Registration using Dynamic Data

-- Data acquisition and analysis of dynamic data

journee IRMC de Strasbourg

Hyewon Seo
LSIIT - CNRS
June15th, 2010

Outline

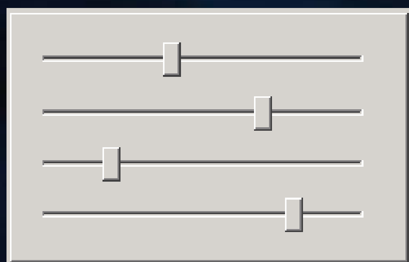
Registration?

- 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?

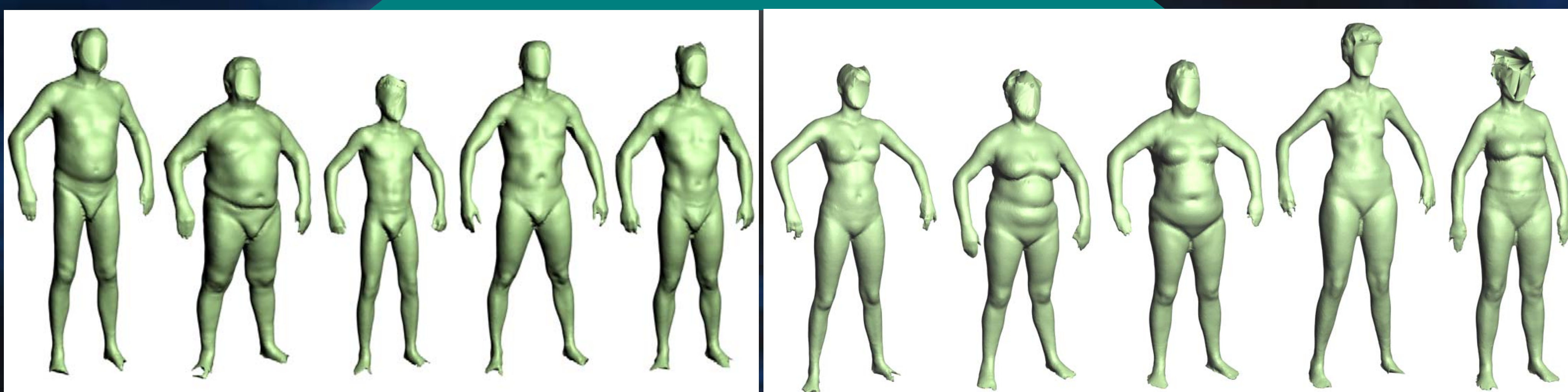
- Extrinsic vs. intrinsic
- 2D vs. 3D
- Rigid vs. non-rigid
- Inter-subject vs. intra-subject
- Image vs. surface, boundary vs. volume

