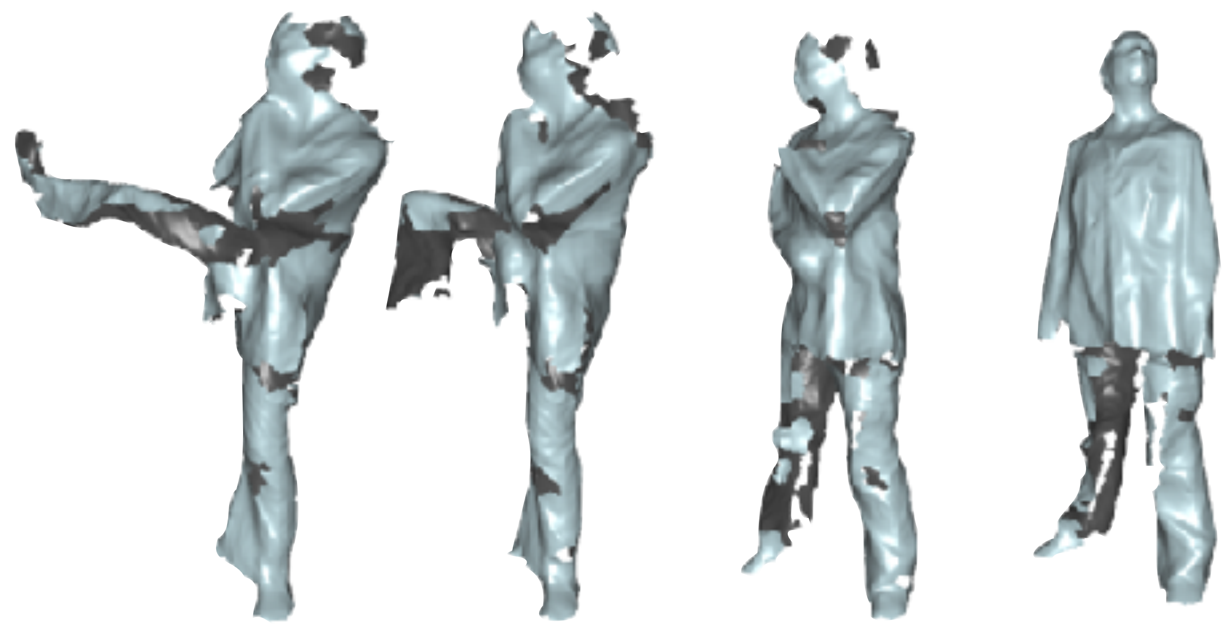
14.1 **Dynamic Geometry Processing I**



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

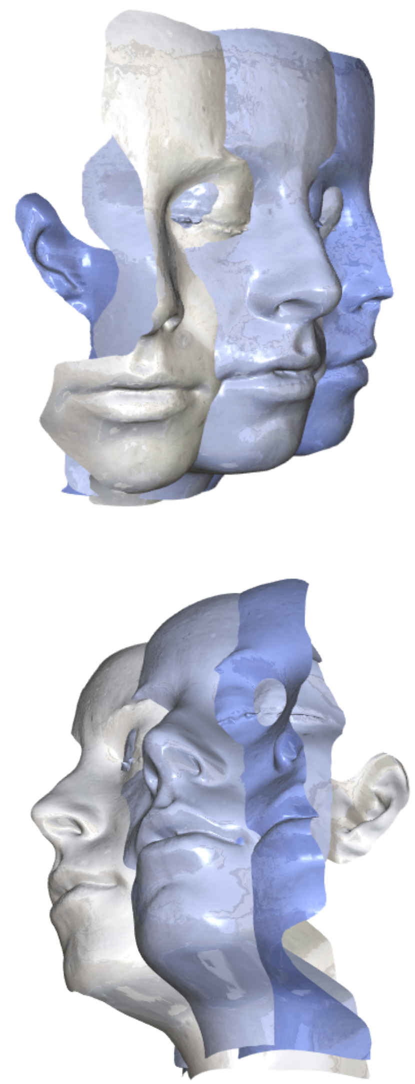
Correspondence Classification

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

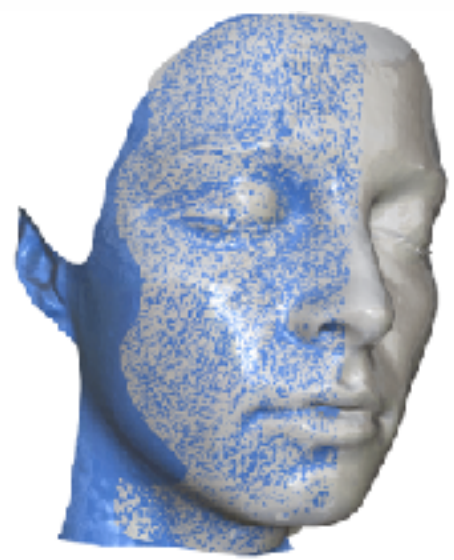
- Data: typical 3D scans
- Application: 3D model reconstruction

3-D Reconstruction

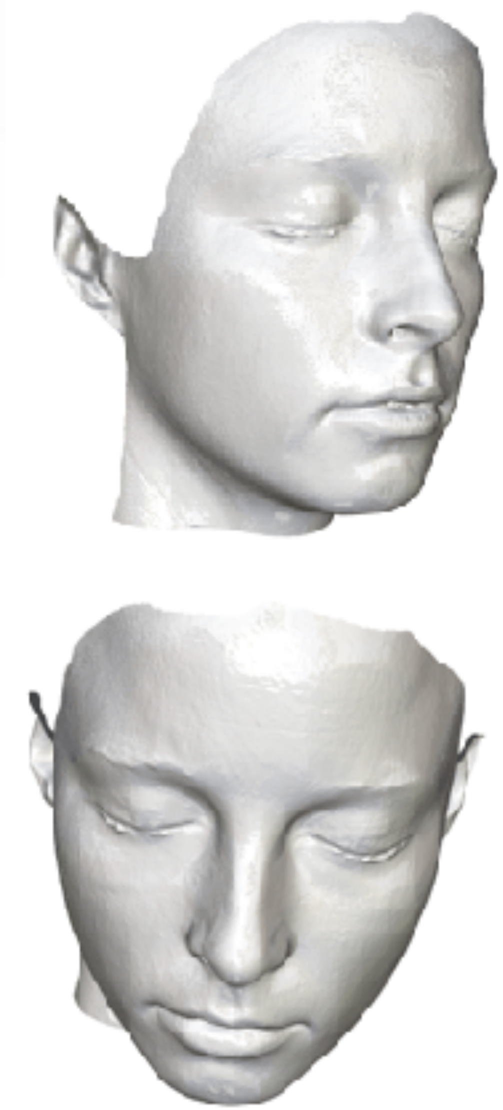
acquisition



initial alignment



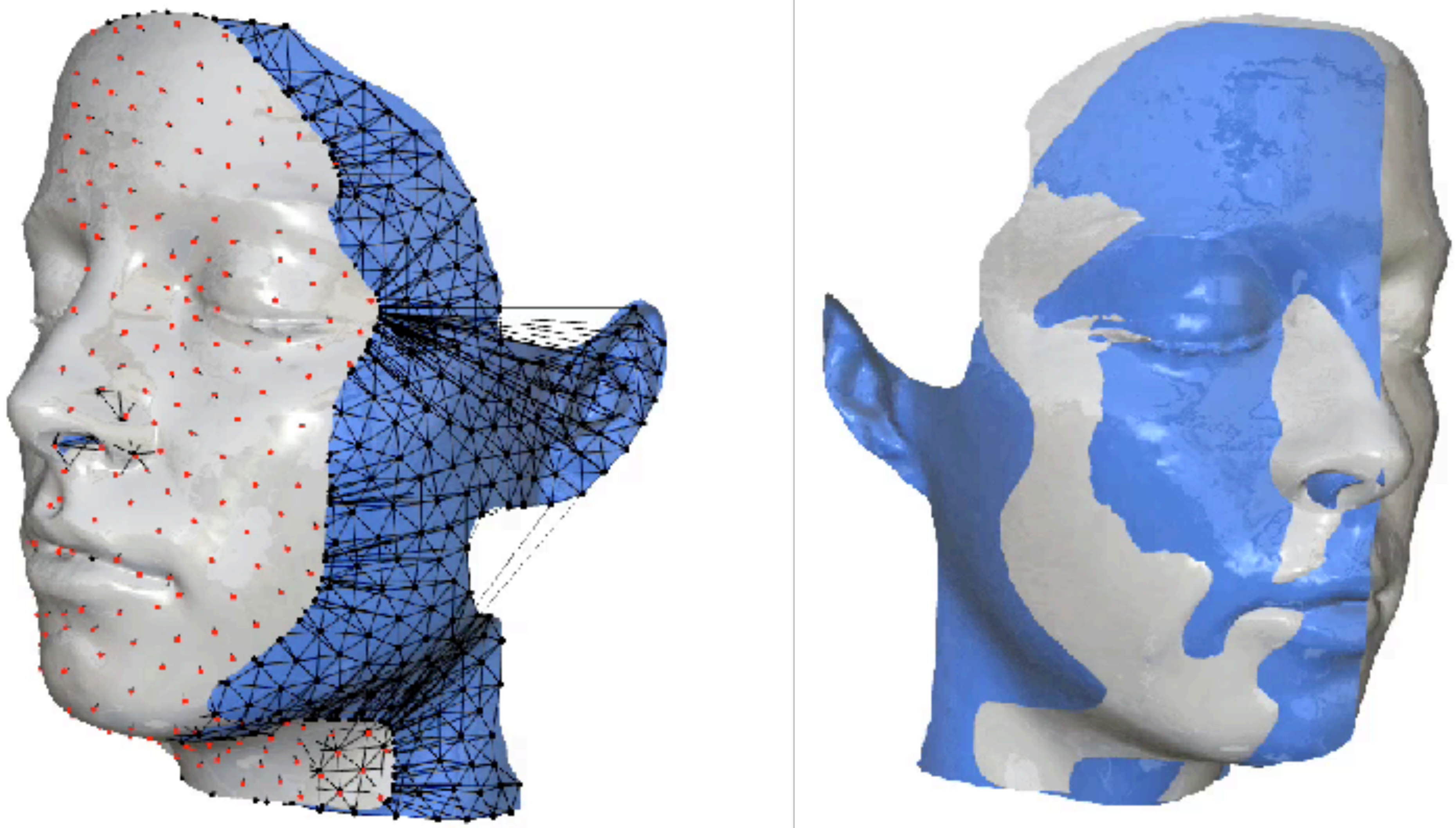
registration



merging

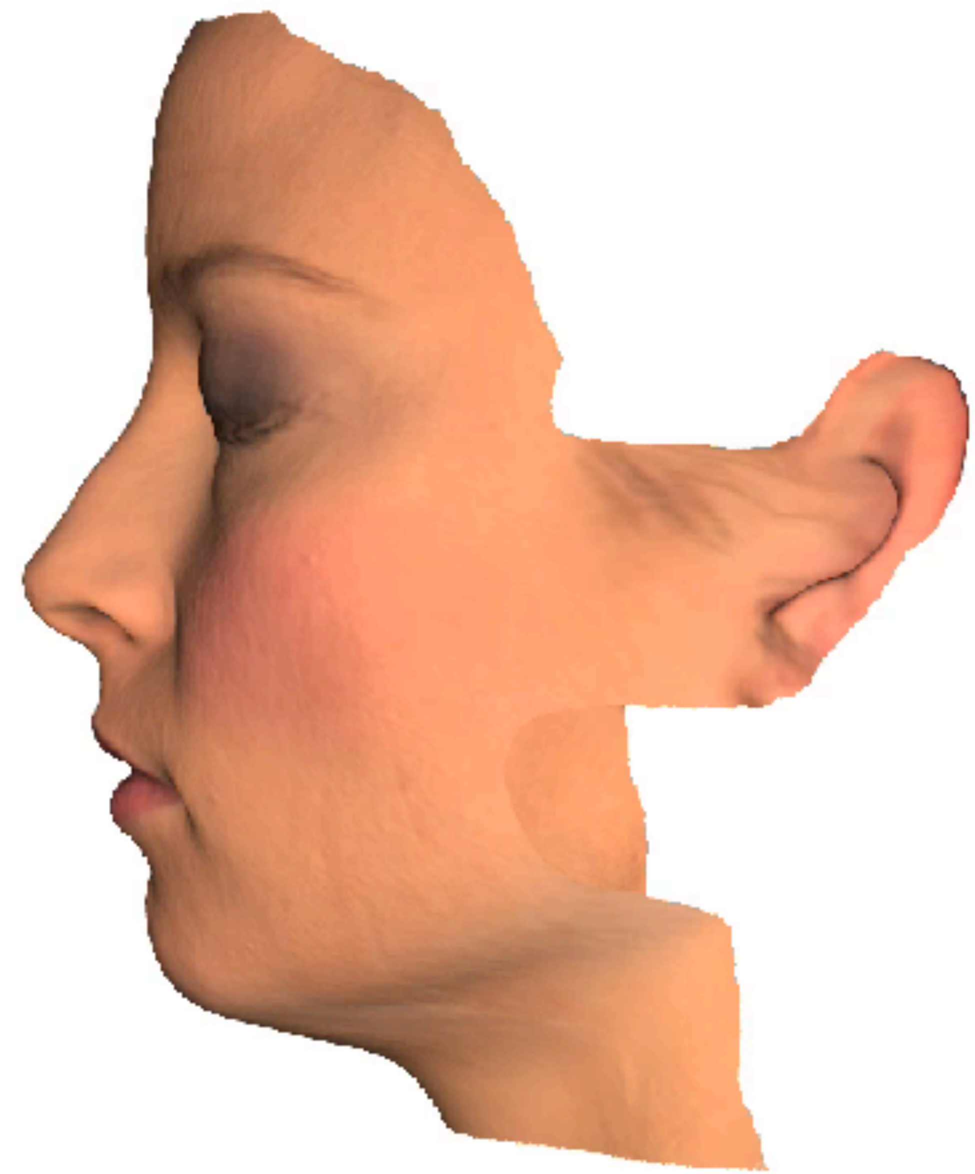
data provided by Paramount Pictures and Aguru Images

Non-Rigid Registration



data provided by Paramount Pictures and Aguru Images

Full Reconstruction



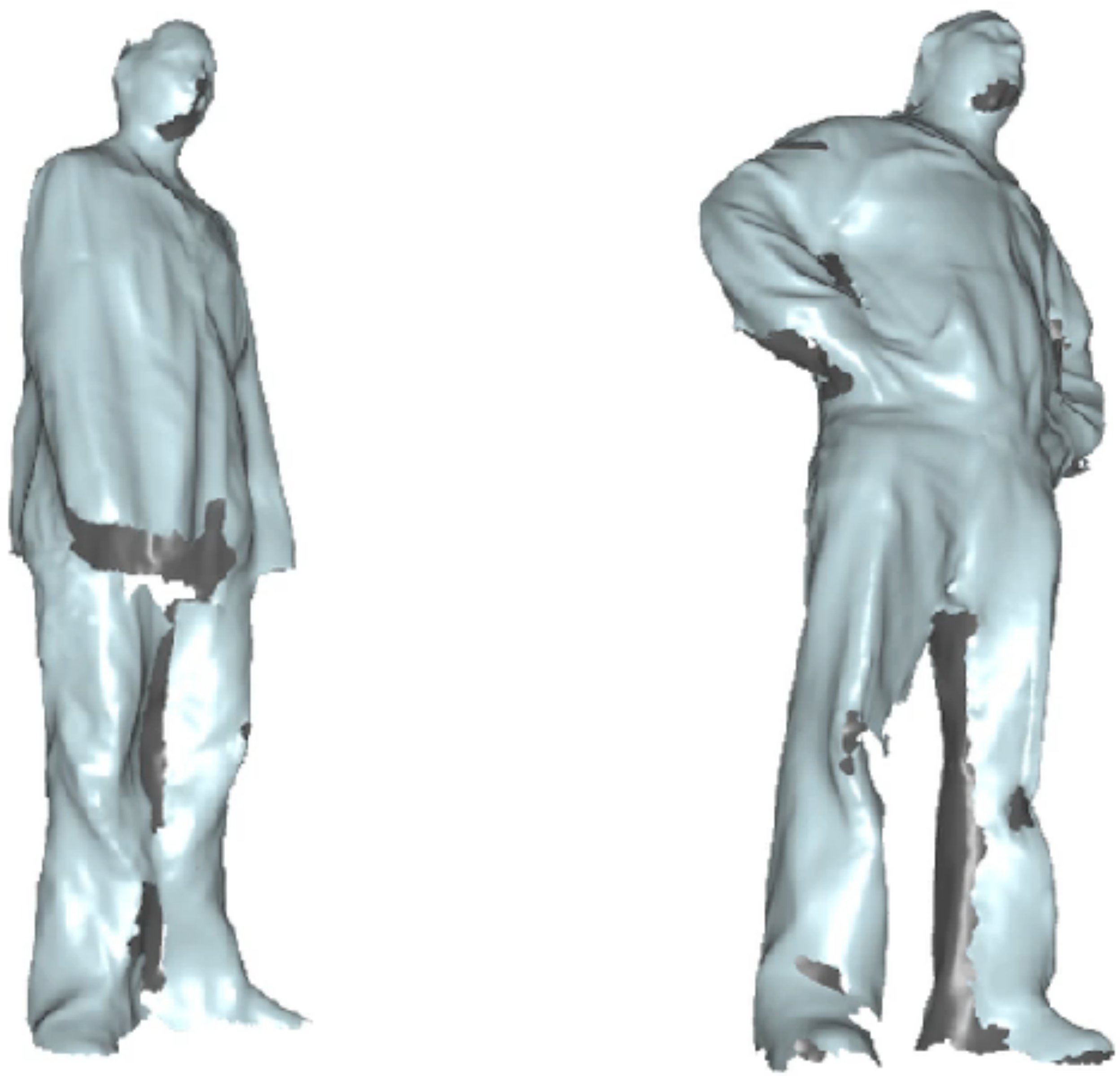
data provided by Paramount Pictures and Aguru Images

Correspondence Classification

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

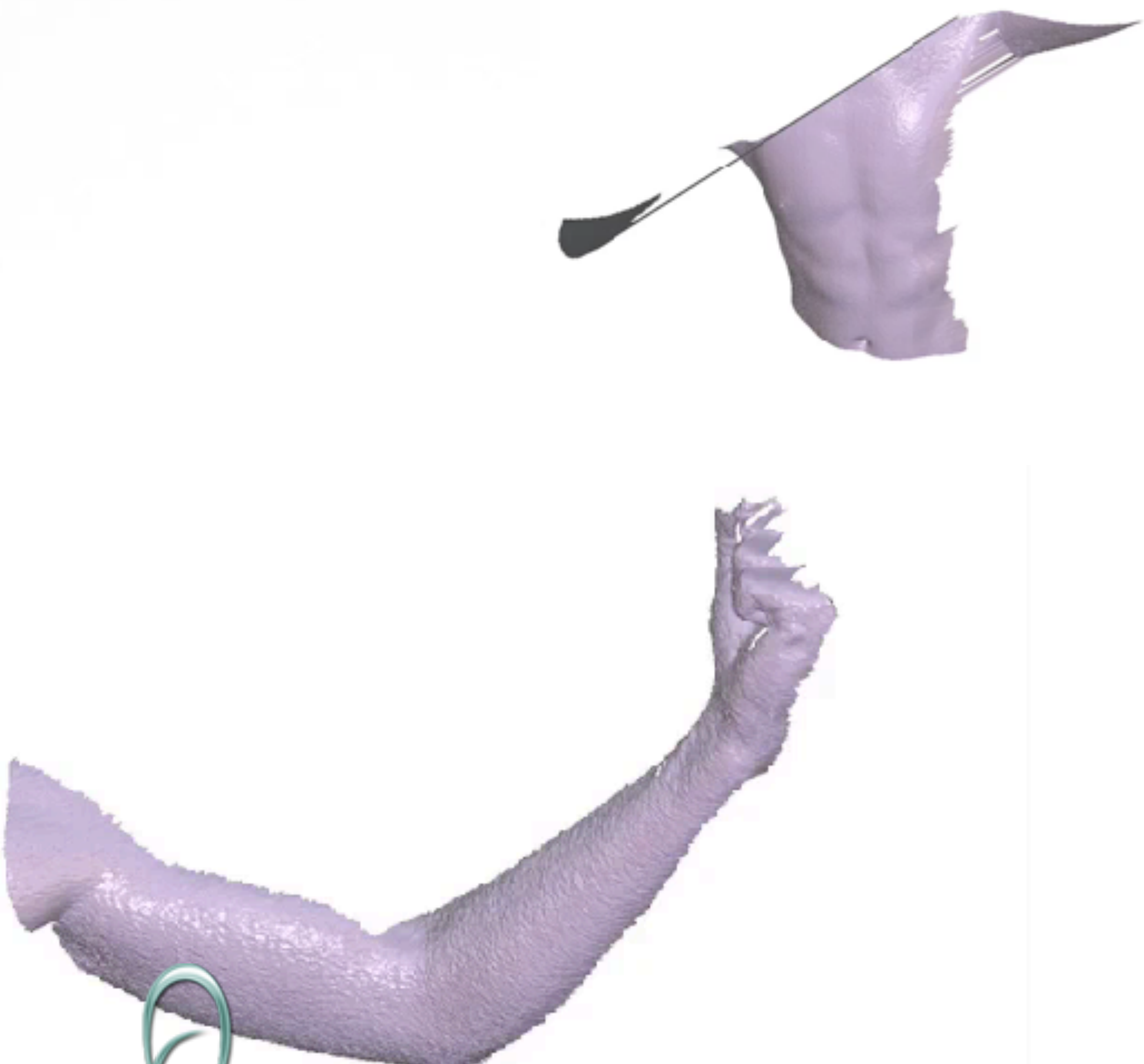
- Data: real-time 3D scans
- Application: animation reconstruction

