Geometric correspondence

Guido Gerig, Utah II

Polina Golland, MIT

Martin Styner, UNC

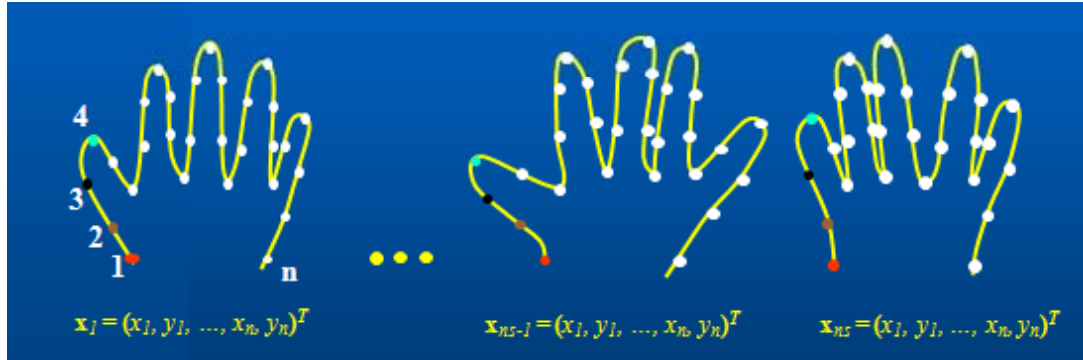Allen Tannenbaum, GT

Ross Whitaker, Utah I

Engineering Core

THE UNIVERSITY OF UTAH

Geometric Correspondence: Shapes

$$\mathbf{x}_1 = (x_1, y_1, ..., x_n, y_n)^T \qquad \mathbf{x}_{ns-1} = (x_1, y_1, ..., x_n, y_n)^T \qquad \mathbf{x}_{ns} = (x_1, y_1, ..., x_n, y_n)^T$$

Finding point to point correspondence for shape modeling and analysis

Figure 5.3. A subset of the correspondences and the alignment used to build the equally spaced Hand model.
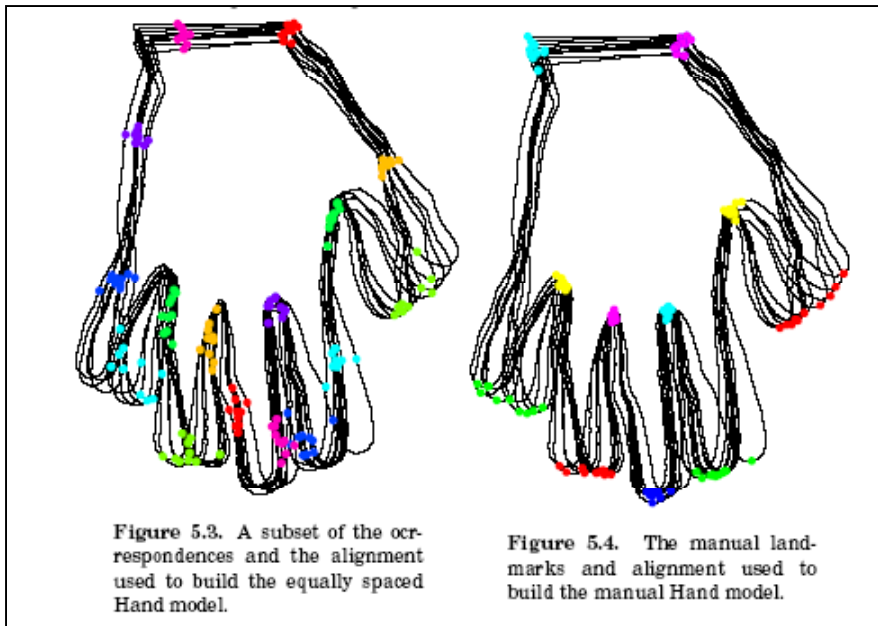
Figure 5.4. The manual landmarks and alignment used to build the manual Hand model.

http://na-mic.org

Geometric Correspondence: Shapes


| 0.0 | 1.5 | 3.0 | 4.5 | 6.0 |
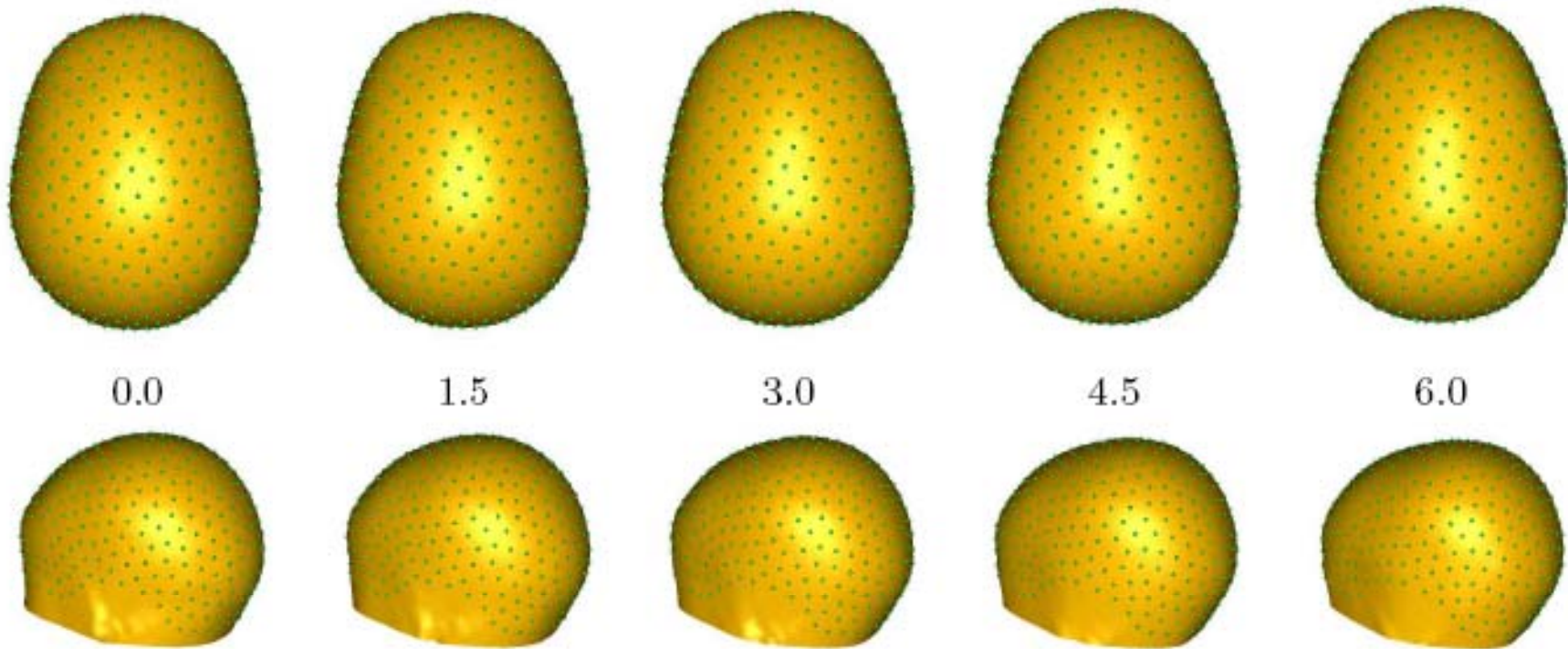
Fig. 3. Overview of head shape regression: Changes in head shape with age

Dense Geometric Correspondence: Images

- Multi-modal registration

- Pre-post imaging & serial staging of individuals

- Mapping of atlas to subject: Use as prior

- Mapping image population into common coordinates: atlas

- Registration for correction of artifacts (distortion, etc.)

