Diffeomorphic Metric Surface Mapping in Superior Temporal Gyrus

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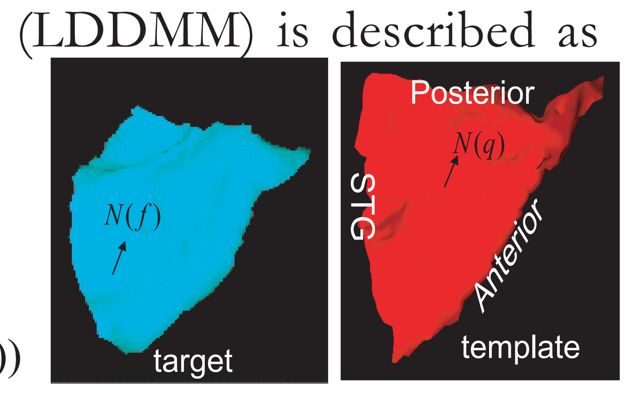
Introduction

We describe the application of large deformation diffeomorphic metric mapping to cortical surfaces based on the shape and geometric properties of subsets of the superior temporal gyrus in the human brain. The anatomical submanifolds are represented as triangulated meshes. The diffeomorphic matching algorithm is implemented by defining a norm between the triangulated meshes, based on the algorithms of Vaillant and Glaunès [1]. The diffeomorphic correspondence is defined as a flow of the extrinsic three dimensional coordinates containing the submanifold surface that registers the initial and target geometry by minimizing the norm. The method is demonstrated in 40 high resolution MRI cortical surfaces of planum temporale (PT) constructed from subsets of the superior temporal gyrus (STG). The effectiveness of the algorithm is demonstrated via the Euclidean distance of these surfaces before and after transformation as well as the comparison with a landmark matching algorithm [2].

LDDMM-Surface Matching

Large Deformation Diffeomorphic Metric Mapping (LDDMM) is described as the following variational problem:



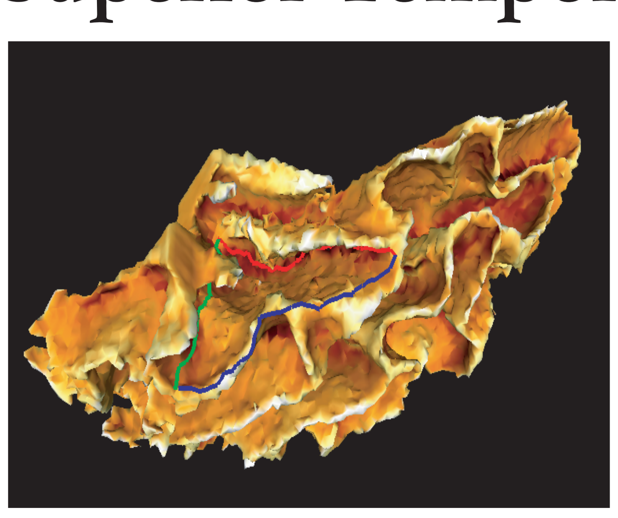
$$\hat{v} = \underset{v:\phi = \int v_t(\phi_t)dt}{\arg\min} \int_0^1 \|v_t\|_V^2 \, dt + C(\phi.I_{temp}, I_{targ}) \quad ,$$

and $C(\phi.I_{temp}, I_{targ}) = \sum_{f,f'} N(\phi(f))^t K(c(\phi(f')), c(\phi(f))) N(\phi(f'))$

$$-2\sum_{f,q} N(\phi(f))^t K(c(q), c(\phi(f))) N(q) + \sum_{q,q'} N(q)^t K(c(q), c(q')) N(q')$$

where ϕ represents the transformation and v is the velocity field of ϕ. f, f' index faces of the target surface, while q, q' index faces of the template surface. $N(f)$ is the normal vector of face f. $c(f)$ is the center of face f. $K(x, y)$ is the kernel of Hilbert space.

