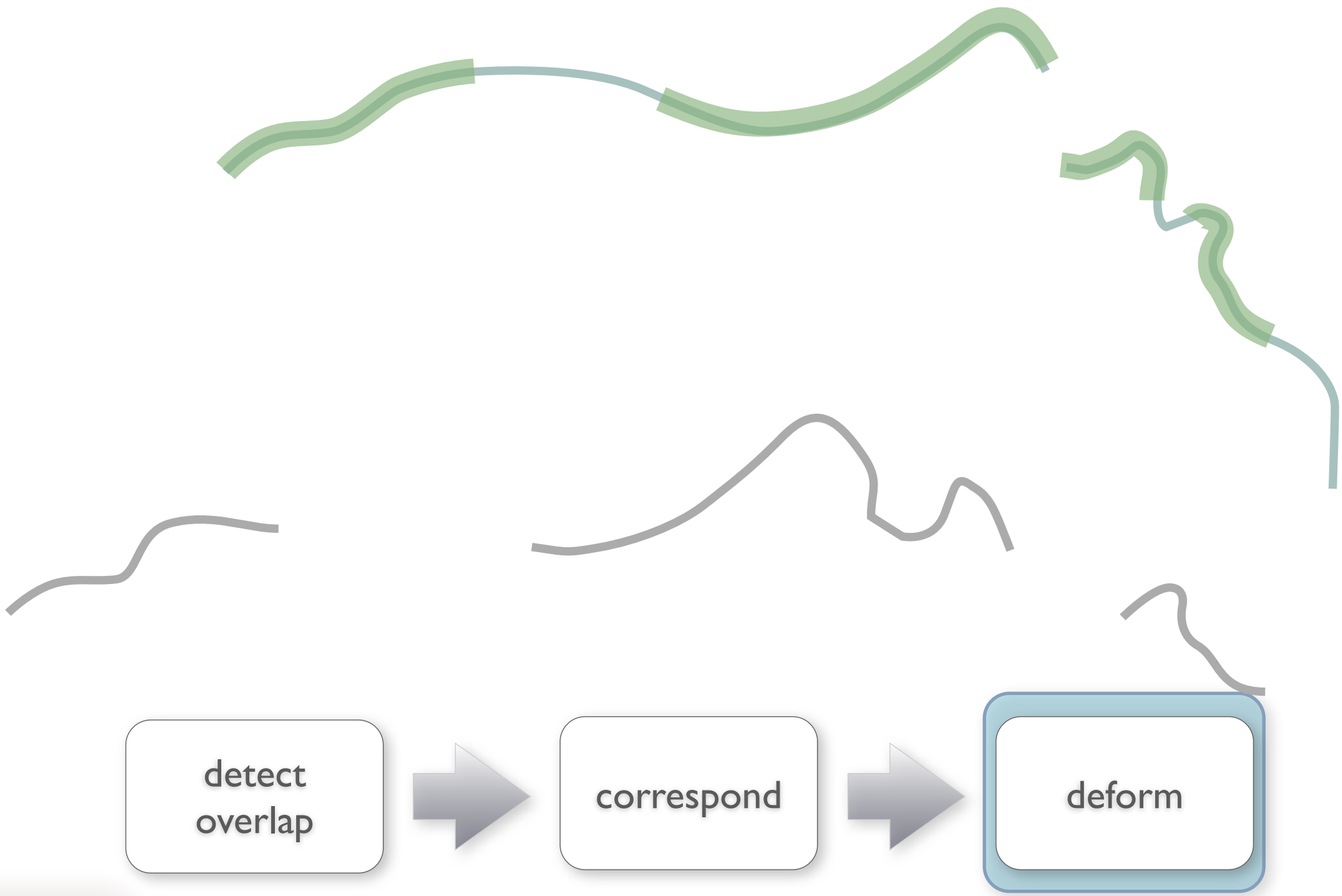

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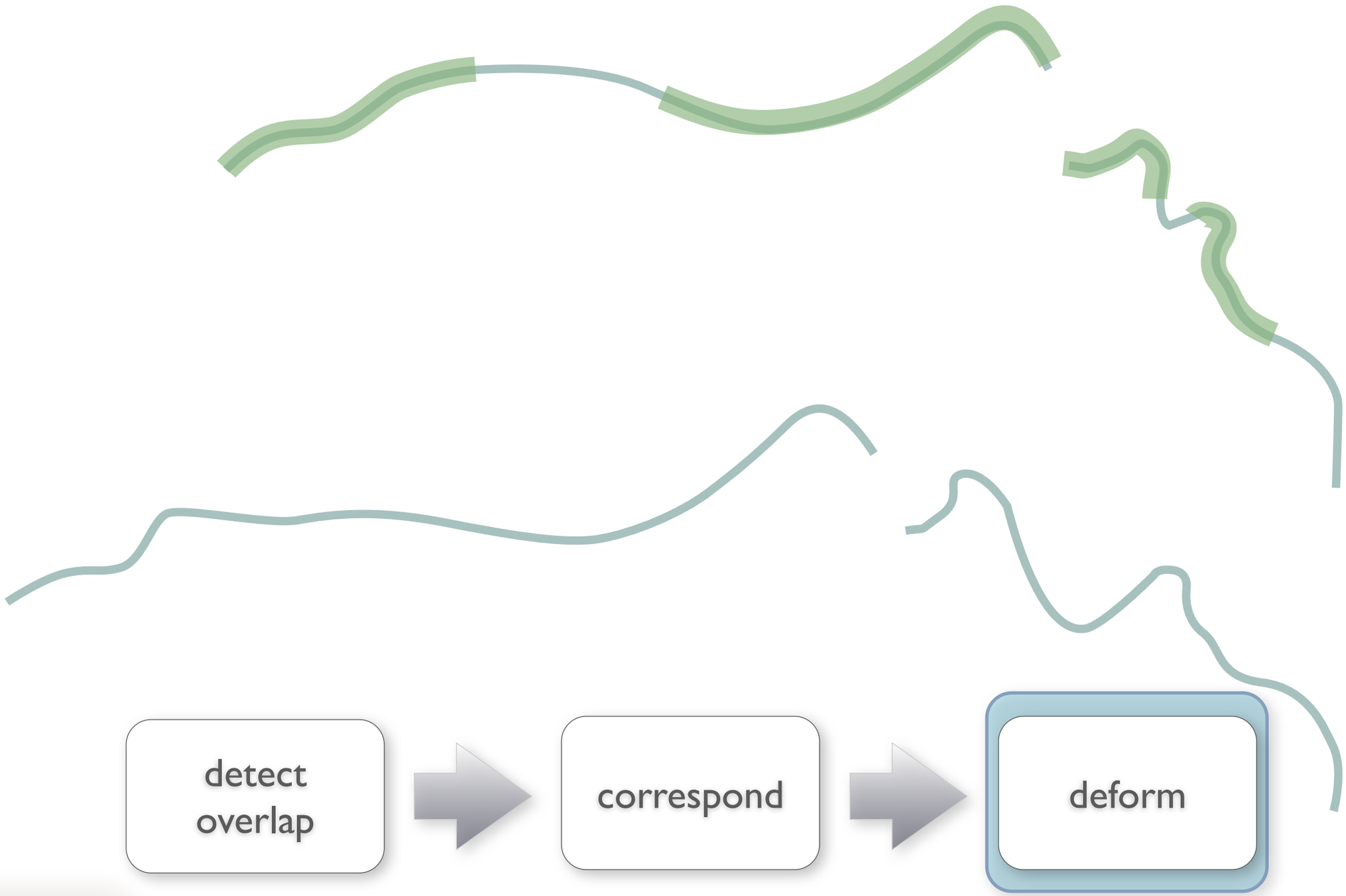

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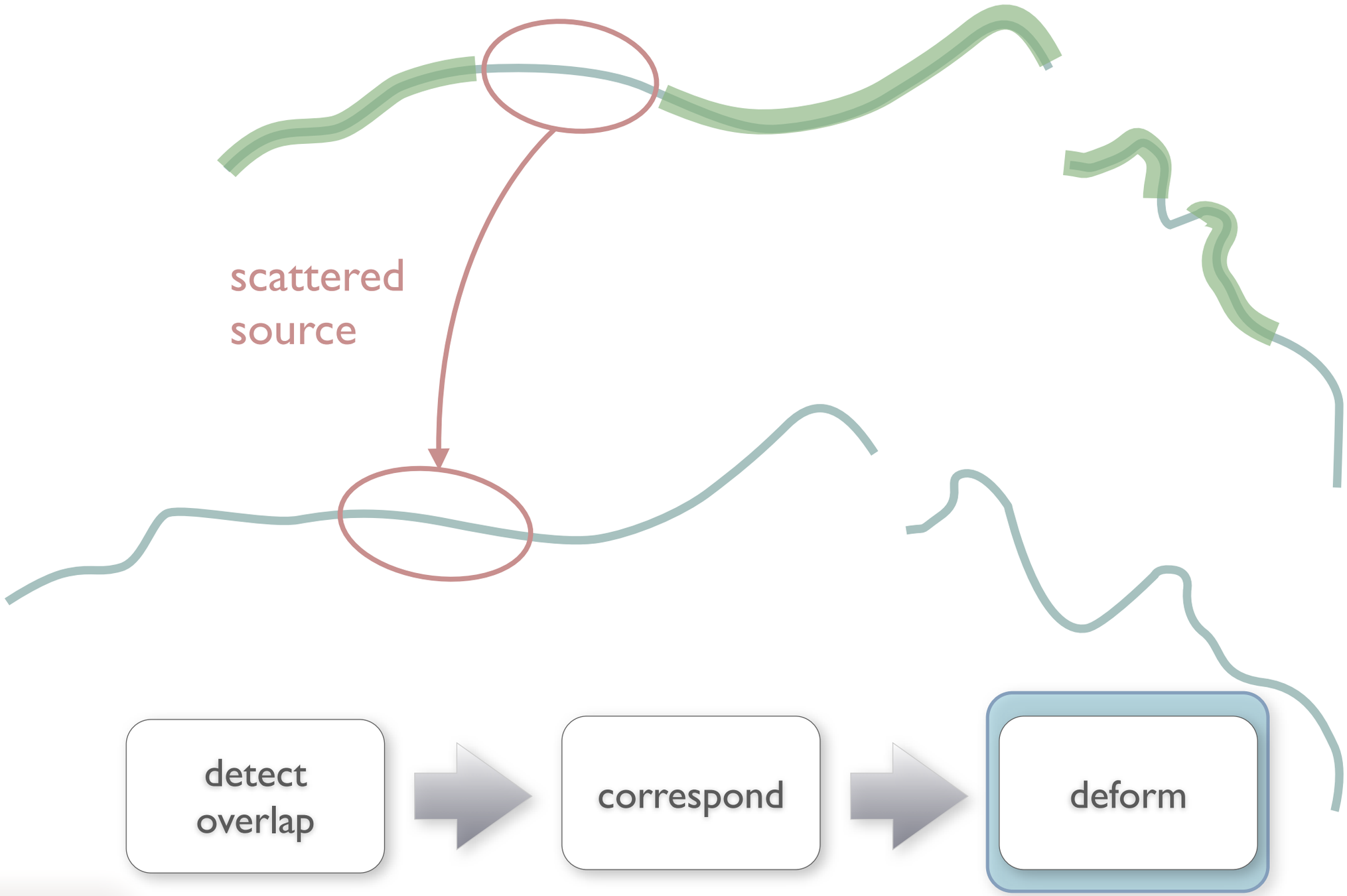

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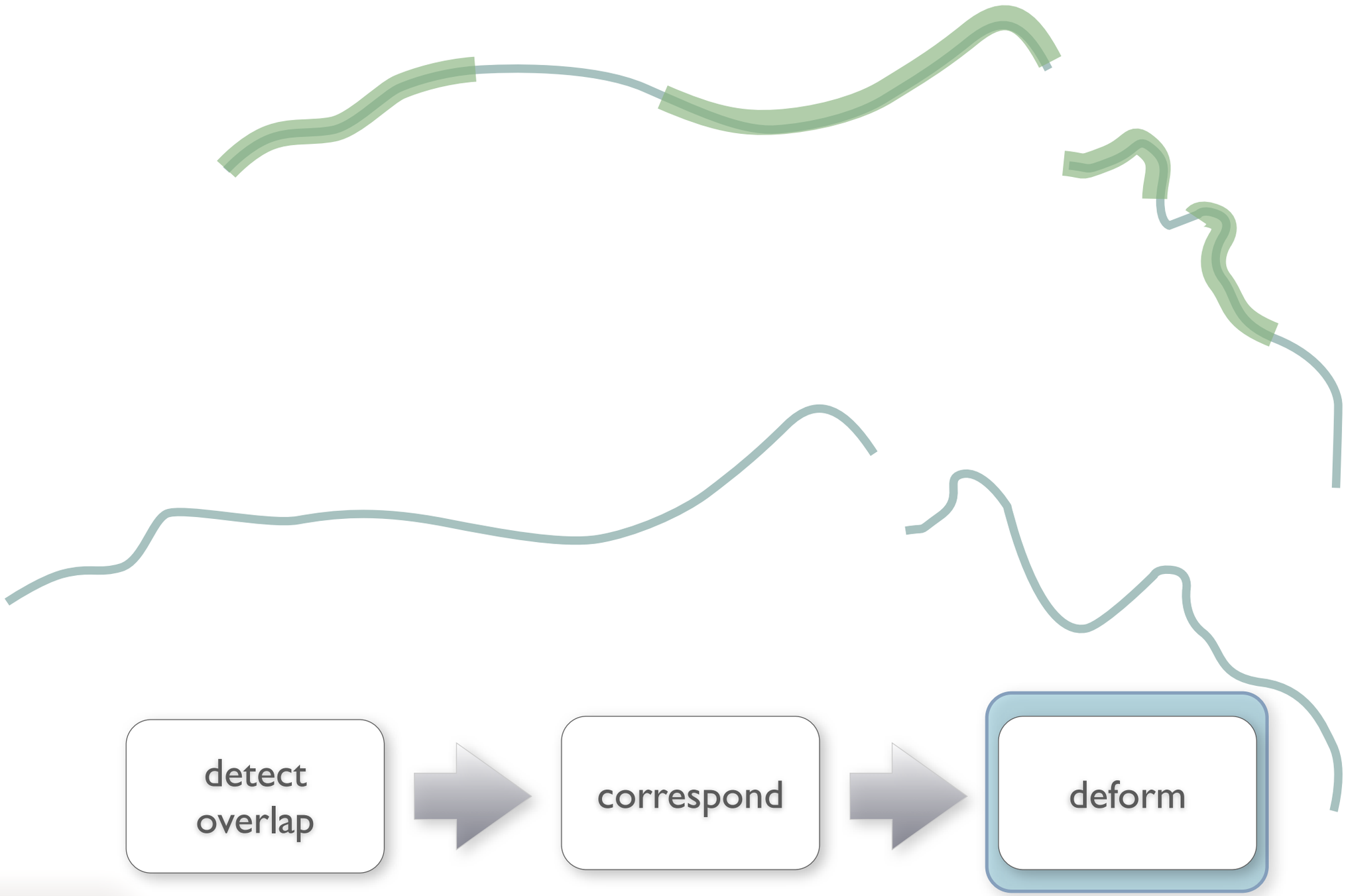

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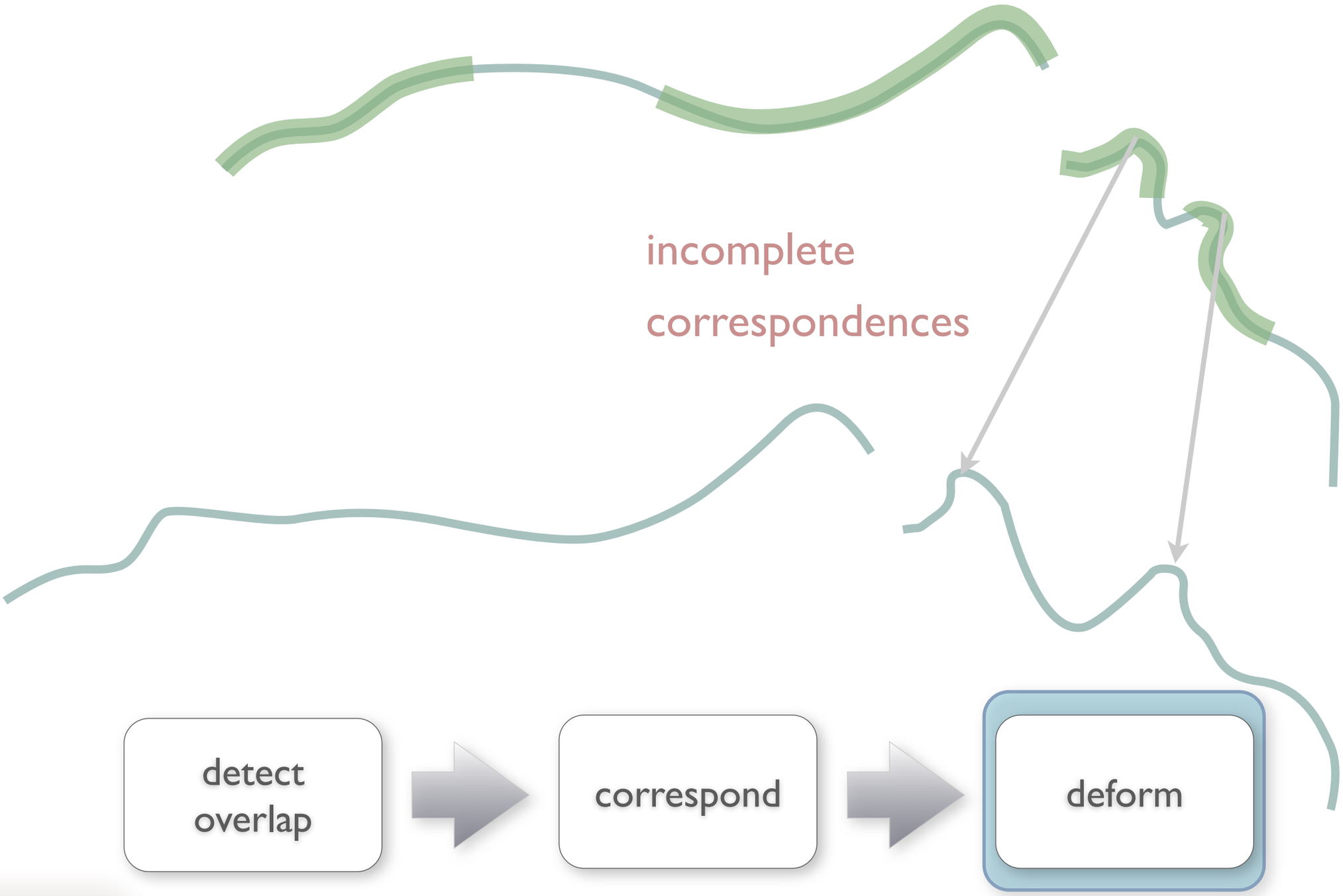

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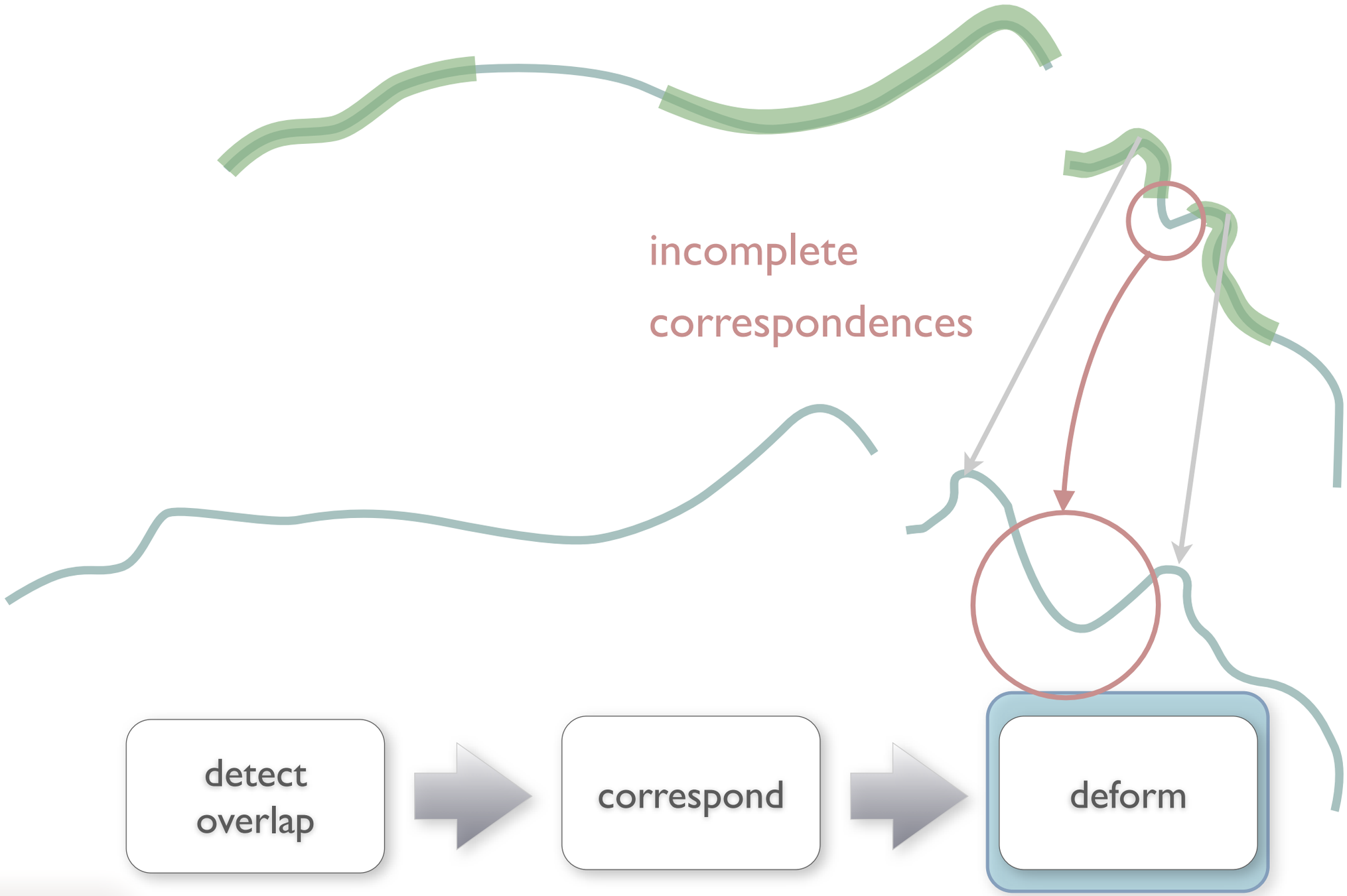


