

# A combined Surface And Volumetric Registration (SAVOR) framework to study cortical biomarkers and volumetric imaging data



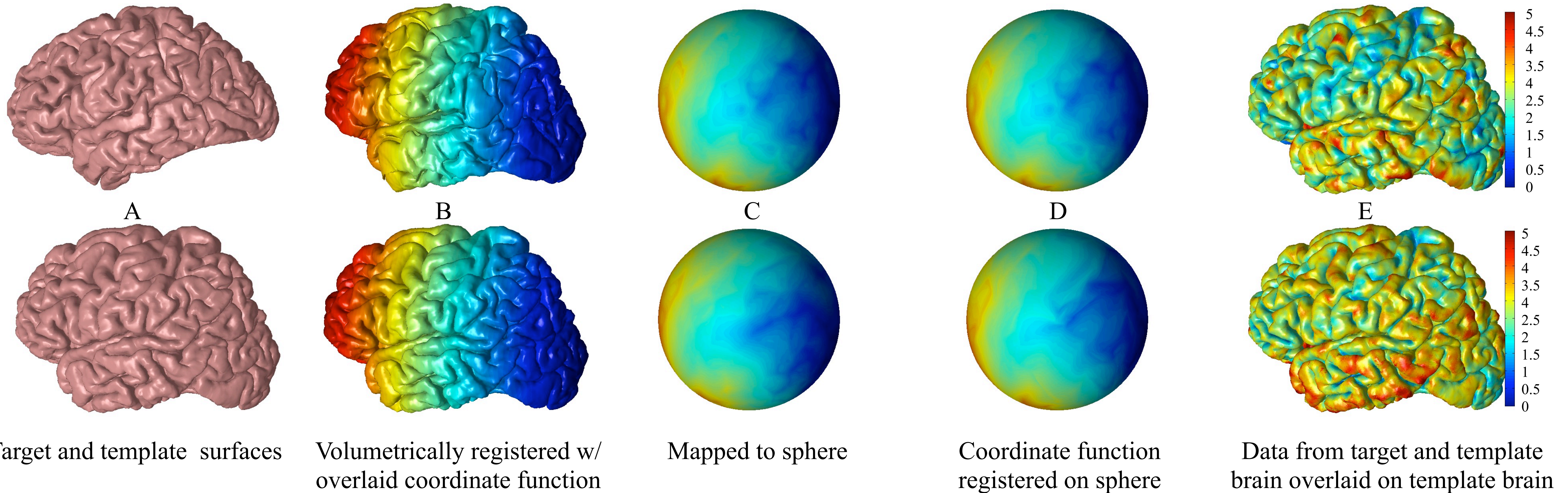
Eli Gibson, Ali R. Khan, Faisal Beg  
<http://autobrainmapping.com/>



Good Volumetric  
Registration

SAVOR Framework

Good Topologically Correct  
Homeomorphic Surface Registration



## Overview

The SAVOR framework generates a homeomorphic topologically correct surface registration of 2 cortical surfaces that closely approximates a given volumetric registration.

Establishing this registration allows the simultaneous statistical analysis of surface biomarkers (e.g. thickness, curvature, gyrification) and volumetric biomarkers (e.g. fractional anisotropy, BOLD signal) using near to the same registration.

## Key Contribution

**Spherically registering coordinate functions**, instead of biomarkers (e.g. curvature or sulcal depth).

## How it works:

Target and template brain surfaces are manifolds embedded in 2 different image spaces. SAVOR uses a chain of several homeomorphic mappings to compose a surface to surface mapping.

- 1) Volumetric registration maps the target surface into the template image space. (B above)
  - 2) Spherical Mapping maps both surfaces to spherical spaces. (C above)
  - 3) Spherical Registration maps between spherical spaces. (D above).
- To get the value of a function at a point on the target brain mapped to the template surface, we compose the mappings:

$$f_{temp}(x) = f_{target}(VolReg(SphMap_{target}^{-1}(SphReg_{temp}(SphMap_{temp}(x))))))$$

## Requirements:

The framework requires three components: a good volumetric registration, a spherical mapping and a spherical registration.

- Initial surfaces should have spherical topology.
- Volumetric registration alone should align analogous regions sufficiently.
- Mappings created by each component should be homeomorphic.
- The spherical mapping and the spherical registration are coupled, in that the spherical registration must be sufficiently flexible to handle deformations induced by the spherical mapping.

