364.1 FLATTENING CORTEX: AN OPTIMAL COMPUTER ALGORITHM AND COMPARISONS WITH PHYSICAL FLATTENING OF THE OPERCULAR SURFACE OF STRIATE CORTEX.

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Recent progress in functional mapping methods, particularly with respect to striate cortex topography, have extended the precision of measurement to the point where errors introduced by the curvature of the cortical surface should be taken into account. Furthermore, the study of any brain surface in which tangential architectural patterns are of interest would greatly benefit by the availability of workable methods of computer aided anatomical display.

We have developed an algorithm which optimally flattens brain surfaces. The geometric aspect of the 3D brain surface which is optimally preserved is its matrix of inter-point distances. We use a variational (hill-climbing) algorithm, together with an algorithm which obtains minimal geodesic distances (in the brain surface). The result is a (near) isometric mapping of the three dimensional cortical surface into the plane, together with a map of the error introduced in this process.

We illustrate this method with examples of macaque striate cortex, in the form of a three-dimensional computer graphics model reconstructed from serial sections. The 3D cortical model, and its flattened representation are used to generate a map of distance error produced by flattening. This error map will be discussed in the context of the measurements of mean and gaussian curvature of the same tissue surface (Merker and Schwartz, ARVO , 26 :164,1985).

In addition, we obtained measurements of error introduced by physically flattening similar samples of macaque striate cortex. The physical flattening was performed by squeezing unfixed, dissected opercular cortex (with pia removed) between glass slides moved in a micromanipulator assembly. The cortex was marked by a grid of india-ink dots, and movie films were taken as the cortex was pressed and relaxed. Sequential movie frames preserve the relative displacement of grid dots, allowing a map of error introduced in flat mounting to be constructed. These maps will be compared with the results of computer flattening described above.

This joint application of neuroanatomy, image processing, computer solids modeling, and differential geometry has wide applicability. Besides providing an understanding of the errors introduced in flattening cortex, it forms an essential part of the general computer aided characterization of cortical surfaces and their embedded functional architectures.

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364.2 COMPUTATIONAL ALGORITHMS FOR THE PRODUCTION OF TWO DIMENSIONAL MAPS OF CEREBRAL CORTEX.

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In order to improve upon existing manual techniques for the construction of two dimensional, unfolded representations of the cerebral cortex (Van Essen and Maunsell, J. Comp. Neurol. 191: 255-281, 1980), we are developing a set of computational algorithms which will allow for the production of such maps by computer. Our procedures use regularly spaced histological sections to create a lattice of points which serves as a three-dimensional reference surface. For each point on this reference surface, a corresponding point is created on a two-dimensional map surface in a fashion which preserves topology. A metric of local distortion termed the energy is determined for each point from a comparison of the local geometry on the map with the corresponding geometry on the reference surface. The sum of energies of all points yields a metric of global distortion that is minimized in order to generate an optimal map of the reference surface.

To find this global energy minimum, we subject the map to simulated annealing (Kirkpatrick et al., Science 220: 671-680, 1983). In our implementation of this iterative algorithm, random displacements of points are attempted within the plane of the map. Displacements resulting in a more accurate local geometry (decrease in energy) are always accepted, while those resulting in a less accurate local geometry (increase in energy) are accepted with a probability dependent upon a control parameter termed the temperature. Initially, the temperature is set high to allow positions of points on the map to become randomized. The temperature is then gradually reduced over successive iterations, allowing the points to approach their optimal local geometries and resulting in the emergence of an optimal global conformation of the map.

These procedures have demonstrated their ability to maintain topology while generating minimally distorted two-dimensional maps of three-dimensional mathematical surfaces. We are extending these procedures to the mapping of large regions of visual cortex of the macaque monkey. Although certain aspects of the implementation remain to be developed, the results obtained thus far demonstrate that these algorithms provide a practical means for the computation of unfolded, two-dimensional maps of the cortex. (Supported by NRSA 2 T32 GM07737.)