Challenges

detect overlap

correspond

deform

Challenges

correspond

detect
overlap

deform

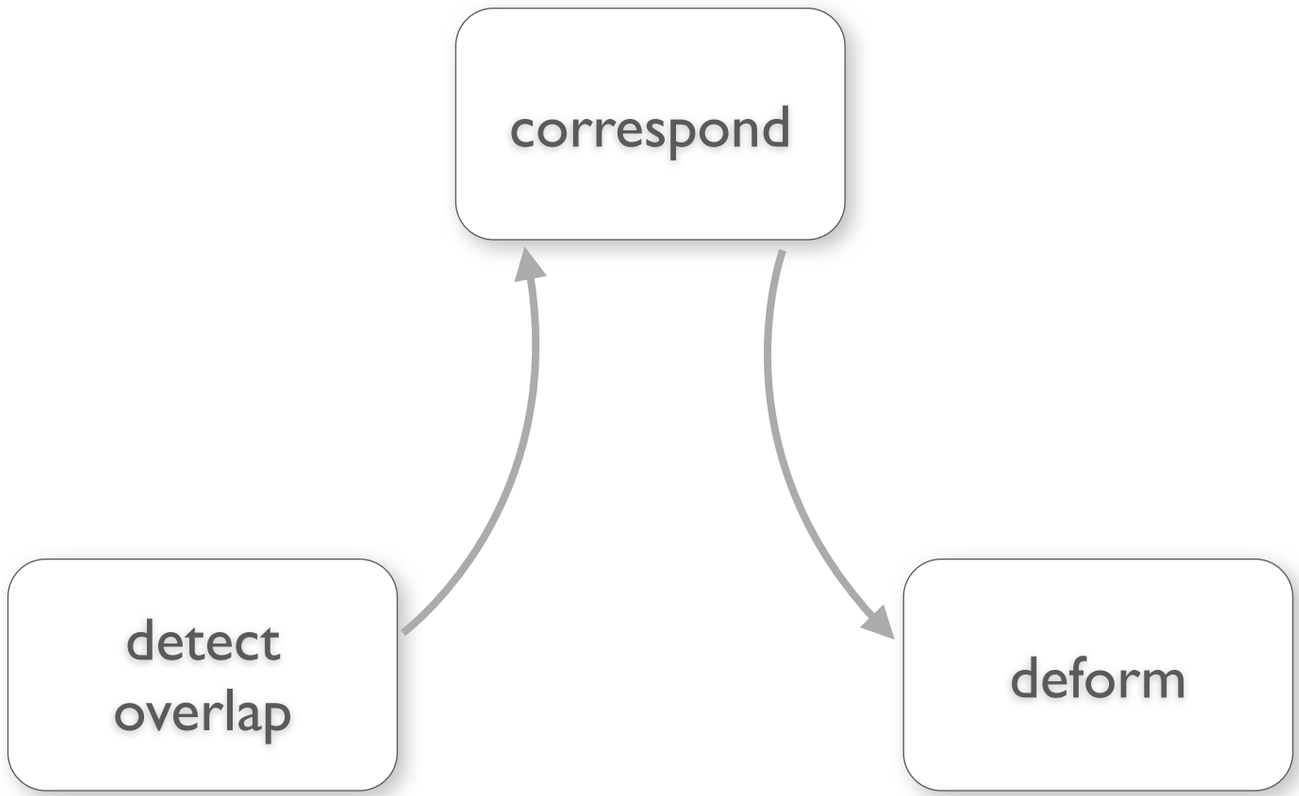
Observation

correspond

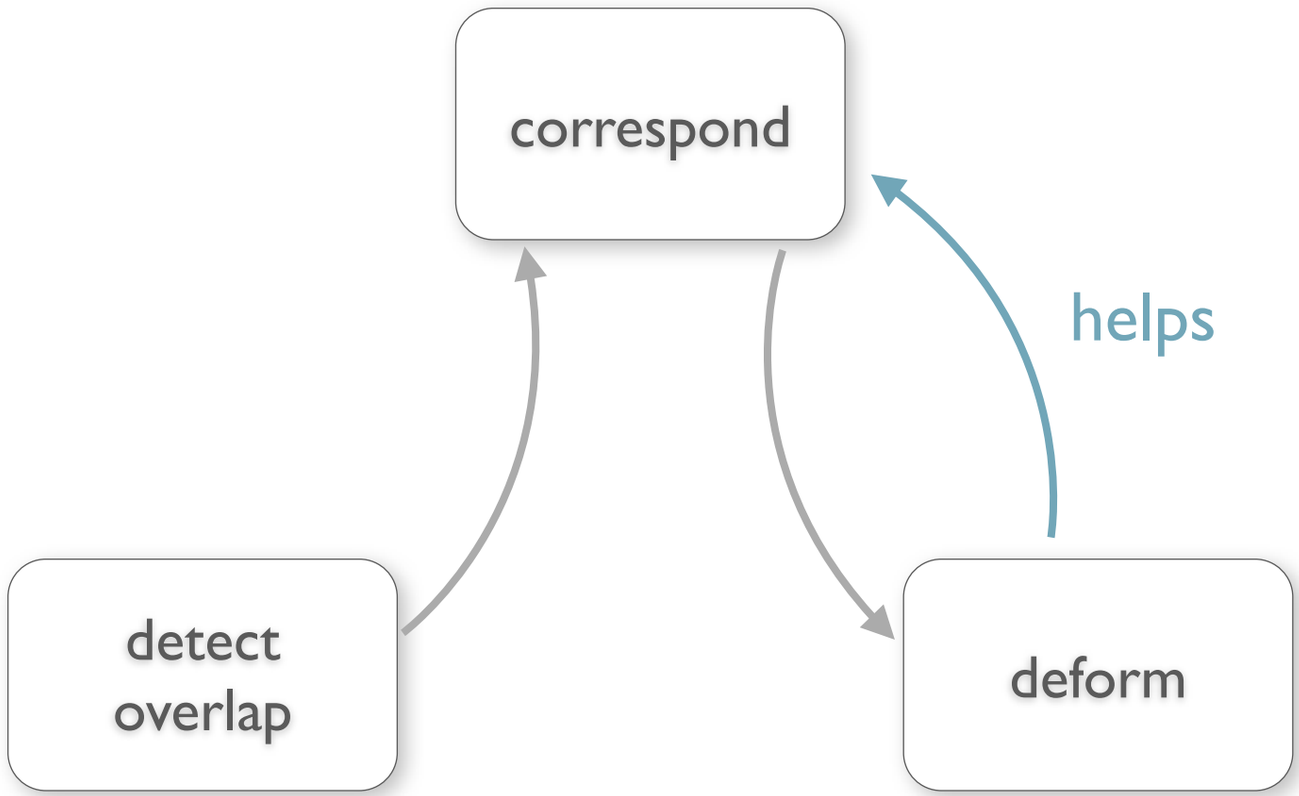
detect
overlap

deform

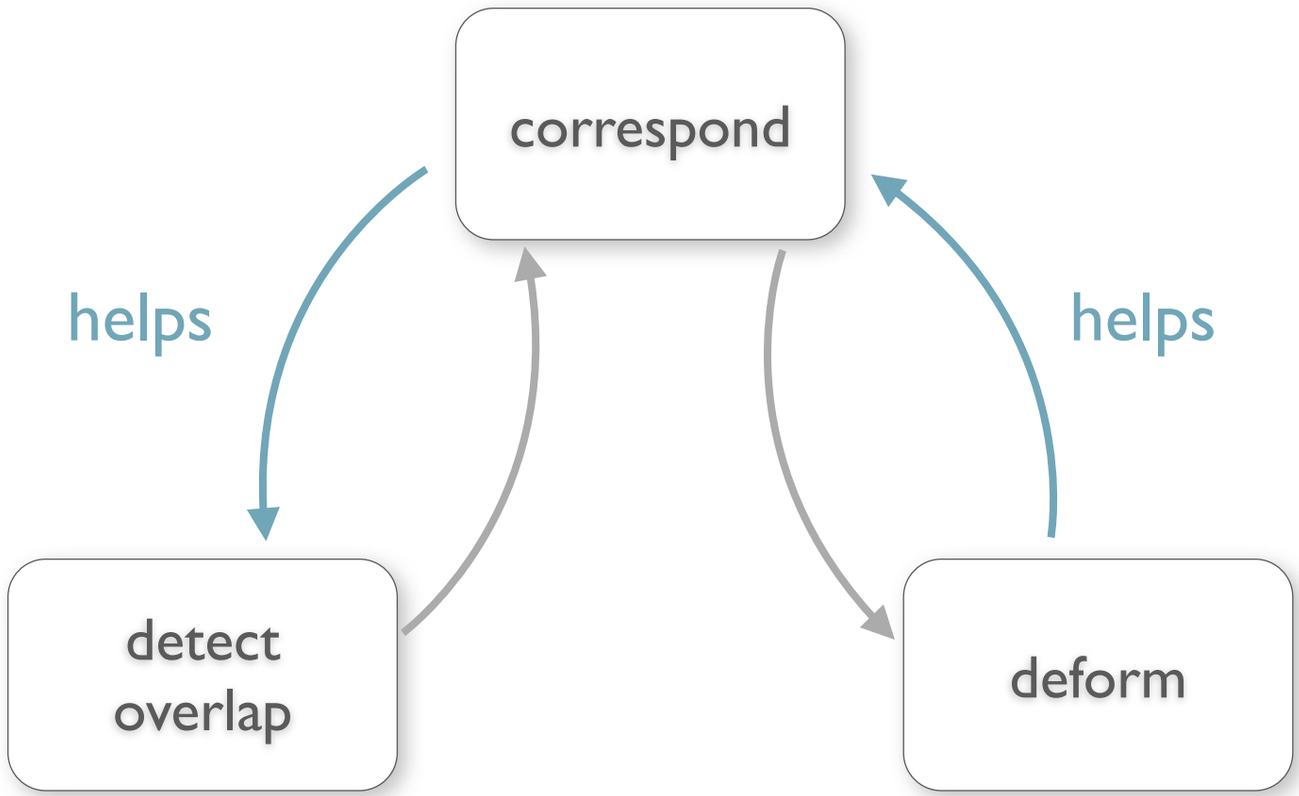
Observation



Observation



Observation



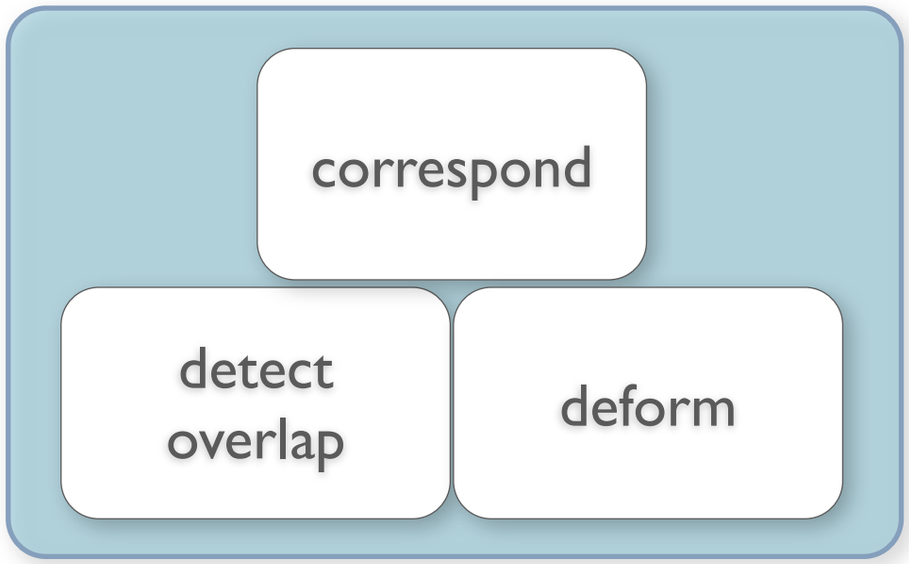
Observation

correspond

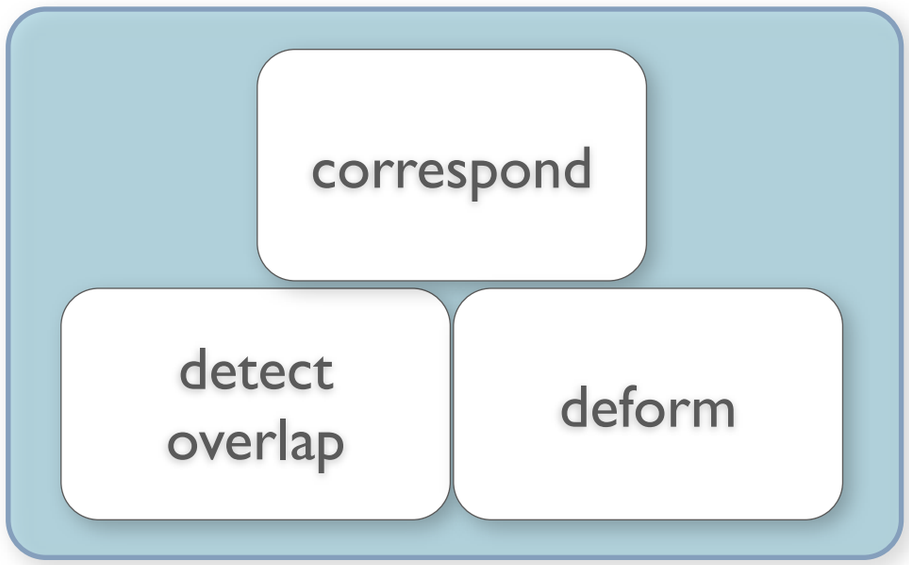
detect
overlap

deform

Observation



Observation



global optimization via local refinement

Iterative Global Optimization

correspond

detect overlap

deform

Iterative Global Optimization

correspond

detect overlap

deform

Iterative Global Optimization

correspond

detect overlap

deform

Iterative Global Optimization

correspond

detect overlap

deform

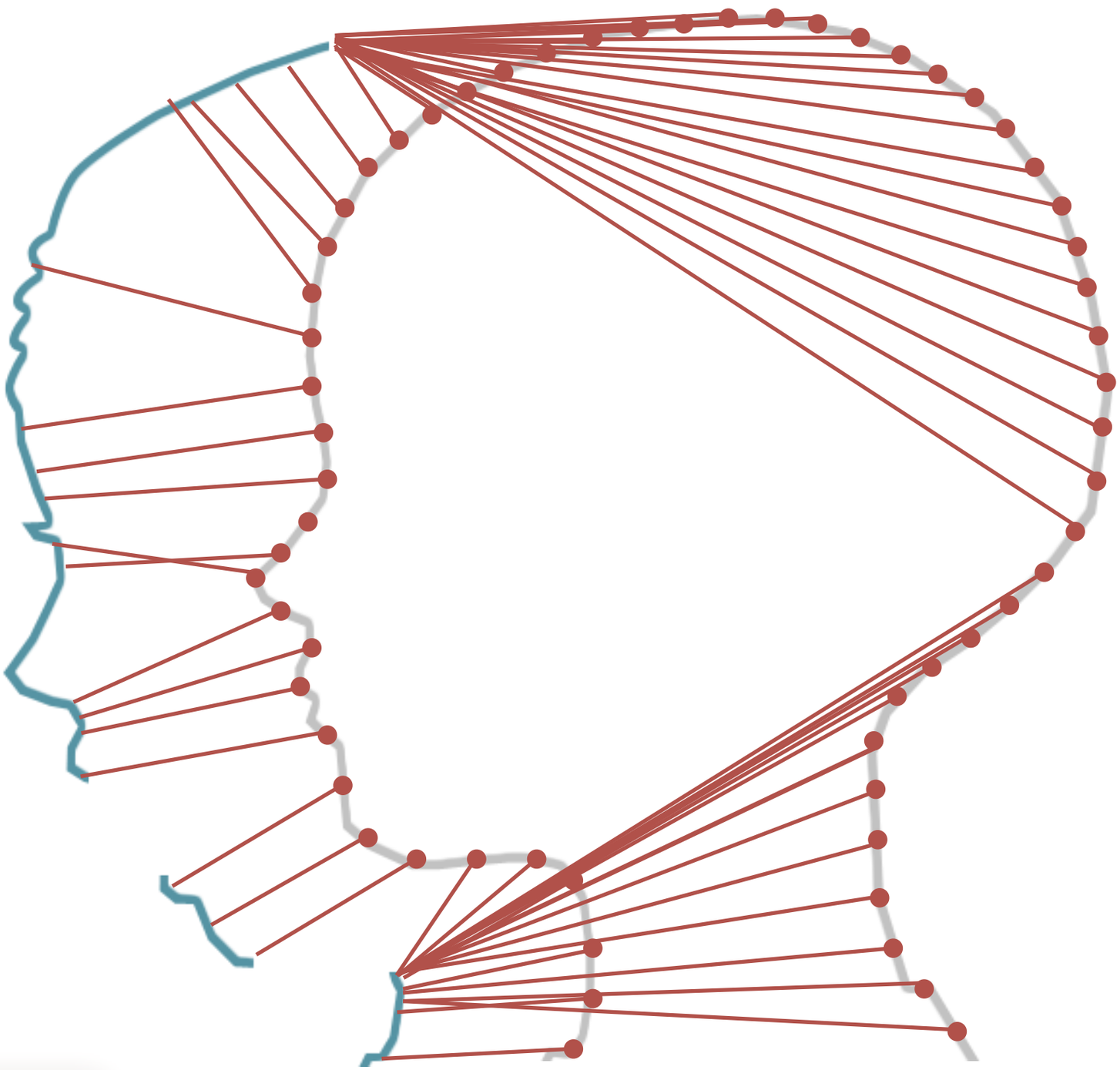
Iterative Global Optimization

closest point

detect overlap

deform

Iterative Global Optimization

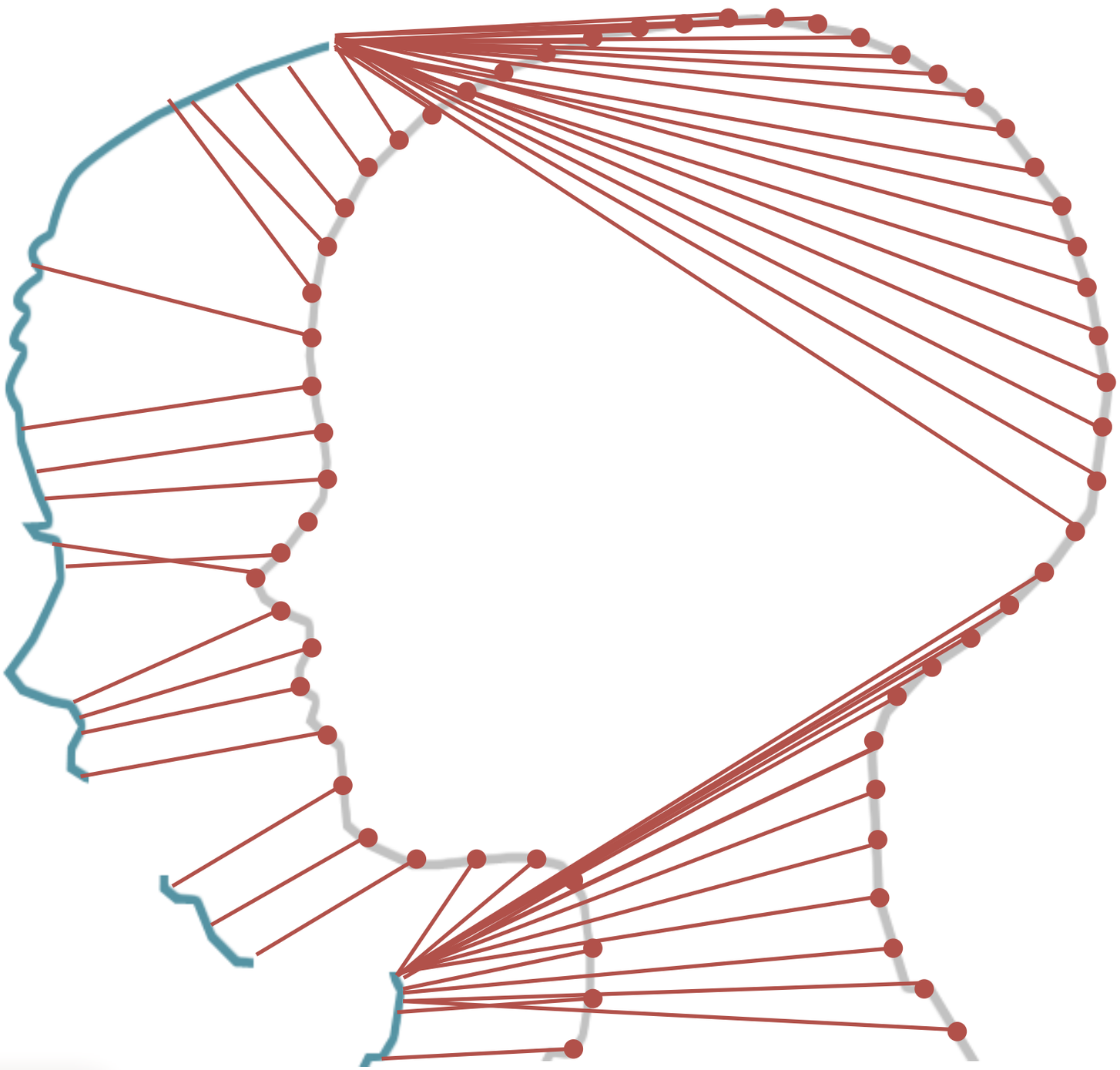


closest point

detect overlap

deform

Iterative Global Optimization

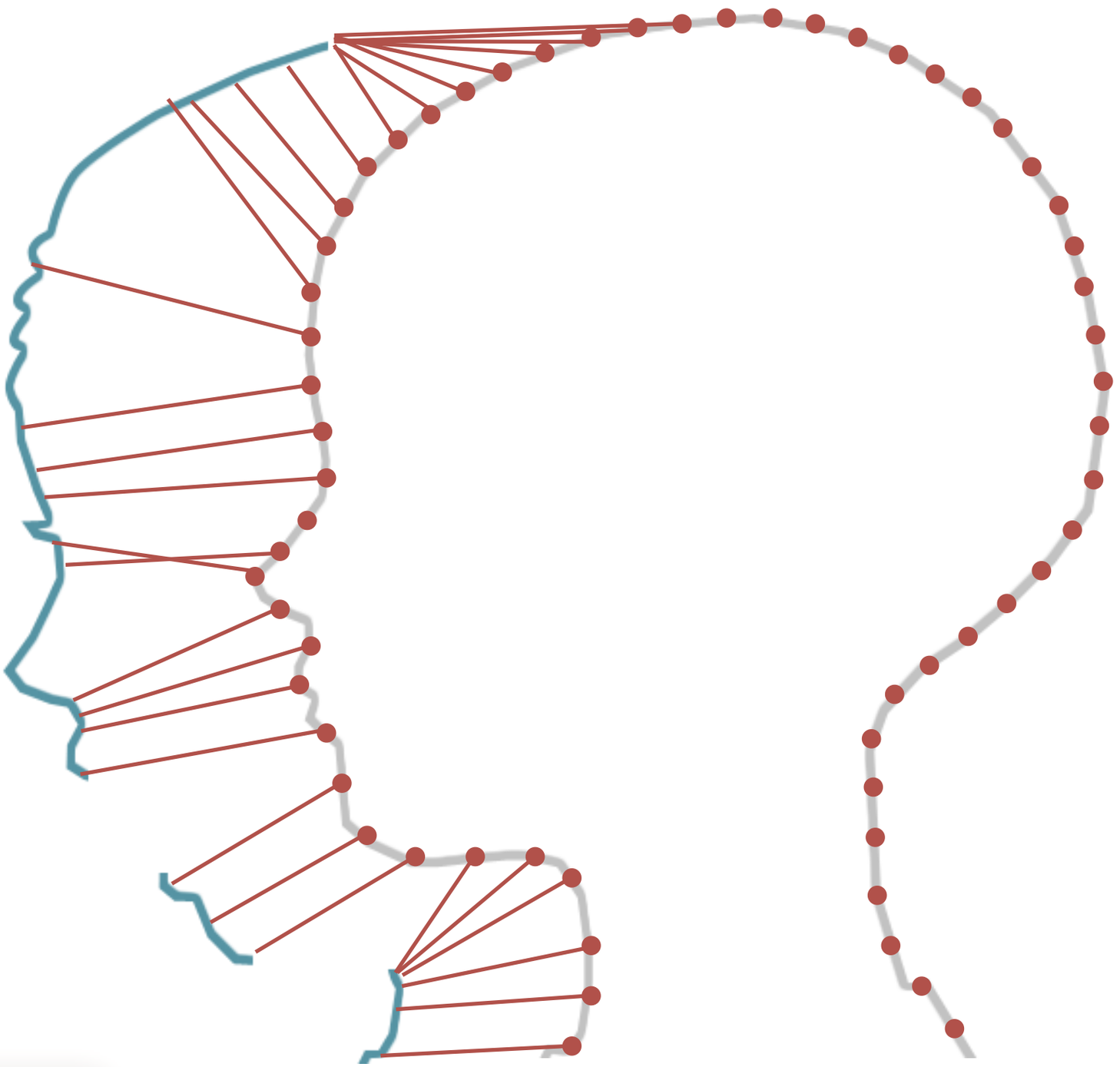


closest point

pruning

deform

Iterative Global Optimization

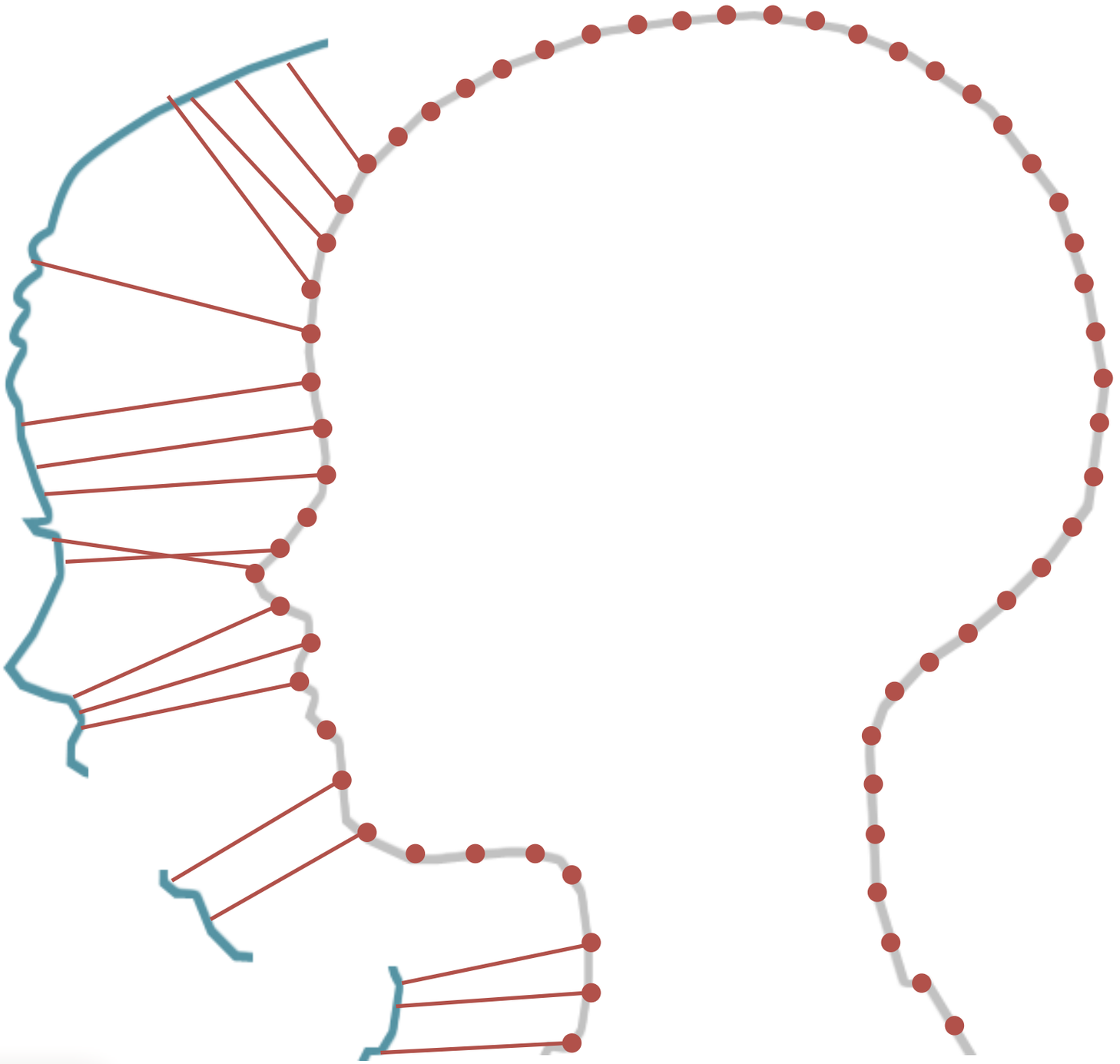


closest point

pruning

deform

Iterative Global Optimization

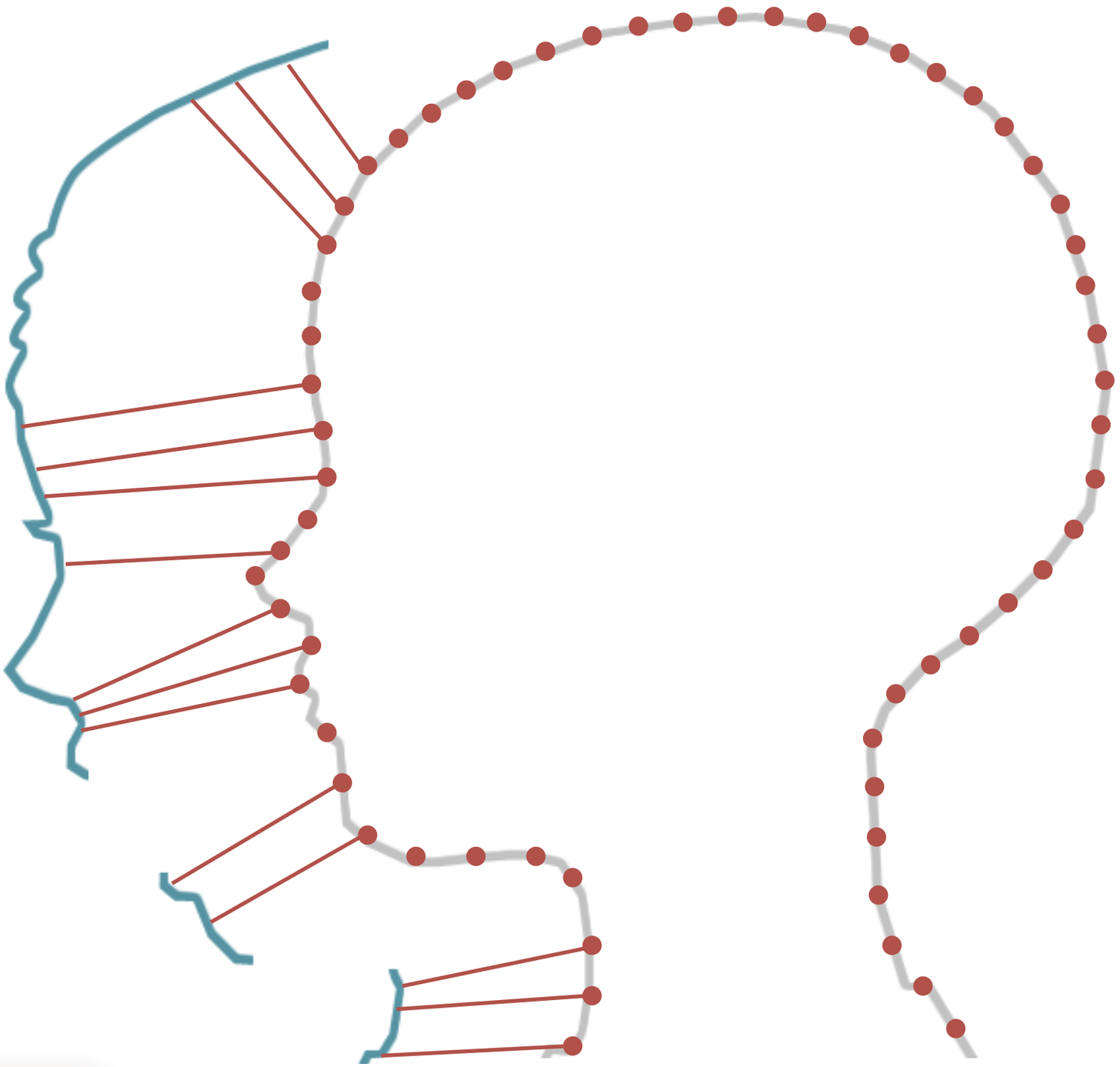


closest point

pruning

deform

Iterative Global Optimization



closest point

pruning

deform

Iterative Global Optimization

closest point

pruning

deform

Iterative Global Optimization

closest point

pruning

global optimization

Iterative Global Optimization

closest point

pruning

global optimization

Iterative Global Optimization

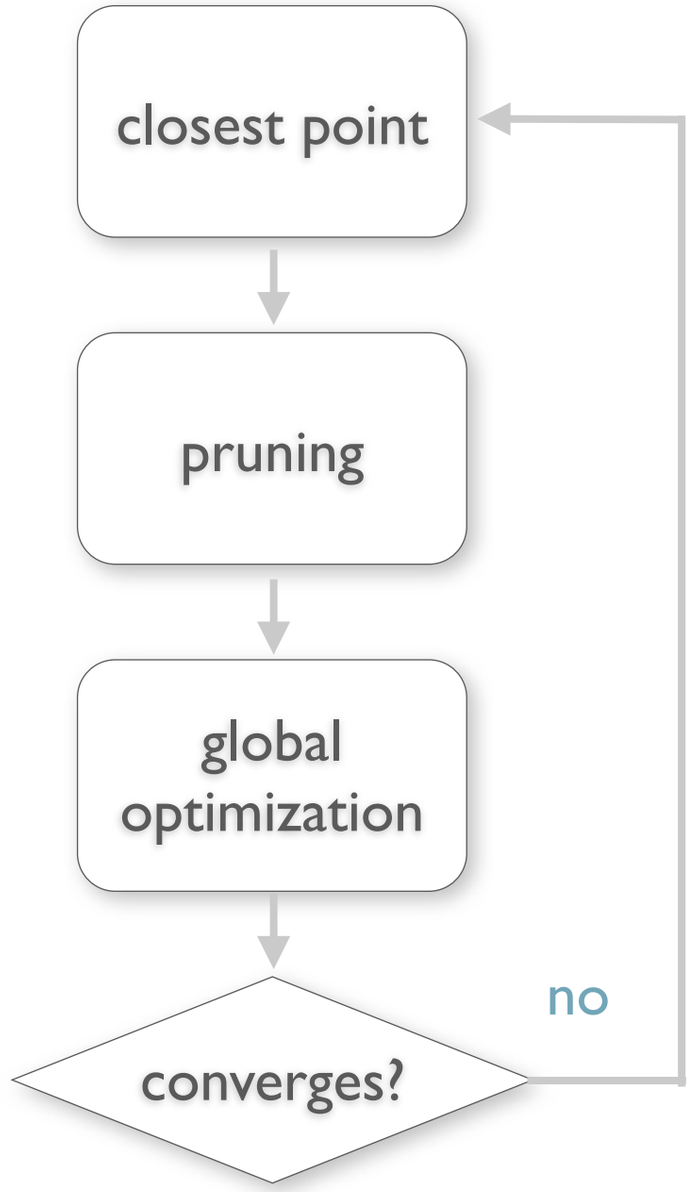
closest point

pruning

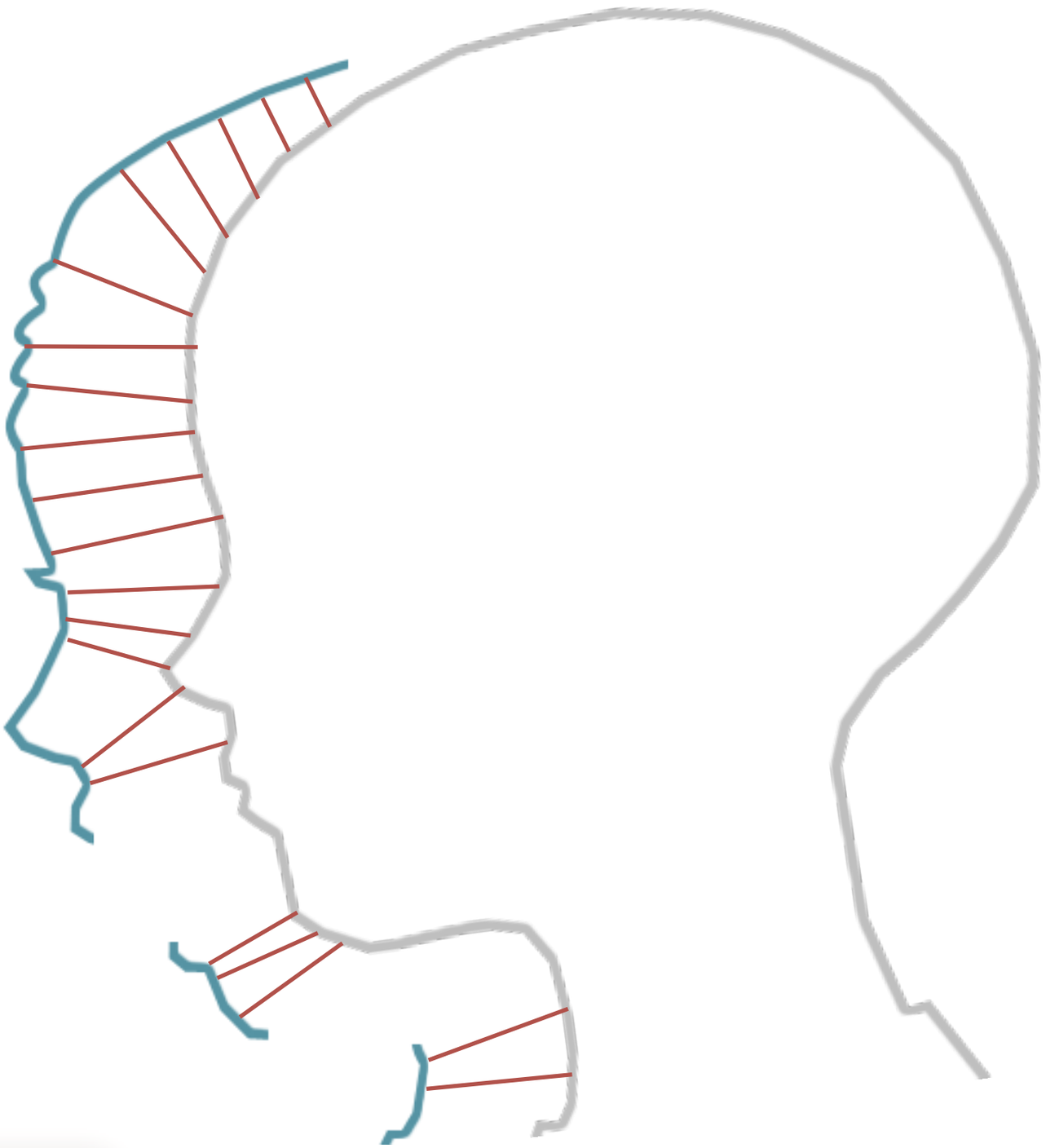
global optimization

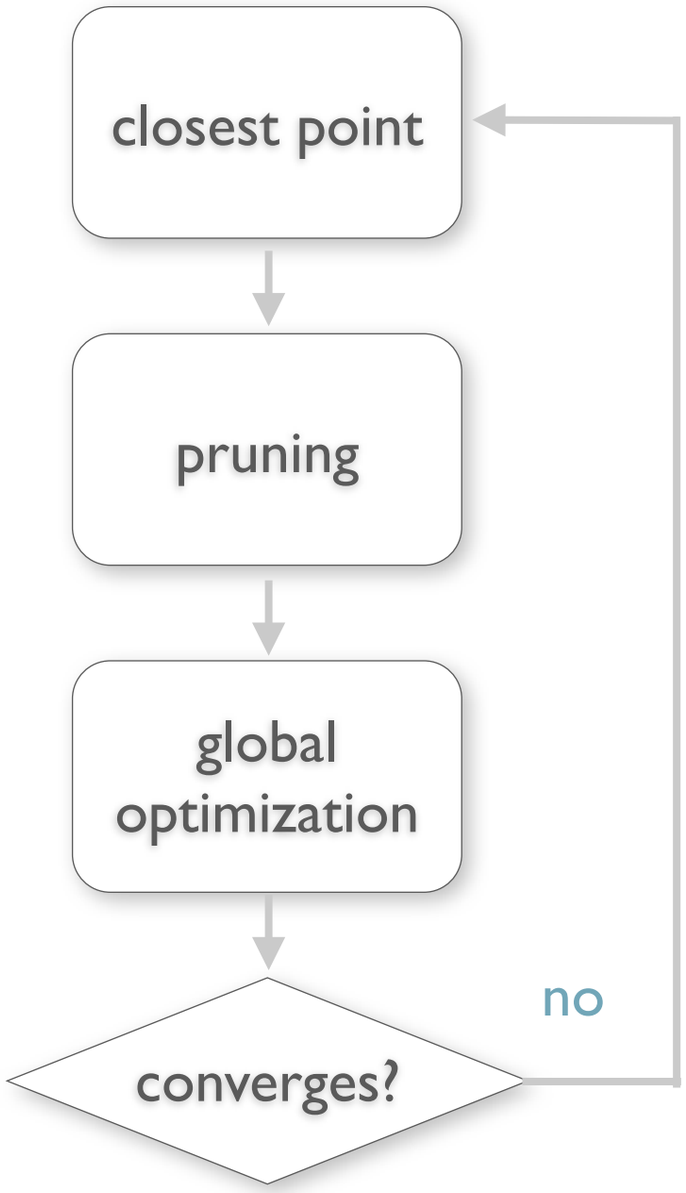
converges?

