

Registration using Dynamic Data

-- Data acquisition and analysis of dynamic data

journée IRMC de Strasbourg

Hyewon Seo
LSIIT - CNRS
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Outline

- 1 Introduction
- 2 Previous work
- 3 Overview of the planned work
- 4 Methodology: Data acquisition and analysis of dynamic data
- 5 Results
- 6 Conclusion

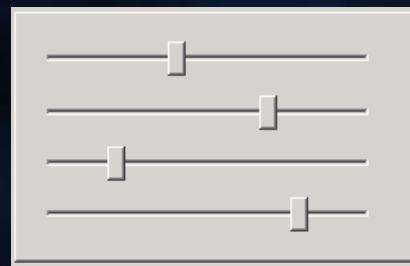
Registration?

- How to:
 - Optimally align two shapes in arbitrary configurations?
- Central problem in:
 - Image processing
 - Shape acquisition
 - Modeling
- Used to:
 - Compare
 - Integrate data
 - ✓ different measurement devices, viewpoints, times of measurement, ...
 - ✓ different subjects

Registration?

- Extrinsic vs. intrinsic
- 2D vs. 3D
- Rigid vs. non-rigid
- Inter-subject vs. intra-subject
- Image vs. surface, boundary vs. volume

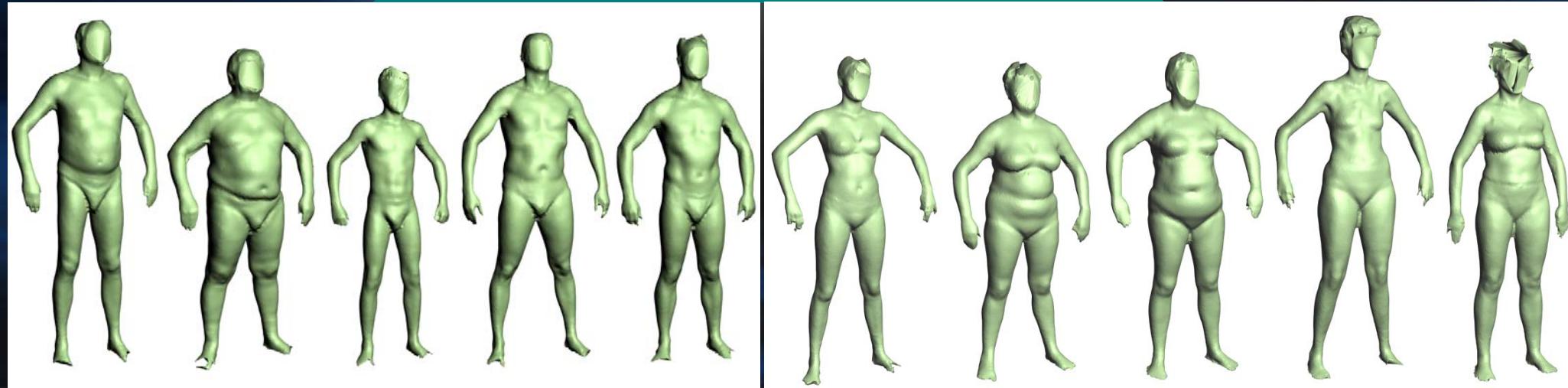
Example: 3D intra-subject surface registration