Acute   Follow-up

Post-ablation   Follow-up

THE UNIVERSITY OF UTAH
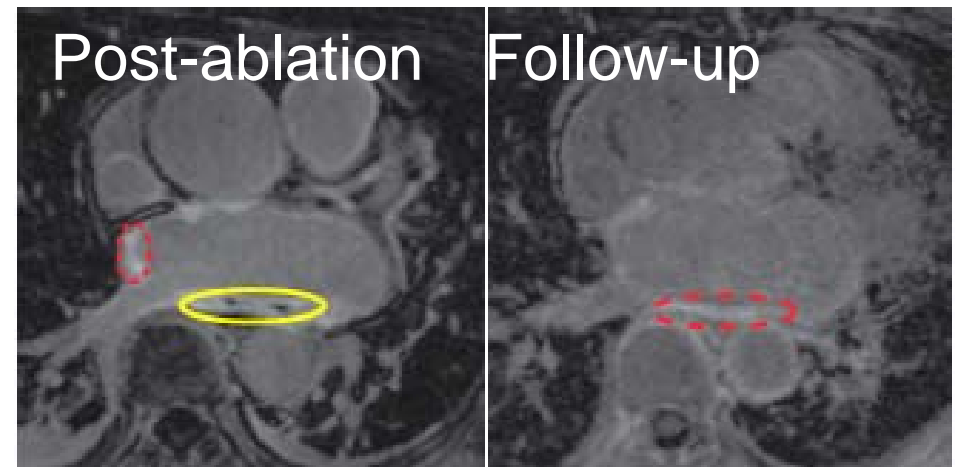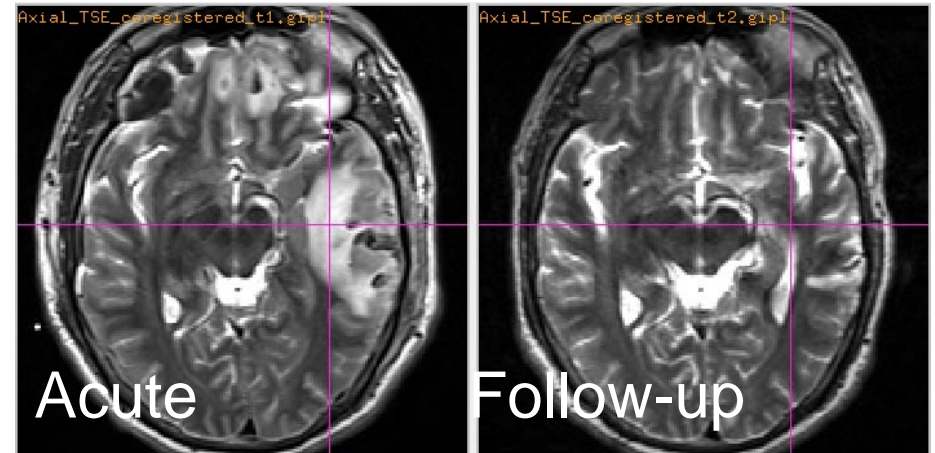
Co-Registration of structural MRI: Multi-contrast analysis of tissue & pathology
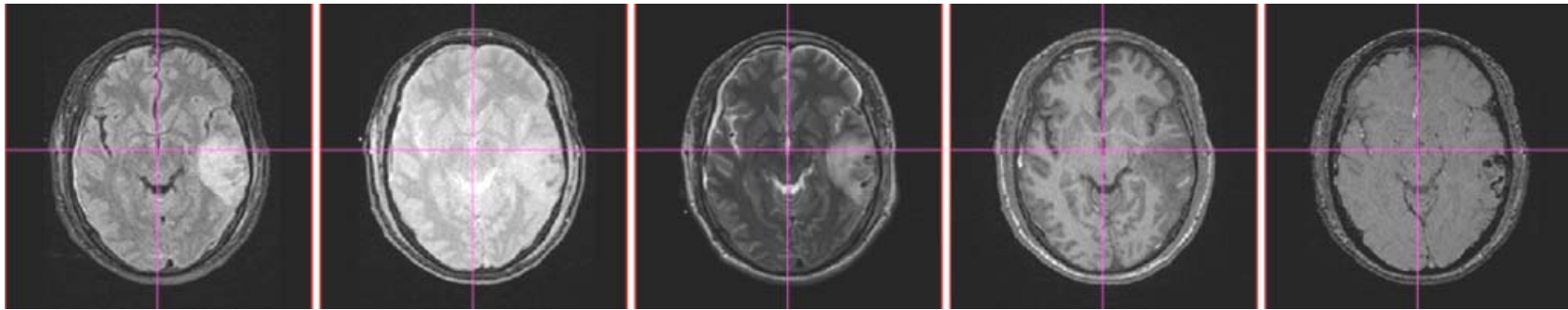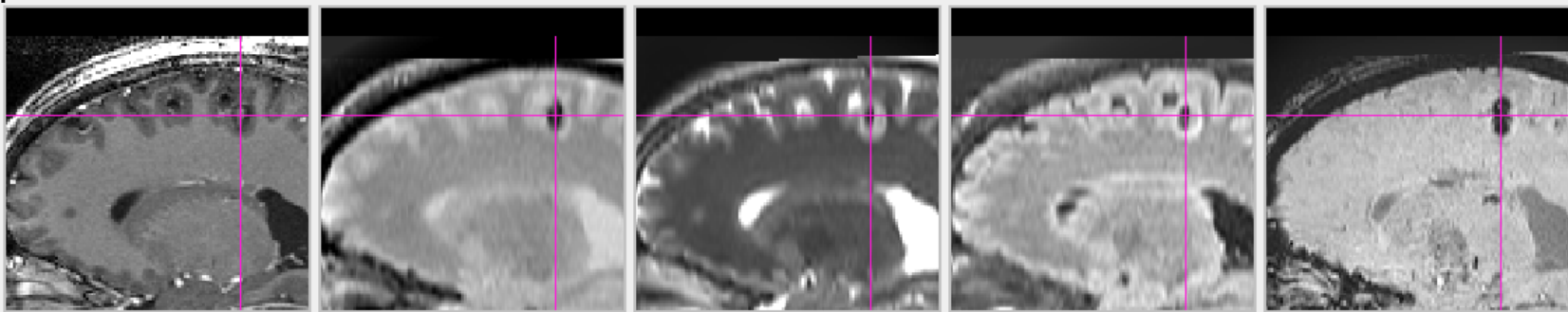
TBI case: J. Horn , Paul Vespa, D. Hovda, UCLA

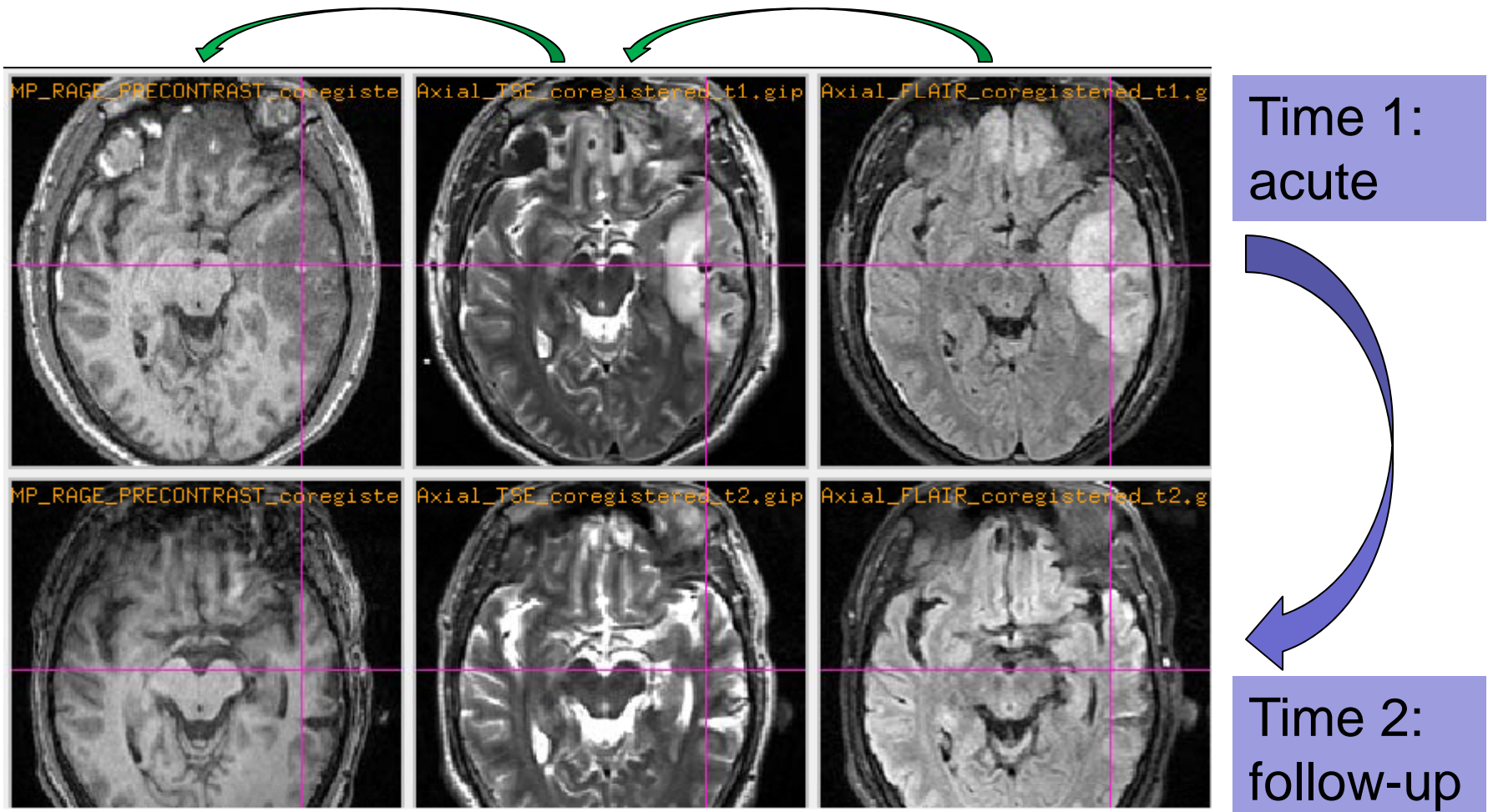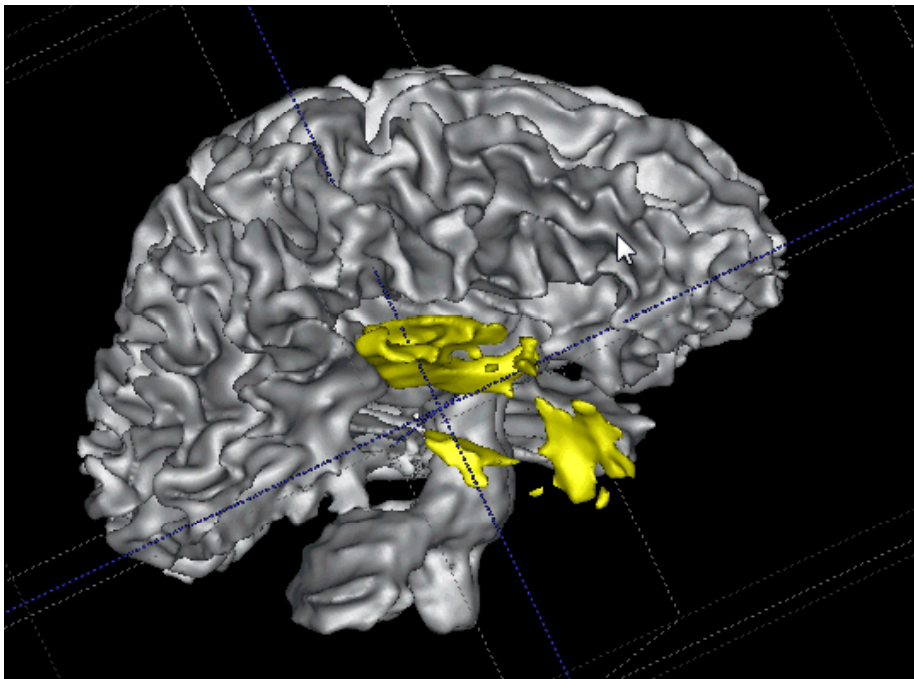# Multi-contrast & multi-time point co-registration in presence of pathology