Dynamic Input Data



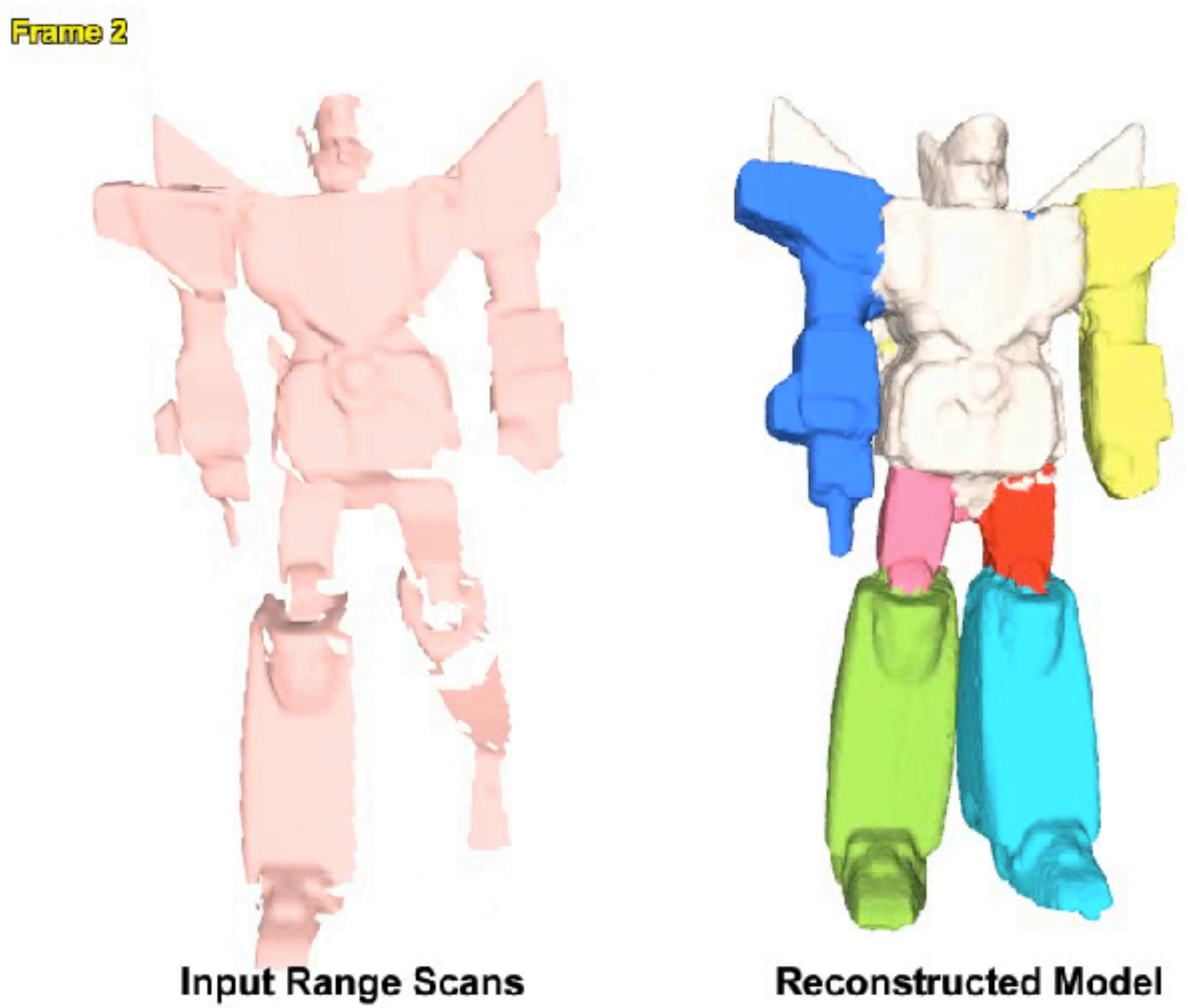
continuous motion / general deformation

Dynamic Input Data



Data provided with T. Weise and L. Van Gool

Dynamic Input Data

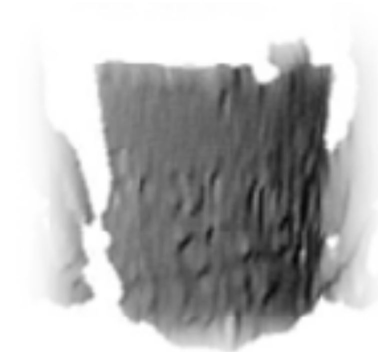


momentary motion / articulated deformation

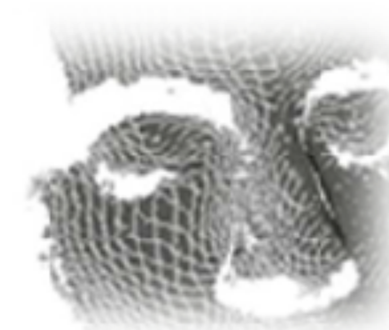
Animation Reconstruction

Problems

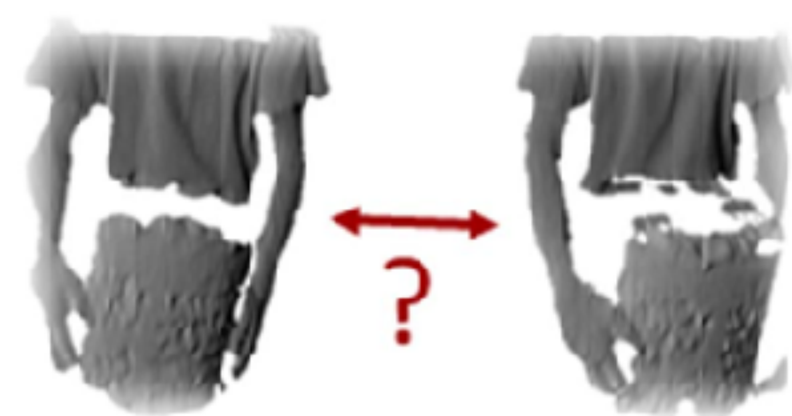
- Noisy data
- Incomplete data (acquisition holes)
- No correspondences



noise



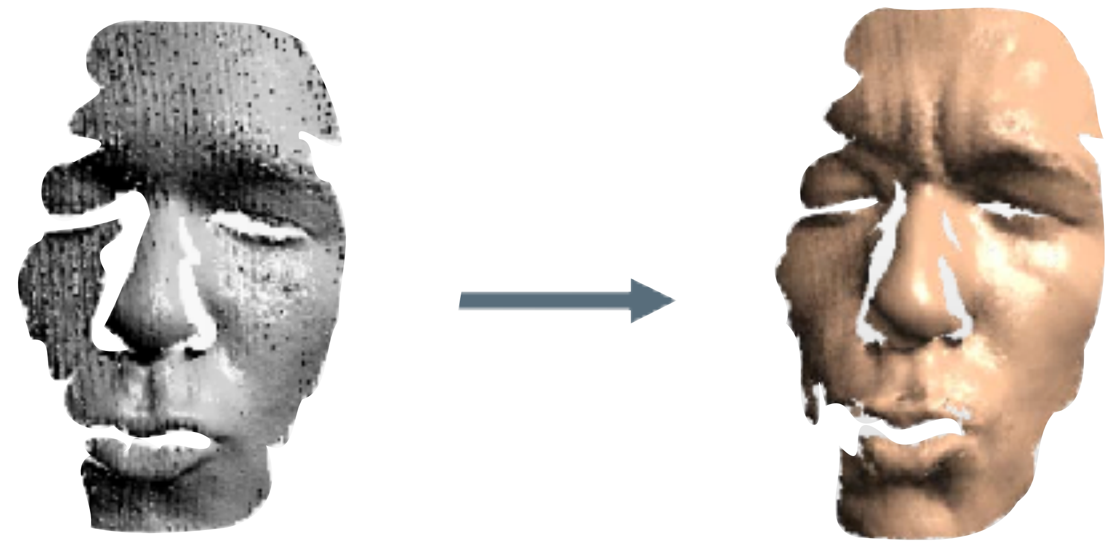
holes



missing correspondences

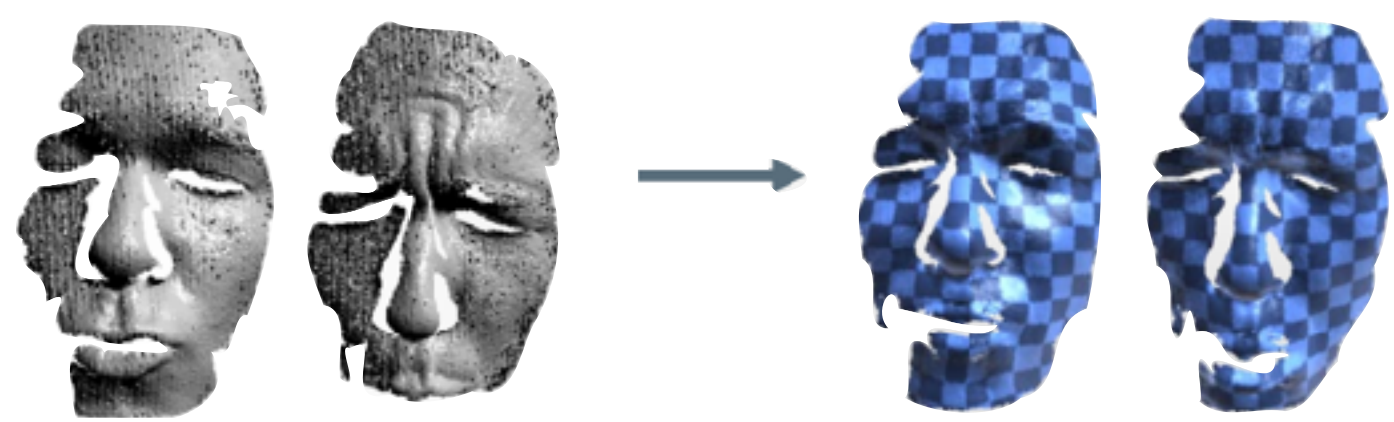
Animation Reconstruction

Remove noise, outliers

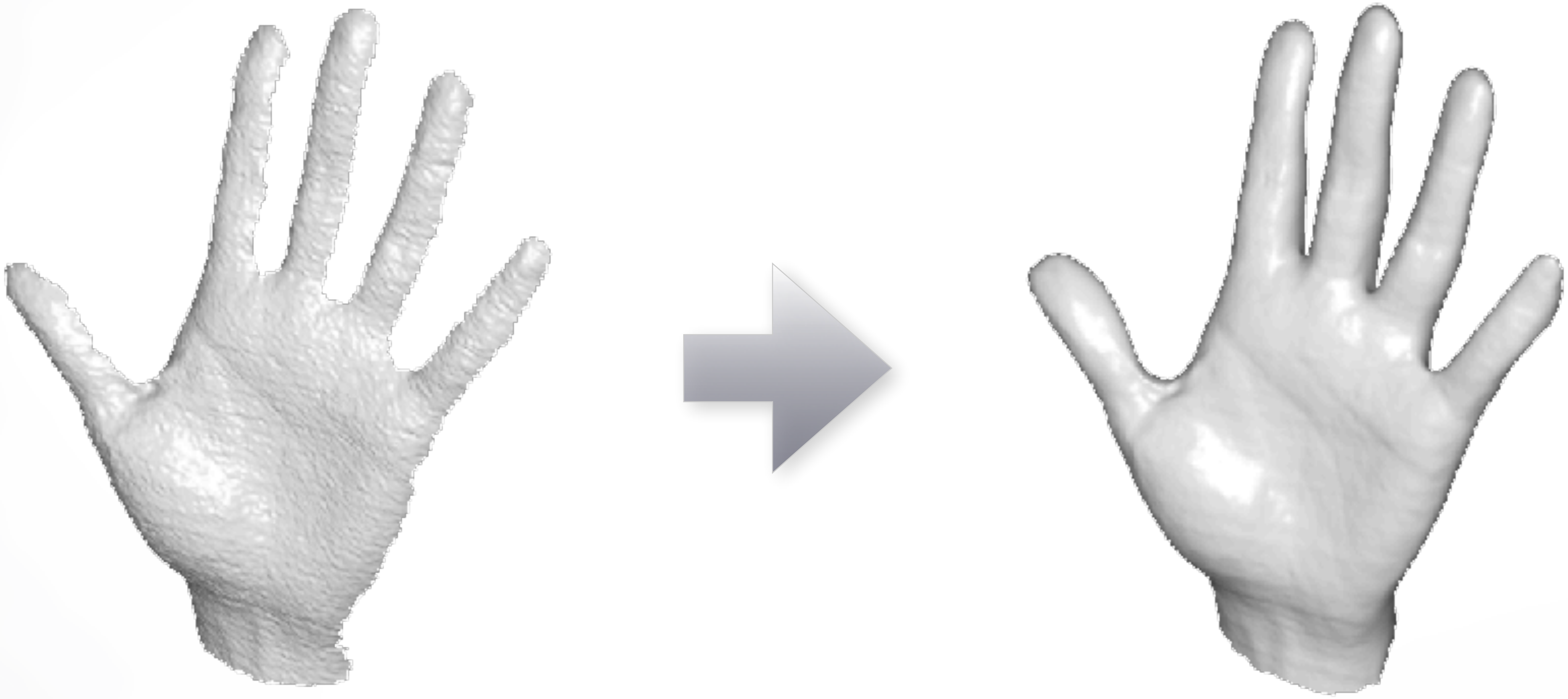


Fill in holes
(from all frames)

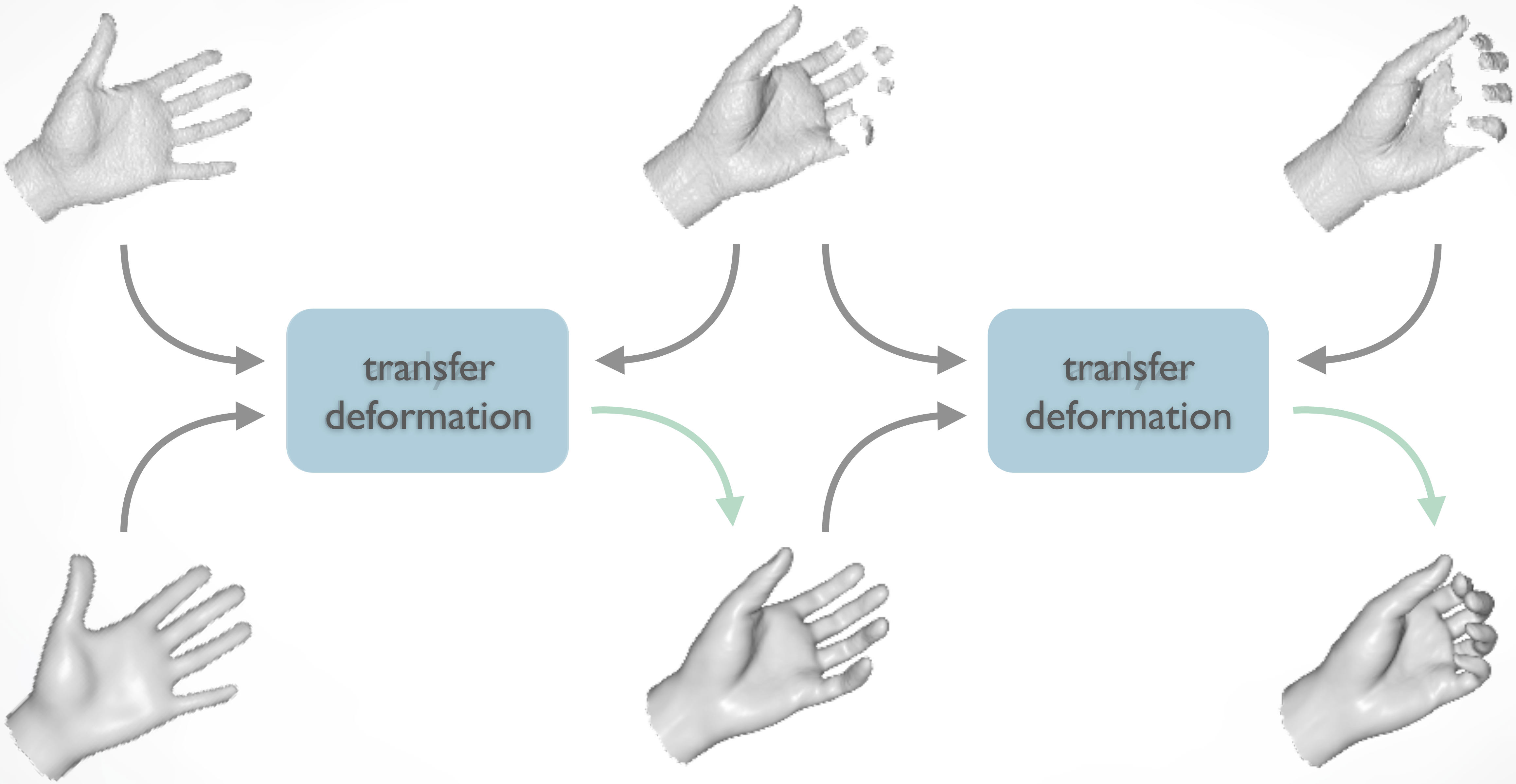
Find dense, temporally
coherent correspondences



Dynamic Shape Reconstruction



Template-Based Reconstruction

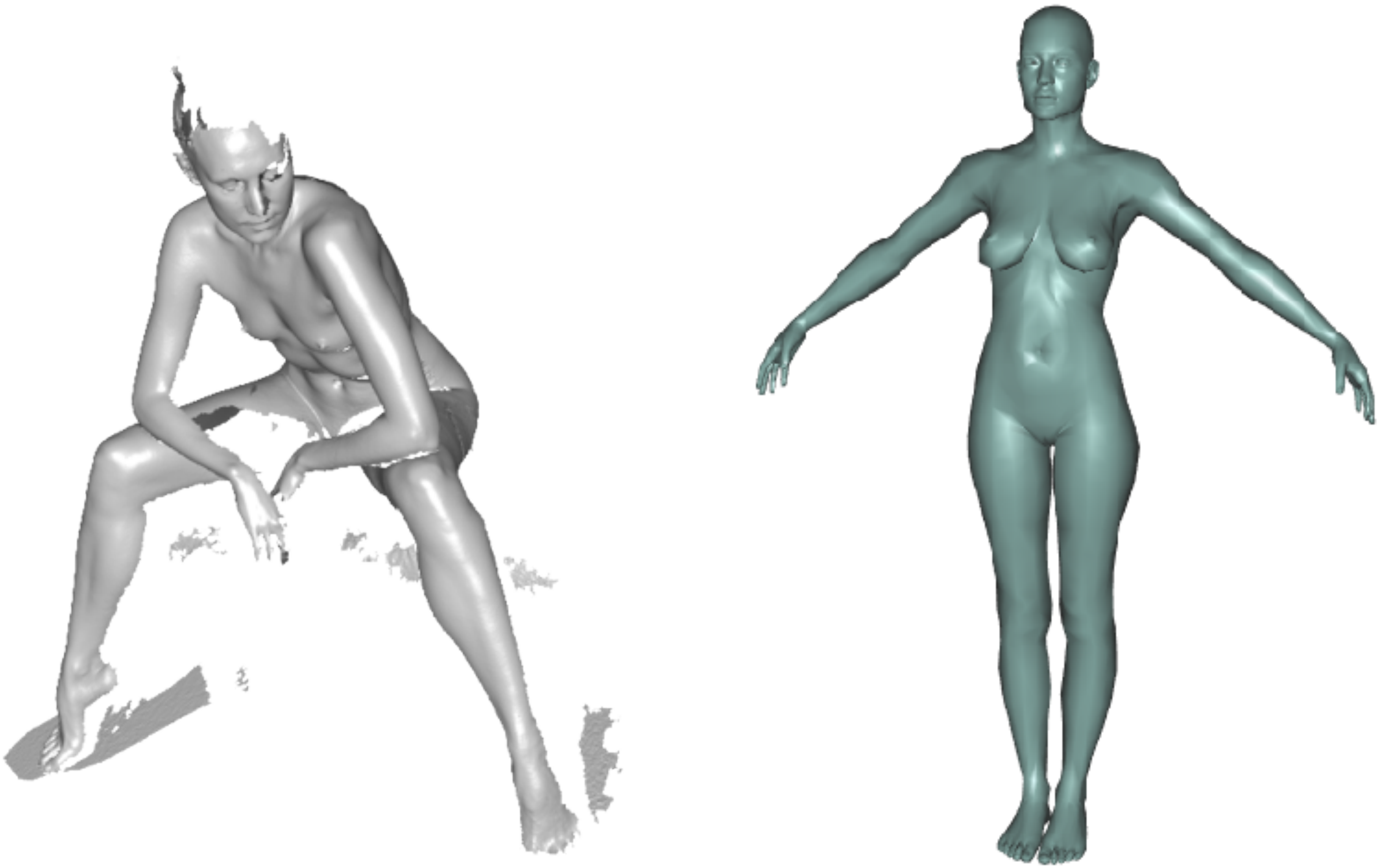


Correspondence Classification

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

Building such models requires correspondences

Courtesy of N. Hassler, MPI Informatik

Courtesy of N. Hassler, MPI Informatik

Scan Data - Challenges

"Real world data" is challenging, due to limitations in acquisition

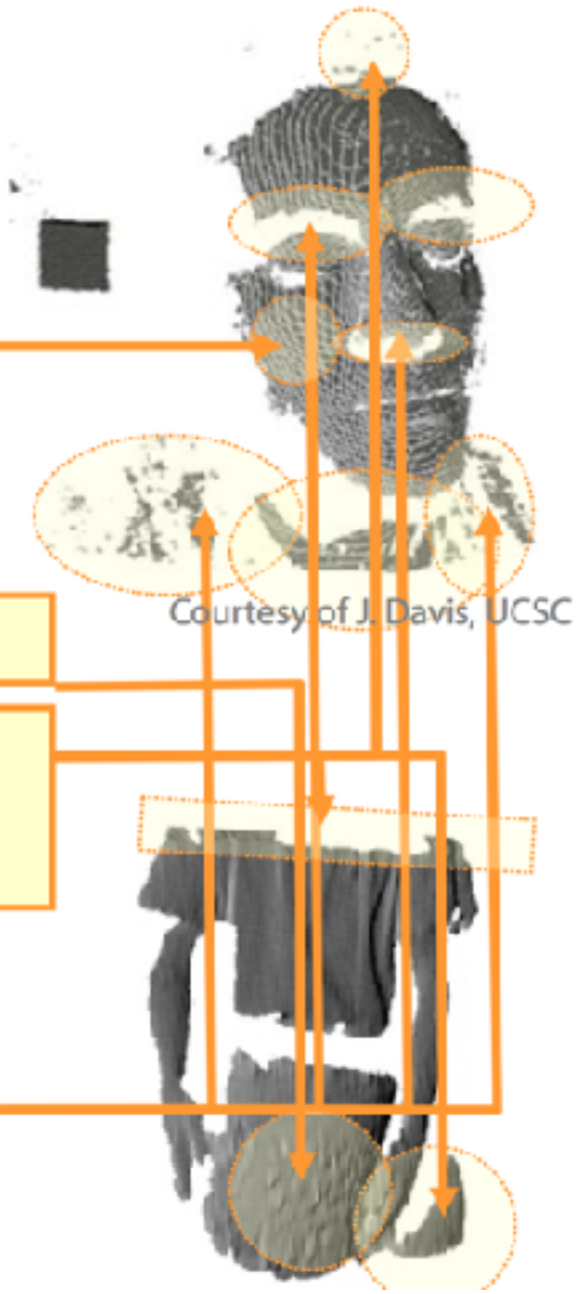
- More noise for large working volumes
- Dynamic harder than static
- Passive (e.g. stereo) less robust than active

More than just "Gaussian noise"…

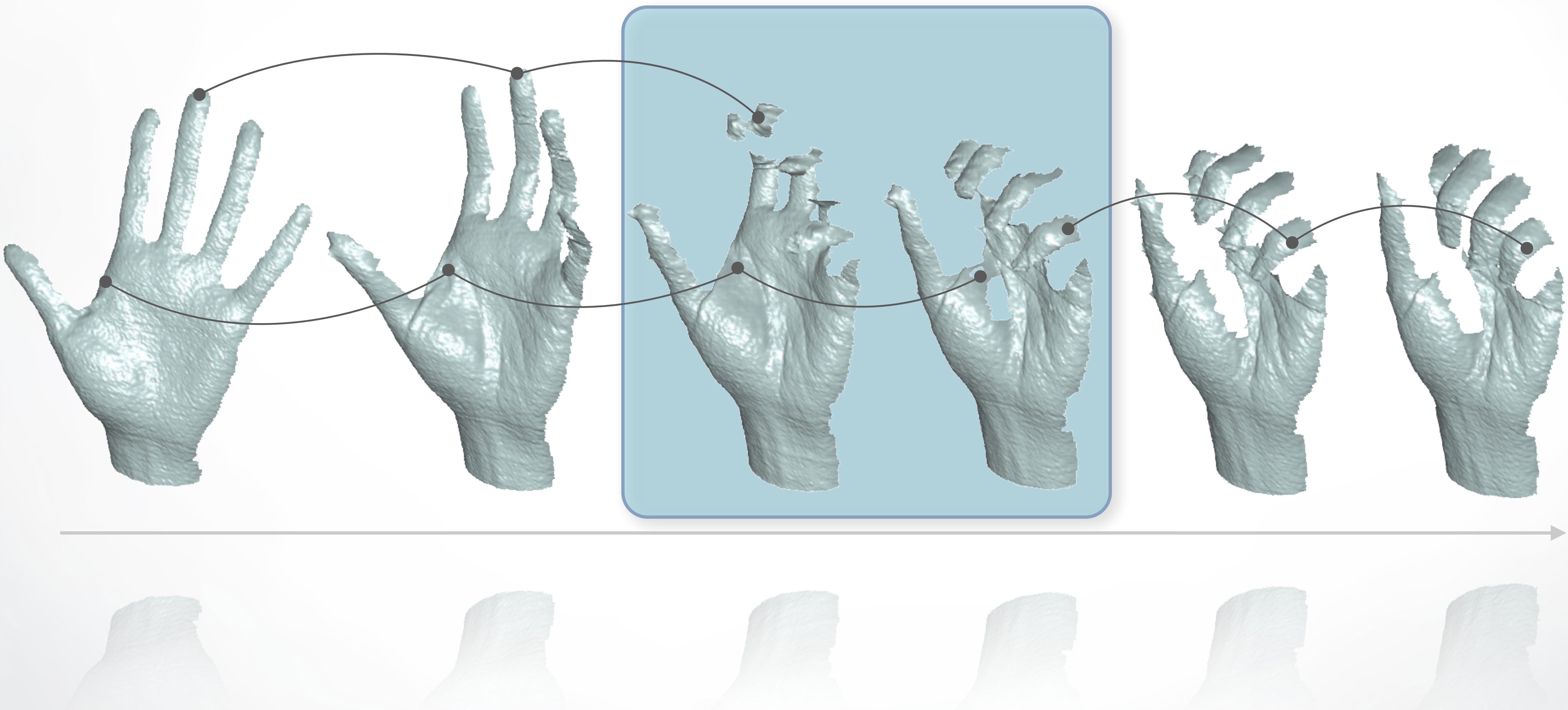
Challenges

"Noise"