Body Modeler

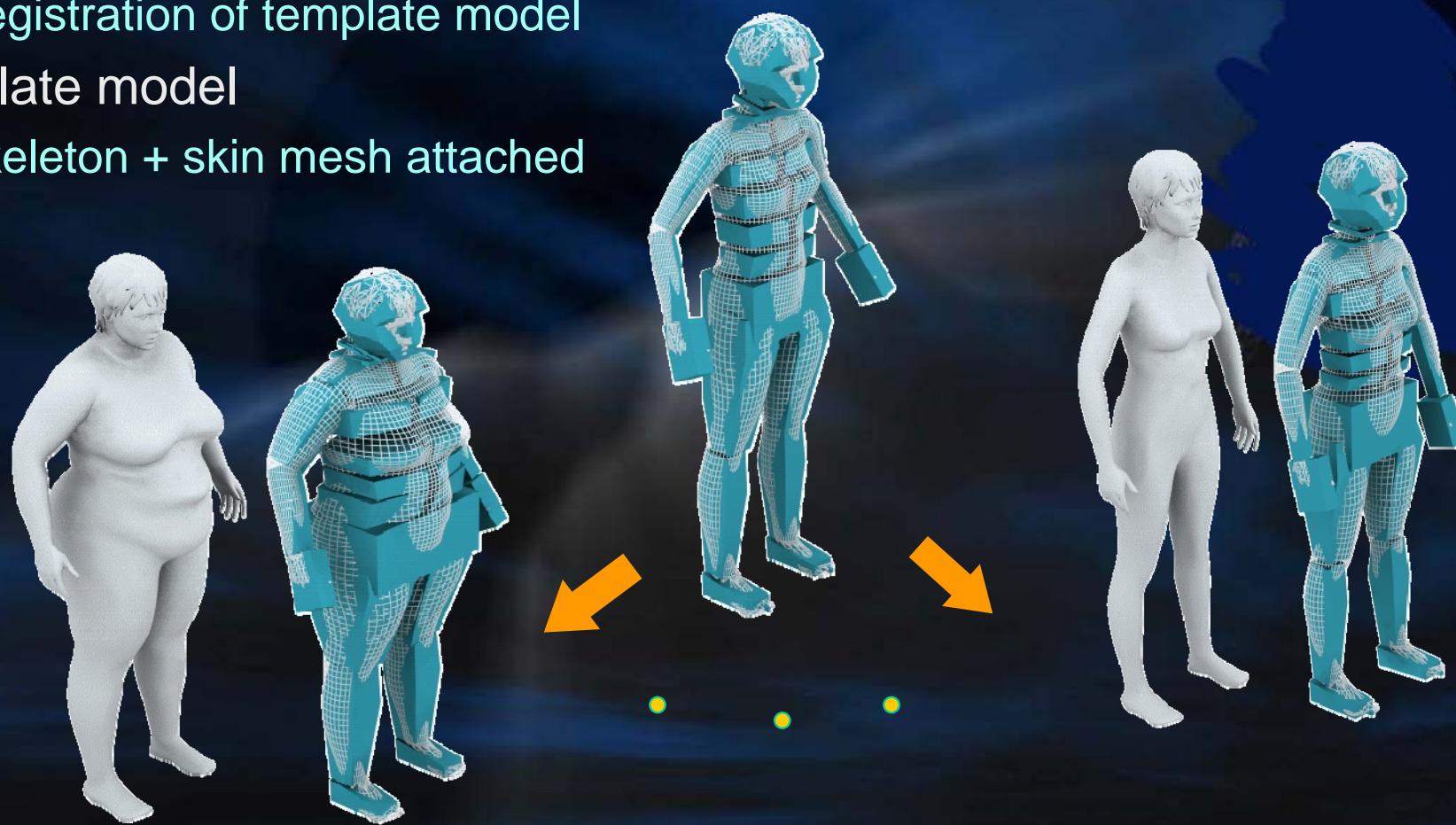


- Possible shape space
- Statistical tendencies



Example: 3D intra-subject surface registration

- Correspondence finding
 - Registration of template model
- Template model
 - Skeleton + skin mesh attached



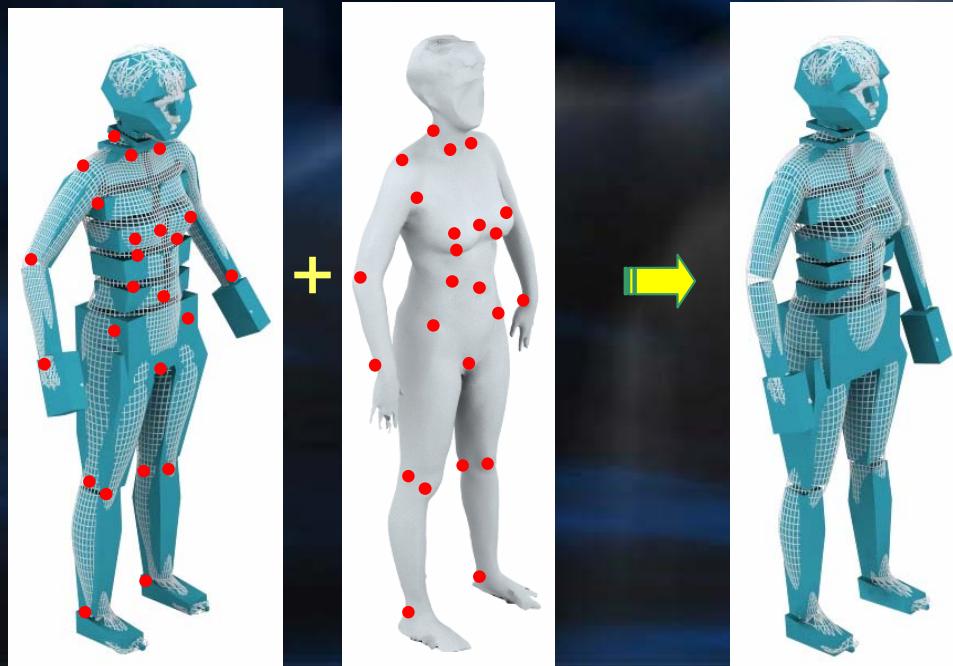
Example: 3D intra-subject surface registration