Iterative Global Optimization

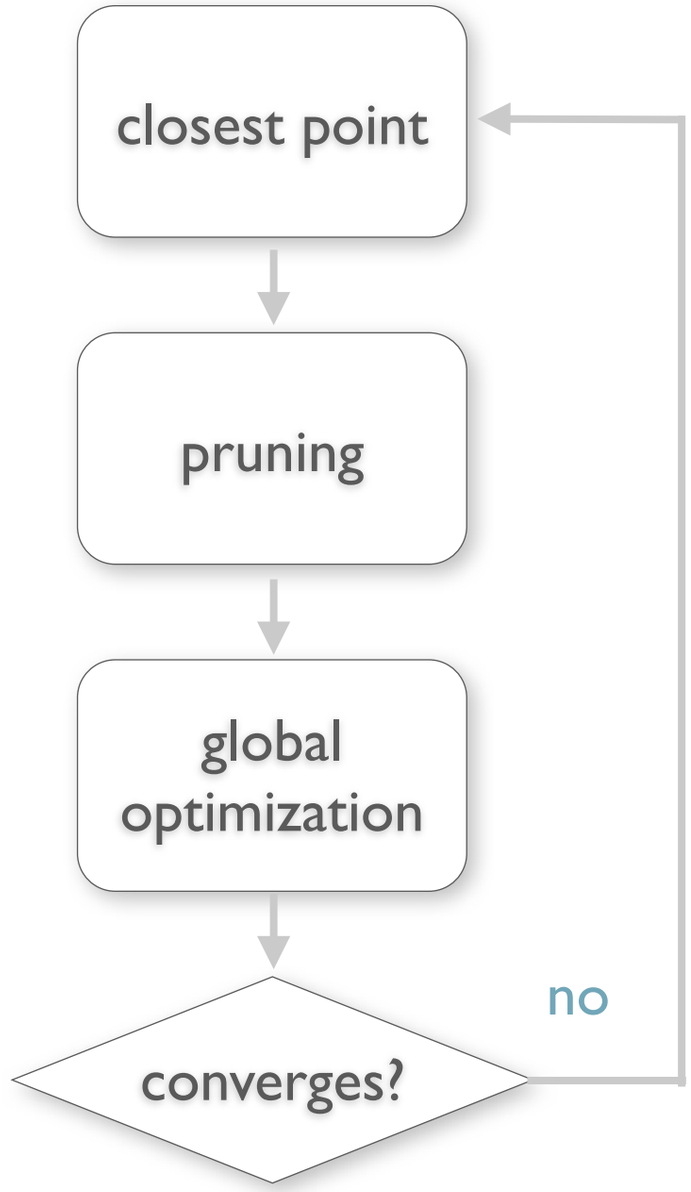


Iterative Global Optimization

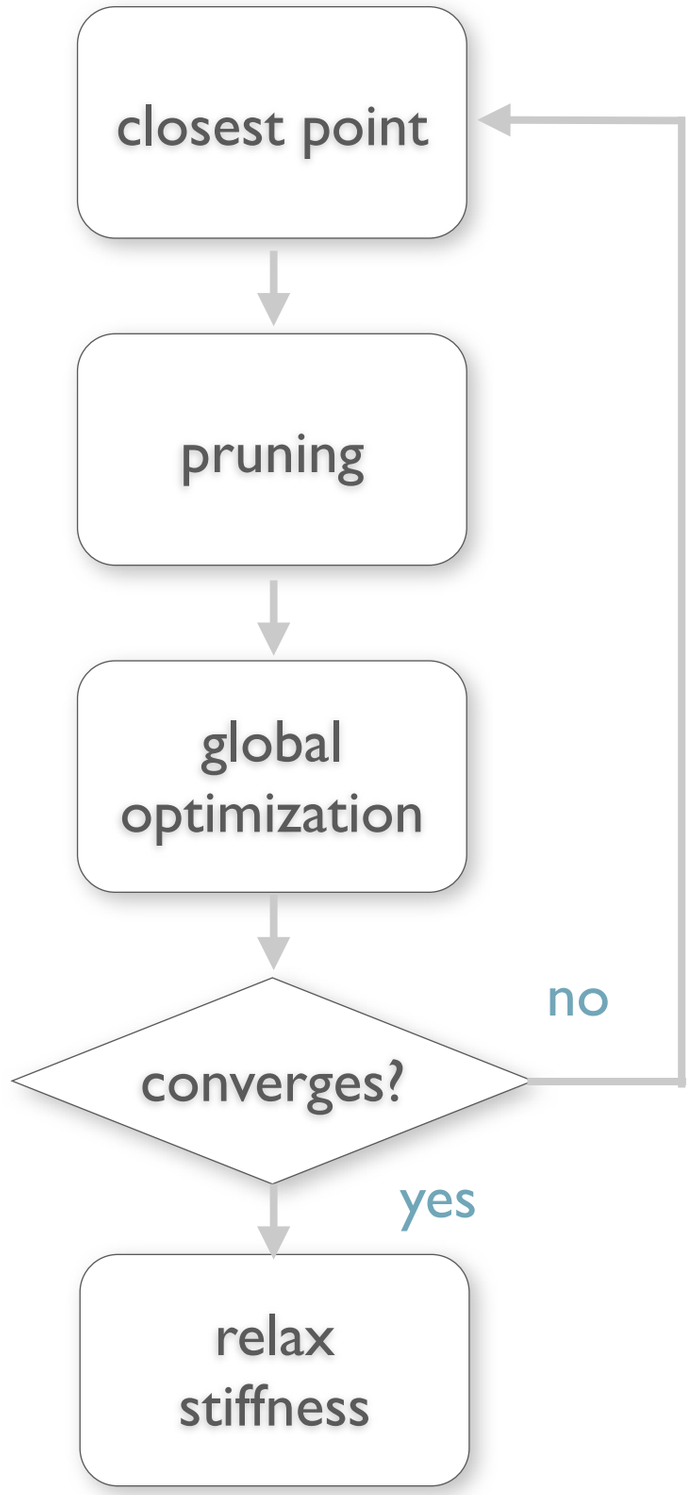




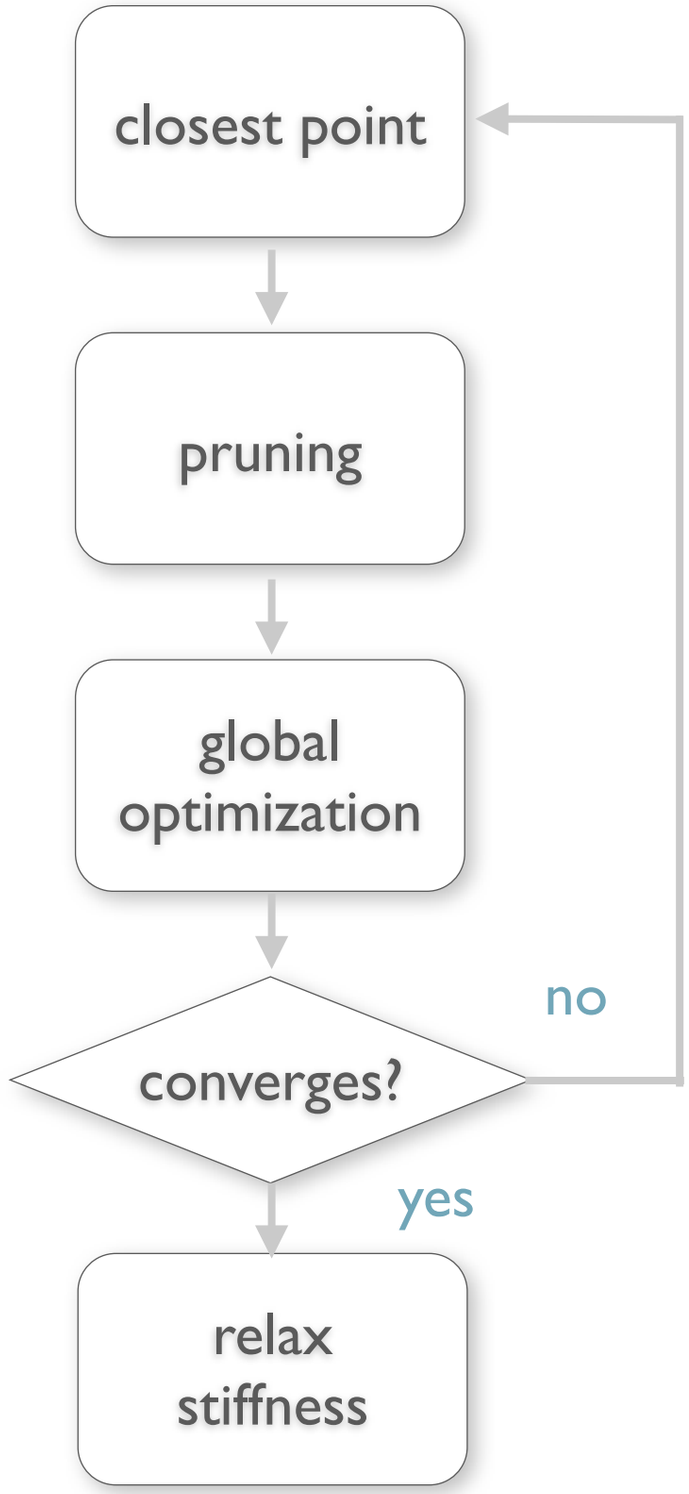
Iterative Global Optimization



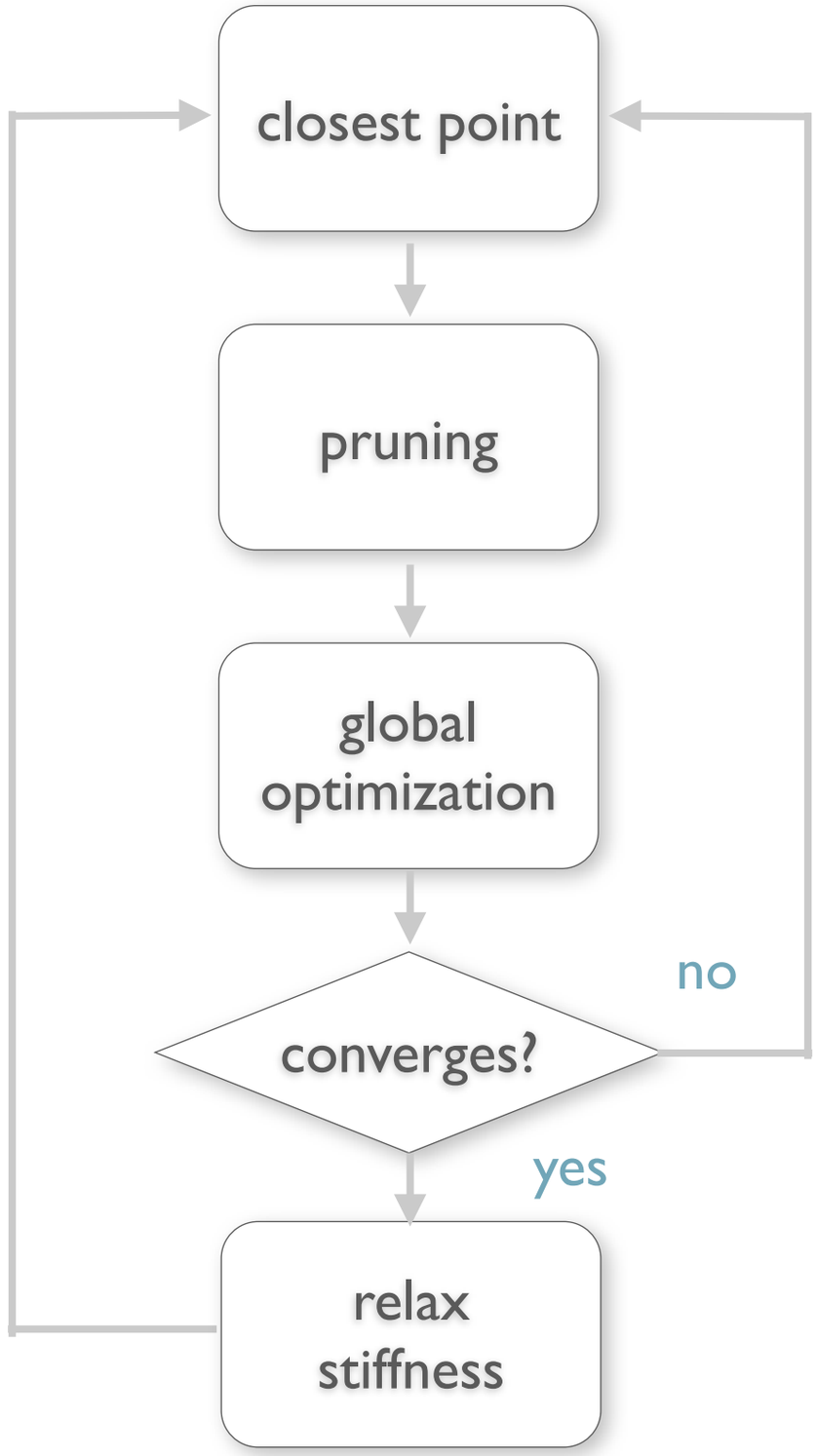
Iterative Global Optimization



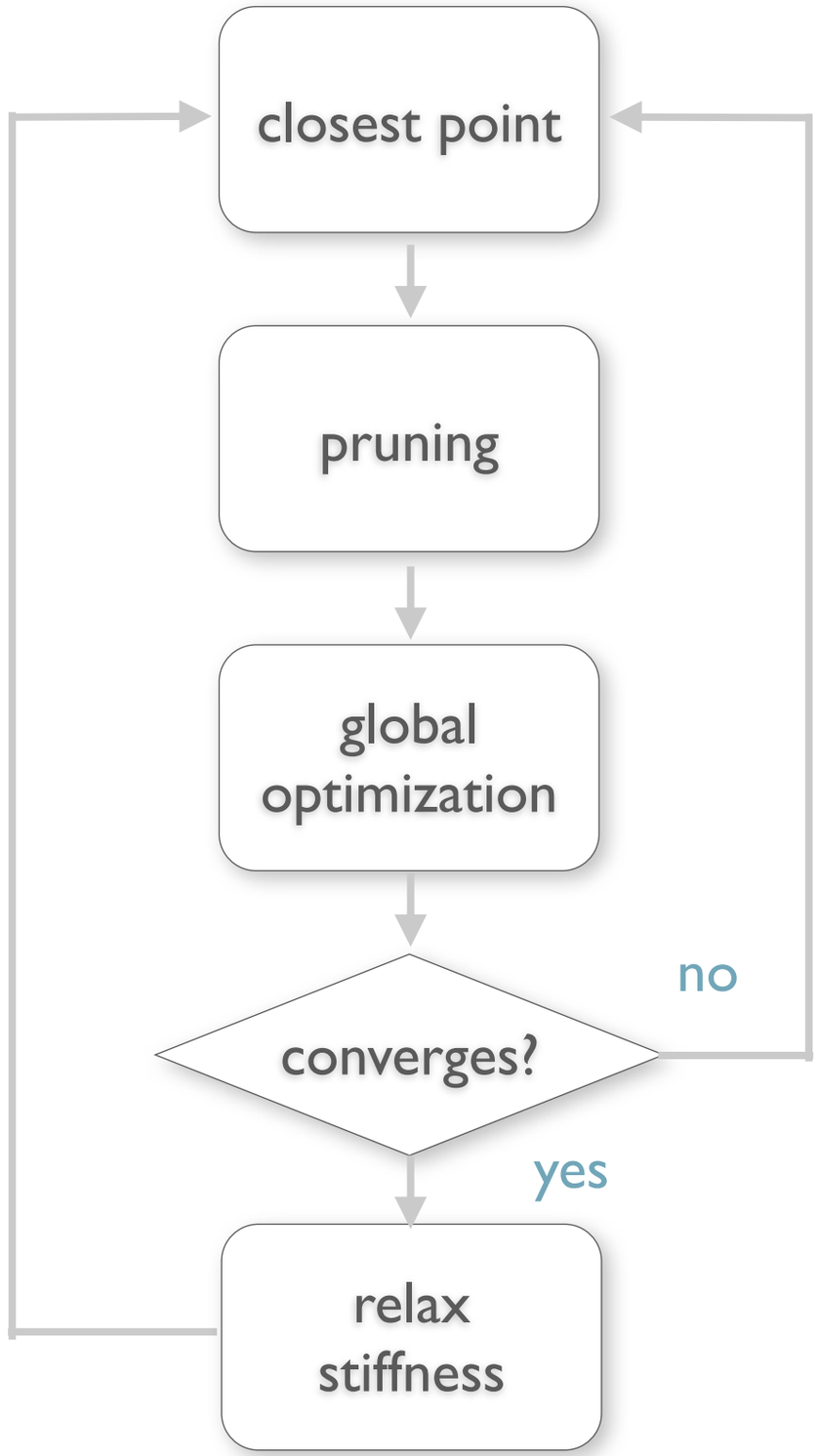
Iterative Global Optimization



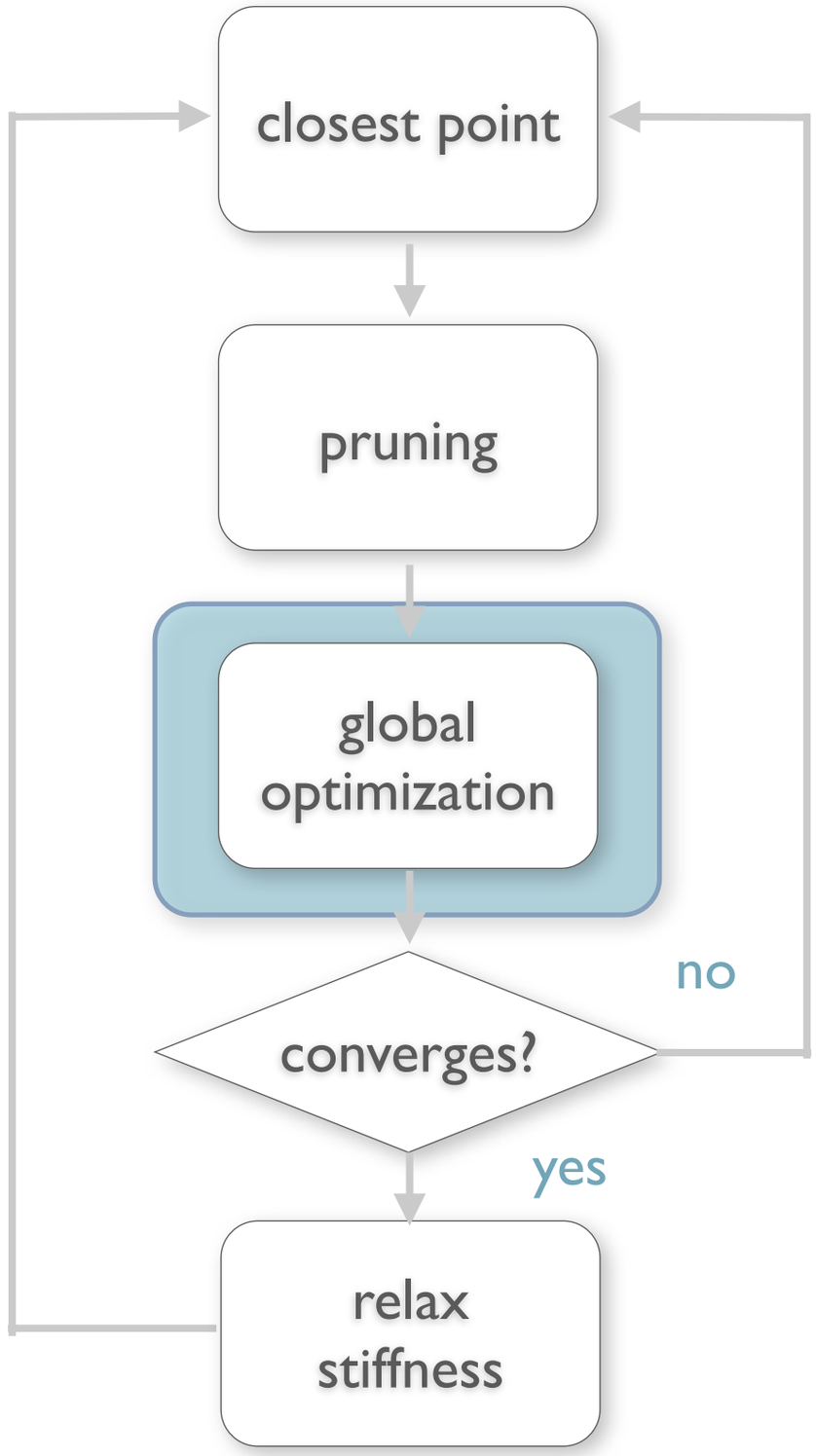
Iterative Global Optimization



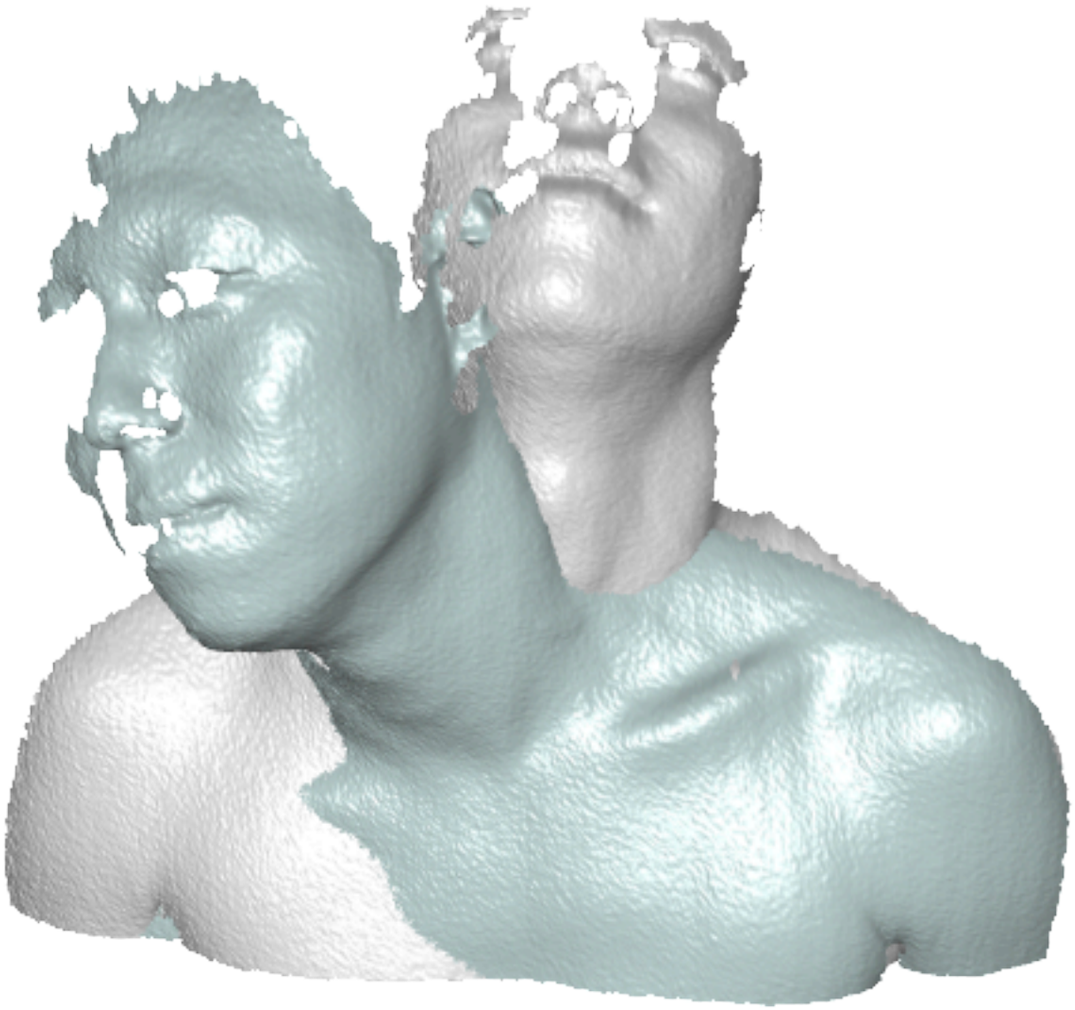
Iterative Global Optimization



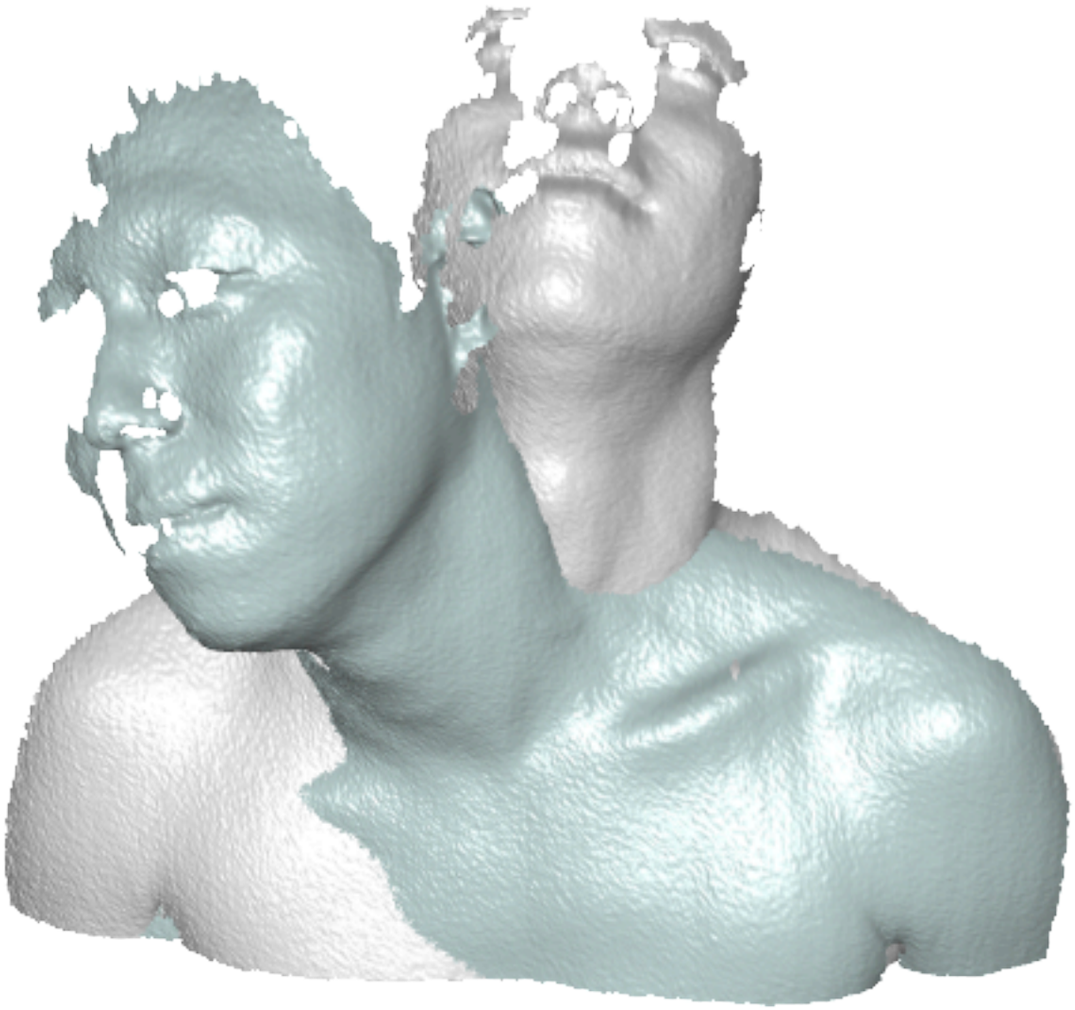
Iterative Global Optimization



Deformation Model

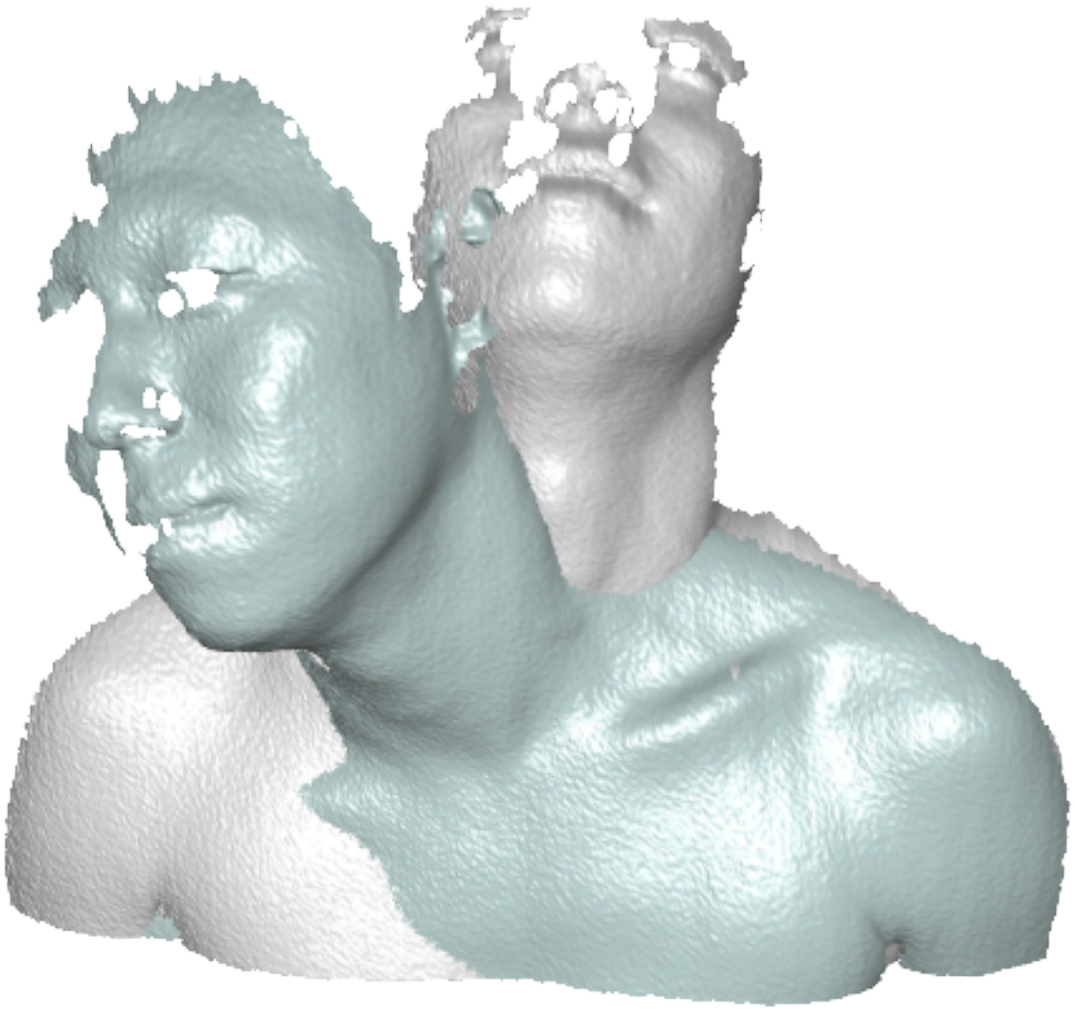


Deformation Model



Embedded Deformation

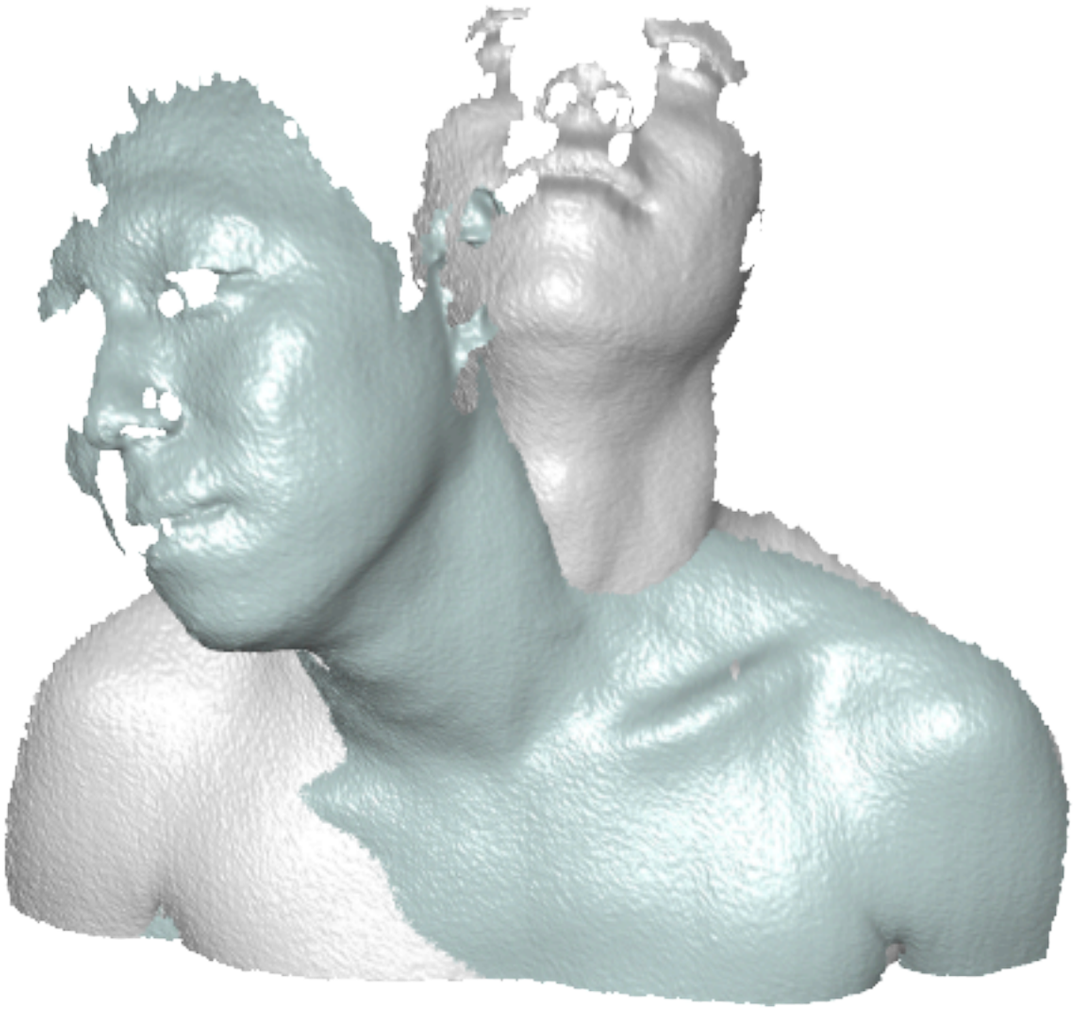
Deformation Model



Embedded Deformation

incomplete scan

Deformation Model

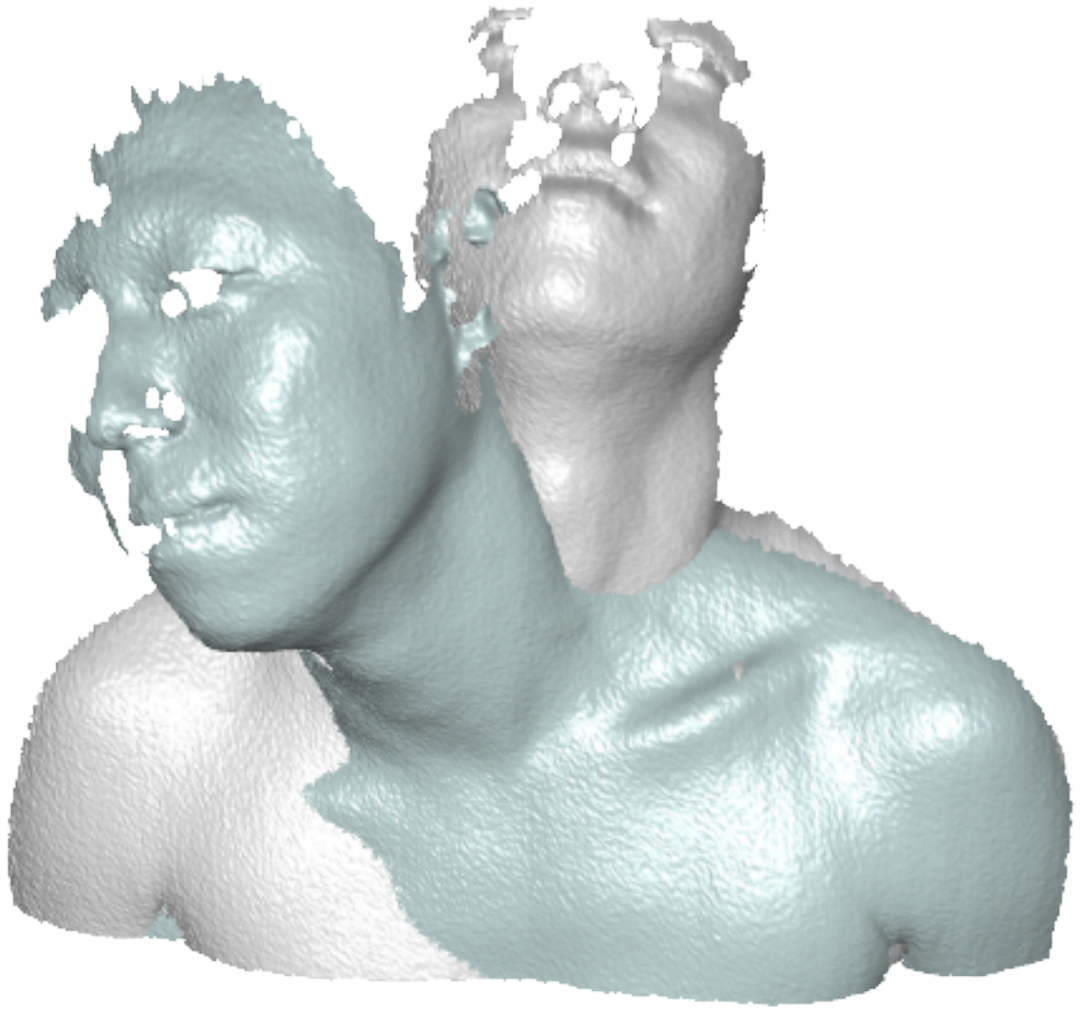


Embedded Deformation

incomplete scan

space deformation

Deformation Model



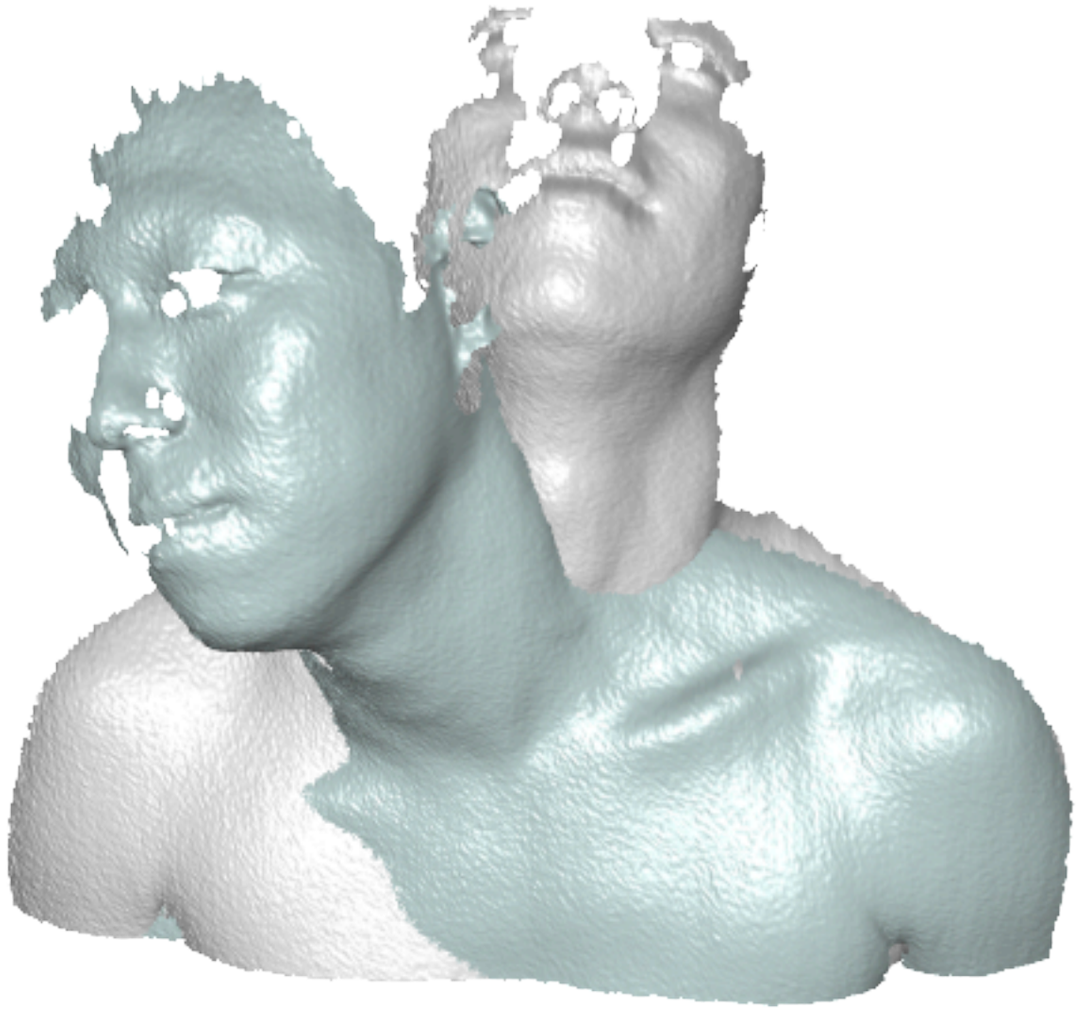
Embedded Deformation

incomplete scan

space deformation

high-resolution

Deformation Model

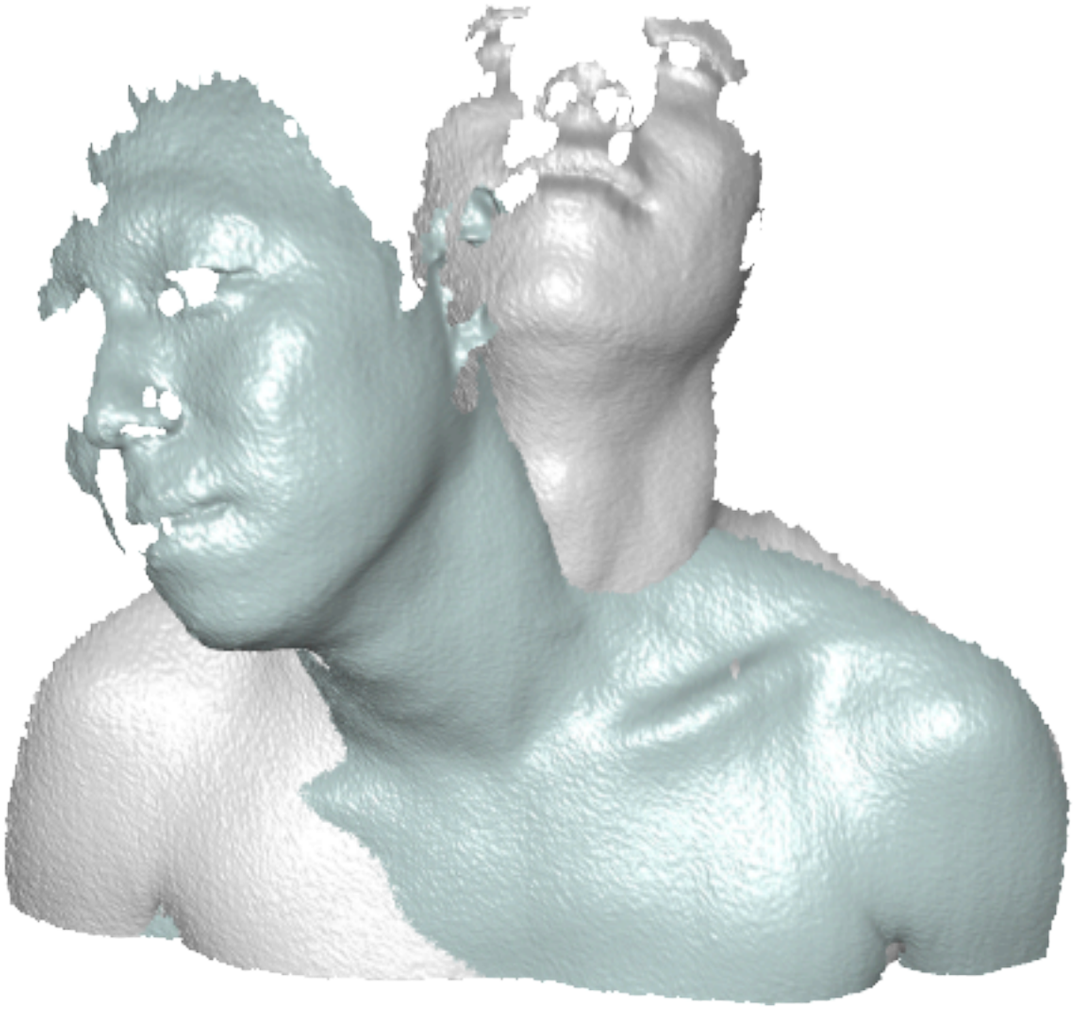


Embedded Deformation

incomplete scan — space deformation

high-resolution — decoupled complexity

Deformation Model



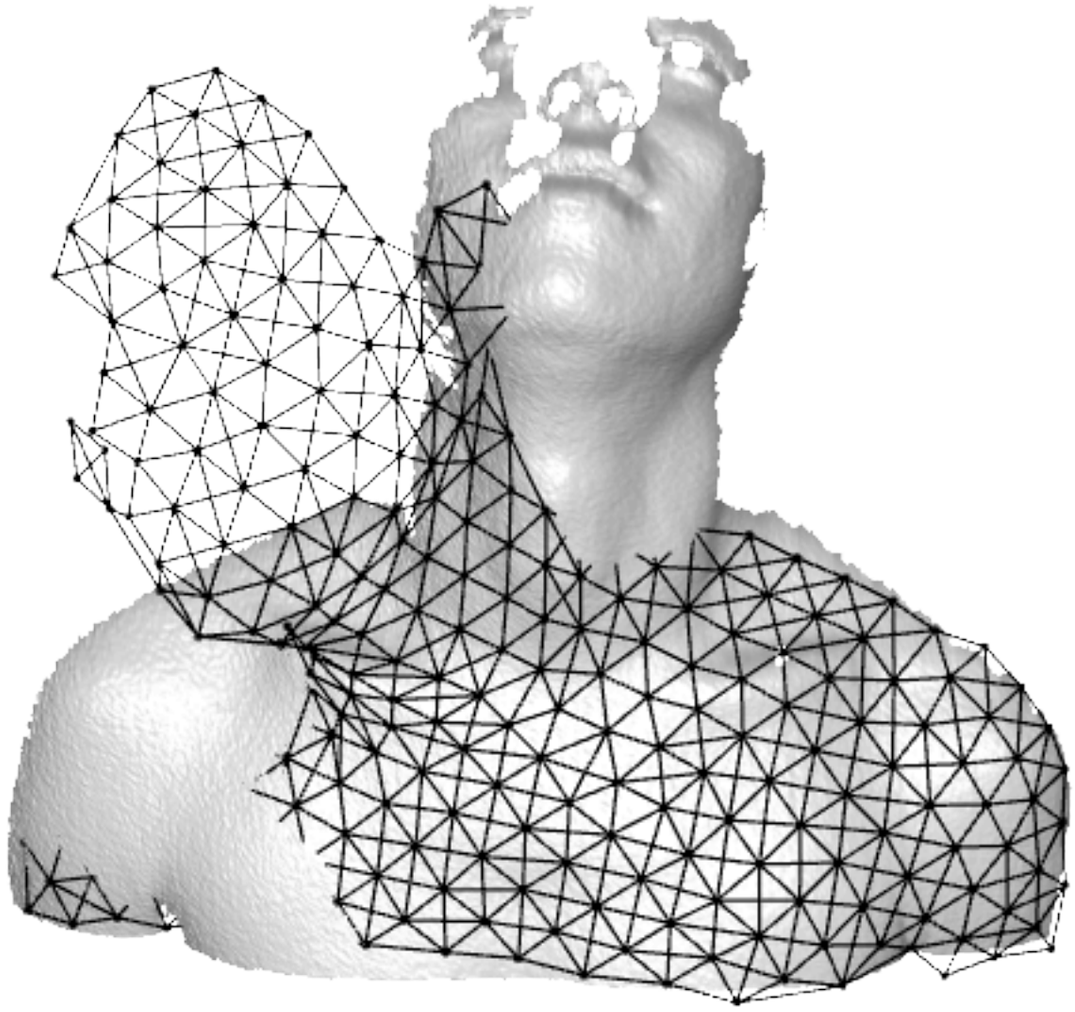
Embedded Deformation

incomplete scan

high-resolution

deformation graph

Deformation Model



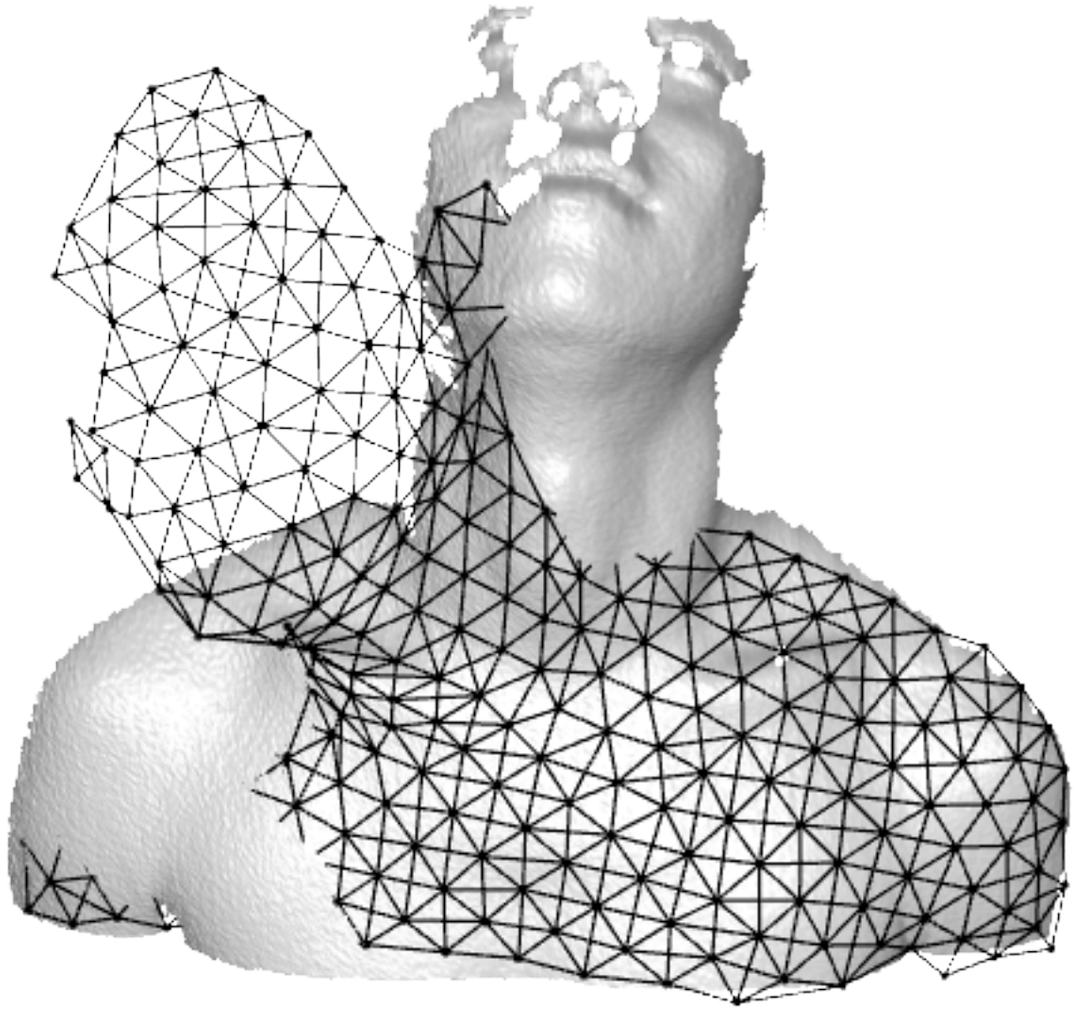