- "Standard" noise types:
  - Gaussian noise (analog signal processing)
  - Quantization noise
- More problematic: structured noise
  - Spatio-temporal correllations
  - Structured outliers
  - Reflective / transparent surfaces
- Incomplete Acquisition
  - Missing parts
  - Topological noise

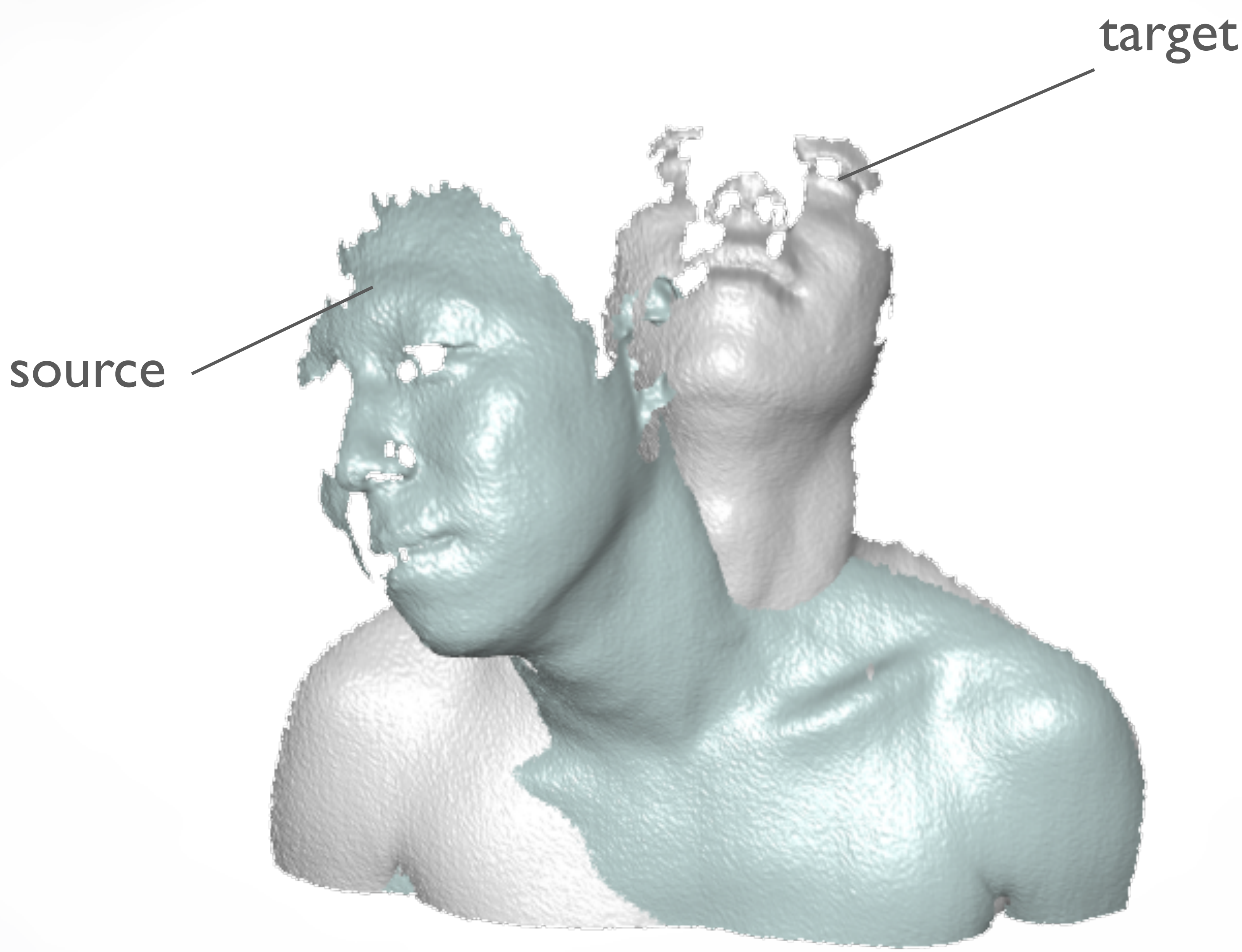


Correspondence Problem

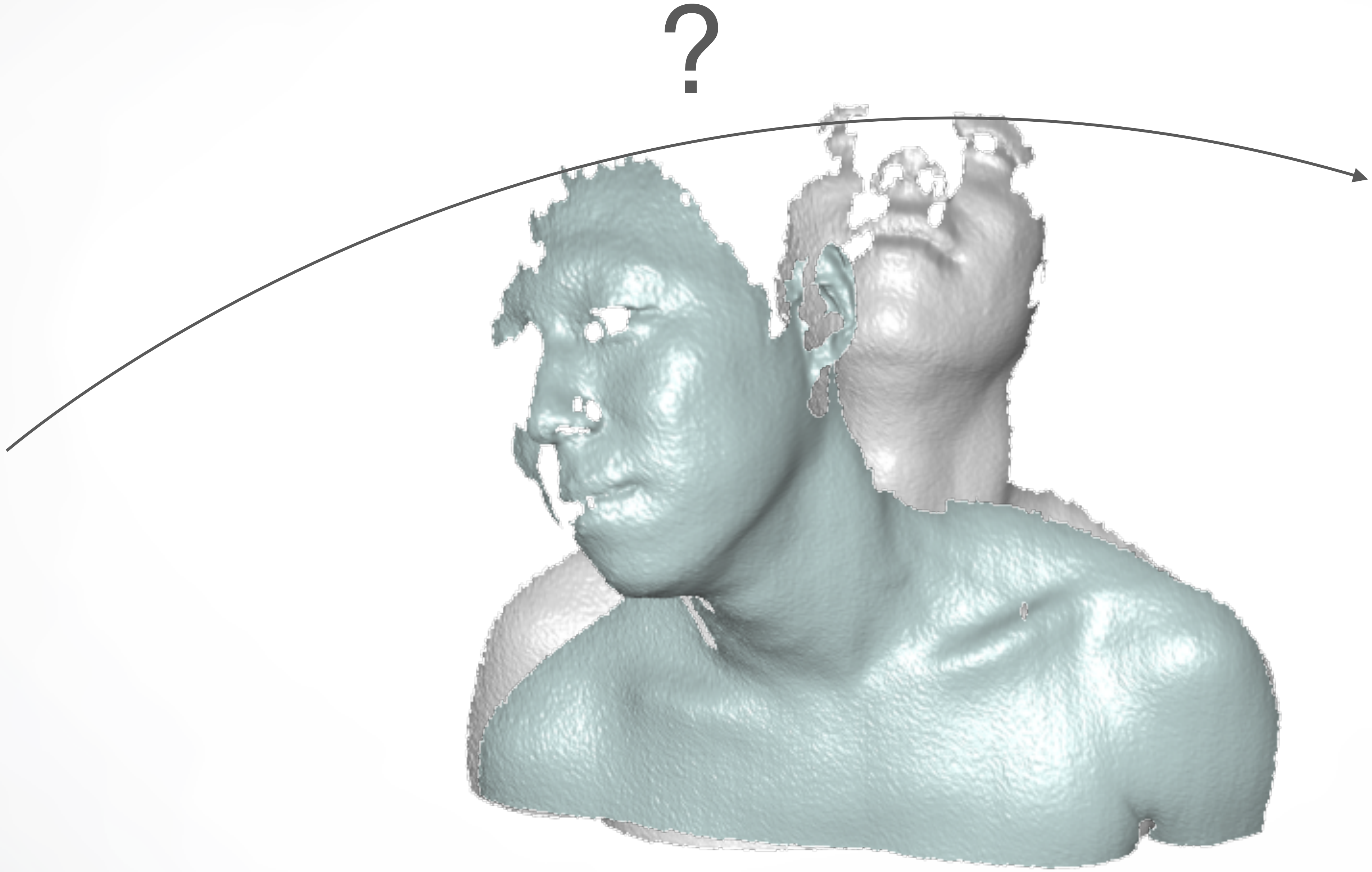


Non-Rigid Registration

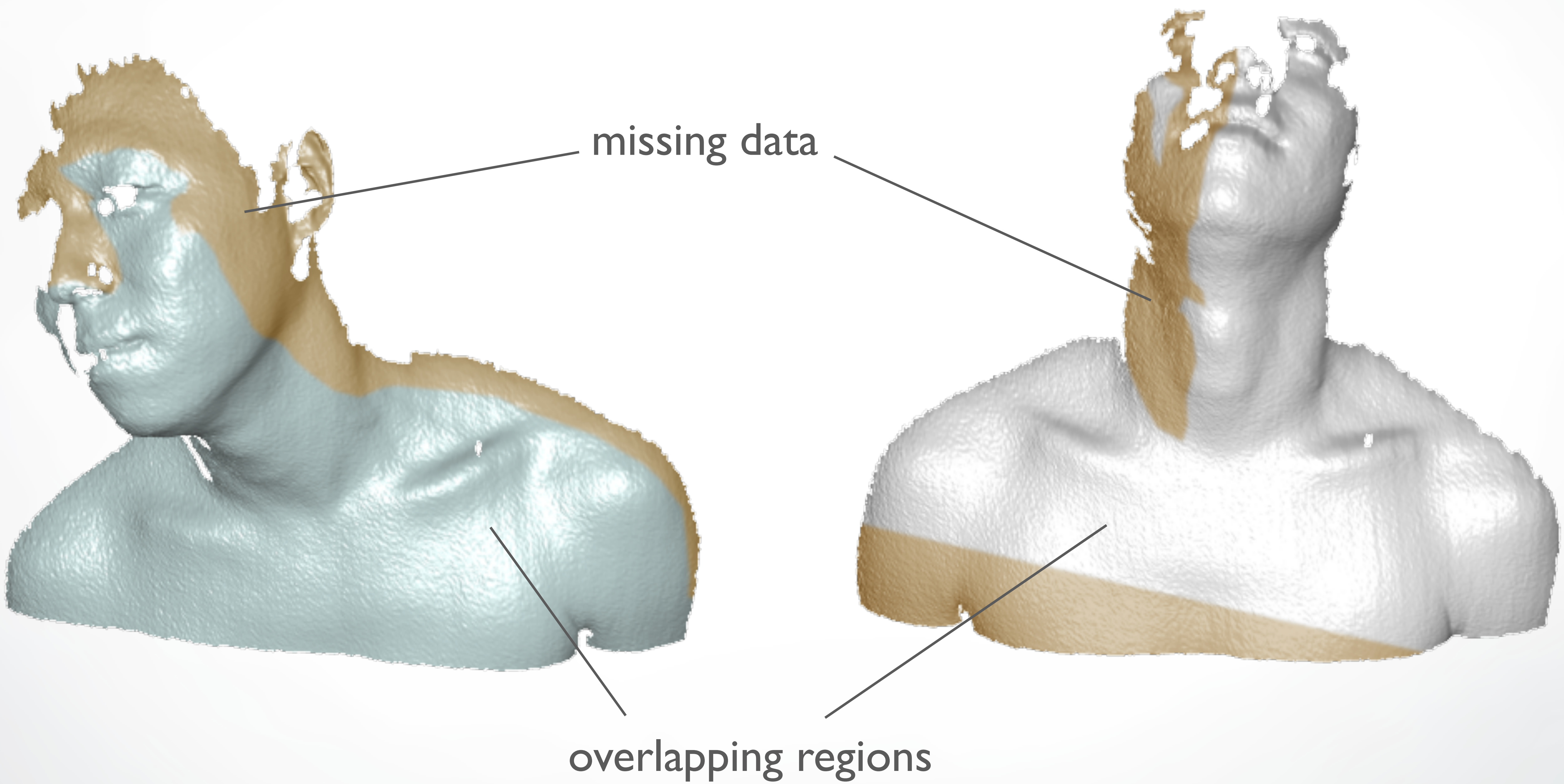
Pair of 3D Scans



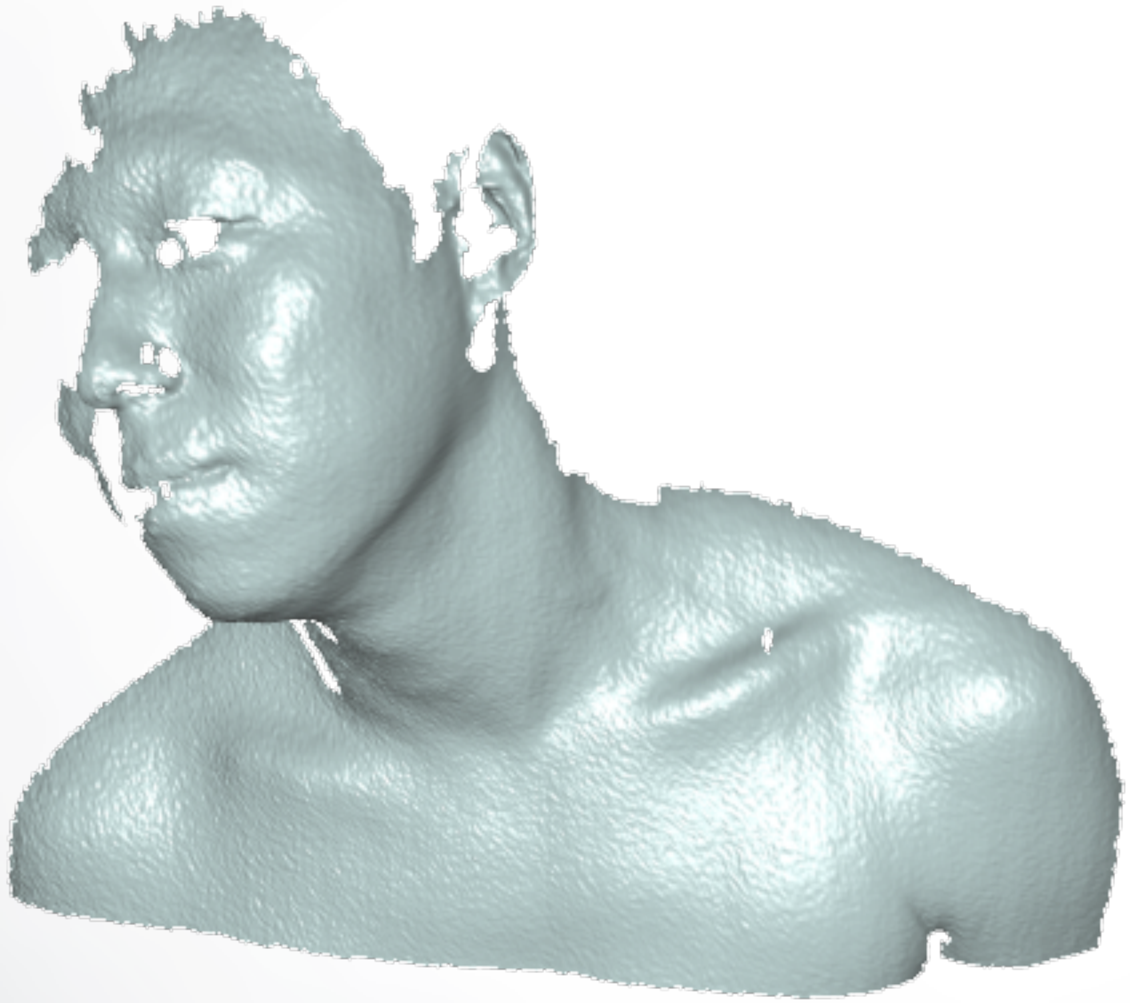
Correspondences are Lost

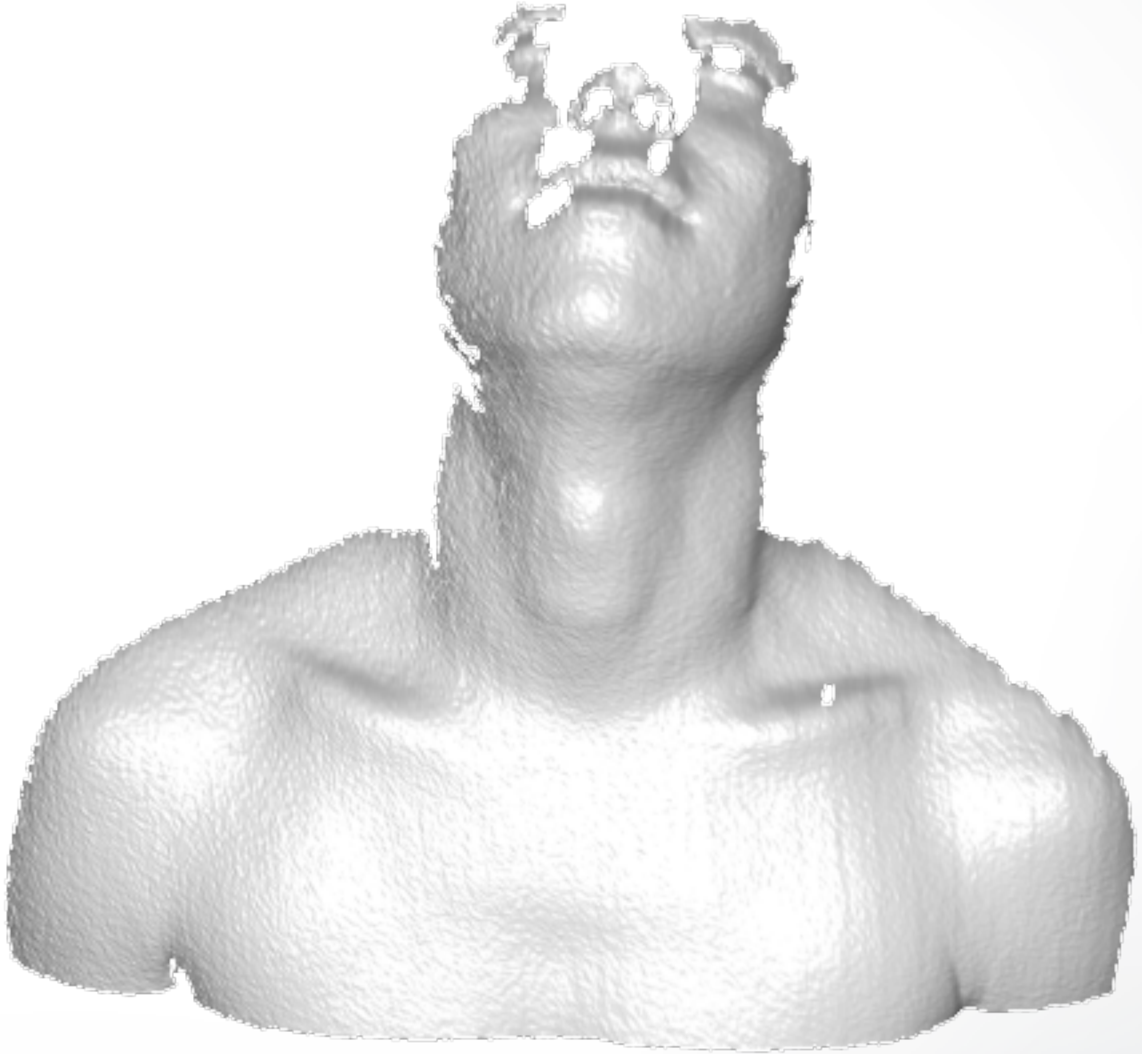


Overlapping Regions are Lost