➤ Feature based approach

- to measure the fitting accuracy
- to guide the conformation

➤ 2 steps

- Joint transformation
- Vertex displacement



Registration of the template: problem formulation

- Joint transformation: Find \mathbf{x} such that $E(\mathbf{x})$ is minimized, where

$\mathbf{x} = ([t_{x1}, t_{y1}, t_{z1}, \theta_{x1}, \theta_{y1}, \theta_{z1}, s_{x1}, s_{y1}, s_{z1}], \theta_{x2}, \dots, s_{xn})$,
translation, rotation, and scale of root joint

$$E(\mathbf{x}) = \sum |P_i(\mathbf{x}) - P'_i|.$$

Distance between corresponding feature points

- Vertex displacement: Find vertex displacement \mathbf{d} that minimizes $E(\mathbf{d})$:

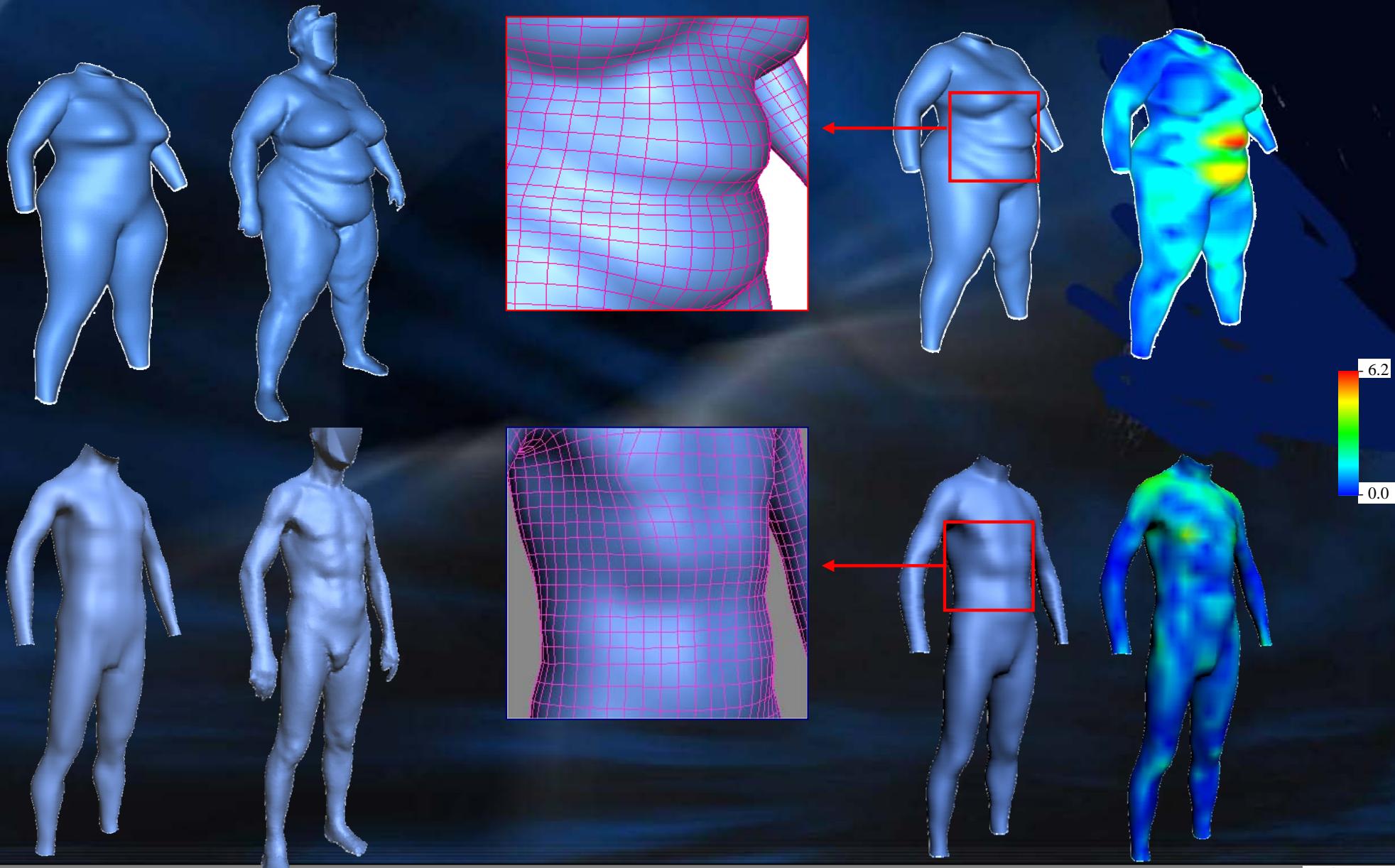
$$E(\mathbf{d}) = \alpha E_p(\mathbf{d}) + \beta E_s(\mathbf{d}) + \gamma E_d(\mathbf{d}).$$

Feature point
distance

Distortion
energy

Surface
distance

Registration of the template: results



Summary of registration in medical imaging

- Landmark based
 - Anatomical
 - geometrical
- Segmentation based
 - Rigid
 - Deformable model
- Voxel property based
 - Reduction to scalars/vectors (moments, principal axes)
 - Using full image content

Previous methods do not consider dynamic, time-varying features, despite their increasing clinical relevance!!