Superior Temporal Gyrus

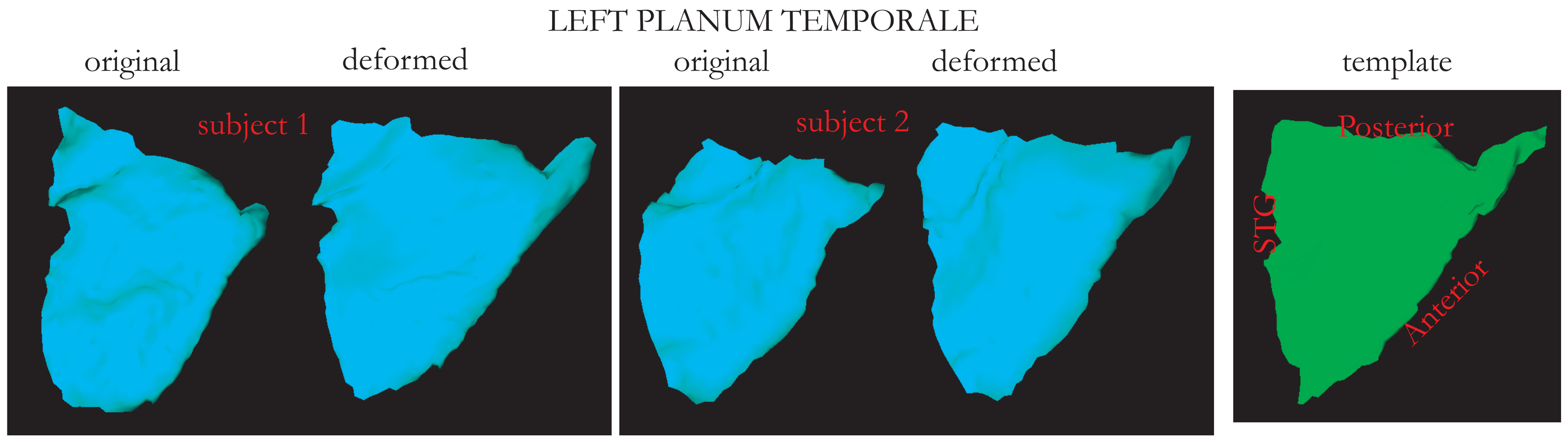


red	Heschl's Sulcus (HS)
blue	Superior Temporal Gyrus (STG)
green	near to Sylvian Fissure

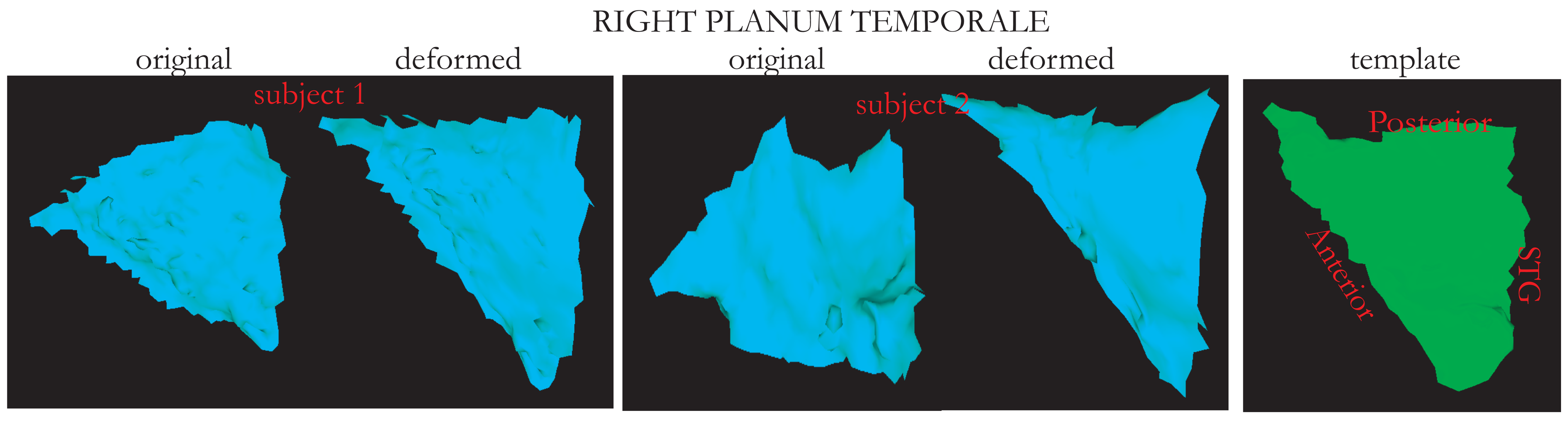
Results

Twenty healthy controls (10 men and 10 females, age: 36.5±11.2) were mapped to the template.