Time 1: acute
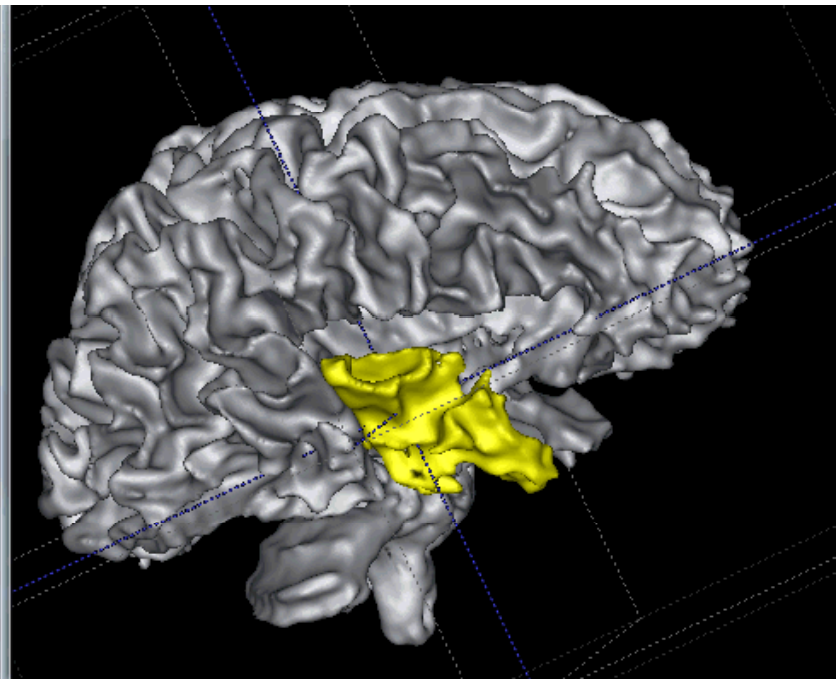
Time 2: follow-up
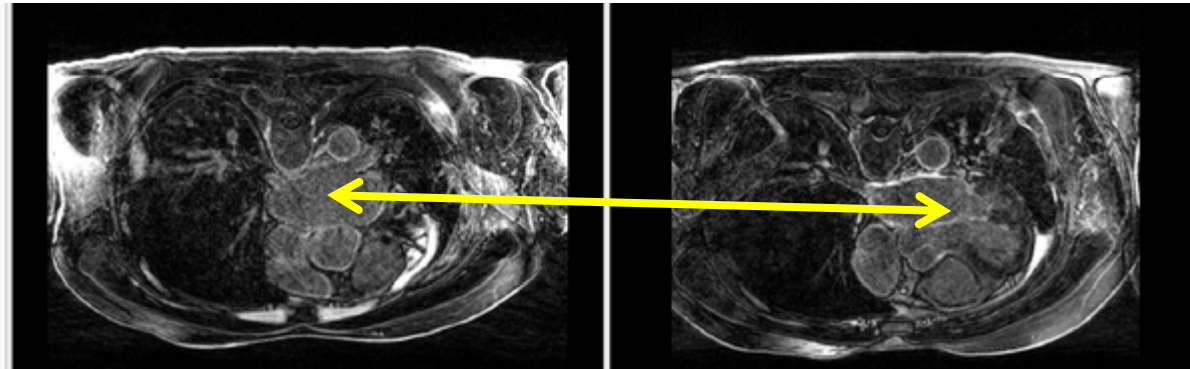
TBI case longitudinal

acute   folllow-up

TBI case #3, multi-modal and multi-time registration,
segmented with Slicer plug-in "ABC"

THE
UNIVERSITY
OF UTAH

DBP Utah: AFIB: Need for point-to-point correspondence

Before registration
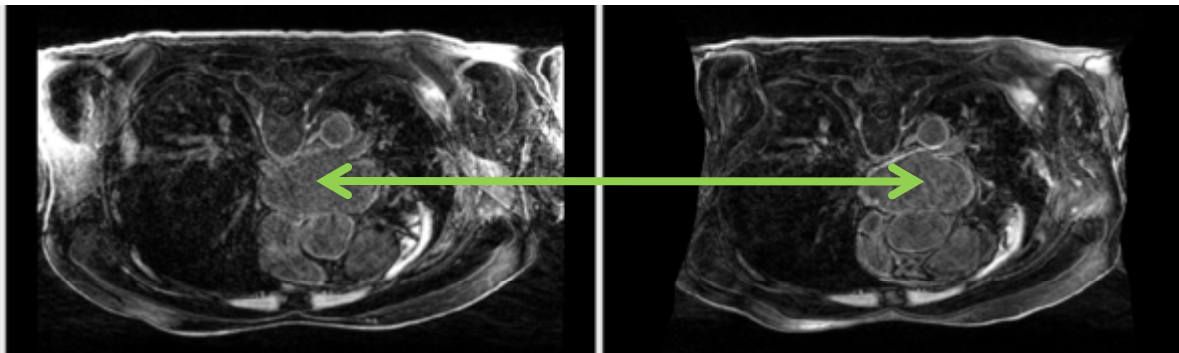
After registration

Pre-ablation   Post-ablation

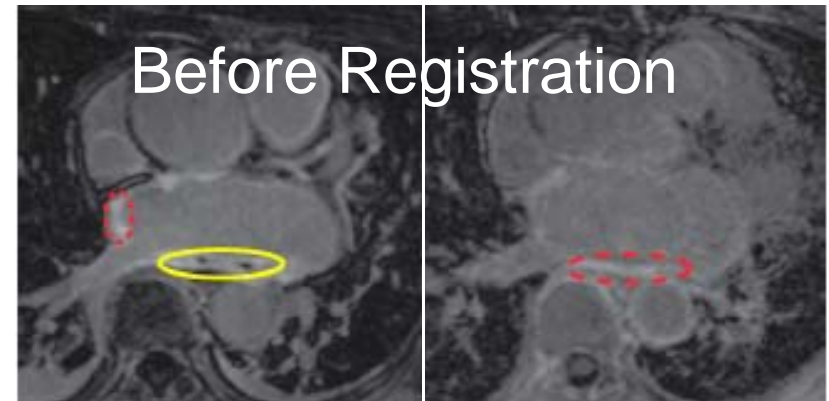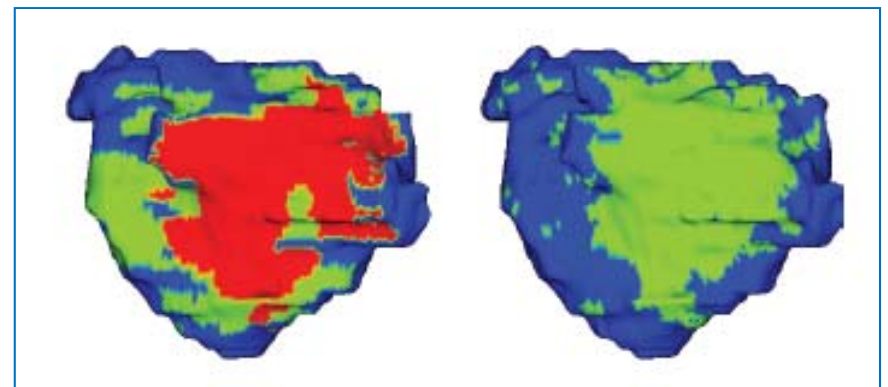THE UNIVERSITY OF UTAH