Overview

0. Motion data acquisition

- Movement data in temporal correspondence

1. Analysis of dynamic data

- Extraction of dynamic features

2. Registration using dynamic data

- Correspondence computation among dynamic features
- Transformation

3. Statistical atlas construction

- Dimension reduction
- Joint probabilistic map

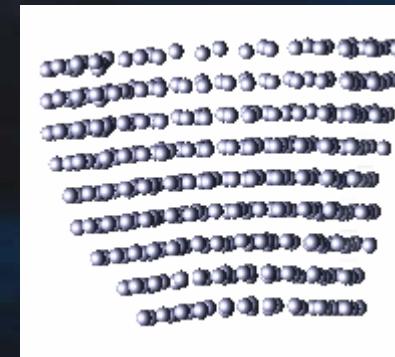
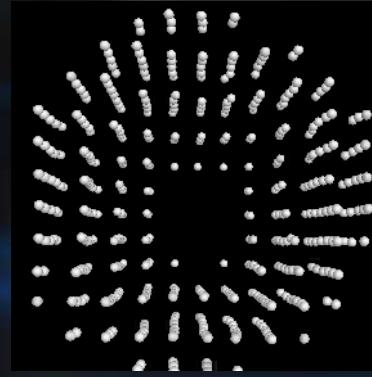
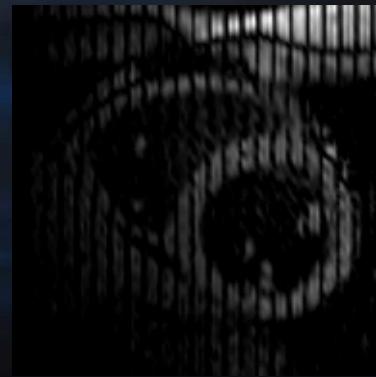
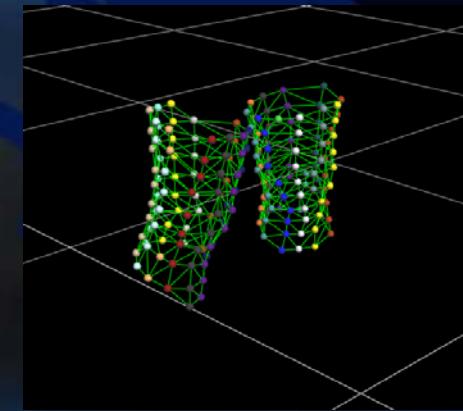
- Compact mathematical representation of movement data
- Posterior probability of segmentation elements, the current shape and its motion at each time step
- Incorporates registration variations (due to anatomical identity and due to movement)

