Multi-Scale Cortical Surface Representation using Normal Meshes

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Introduction

Many studies have highlighted the different stages of the human brain development; current scientific knowledge supposes different growth speed or decrease of the cortical surface in time and space. Examples of these changes are sulci opening as the brain ages or the transformation from a flat surface in the prenatal brain to the highly convoluted surface of a child's brain. It could therefore be interesting to define a metric to capture locally this information. Some metrics have already been proposed to capture these changes, such as curvature, a distance measure or fractal dimension [2,3,4]; however they have drawbacks when trying to capture the local complexity of the cortical surface. The proposed improvement are therefore to develop a surface representation using only a scalar value per vertex that correlates to the local structure of the cortical surface. The scalar term should also be a smooth representation of the target surface, be independent of the specific placement of points on a given surface and should not be dependent of any preprocessing step such as sulcal extraction.

Method

The use of normal meshes [1] is therefore investigated for this purpose. Normal meshes are a multi-scale representation of a surface that is built by evolving a surface in the direction of its normal at each vertex. The algorithm starts with a coarse representation, for example an icosahedron, of the target structure and the normal at each vertex is computed. Afterward, the algorithm tries to minimize the distance between the coarse representation and the target surface by restraining the movement at each vertex to lie along the computed normal. Support regions on the target surface are computed for each vertex such that the perpendicular displacement to the normal vector is minimized. Quadrisection of the coarse mesh is afterward performed and the steps are iterated until the mesh is close enough to the target mesh. The total displacement at each vertex gives a scalar value that represents the local structure of this surface.

Results

This algorithm was tested on human cortical surfaces and some coarse representation of a human brain are shown. The computed scalar term shown on the picture shows that it correlates with the local structure of the target surface. Sulci are identifiable on the sphere and the reconstructed brain shows also that the scalar term correlates as well with the local structure. Advantages of this scalar term over other terms are that it correlates directly to sulcal depth and is independent of specific placement of points. It is not dependent as well to previous pre-processing steps such as gyrii identification and it gives a multi-scale representation of the surface that permits reconstruction of the target surface.

References

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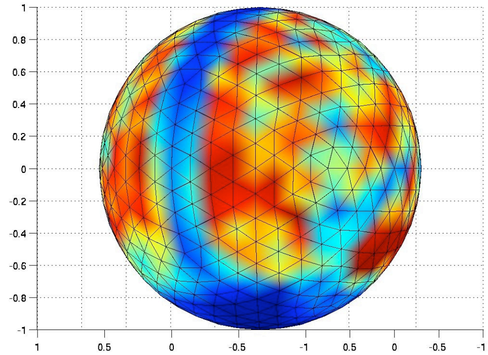
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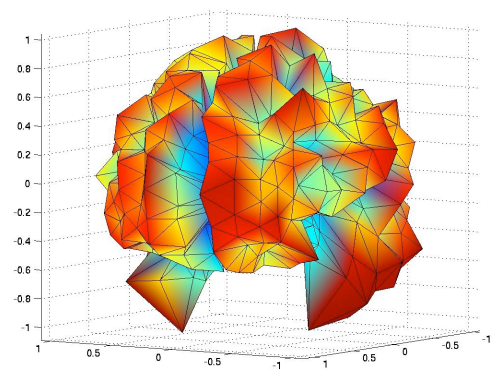
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