Example: 3D intra-subject surface registration



Body Modeler

- Possible shape space
- Statistical tendencies

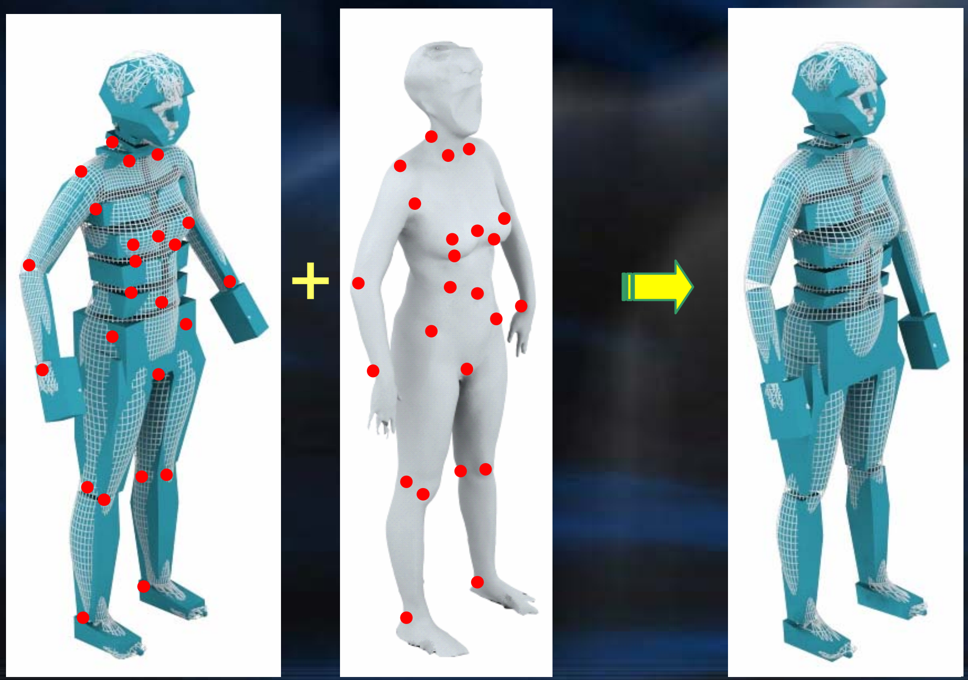


Example: 3D intra-subject surface registration

- 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 **x** such that ***E***(**x**) is minimized, where

$$\mathbf{x} = ([t_{x1}, t_{y1}, t_{z1}, \theta_{x1}, \theta_{y1}, \theta_{z1}, s_{x1}, s_{y1}, s_{z1}], \theta_{x2}, \ldots, s_{xn}),$$

translation, rotation, and scale of root joint

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

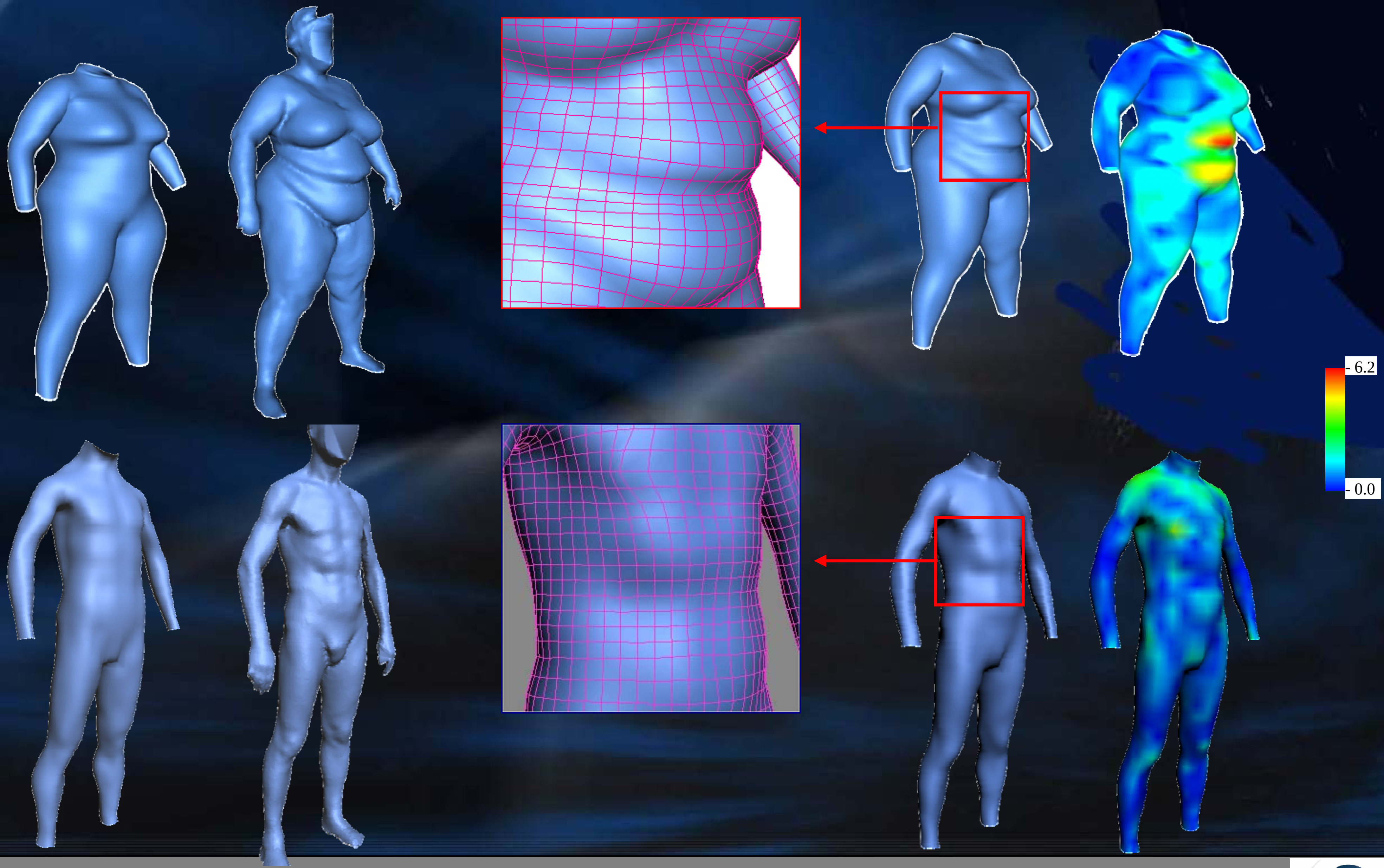
Distance between corresponding feature points

