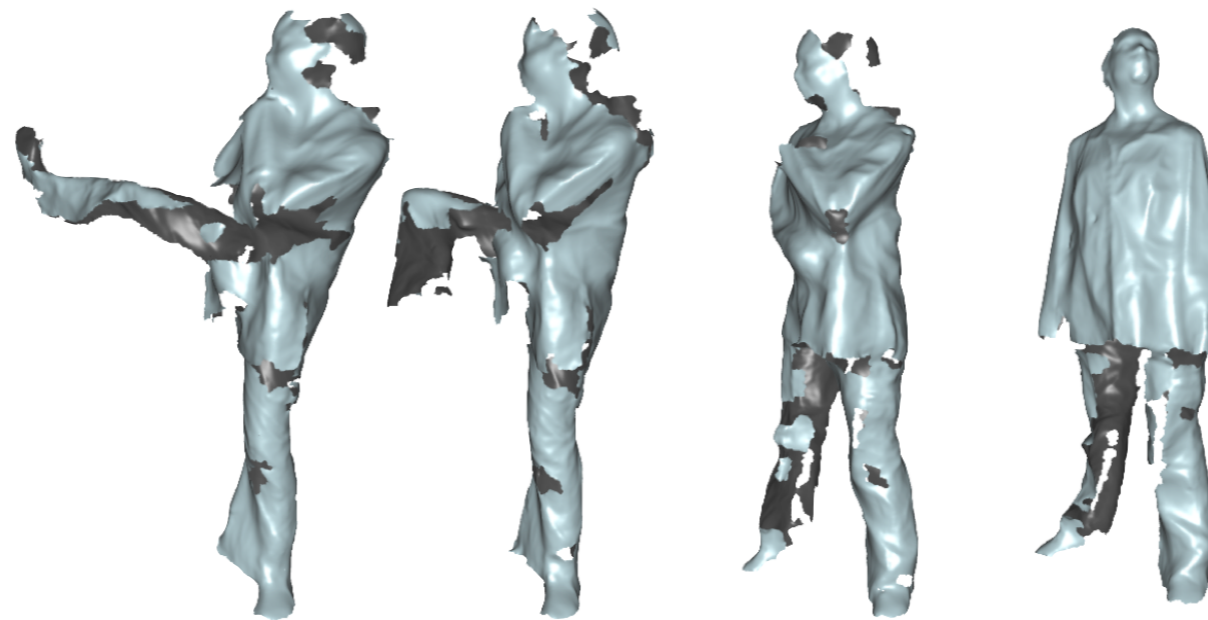


13.1 **Dynamic Geometry Processing I**



Hao Li

<http://cs621.hao-li.com>

Problem Classification

Correspondence Classification

How many meshes?

- **Two:** Pairwise registration
- **More than two:** multi-view registration

Initial registration available?

- **Yes:** Local optimization methods
- **No:** Global methods

Class of transformations?

- **Rotation and translation:** Rigid-body
- **Non-rigid deformations**

Correspondence Classification

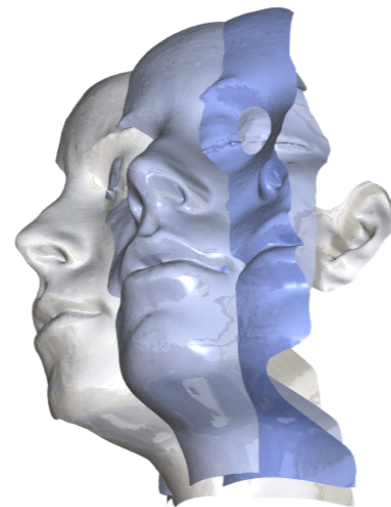
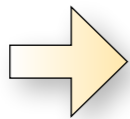
Type of algorithm can depend on type of data that is available, or desired application

- Data: typical 3D scans
- Application: 3D model reconstruction

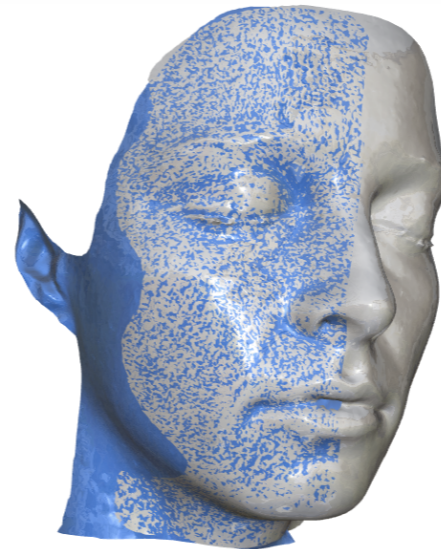
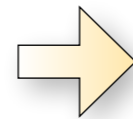
3-D Reconstruction



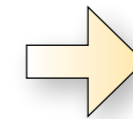
acquisition



initial
alignment



registration

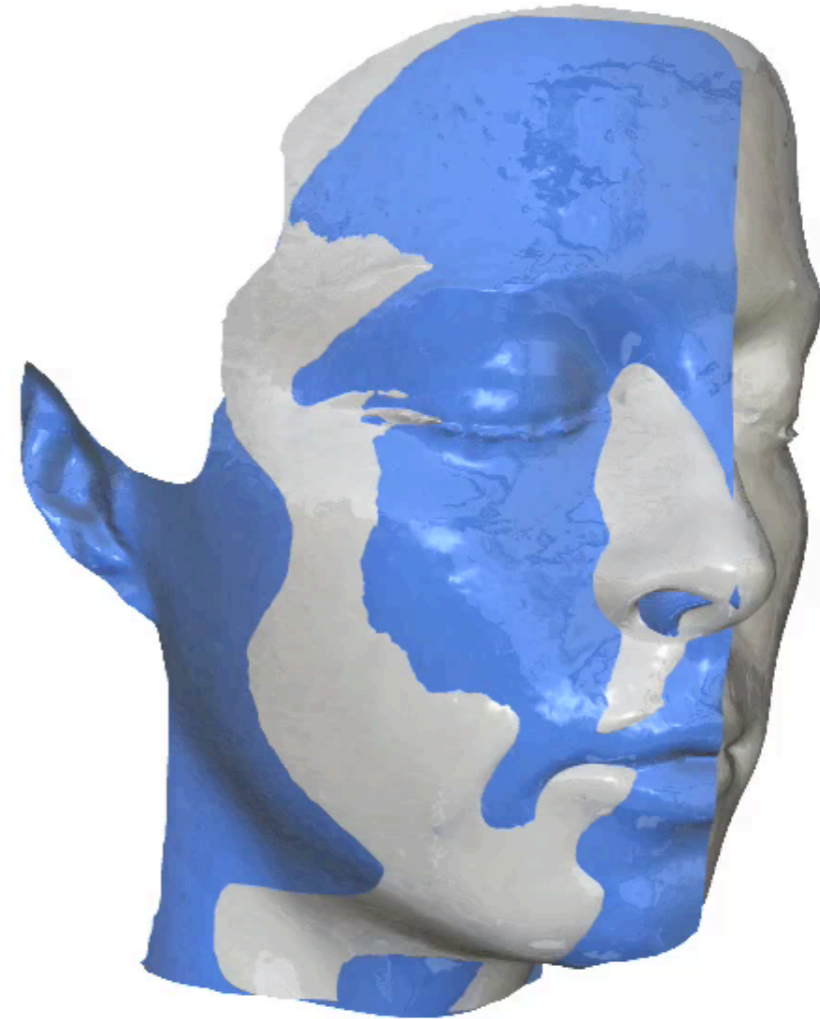
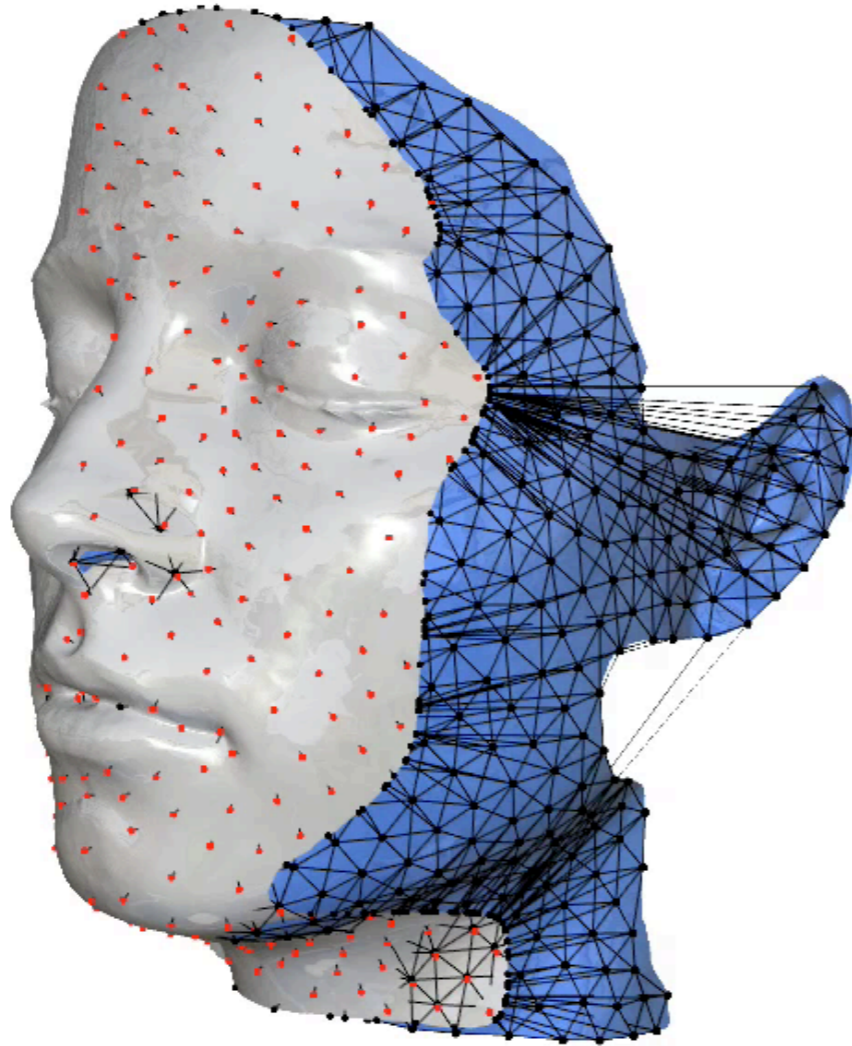


merging



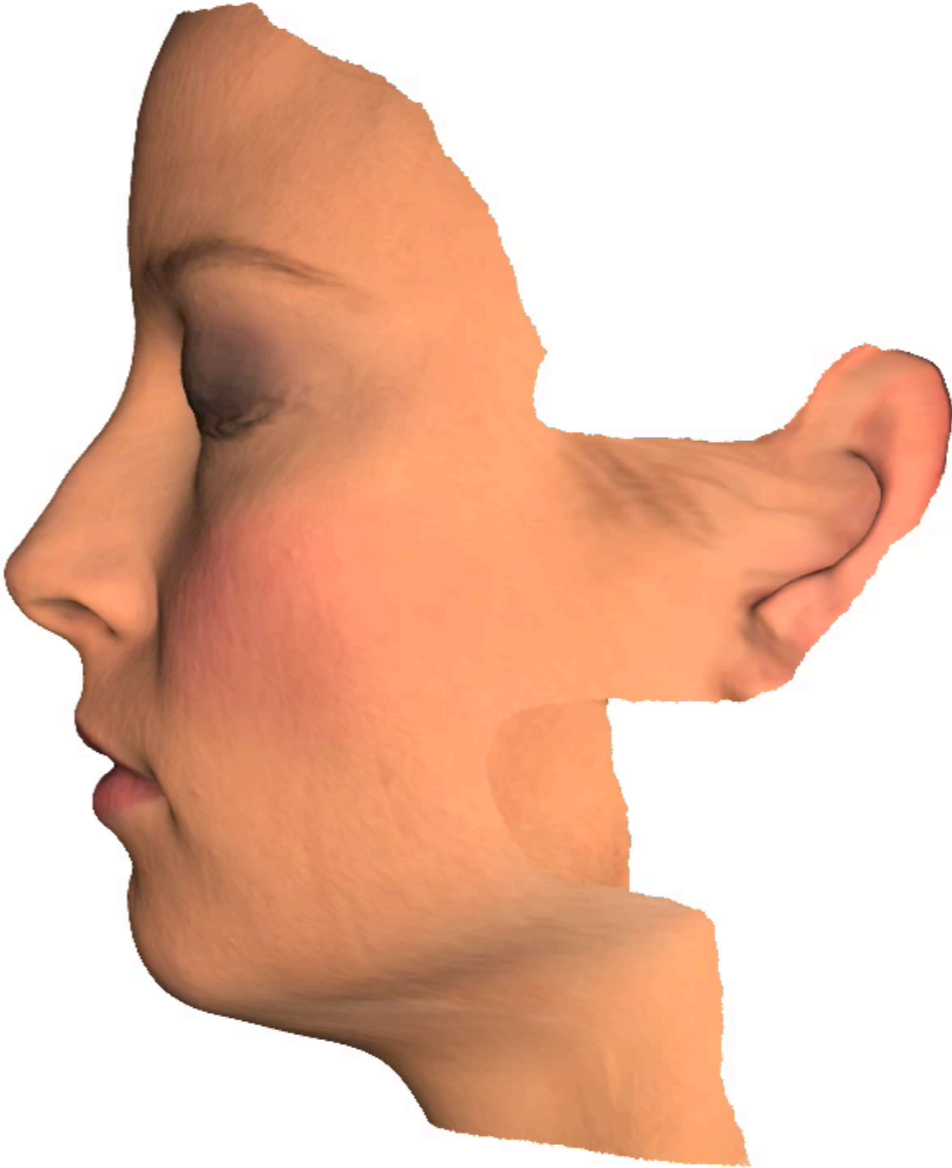
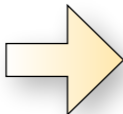
data provided by Paramount Pictures and Aguru Images

Non-Rigid Registration



data provided by Paramount Pictures and Aguru Images

Full Reconstruction



data provided by Paramount Pictures and Aguru Images



Correspondence Classification

Type of algorithm can depend on type of data that is available, or desired application

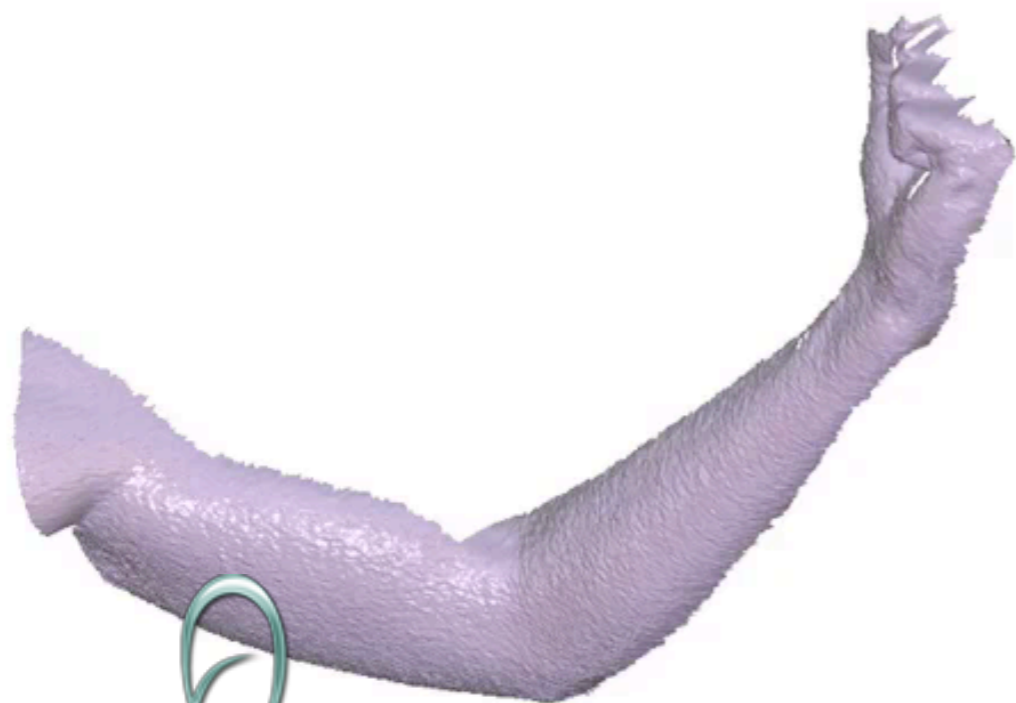
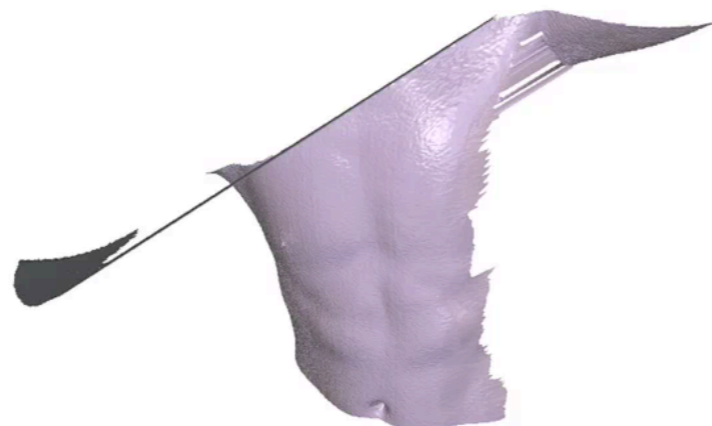
- Data: real-time 3D scans
- Application: animation reconstruction

Dynamic Input Data



continuous motion / general deformation

Dynamic Input Data



Data provided with T.Weise and L.Van Gool

Dynamic Input Data

Frame 2



Input Range Scans



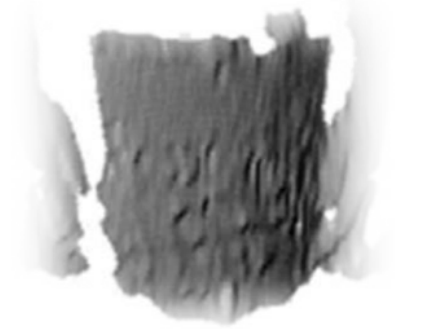
Reconstructed Model

momentary motion / articulated deformation

Animation Reconstruction

Problems

- Noisy data
- Incomplete data (acquisition holes)
- No correspondences



noise



holes



missing correspondences

Animation Reconstruction

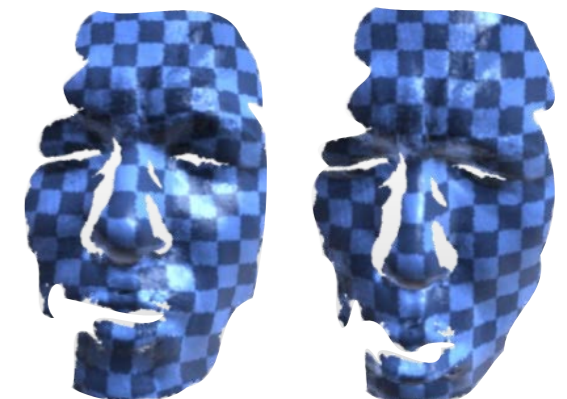
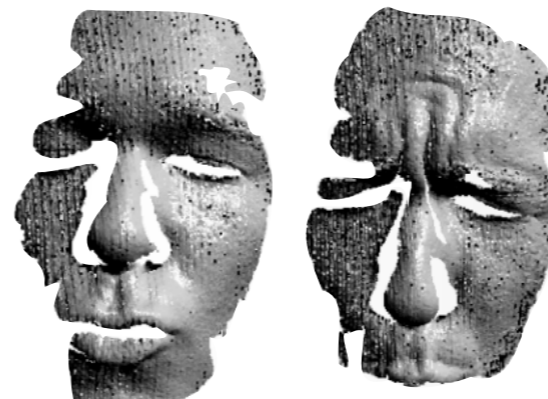
Remove noise, outliers