Embedded Deformation

incomplete scan

high-resolution

deformation graph

Deformation Model



Embedded Deformation

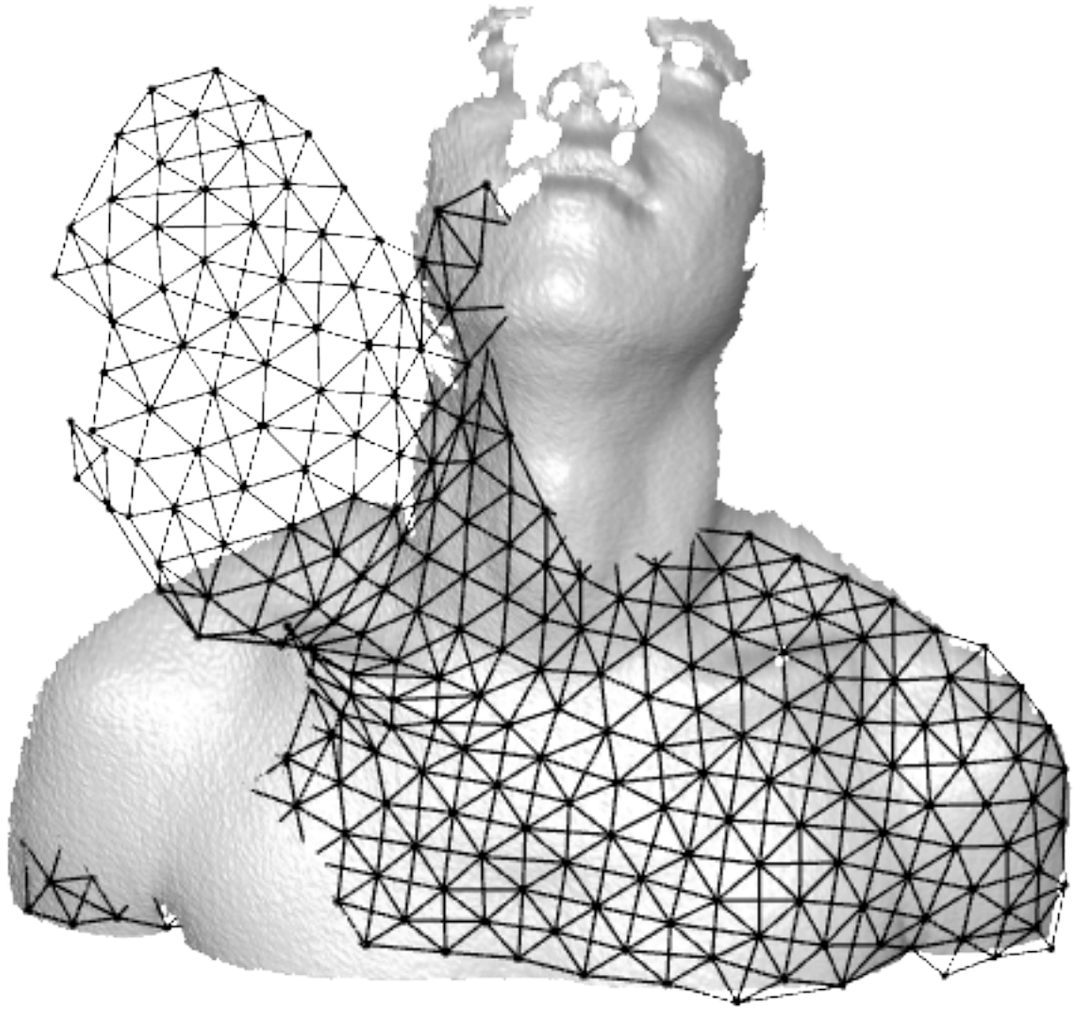
incomplete scan

high-resolution

unknown warp

deformation graph

Deformation Model



Embedded Deformation

incomplete scan

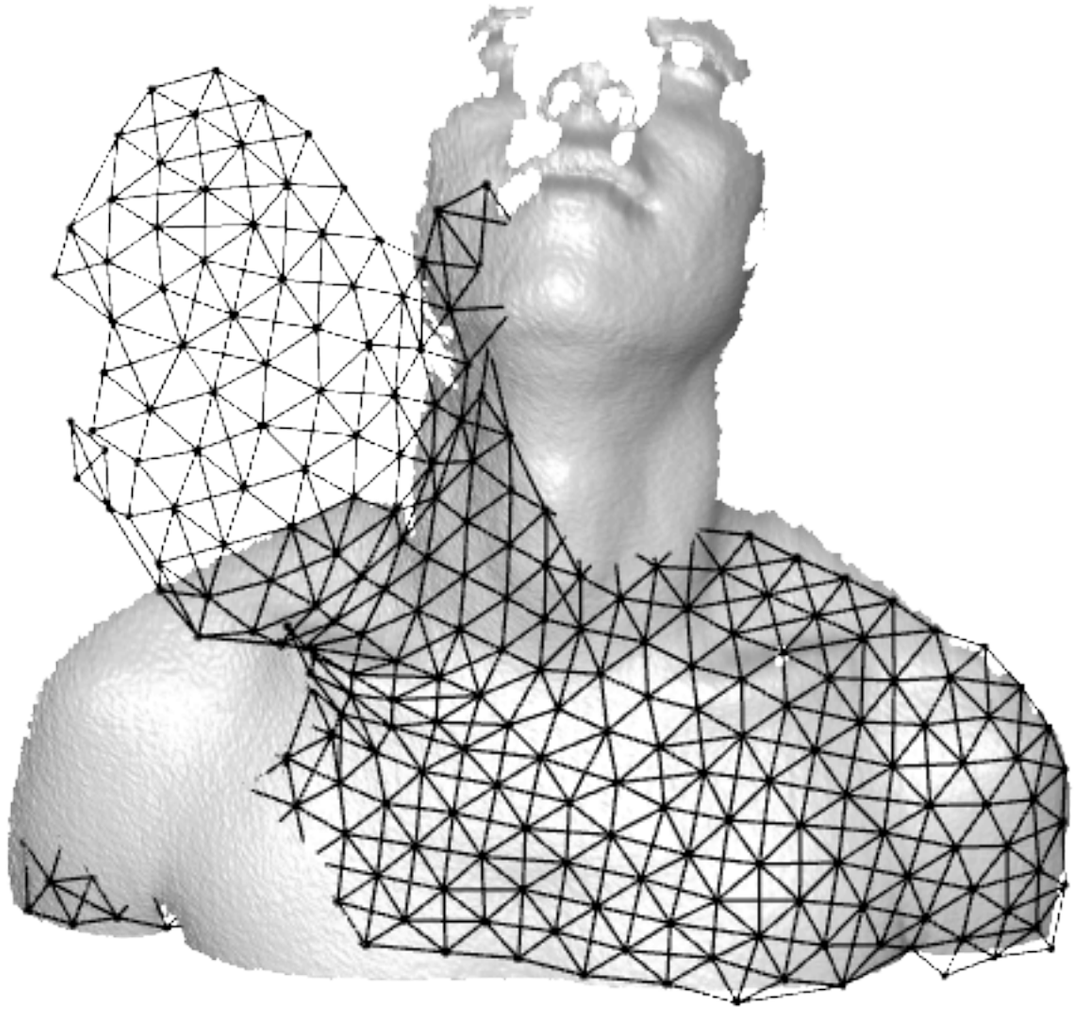
high-resolution

unknown warp

incomplete match

deformation graph

Deformation Model



Embedded Deformation

incomplete scan

high-resolution

unknown warp

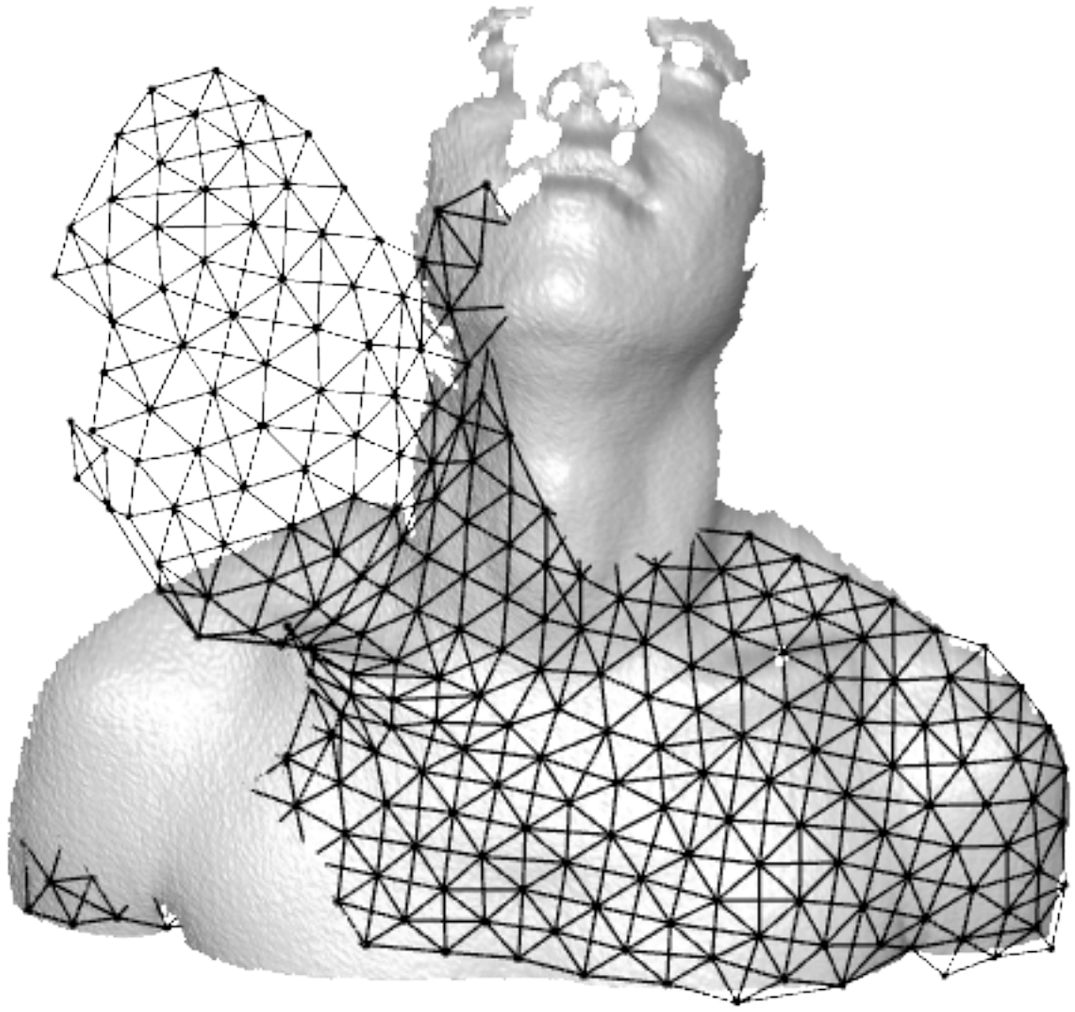
incomplete match

deformation graph

detail preservation

global consistency

Deformation Model



Embedded Deformation

incomplete scan

high-resolution

unknown warp

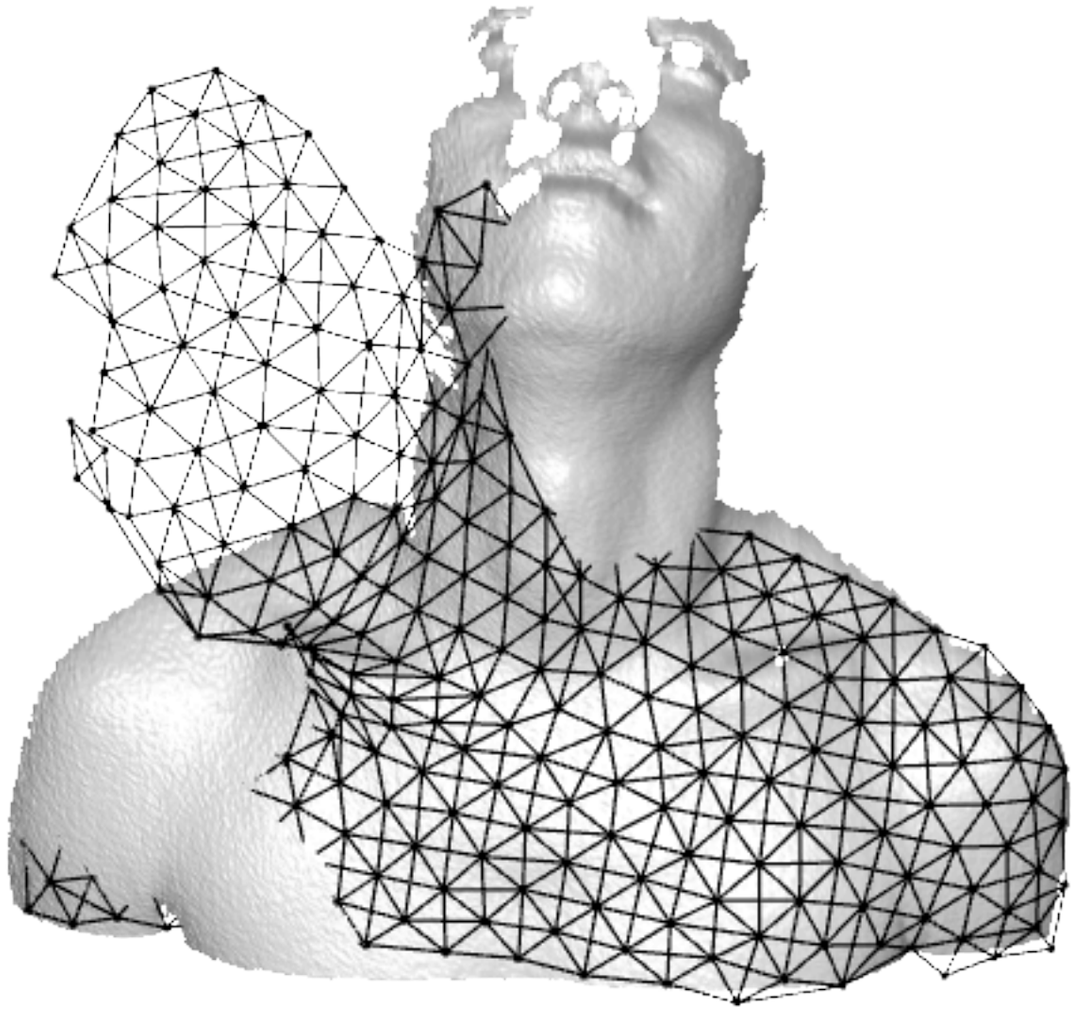
incomplete match

deformation graph

detail preservation

global consistency

Deformation Model



Embedded Deformation

incomplete scan

high-resolution

deformation graph

unknown warp

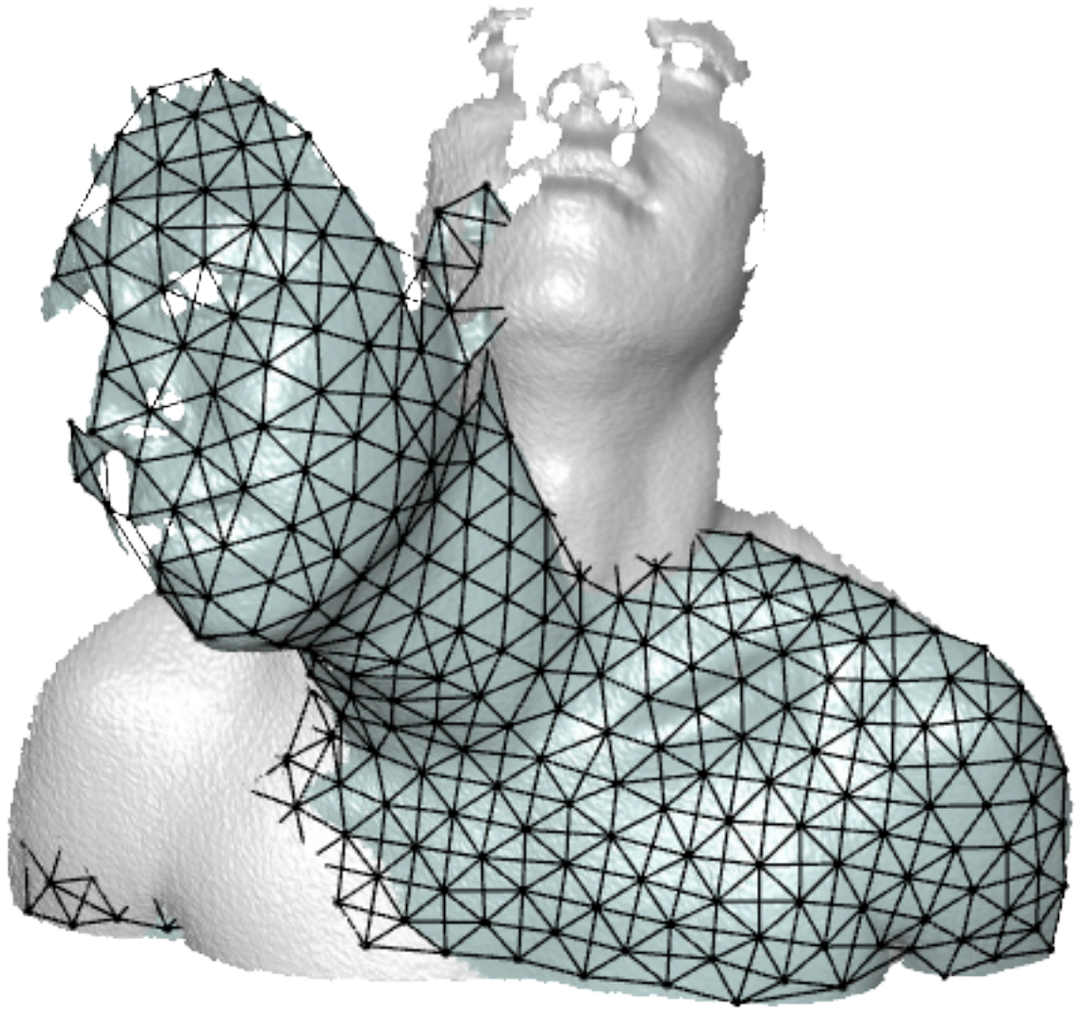
incomplete match

detail preservation

global consistency

Linear Blend Skinning

Deformation Model



Embedded Deformation

incomplete scan

high-resolution

unknown warp

incomplete match

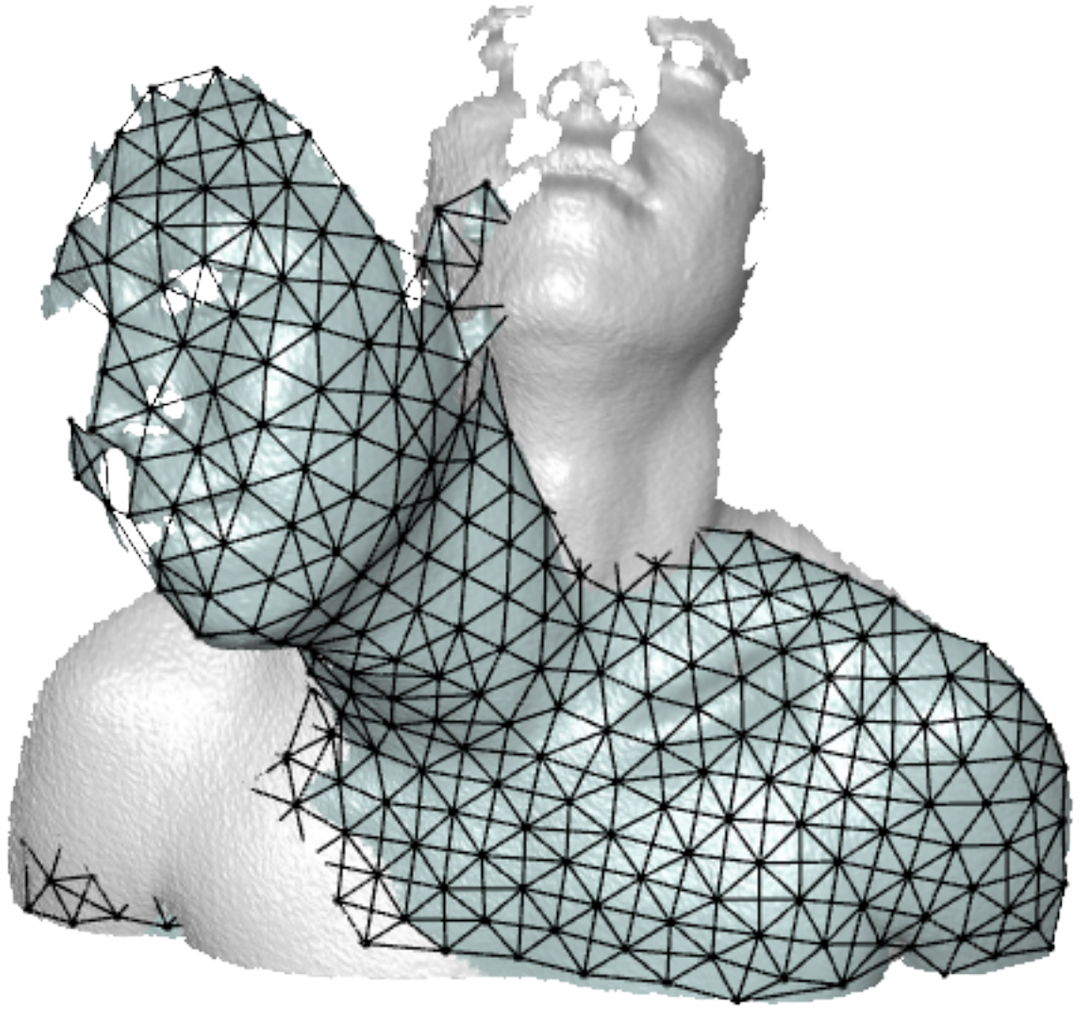
deformation graph

detail preservation

global consistency

Linear Blend Skinning

Deformation Model



Embedded Deformation

incomplete scan

high-resolution

unknown warp

incomplete match

deformation graph

detail preservation