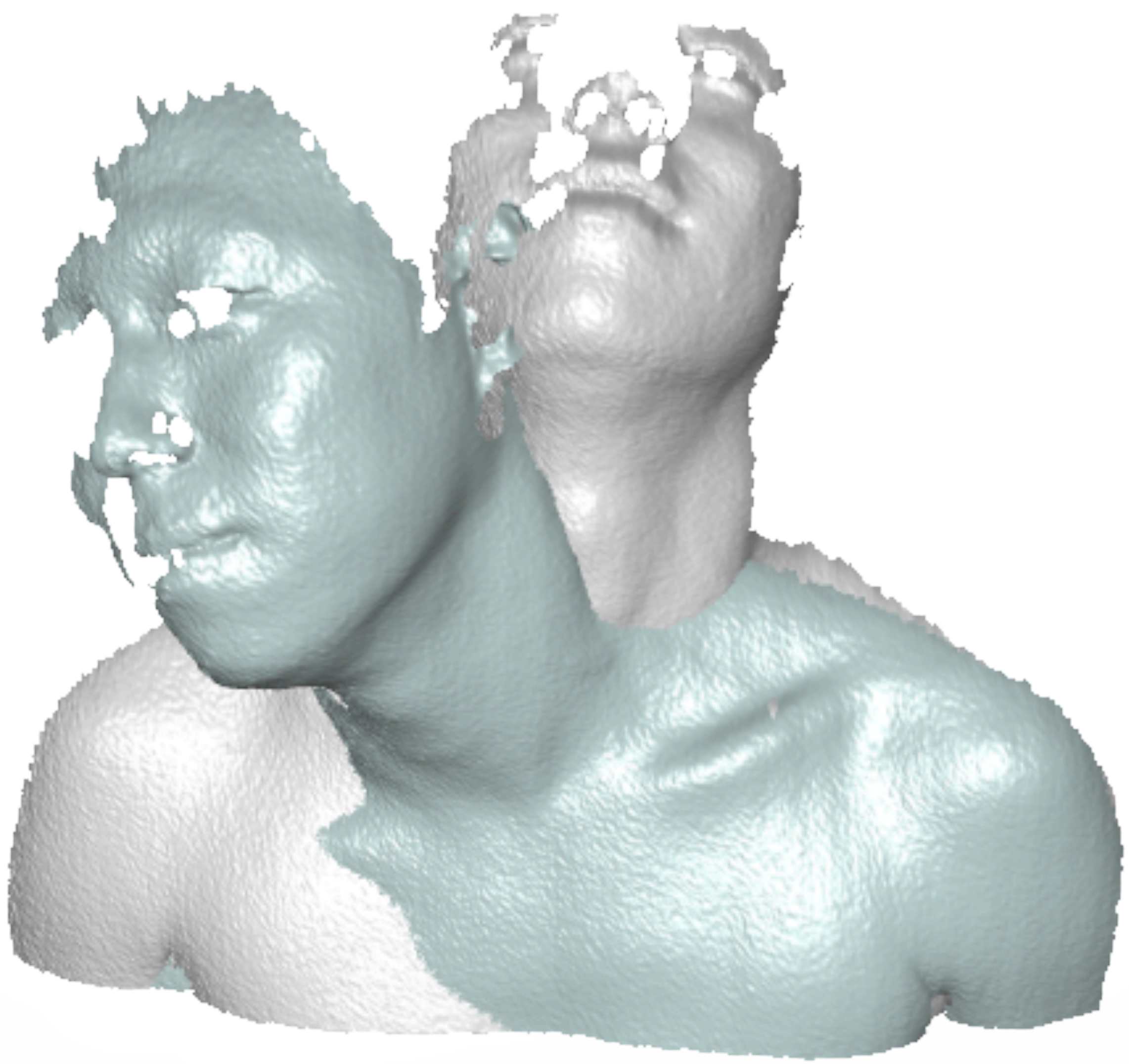


Overlapping Regions are Lost

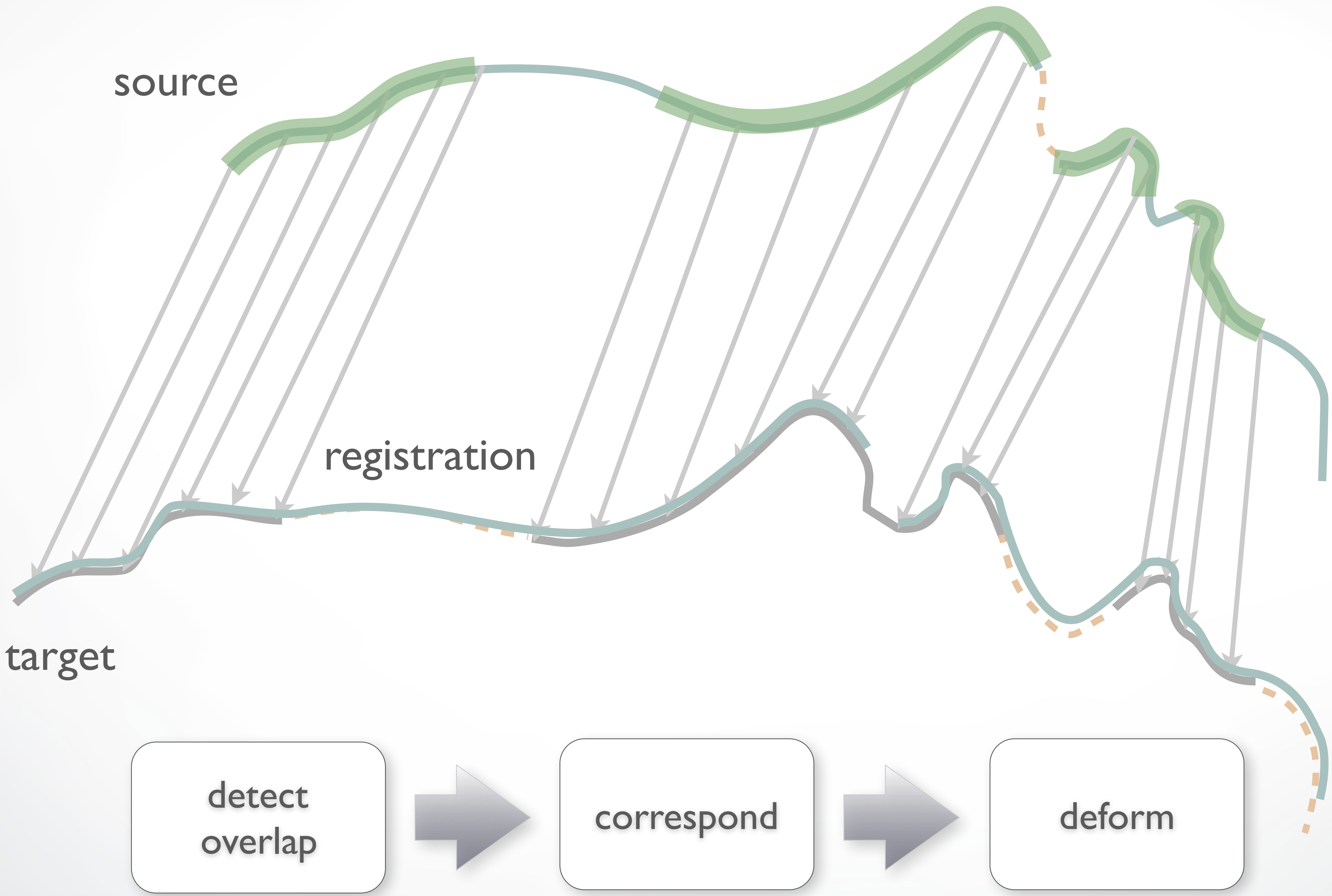




Non-Rigid Registration

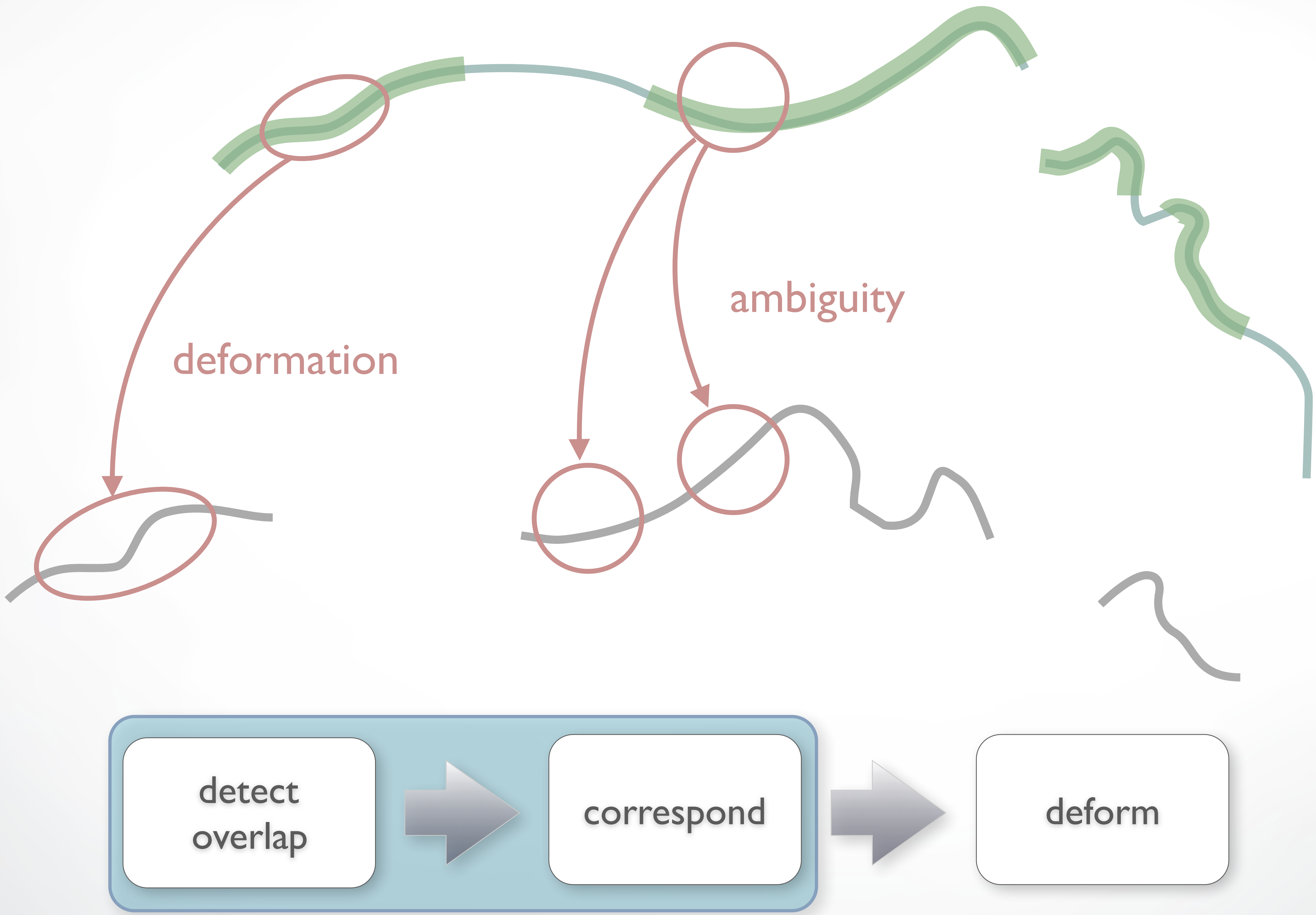


The Recipe

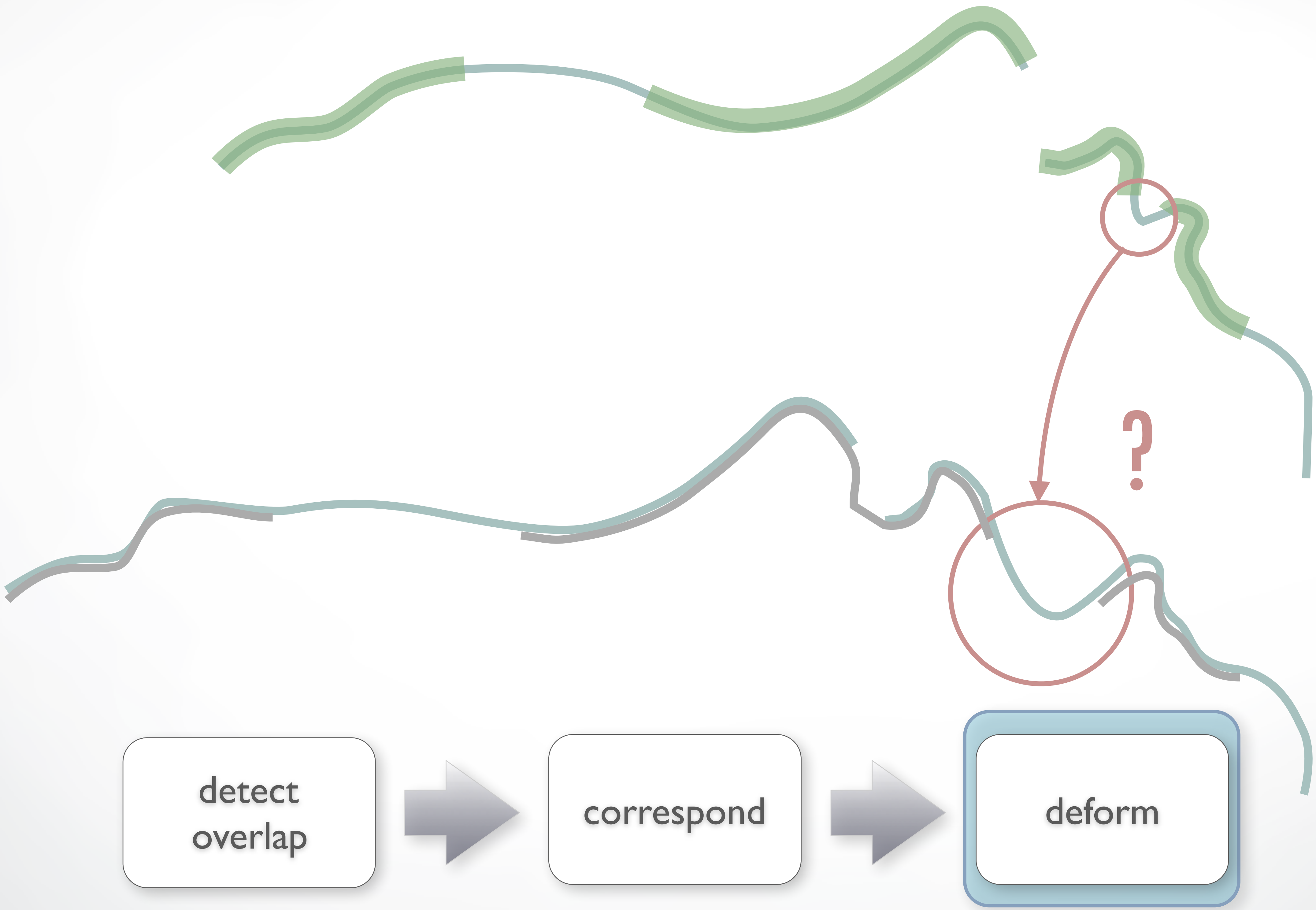


source
registration
target
detect overlap
correspond
deform

The Challenge



The Challenge



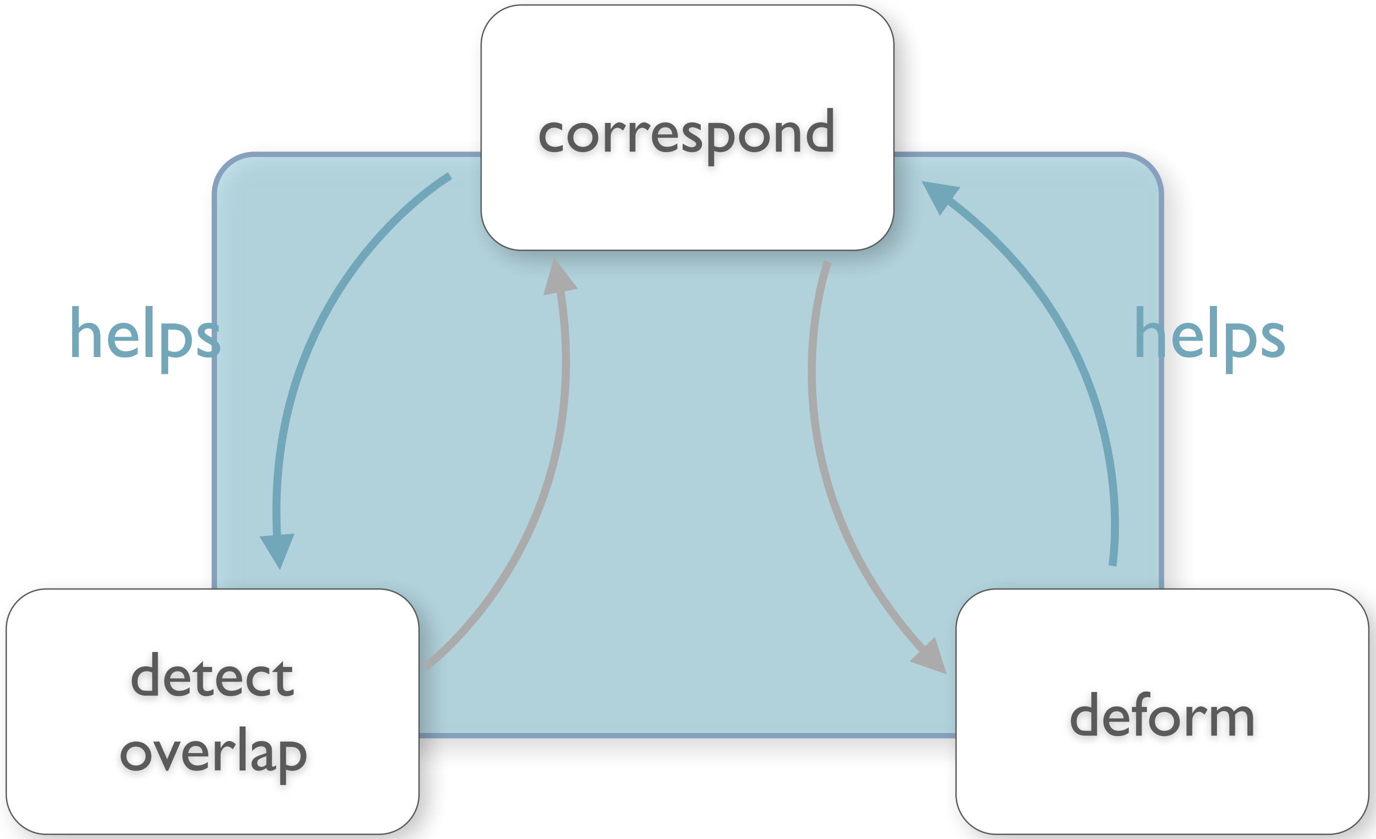
The Challenge

detect overlap

correspond

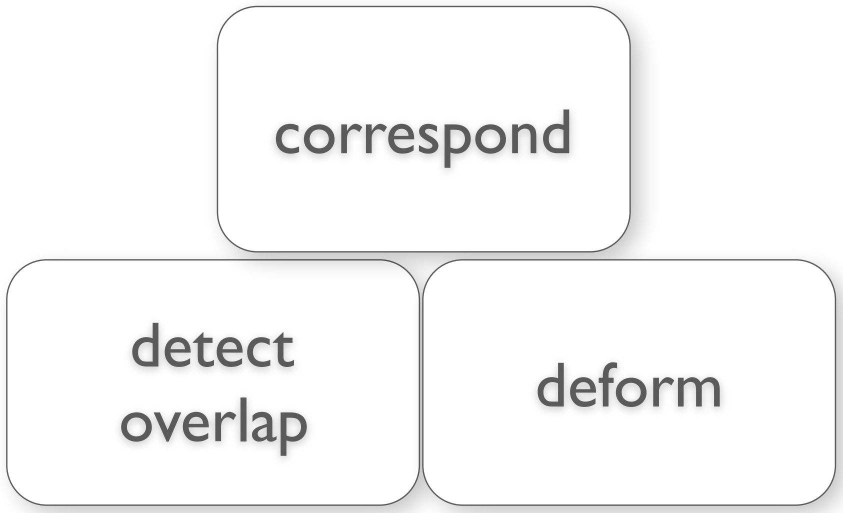
deform

Observation

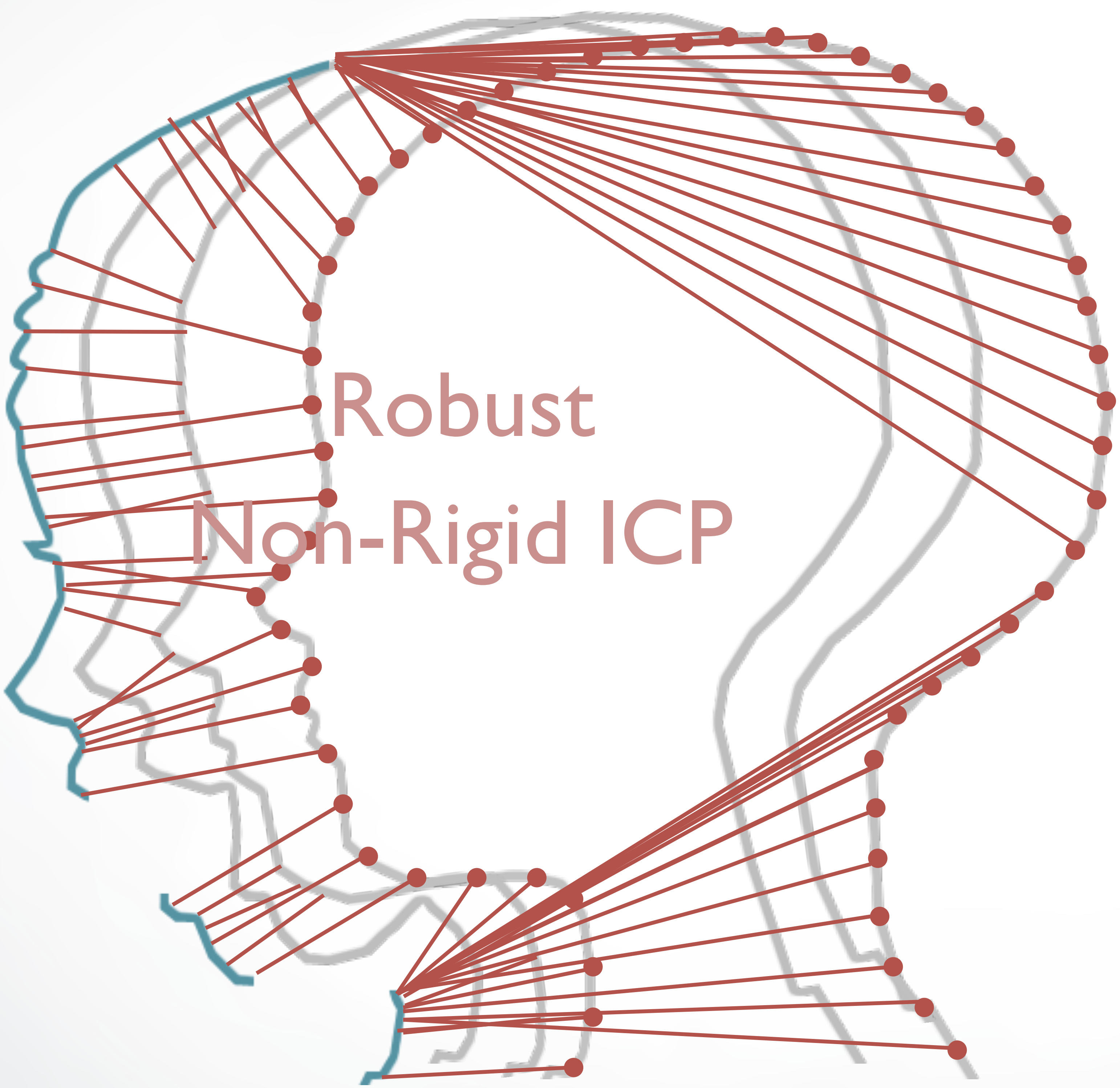


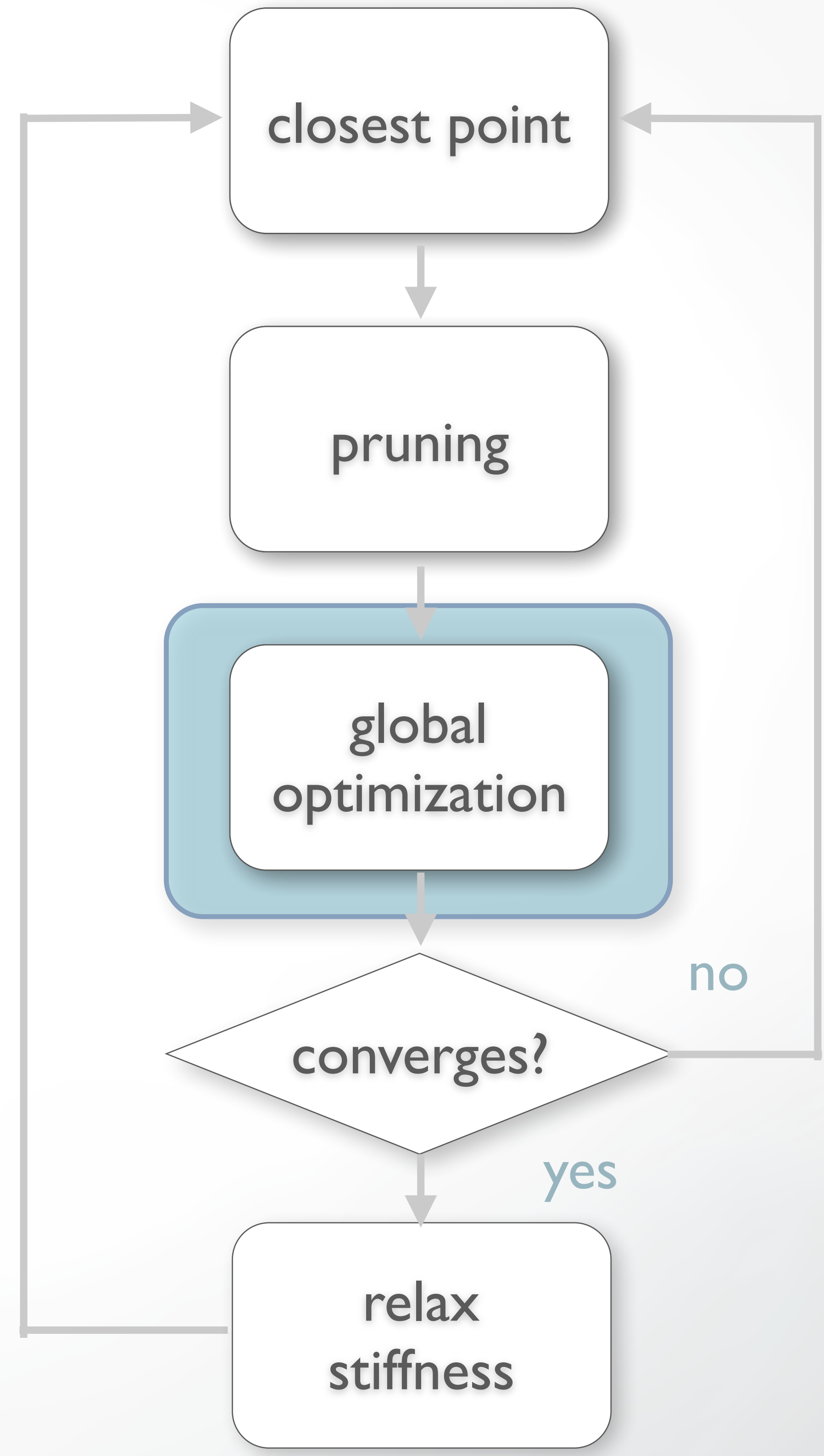
global optimization via local refinement

