QUANTITATIVE EVALUATION AND COMPARISON OF CORTICAL FLATTENING ALGORITHMS

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May 15, 2006

Abstract

Computational methods for flattening cortical surfaces have proven to be valuable in the analysis of spatial patterns of activity in the brain, with the study of topographic maps in visual cortex being the most prominent area of application. The past decade has seen the introduction of several algorithms for flattening cortex in order to compute surface coordinates or visualize patterns of activity within cortex (e.g., the methods implemented in CARET, FreeSurfer and mrFlatMesh). While any of these methods are sufficient for visualization purposes, some may be inappropriate as tools for quantitative, surface-based analyses.

In previous work [Balasubramanian et al., Soc Neurosci Abstr, 2005] we specified a list of criteria that ought to be satisfied by any quantitative flattening algorithm that seeks to minimize metric distortion. Such an algorithm is one that (i) computes a homeomorphism, i.e., prohibits edge crossings in the flattened mesh; (ii) produces the identity mapping when the input surface is already flat; (iii) correctly flattens surfaces with zero Gaussian curvature, e.g., the hemicylinder; (iv) correctly flattens spherical caps; (v) is insensitive to small perturbations in the input; and (vi) computes surface flattenings that are mesh-independent, i.e., insensitive to the particular choice of mesh used to represent the underlying surface.

Here we propose a set of test surfaces to probe each of the criteria listed above, and use these surfaces and criteria to evaluate several commonly-used flattening algorithms. The careful testing and evaluation of flattening algorithms has important practical consequences: recent studies using rigorous, near-isometric flattening algorithms have revealed a remarkable consistency in the shape [Hinds et al., Soc Neurosci Abstr, 2005] and the visuotopic structure [Polimeni et al., Soc Neurosci Abstr, 2005] of visual cortical areas, within and across humans and macaques. The use of inaccurate flattening techniques is likely to introduce an unnecessary amount of error and variance, which could obscure the level of consistency inherent to these areas, within and across species.