4. Revision of registration

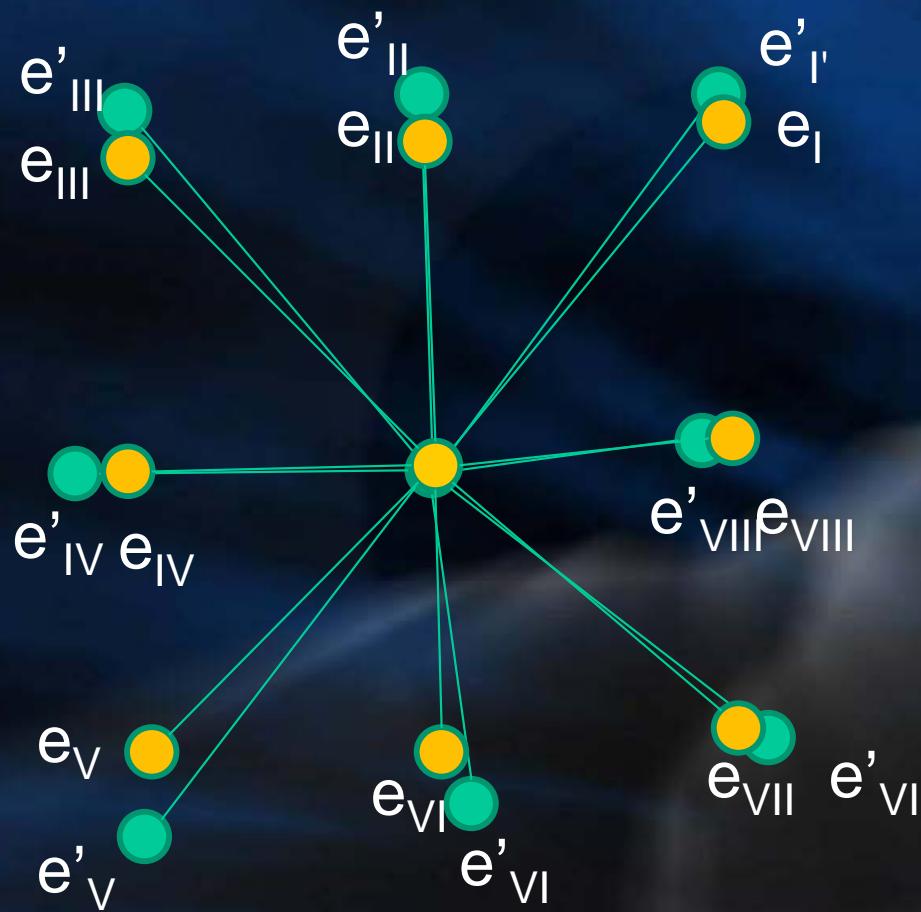
- Statistical atlas based registration

Motion data acquisition

- 3D scanner
 - With color markers
- Optical motion capture device
 - High frequency
- Tagged MRI
 - Temporal correspondence



Analysis of deforming surface



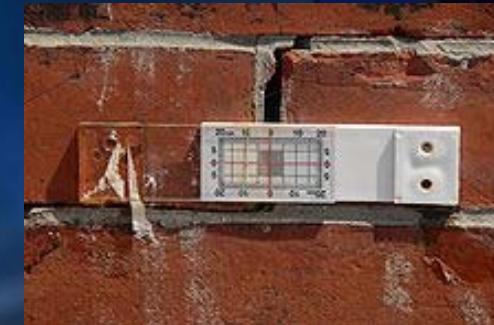
$$\varepsilon_I = \frac{e'_I - e_I}{e_I}$$

$$\varepsilon_{VIII} = \frac{e'_{VIII} - e_{VIII}}{e_{VIII}}$$

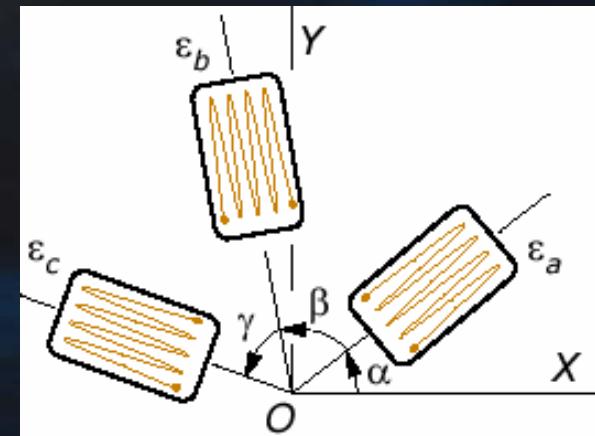
- Adopt virtual strain gages and perform local strain analysis!!

Strain gage

- Used to measure the strain of an object
- Linear strain gage
 - Strain along one direction
- Rosette strain gage
 - To determine the three independent components of plane strain, three linearly independent strain measures are needed