DBP Utah: AFIB: Need for point-to-point correspondence
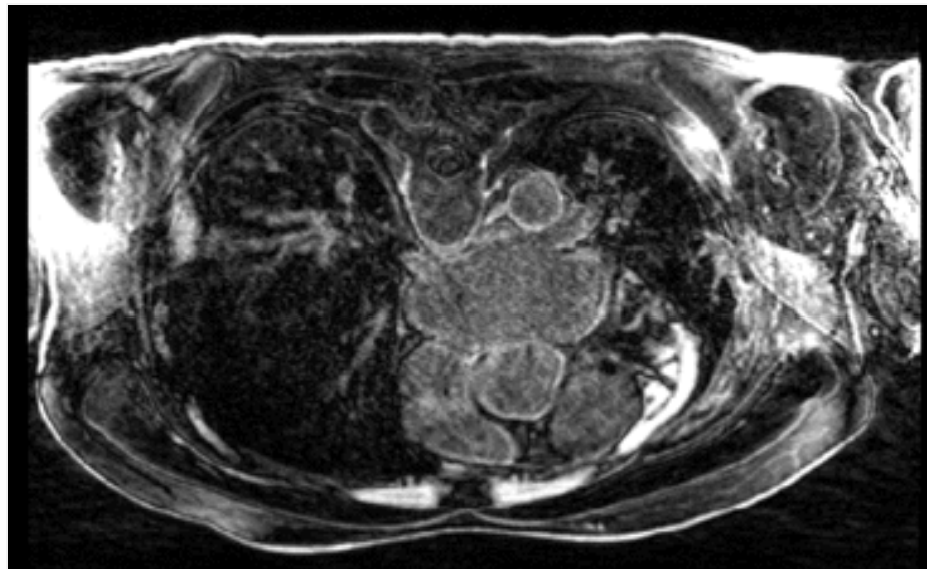
Pre- to Post-ablation

Before Registration

Post-ablation   Follow-up

After registration: IPA→3PA

JJE Blauer J Cates, CJ McGann, EG Kholmovski , A Alexander, MW Prastawa , S Joshi , NF Marrouche , RS MacLeod, Computing in Cardiology
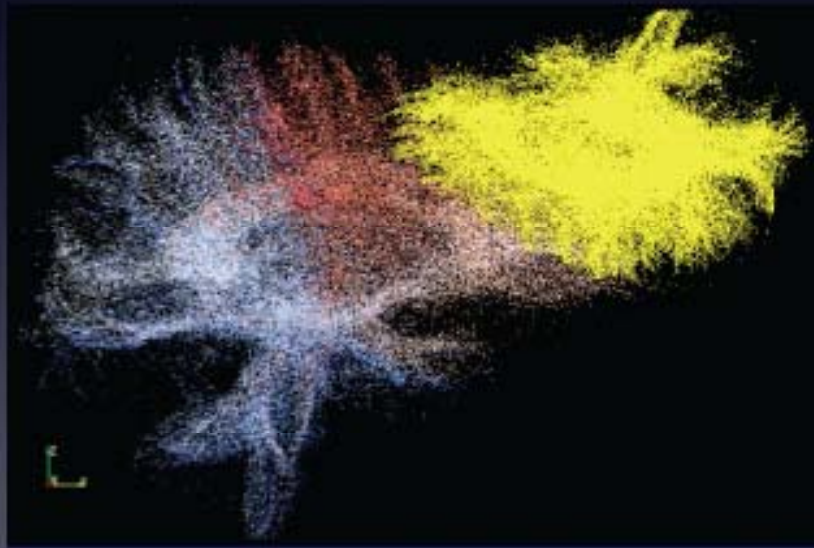
THE UNIVERSITY OF UTAH

Registration

Original Data Sets (3 Patient to Patient Sets)

Set II

Set I

Set III

Solution via Particle Filter

- Exists: Iterative closest points: Efficient solution?
- **New**: Consider registration as posterior estimation problem
- Hidden state variable to estimate is TRANSFORMATION
- Two part problem:
  - Establishing correspondence
  - Estimate Transformation parameters

Filtering (Granger and Pennec 02, Ma and Ellis 05, Moghari and Abolmaesumi 07,

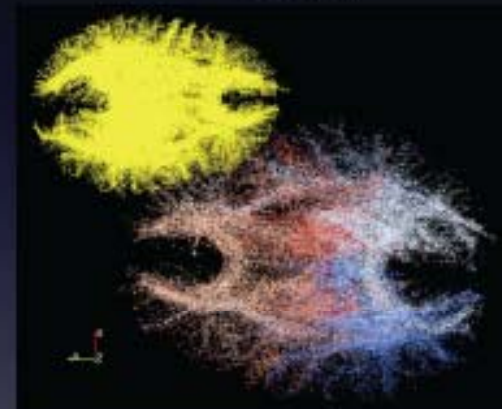# Registration

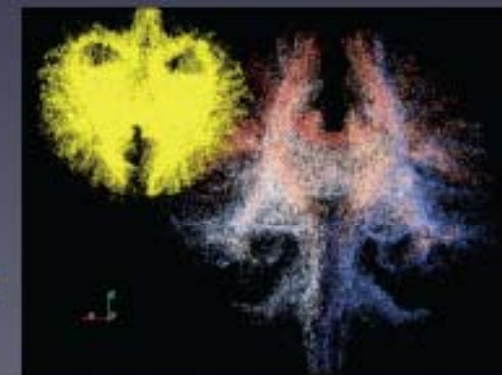## Final Result (3 Patient to Patient Sets)

Set I

Set II

Set III
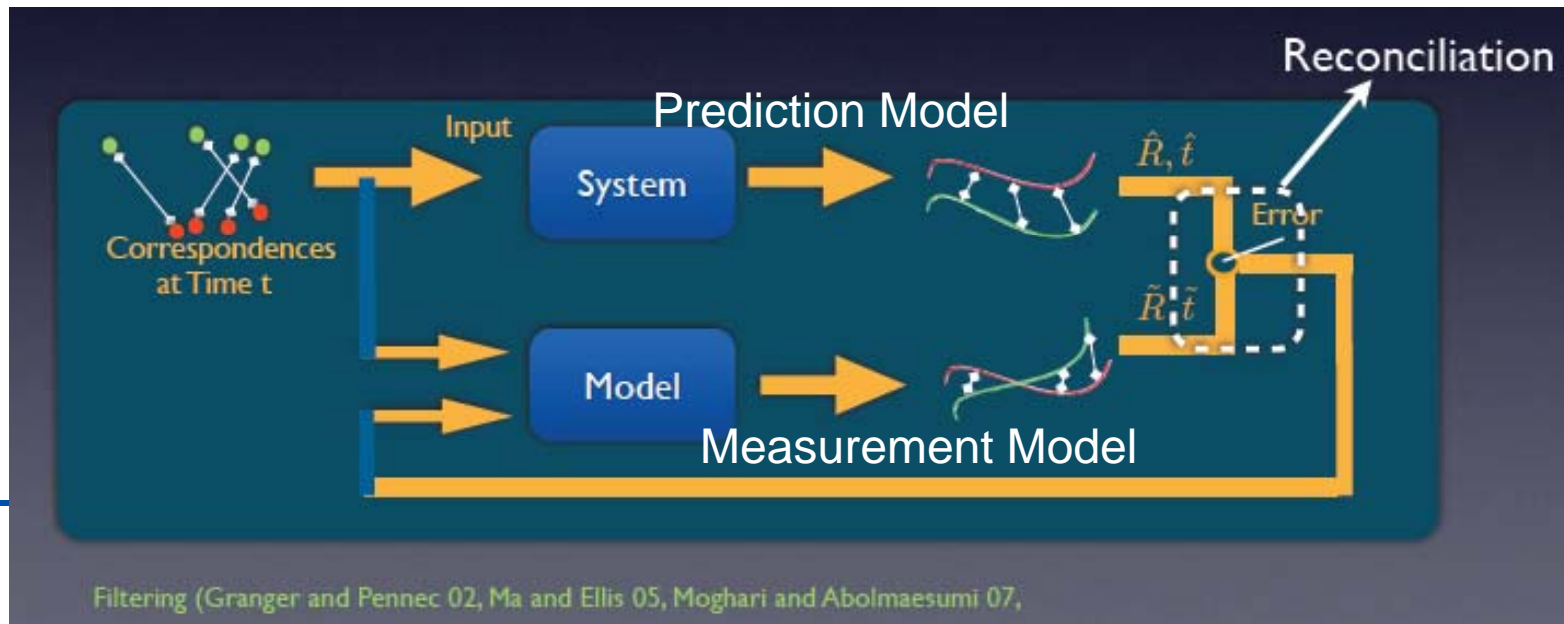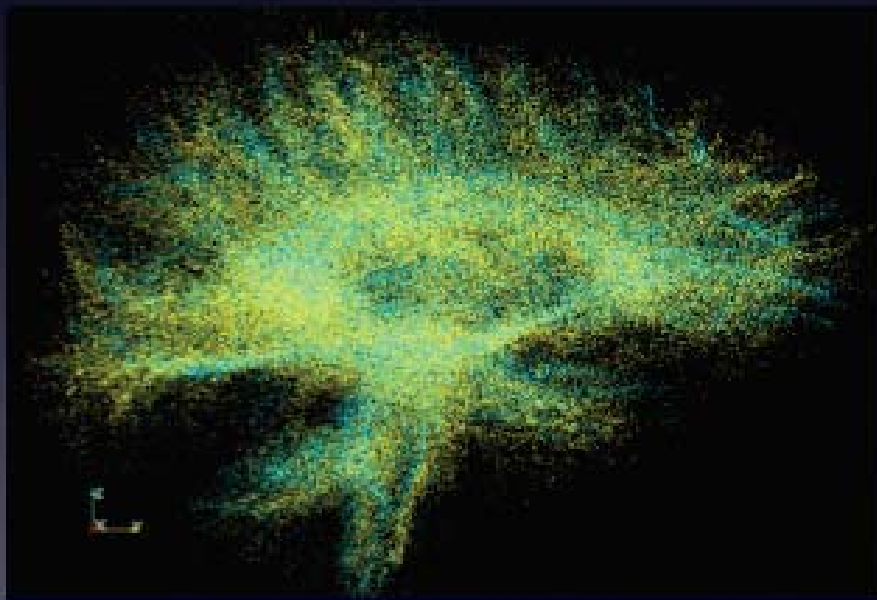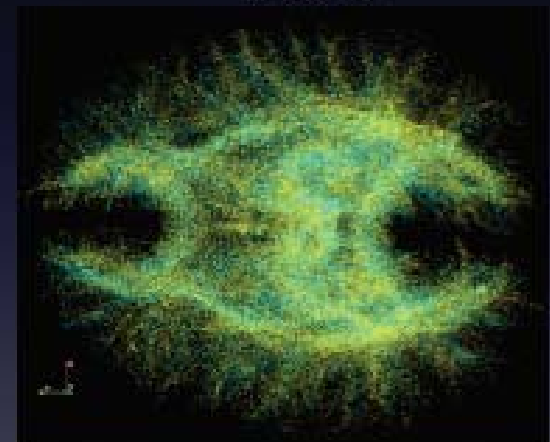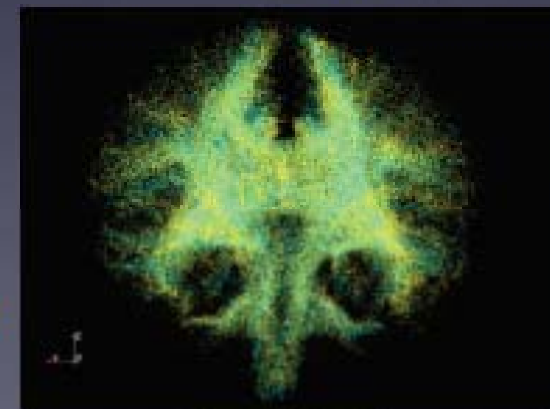
Note 1: This is on-going work done in conjunction with **_Dr. Yogesh Rathi_** at the Brigham Women's Hospital, Harvard Medical School.