LEFT PLANUM TEMPORALE



RIGHT PLANUM TEMPORALE



Euclidean Validation

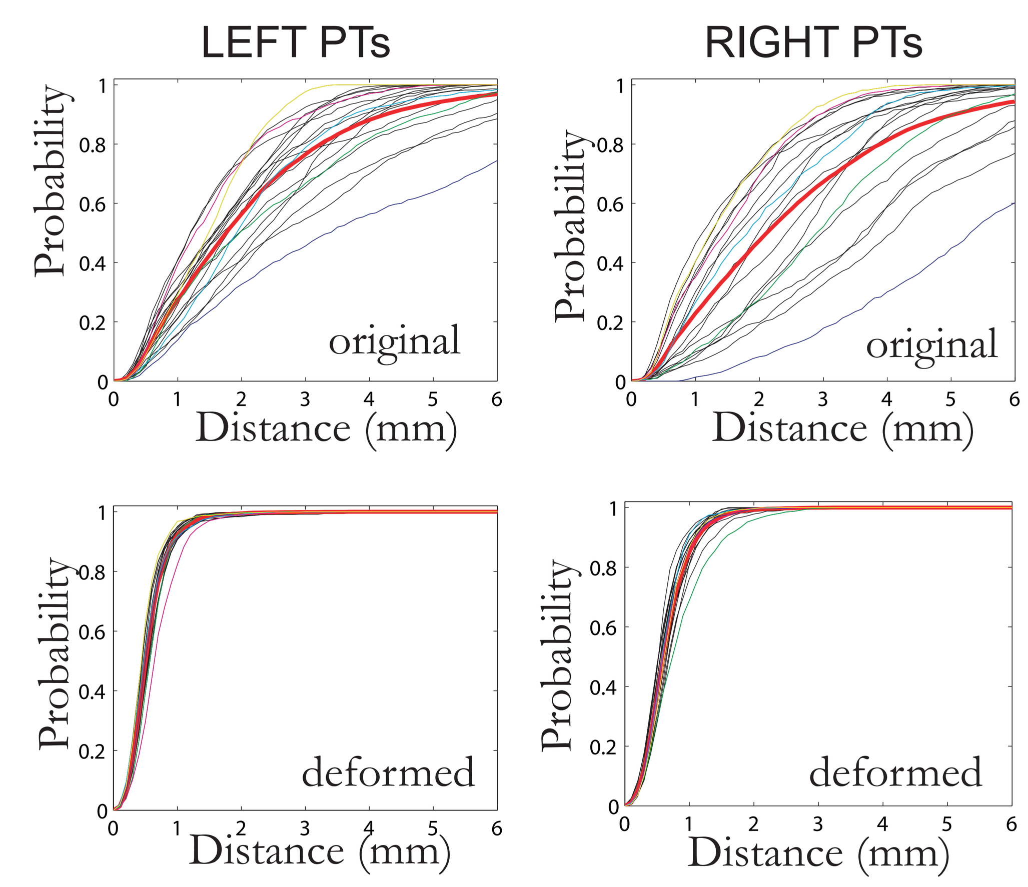
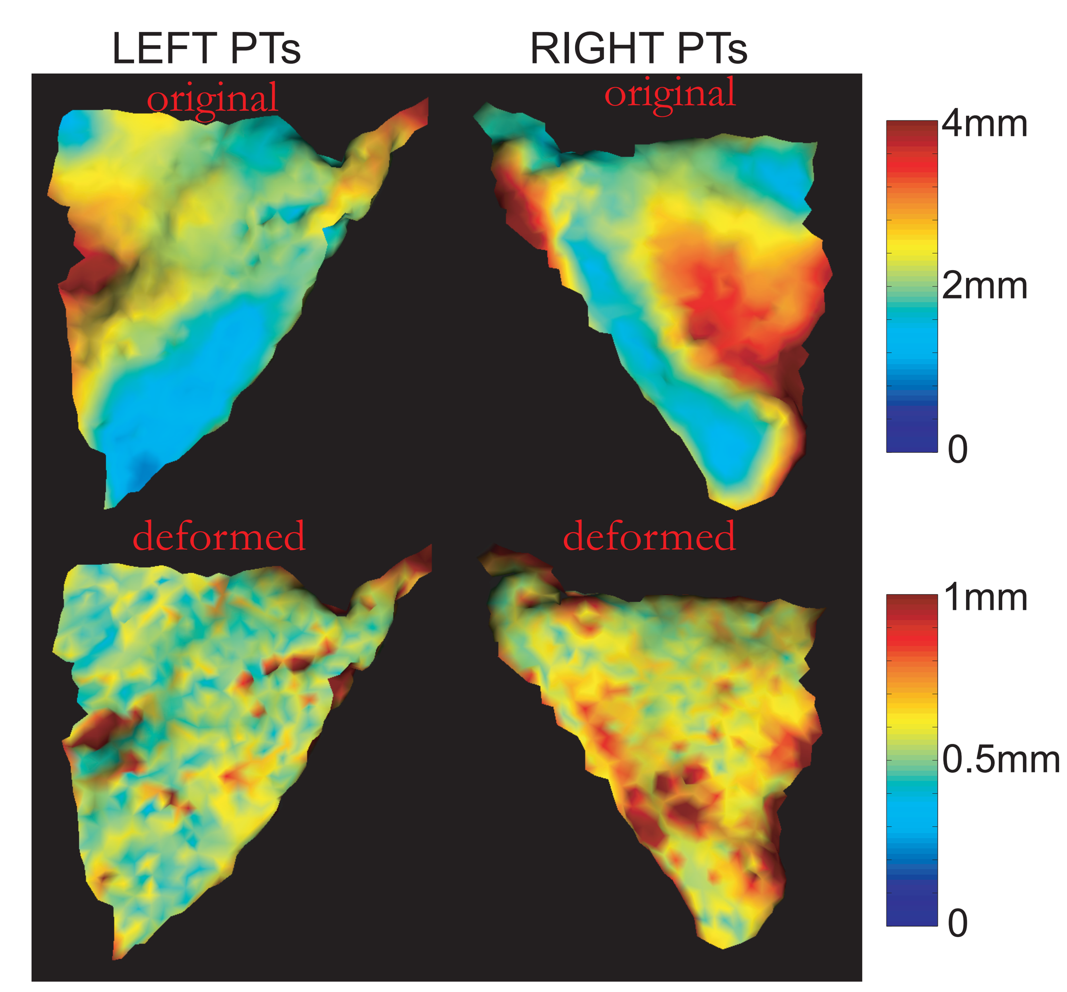