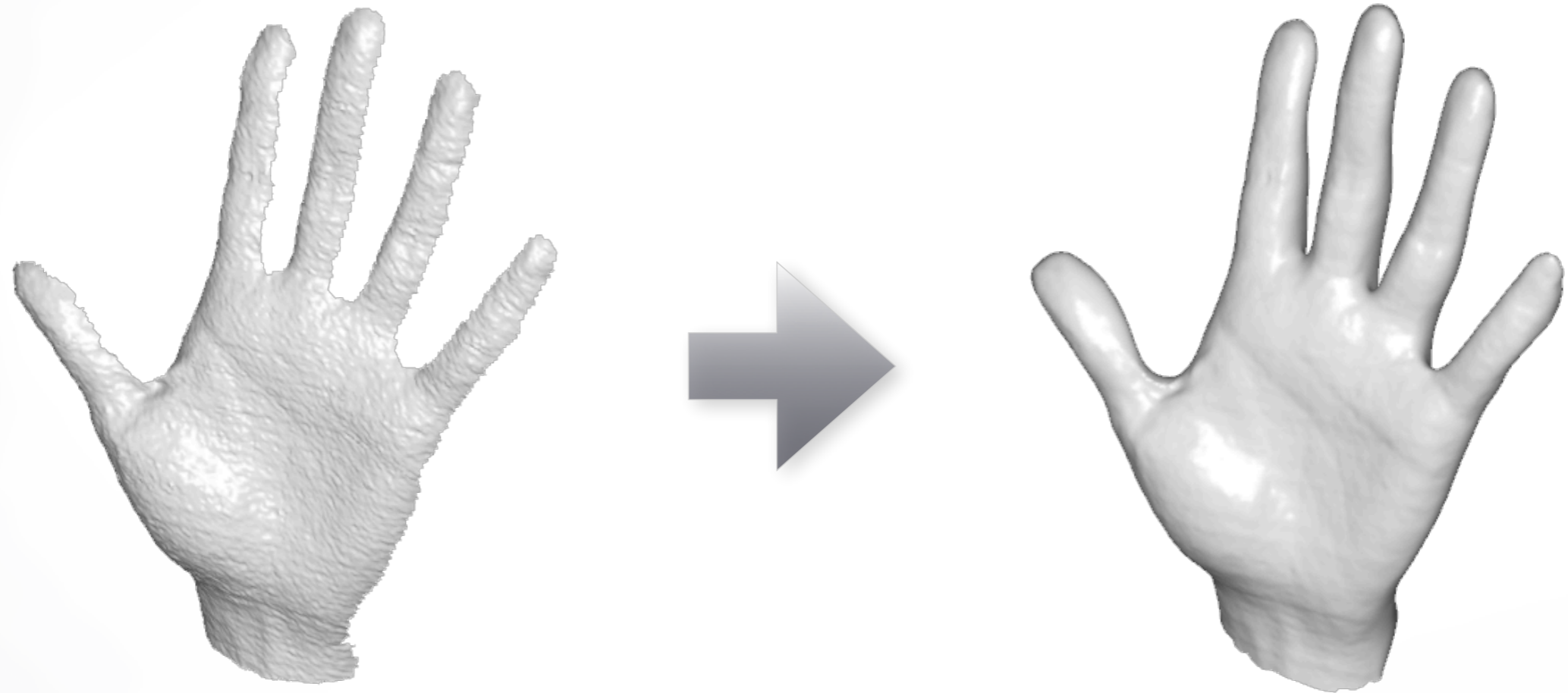
Fill in holes
(from all frames)



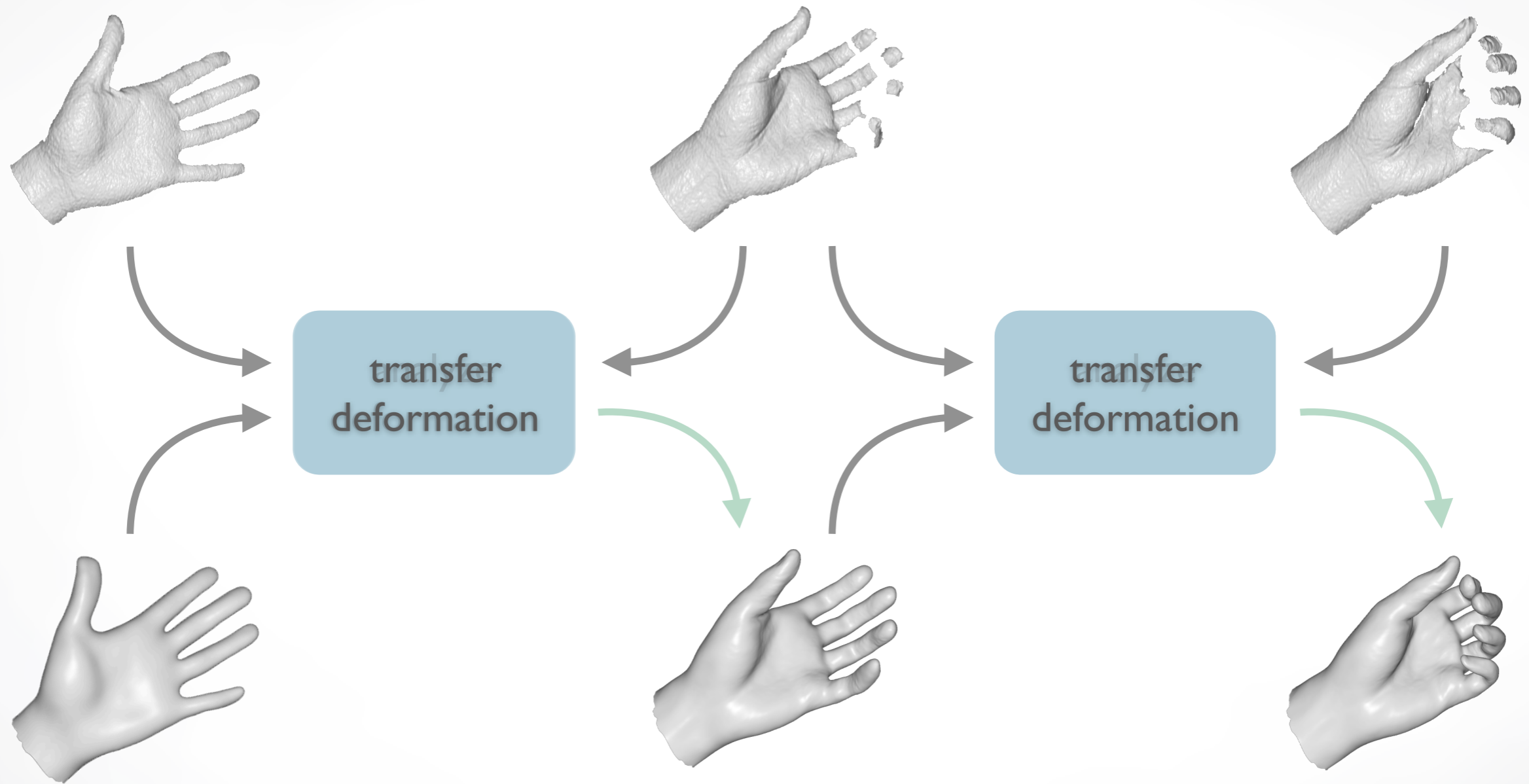
Find dense, temporally
coherent correspondences



Dynamic Shape Reconstruction



Template-Based Reconstruction

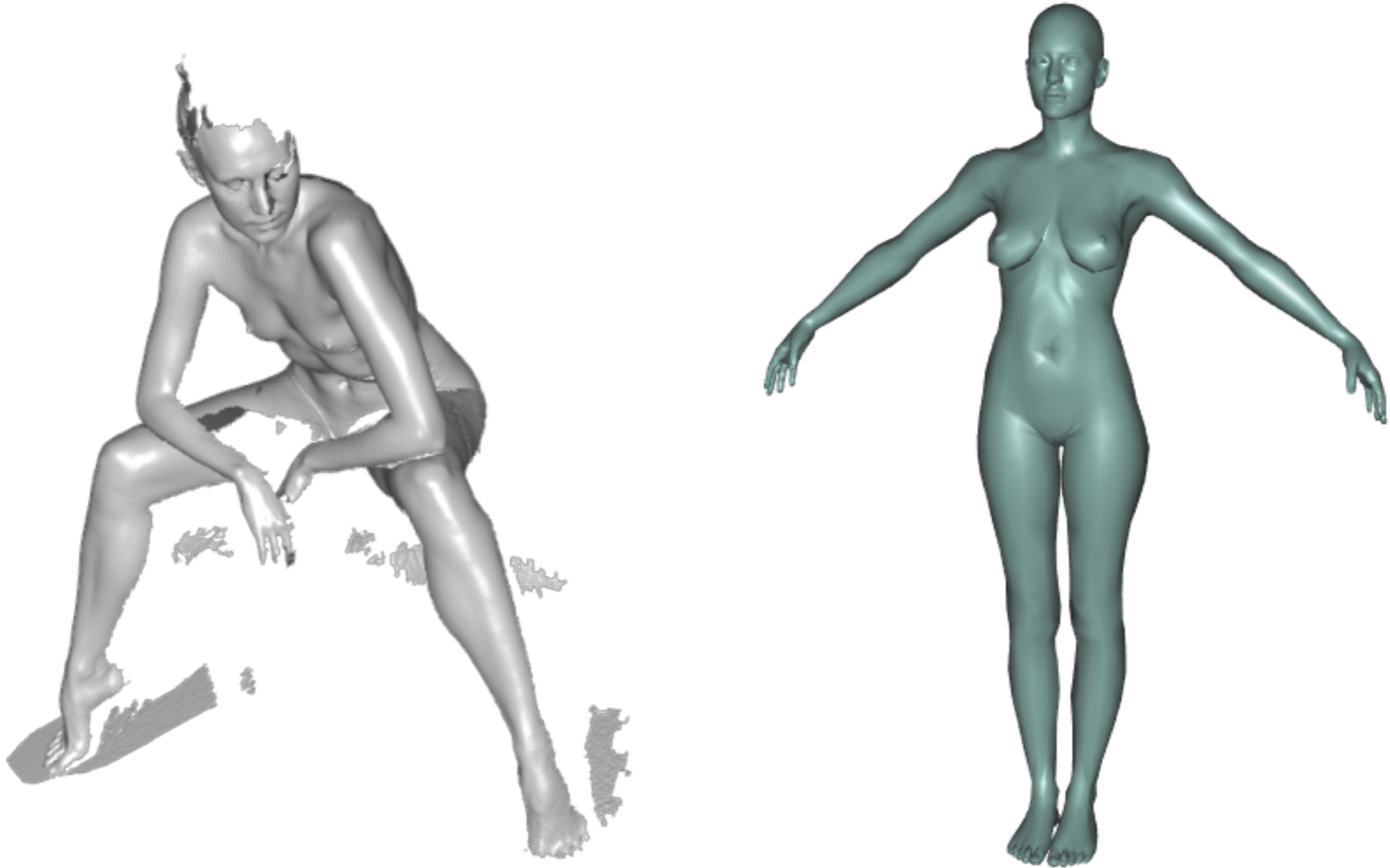


Correspondence Classification

Type of algorithm can depend on type of data that is available, or desired application

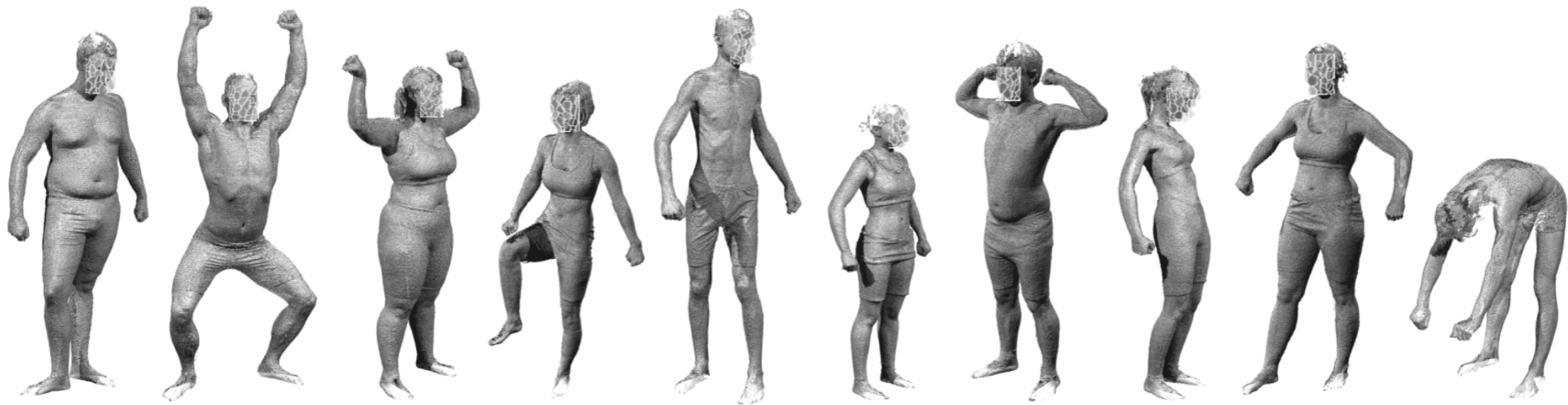
- Data: collection of models
- Application: statistical shape model

Pairwise Correspondence



shape & pose / general deformation

Statistical Shape Spaces



Courtesy of N. Hassler, MPI Informatik

- Scan a large number of individuals
 - Different poses
 - Different people
- Compute correspondences
- Build shape statistics (PCA, non-linear embedding)

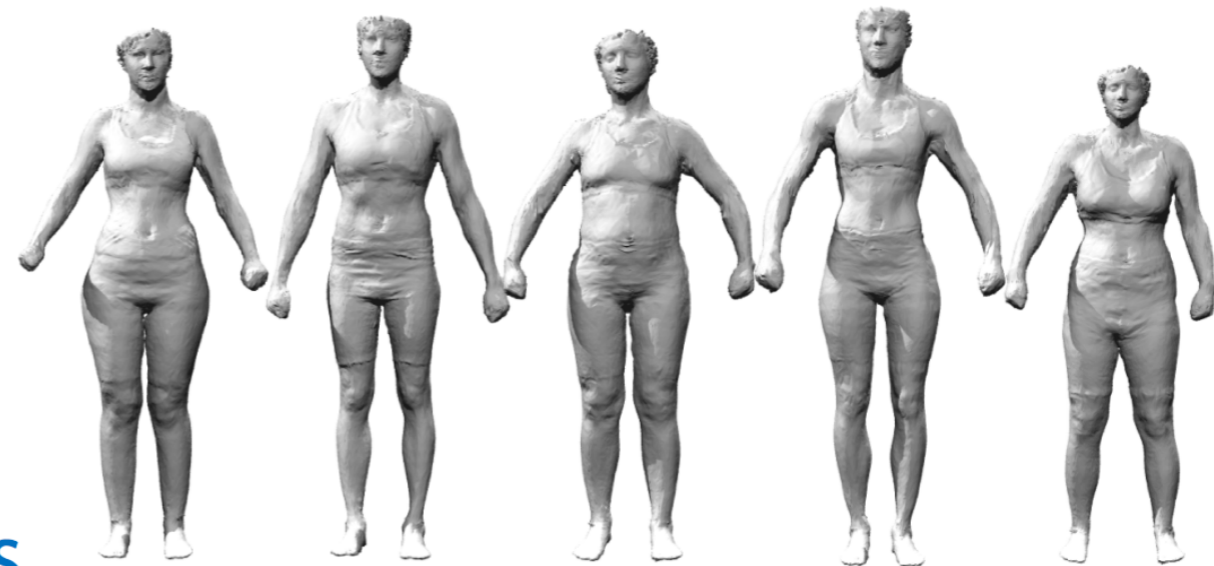
Statistical Shape Spaces

Numerous Applications:

- Fitting to ambiguous data (prior knowledge)
- Constraint-based editing
- Recognition, classification, regression



Courtesy of N. Hassler, MPI Informatik



Courtesy of N. Hassler, MPI Informatik

Building such models
requires correspondences

Scan Data - Challenges

“Real world data” is challenging, due to limitations in acquisition

- More noise for large working volumes
- Dynamic harder than static
- Passive (e.g. stereo) less robust than active

More than just “Gaussian noise”...

Challenges

“Noise”

- “Standard” noise types:

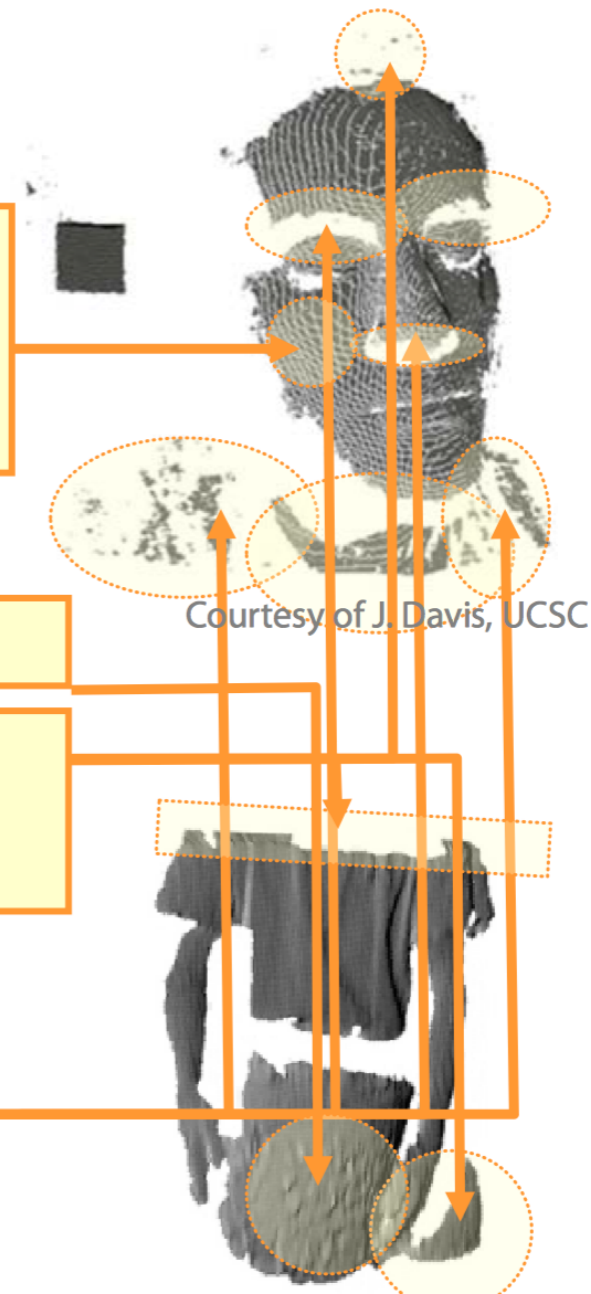
- Gaussian noise (analog signal processing)
- Quantization noise

- More problematic: structured noise

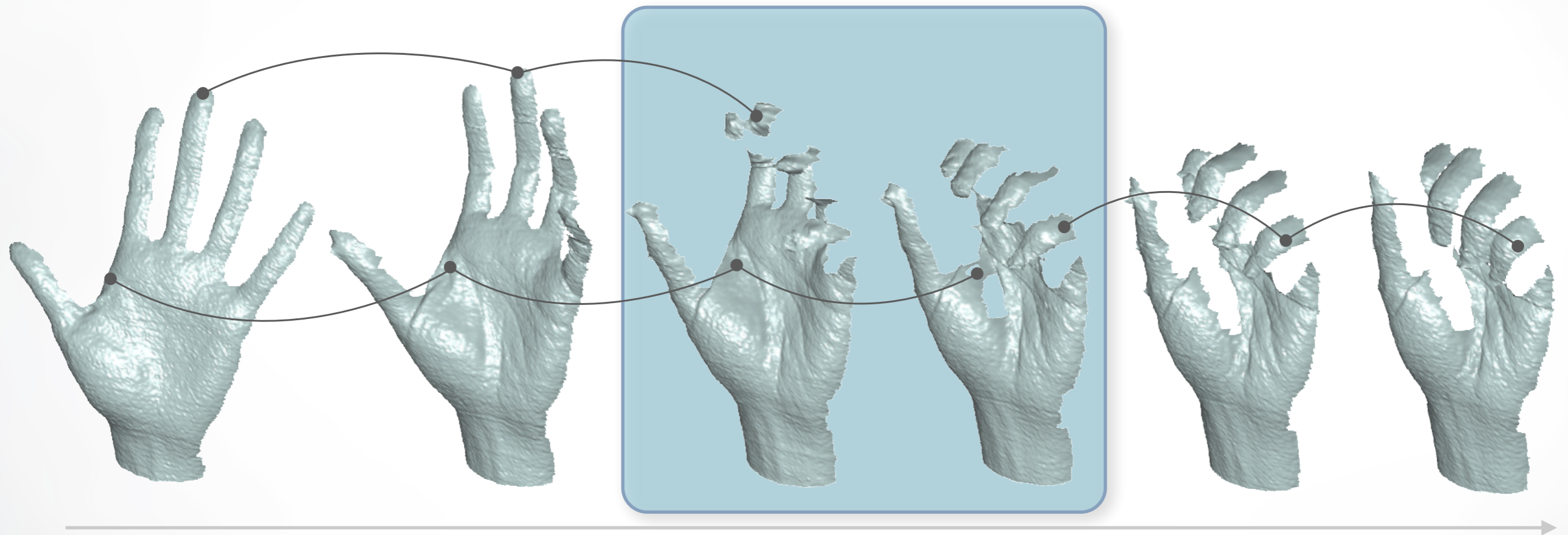
- Spatio-temporal correlations
- Structured outliers
- Reflective / transparent surfaces

