Thin Plate Spline Cortical Registration in the Intrinsic Geometry of the Surface.

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Objective

We present a method for registration of cortical surfaces to a surface atlas or template using labelled sulcal maps as constraints. We minimize a thin plate spline energy defined on the surface by solving the associated PDEs. Using covariant derivatives in solving these PDEs, we compute the bending energy with respect to the intrinsic geometry of the surface rather than the parameter space in which we are working, and thus minimize the effects of surface parameterization on the resulting registration.

Methods

We first extract a mask for the cortical surface from an MRI volume using the Brainsuite software [1]. The topology of the mask is corrected automatically using a graph based approach and tessellated to produce a genus zero surface. We then use a p-harmonic functional minimization scheme [2] to map the each cortical hemisphere onto a unit square. The result is a bijective mapping between each hemisphere and the unit square in which the interhemispherical fissure is constrained to lie on the boundary of the unit square. This allows us to calculate partial derivatives across the boundary and explicitly model continuity between the two cortical hemispheres. Having parameterized the cortical surfaces of the subject and atlas, we align the coordinate systems between the subject and atlas such that a set of hand-labelled sulci are brought into register, i.e. we find a warping field which when applied to the subjects surface parameters aligns the subjects sulcal features with those of the atlas. The alignment uses a set of interactively labeled sulci, sampled uniformly along their lengths, as a set of point constraints. To compute a smooth warping from one coordinate system to the other we use the thin plate spline bending energy on the atlas surface as a regularizing function. Since the mapping onto the unit square will inevitably produce distortion relative to the original surface, it is attractive to compute the bending energy with respect to the intrinsic geometry of the surface rather than the parameter space itself [3]. To do this, we solve the biharmonic equation using covariant derivatives to obtain a thin-plate spline warp from subject to atlas coordinates.

Results and Discussion

We illustrate the method in Fig. 1: in the upper left we show the sulci traced on the original cortical surface; the upper right figure shows the mapping of one hemisphere onto the unit square. The lower two images show the sulci of the subject and atlas before (right) and after (left) registration.

Conclusions
[to be added]

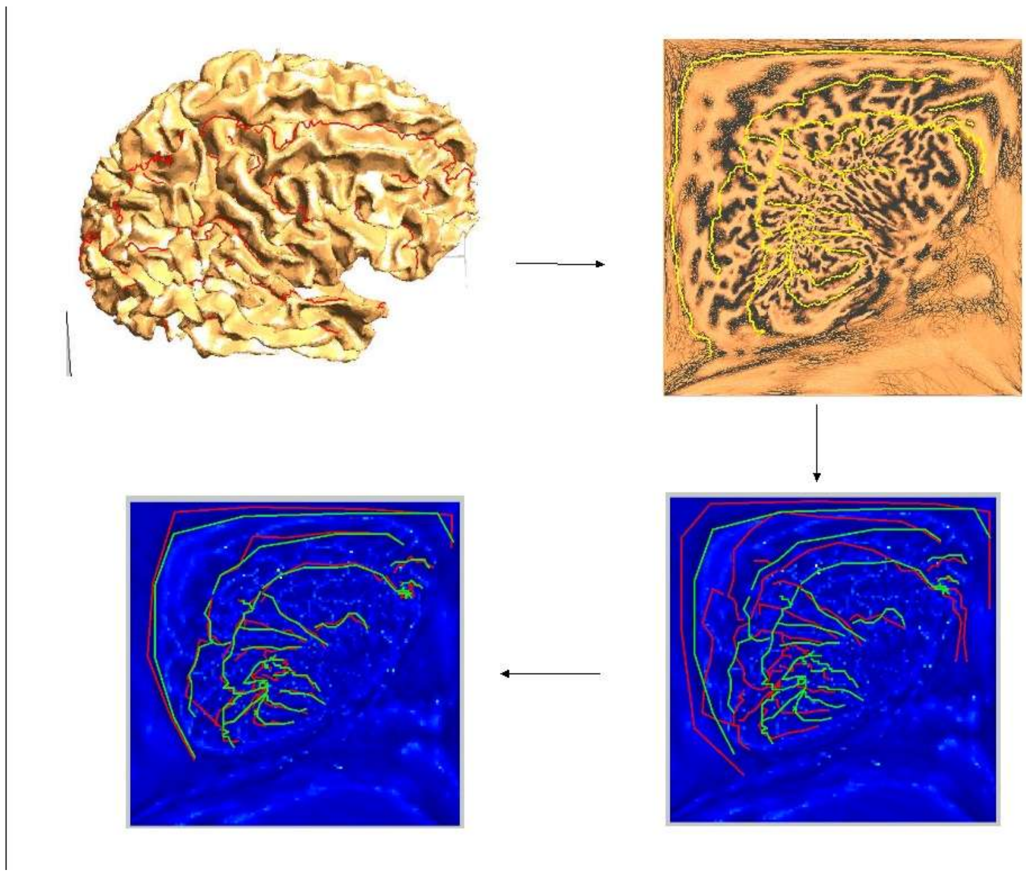

Fig. 1: Illustration of the warping process: see text for details.

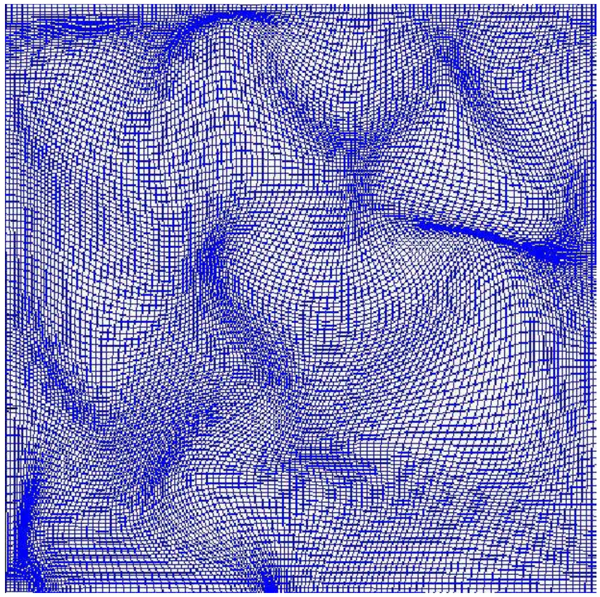

Fig. 2: The thin plate spline deformation field

References and Acknowledgements

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