Figure shows the surface distance graph that gives the percentage of vertices on a template surface having the distance to a surface less than d mm.

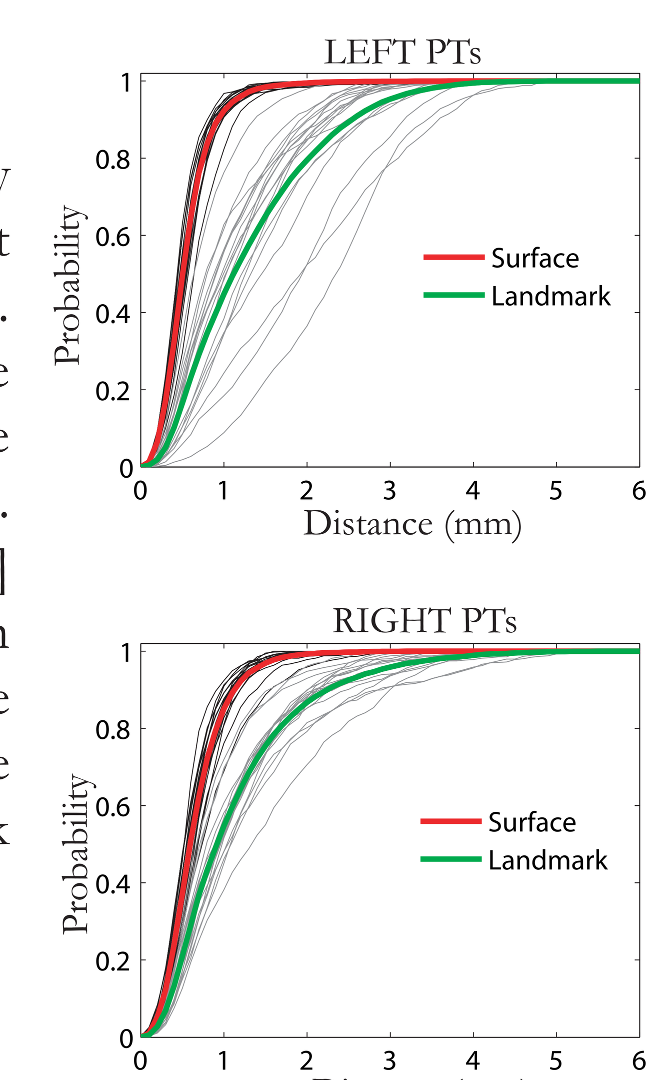
- Left PT: average median of distances 1.92mm vs. 0.55mm before and after matching.
- Right PT: average median of distances 2.40mm vs. 0.65mm before and after matching.

The intuitive illustration of where PT surfaces are far apart from the template surfaces before and after matching is demonstrated in Figure. The template surfaces are colored by average distance at each vertex of the templates over PT surfaces.



Comparison with Landmark Matching

Three corner points and three boundary curves of the PT were considered as point and curve landmarks across the population. Therefore, the three corner points and five points equally spaced on each boundary were chosen as landmarks on each PT surface. Then, the landmark matching algorithm [2] was applied to PTs to obtain the deformation field used to deform PT surfaces to the template. Comparisons of surface distance graphs between both surface and landmark matching methods are shown.



Conclusion

The results demonstrate that both the positional and shape variability of the anatomical configurations can be represented by the diffeomorphic maps.

References:
[1] M. Vaillant and J. Glaunès, "Surface matching vis currents", IPMI, 3565:381-392, 2005.
[2] S. Joshi and M. I. Miller, "Landmark matching via large deformation diffeomorphisms", IEEE TIP, 9: 1357-1370, 2000.

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