- Vertex displacement: Find vertex displacement **d** that minimizes ***E***(**d**):

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

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

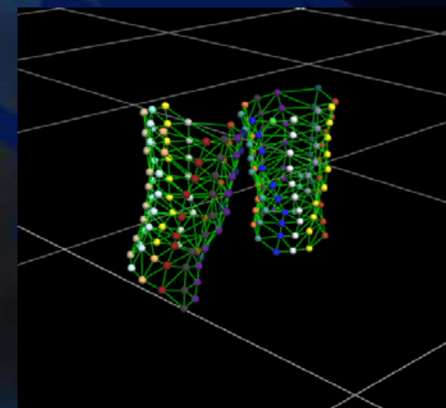
3. Statistical atlas construction
- Dimension reduction
- Joint probabilitstic map

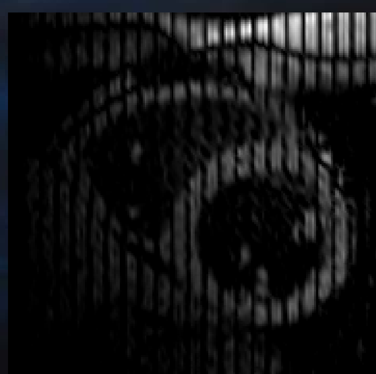
4. Revision of registration
- Statistical atlas based registration

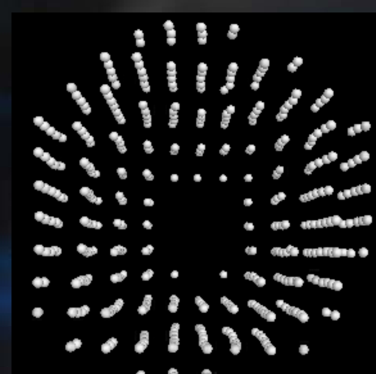
- Compact mathematical representation of dynamic population data analysis
- Incorporates 2 distinct variations (due to anatomical identity and due to movement)
- Posterior probability of the current shape and its motional behavior
- Segmentation according to dynamic features
- Similarity measures between vector fields