- Incomplete Acquisition

- Missing parts
- Topological noise

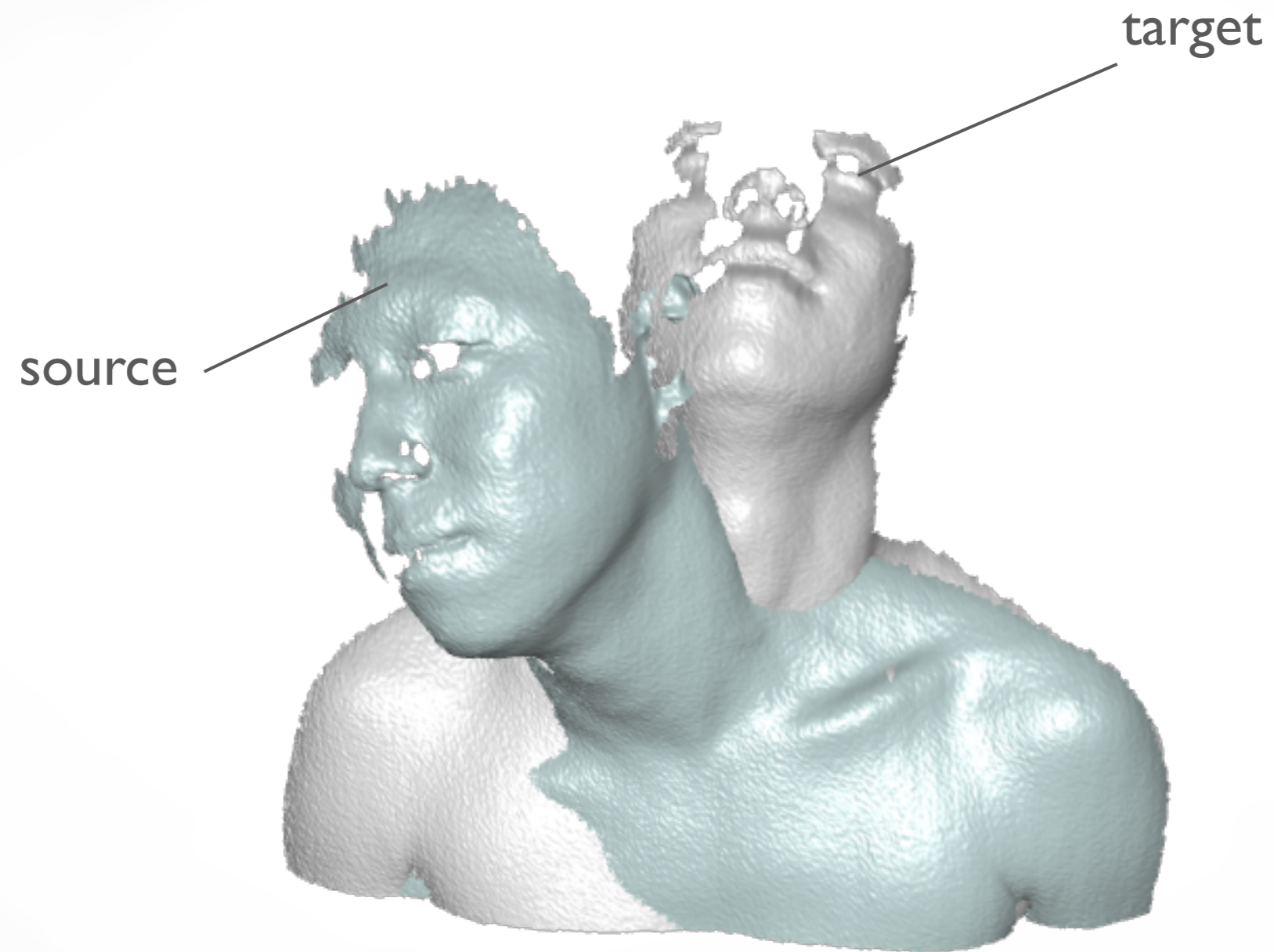


Correspondence Problem



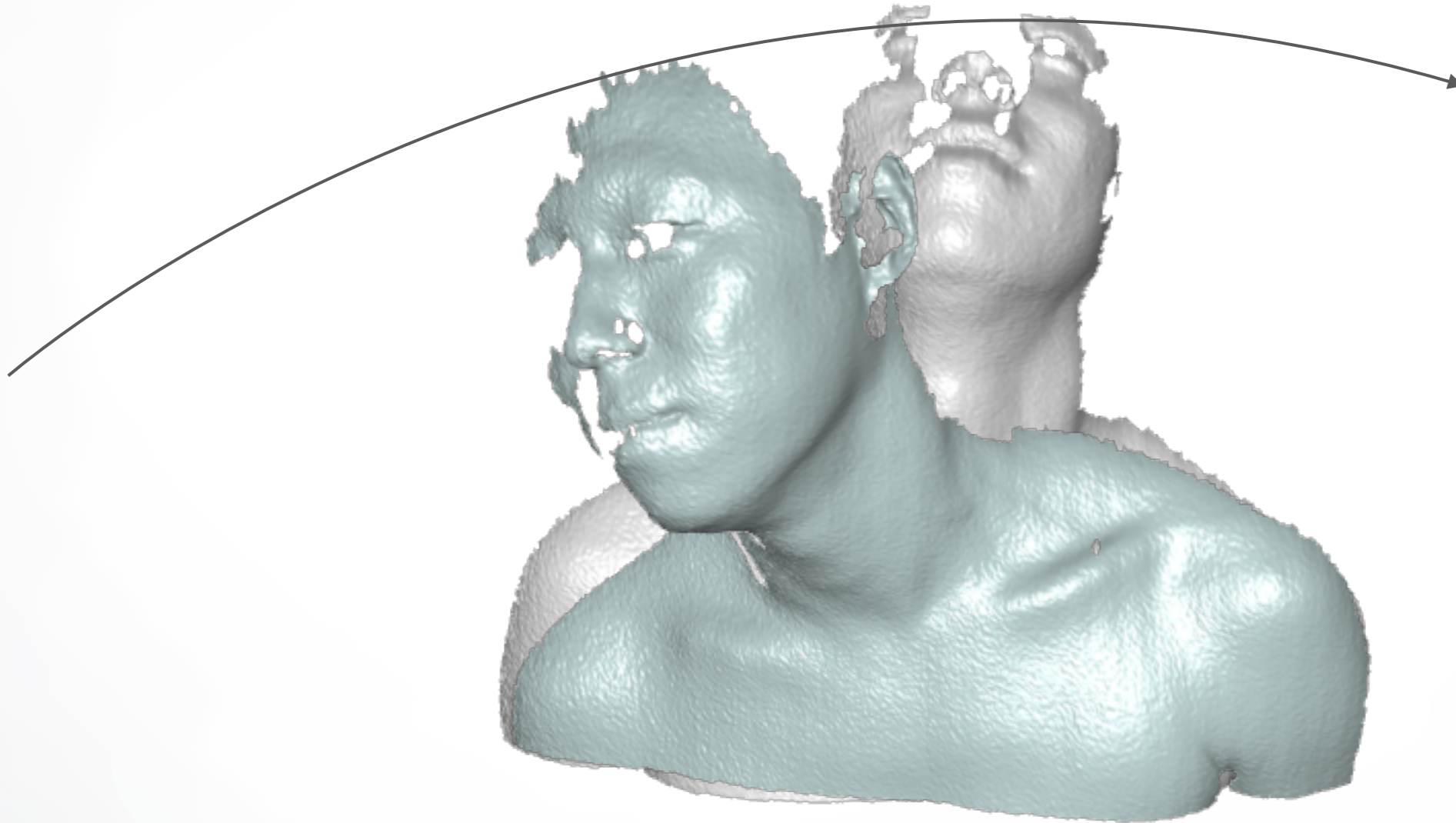
Non-Rigid Registration

Pair of 3D Scans

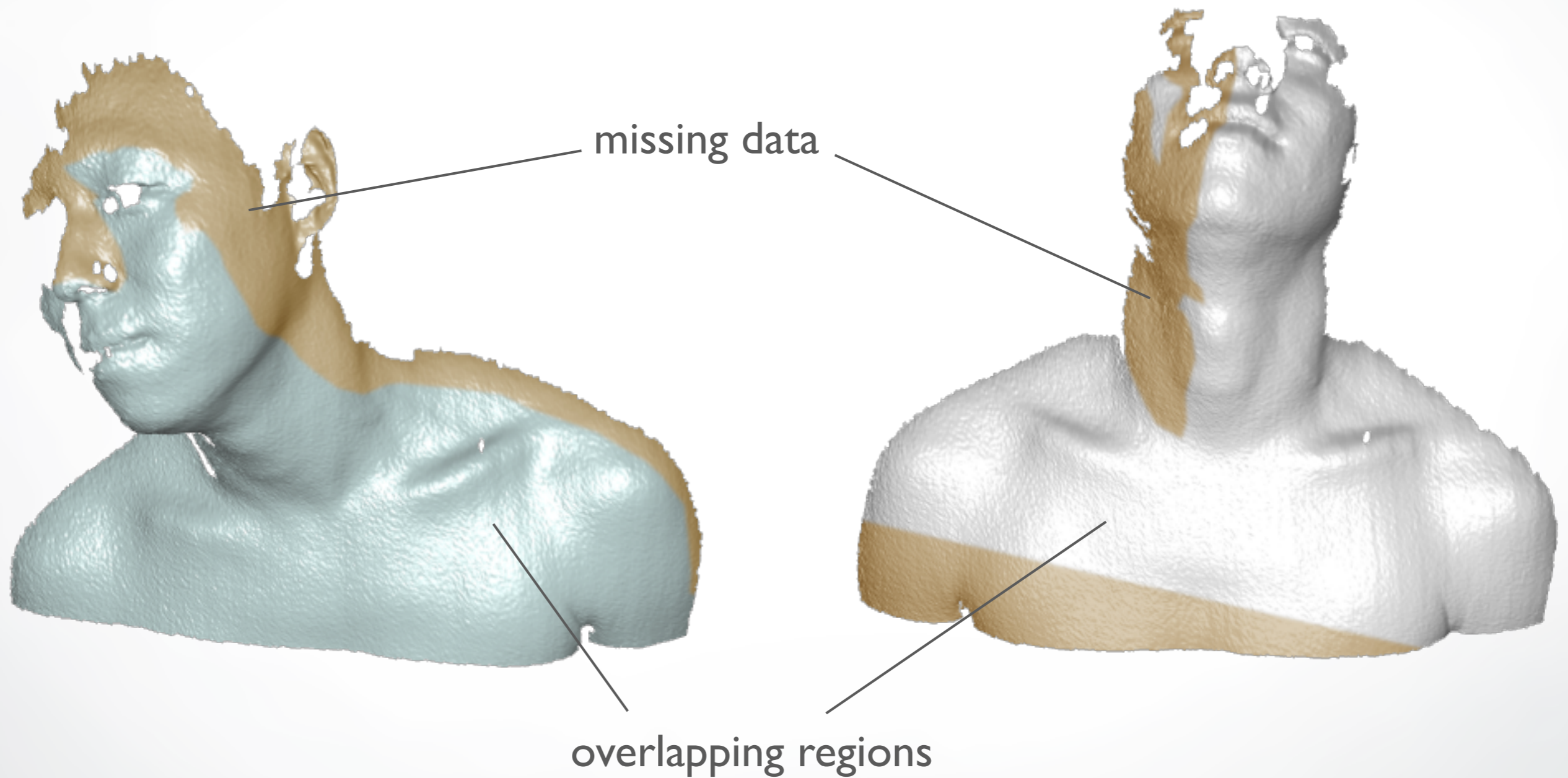


Correspondences are Lost

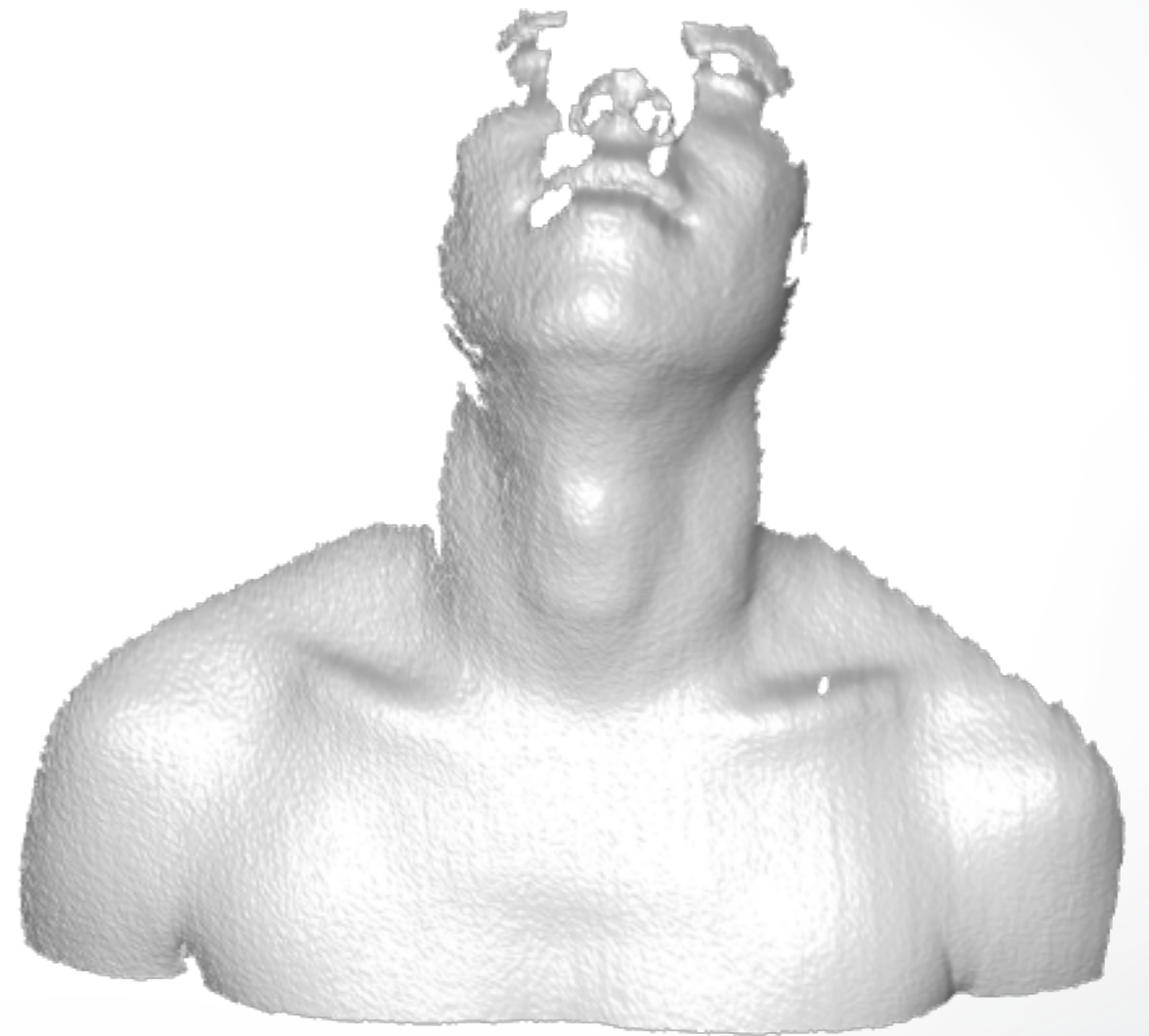
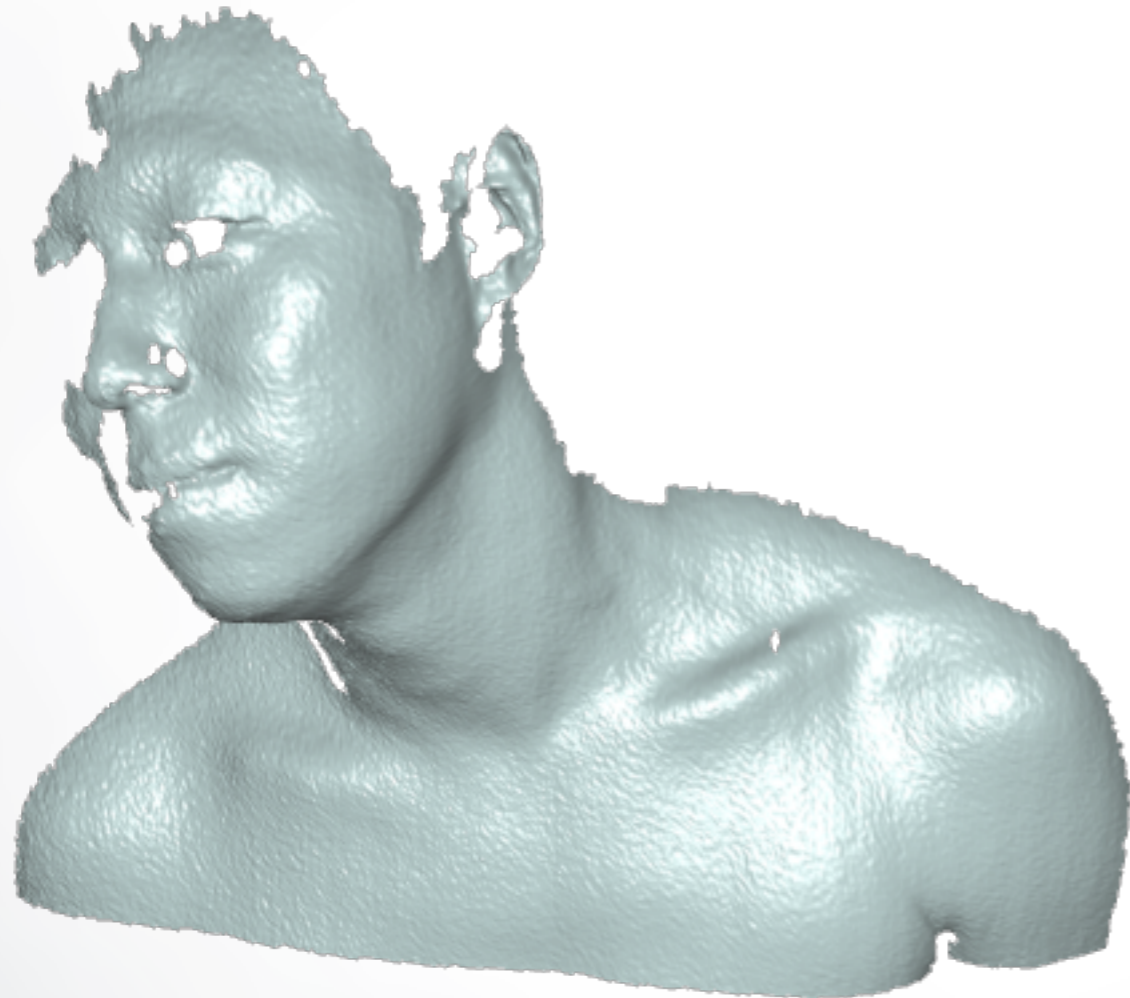
?