Particle Correspondence

- Particle system correspondence (Utah)
  - 2 entropy terms
    - Ensemble entropy -> how are particles similar across a set of surfaces
    - Surface entropy -> distribute the particles "evenly" across surfaces

- **Problem**: Highly convoluted surfaces (cortical surface) or very "skinny" surfaces
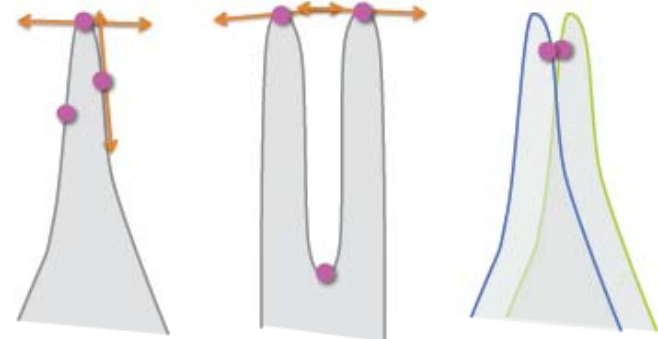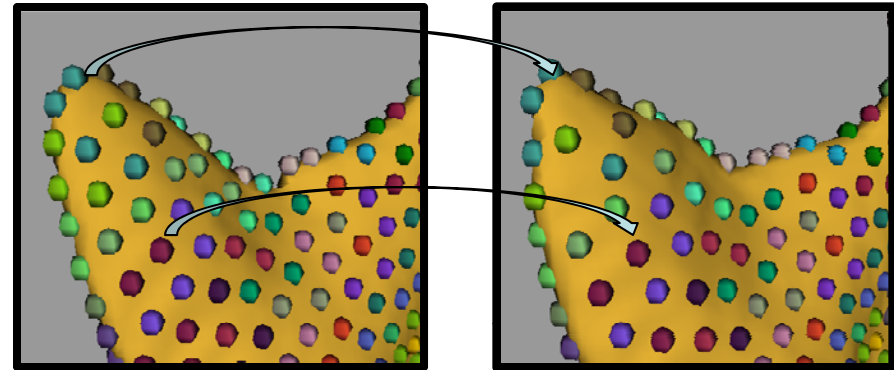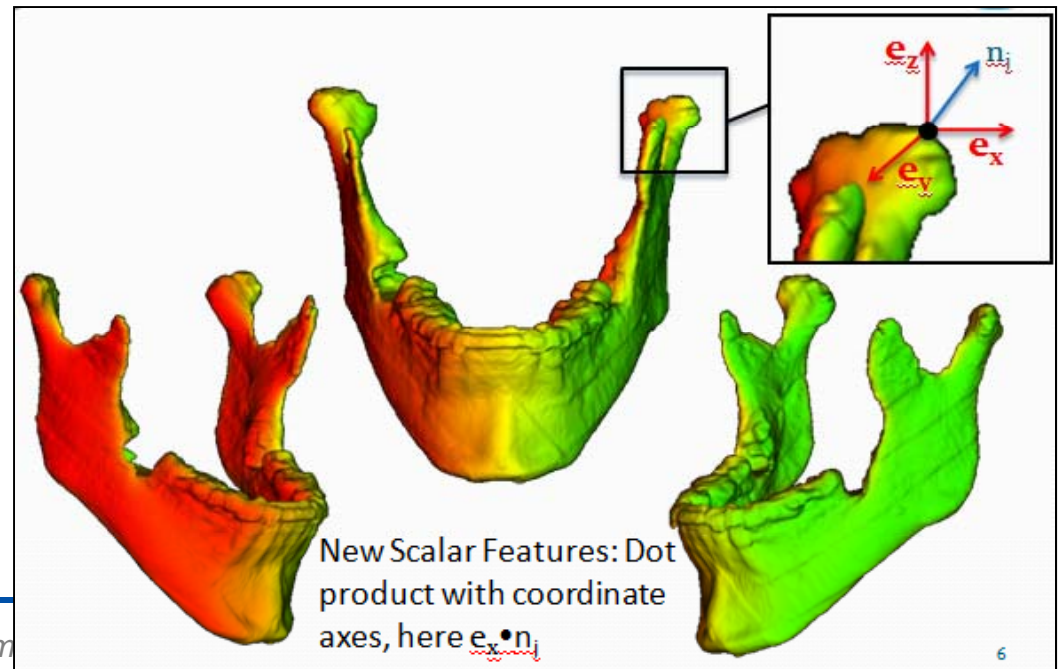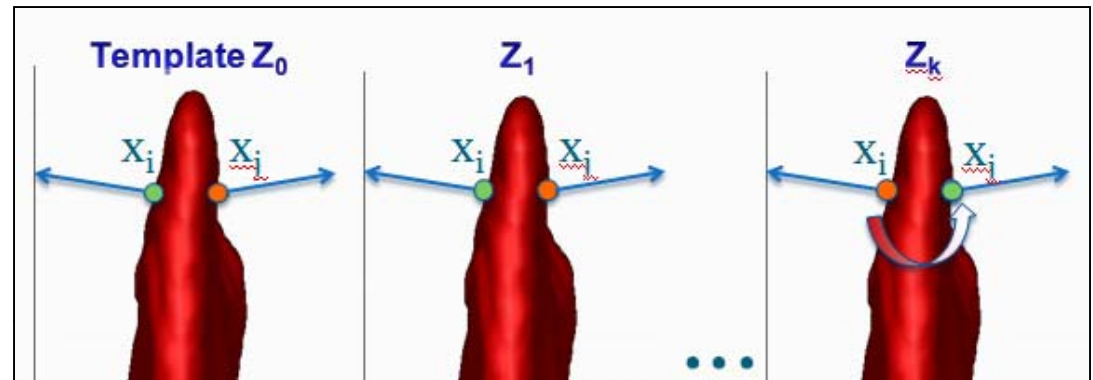

Euclidean distance very different from geodesic distance: Points do not lie in each other's tangent space
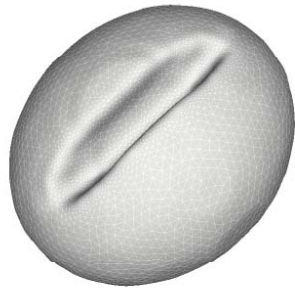
THE UNIVERSITY OF UTAH

