Geometric Registration for Deformable Shapes

1.1 Introduction

Overview · Data Sources and Applications · Problem Statement

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Overview

Presenters

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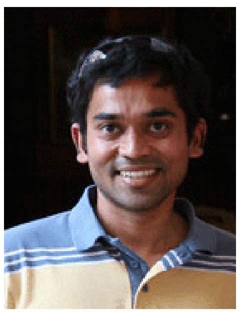

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Tutorial Outline

Overview

- **Part I:** Introduction (1.25h)
- **Part II:** Local Registration (1.5h)
- **Part III:** Global Matching (1.75h)
- **Part IV:** Animation Reconstruction (1.25h)
- Conclusions and Wrap up (0.25h)

Part I: Introduction

Introduction (Michael)

- Problem statement and motivation
- Example data sets and applications

Differential geometry and deformation modeling (Mark)

- Differential geometry background
- Brief introduction to deformation modeling

Kinematic 4D surfaces (Niloy)

- Rigid motion in space-time
- Kinematic 4D surfaces

Part II: Local Registration

ICP and of rigid motions (Niloy)

- Rigid ICP, geometric optimization perspective
- Dynamic geometry registration (Intro)

Deformable Registration (Michael)

- A variational model for deformable shape matching
- Variants of deformable ICP

Subspace Deformation, Robust Registration (Hao)

- Subspace deformations / deformation graphs
- Robust local matching

Part III: Global Matching

Features (Will)

- Key point detection and feature descriptors

Isometric Matching and Quadratic Assignment (Michael)

- Extrinsic vs. intrinsic geometry
- Global matching techniques with example algorithms

Advanced Global Matching (Will)

- Global registration algorithms

Probabilistic Techniques (Michael)

- Ransac and forward search

Articulated Registration (Will)

- Articulated registration with graph cuts

Part IV: Animation Reconstruction

Dynamic Geometry Registration (Niloy)

- Multi-piece alignment

Deformable Reconstruction (Michael)

- Basic numerical algorithm
- Urshape/Deformation Factorization

Improved Algorithm (Hao)

- Efficient implementation
- Detail transfer

Part V: Conclusions and Wrap-up

Conclusions and Wrap-up (Mark)

- Conclusions
- Future work and open problems

In the end:

- Q&A session with all speakers
- But feel free to ask questions at any time

Problem Statement and Motivation

Deformable Shape Matching

What is the problem?

Settings:

- We have two or more shapes
- The same object, but deformed

Data courtesy of C. Stoll, MPI Informatik

Deformable Shape Matching

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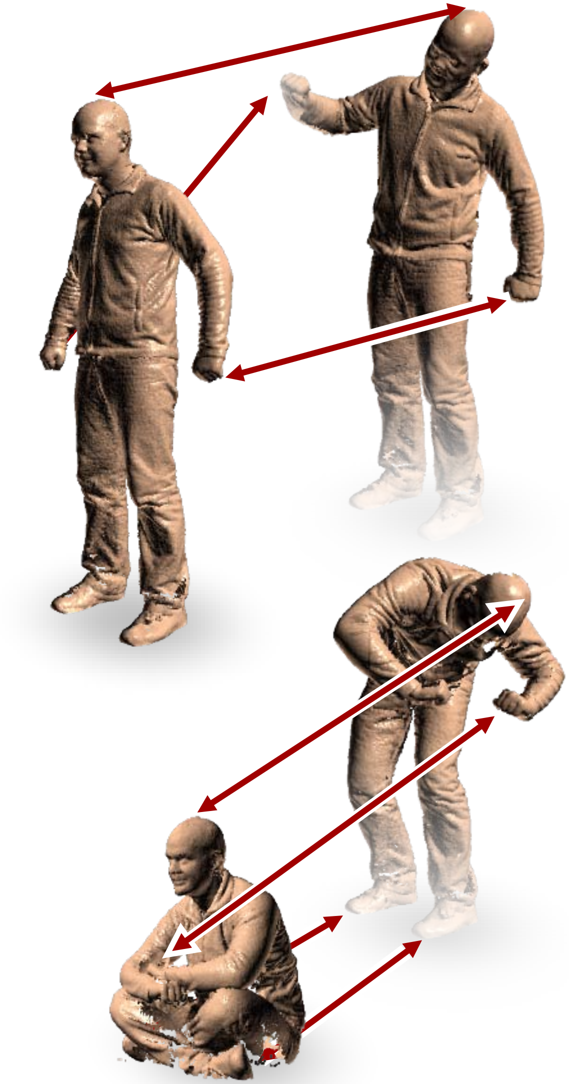
Settings:

- We have two or more shapes
- The same object, but deformed

Question:

- What points correspond?



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Applications

Why is this an interesting problem?

Building Block:

- Correspondences are a building block for higher level geometry processing algorithms

Example Applications:

- Scanner data registration
- Animation reconstruction & 3D video
- Statistical shape analysis (shape spaces)

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Deformable Scan Registration

Scan registration

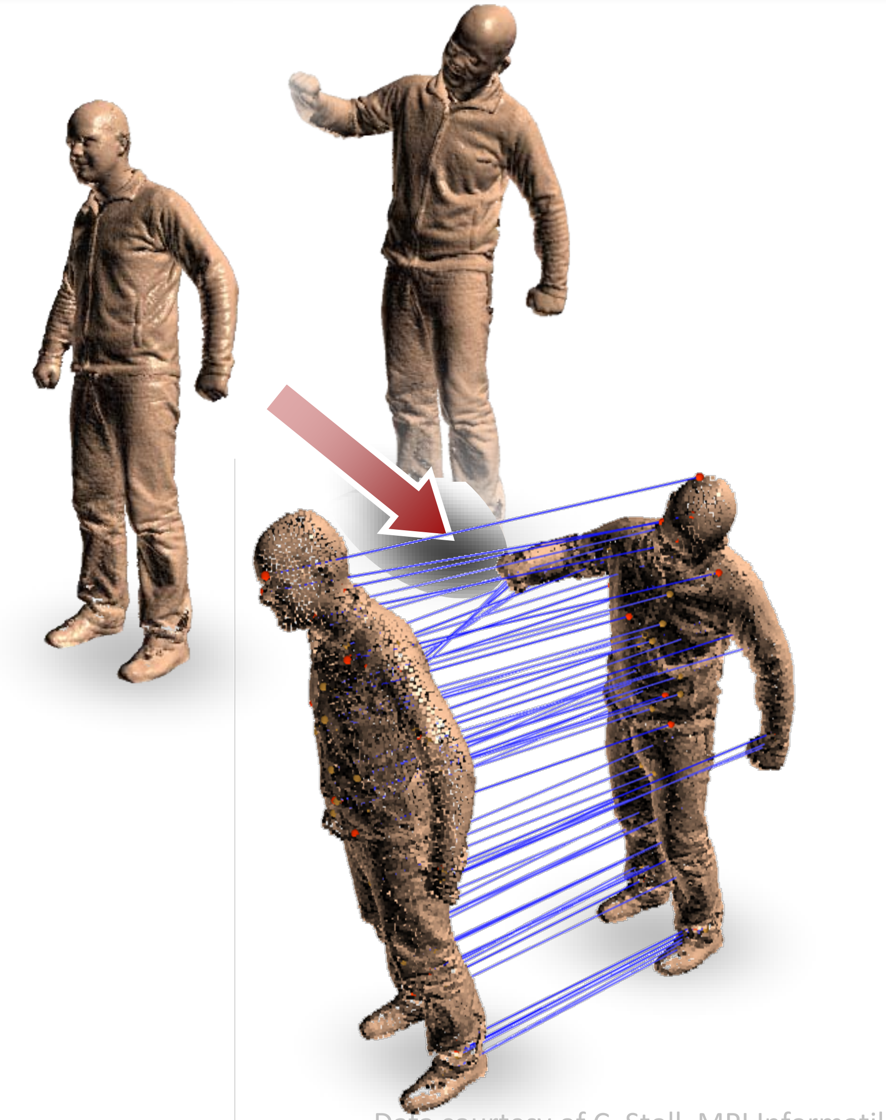
- Rigid registration is standard

Why deformation?