global consistency

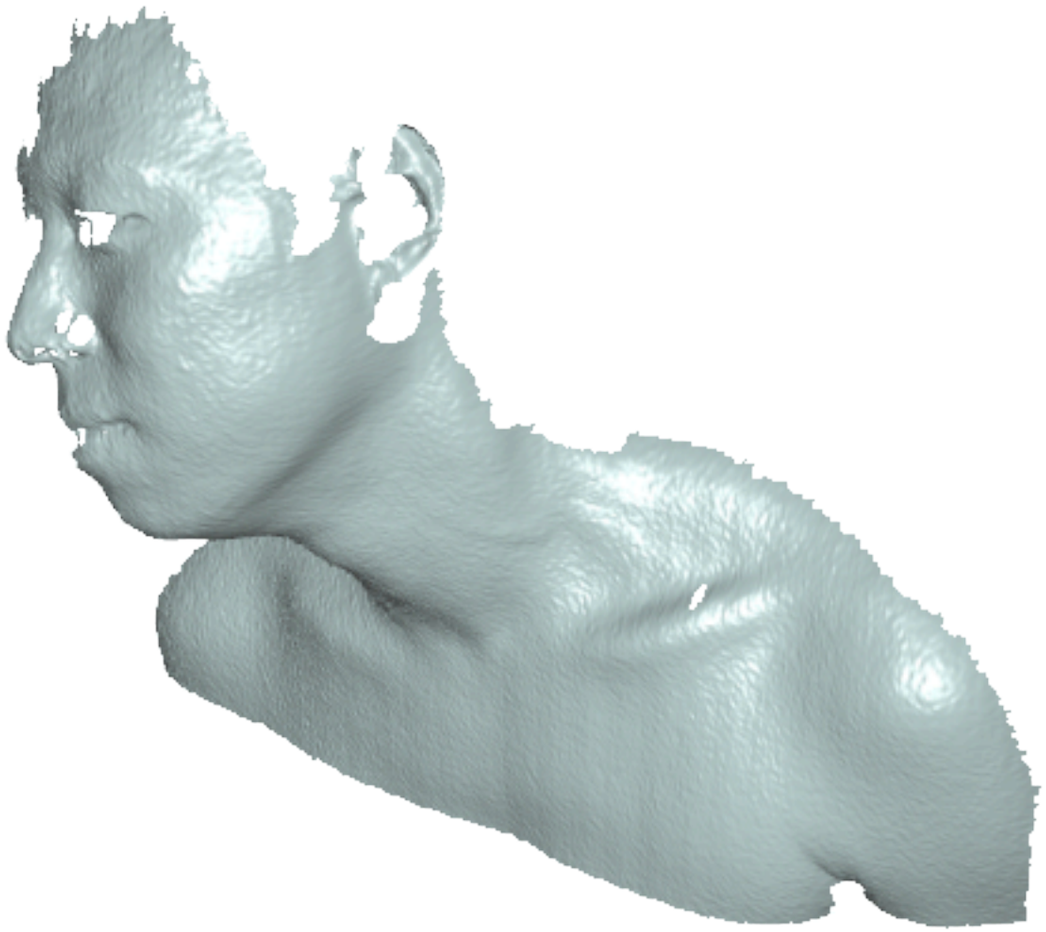
Linear Blend Skinning

Deformation Model

detail preservation

global consistency

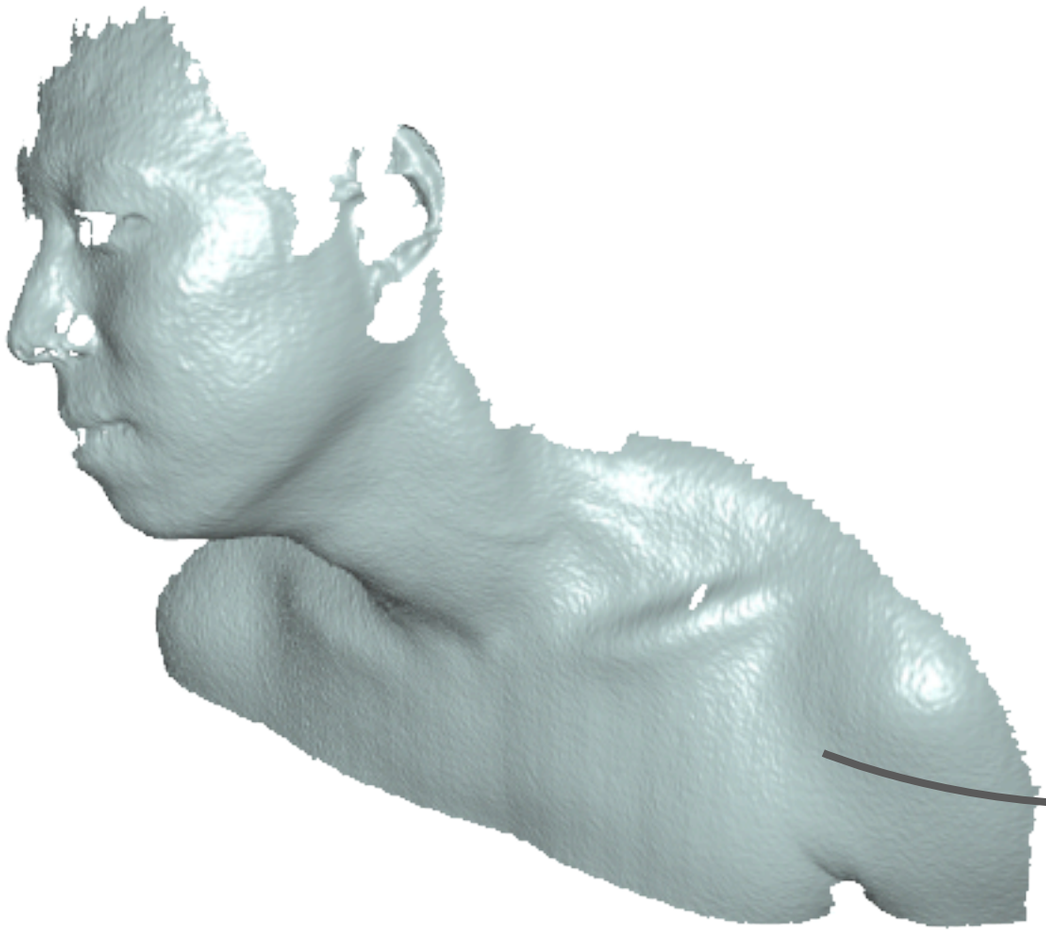
Deformation Model



detail preservation

global consistency

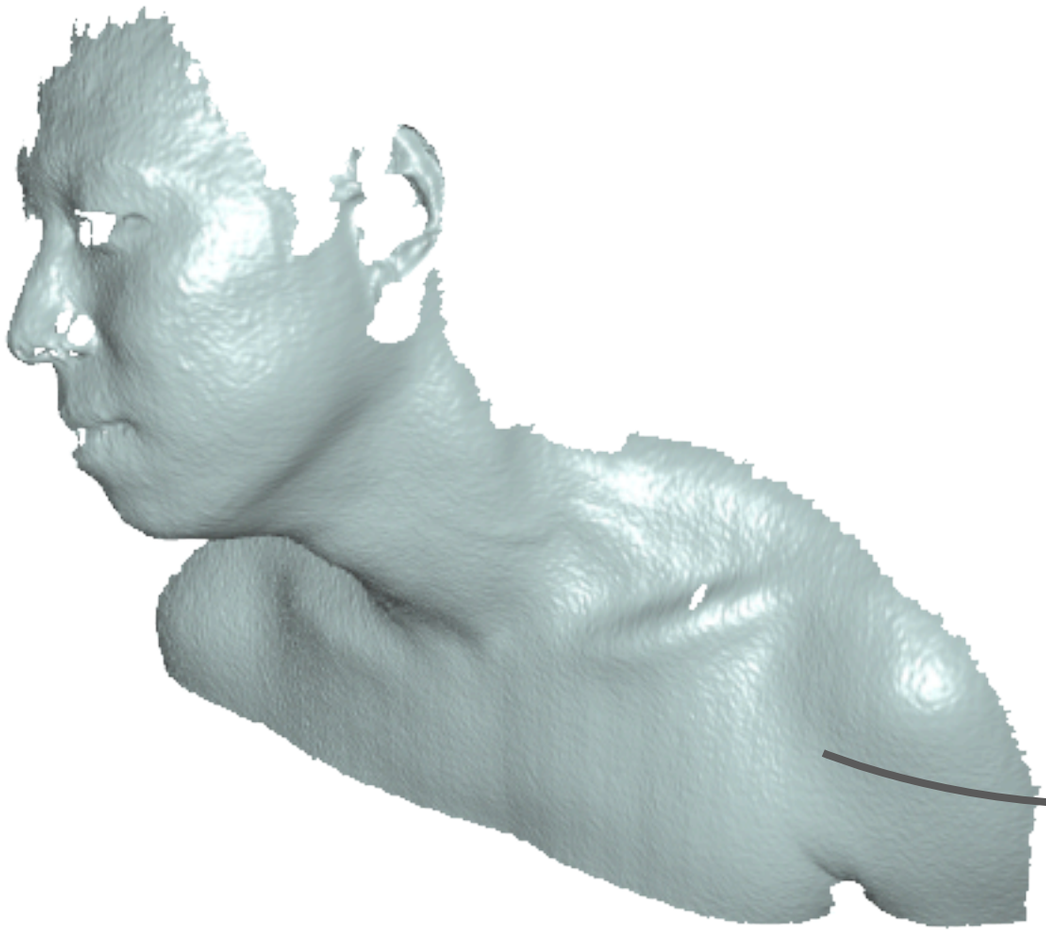
Deformation Model



detail preservation

global consistency

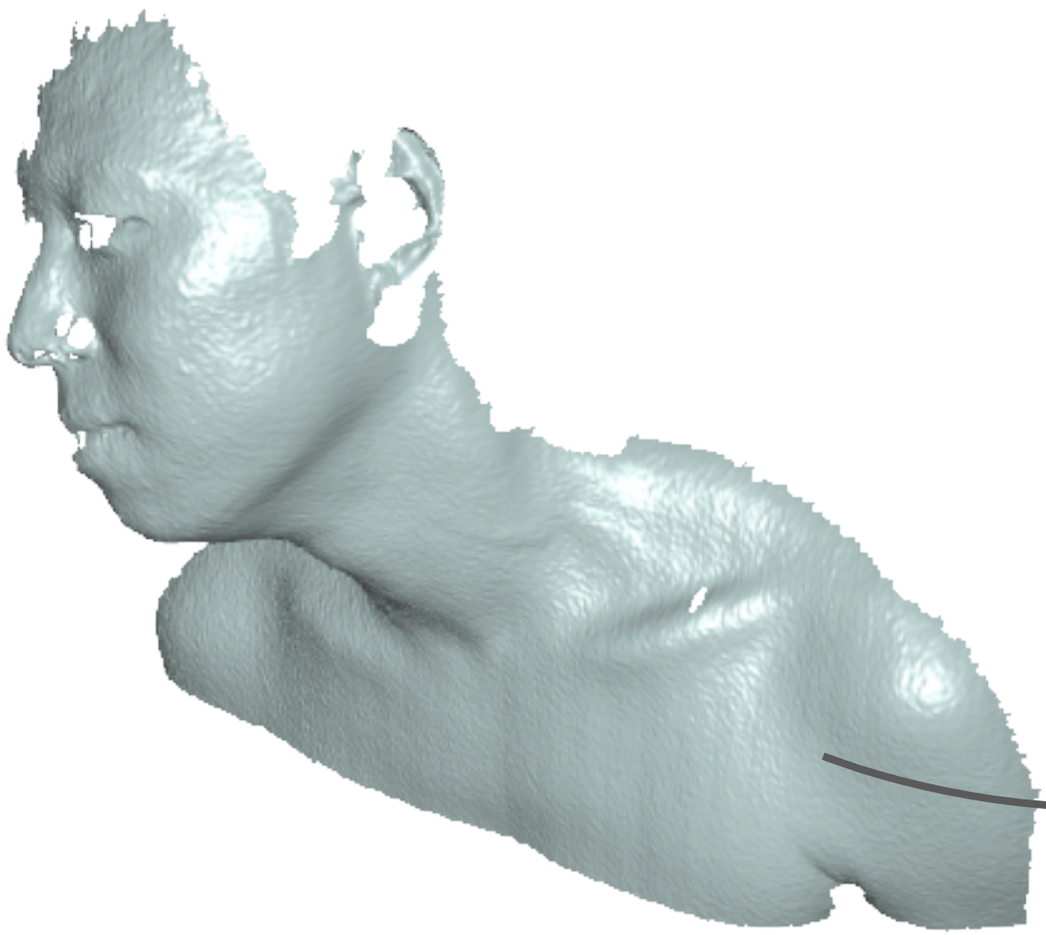
Deformation Model



detail preservation

global consistency

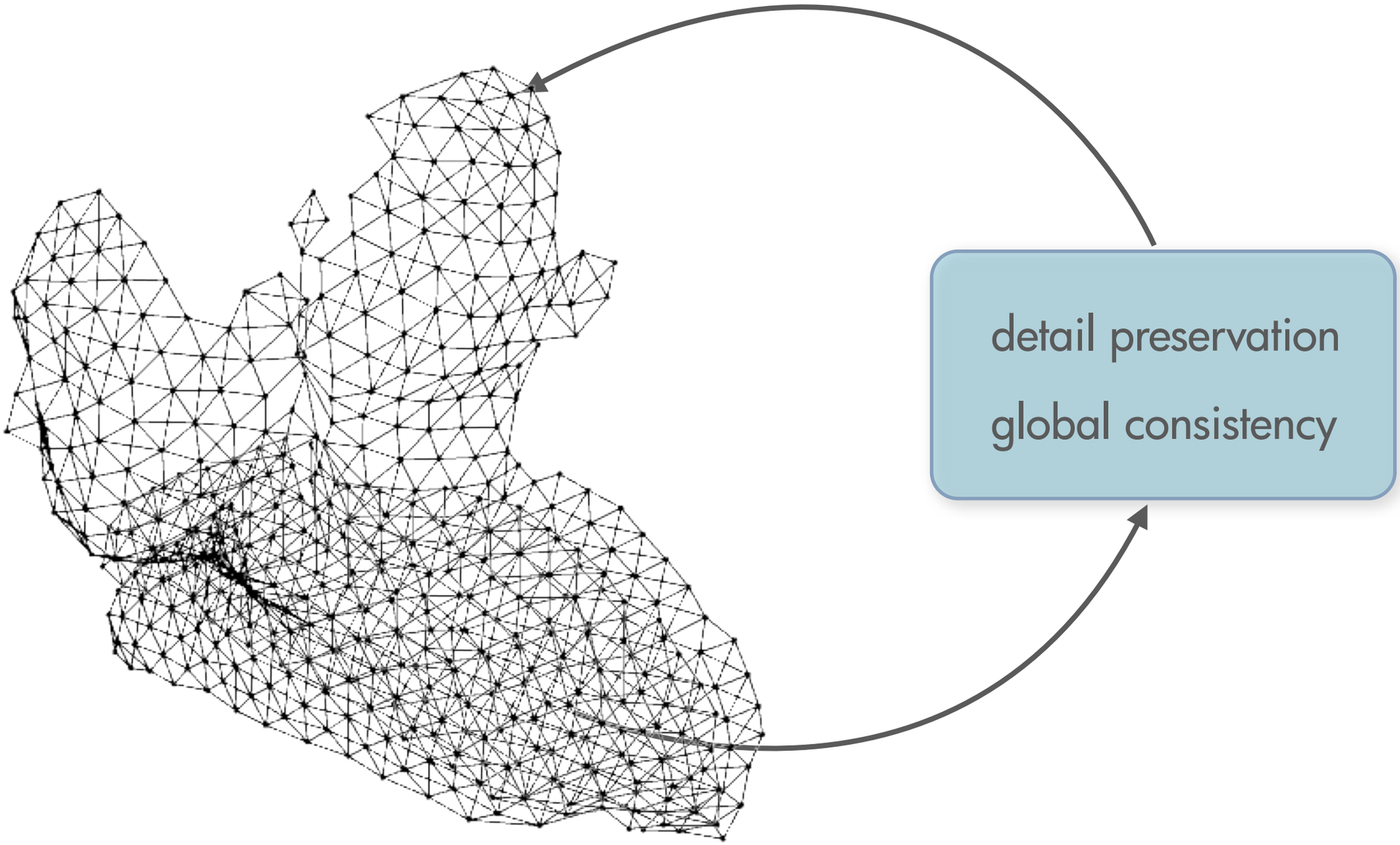
Deformation Model



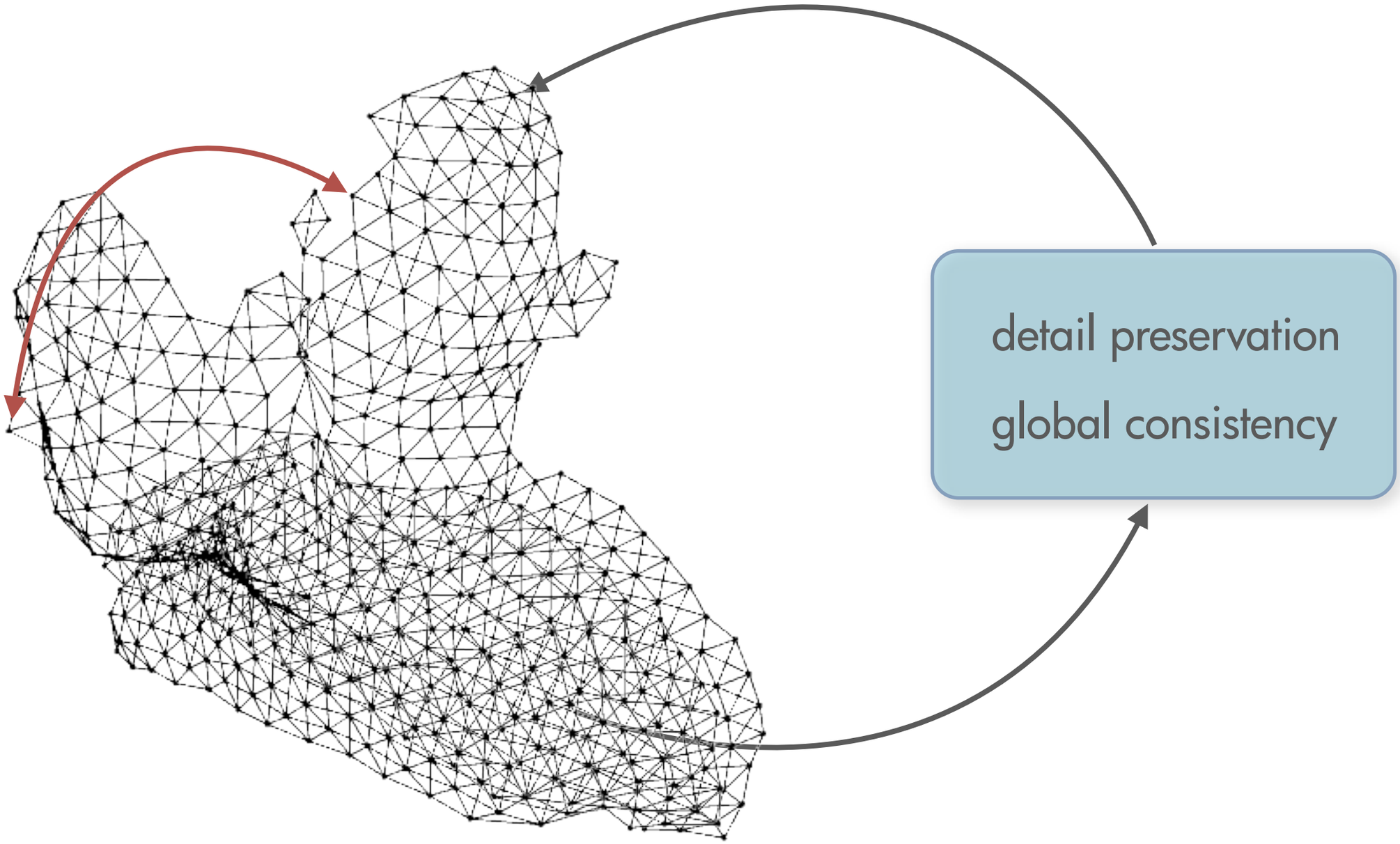
detail preservation

global consistency

Deformation Model

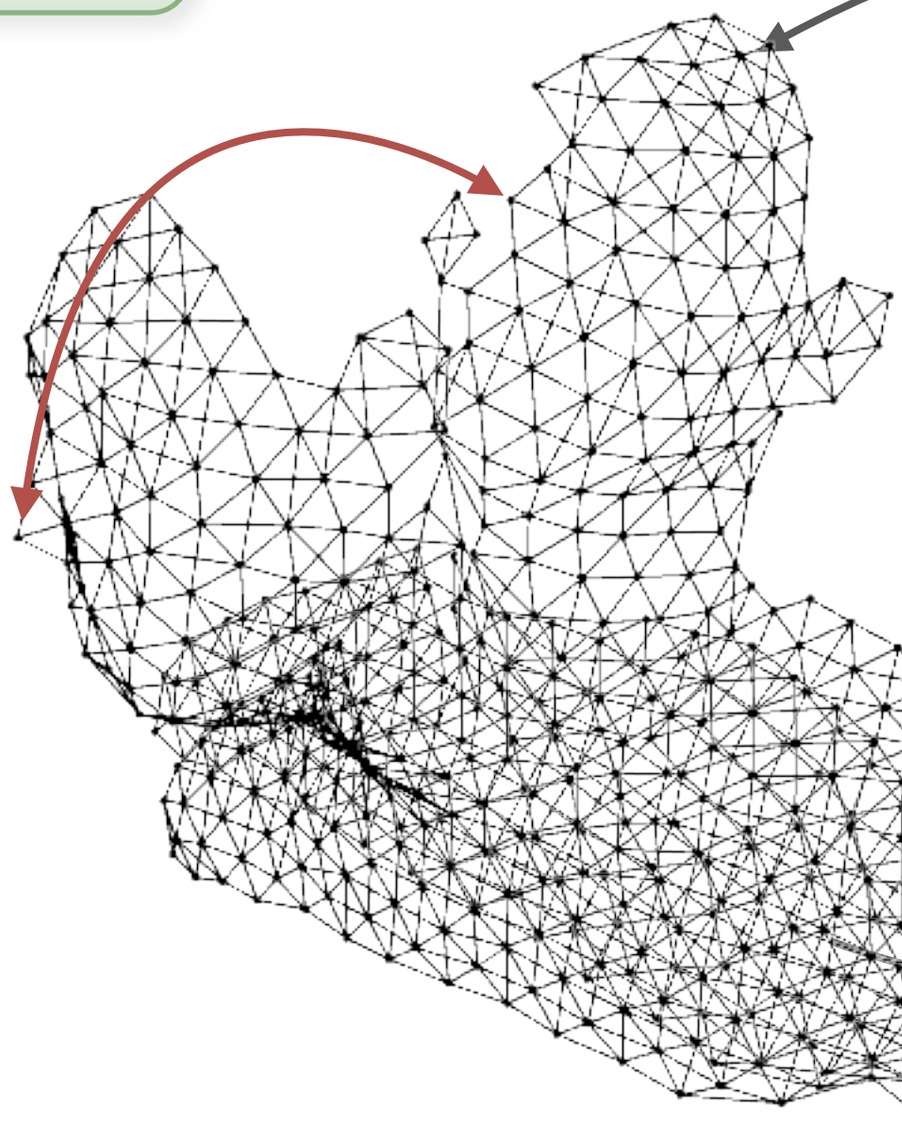


Deformation Model



Deformation Model

E_{rigid}



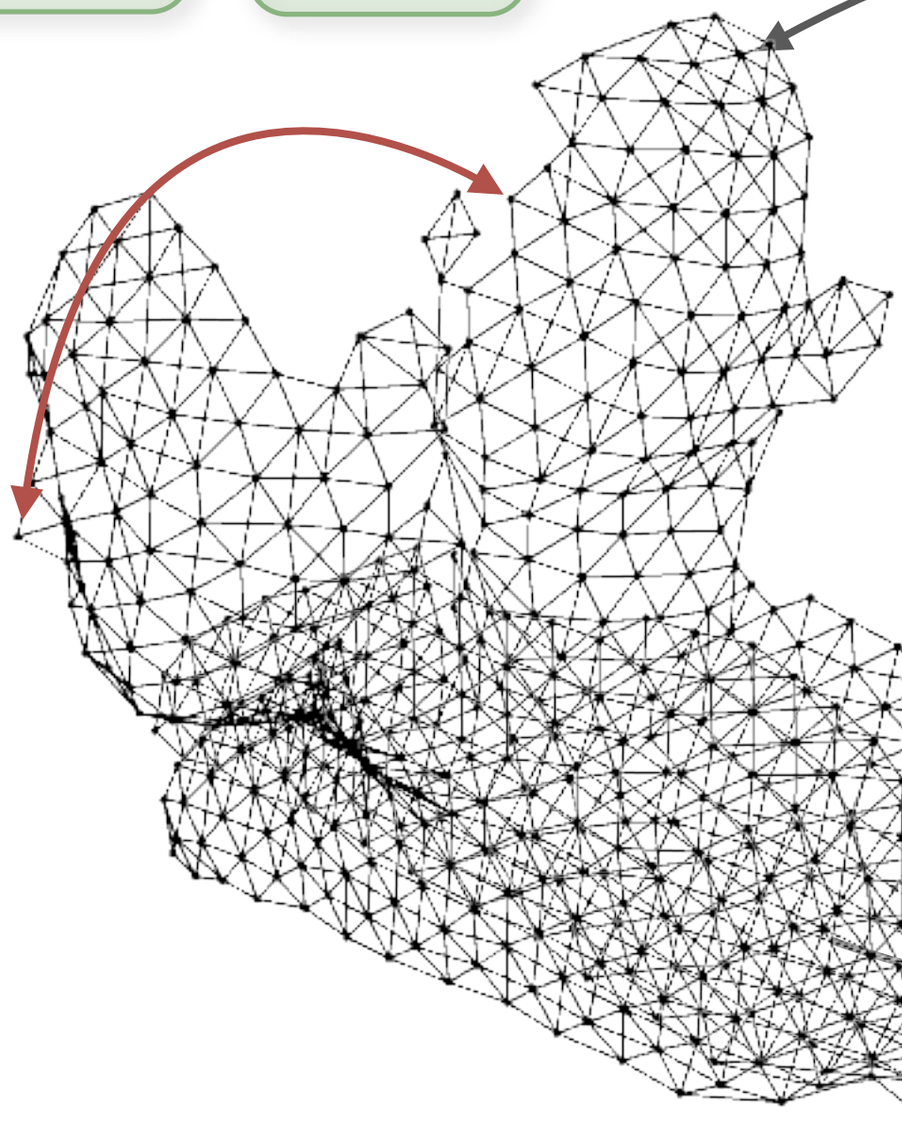
detail preservation

global consistency

Deformation Model

E_{rigid}

E_{smooth}



detail preservation

global consistency

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}

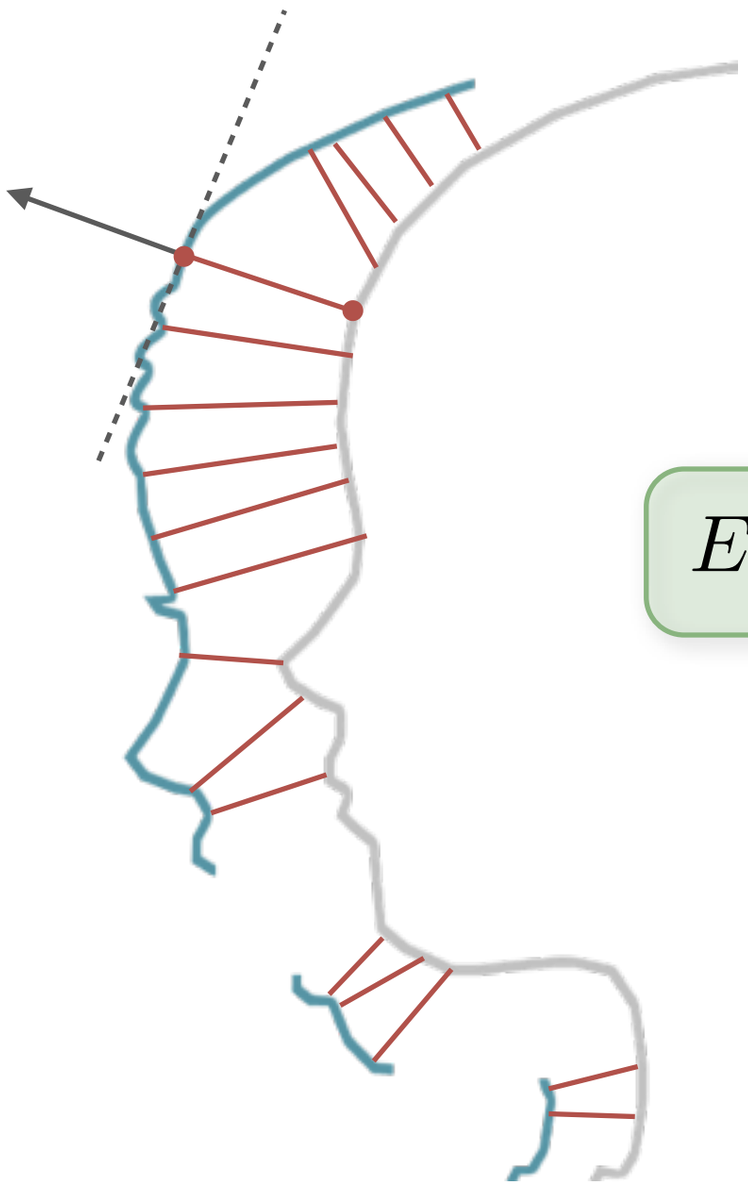
Non-Linear Energy Minimization

E_{point}

E_{rigid}

E_{smooth}

Non-Linear Energy Minimization



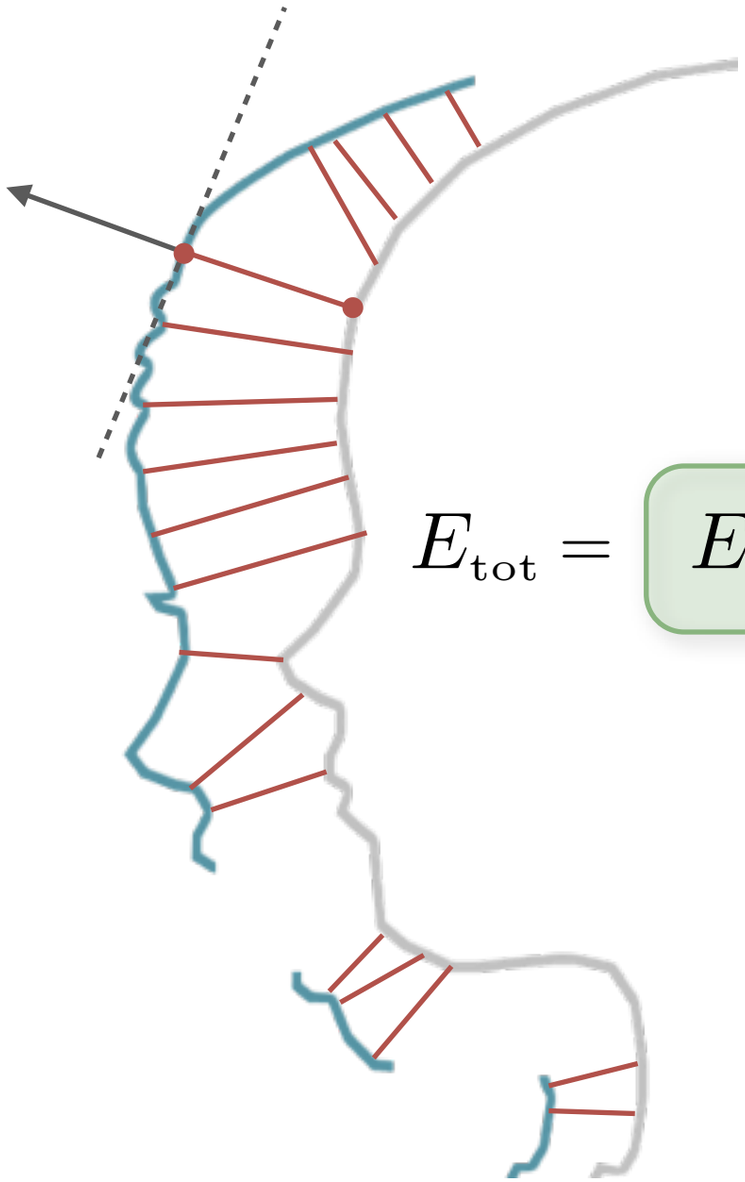
E_{plane}

E_{point}

E_{rigid}

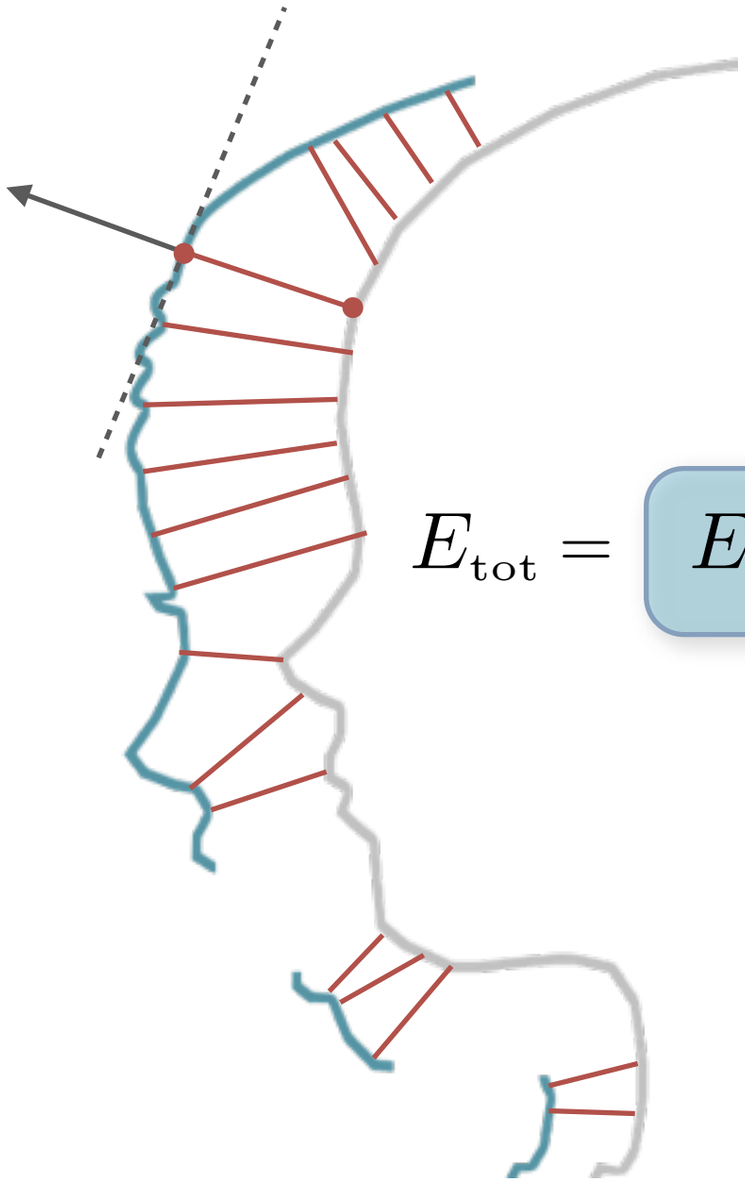
E_{smooth}

Non-Linear Energy Minimization



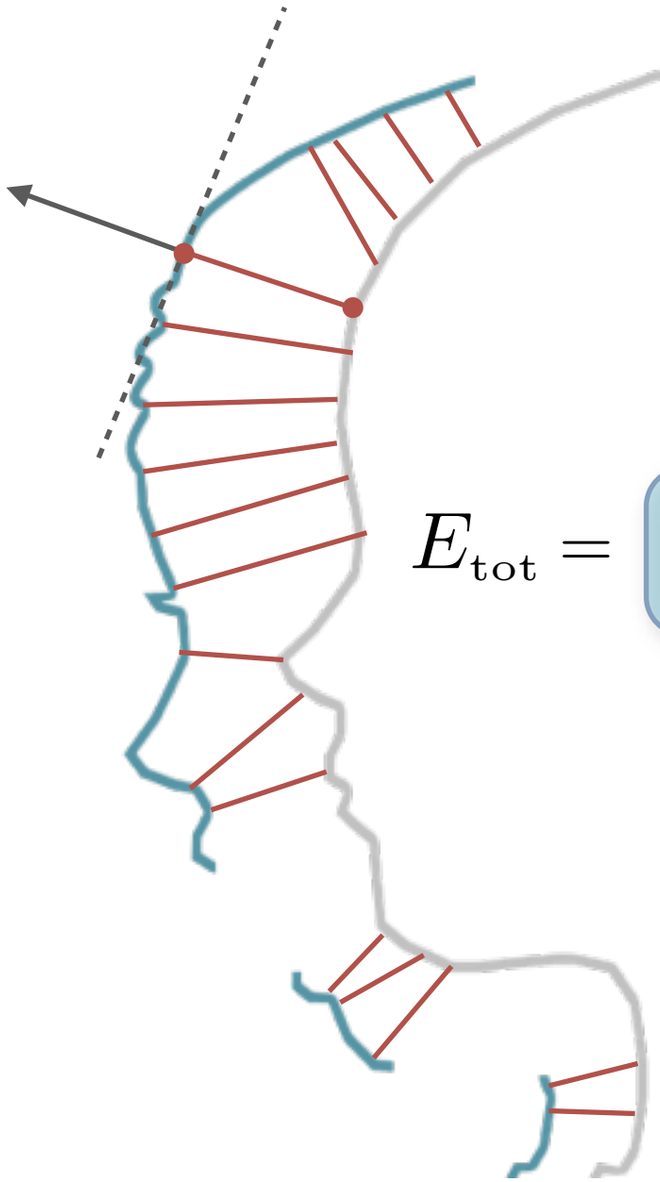
$$E_{\text{tot}} = E_{\text{plane}} + \alpha_{\text{point}} E_{\text{point}} + \alpha_{\text{rigid}} E_{\text{rigid}} + \alpha_{\text{smooth}} E_{\text{smooth}}$$