Iterative Global Optimization



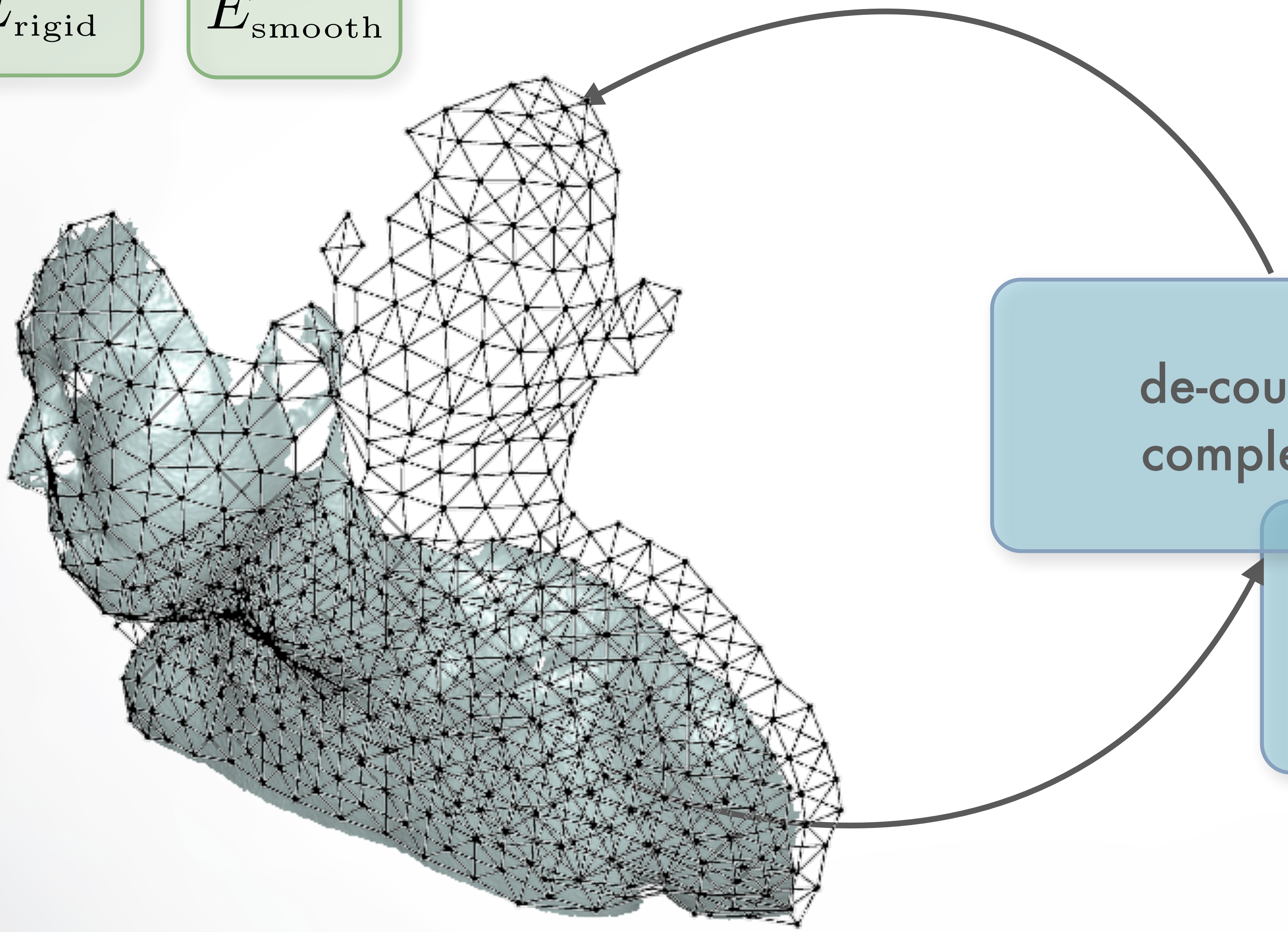
Iterative Global Optimization





Deformation Model

E_{rigid} E_{smooth}

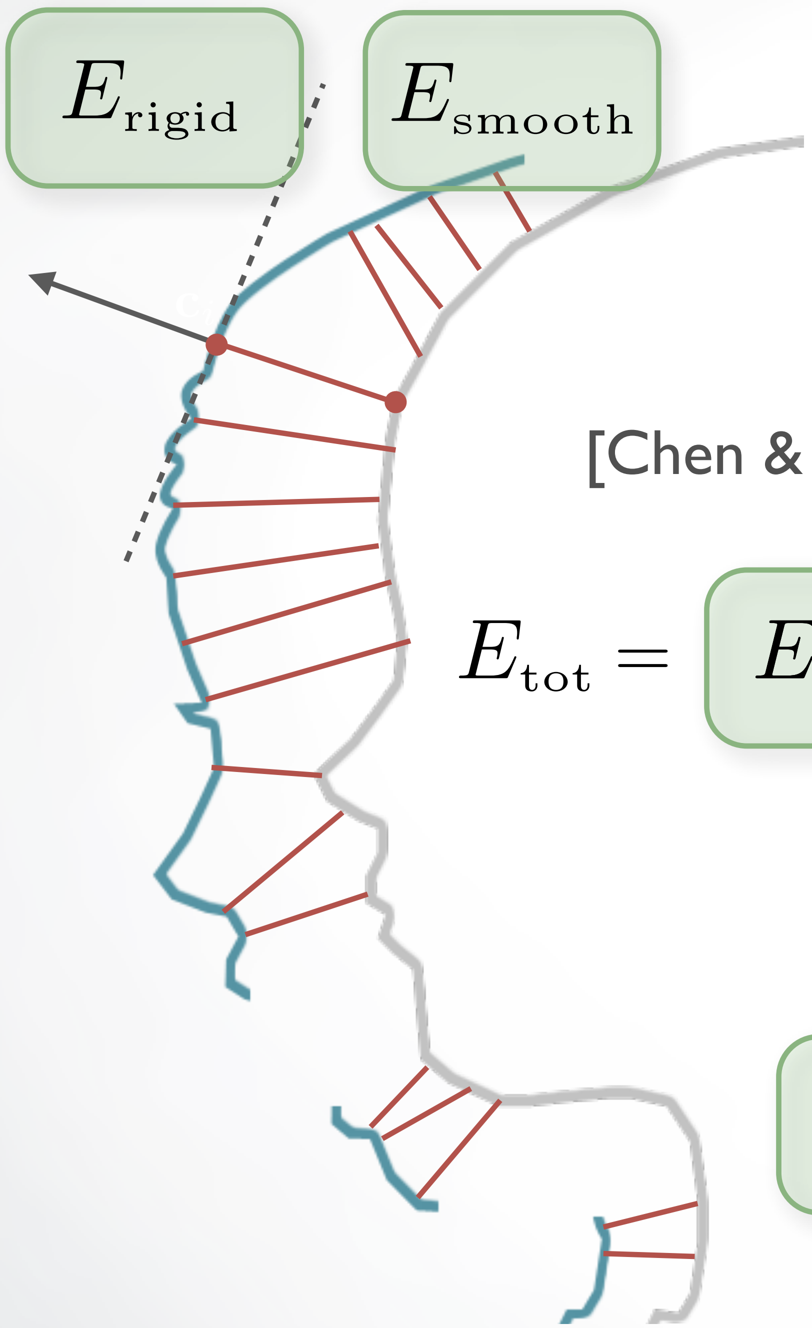


de-coupled complexity

detail preservation

global consistency

Non-Linear Energy Minimization



[Chen & Medioni '92]

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

non-linear least squares minimization

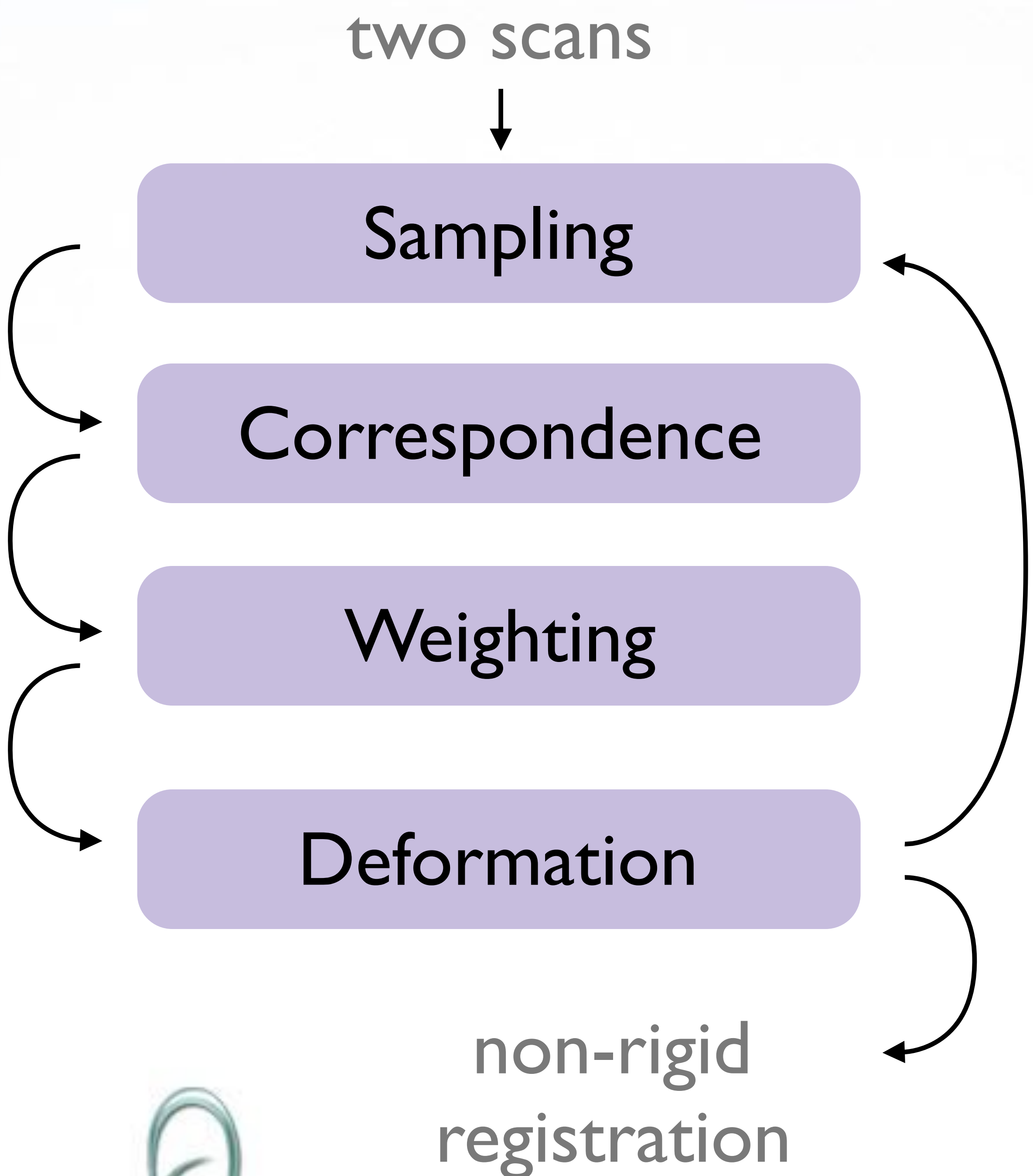
Gauss-Newton method

Jacobian is sparse

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

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

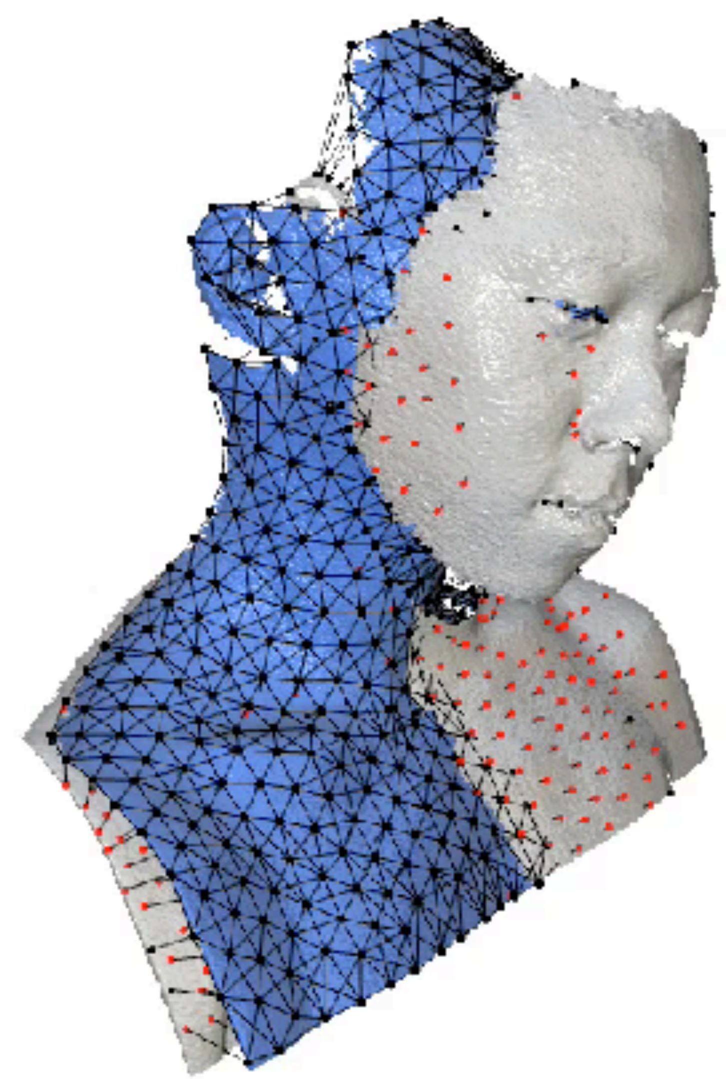
Relax Regularization

Correspondence

Weighting

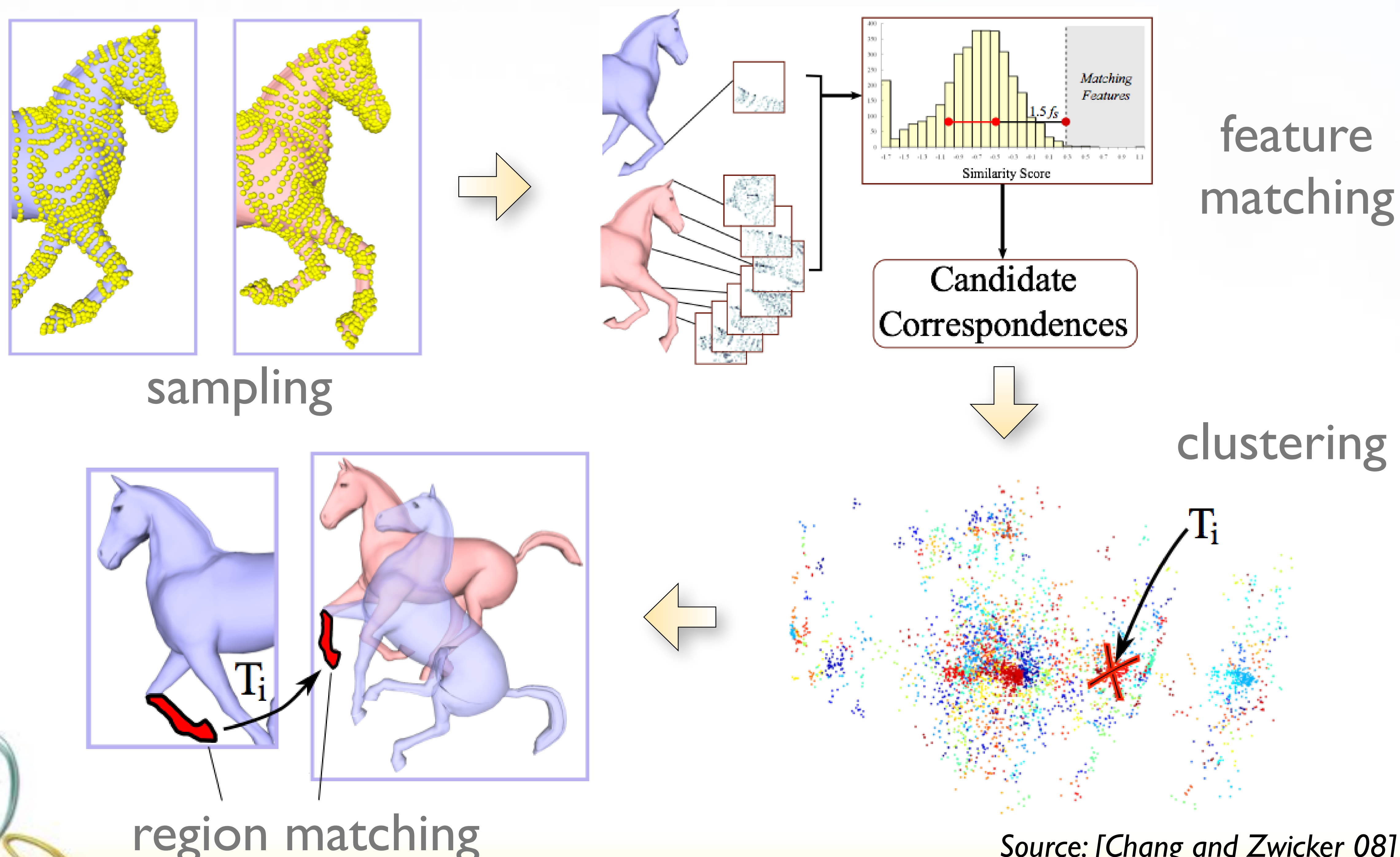
Deformation

non-rigid
registration



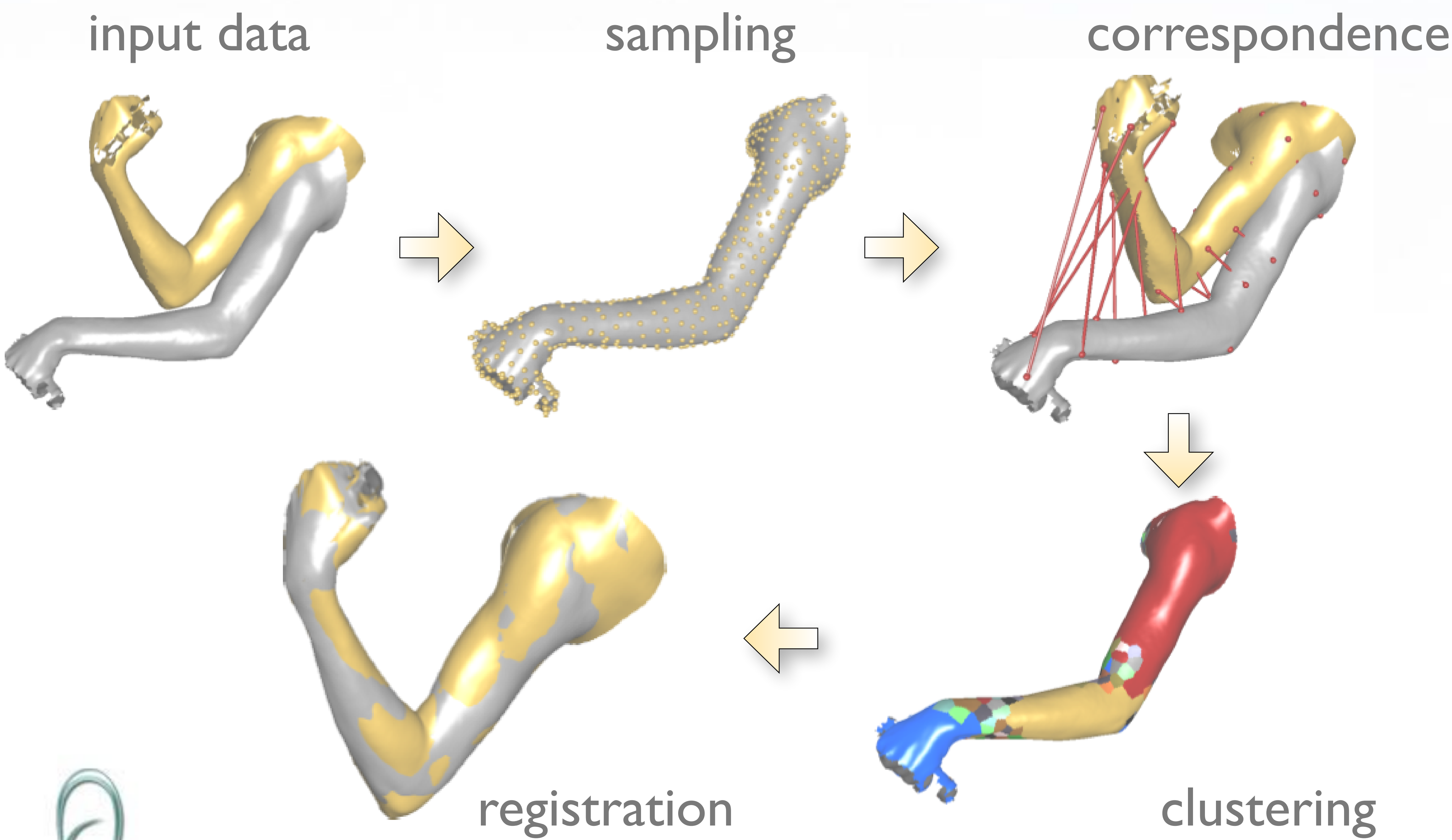
- Example with Embedded Deformation Model

Symmetries



Source: [Chang and Zwicker 08]