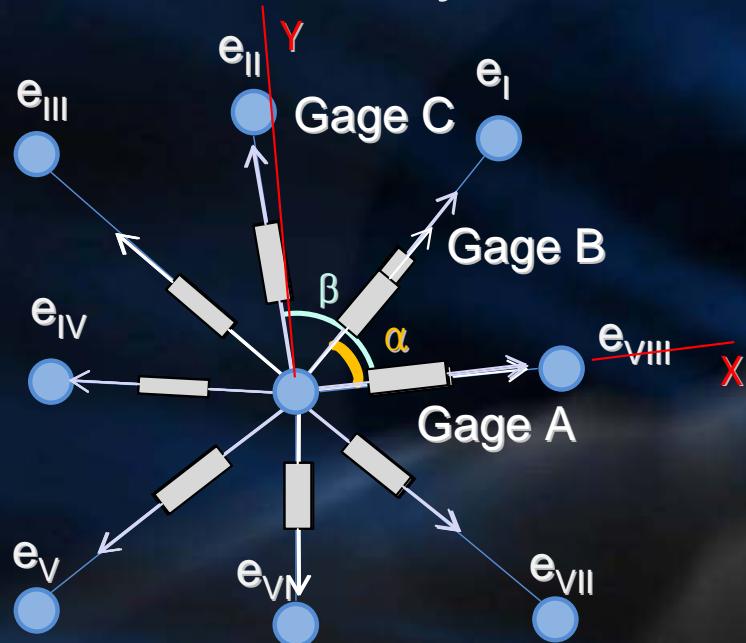


$$\begin{aligned}\varepsilon_a &= \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2} \cos 2\alpha + \gamma_{xy} \sin 2\alpha \\ \varepsilon_b &= \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2} \cos 2\beta + \gamma_{xy} \sin 2\beta \\ \varepsilon_c &= \frac{\varepsilon_x + \varepsilon_y}{2} + \frac{\varepsilon_x - \varepsilon_y}{2} \cos 2\gamma + \gamma_{xy} \sin 2\gamma\end{aligned}$$



Analysis of deforming surface

- Local strain analysis on deforming mesh surface



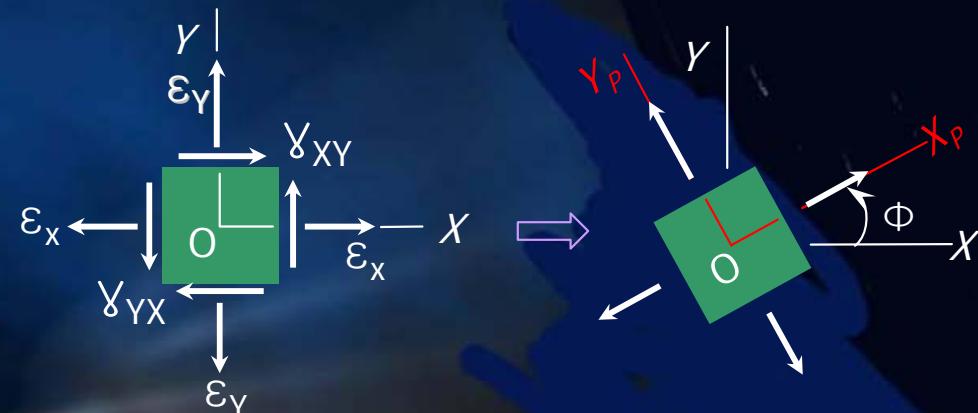
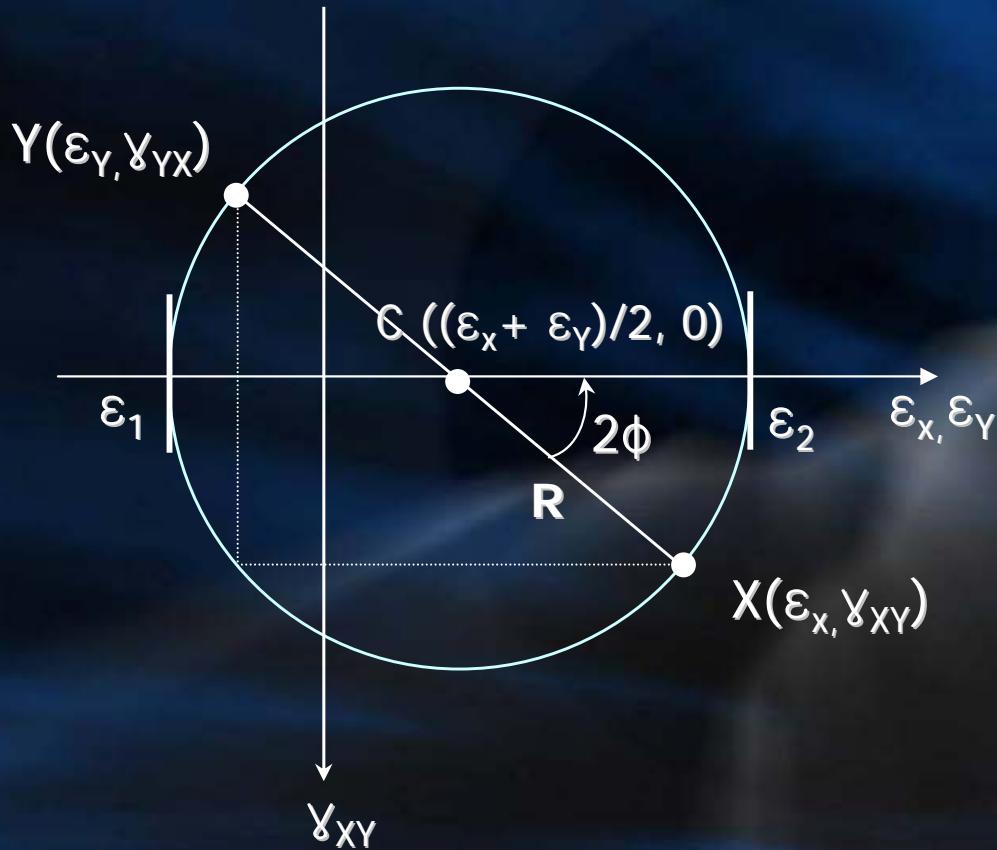
$$\varepsilon_A = \frac{\varepsilon_X + \varepsilon_Y}{2} + \frac{\varepsilon_X - \varepsilon_Y}{2} \cos(2 \times 0) + \frac{\gamma_{XY}}{2} \sin(2 \times 0)$$