Non-Linear Energy Minimization



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

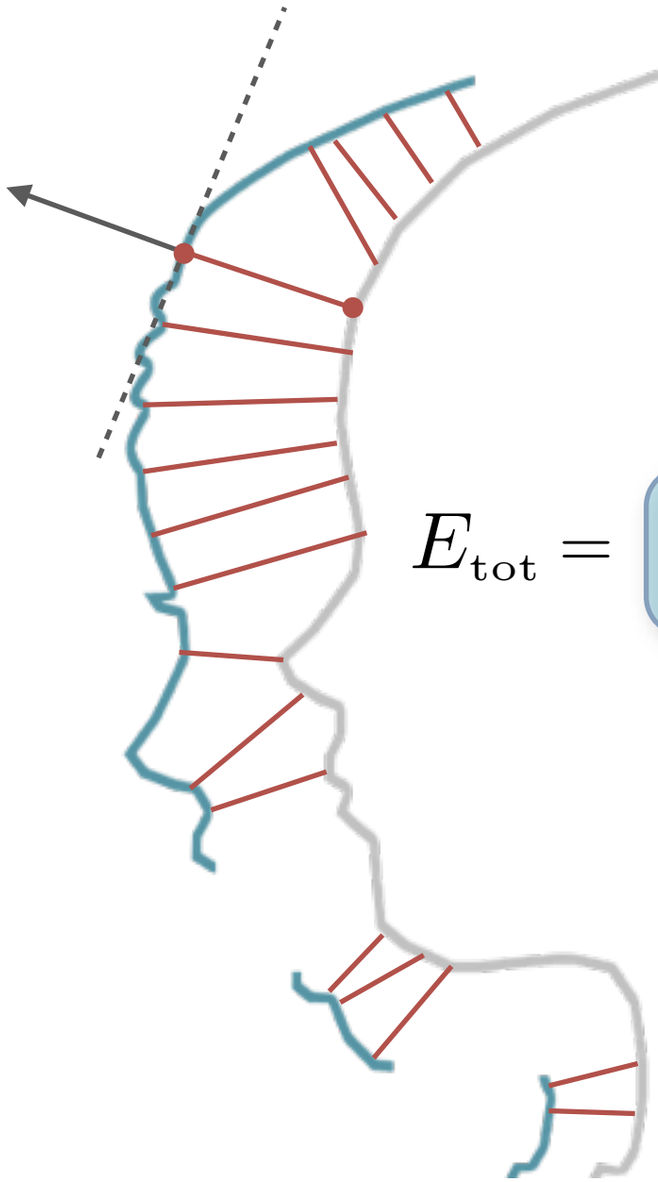
Non-Linear Energy Minimization



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

non-linear least squares minimization

Non-Linear Energy Minimization

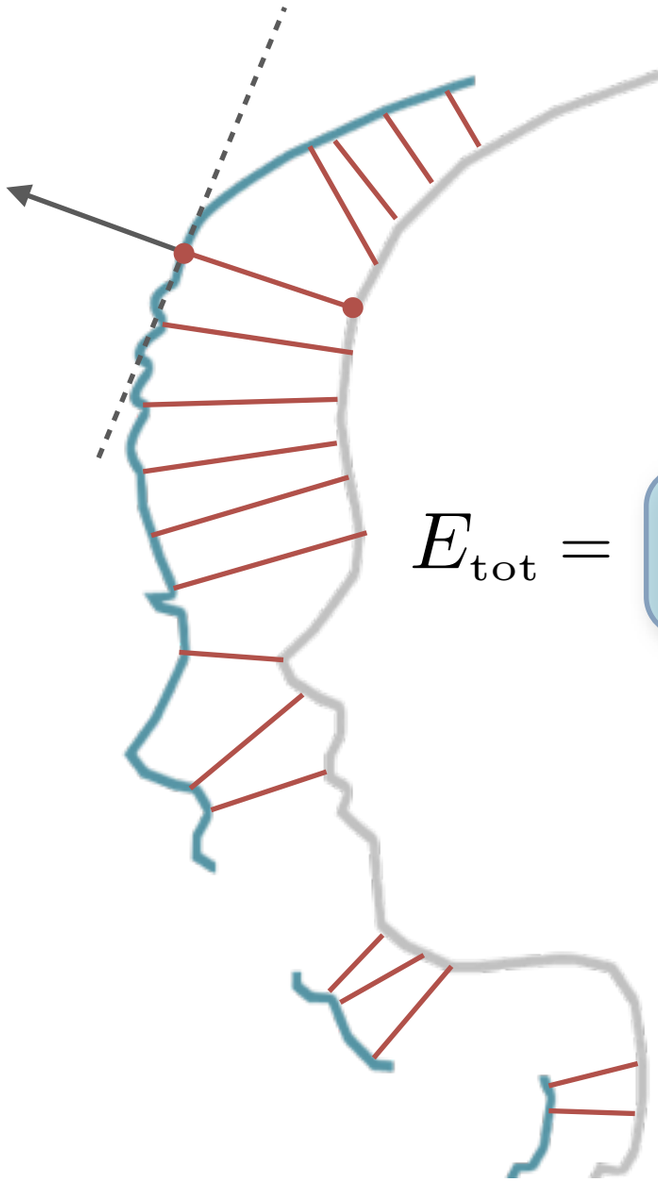


$$E_{\text{tot}} = E_{\text{plane}} + \alpha_{\text{point}} E_{\text{point}} + \alpha_{\text{rigid}} E_{\text{rigid}} + \alpha_{\text{smooth}} E_{\text{smooth}}$$

non-linear least squares minimization

Gauss-Newton method

Non-Linear Energy Minimization



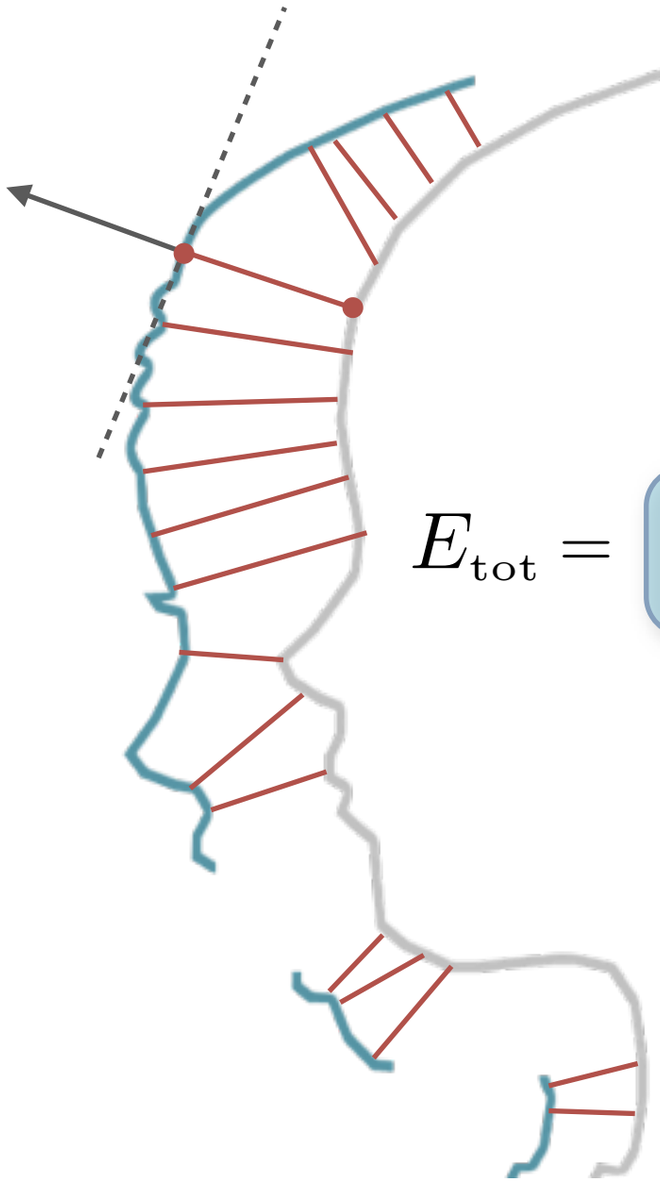
$$E_{\text{tot}} = E_{\text{plane}} + \alpha_{\text{point}} E_{\text{point}} + \alpha_{\text{rigid}} E_{\text{rigid}} + \alpha_{\text{smooth}} E_{\text{smooth}}$$

non-linear least squares minimization

Jacobian is sparse

Gauss-Newton method

Non-Linear Energy Minimization



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

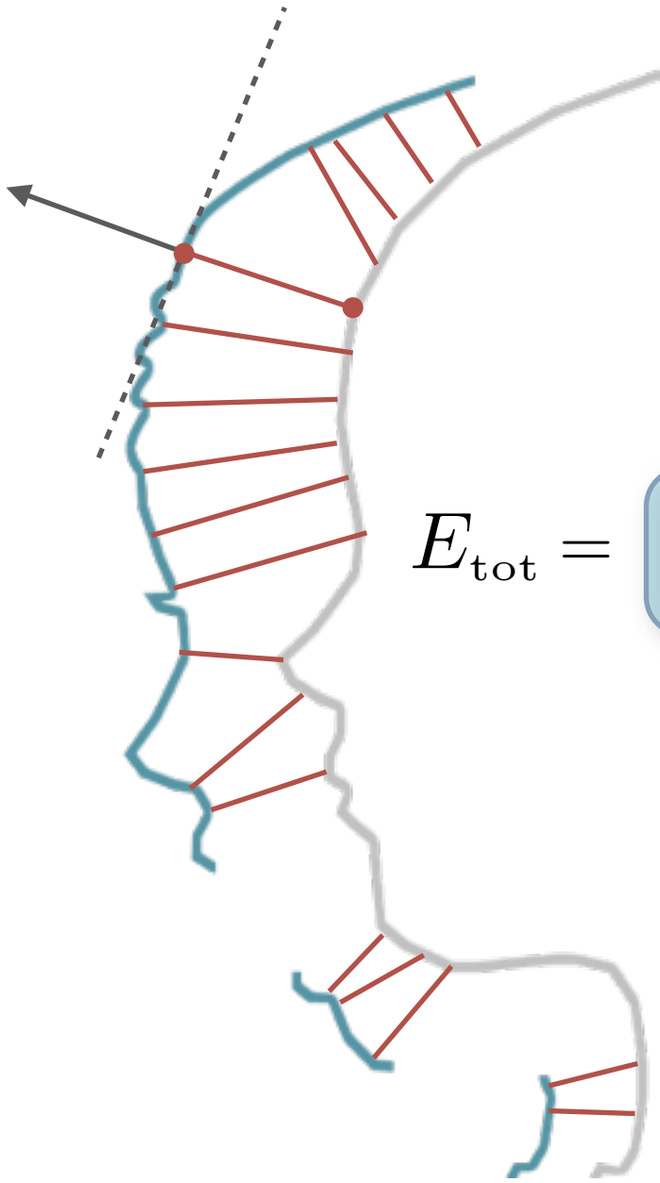
non-linear least squares minimization

Jacobian is sparse

Gauss-Newton method

sparse Cholesky factorization

Non-Linear Energy Minimization



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

non-linear least squares minimization

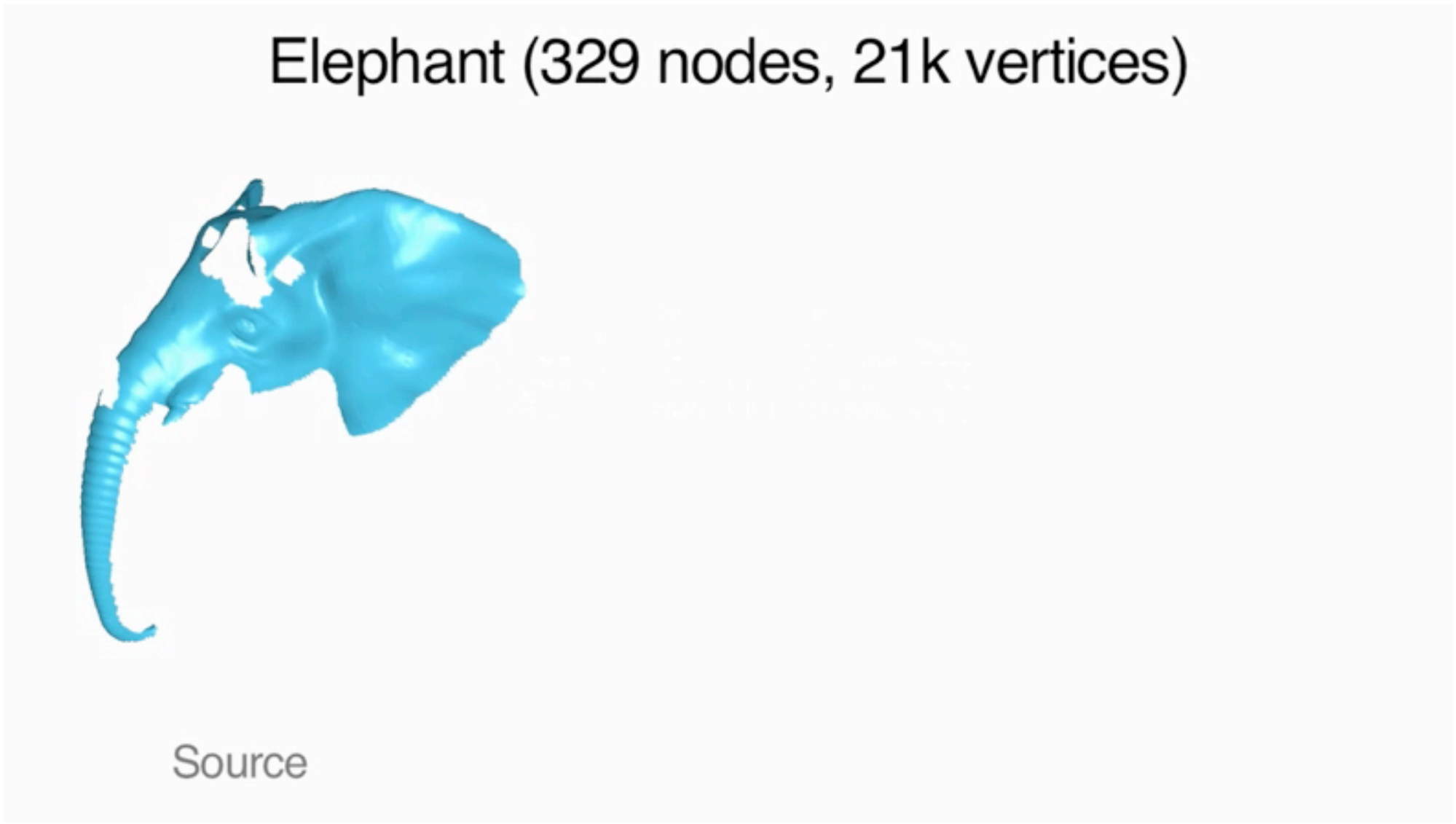
Jacobian is sparse

Gauss-Newton method

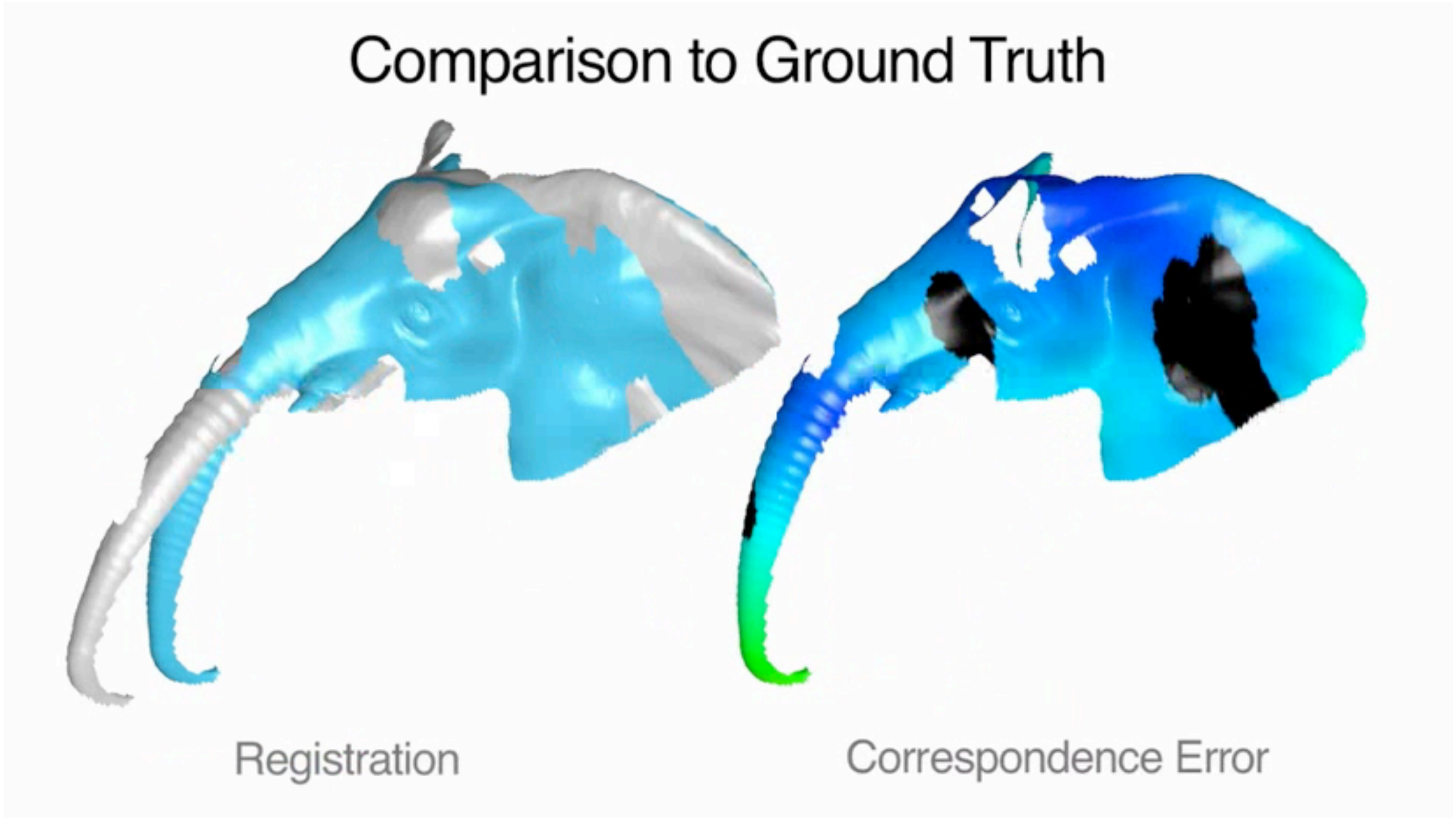
sparse Cholesky factorization

that's it!