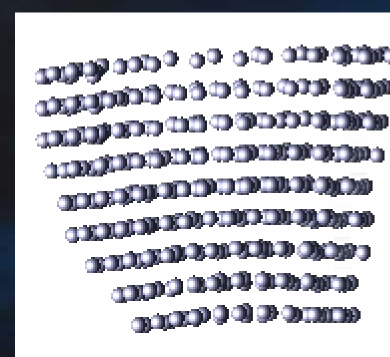
Motion data acquisition

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

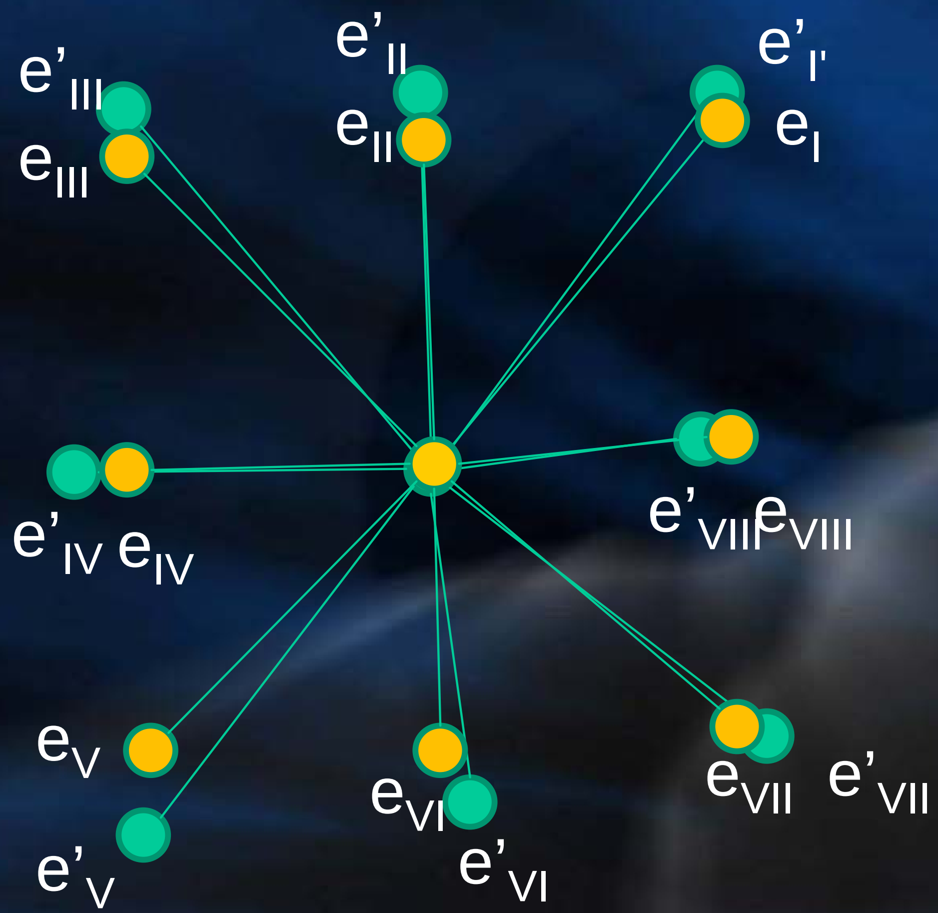








Analysis of deforming surface



$$\varepsilon_{\mathrm{I}} = \frac{e_{\mathrm{I}}' - e_{\mathrm{I}}}{e_{\mathrm{I}}}$$

.

.

.

$$\varepsilon_{\mathrm{VIII}} = \frac{e_{\mathrm{VIII}}' - e_{\mathrm{VIII}}}{e_{\mathrm{VIII}}}$$

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

Strain gage

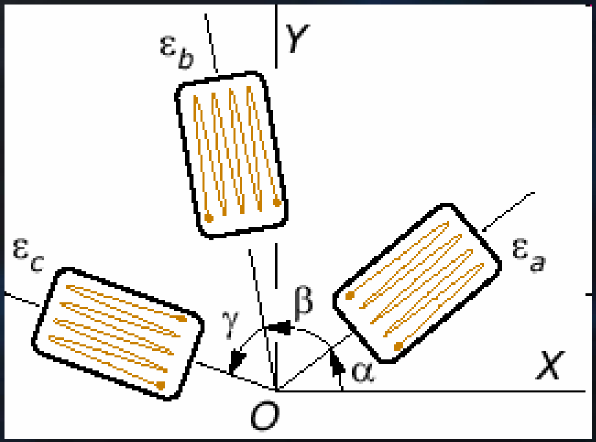
- Used to measure the strain of an object
- Linear strain gage
  - Strain along one direction