## Framework Components

Volumetric Registration

multi-channel-LDDMM [2]

Spherical Mapping

FreeSurfer Spherical Inflation [1]

Spherical Registration

Spherical Demons [3]

## Coordinate Functions

Typically, surface registrations algorithms use biomarkers in the cost function, aligning regions with similar biomarkers.

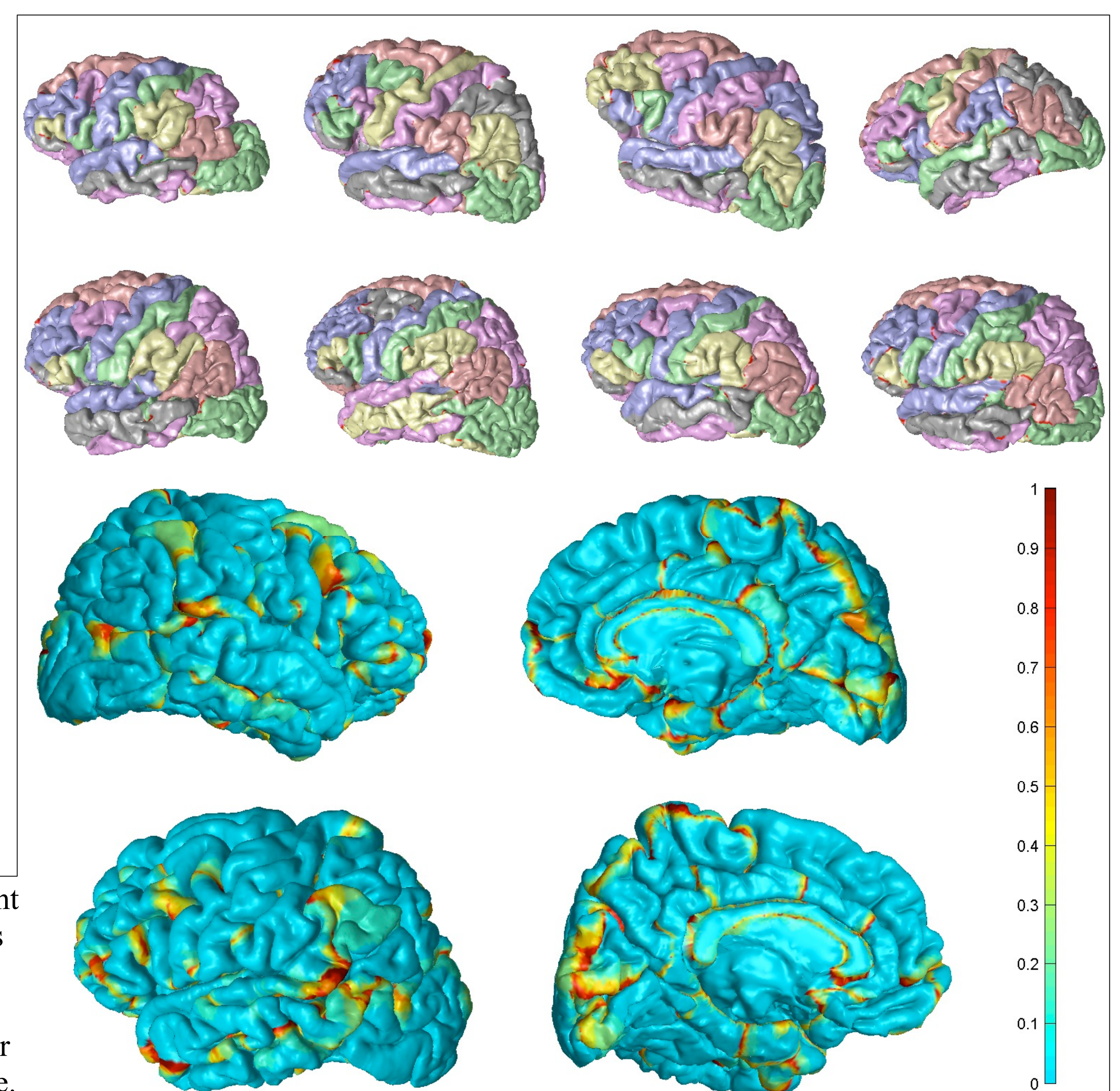
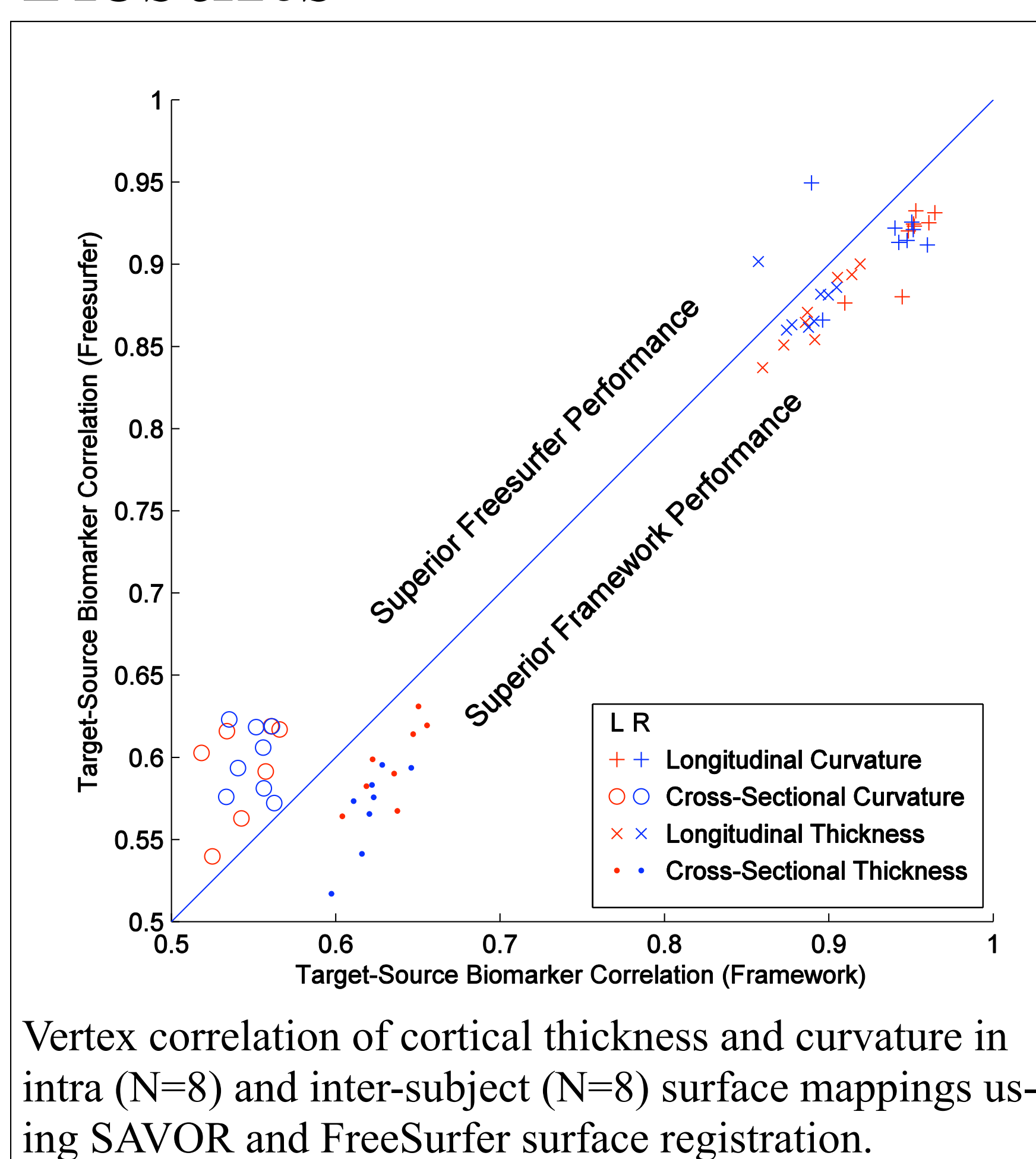
SAVOR uses coordinate functions, instead. Coordinate functions are vector valued functions which reflect the position of the volumetrically aligned surfaces. SAVOR aligns regions with similar positions, thereby minimizing the deviation from the volumetric registration.

Alignment of analogous regions is handled by the volumetric registration.

## References

- Fischl, B.R., Sereno, M.I., Dale, A. M. Cortical Surface-Based Analysis II: Inflation, Flattening, and Surface-Based Coordinate System. NeuroImage, 9, (1999) 195-207.  
 Khan, A.R., Beg, M.F. "Multi-structure Whole Brain Registration and Population Average." Conf Proc IEEE Eng Med Biol Soc. (2009) 5797-5800  
 Yeo, B.T.T., Sabuncu, M., Vercauteren, T., Ayache, N., Fischl, B., Golland, P.: Spherical demons: fast surface registration. MICCAI 11(Pt 1) (2008) 745-753

## Results



Upper: Intra-subject misalignment (in red) of mapped cortical labels  
 Lower: Average surface-registration error map showing fraction of misaligned labels after inter-subject mapping to template.