- Scanner miscalibrations
  - Sometimes unavoidable, esp. for large acquisition volumes
- Scanned Object might be deformable
  - Elastic / plastic objects
- In particular: Scanning people, animals
  - Need multiple scans
  - Impossible to maintain constant pose

Example: Full Body Scanner

Full Body Scanning



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3D Animation Scanner

New technology

- 3D animation scanners
- Record 3D video
- Active research area

Photo: P. Jenke, WSI/GRIS Tübingen

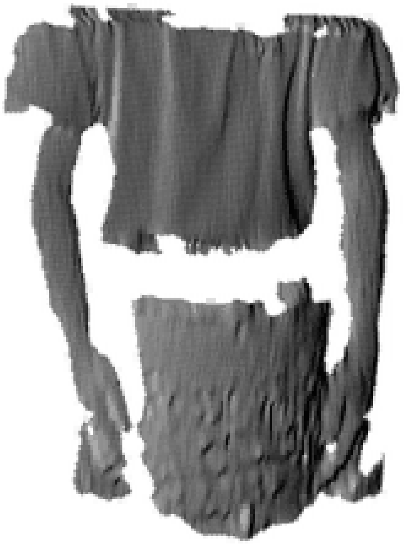
Ultimate goal

- 3D movie making
- New creative perspectives

Structured Light Scanners

space-time stereo

courtesy of James Davis, UC Santa Cruz



color-coded structured light

courtesy of Phil Fong, Stanford University

motion compensated structured light

courtesy of Sören König, TU Dresden

Passive Multi-Camera Acquisition

segmentation & belief propagation

[Zitnick et al. 2004]
Microsoft Research

photo-consistent space carving

Christian Theobald
MPI-Informatik

Time-of-Flight / PMD Devices

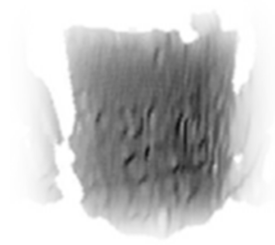
PMD Time-of-flight camera

Minolta Laser Scanner (static)

Animation Reconstruction

Problems

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



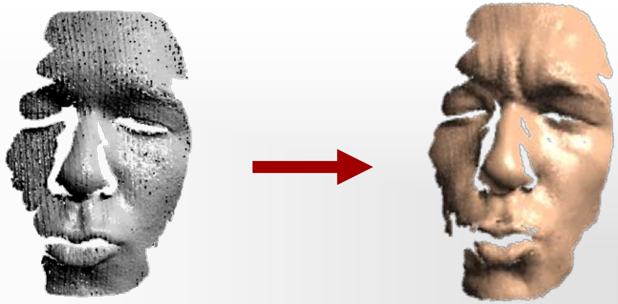
noise

holes

missing correspondences

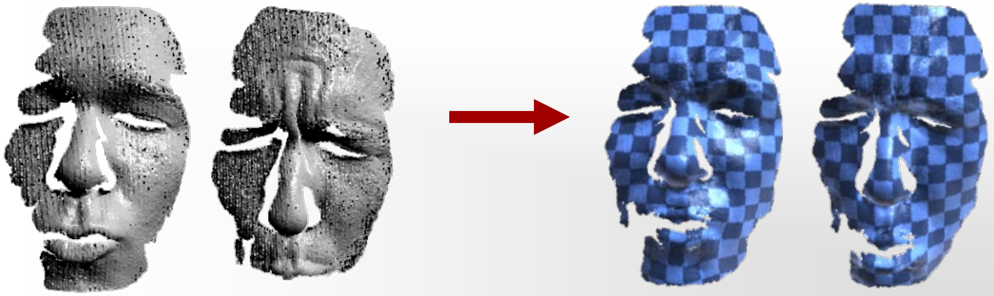
Animation Reconstruction

Remove noise, outliers



Fill-in holes
(from all frames)