- Rosette strain gage
  - To determine the three independent components of plane strain, three linearly independent strain measures are needed

$$\varepsilon_a = \frac{\varepsilon_X + \varepsilon_Y}{2} + \frac{\varepsilon_X - \varepsilon_Y}{2}\cos 2\alpha + \gamma_{XY}\sin 2\alpha$$

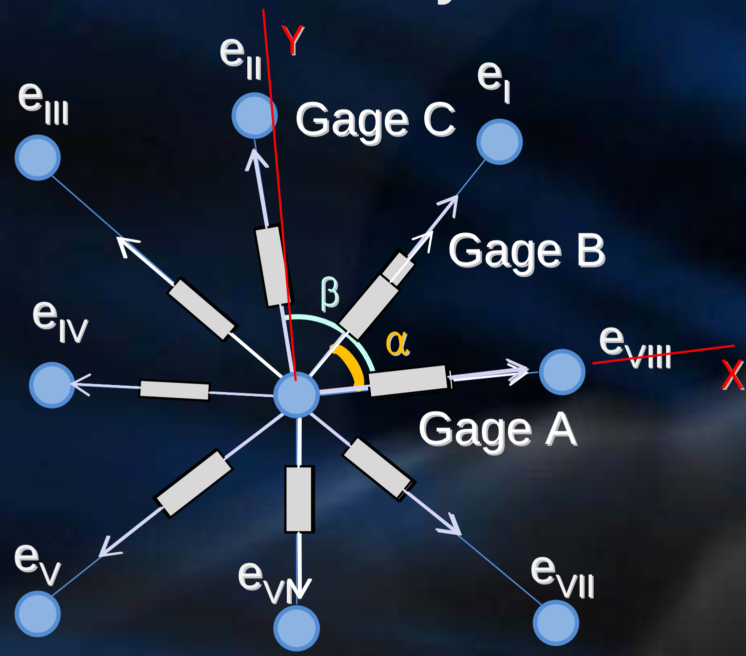
$$\varepsilon_b = \frac{\varepsilon_X + \varepsilon_Y}{2} + \frac{\varepsilon_X - \varepsilon_Y}{2}\cos 2\beta + \gamma_{XY}\sin 2\beta$$

$$\varepsilon_c = \frac{\varepsilon_X + \varepsilon_Y}{2} + \frac{\varepsilon_X - \varepsilon_Y}{2}\cos 2\gamma + \gamma_{XY}\sin 2\gamma$$