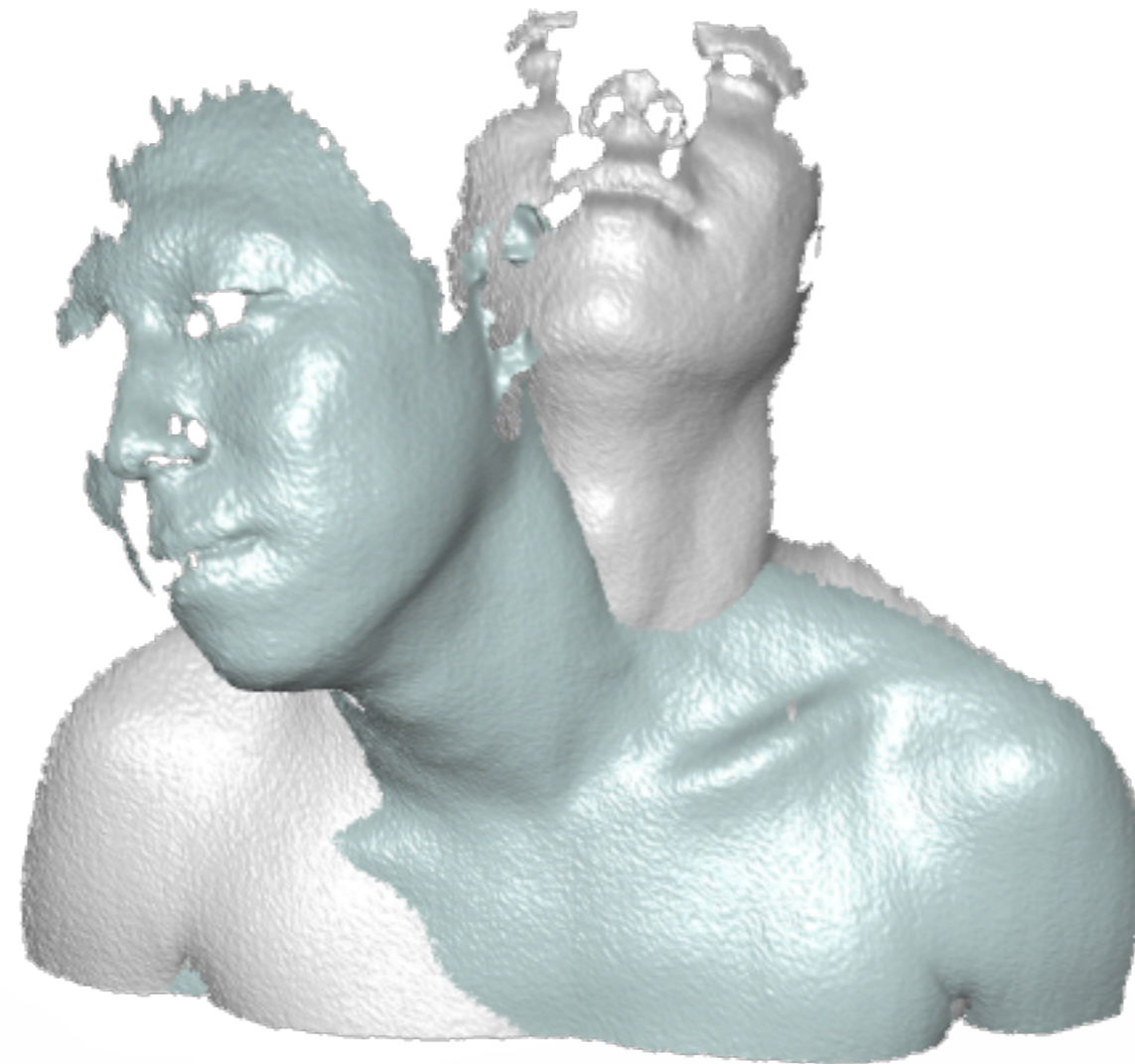
Overlapping Regions are Lost



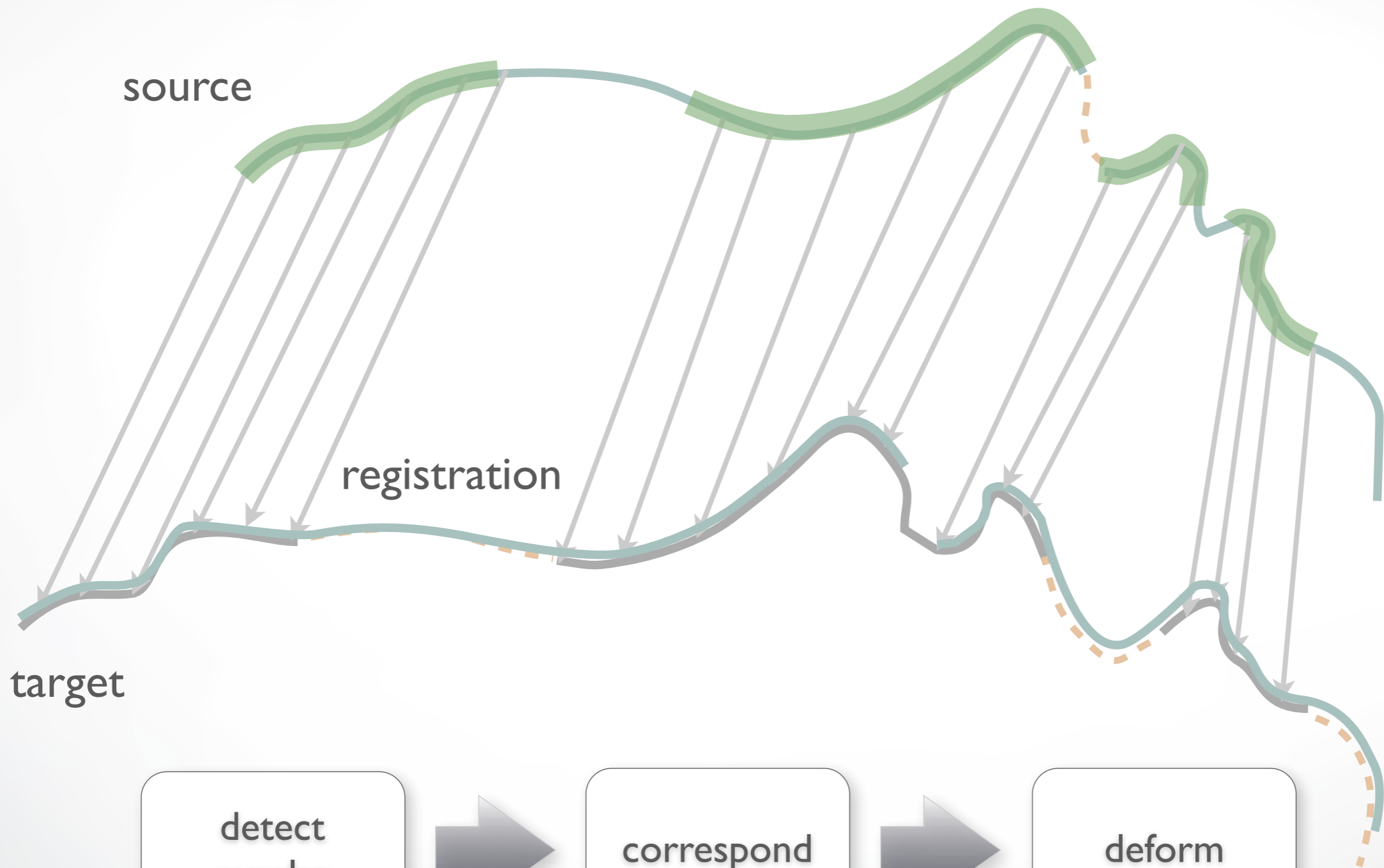
Overlapping Regions are Lost



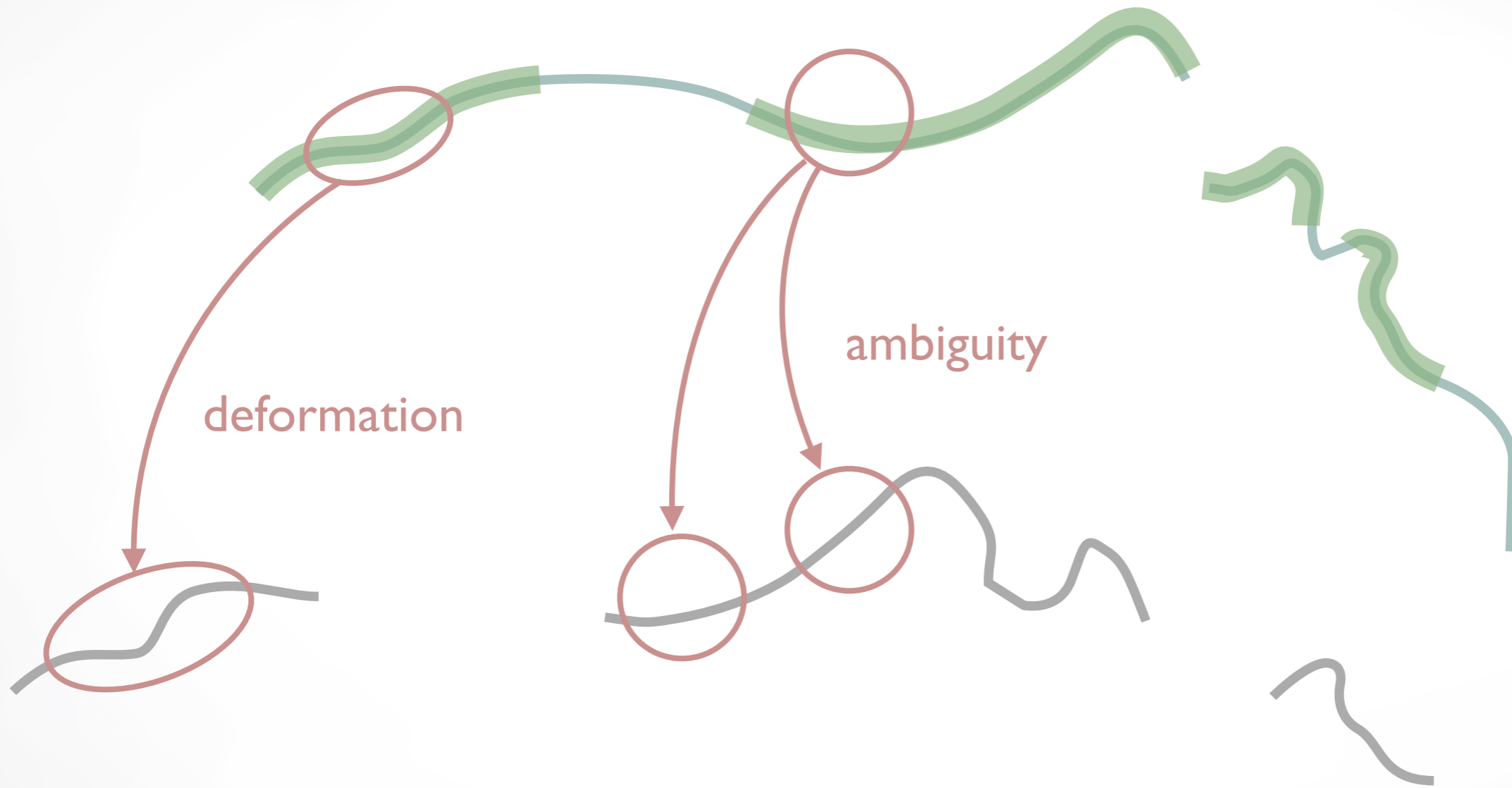
Non-Rigid Registration



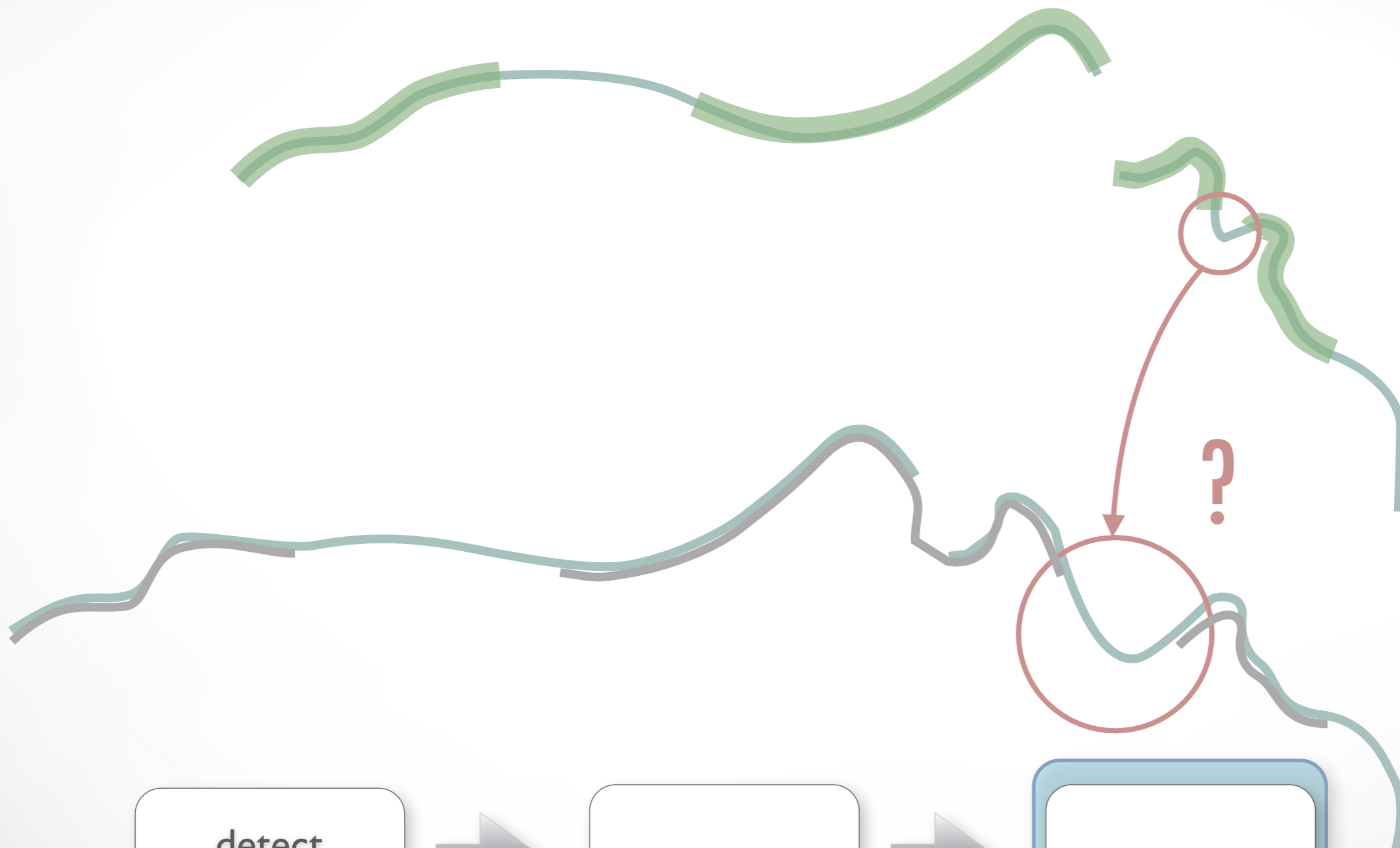
The Recipe



The Challenge



The Challenge



detect
overlap



correspond



deform

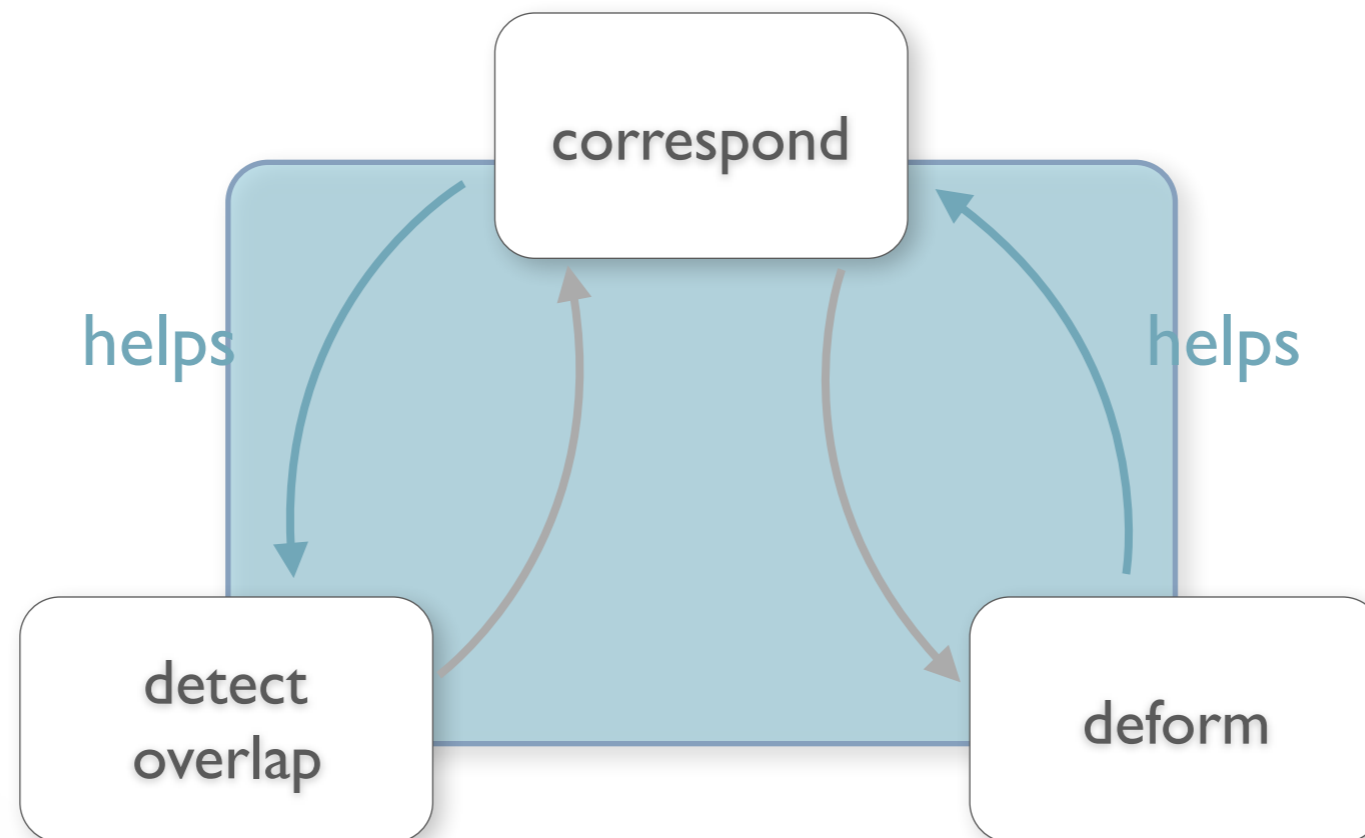
The Challenge

detect
overlap

correspond

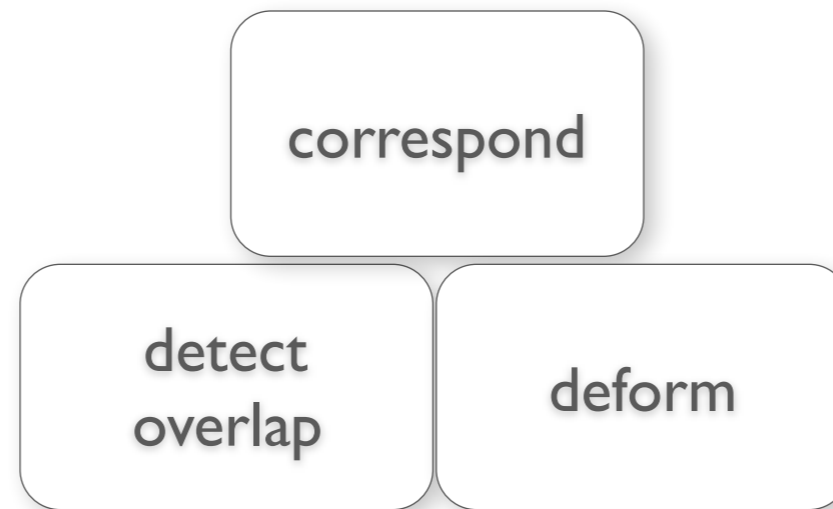
deform

Observation

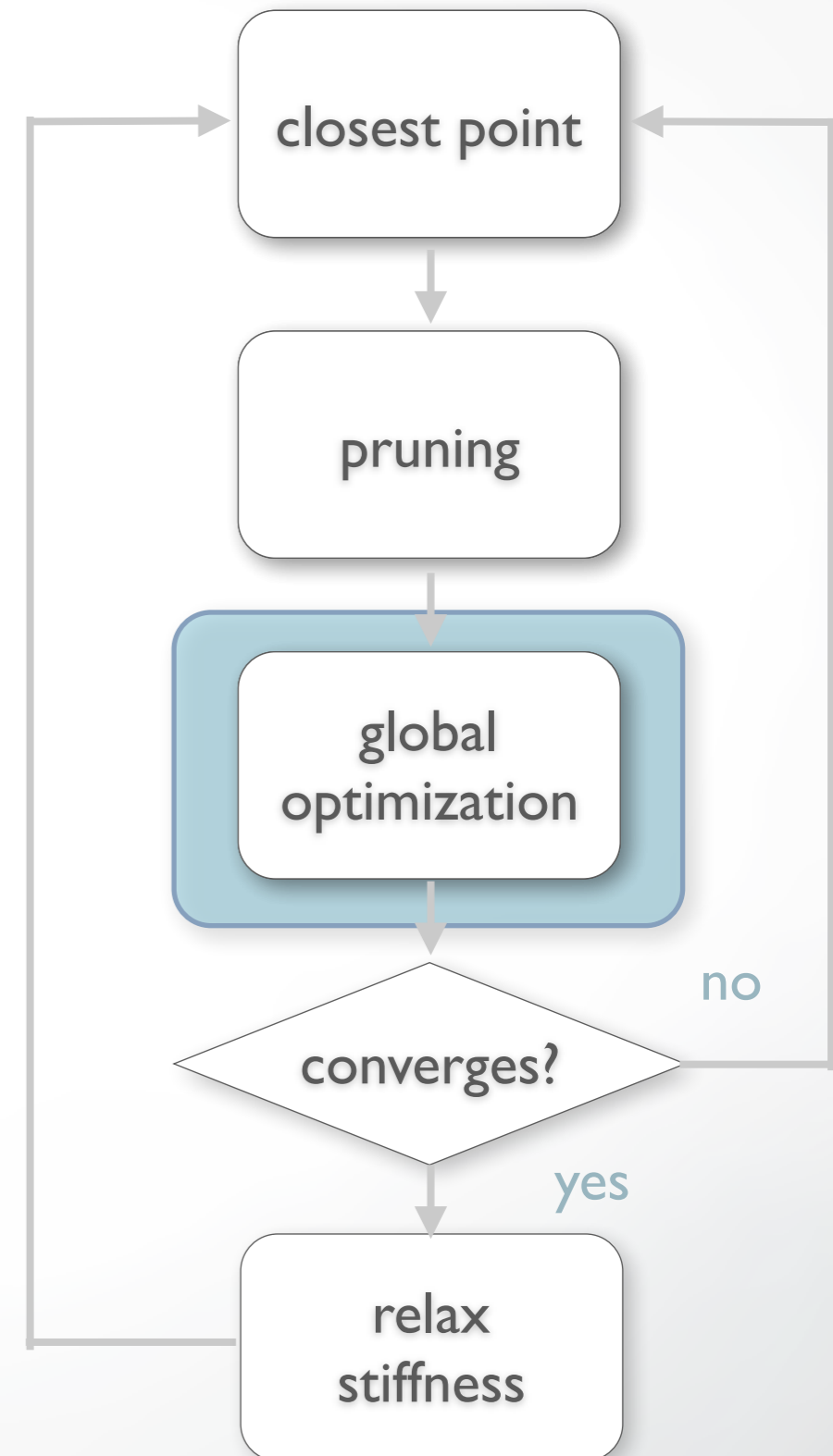
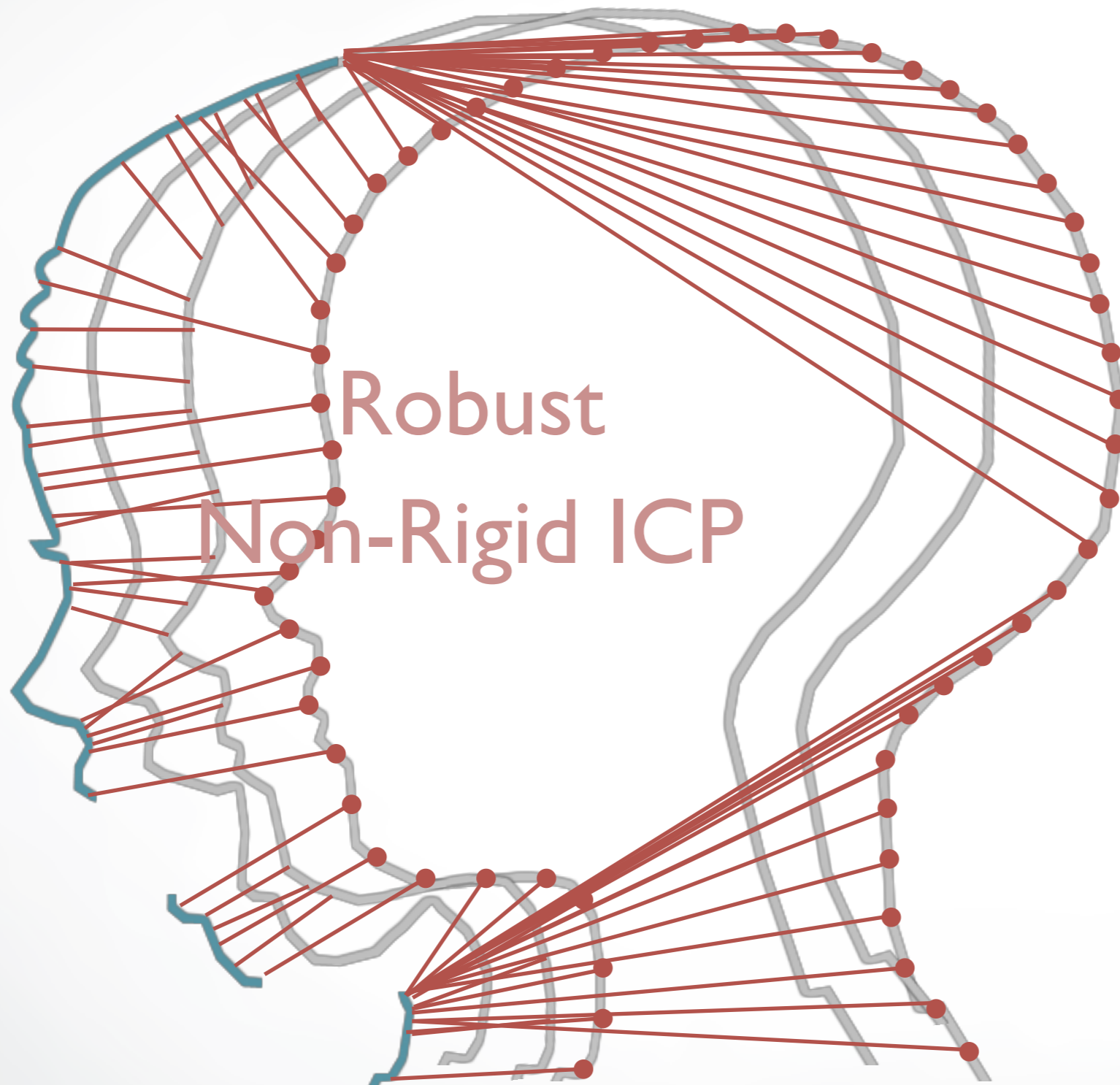