In progress …

- Use Geodesic instead of Euclidean distances

- Optimize ensemble entropy for consistency of the <u>normal orientation</u>

- Utah-UNC collaboration

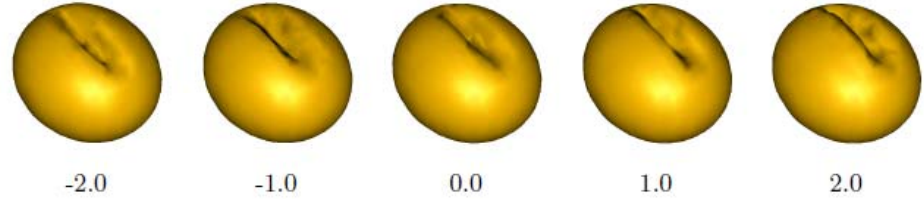New Scalar Features: Dot product with coordinate axes, here $e_x \cdot n_j$

Early results
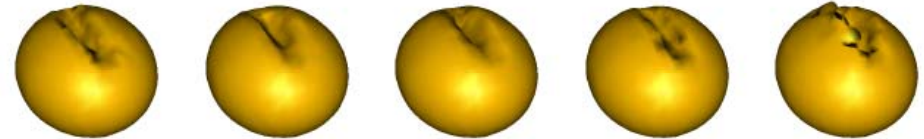
new method

old method

Fig. 4. Mean shape computed from the proposed method (top) and the original method (bottom), projected onto the first PCA mode, upto 2 standard deviations

DBP:
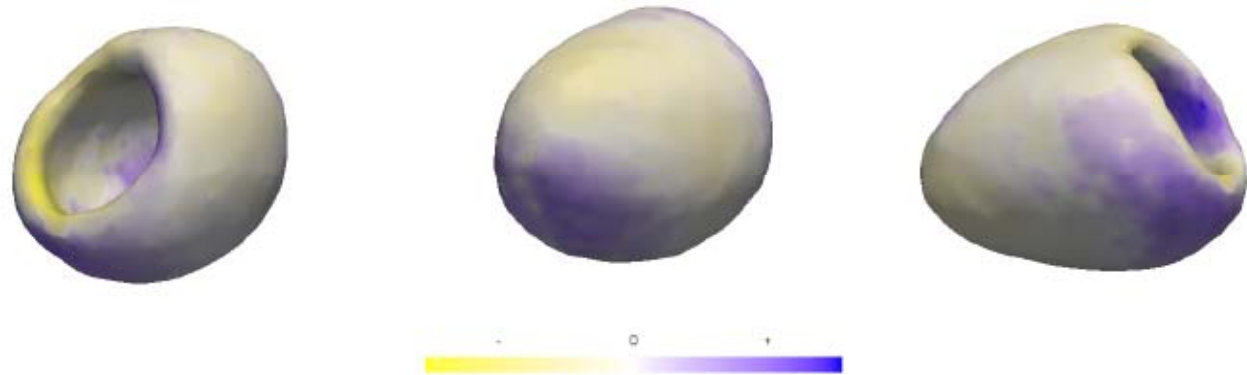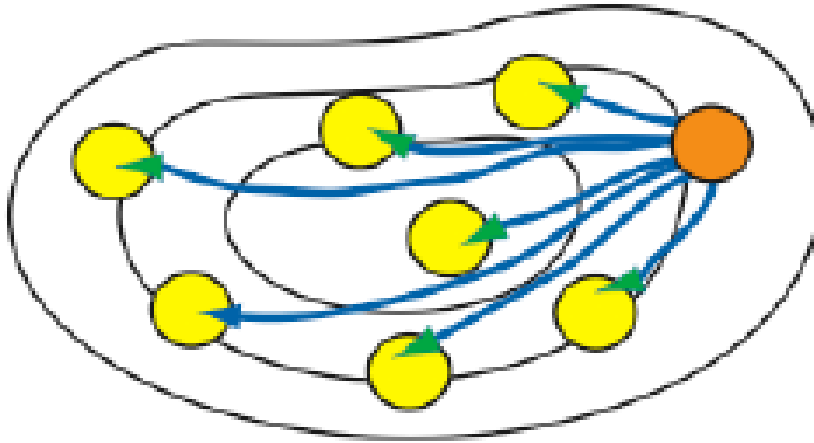Utah AFIB

Fig. 5. Visualizing mean differences between normal and ischemic groups (blue denotes expansion and yellow denotes contraction).

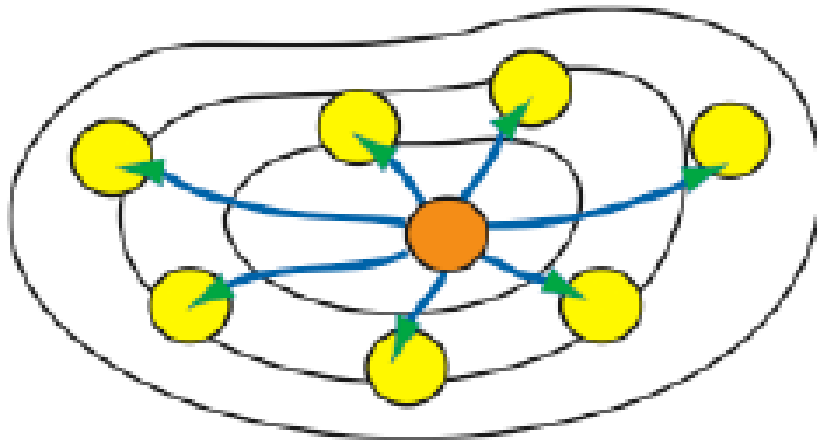# Group-wise Registration

Problem: Find optimal template ("average")

Minimize total "distance" beetween population and template: UNBIASED ATLAS BUILDING

- Joshi&Fletcher
- Gee & Avants, 2006)
- Balci, Golland, Wells 2007

THE UNIVERSITY OF UTAH

NAMIC work in progress

- **Method**: Free-Form B-spline Deformation Model for Groupwise Registration

- **Joint alignment criterion**: Sum of pixelwise entropies:

$$f = \sum_{v=1}^{V} H(I(T(x_v))).$$

- **Result:**
  - Set of deformed images
  - Set of deformation fields h_i

- **Use**: Normative atlases, establishing correspondence across subjects/time
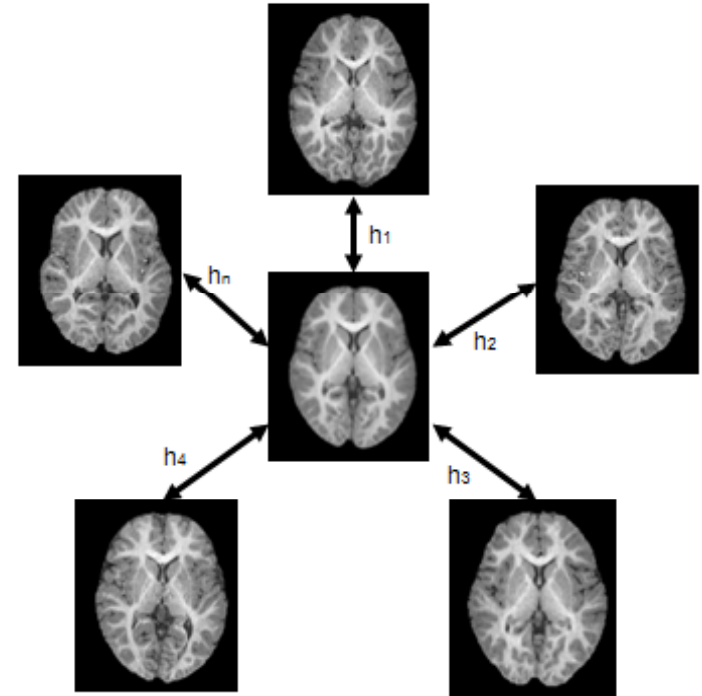
Serdar K. Balci, Polina Golland, Martha Shenton, and William M. Wells, 2007