Analysis of deforming surface

➢ Local strain analysis on deforming mesh surface



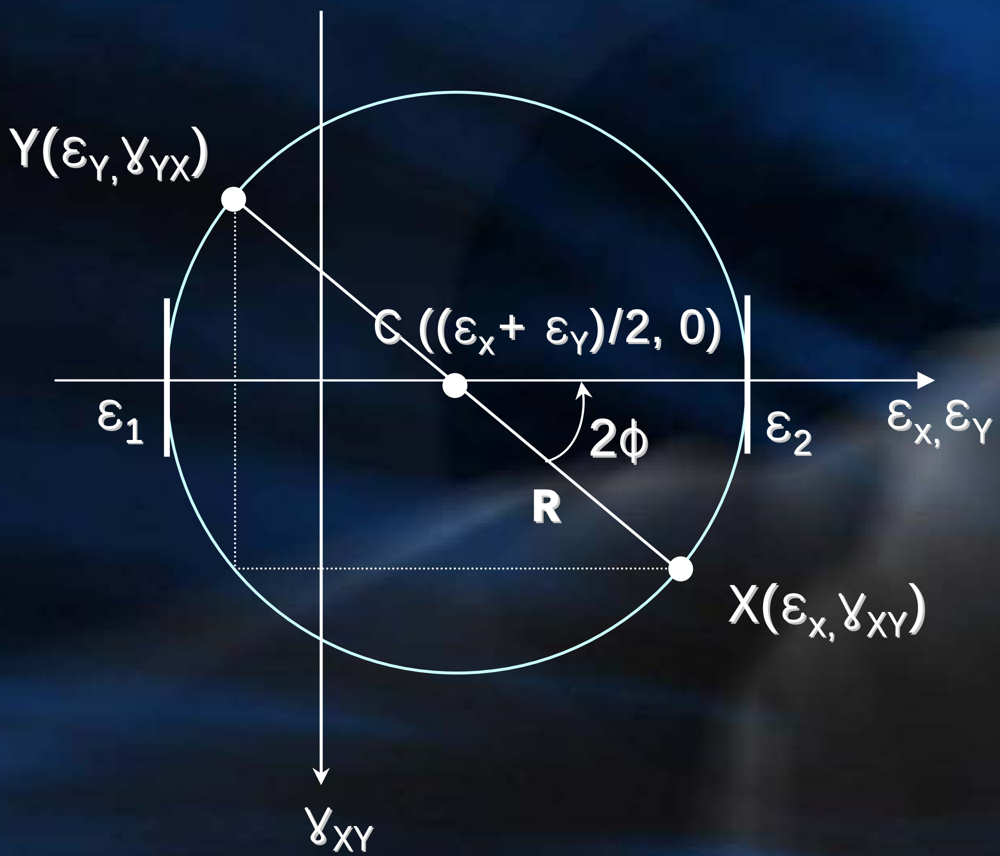
$$\varepsilon_A = \frac{\varepsilon_X + \varepsilon_Y}{2} + \frac{\varepsilon_X - \varepsilon_Y}{2}\cos(2\times 0) + \frac{\gamma_{XY}}{2}\sin(2\times 0)$$

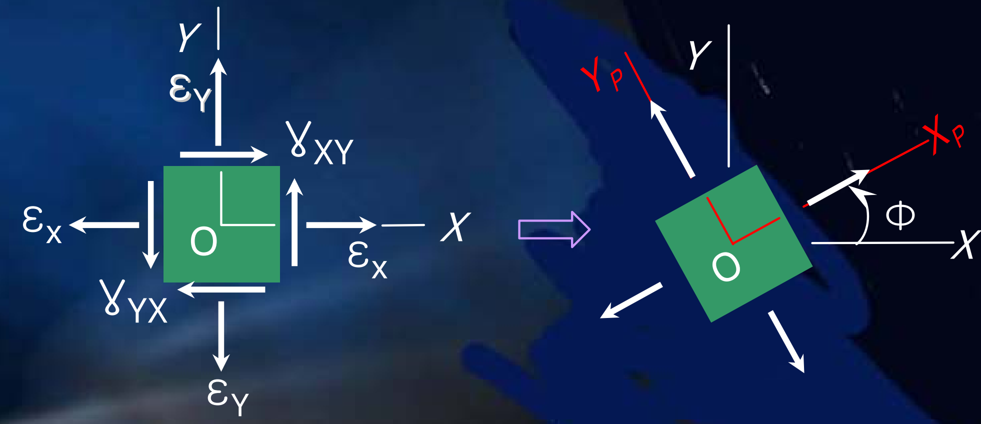
$$\varepsilon_B = \frac{\varepsilon_X + \varepsilon_Y}{2} + \frac{\varepsilon_X - \varepsilon_Y}{2}\cos(2\times \alpha) + \frac{\gamma_{XY}}{2}\sin(2\times \alpha)$$