global optimization via local refinement

Iterative Global Optimization



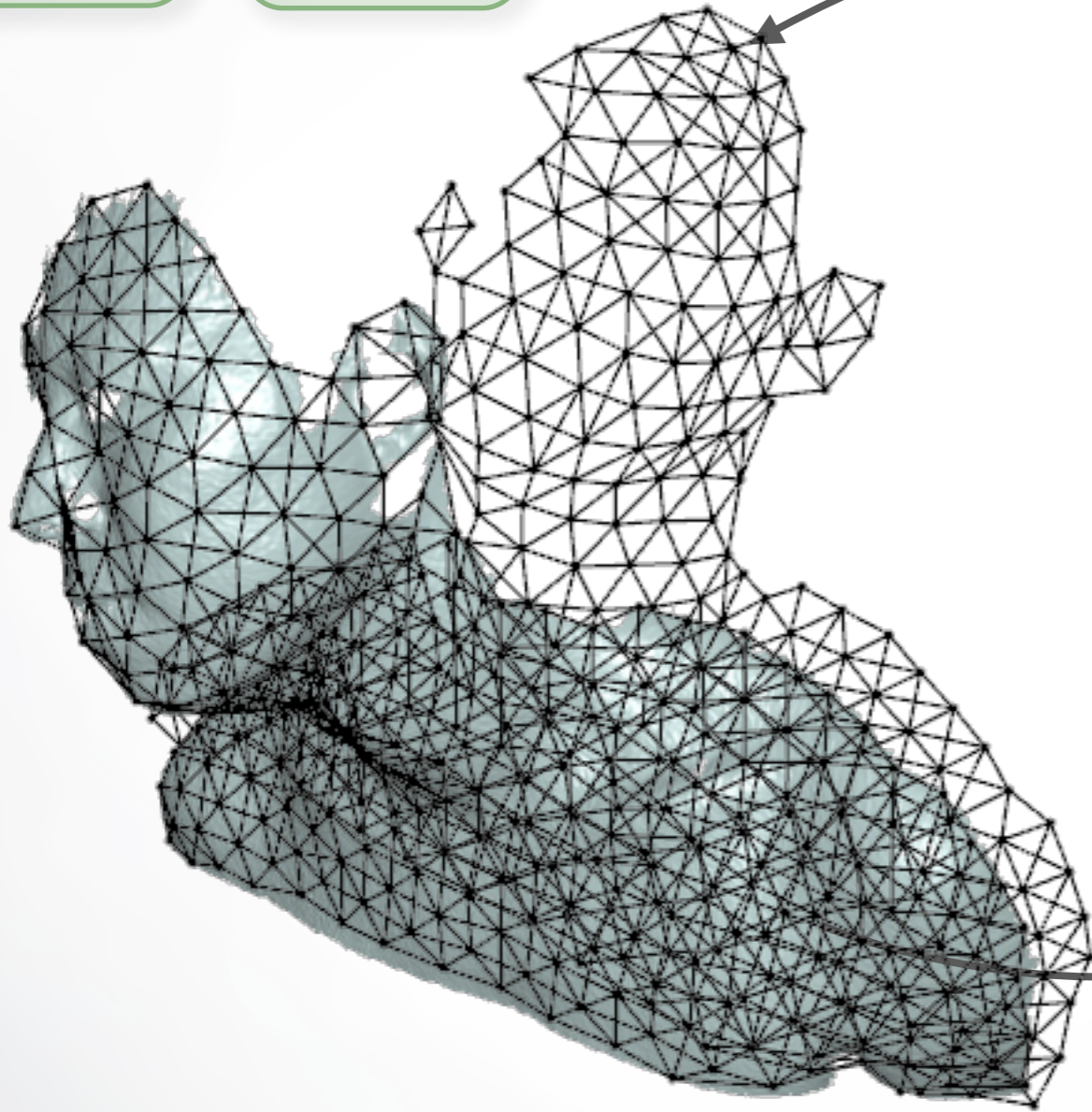
Iterative Global Optimization



Deformation Model

E_{rigid}

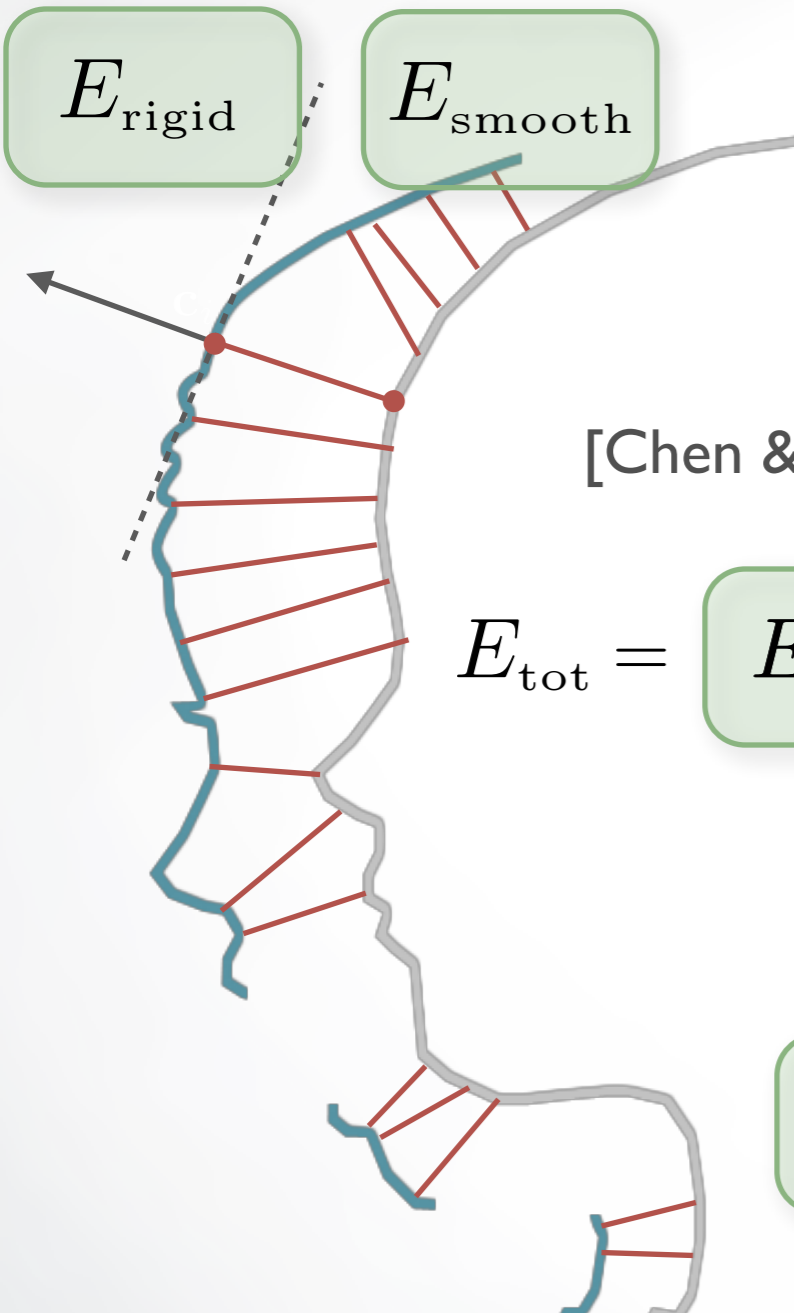
E_{smooth}



de-coupled
complexity

detail preservation
global consistency

Non-Linear Energy Minimization



[Chen & Medioni '92]

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

non-linear least squares
minimization

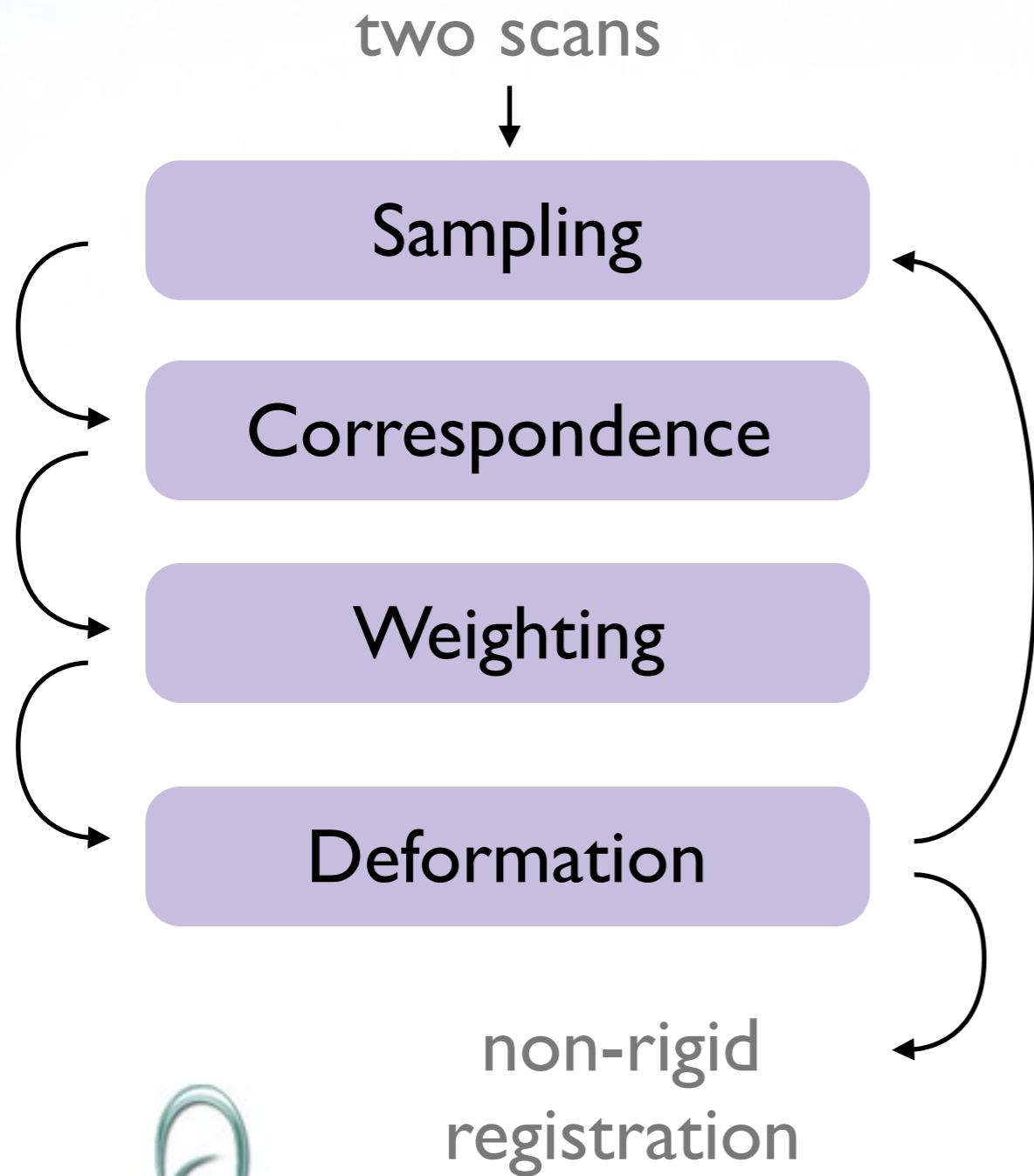
Jacobian is
sparse

Gauss-Newton method

sparse Cholesky factorization

that's it!

Summary



Correspondence must be robust w.r.t. underlying deformation

In general: Non-linear problem

$$E_{\text{tot}} = \alpha_{\text{fit}} E_{\text{fit}} + \alpha_{\text{reg}} E_{\text{reg}}$$



Summary

$$\alpha_{\text{smooth}} \rightarrow 0 \quad \alpha_{\text{rigid}} \rightarrow 0$$

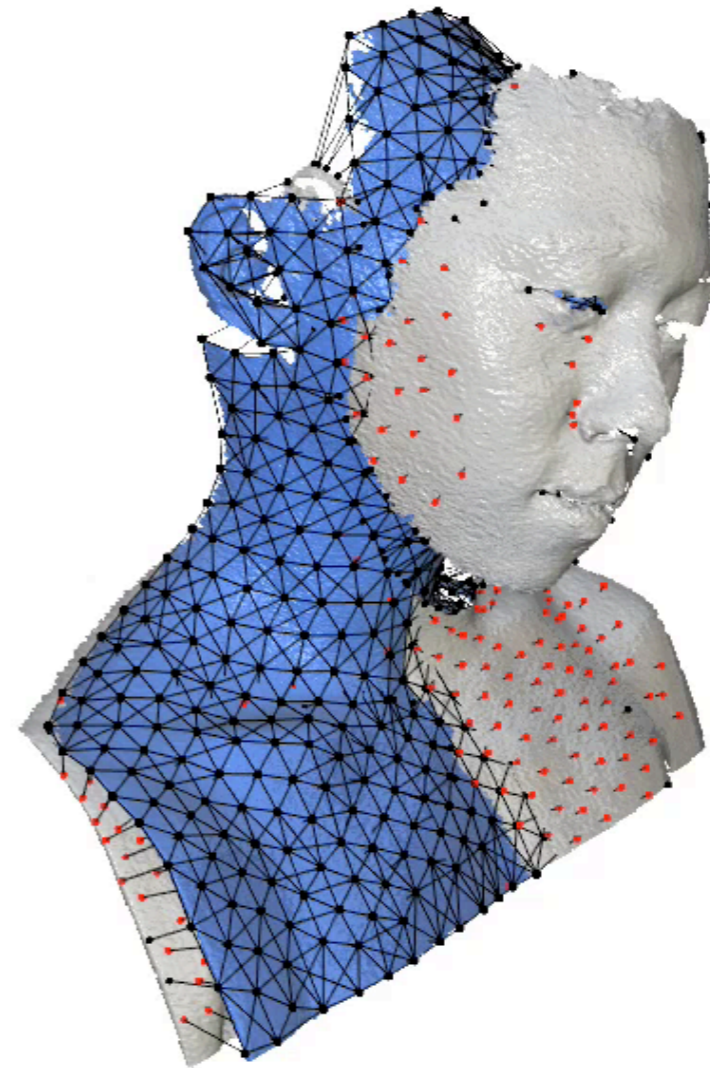
Relax Regularization

Correspondence

Weighting

Deformation

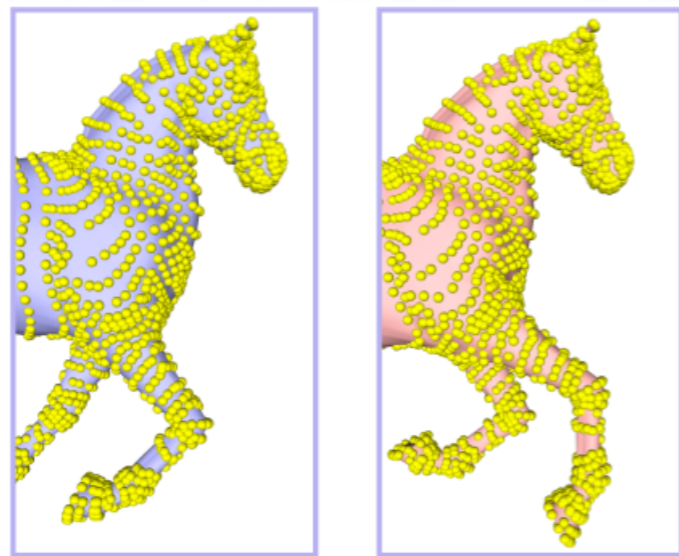
non-rigid
registration



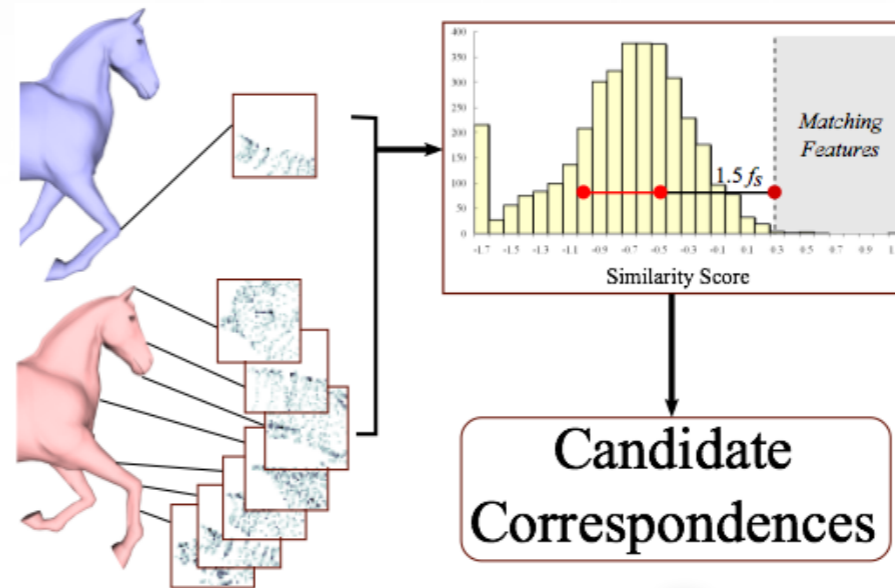
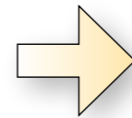
- Example with Embedded Deformation Model



Symmetries



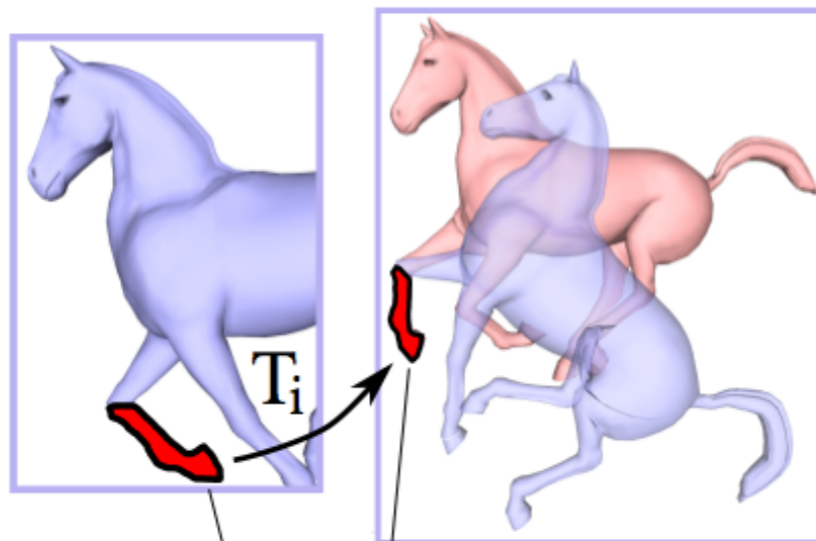
sampling



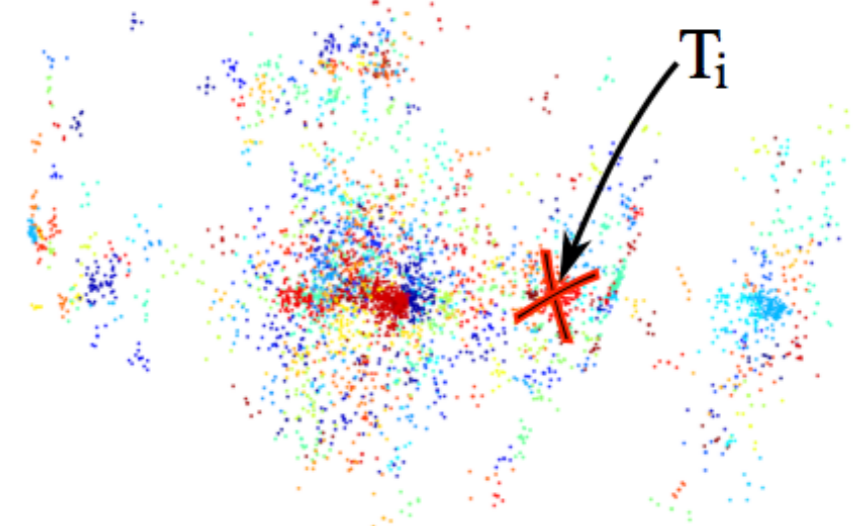
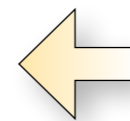
feature matching



clustering



region matching



Source: [Chang and Zwicker 08]