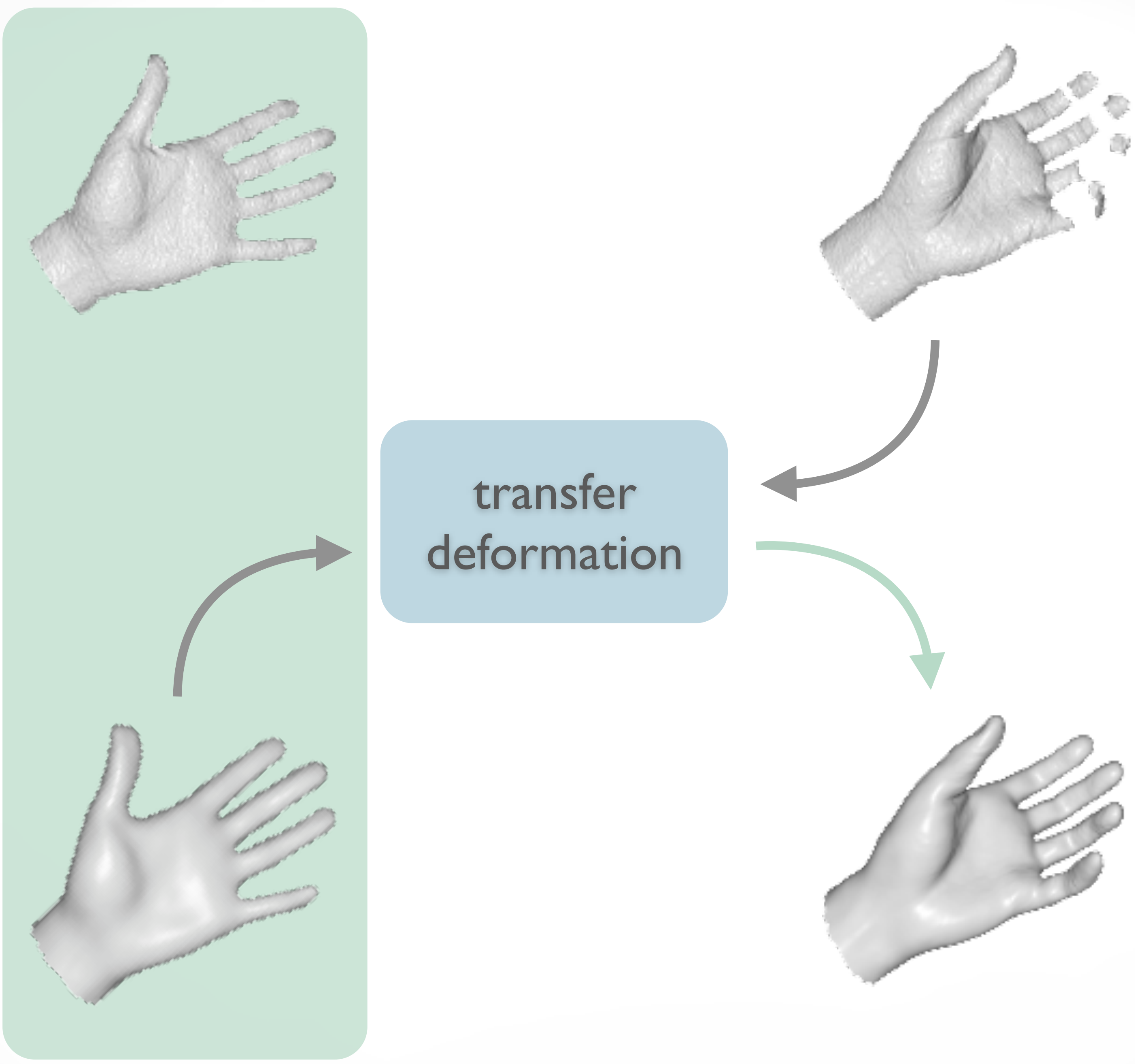
Isometry Preservation



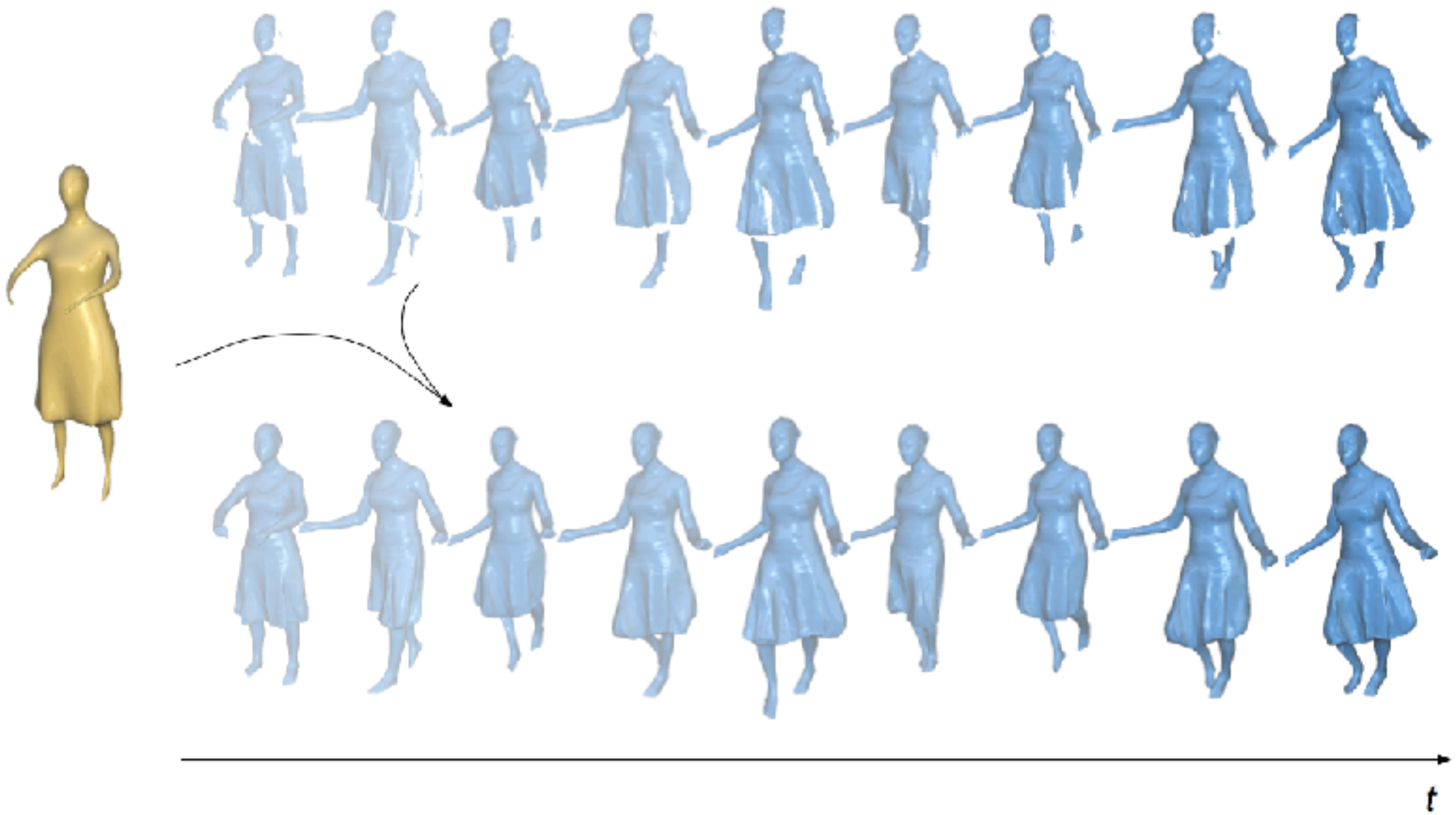
Source: [Huang et al. 08]

Dynamic Shape Reconstruction

Multi-Frame Reconstruction

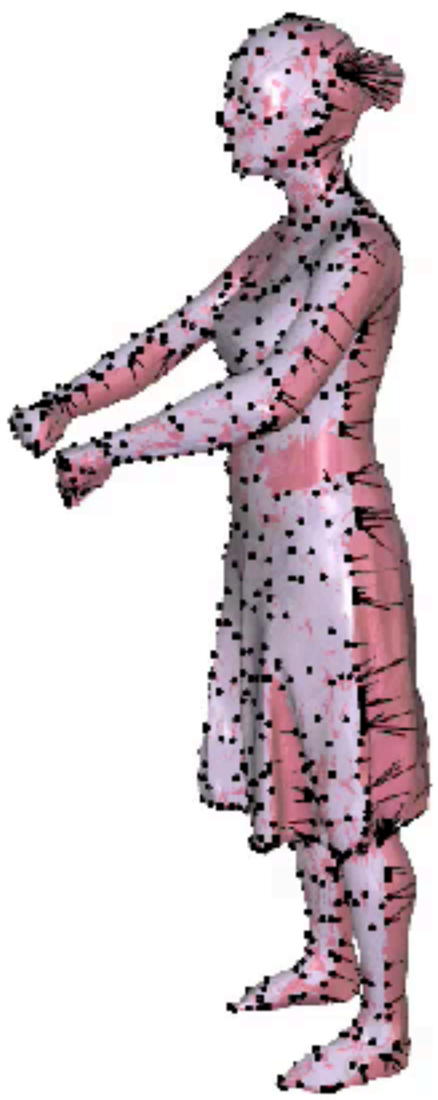


Geometry and Motion Reconstruction



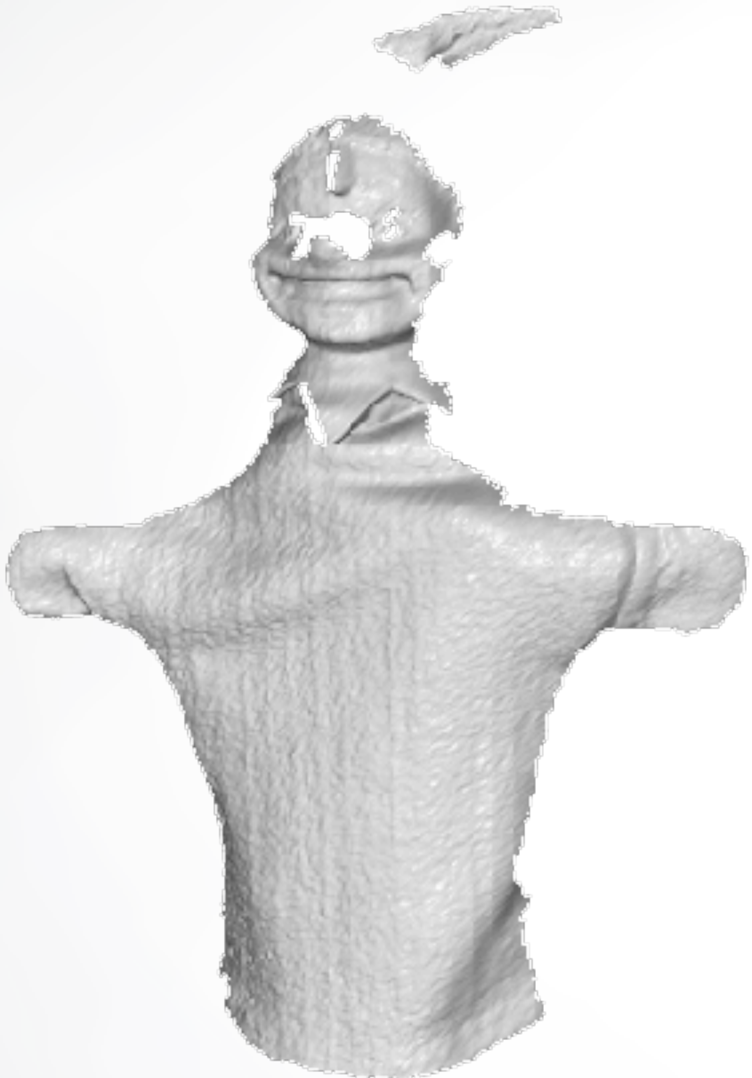
data provided by Stanford and MPI Saarbrücken input data

