Diffeometric Anatomical Registration on the Surface

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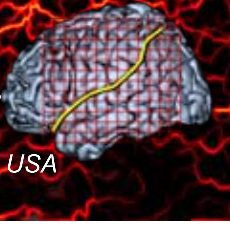


Motivation

Surface-based registration approaches may achieve higher accuracy than volume-based approaches (Anticevic, 2008). Furthermore, a registration approach that uses landmark features often requires manual intervention, thus introducing a dependency on the anatomist. Surface-based approaches may either be iterative or diffeomorphic. Diffeomorphic approaches have the advantage that an exact inverse transformation can be calculated. Here, we adapt the volume-based diffeomorphic DARTEL algorithm to the surface (Ashburner, 2007).

Methods

INITIALIZATION:

- calculate shape index (SI) for highly smoothed source and target surfaces

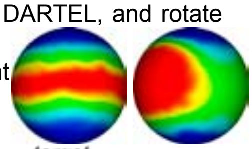
$$c = -\frac{2}{\pi}\arctan\left(\frac{k1+k2}{k1-k2}\right)$$

- Re-parameterize target SI values onto source sphere & perform affine alignment using RMS error. Rotate source sphere.

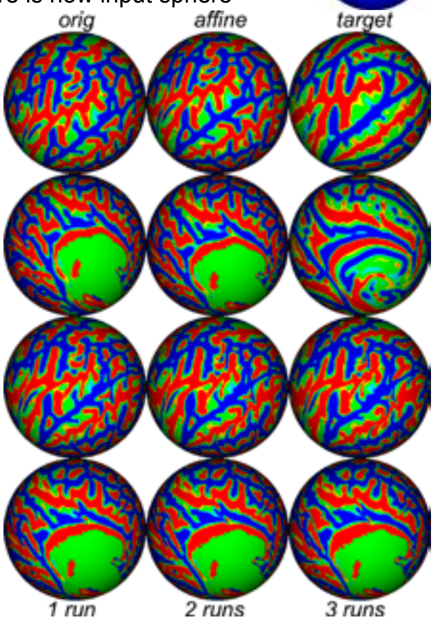
FOR run=1:3

- FOR step=1:6
  - smooth and inflate surfaces… step=1::high-smoothing; step=3+::low-smoothing
  - calculate SI values for smoothed surfaces
  - re-parameterize source and target SI using regularly-sampled points along θ and φ
  - solve flow field with 2D DARTEL using FMG solver
- END
- apply flow field to sphere, using exponential weighting curve for poles

- for solution near poles: rotate all spheres by 90° along x-axis, generate new SI maps, solve again with DARTEL, and rotate back to original orientation
- combine both solutions using φ-dependent Gaussian weighting function
- warped sphere is now input sphere



END



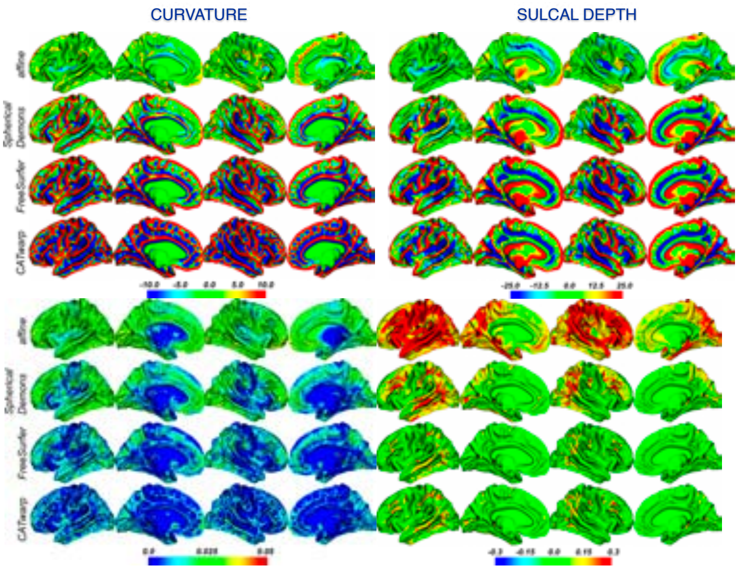
Validation

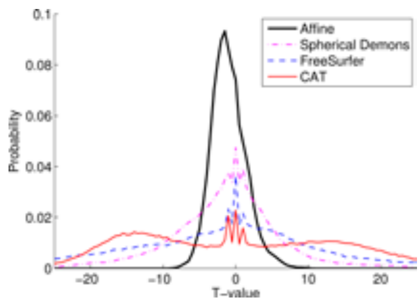
- 74 T1-weighted MRI images for control subjects
- T-value, residual mean square, and average maps for curvature and sulcal depth

$$T(c) = \frac{\bar{c}}{\sigma(c)^2}$$

- Comparison with FreeSurfer (Fischl, 1999) and Spherical Demons (Yeo, 2010)

Results



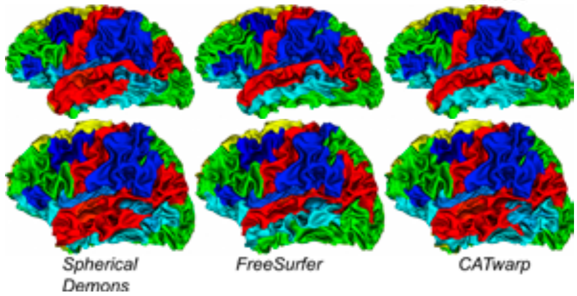


Above upper: T-maps for mean curvature (left) and sulcal depth (right).

Above lower: Residual mean square for mean curvature (left) and sulcal depth (right).

Left: Histogram for mean curvature T-values. Larger values indicate better match.

~15 minutes on a 2.4 GHz iMac for a mesh with 150,000 vertices



Left: Annotation from *fsaverage* template, resampled to subjects space

Future Work

Validate using manually-labeled surfaces (Dice coefficient). "Biological" similarity using twin data. Explore solution directly on the sphere (no reparameterization of individual subject data).

The above results are for shape index. It may be possible to achieve different analysis targets by using a different measurement for the source and target maps, e.g., sulcal depth.

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