Synthetic Model

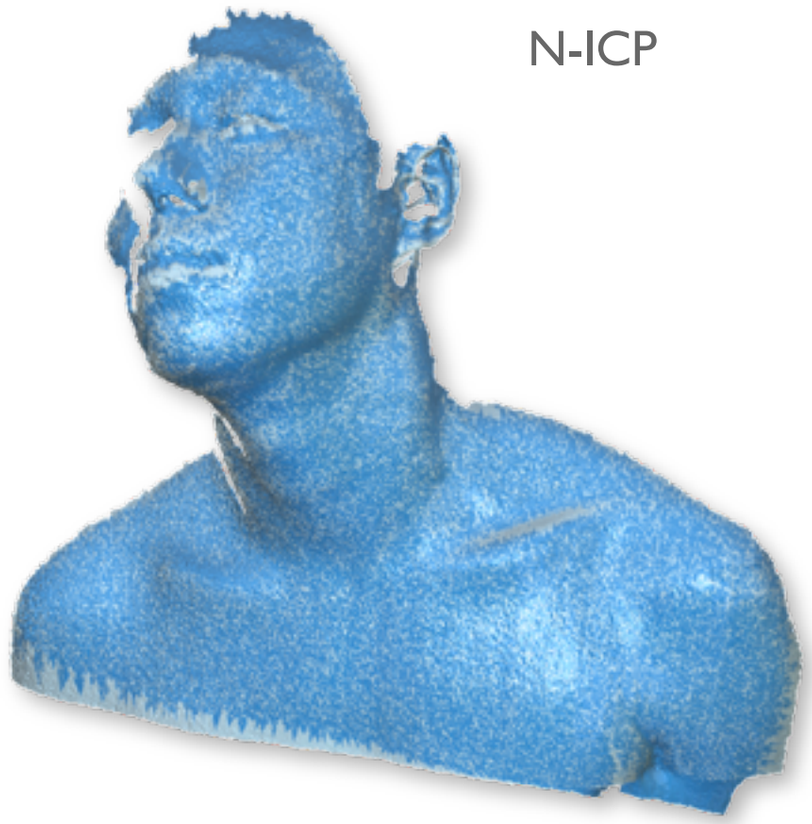


Comparison to Ground-Truth

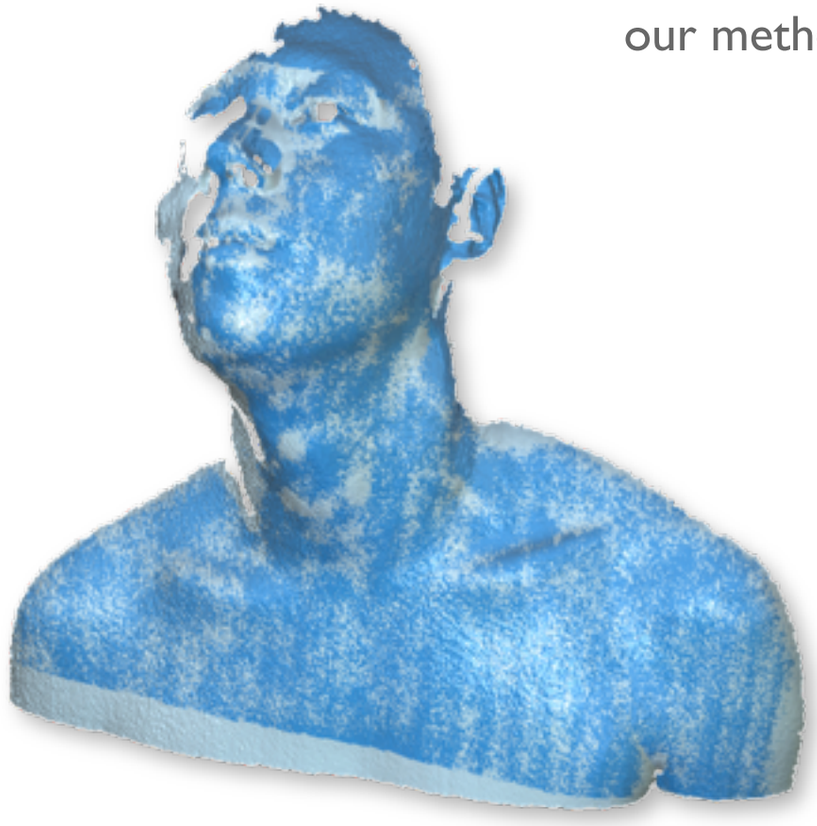


Comparison with other N-ICP

[Pauly et al. '05] [Pottmann et al. '06]



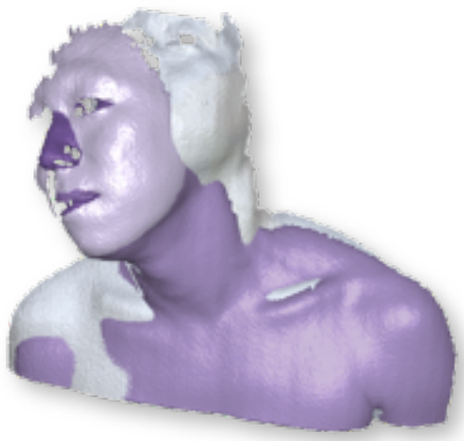
N-ICP



our method

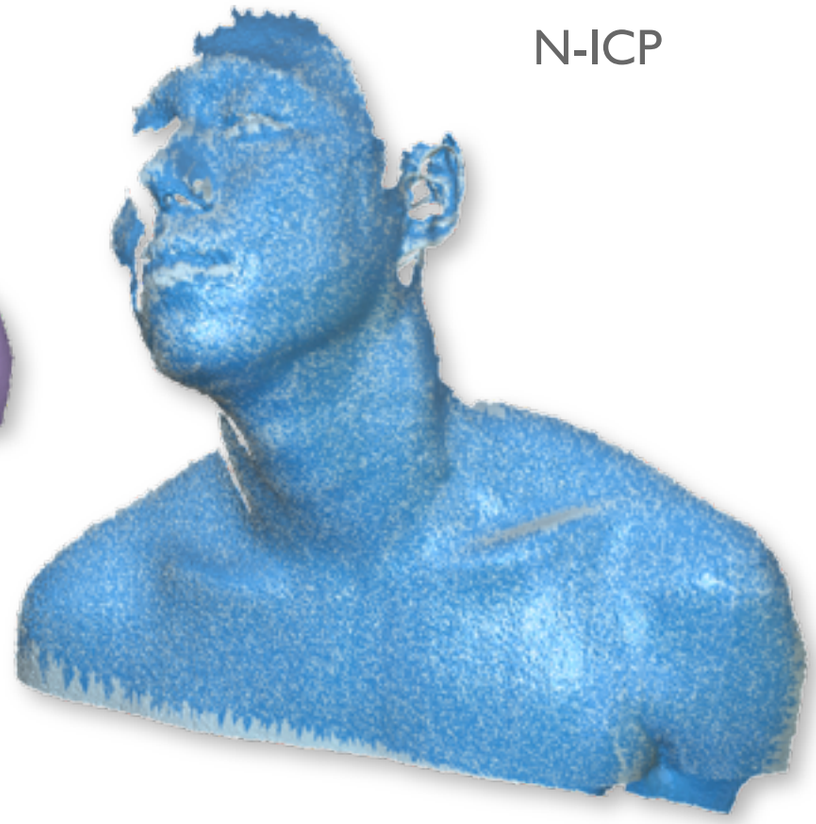
Comparison with other N-ICP

[Pauly et al. '05] [Pottmann et al. '06]

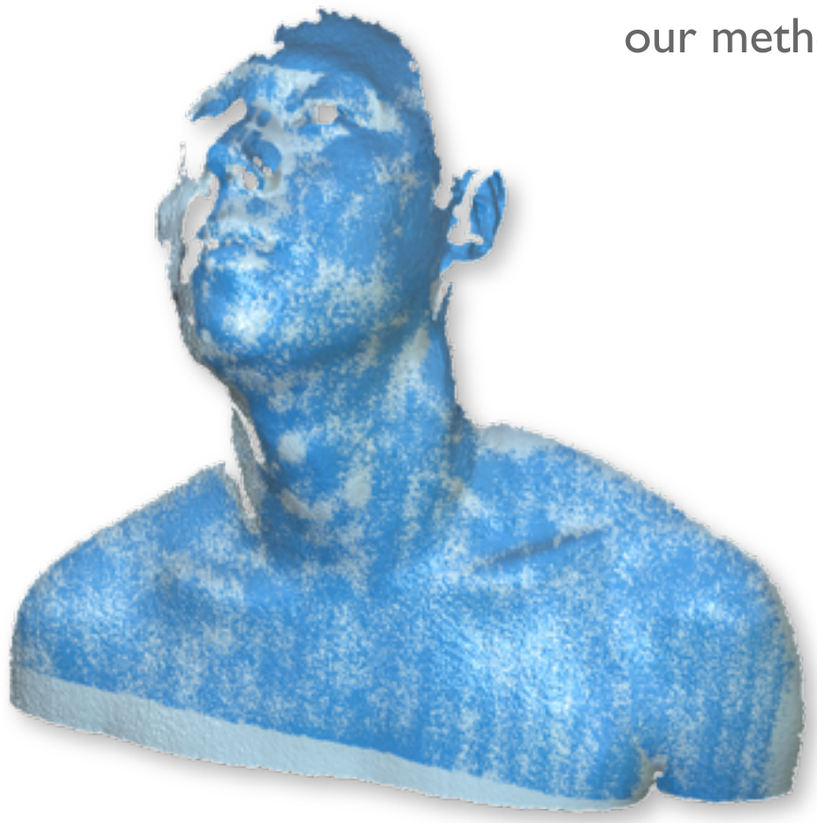


texturing

N-ICP



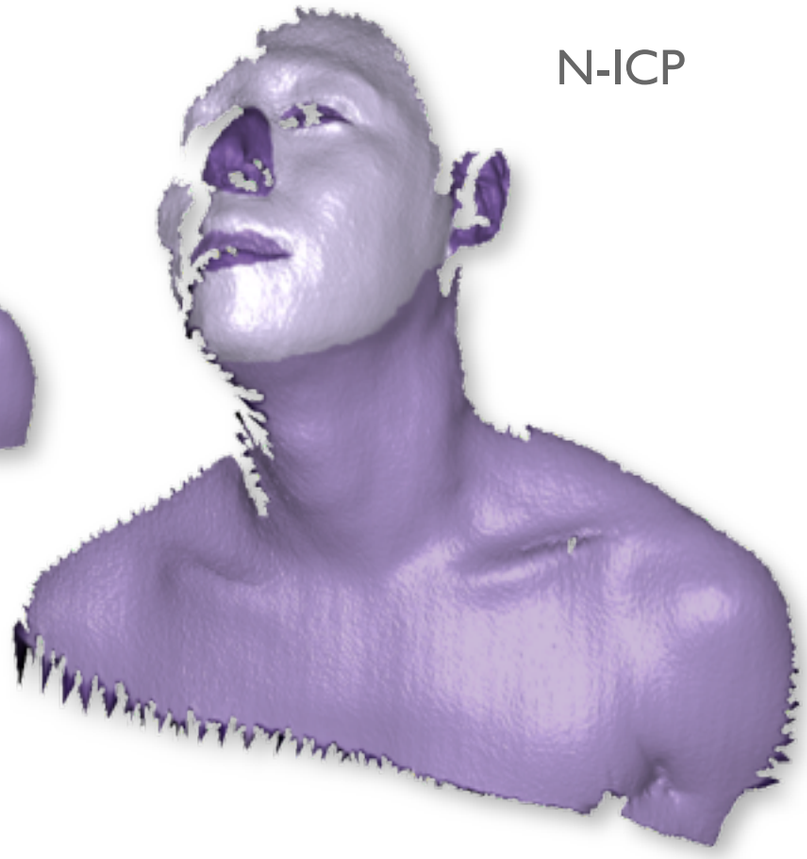
our method



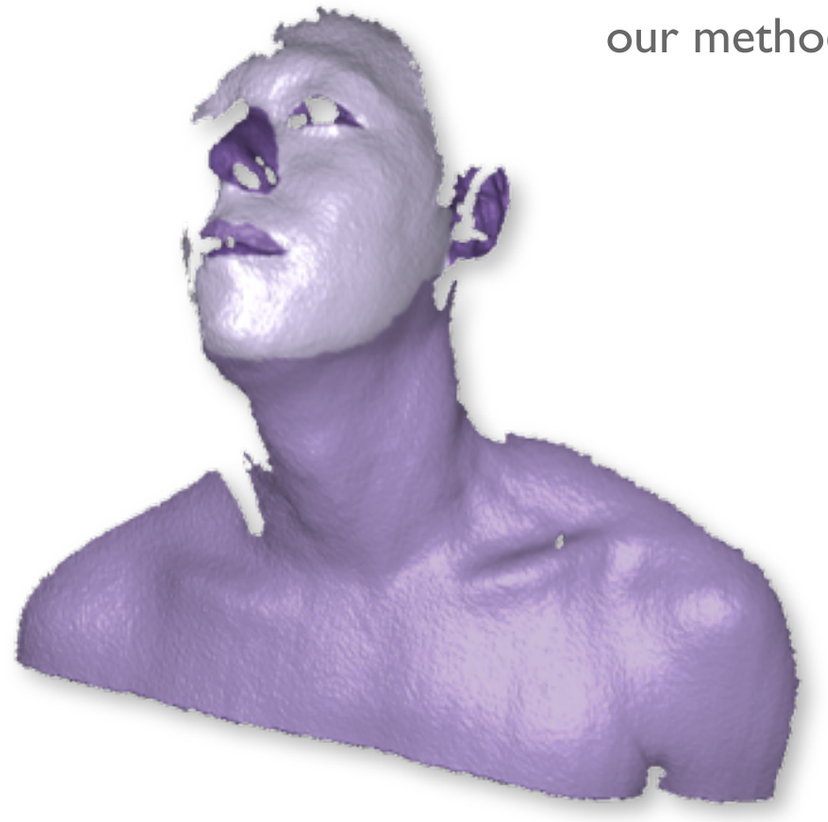
Comparison with other N-ICP

[Pauly et al. '05] [Pottmann et al. '06]

texturing



N-ICP

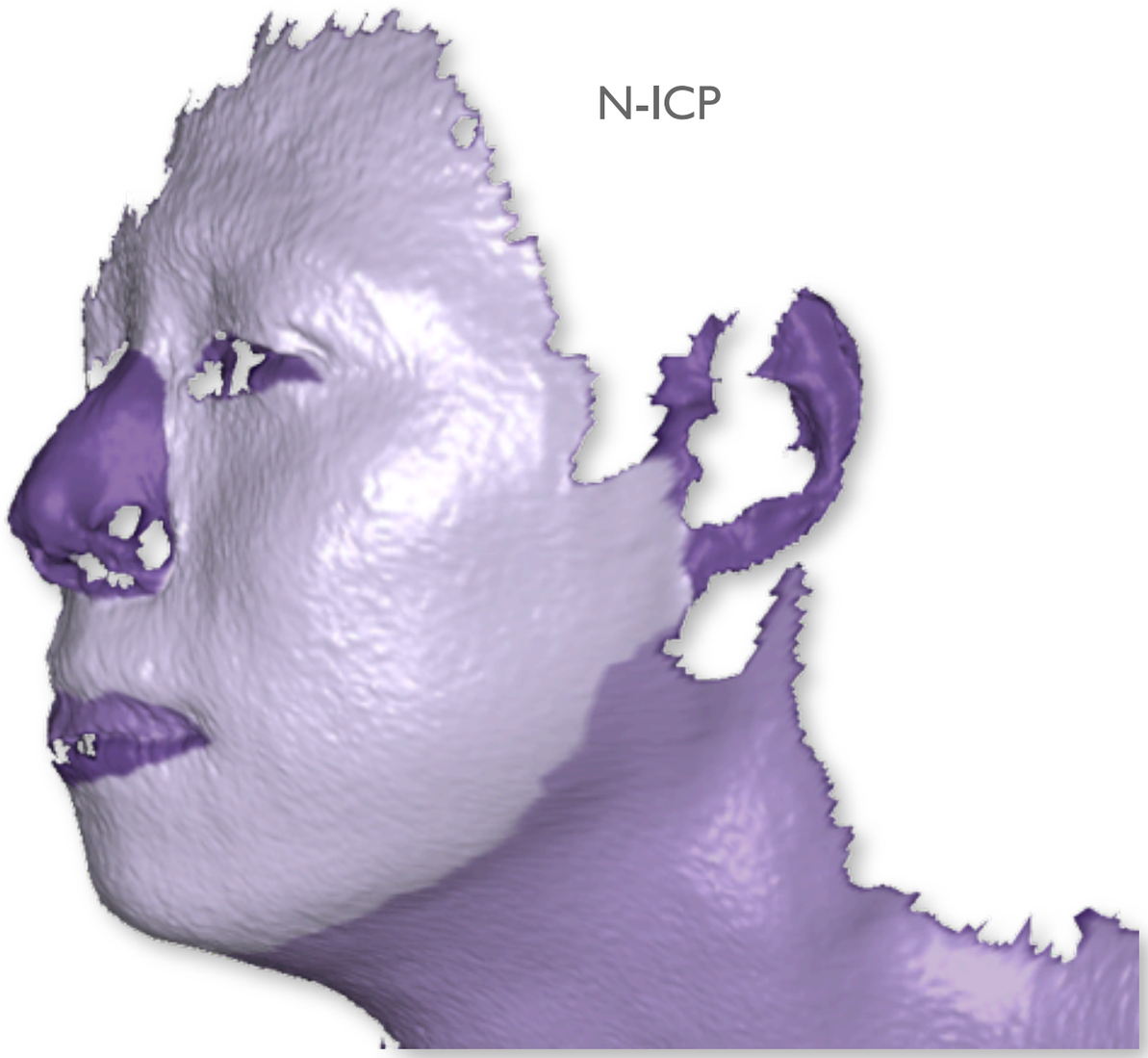


our method

Comparison with other N-ICP

[Pauly et al. '05] [Pottmann et al. '06]

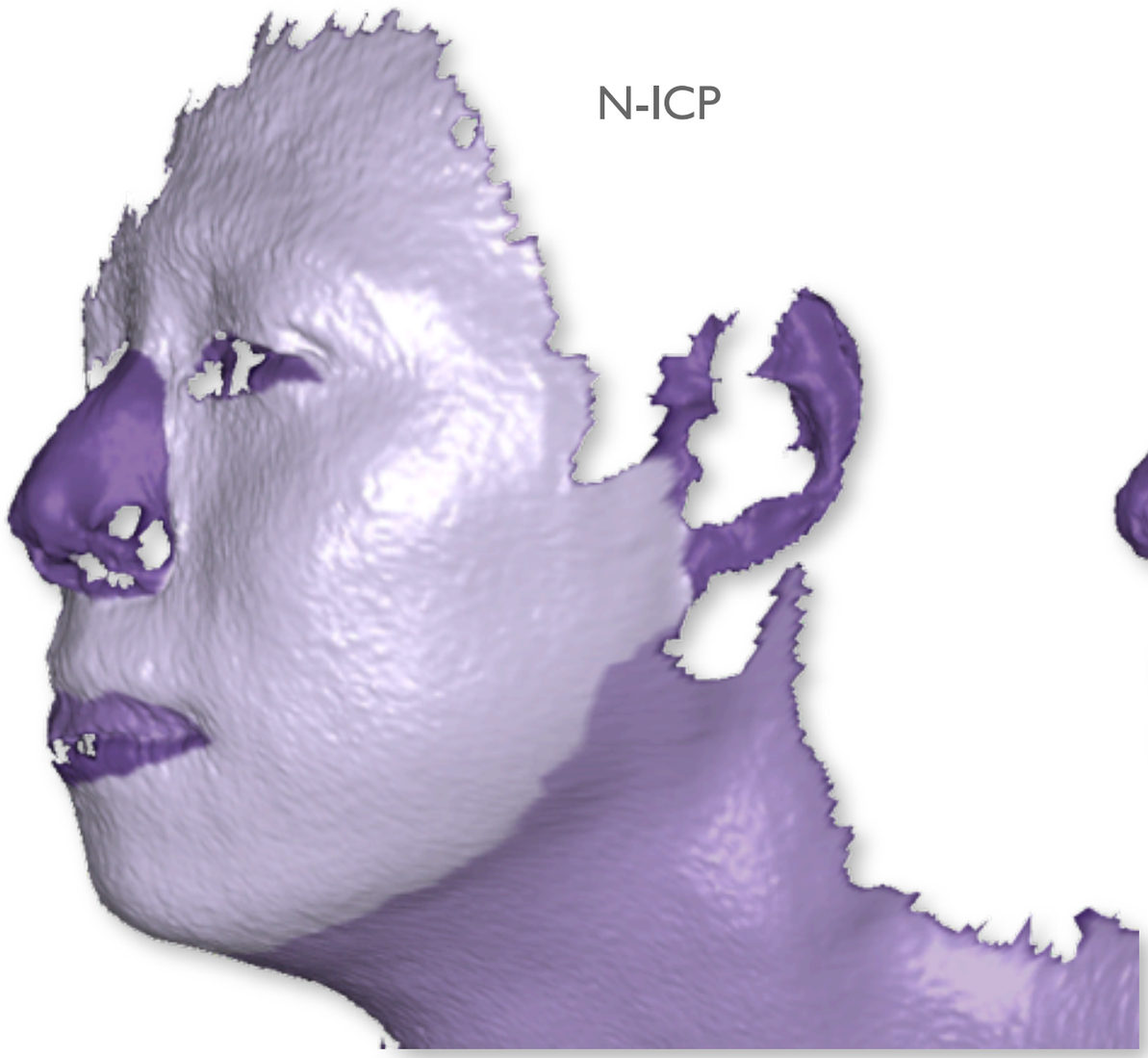
N-ICP



Comparison with other N-ICP

[Pauly et al. '05] [Pottmann et al. '06]

N-ICP

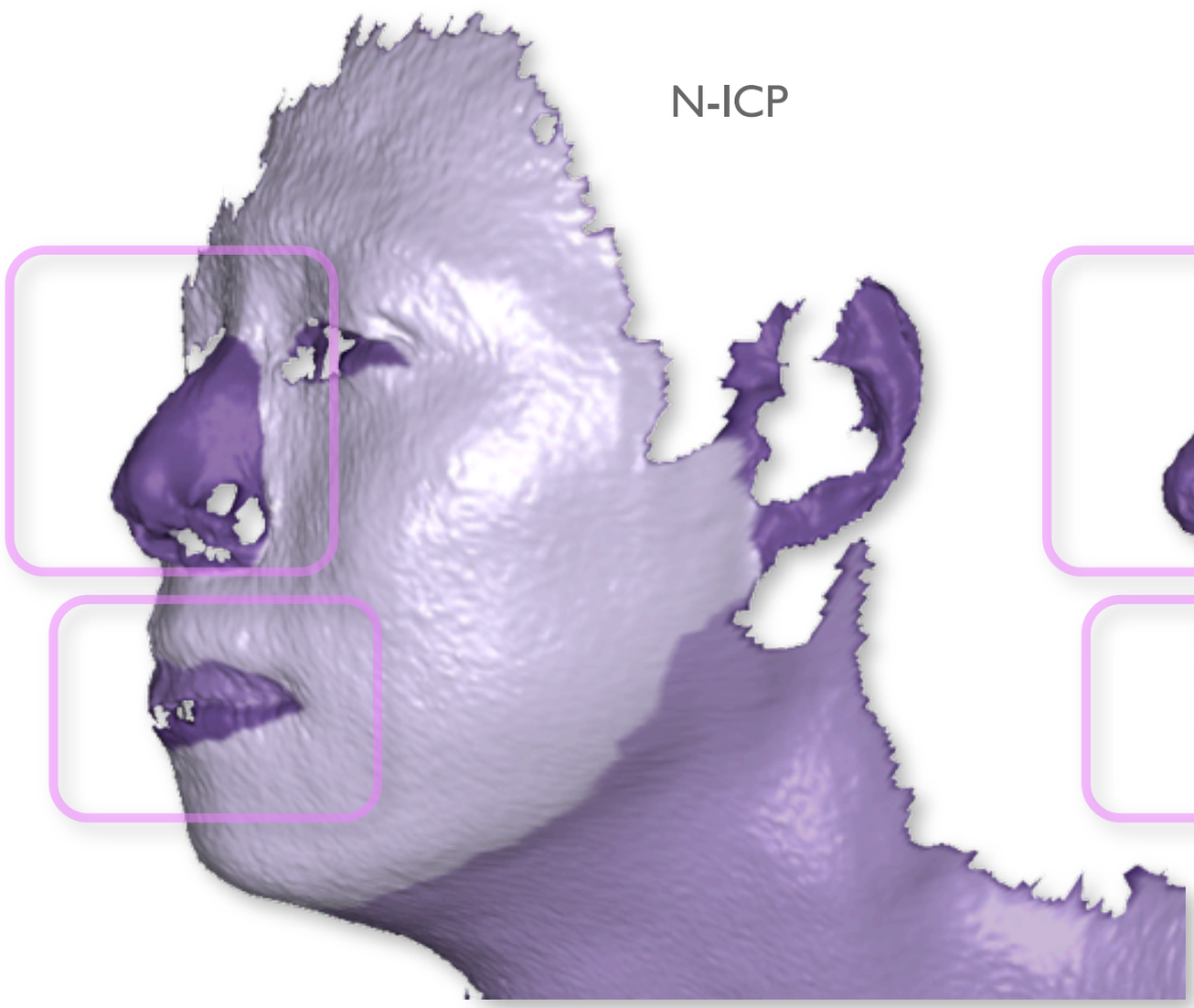


our method

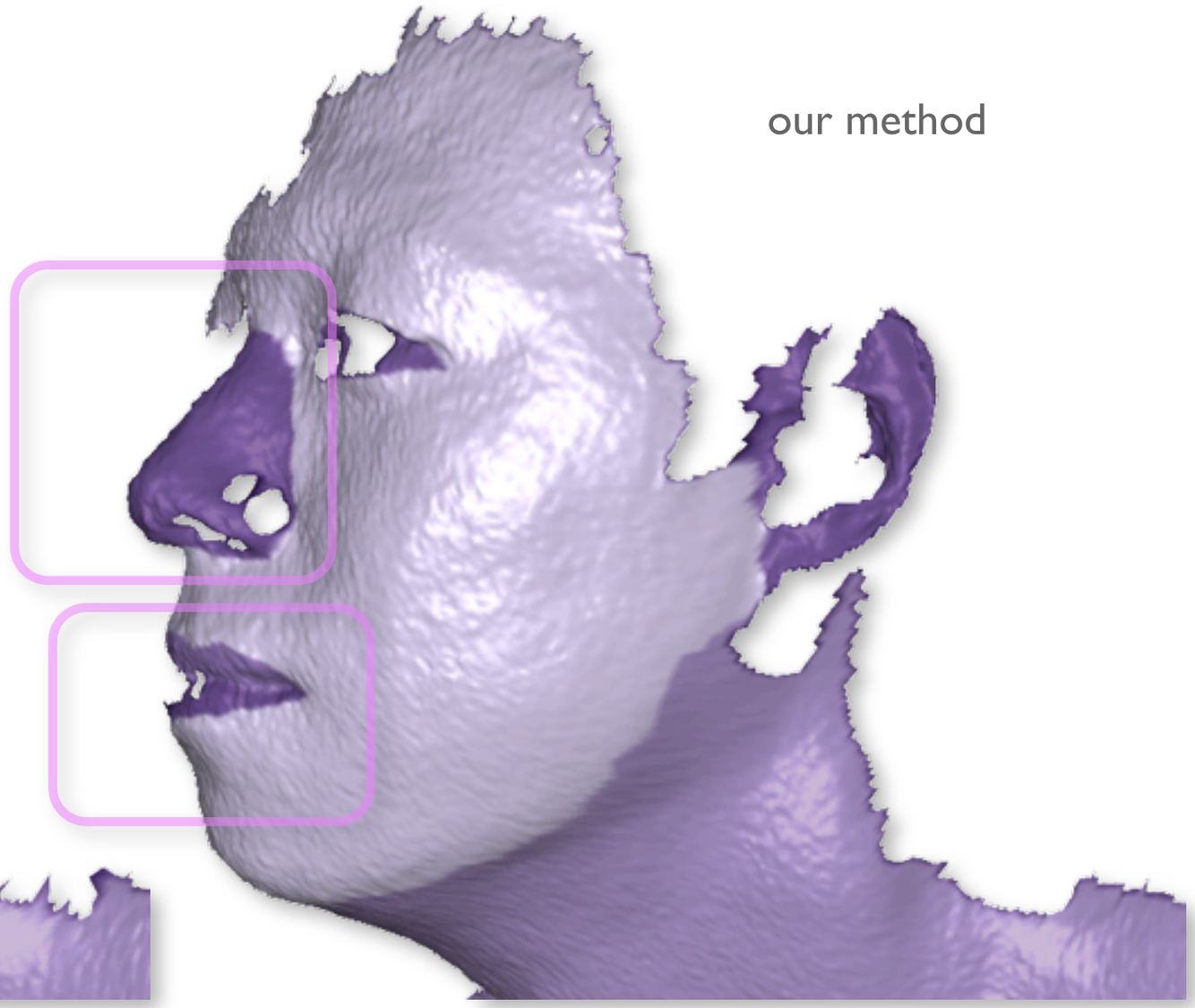
Comparison with other N-ICP

[Pauly et al. '05] [Pottmann et al. '06]