template fitting

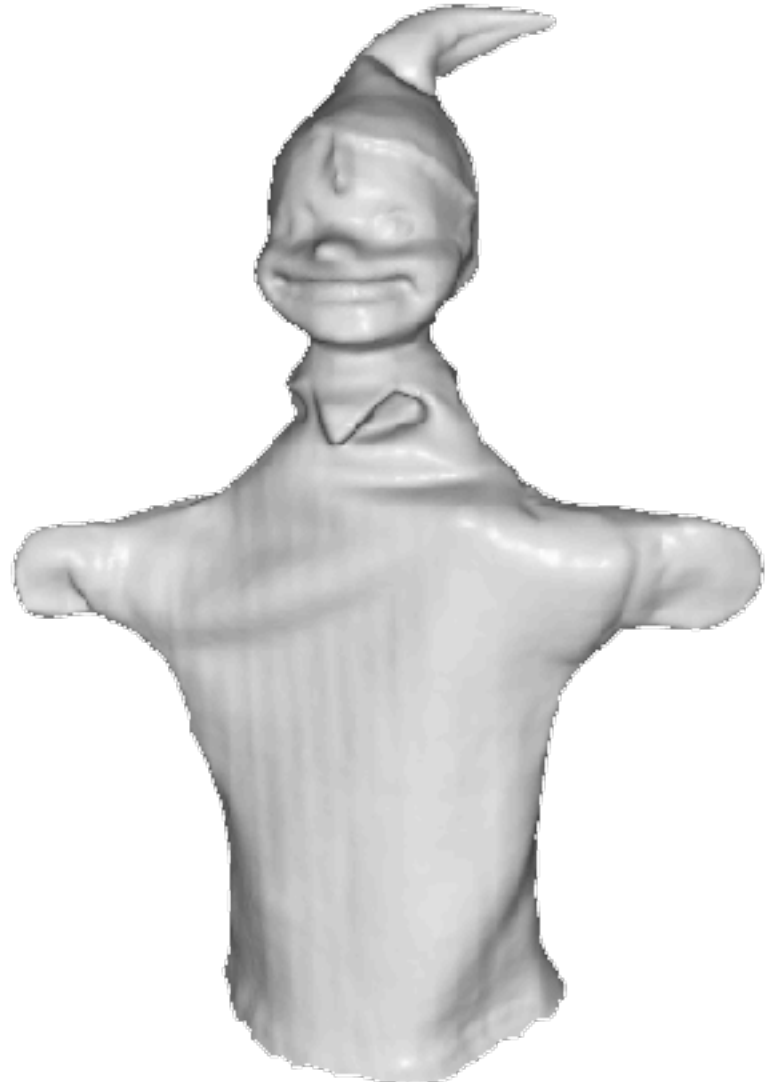


data provided by Stanford and MPI Saarbrücken

More Results



Input Scans



Reconstruction

Textured Reconstruction

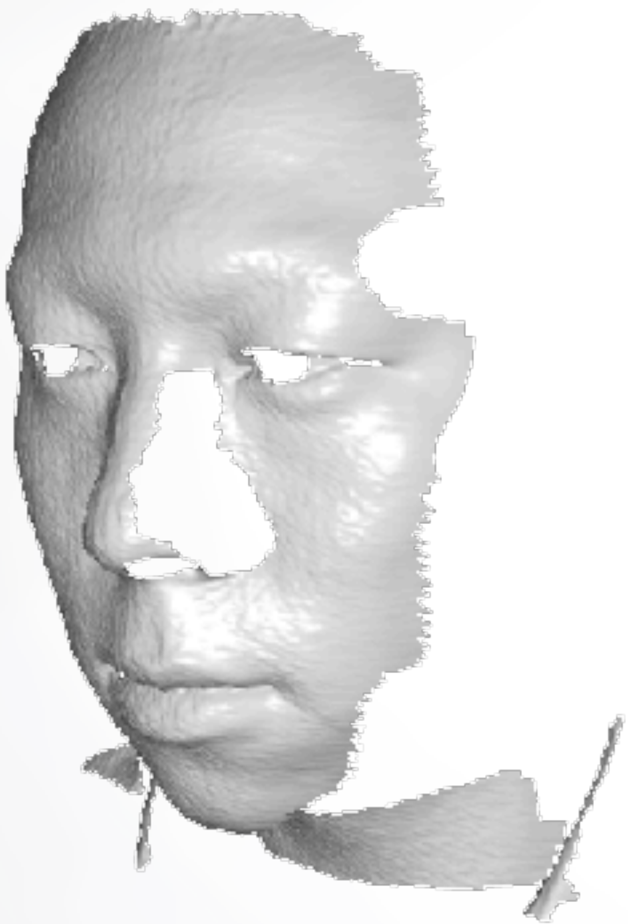
More Results

Input Scans

Reconstruction

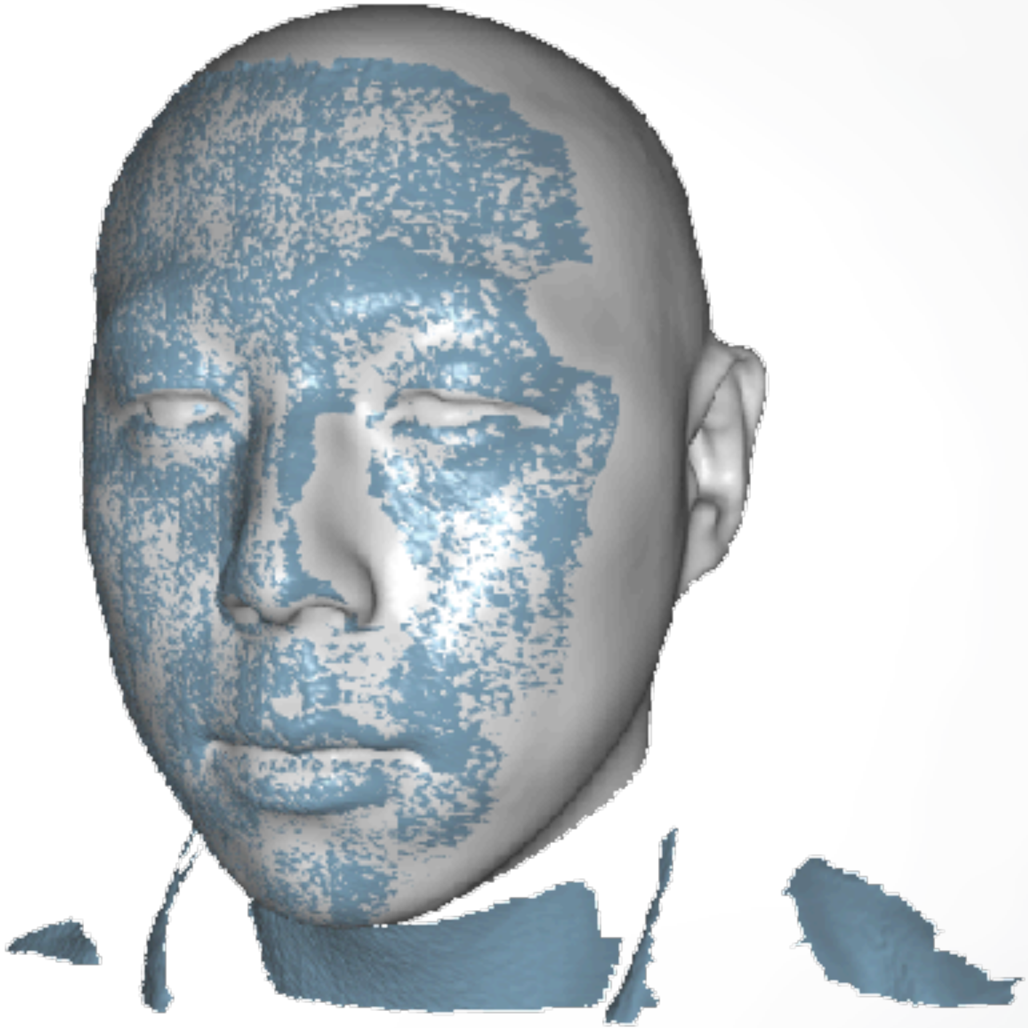
Textured Reconstruction

More Results



Input Scans

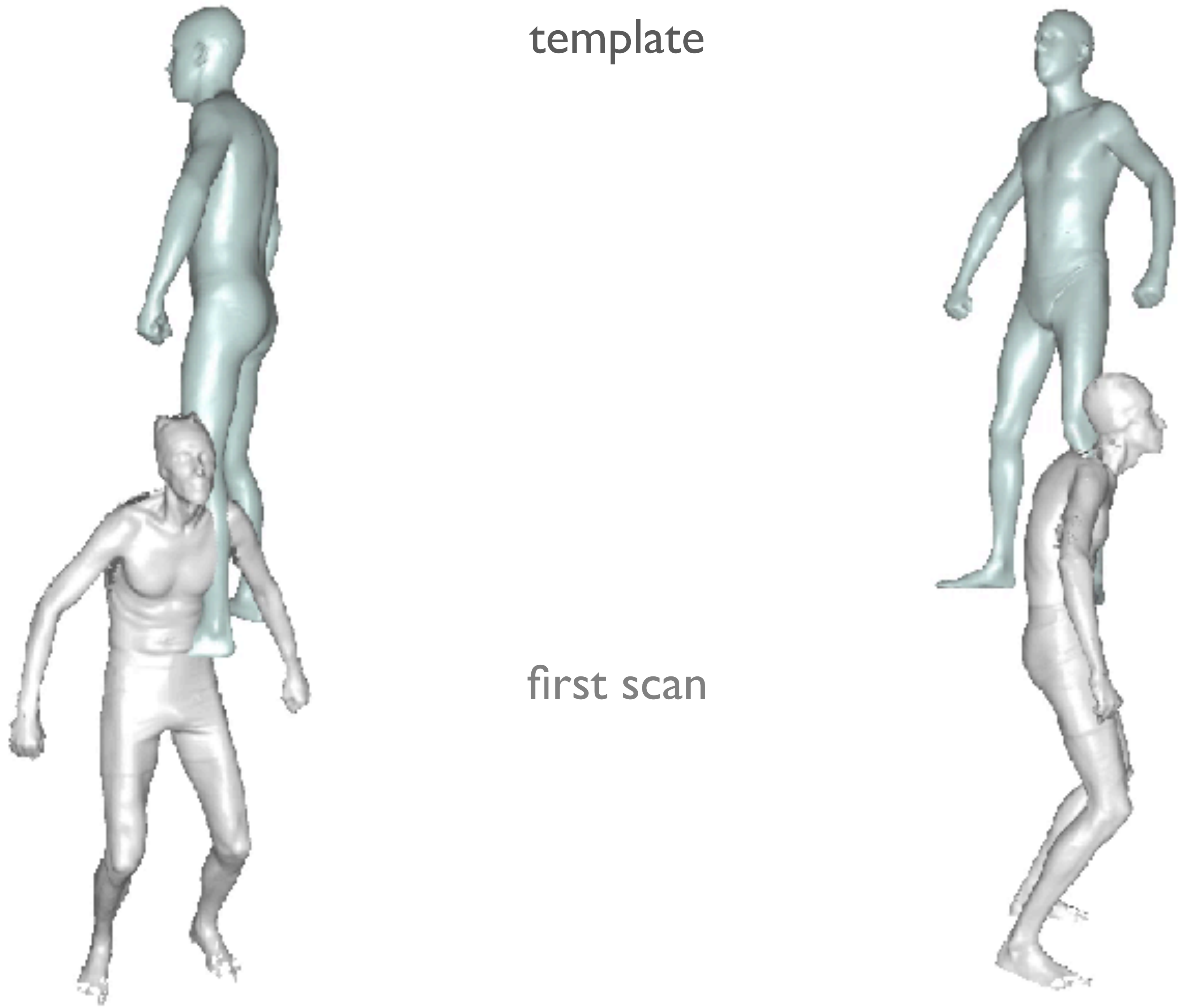
Reconstruction



Overlaid Scans

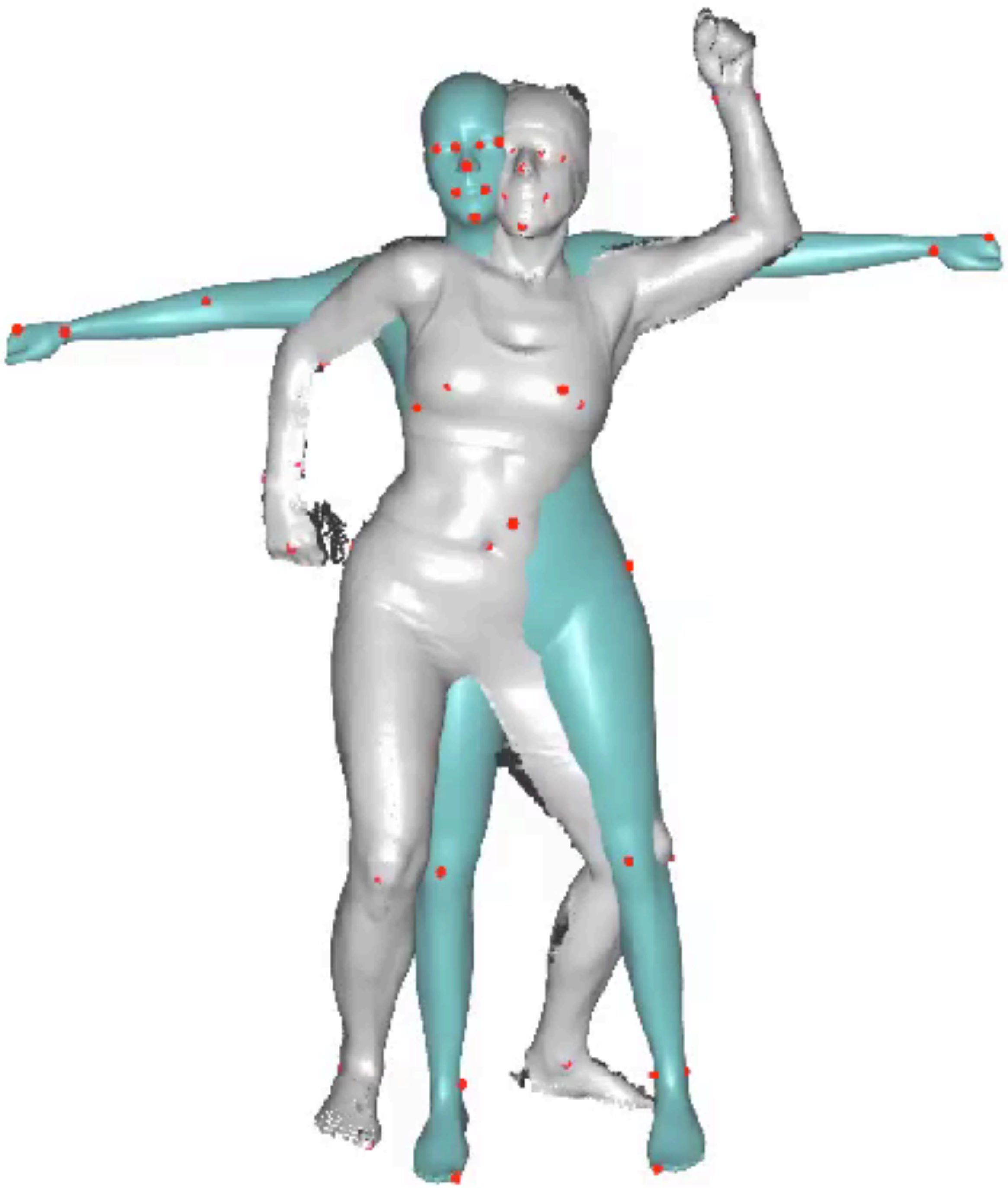
Template Fitting

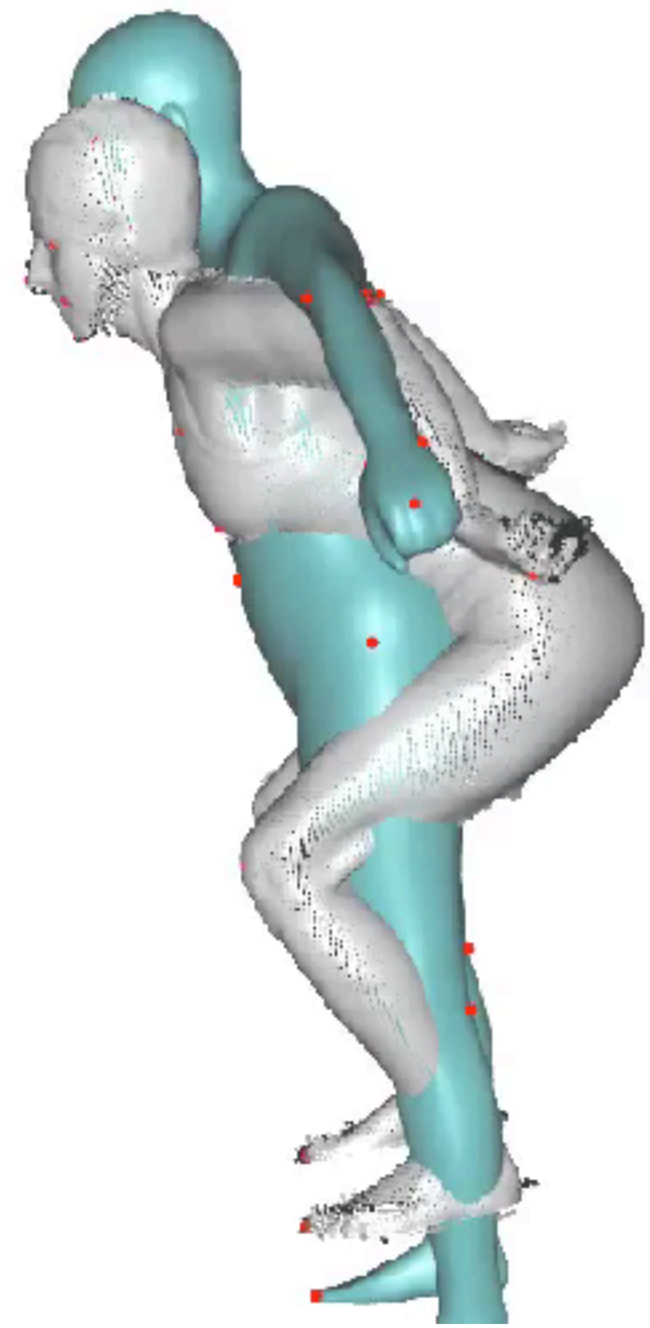
Initial Alignment



collaboration with MPI Tübingen/Brown University

In Practice: Need Some Correspondences





Collaboration with MPI Tübingen

Improving SCAPE

non-rigid alignment

pose estimation

regression

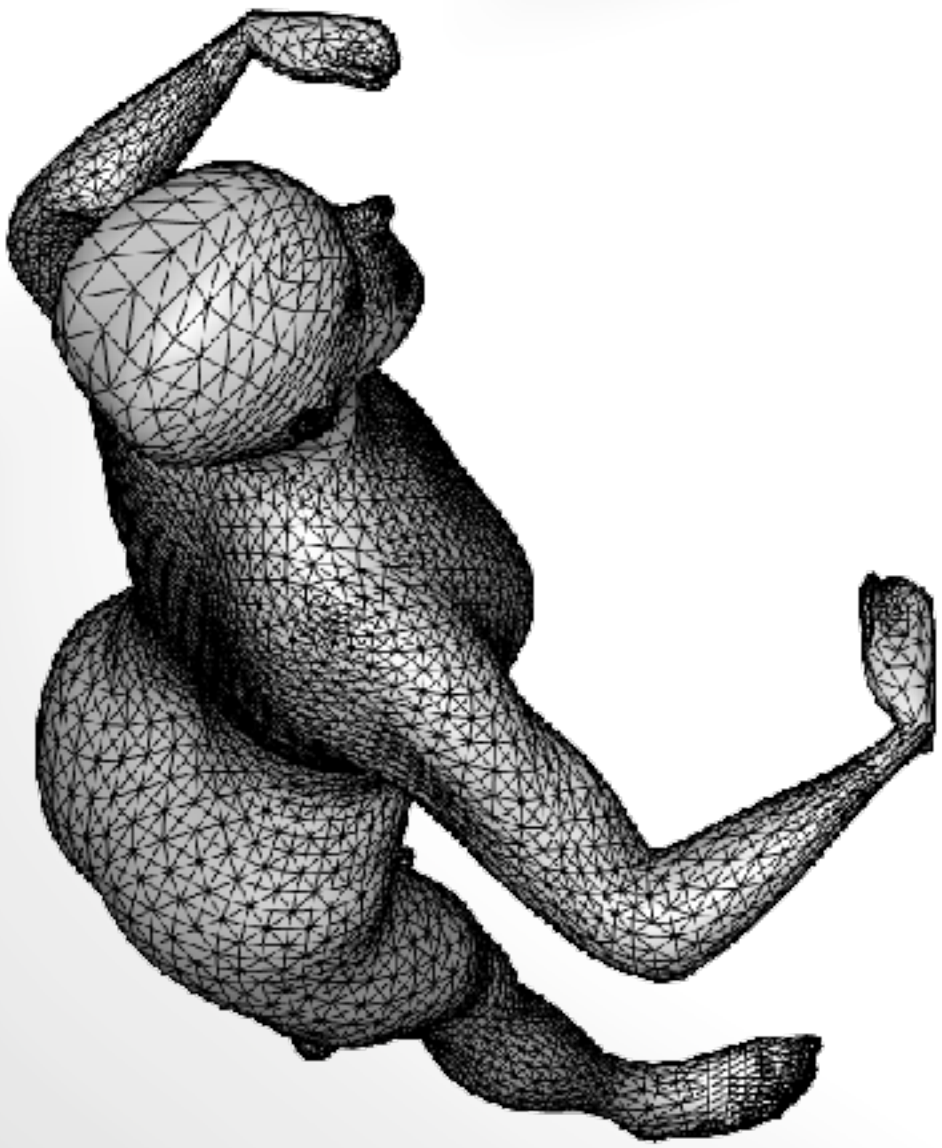
sparse/partial matching → SCAPE model → accurate model

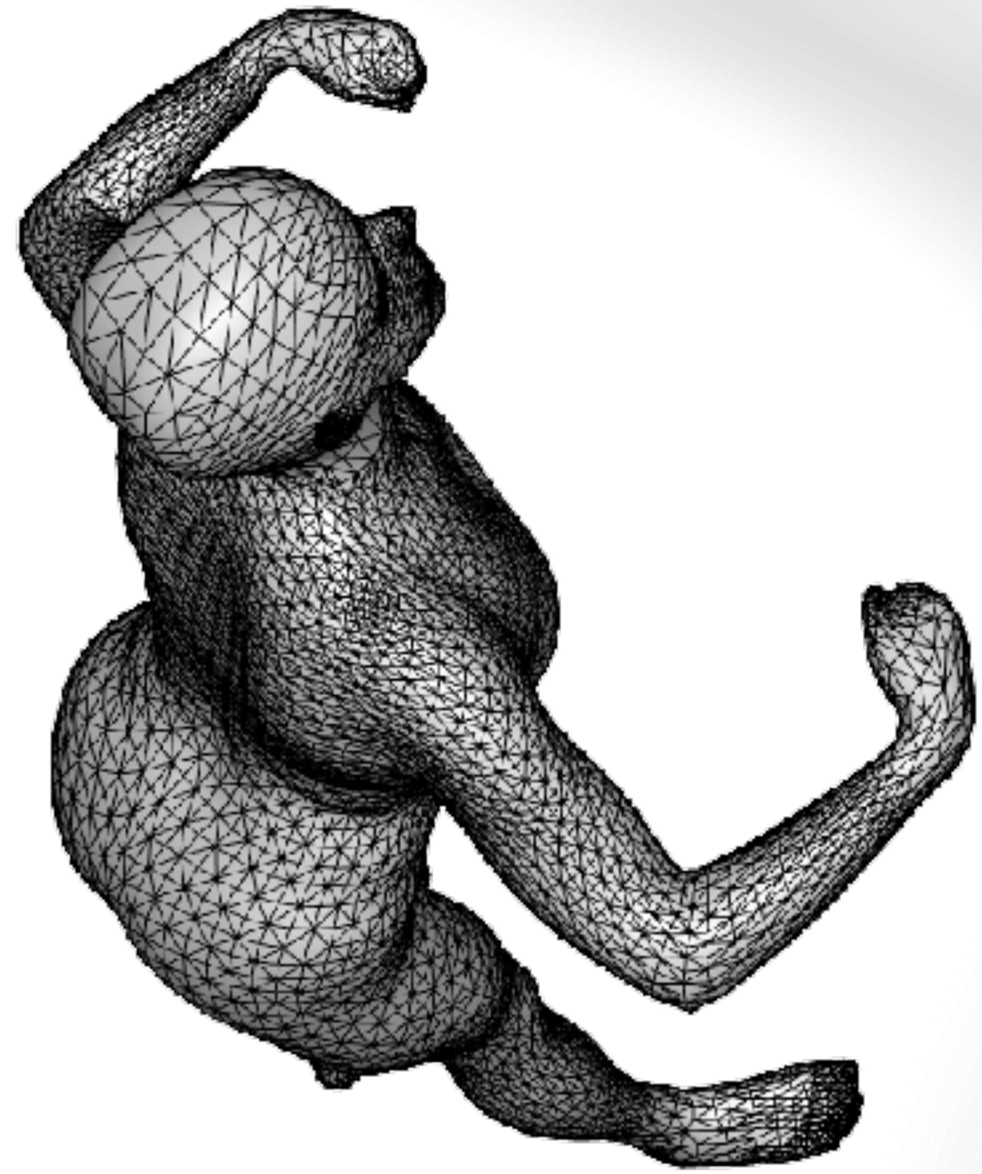
Collaboration with MPI Tübingen

Regression Results

> 50% more accuracy

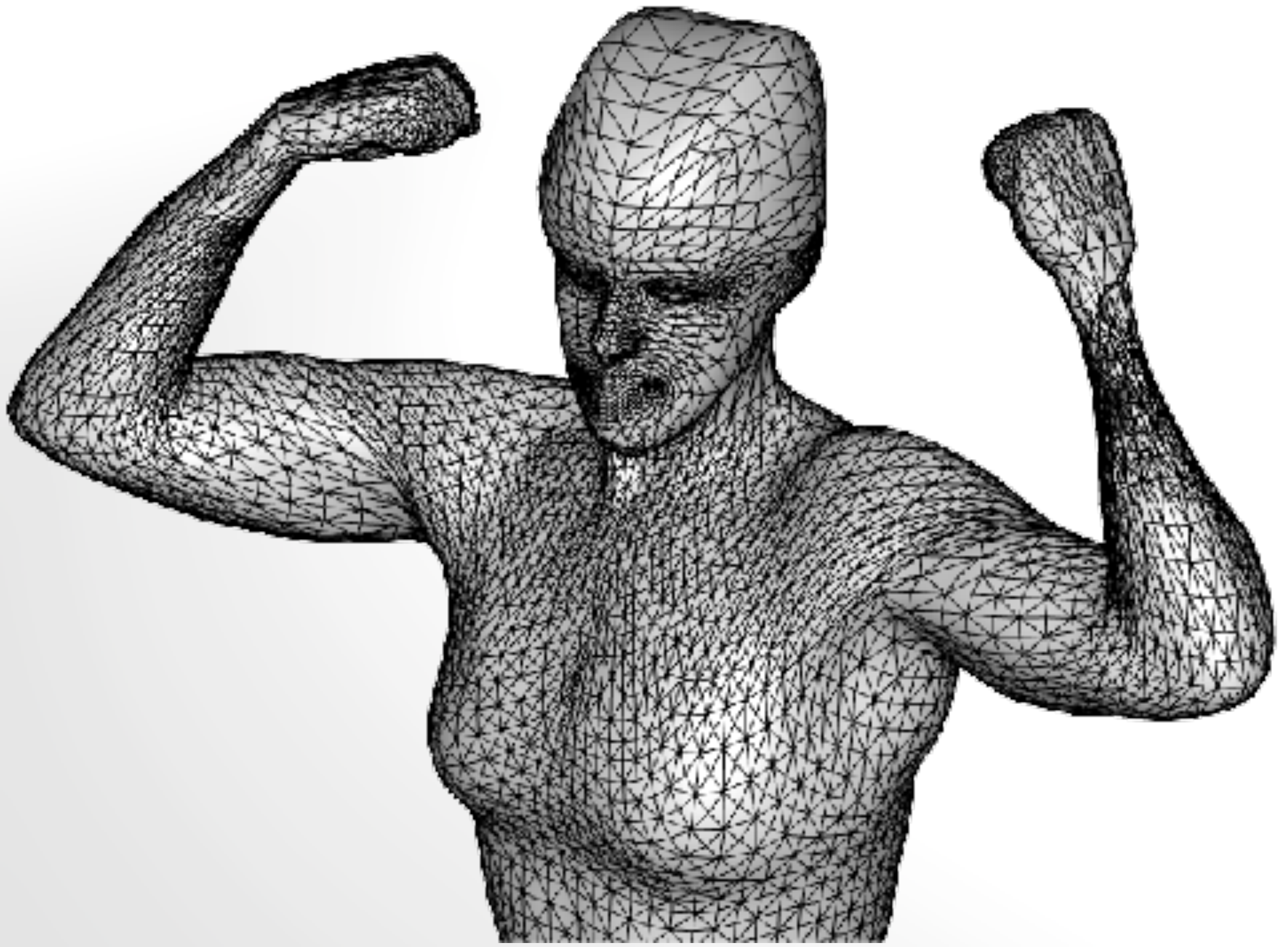
Alignment Comparison

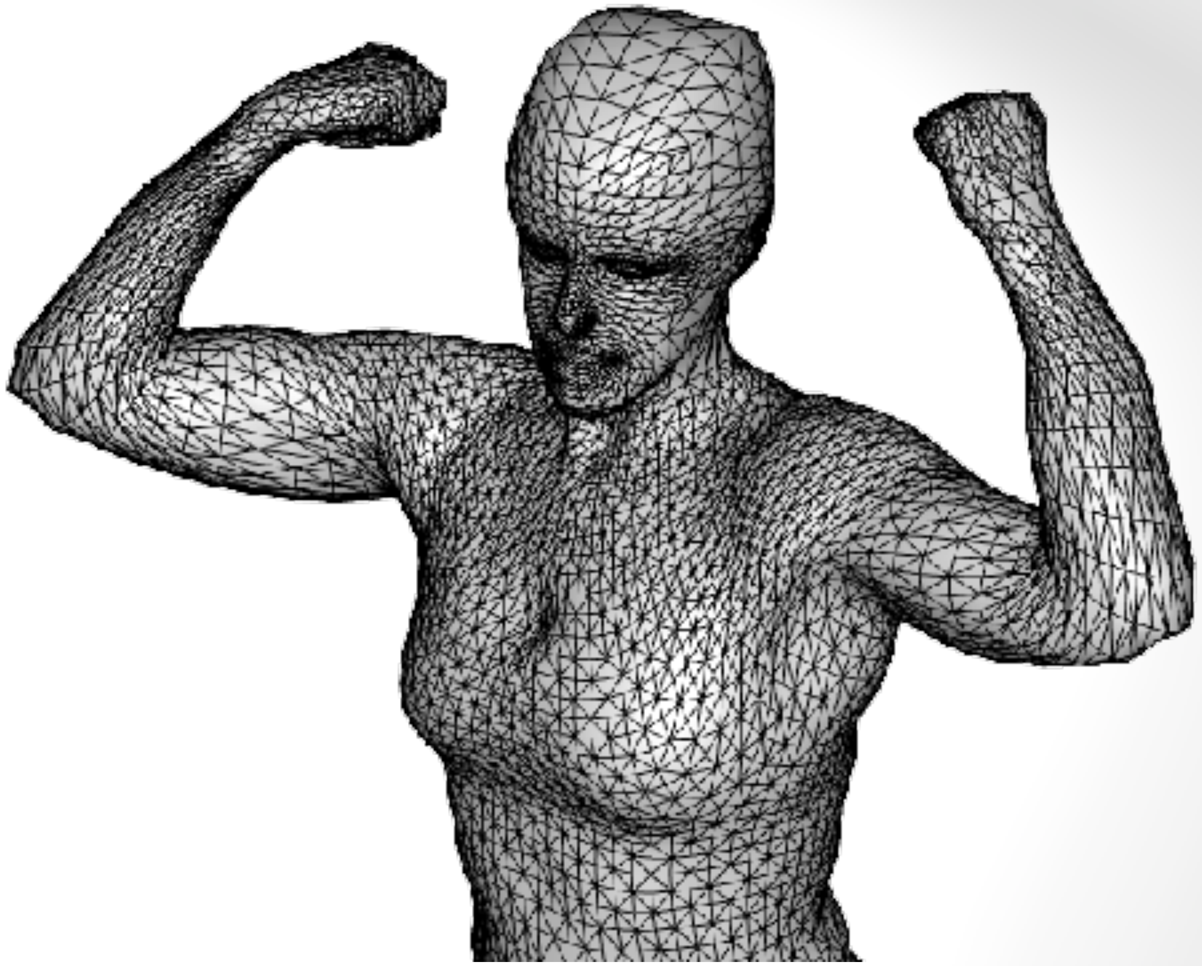




Collaboration with MPI Tübingen

Alignment Comparison



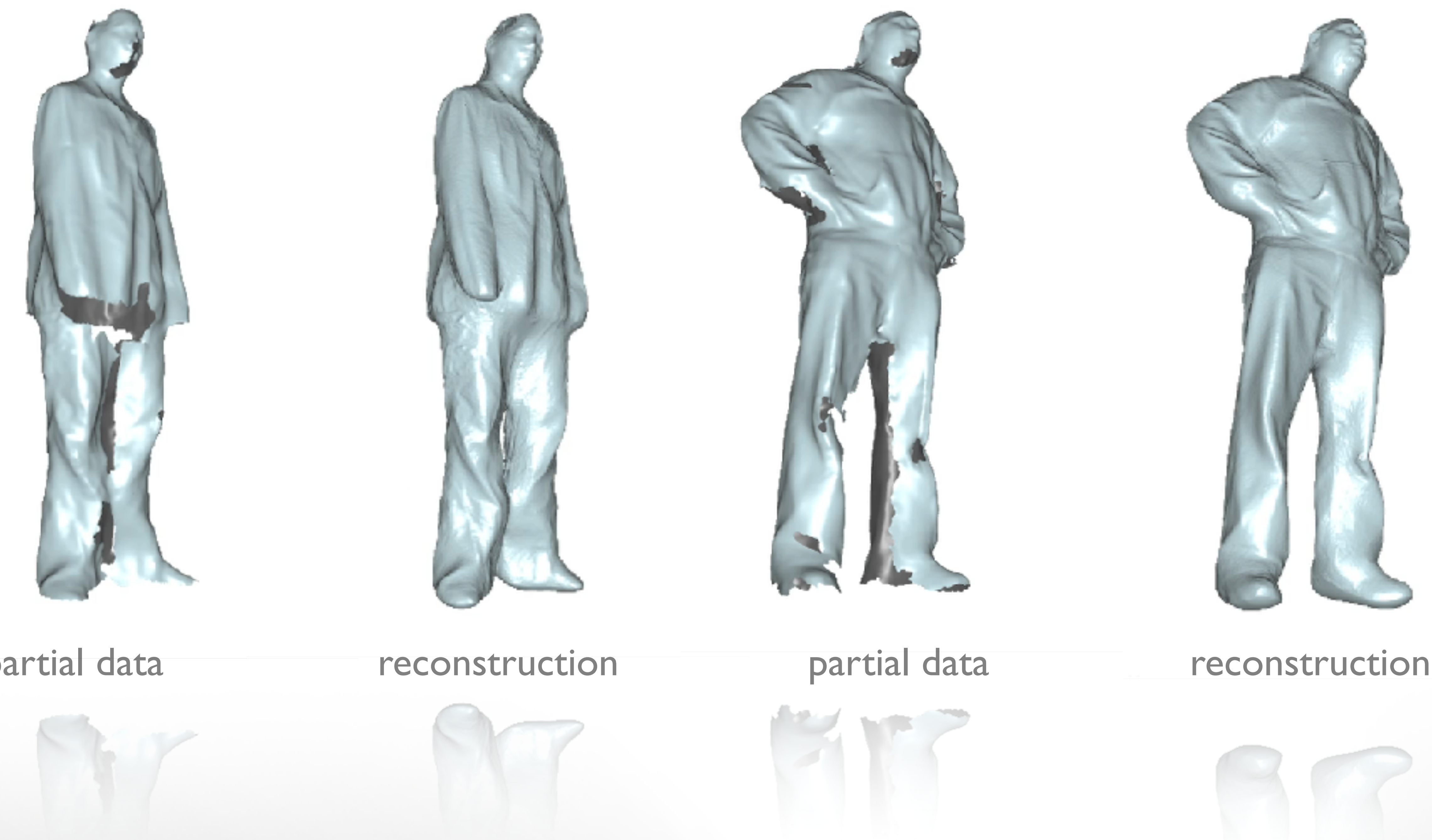


Collaboration with MPI Tübingen

Template Free-Reconstruction

Temporally-Coherent Shape Completion

[Li et al. '11]