Dense correspondences



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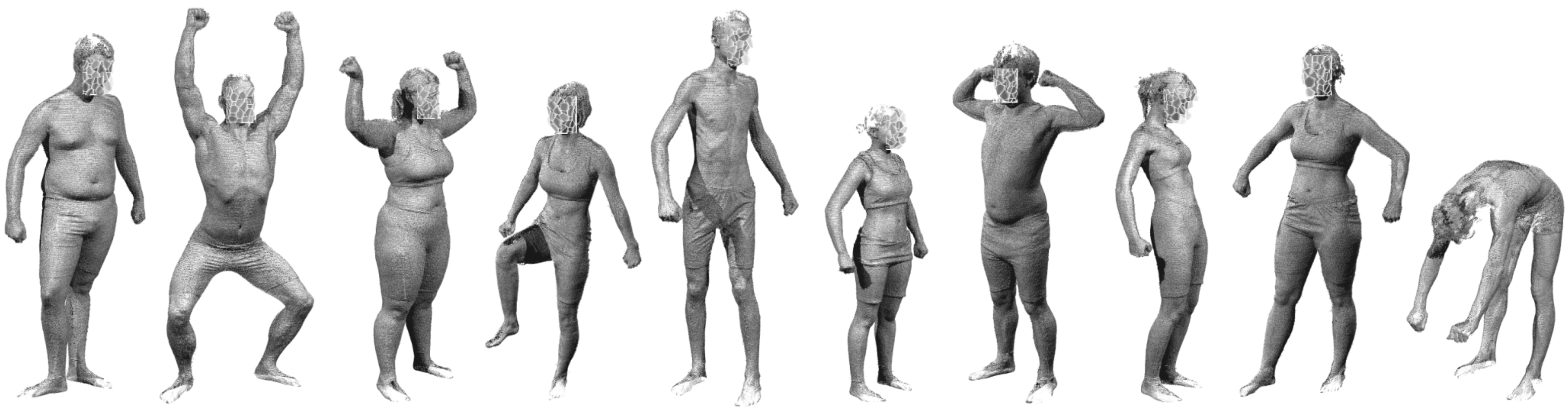
Statistical Shape Spaces



Courtesy of N. Hassler, MPI Informatik

Morphable Shape Models

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

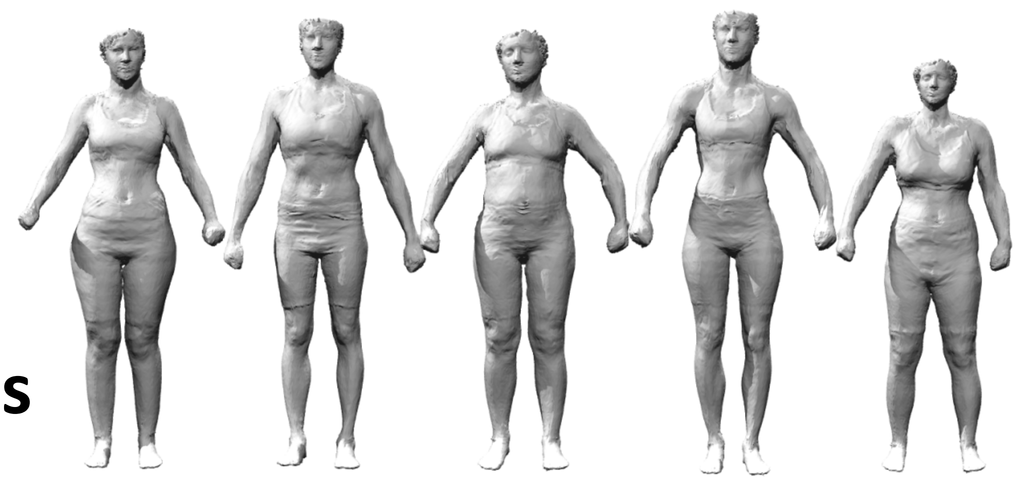
Statistical Shape Spaces

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

Data Characteristics

Scanner Data – Challenges

"Real world data" is more challenging

- 3D Scanners have artifacts

Rules of thumb:

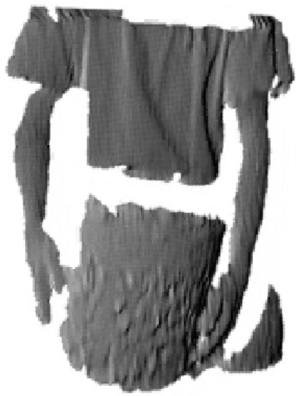
- The faster the worse (real time vs. static scans)
- Active techniques are more accurate
  (passive stereo is more difficult than laser triangulation)
- There is more than just "Gaussian noise"…

Challanges

"Noise"

- "Standard" noise types:
  - Gaussian noise (analog signal processing)
  - Quantization noise
- More problematic: Structured noise
  - Structured noise (spatio-temporally correlated)
  - Structured outliers
  - Reflective / transparent surfaces
- Incomplete Acquisition
  - Missing parts
  - Topological noise

Courtesy of J. Davis, UCSC



Courtesy of P. Phong, Stanford University

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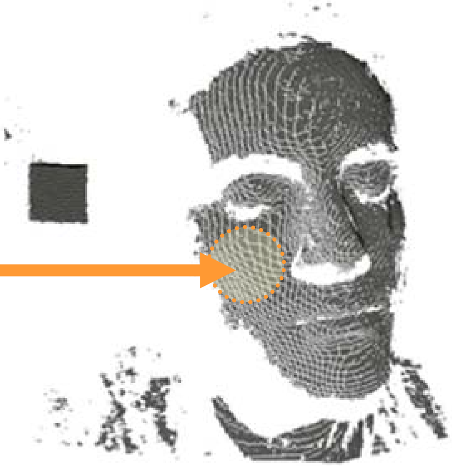

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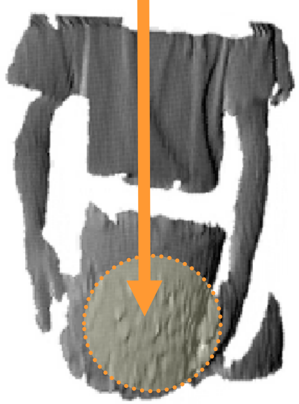

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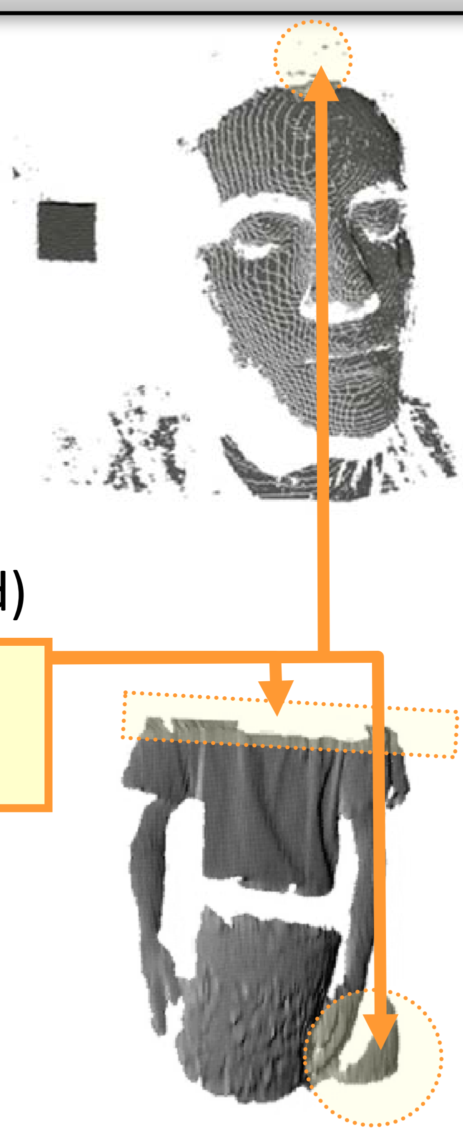