$$\varepsilon_B = \frac{\varepsilon_X + \varepsilon_Y}{2} + \frac{\varepsilon_X - \varepsilon_Y}{2} \cos(2 \times \alpha) + \frac{\gamma_{XY}}{2} \sin(2 \times \alpha)$$

$$\varepsilon_C = \frac{\varepsilon_X + \varepsilon_Y}{2} + \frac{\varepsilon_X - \varepsilon_Y}{2} \cos(2 \times \beta) + \frac{\gamma_{XY}}{2} \sin(2 \times \beta)$$

- Use measured values ε_A , ε_B , ε_C and compute ε_x , ε_y , γ_{xy}
normal strain shear strain
- Compute principal strains using Mohr's circle
- Average all principal strains

Mohr's circle for strain element



$$R = \frac{1}{2} \sqrt{(2\gamma_{XY})^2 + (\varepsilon_x - \varepsilon_y)^2}$$

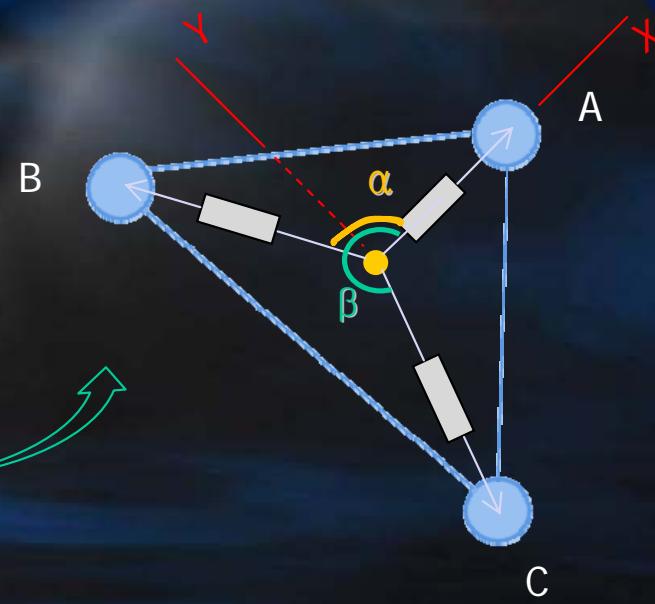
$$\varepsilon_1 = \frac{\varepsilon_x + \varepsilon_y}{2} - R \quad \varepsilon_2 = \frac{\varepsilon_x + \varepsilon_y}{2} + R$$

$$\Phi = \frac{1}{2} \tan^{-1} \left(\frac{\gamma_{XY}}{\varepsilon_x - \varepsilon_y} \right)$$

$\varepsilon_x, \varepsilon_y, \gamma_{XY} \Rightarrow$ compute principal strain values $\varepsilon_1, \varepsilon_2$, and directions Φ