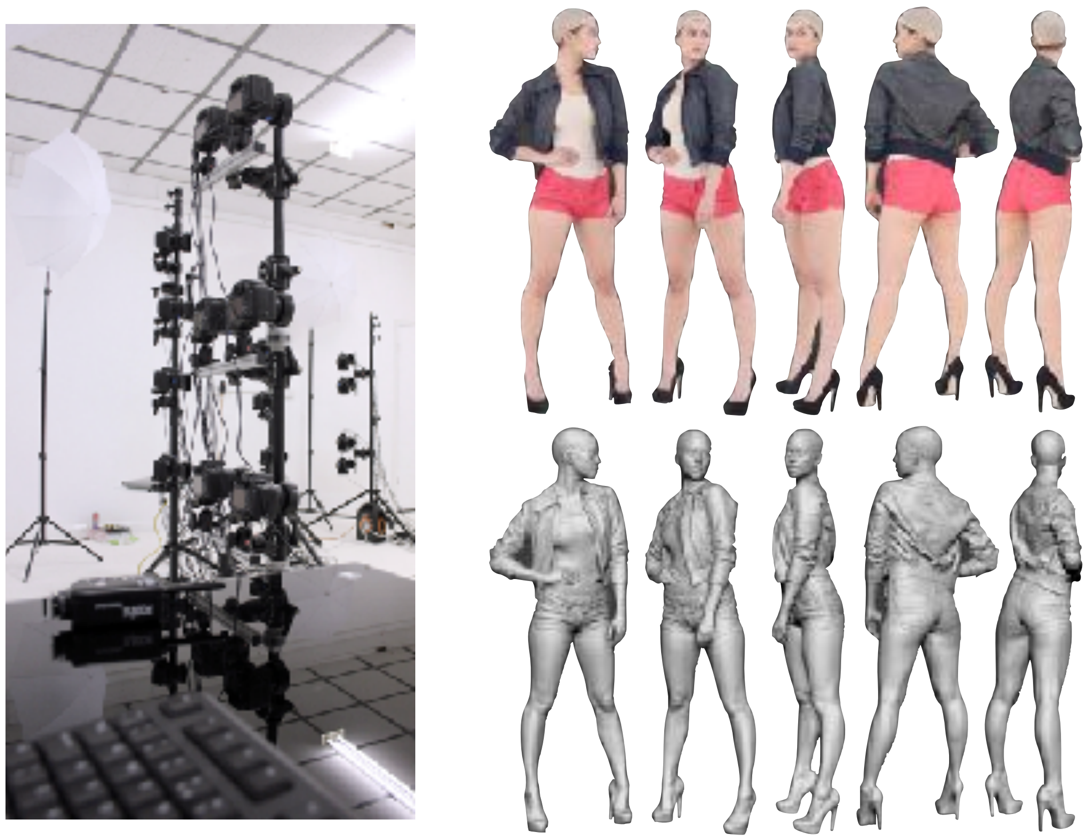


Free-Viewpoint Video

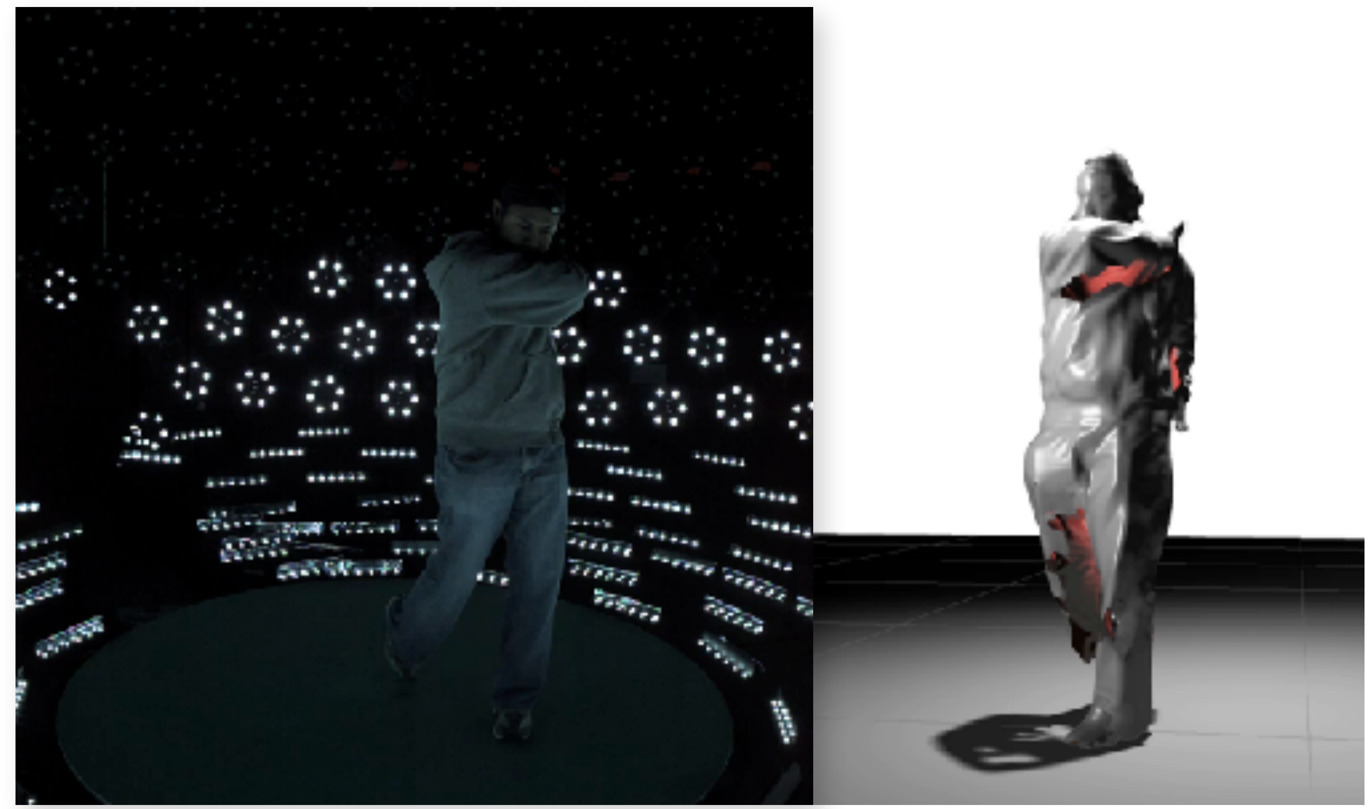
[Li et al. '11]

3D Reconstruction

Multi-View Capture

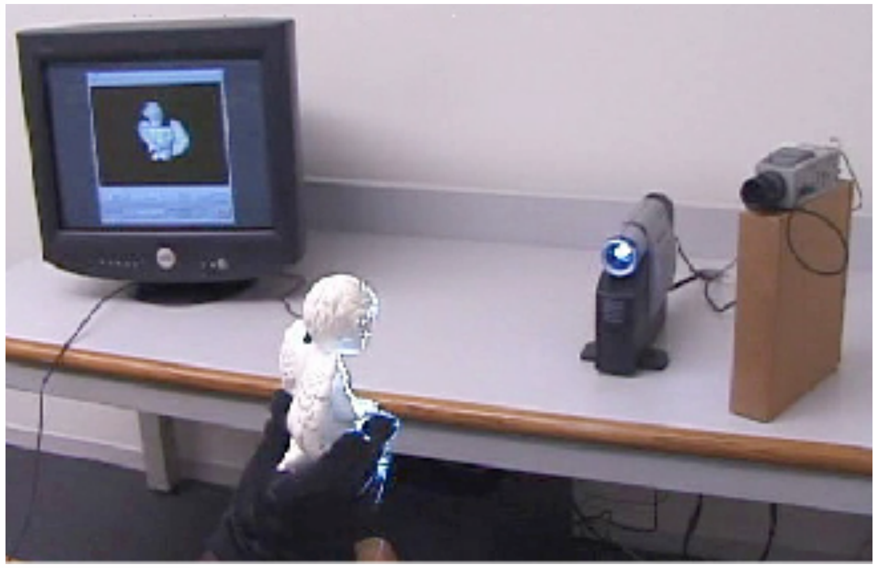


multi-view stereo



multi-view photometric stereo

Single-View Capture

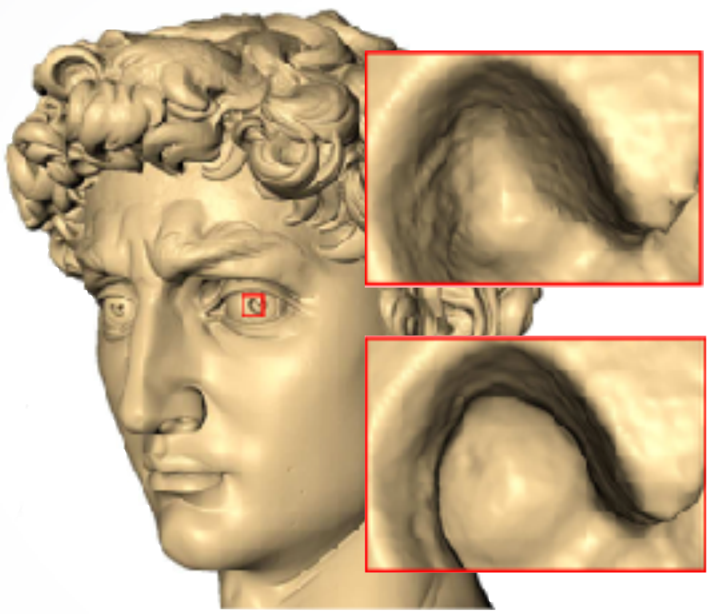


[Rusinkiewicz et al. ‘02]

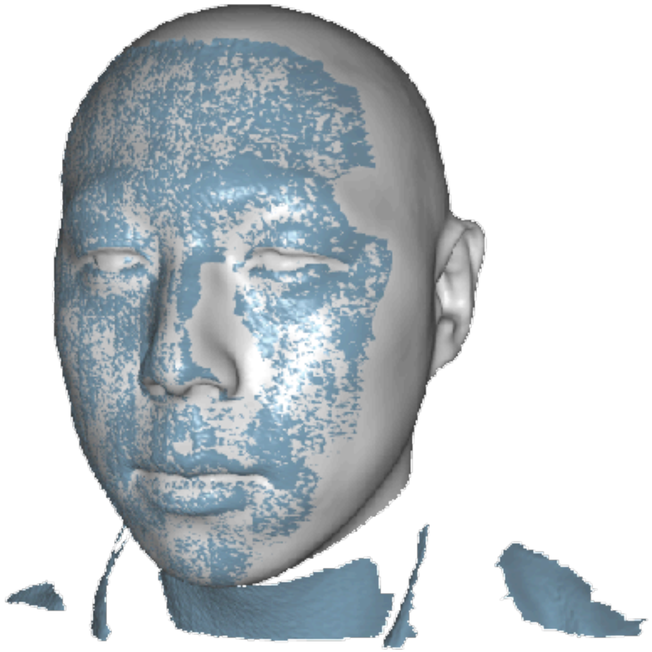
Artec Group

[Newcombe et al. ’11]
KinectFusion

Handling Deformations



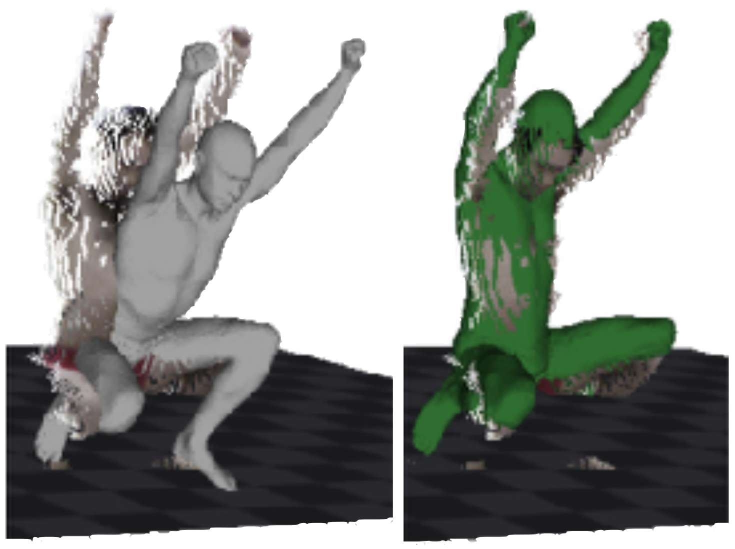
[Brown & Rusinkiewicz '07]



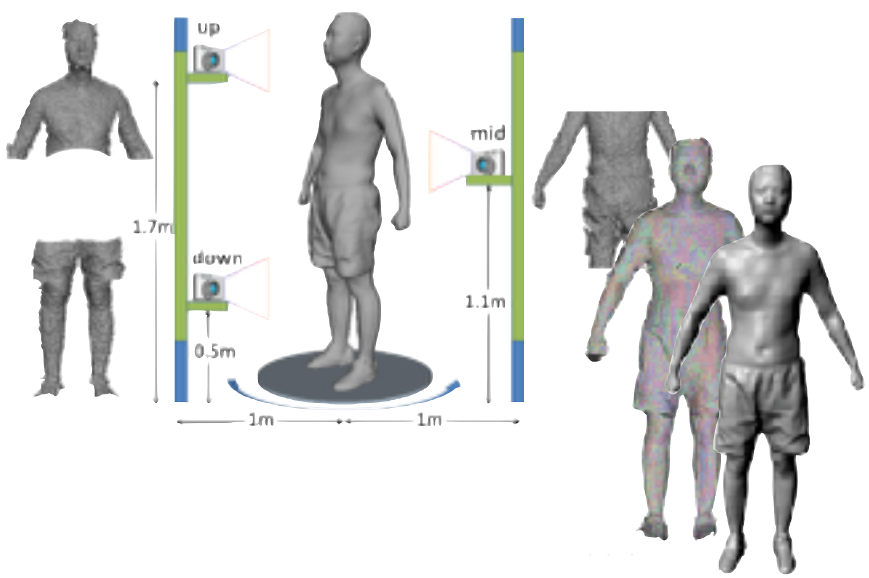
[Li et al. '09]

[Chang & Zwicker '11]

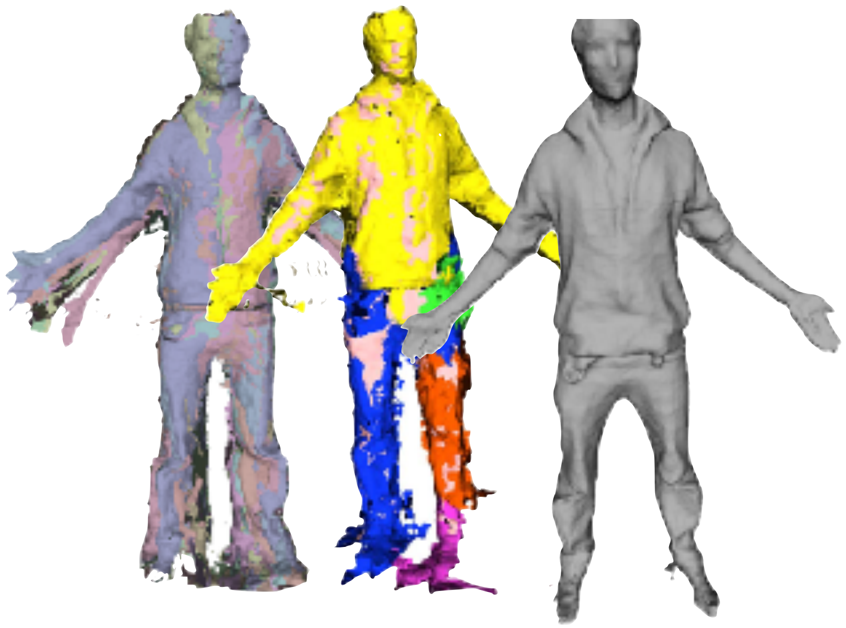
Using Human Body Priors



[Weiss et al. ’11]



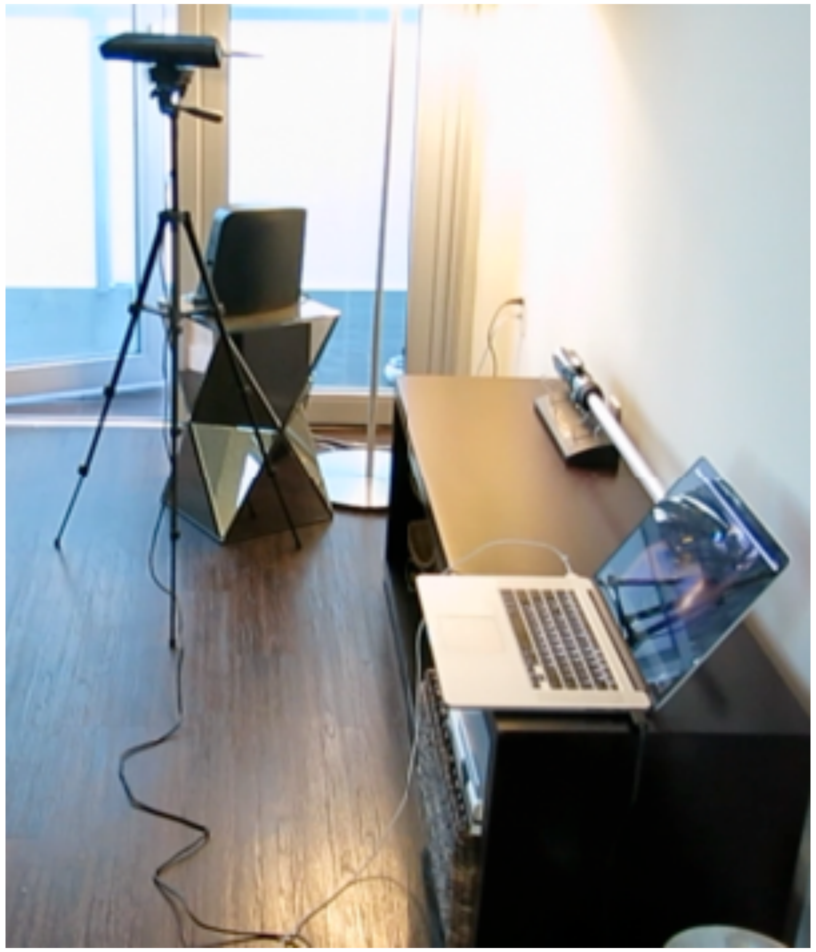
[Tong et al. ‘12]



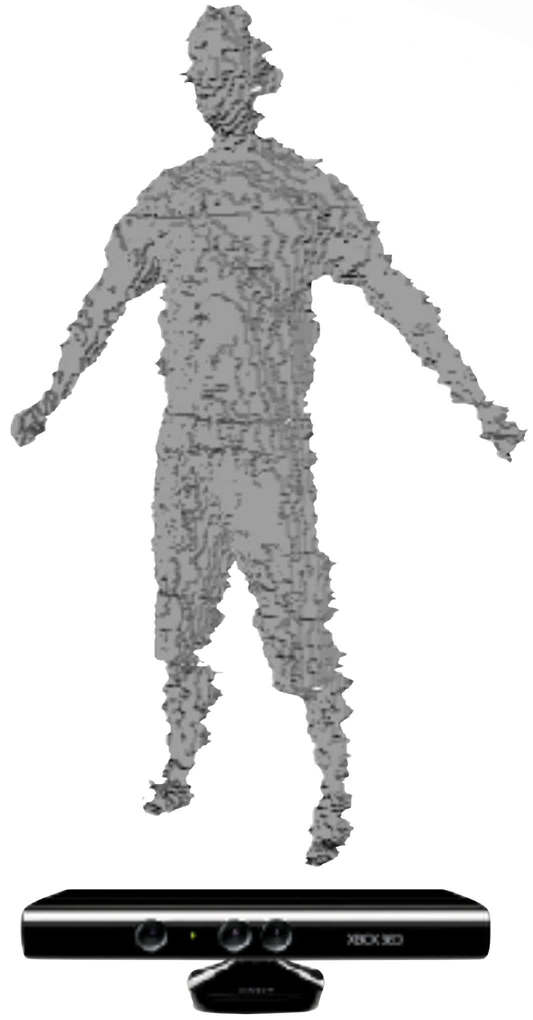
[Cui et al. ‘12]

Challenges

deformation, clothing & props



daily environment

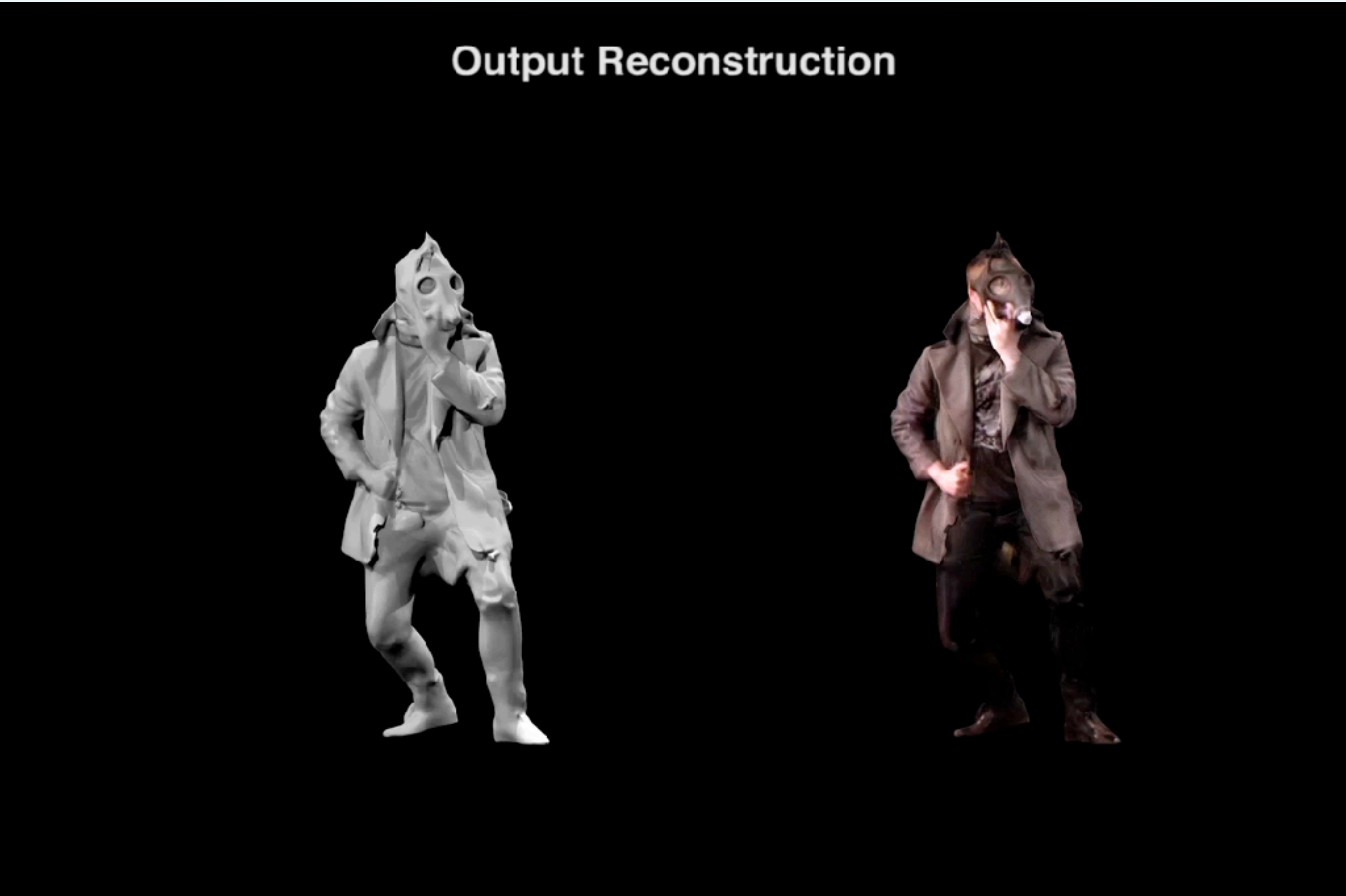


low cost

Global Non-Rigid Registration

3D Scanning

Automatic Reconstruction



3D Printing

http://cs621.hao-li.com

Thanks!