THE UNIVERSITY OF UTAH

Correspondences via embedded shapes

Correspondence-free Registration

Topology and shape differences can make point-to-point correspondence hard:
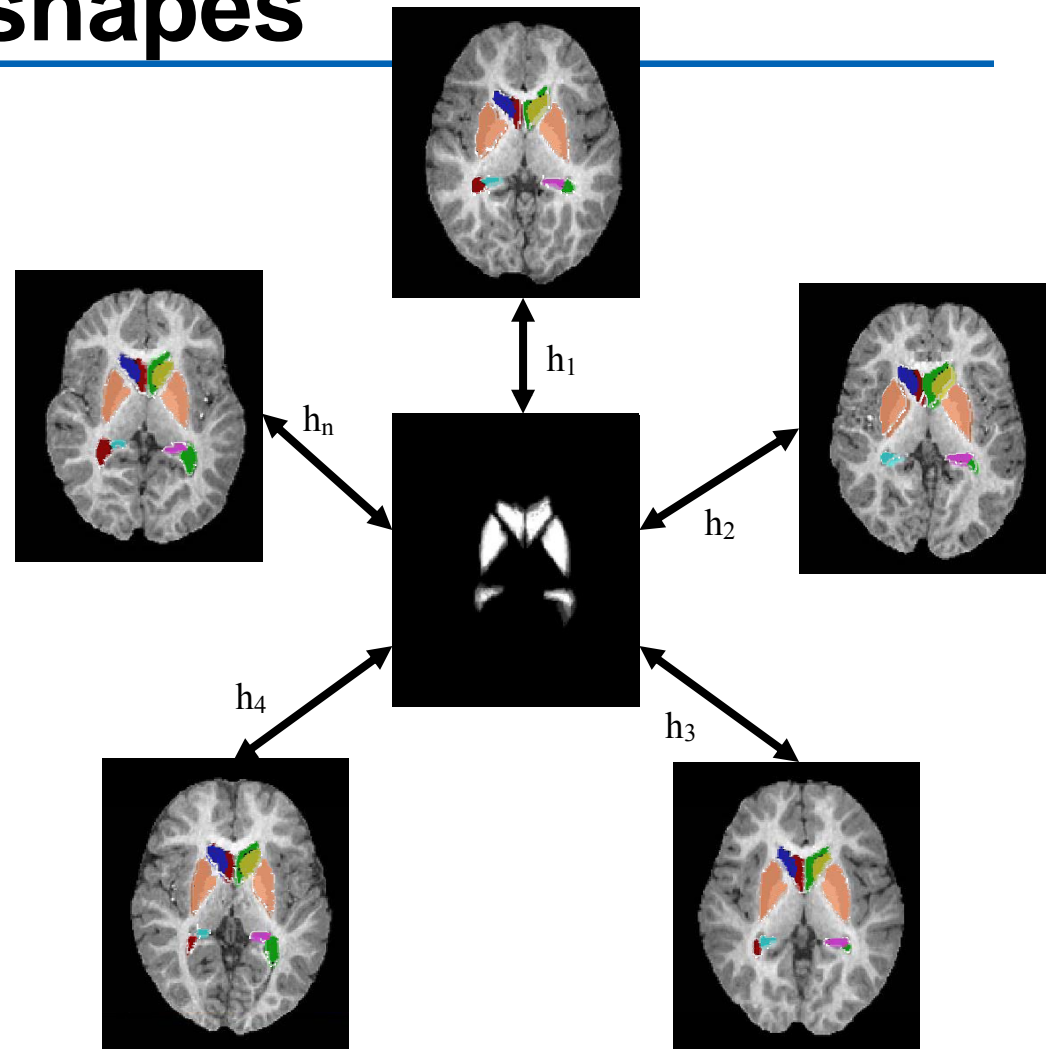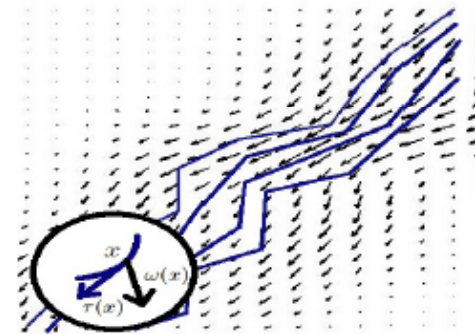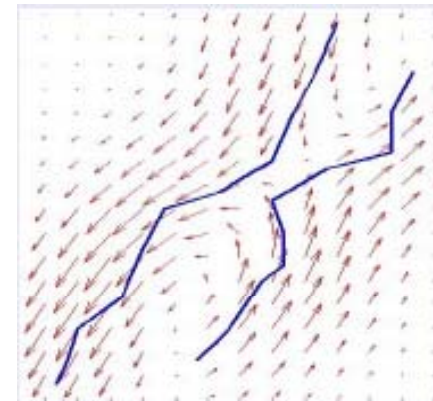
- **Currents**: Objects that integrate vector fields

- **Shape**: Oriented points = Set of normals (tangents)

- **Distance** between curves:

$$d(L_1, L_2)^2 = \int_{L_1} \omega_1(x)^t \tau_1(x)dx + \int_{L_2} \omega_2(x)^t \tau_2(x)dx$$
$$- \int_{L_1} \omega_2(x)^t \tau_1(x)dx - \int_{L_2} \omega_1(x)^t \tau_2(x)dx$$

$$L(\omega) = \sum_{i=1\ldots4} \int_{L_i} \omega(x)^t \tau(x) d\lambda(x)$$

[Glaunes2004] Glaunes, J., Trouve, A., Younes, L. Diffeomorphic matching of distributions: a new approach, … CVPR 2004.

[Durrleman2008] S. Durrleman, X. Pennec, A. Trouvé, P. Thompson, N. Ayache, Inferring Brain Variability from Diffeomorphic Deformations of Currents: an integrative approach, Medical Image Analysis 2008

THE UNIVERSITY OF UTAH

Relevance to NAMIC: Registration in presence of large deformations
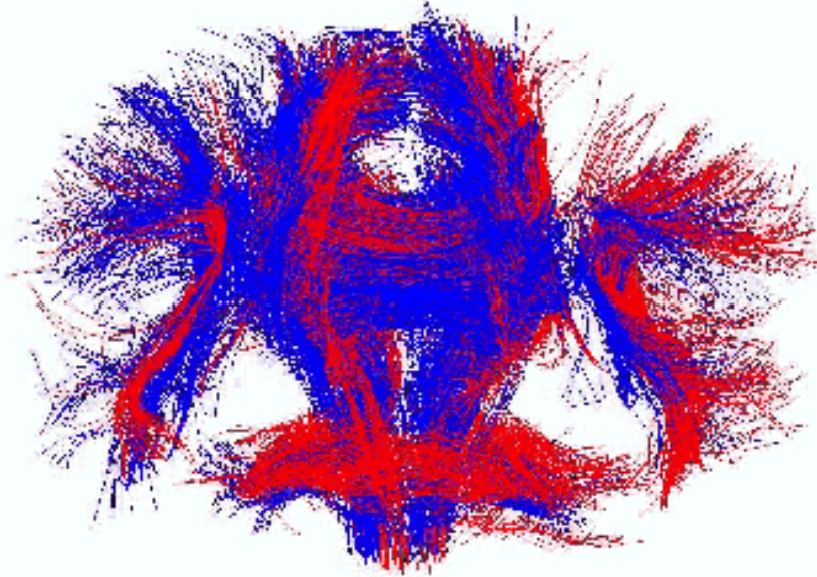
t=10
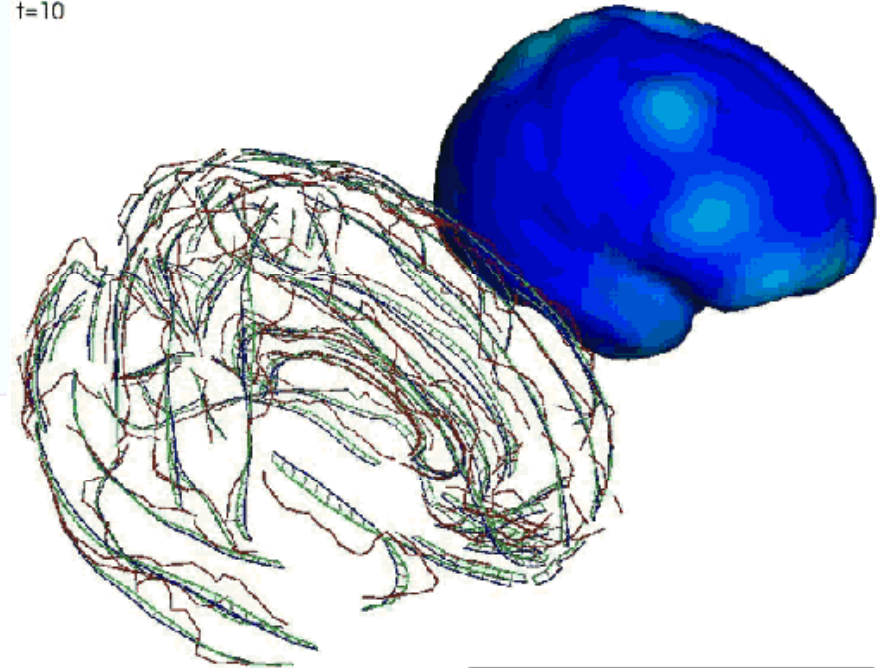
Registration <u>without</u> explicit point-to-point correspondence.