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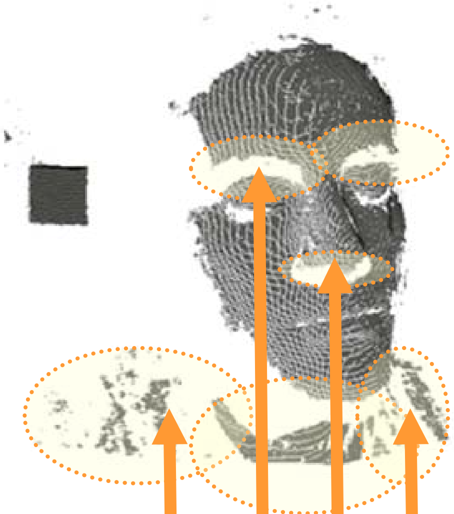


Outlook

This Tutorial

Different aspects of the problem:

- Shape deformation and matching
  - How to *quantify deformation*?
  - How to *define deformable shape matching*?
- Local matching
  - Known initialization
- Global matching
  - No initialization
- Animation Reconstruction
  - Matching temporal sequences of scans

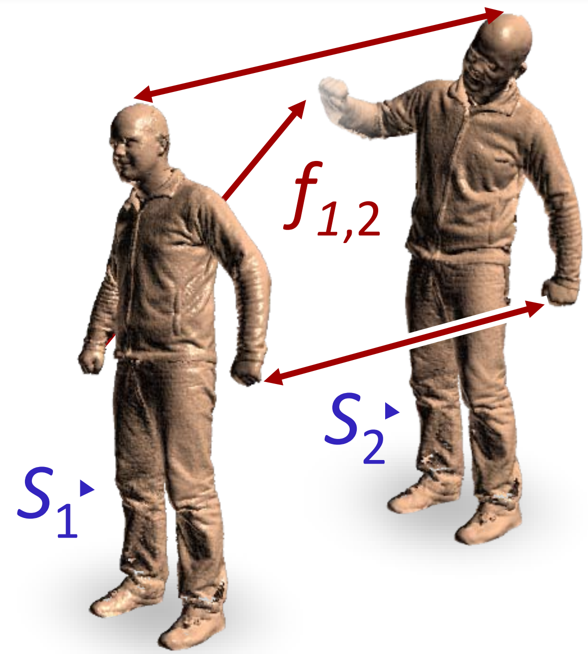
Problem Statement:

Pairwise Deformable Matching

Problem Statement

Given:

- Two surfaces $S_1, S_2 \subseteq \mathbb{R}^3$
- Discretization:
  - Point clouds $S = \{s_1,\ldots,s_n\}$, $s_i \in \mathbb{R}^3$ or
  - Triangle meshes



We are looking for:

- A deformation function $f_{1,2}: S_1 \rightarrow \mathbb{R}^3$ that brings S_1 close to S_2

Problem Statement

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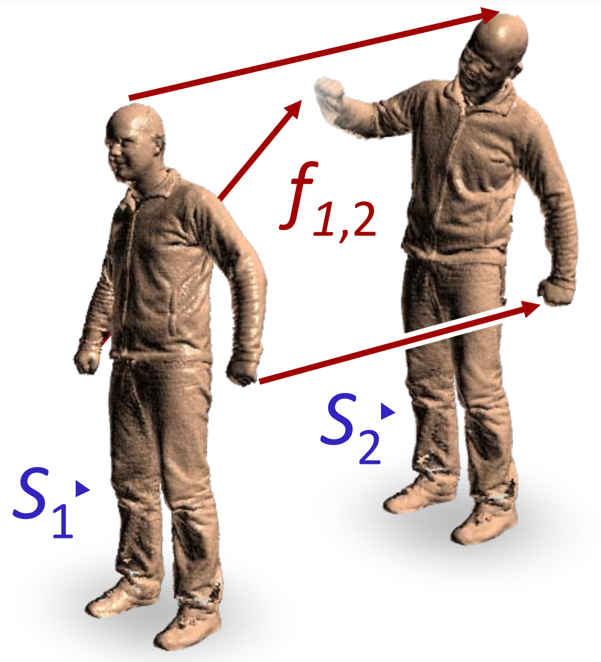

Open Questions:

- What does "close" mean?
- What properties should f have?

Next part:

- We will now look at these questions more in detail