N-ICP



our method



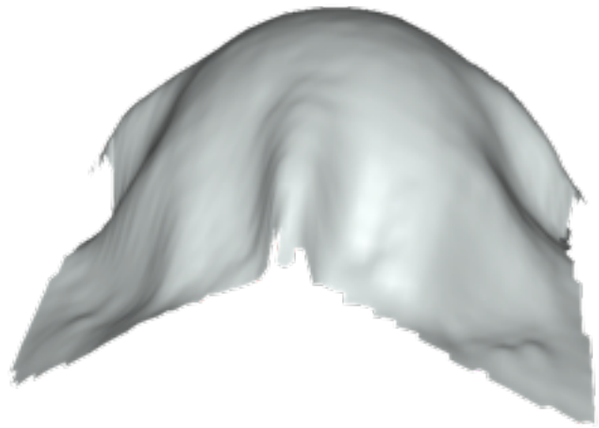
Draping Table Cloth

source

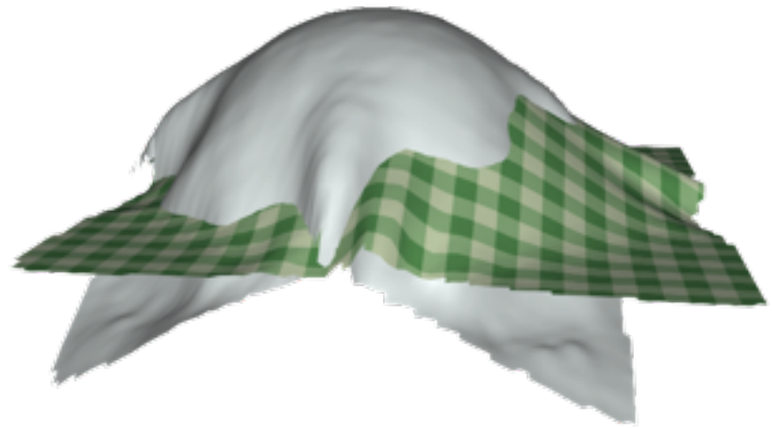
Draping Table Cloth

source

target



initial alignment



Suitable for Isometric Deformations

N-ICP

our method

Suitable for Isometric Deformations

N-ICP

our method

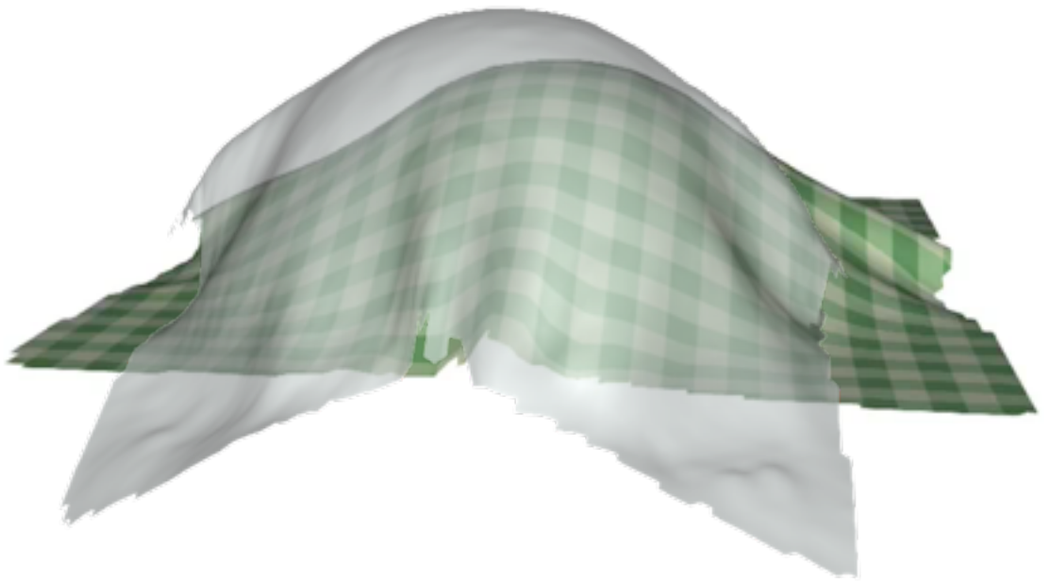
Suitable for Isometric Deformations

N-ICP

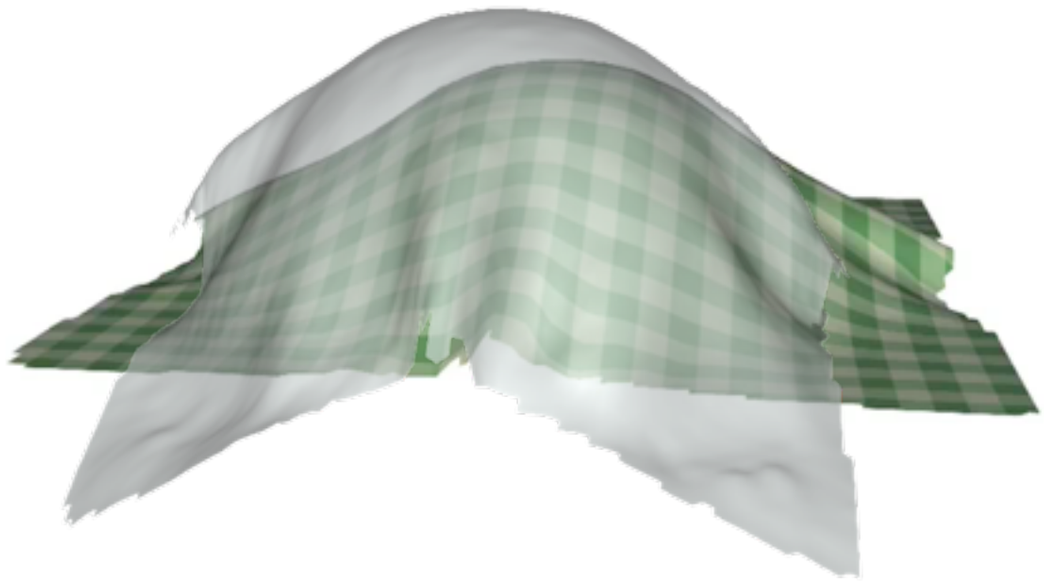
our method

Suitable for Isometric Deformations

N-ICP



our method



Some Examples

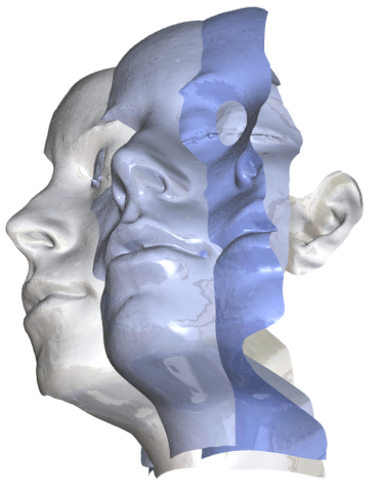
Face Capture Pipeline

acquisition

data provided by Paramount Pictures and Aguru Images

Face Capture Pipeline

acquisition

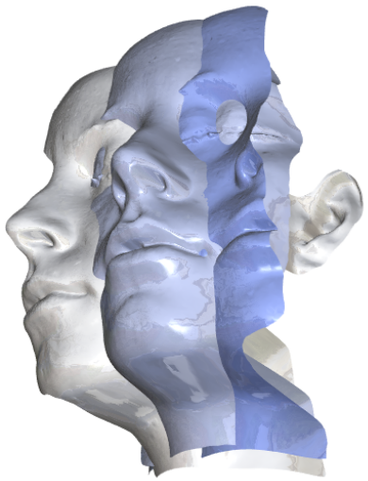


initial
alignment

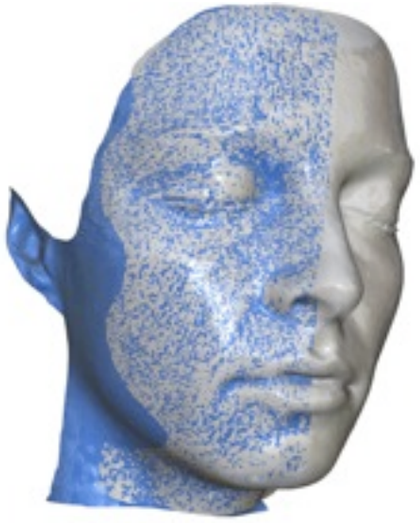
data provided by Paramount Pictures and Aguru Images

Face Capture Pipeline

acquisition



initial alignment

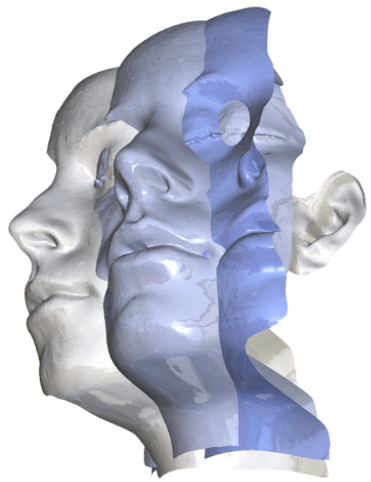


registration

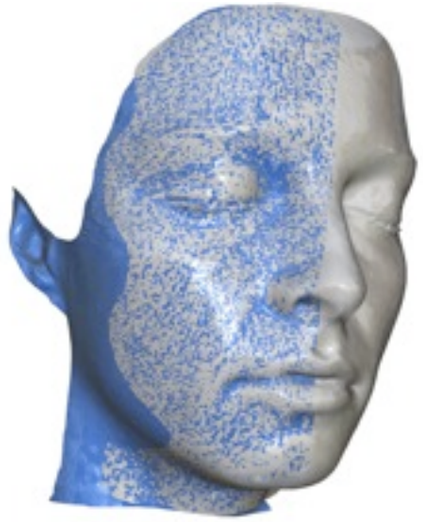
data provided by Paramount Pictures and Aguru Images

Face Capture Pipeline

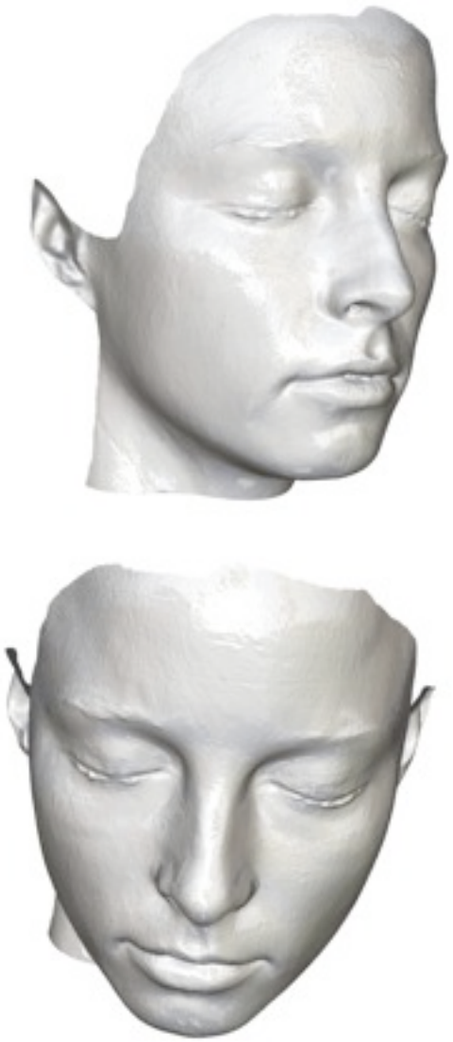
acquisition



initial alignment



registration



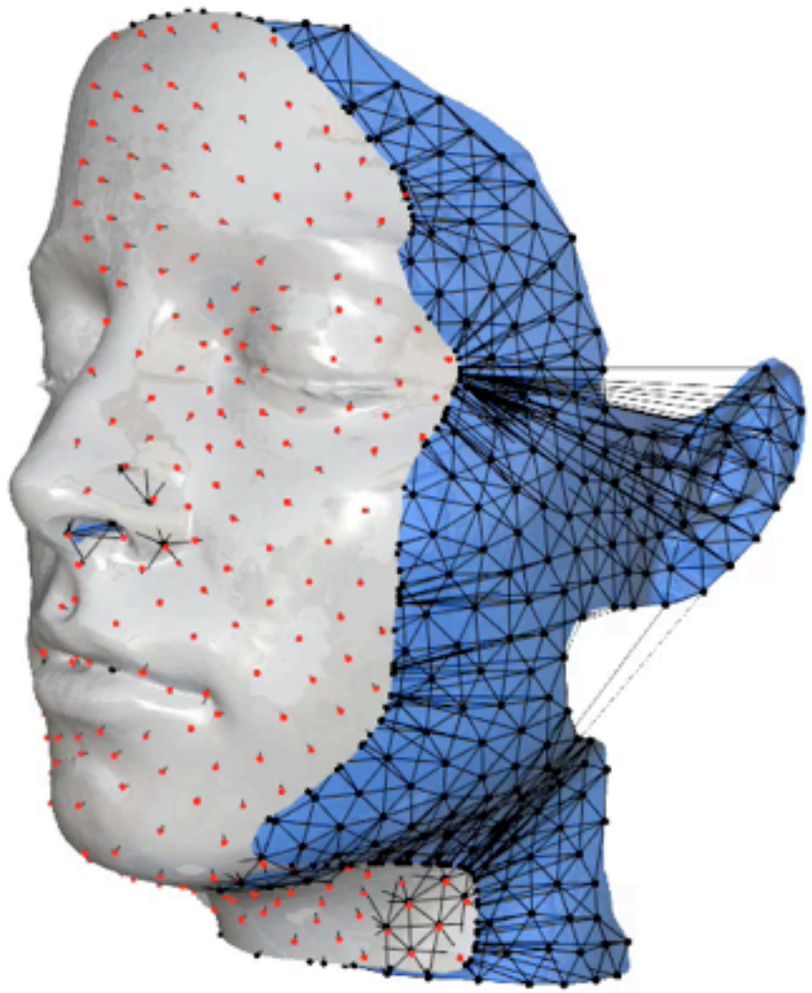
merging

data provided by Paramount Pictures and Aguru Images

Digital Face Cloning (scan-to-scan)

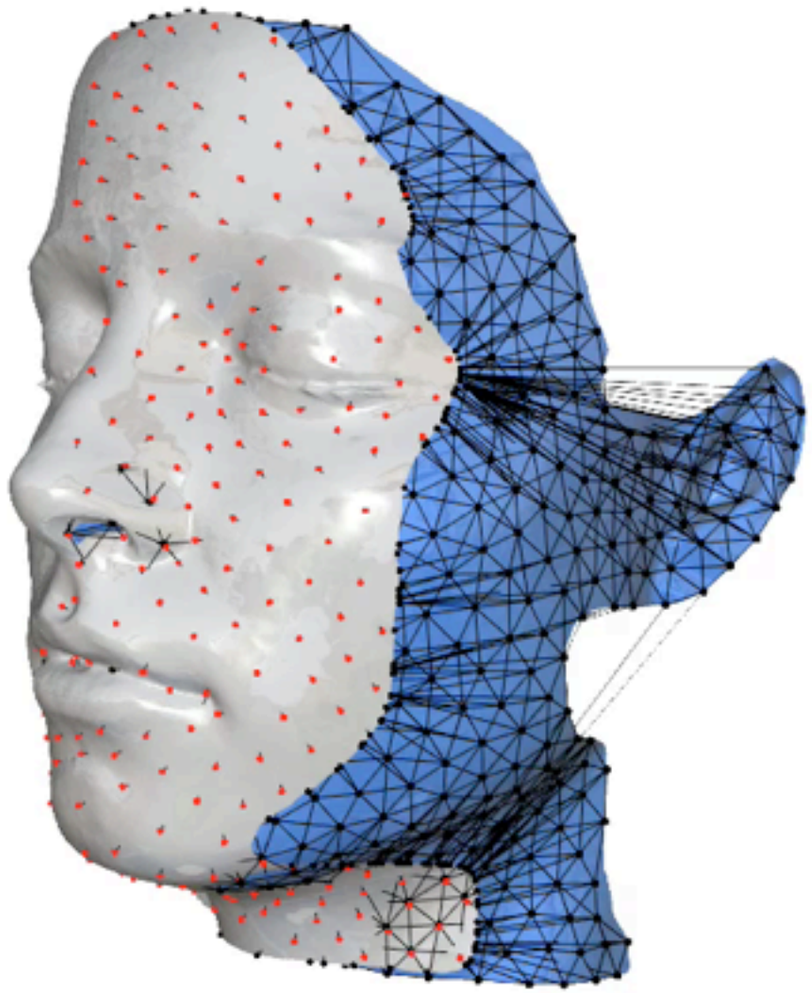
data provided by Paramount Pictures and Aguru Images

Digital Face Cloning (scan-to-scan)



data provided by Paramount Pictures and Aguru Images

Digital Face Cloning (scan-to-scan)

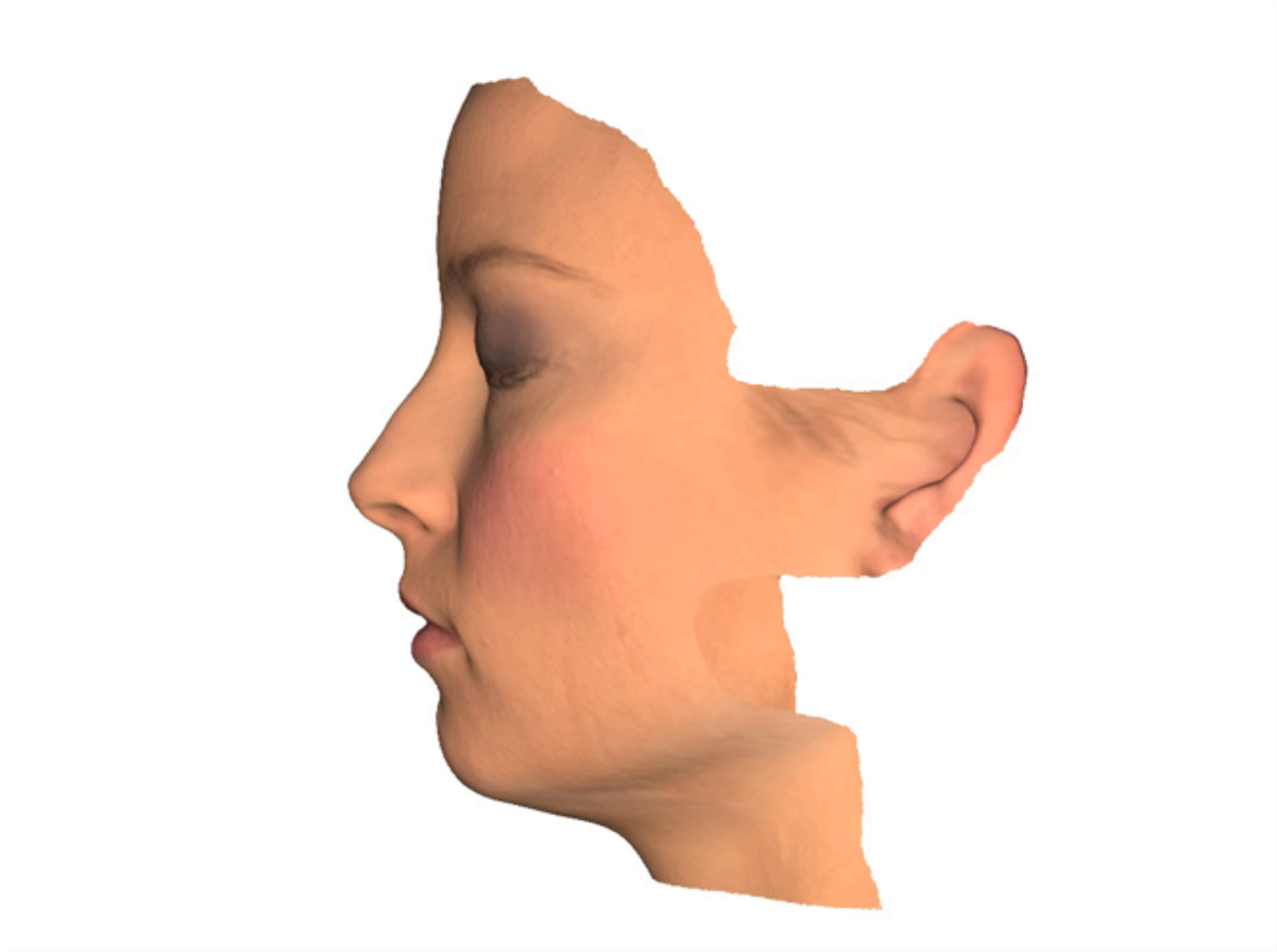


data provided by Paramount Pictures and Aguru Images

Digital Face Cloning

data provided by Paramount Pictures and Aguru Images

Digital Face Cloning

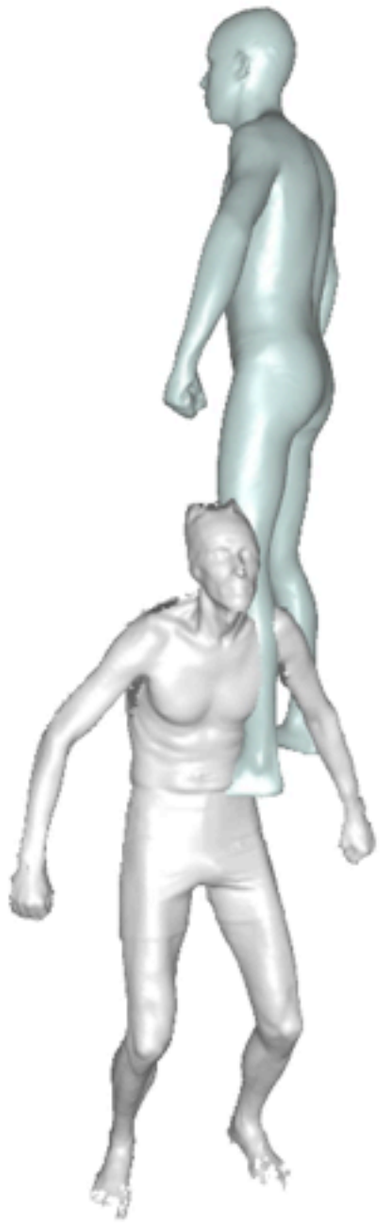


data provided by Paramount Pictures and Aguru Images

It’s pretty robust

Caesar Data Set – Test with Michael Black

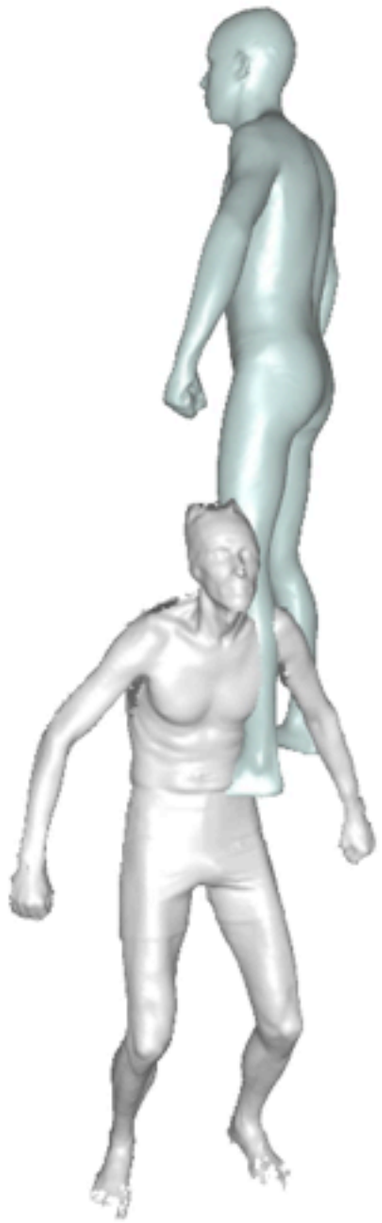
It’s pretty robust



custom scan

Caesar Data Set – Test with Michael Black

It’s pretty robust

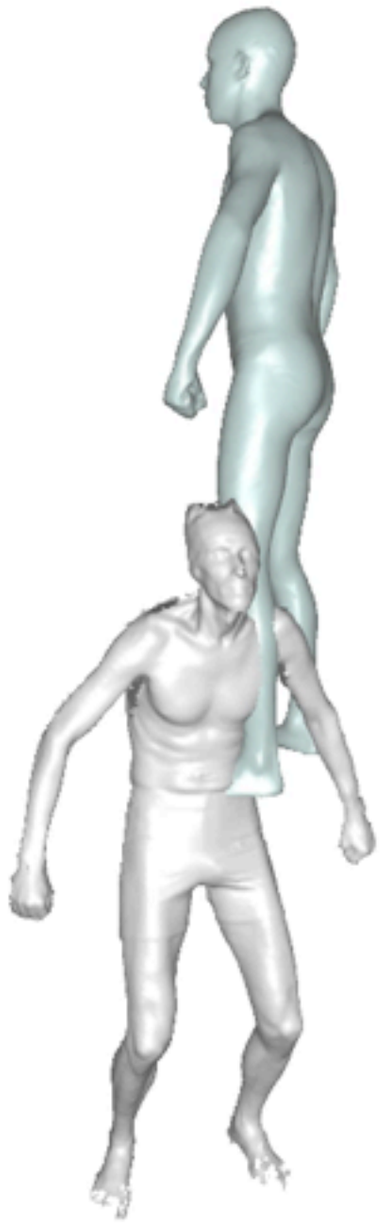


generic template

custom scan

Caesar Data Set – Test with Michael Black

It’s pretty robust

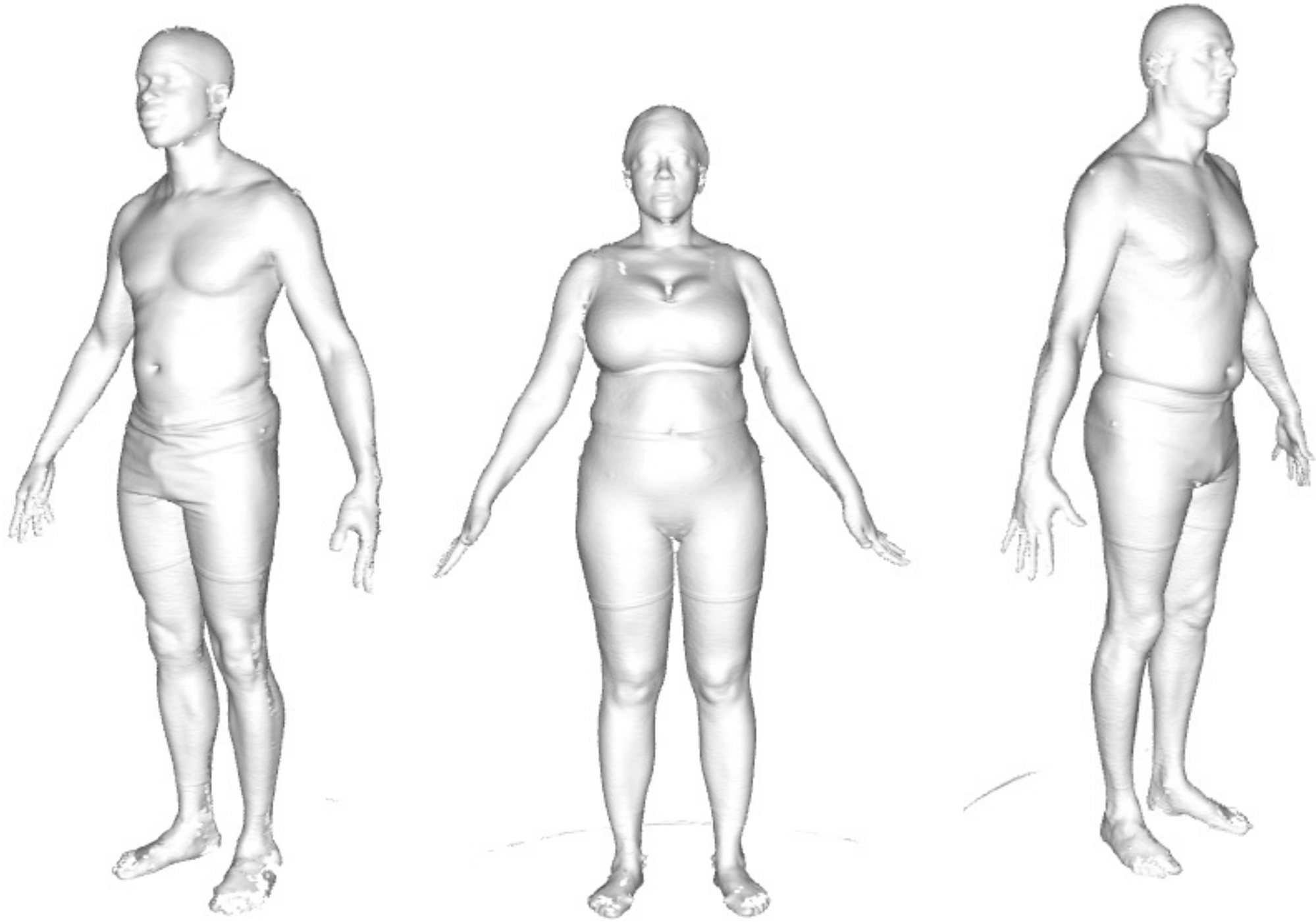


Caesar Data Set – Test with Michael Black

Application: Statistical Database

Caesar Data Set – Test with Michael Black

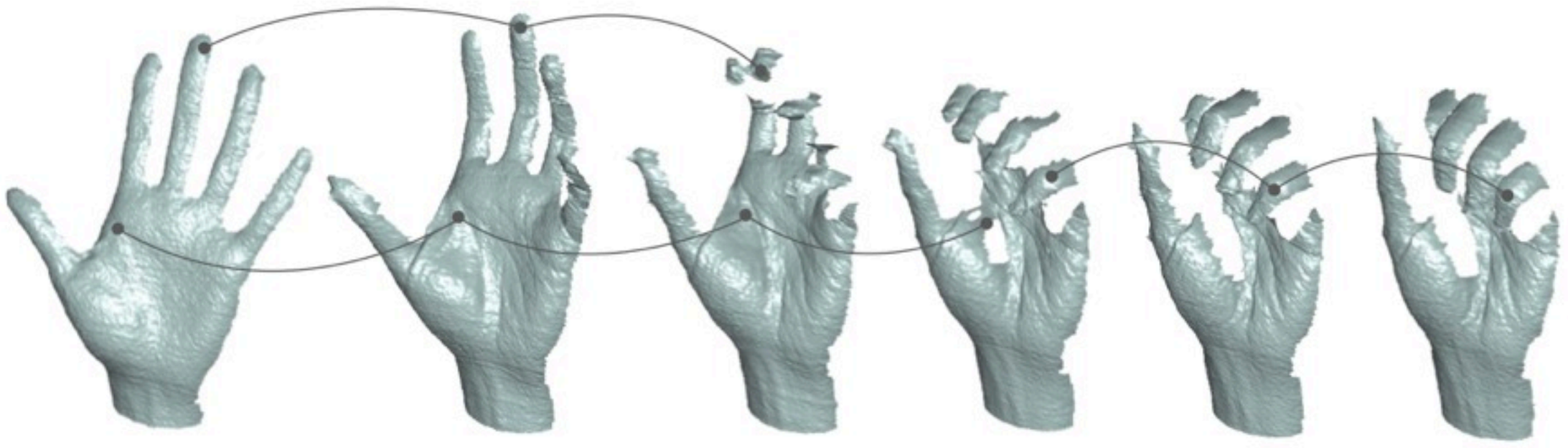
Application: Statistical Database



Caesar Data Set – Test with Michael Black

What's Next?

What's Next?



What's Next?

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