Material courtesy of Stanley Durrleman

THE UNIVERSITY OF UTAH

Correspondence-free mapping

Problem: Nonlinear mapping of point sets with different resolutions.
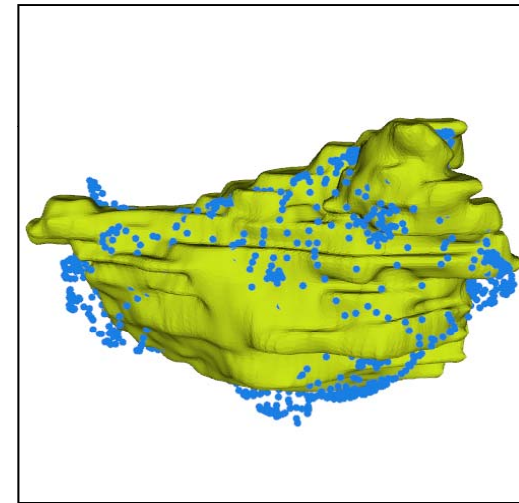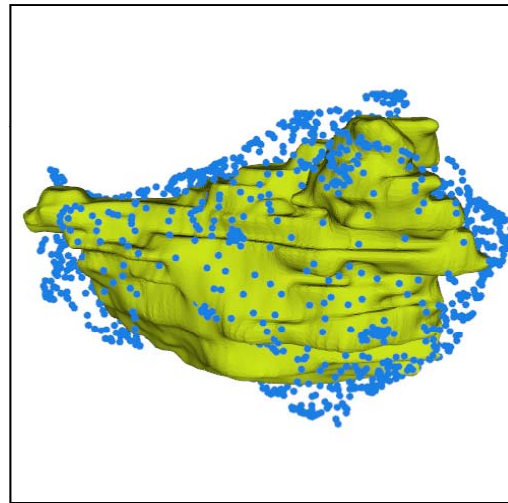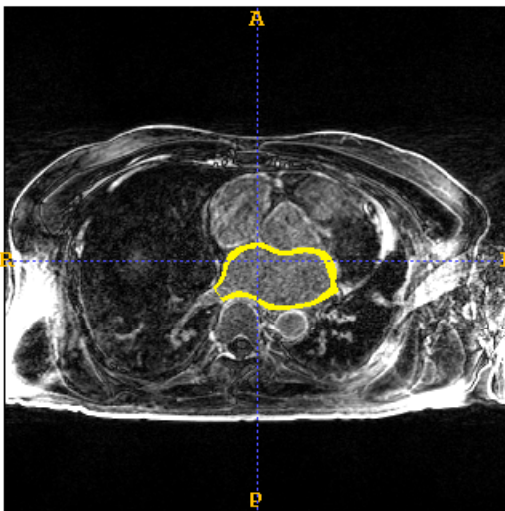
Yellow: high resolution surface from MRI segmentation (32172 points). Blue: low resolution surface from catheter tracking (1803 points). Left: Initial manual alignment. Right: Automatic alignment using currents measure with a combination of affine and elastic transformations.

Correspondence-free mapping

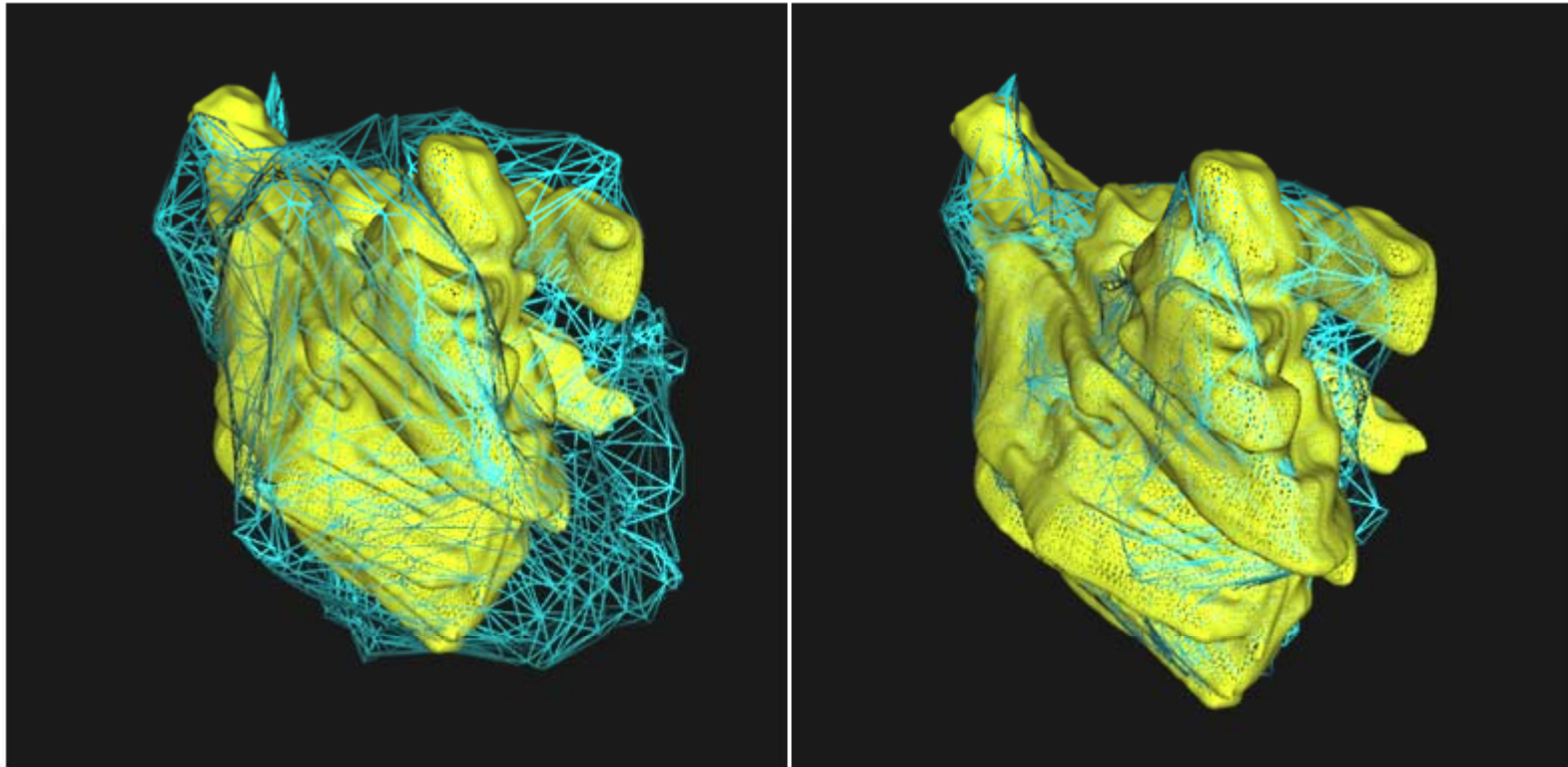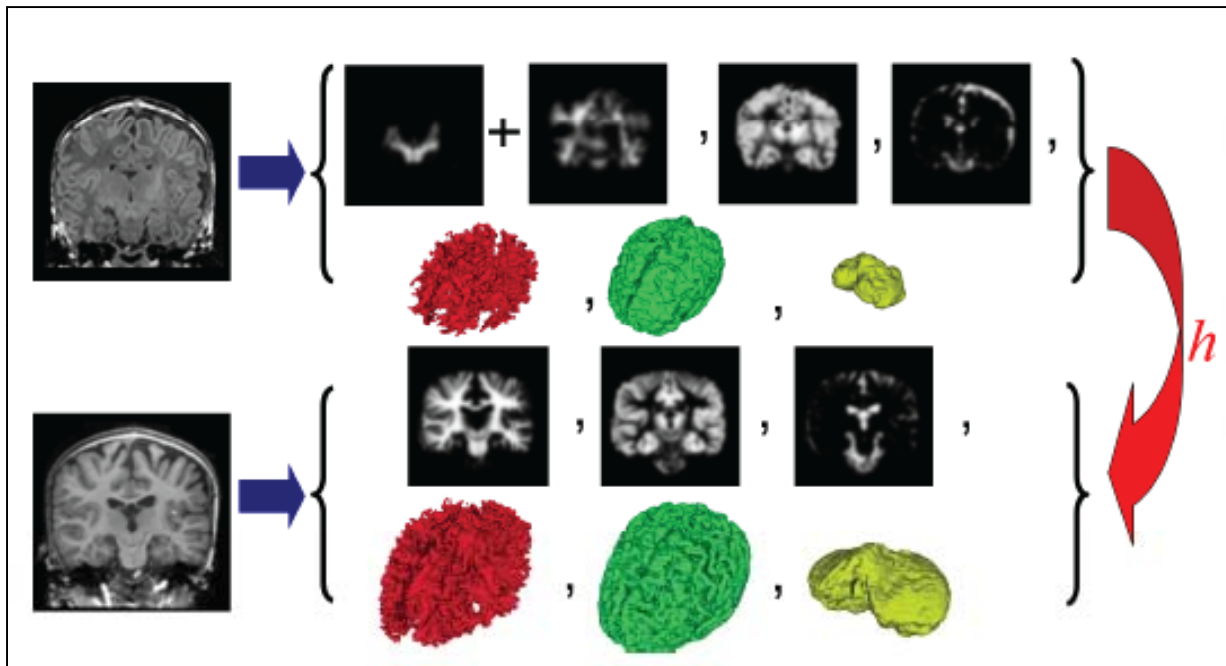# Registration via Combined Probabilistic and Geometric Descriptors

Deformable image registration in the presence of considerable contrast differences and large-scale size and shape changes represents a significant challenge for image registration → **Use Appearance and Geometric Features**

Linh Ha, Marcel Prastawa, Guido Gerig, John H. Gilmore, Claudio T. Silva, and Sarang Joshi. *Image Registration Driven by …, MICCAI 2010*

THE UNIVERSITY OF UTAH

Conclusions

- NAMIC R&D has to tackle challenging scientific problems w.r.t. geometric correspondence and registration:
  - Longitudinal/serial data presenting significant changes
  - Complex expression of pathology: New objects, change of topology
  - Multi-modal longitudinal registration

- Core methods are not yet readily available, <u>no off-the-shelf solutions</u>

- Very promising quick start on DBP problems

- Strong Core1a/b team effort towards short-/mid- and long-term solutions, driven by needs of DBPs and NAMIC-associated projects

THE
UNIVERSITY
OF UTAH