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

- 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





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

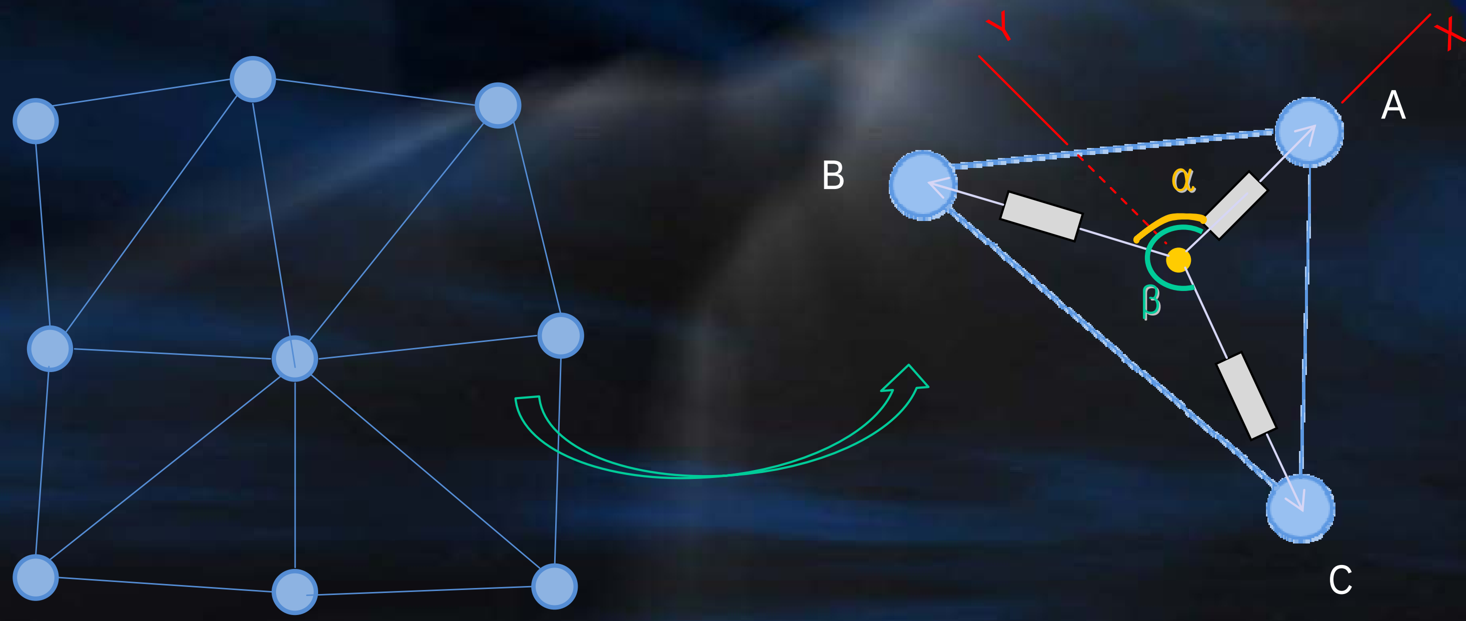
$$\varepsilon_1 = \frac{\varepsilon_x + \varepsilon_y}{2} - R \qquad \varepsilon_2 = \frac{\varepsilon_x + \varepsilon_y}{2} + R$$

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

ε_x, ε_y , γ_{XY} => compute principal strain values ε_1, ε_2, and directions *Φ*