Isometry Preservation

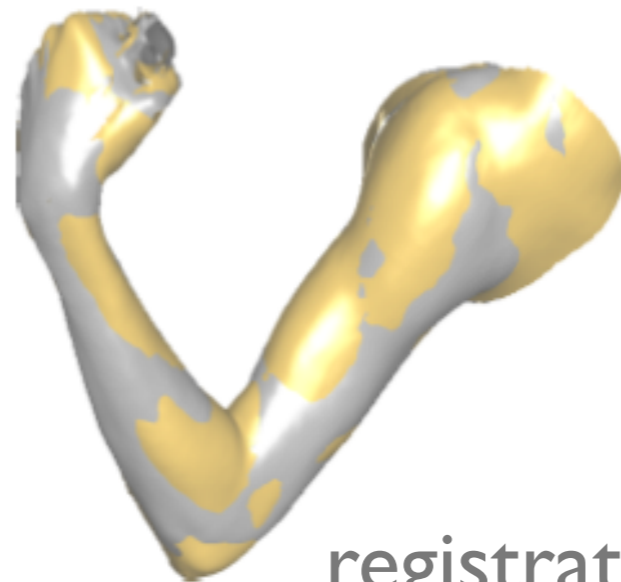
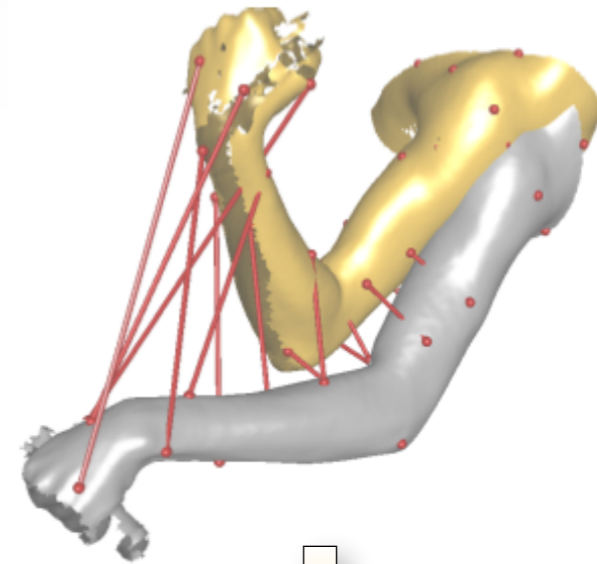
input data



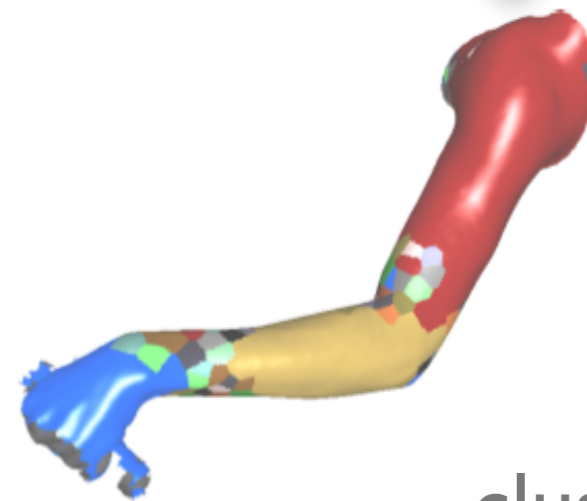
sampling



correspondence



registration



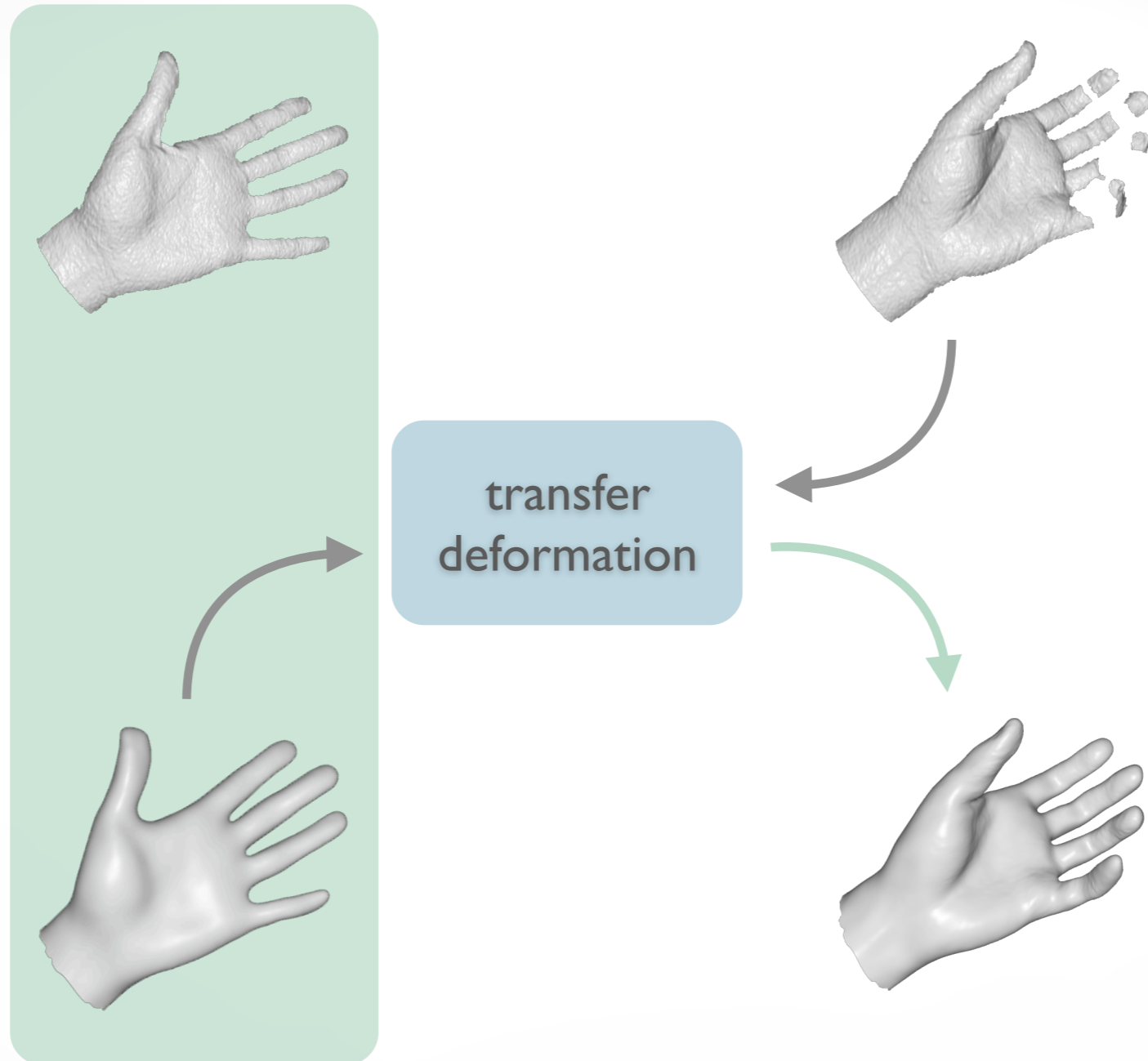
clustering



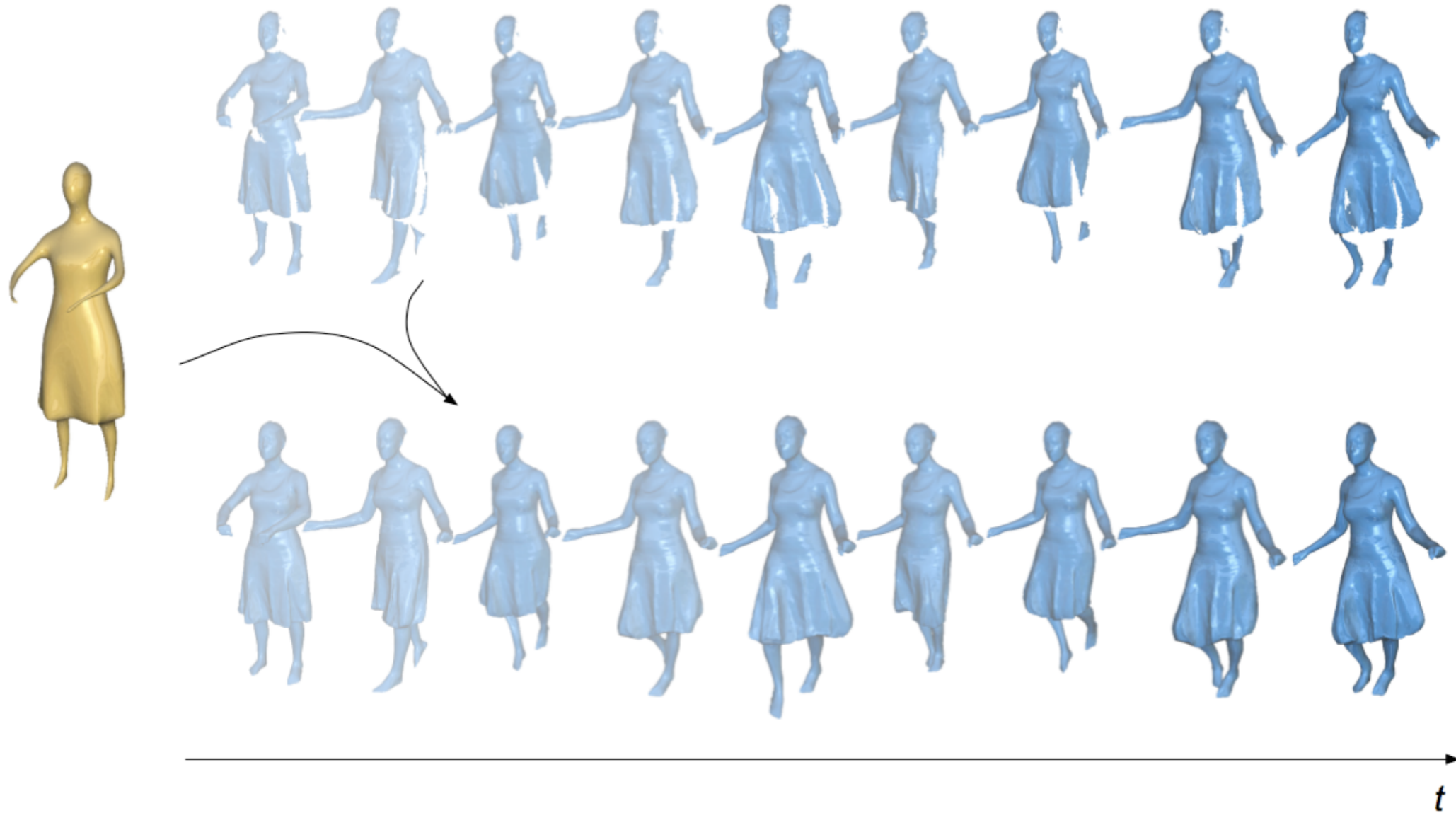
Source: [Huang et al. 08]

Dynamic Shape Reconstruction

Multi-Frame Reconstruction



Geometry and Motion Reconstruction



data provided by Stanford and MPI Saarbrücken



input data



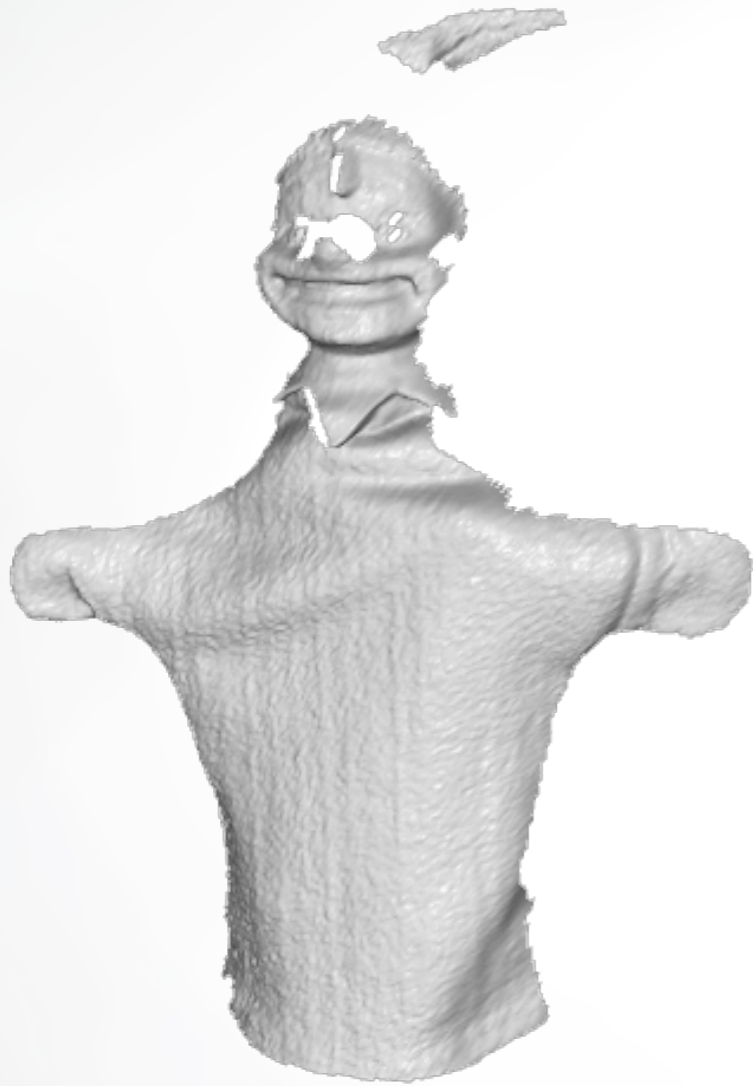
template fitting



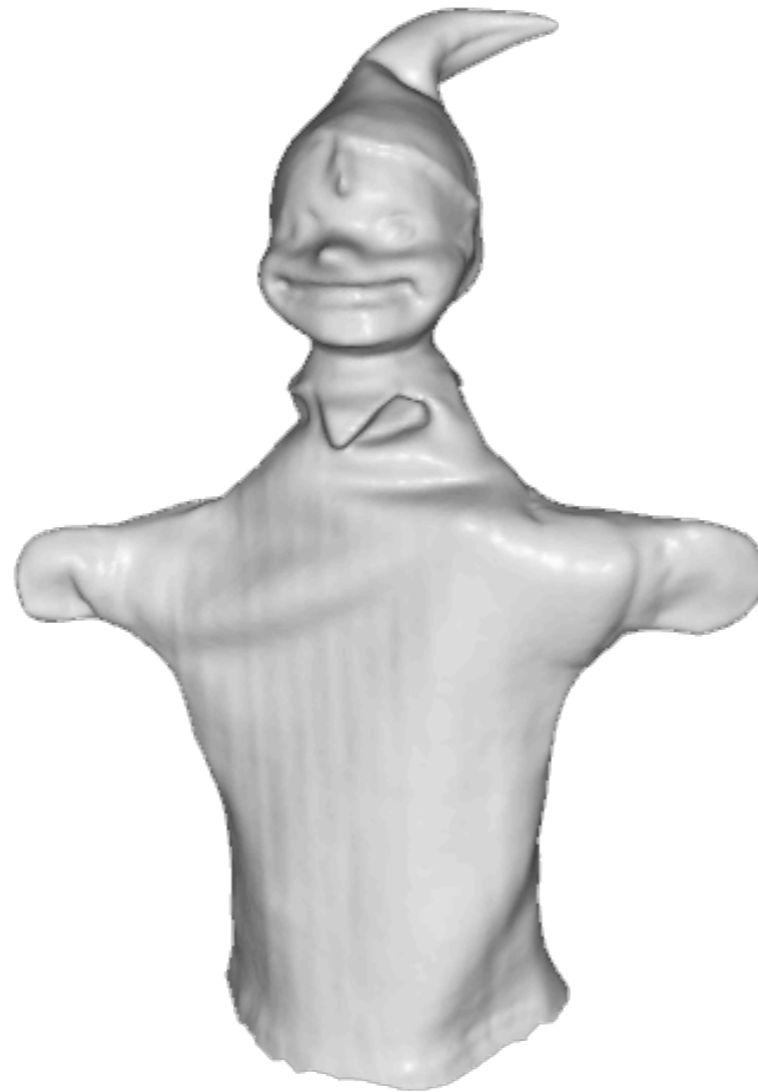
data provided by Stanford and MPI Saarbrücken