Problems

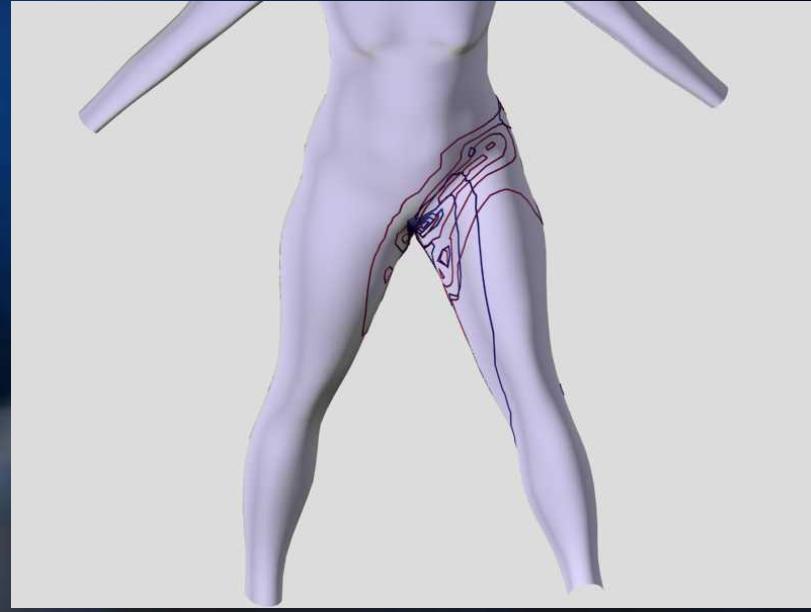
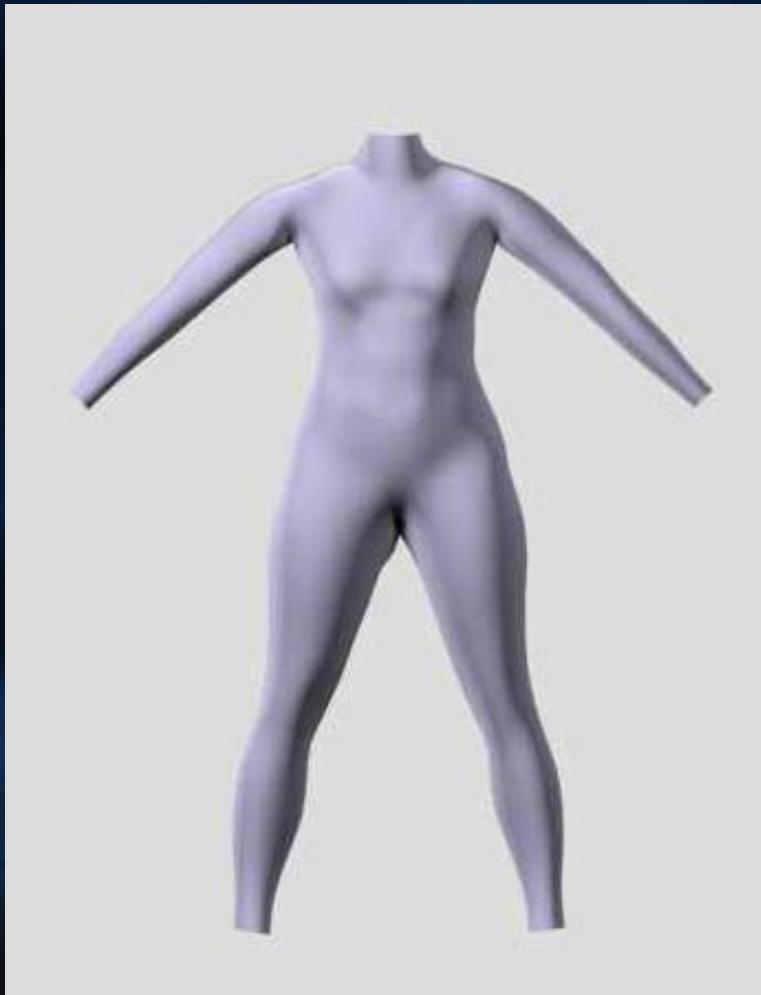
- Principal directions NOT tangential to the surface!!
- Solution: virtual strain gage on triangles



Results on a deforming mesh

- Maximum strain directions and values
 - Maximum strain values on bending knees
 - Maximum strain values on raising legs
 - Maximum strain directions on bending knees

Isocurves based on the maximum strain



Potential application

- Langer's lines
 - After an Austrian anatomist Karl Langer
 - ✓ first discovered by a French surgeon Baron Dupuytren
 - Predominant alignment of collagen fibers within the dermis
 - Important for surgical operation
 - ✓ Incisions made parallel to Langer's lines may heal better and produce less scarring

LANGER'S LINES

14-5). These maps indicate that there are definite lines of tension or cleavage lines within the skin that are characteristic for each part of the body. In microscopic sections cut parallel with these lines, most of the collagenous bundles of the reticular layer are cut longitudinally, while in sections cut across the lines, the bundles are in cross section. The cleavage lines correspond closely with the crease lines on the surface of the skin in most parts of the body. The pattern of the cleavage lines, according to Cox (1941), varies with body configuration, but is constant for individuals of similar build regardless of age. There are limited areas of the body in which the orientation of the bundles is irregular and confused. The cleavage lines are of particular interest to the surgeon because an incision made parallel to the lines heals with a fine linear scar, while an incision across the lines may set up irregular tensions that result in an unsightly scar.



FIG. 14-5. Cleavage lines (Langer's lines) of the skin. Head and neck. (Eliel.)

Carl Ritter von Eldenberg von Langer (1819-1887) Austrian anatomist
REF: ANATOMY OF THE HUMAN BODY, HENRY GRAY



Conclusion

- Registration
- New objectives
 - Registration using dynamic features
 - Overall framework
- On-going work on
 - Data acquisition
 - Data analysis
 - ✓ Local strain analysis adopting virtual strain gage
 - ✓ Extracted features: principal strain values and directions
 - Results

Acknowledgment

- Prof. M. de Mathelin and Dr. P. Germain
 - Introduction and access to tagged MRI data