Problems

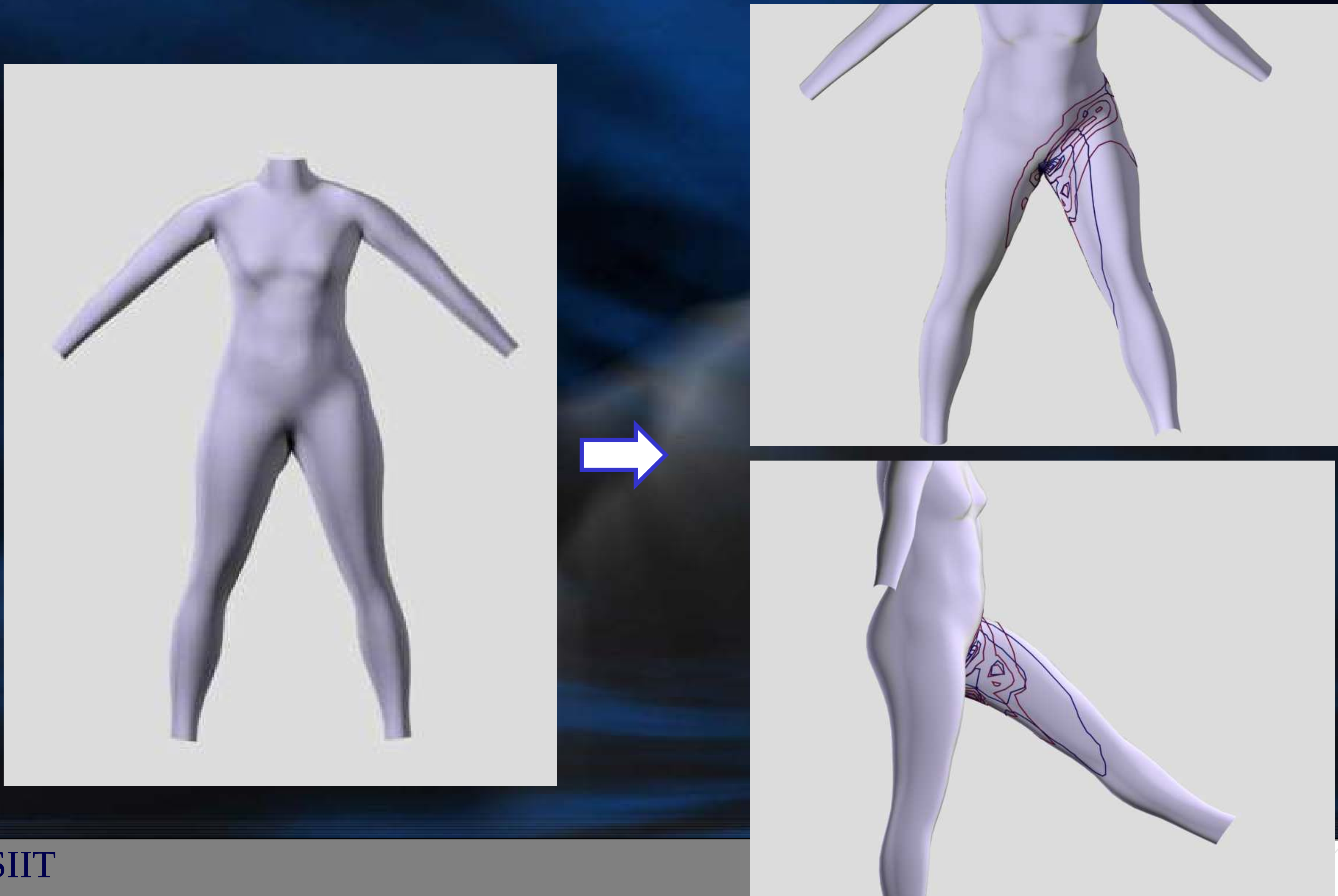
- Principal directions NOT tangential to the surface!!
- Solution: virtual strain gage on triangles



Results on a deforming mesh

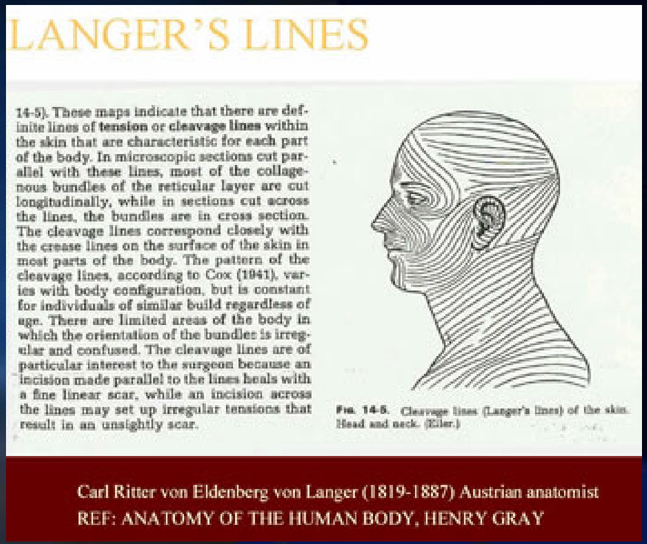
- Maximum strain directions and values
  - Maximum strain values on bending knees
  - Maximum strain values on raising legs
  - Maximum strain directions on bending knees

Isocurves based on the maximum strain



Potential application

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



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