More Results



Input Scans



Reconstruction



Textured Reconstruction

More Results



Input Scans

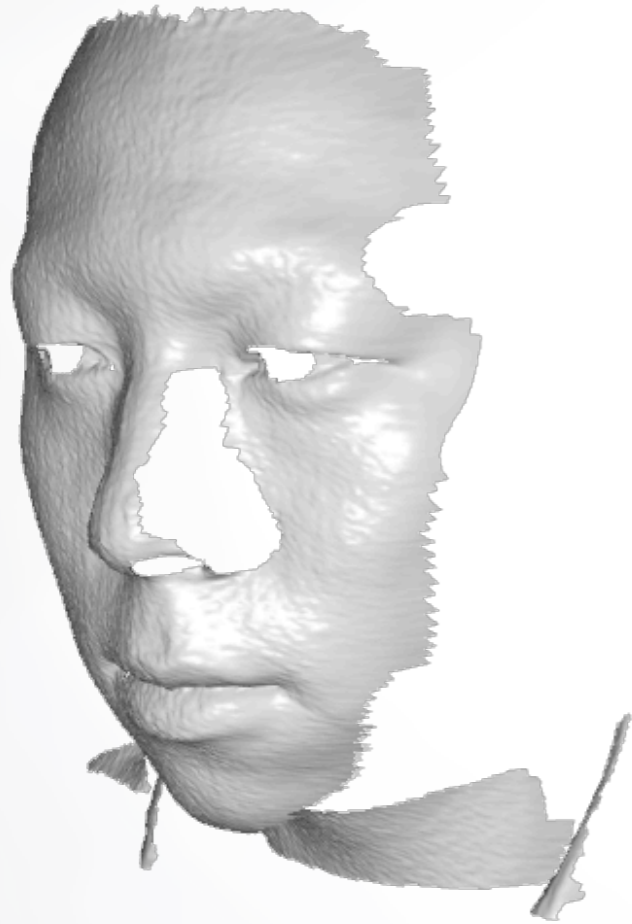


Reconstruction



Textured Reconstruction

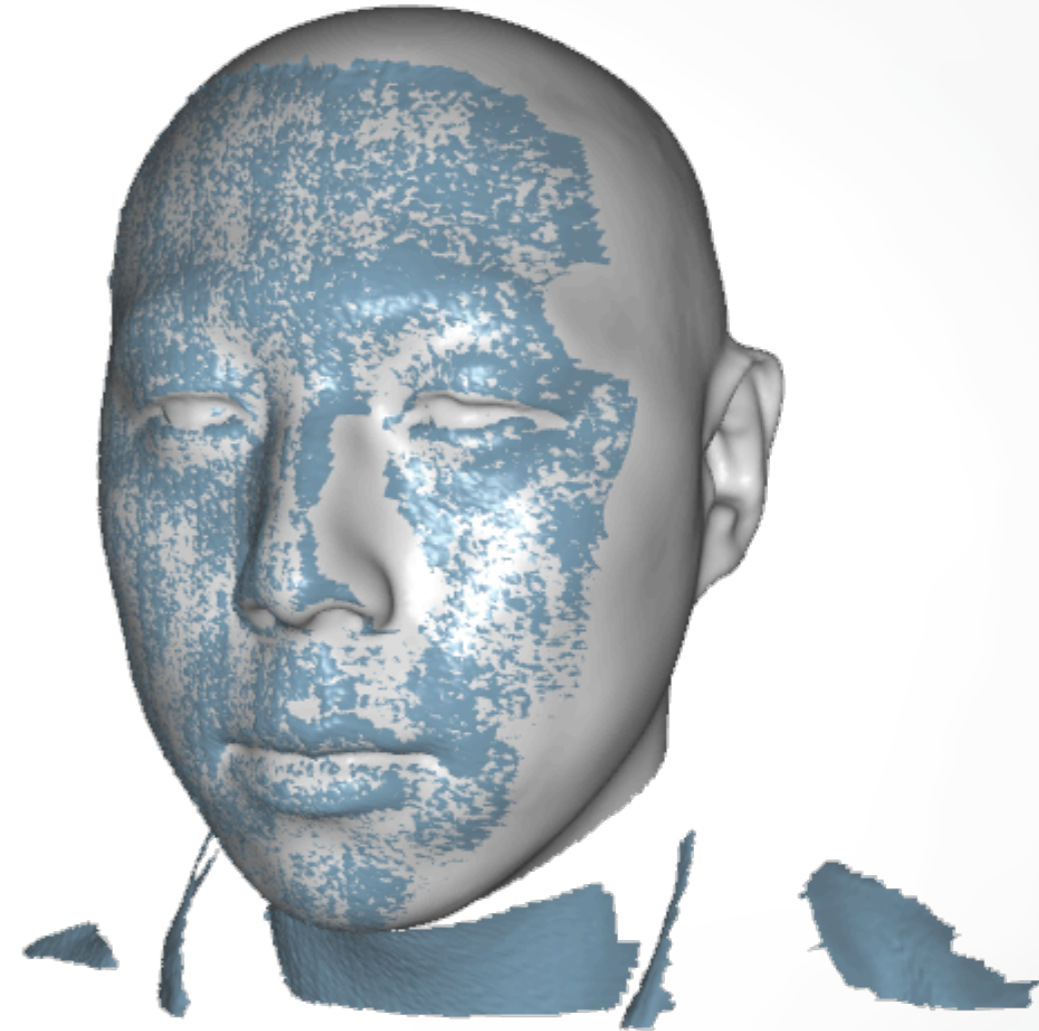
More Results



Input Scans



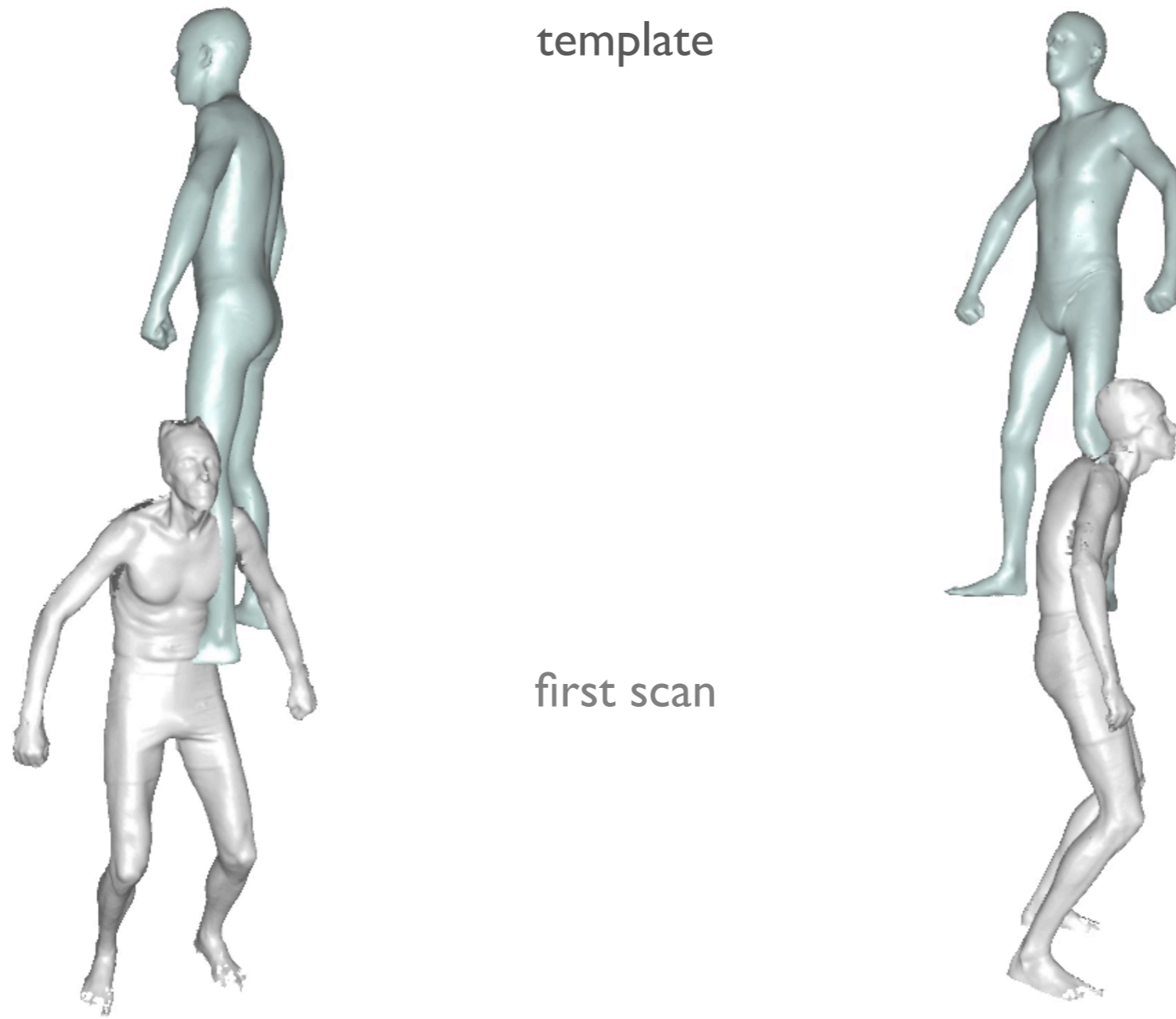
Reconstruction



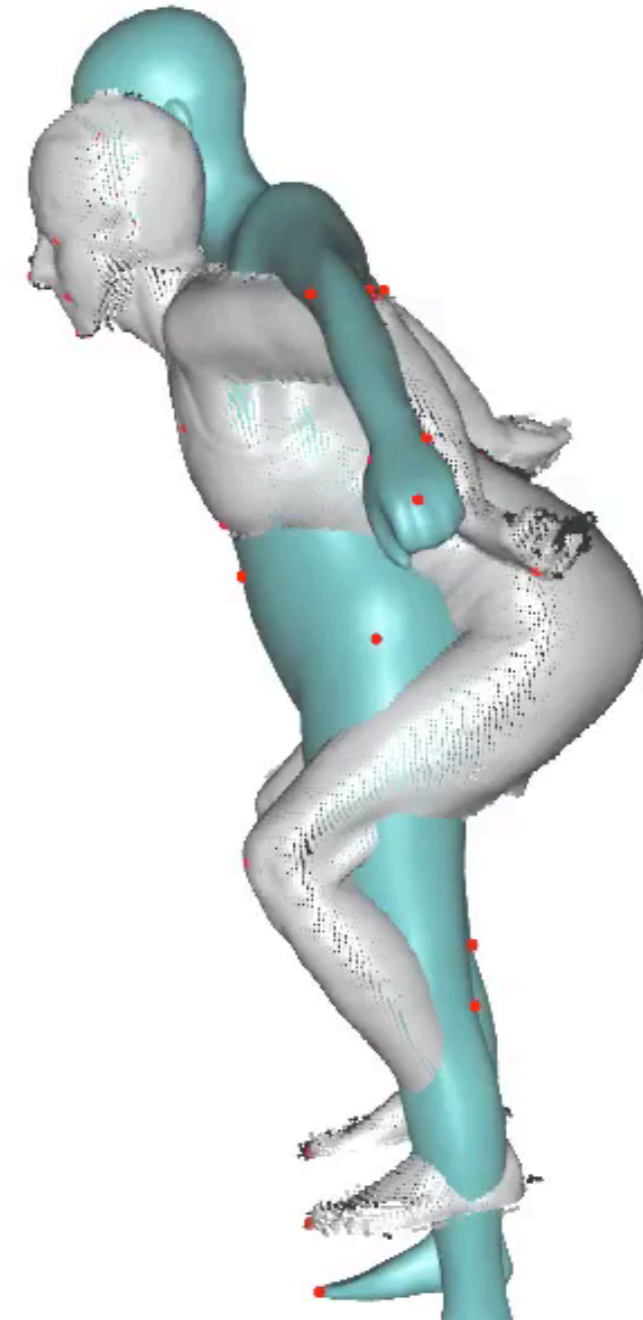
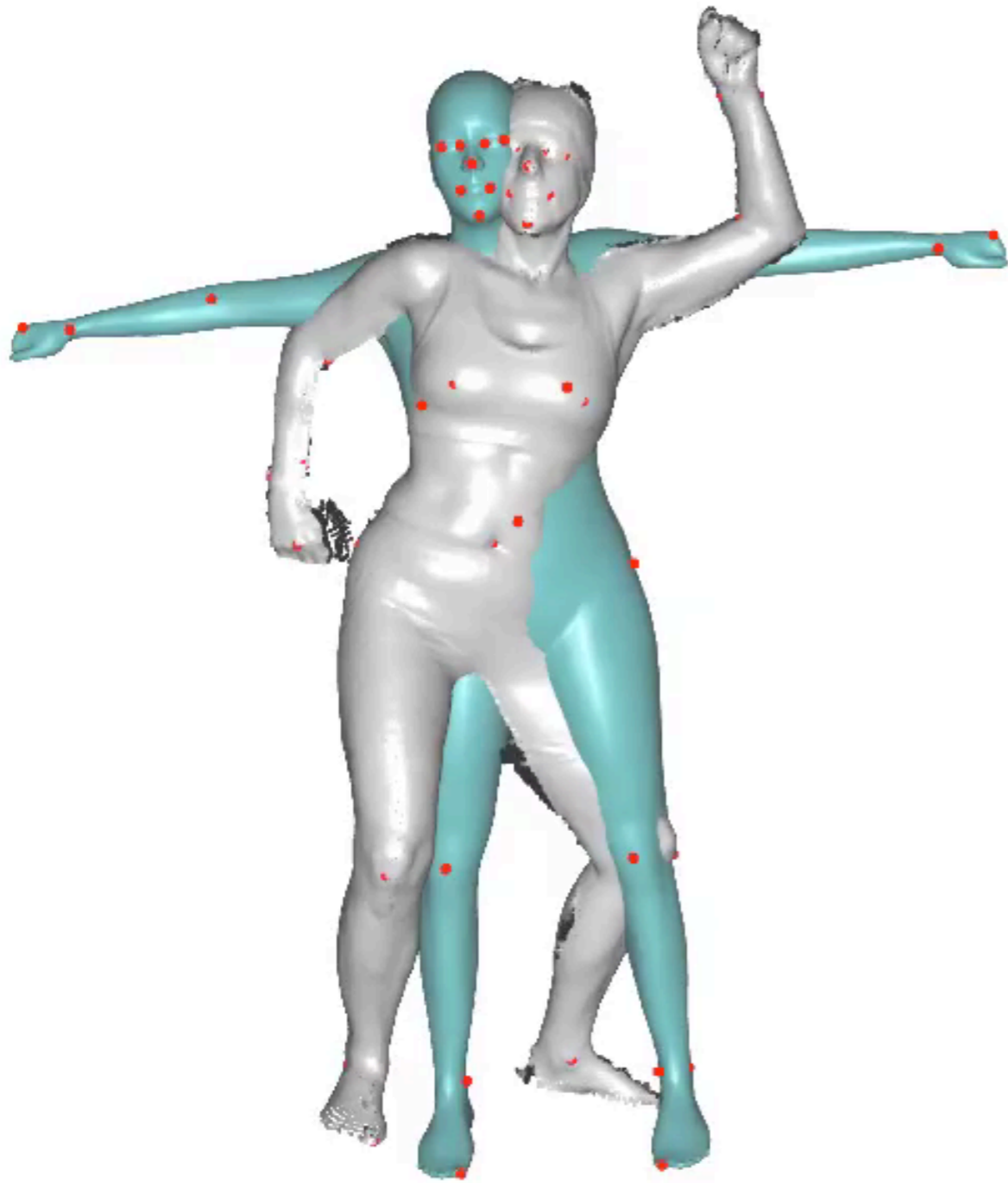
Overlaid Scans

Template Fitting

Initial Alignment



In Practice: Need Some Correspondences



Improving SCAPE



non-rigid alignment



pose estimation



regression



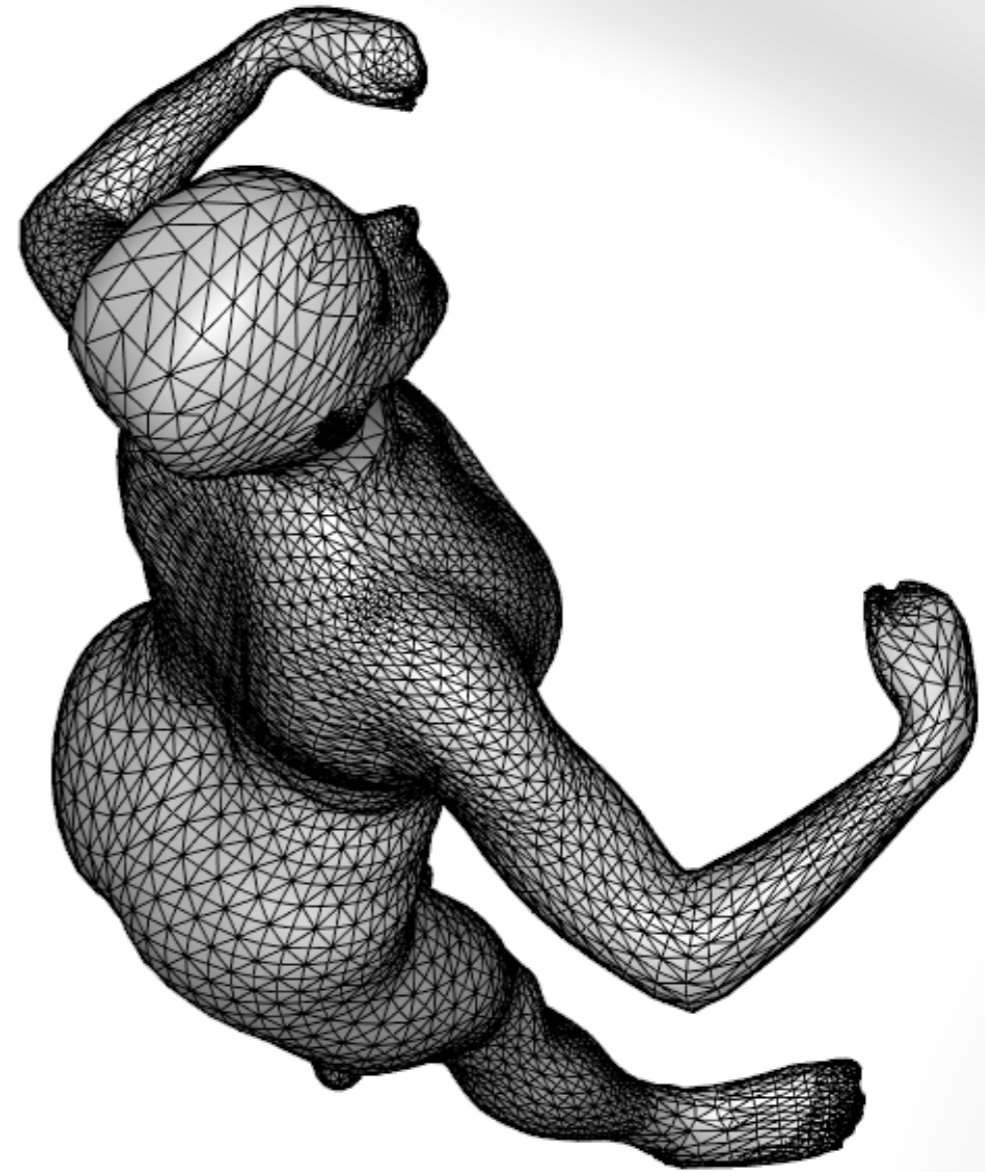
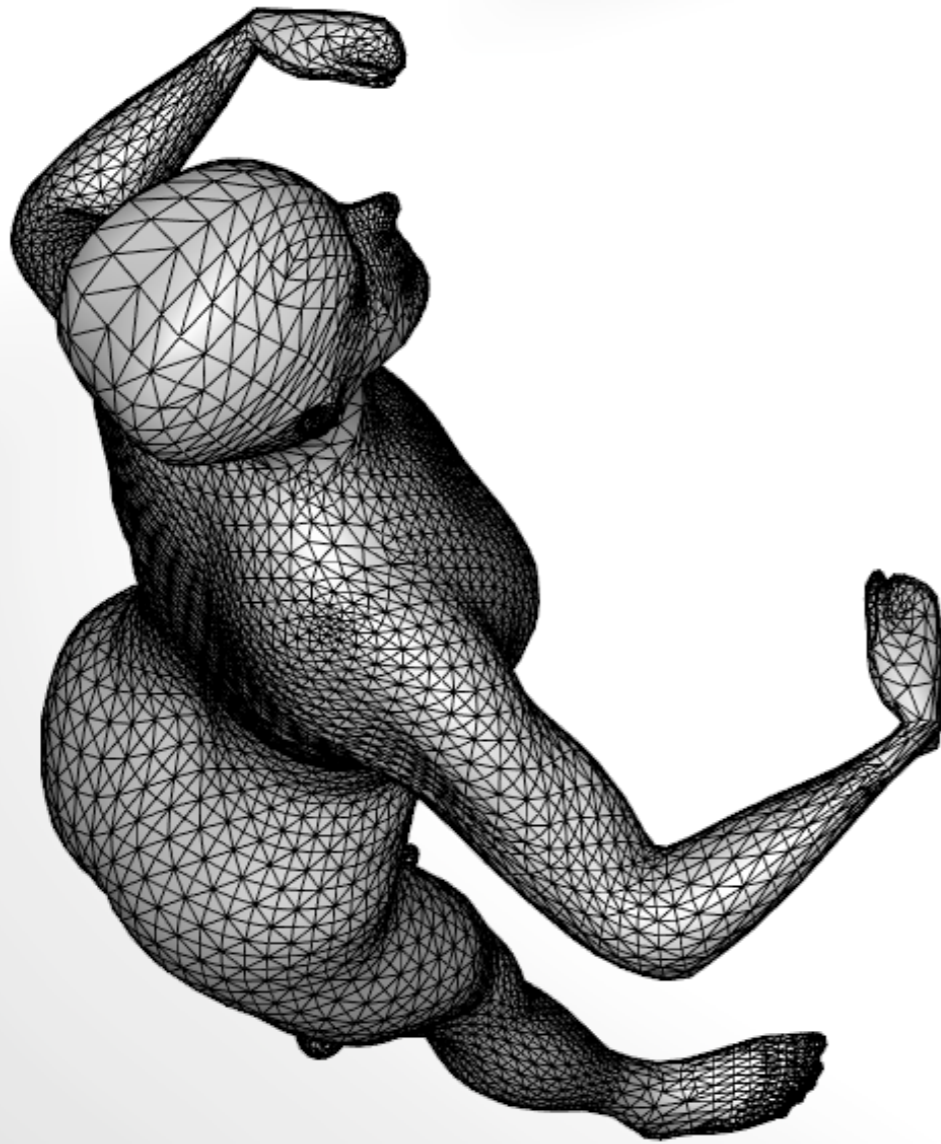
sparse/partial matching → SCAPE model → accurate model

