Evaluation of a Landmark Curve Matching Technique in Brain Mapping based on the Level Set Method

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Introduction

The level set method using implicit representation has recently been developed and shown to be capable of matching all types of geometric objects. The method was evaluated in this study for its ability to perform brain surface warping subject to landmark curve constraints. This key step in brain mapping allows multiple subjects' data to be compared after adjusting for gyral differences. Other methods that match equidistant landmark points on the curves via point matching do not allow relaxation along the curves. Moreover, it is difficult to incorporate these techniques into other methods due to the non-variational nature of point constraints. The method we use incorporates the level set method into image warping, offering a unifying approach for different types of feature-based matching. A diffeomorphic, one-to-one, and onto mapping can be generated using this approach subject to different kinds of feature-based constraints.

Methods

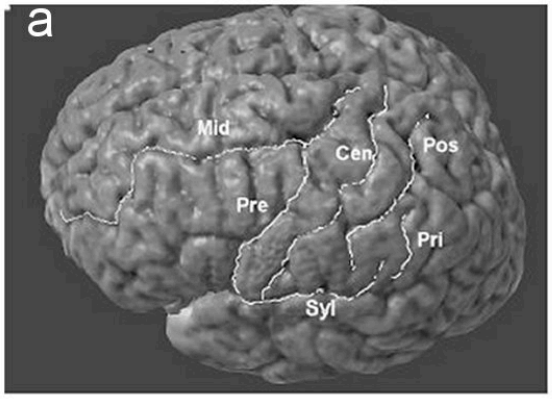
The brain surfaces of 4 normal individuals were flattened to the unit square in which a flattened brain surface of an average human template was defined. Nine sulcal curves (the central, precentral, postcentral, middle frontal, primary intermediate, collateral, and olfactory sulci, an olfactory control line and the Sylvian fissure) were chosen for testing our curve based warping method. Each sulcal curve was represented by the intersection of two level set functions. The resulting transformation was interpolated and applied to warp the brain surface, thus establishing a mapping between the individual and the average human brain. A set of coupled PDEs was used to guarantee a smooth, diffeomorphic mapping. As a measure of the adequacy of the method, the deviation of warped subjects' data from the average template was calculated using the partial Hausdorff metric from the individual sulcal curves to the corresponding average curves. The partial Hausdorff distance between two sulcal curves is defined as the maximal value of the distance from any point on the individual curve to the corresponding average curve. The value was averaged over all selected sulci for each individual and then the maximum deviation over the four individuals was reported (see Results).

Results

The level-set based method was successful in landmark curve matching for all 4 subjects. To compute the partial Hausdorff distance numerically, we discretized each curve to 100 points and evaluated the distance function of the average curve at the warped positions of these 100 points. The partial Hausdorff distance was then approximated by the maximum of these 100 values. The distances were similar among all 9 pairs of sulci, and consistent among 4 individuals with a maximal value of 0.3 pixel size. Fig. 1(a) shows the brain surface of one individual with the identified landmark sulcal curves. (b) shows the same brain surface in the flattened space with the average sulcal curves while (c) shows the warped brain surface. (d) shows the computed deformation for mapping the brain surface.

Conclusion

The level set method is capable of warping brain surface images to a population average, which allows brain imaging data from multiple subjects to be compared and integrated. The method is also expected to be useful for monitoring disease progression and for evaluation of treatment.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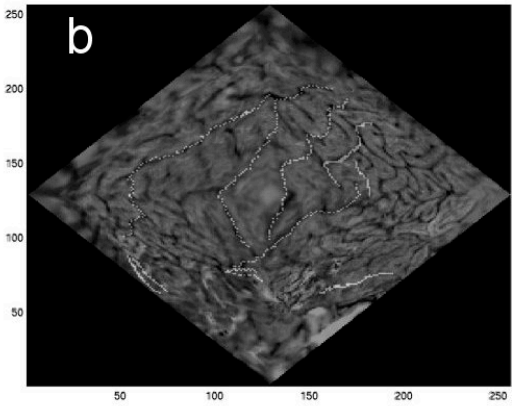
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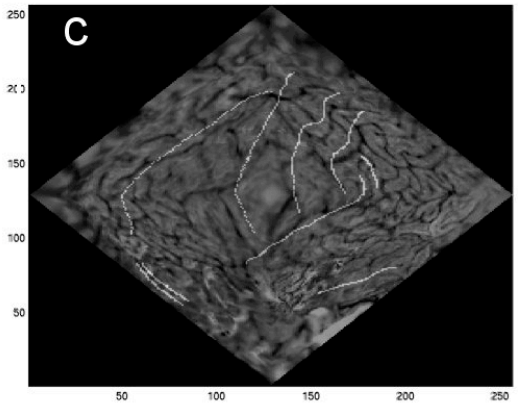
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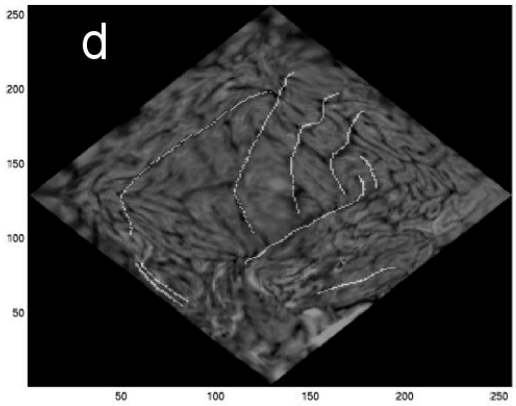
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