Human Cortical Folding and Variability

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Abstract

Cortical complexity, a measure that quantifies the spatial frequency of the folding of the human brain is not well defined. Neither has it been thoroughly characterized with respect to inter-individual differences, nor has its evolution been successfully modelled. Using a new three-dimensional analysis technique with magnetic resonance (MR) imaging, this dissertation presents a novel method to visualize the brain surface and its folding pattern. Furthermore a computational model is proposed that reduces the complexity of the cortical surface by a signal transformation from the spatial to the frequency domain.

Based on MR images, the cortical surface is extracted and rendered as a surface mesh. Then the surface mesh is decomposed into a series of spherical harmonic (SPH) basis functions. A normalization procedure aligns each cortical surface to a common coordinate system. The decomposition of the brain surface into a SPH series allows both to keep track of any detail in the cortical shape, and to generate a multi-resolution description from course to fine folding patterns. Furthermore, the series evolution may be understood to simulate cortical folding as a deformation process from a smooth to a highly convoluted surface.

After giving an basic overview of neuroanatomy, this thesis first compares existing cortical folding hypotheses to one another. A framework relates the hypothesis to the methods and parameters used in the study, comparing their structural similarities. Next the transformation of the cortical surface from the spatial to the frequency domain with the SPH series is developed. The spherical transformation reduces the complexity of the cortical surface and allows easier recognition of convolutional patterns. In order to understand the inter-subject variability in human cortical folding, common gyral patterns will be analyzed and visualized based on a statistical analysis of the cortical surface. Finally a model towards the simulation of changes in cortical shape during cortical development is proposed. As a first step for such a model, a three dimensional simulation based on the folding history of an adult human subject is introduced.

With this contribution a method to analyse cortical folding is presented and its applicability with a group study of human subjects is demonstrated. Thus a major step towards the quantification and qualification of human cortical folding is taken.

Key words: Cortical folding, shape analysis, spherical harmonics.