Regression Results

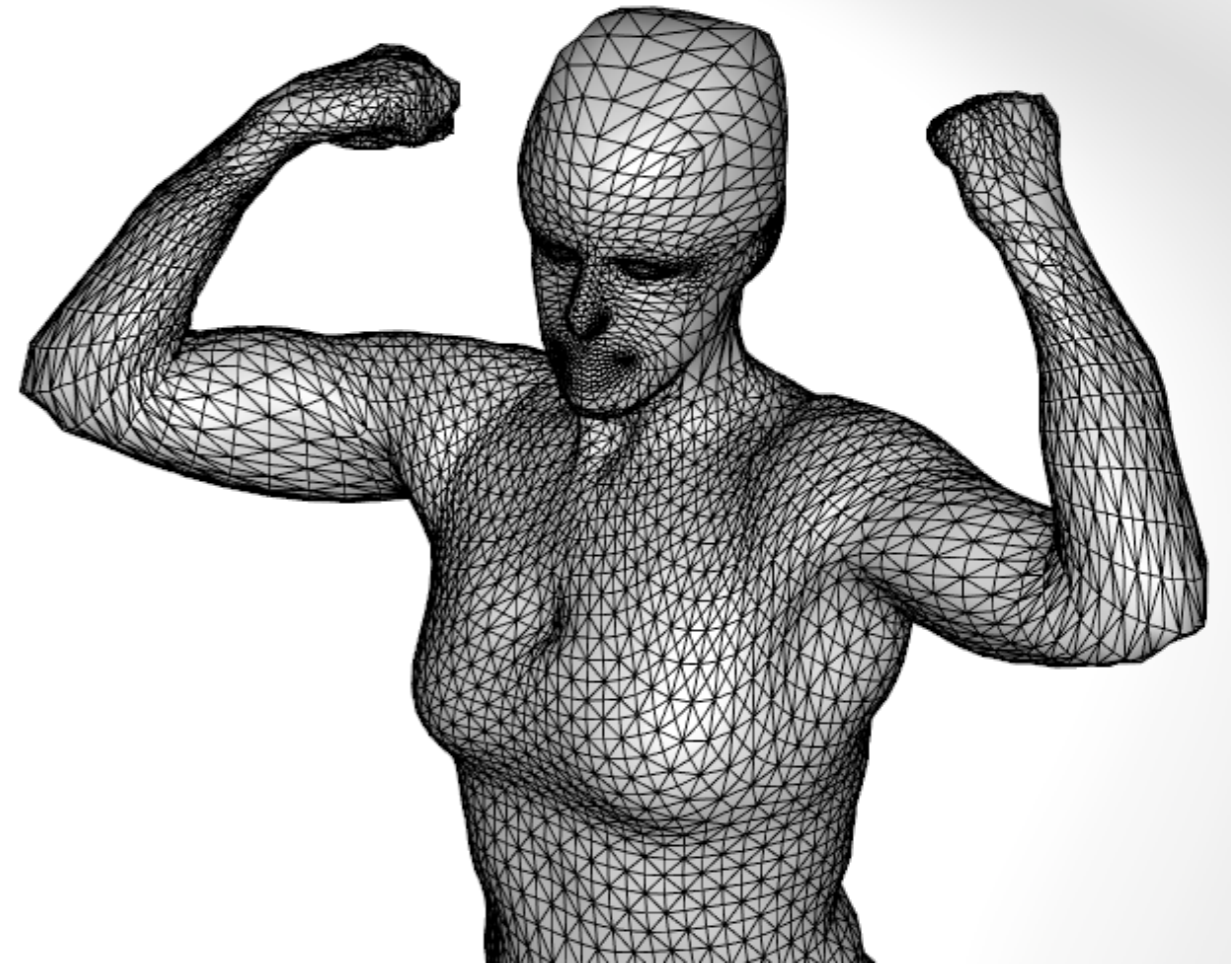
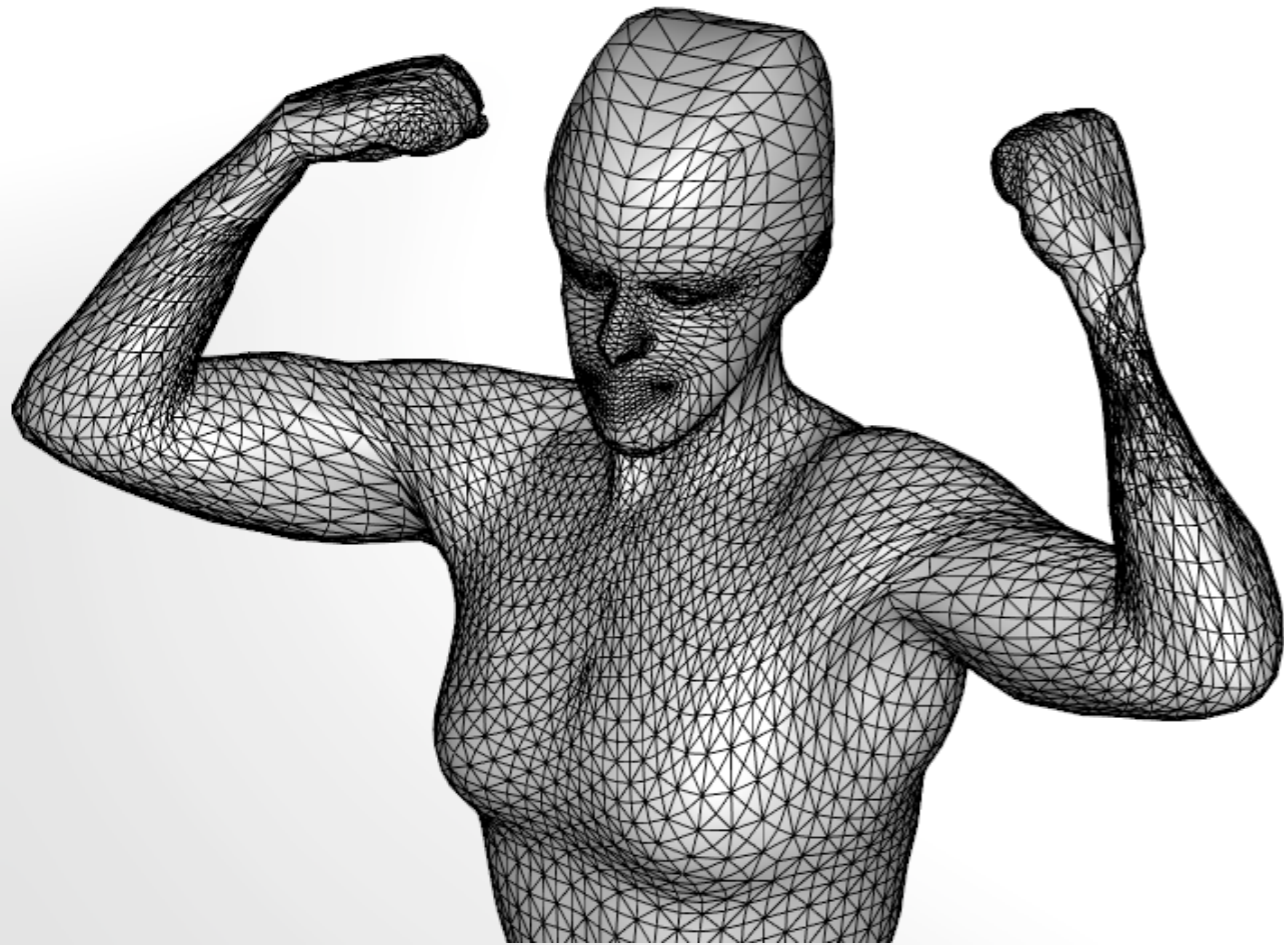


> 50% more accuracy

Alignment Comparison



Alignment Comparison



Template Free-Reconstruction

Temporally-Coherent Shape Completion

[Li et al.'11]



partial data



reconstruction



partial data



reconstruction

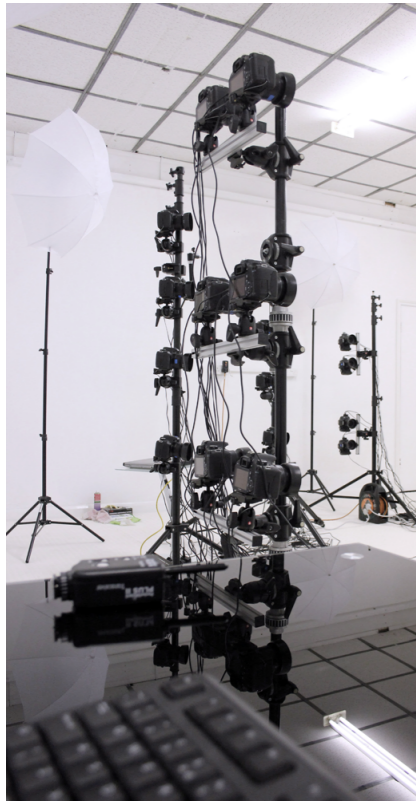
Free-Viewpoint Video

[Li et al. '11]

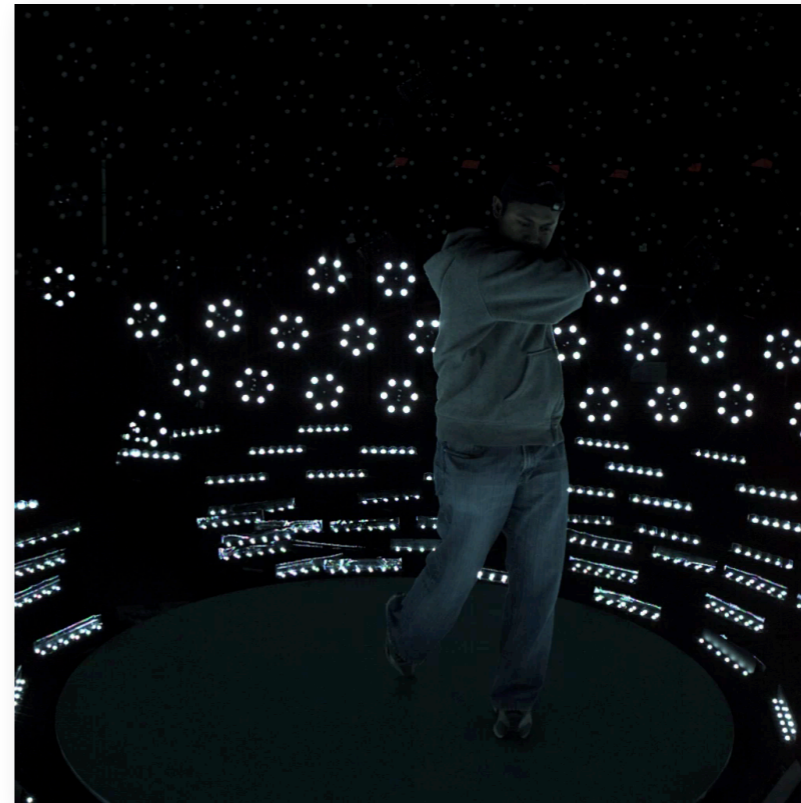


3D Reconstruction

Multi-View Capture

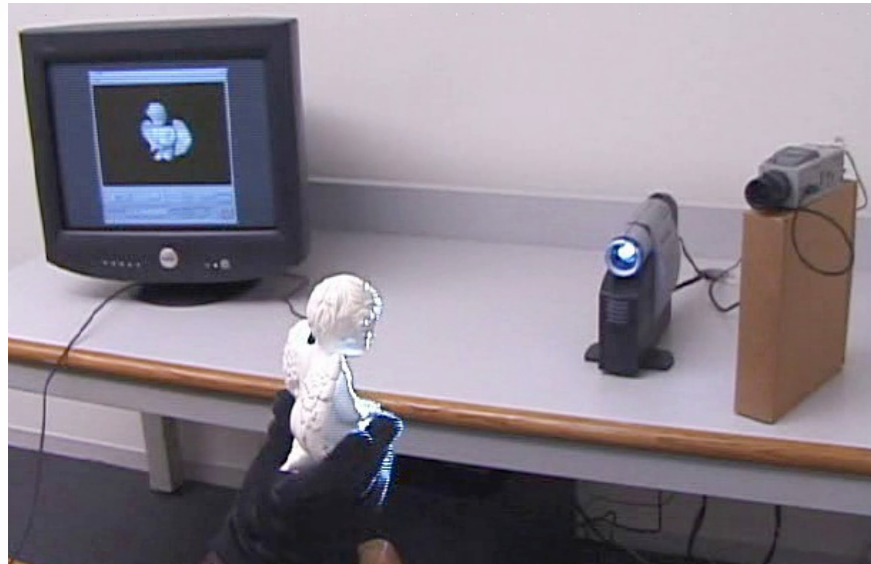


multi-view stereo



multi-view photometric stereo

Single-View Capture



[Rusinkiewicz et al. '02]

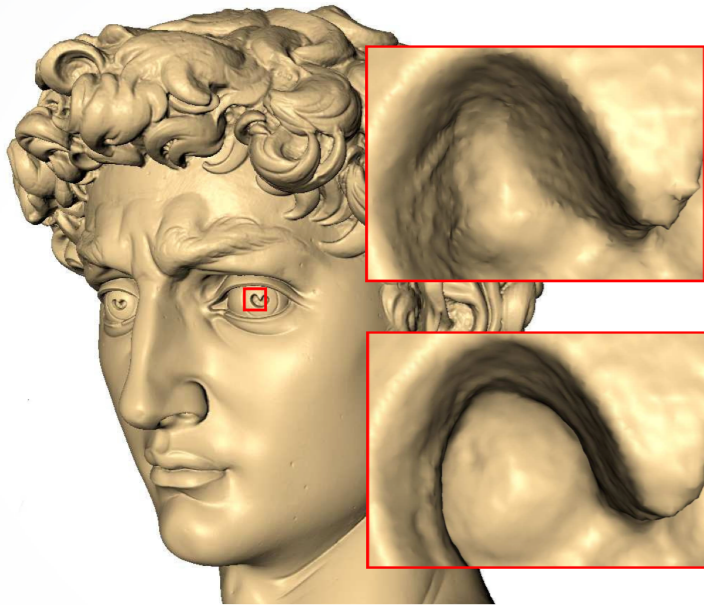


Artec Group

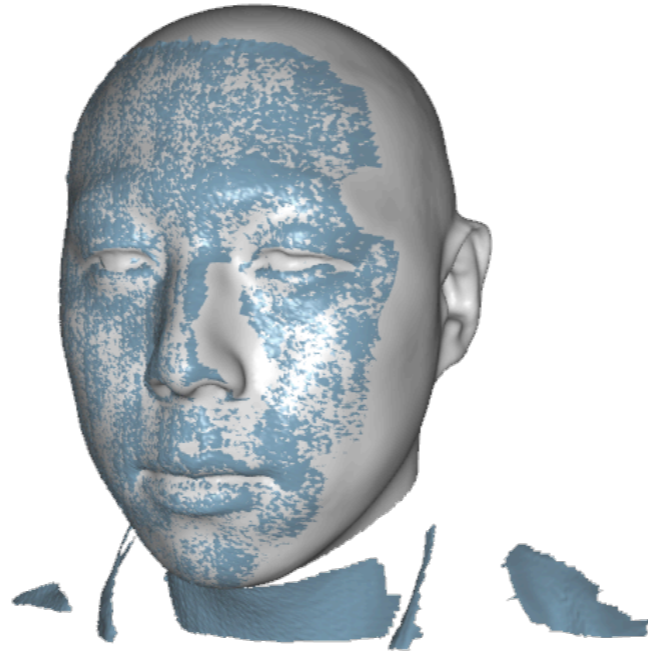


[Newcombe et al. '11]
KinectFusion

Handling Deformations



[Brown & Rusinkiewicz '07]

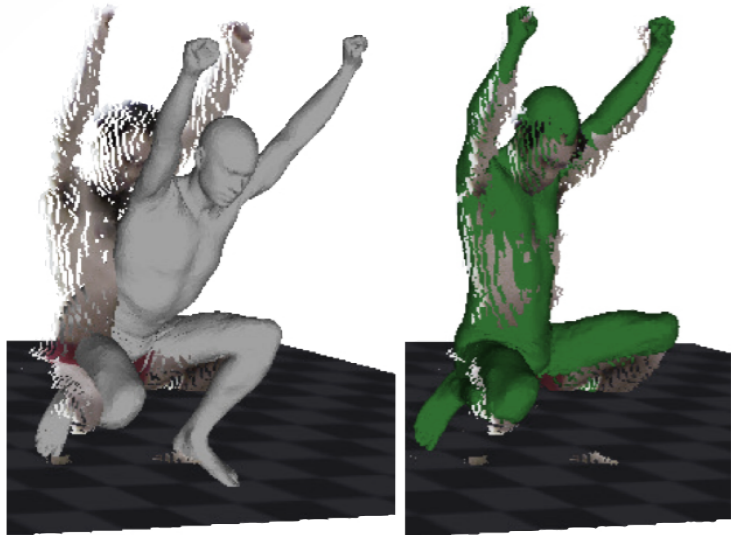


[Li et al. '09]

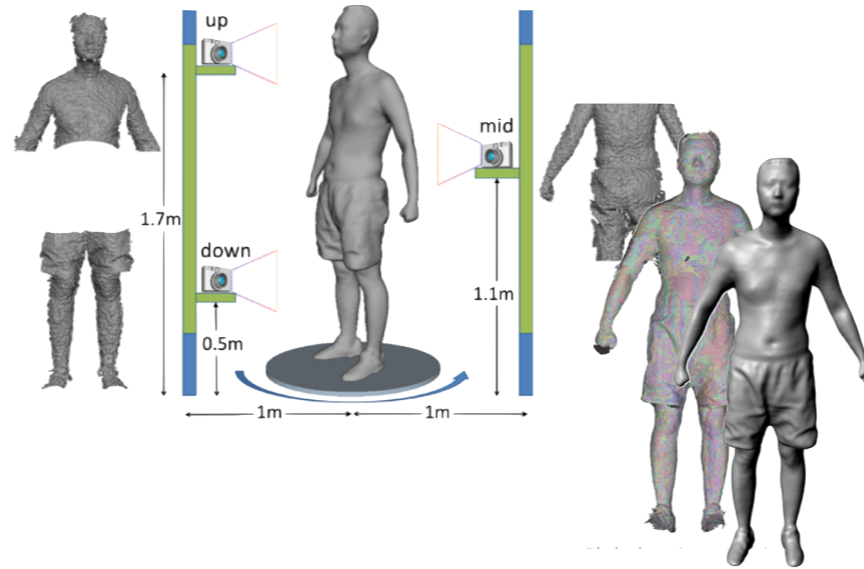


[Chang & Zwicker '11]

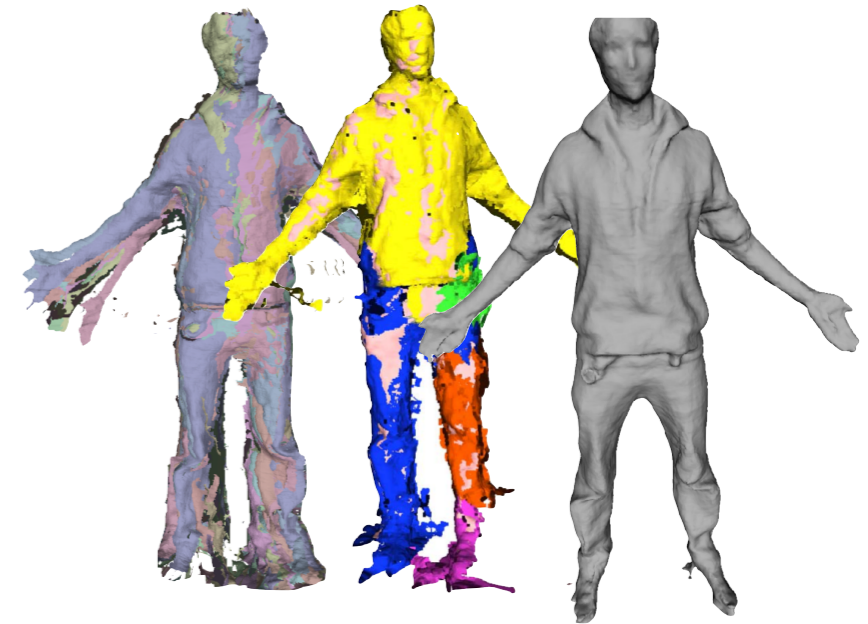
Using Human Body Priors



[Weiss et al. '11]

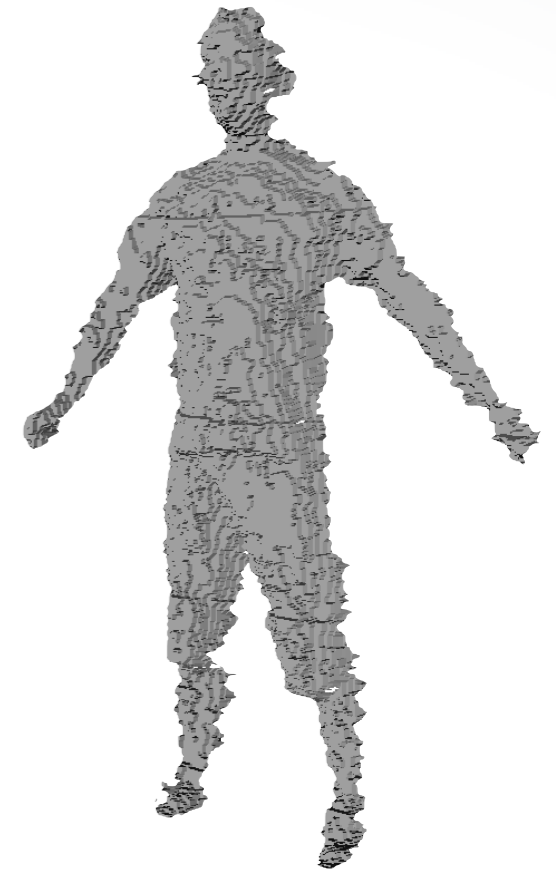
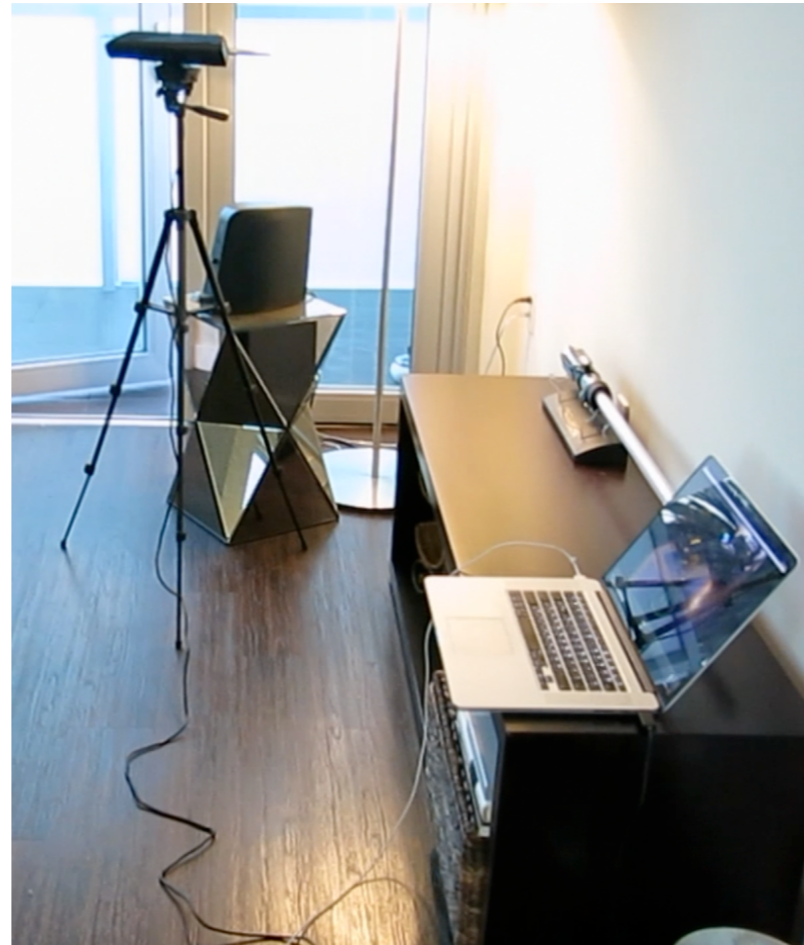


[Tong et al. '12]



[Cui et al. '12]

Challenges



deformation, clothing & props

daily environment

low cost

Global Non-Rigid Registration

3D Scanning



Automatic Reconstruction

Output Reconstruction



3D Printing



<http://cs621.hao-li.com>

Thanks!

