Shape Analysis with Conformal Invariants for Multiply Connected Domains and its Application to Analyzing Brain Morphology

Y. Wang[1,2], X. Gu[3], T. F Chan[2], A. W Toga[1], P. M Thompson[1]

[1]LONI, UCLA, Los Angeles, CA (LAX-Los Angeles Intl.), CA, United States/[2]Mathematics Department, UCLA, Los Angeles, CA, United States/[3]Computer Science Department, Stony Brook University, Stony Brook, CA, United States

Introduction: All surfaces can be classified by the conformal equivalence relation. Conformal invariants, which are shape indices that can be defined intrinsically on a surface, may be used to identify which surfaces are conformally equivalent, and they can also be used to measure surface deformation. Here we propose to compute a conformal invariant, or shape index, that is associated with the perimeter of the inner concentric circle in the hyperbolic parameter plane.

Methods: With the surface Ricci flow method, we can conformally map a multiply connected domain to a multi-hole disk and this conformal map can preserve the values of the conformal invariant. Our algorithm provides a stable method to map the values of this shape index in the 2D (hyperbolic space) parameter domain. After cutting along various landmark curves on surface models of the cerebral cortex or hippocampus, we obtained multiple connected domains. With the surface Ricci flow method, we conformally projected the surfaces to hyperbolic plane, and accurately computed the proposed conformal invariant for each selected landmark curve, and assembled these into a feature vector. We detected group differences in brain structure based on multivariate analysis of the surface deformation tensors induced by these Ricci flow mappings.

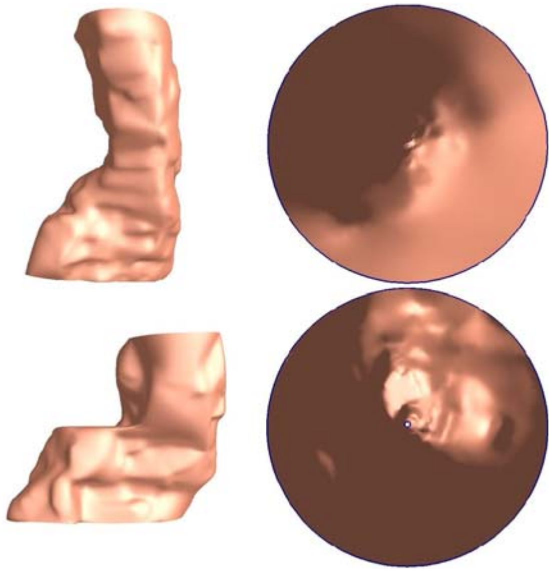
Results: We also applied this new shape index for analyzing abnormalities in brain morphology in Alzheimer's disease (AD) and Williams syndrome (WS). Experimental results with 3D MRI data from 80 subjects demonstrate that our method powerfully detects brain surface abnormalities when combined with a constrained harmonic map based surface registration method.

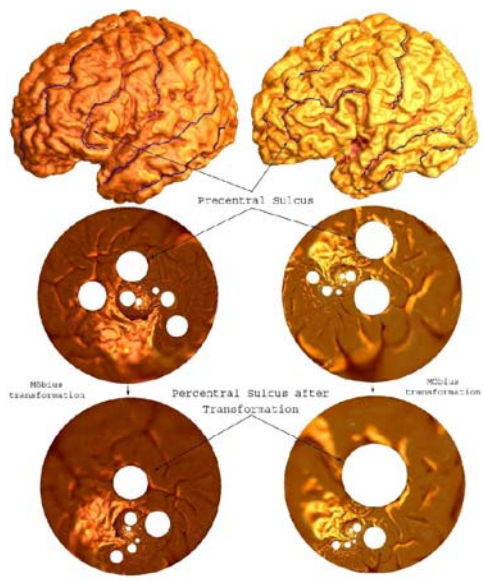
Figure 1 illustrates conformal invariant for hippocampal surfaces. The surface on the first row is from a control subject and the second row is from an AD patient. The computed conformal invariants are 0.009(for the control subject) and 0.123(for the AD patient), respectively.

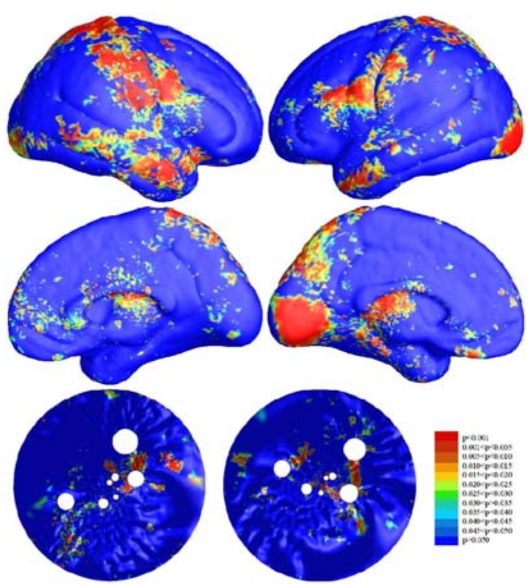
Figure 2 illustrates conformal invariant for Precentral Sulcus. The first column is a cortical surface from a control subject and the second column is from a WS patient. The computed conformal invariants are 0.472(for the control subject) and 1.513(for the WS patient), respectively.

Figure 3 shows map of statistically significant differences in cortical morphometry between 40 controls and 40 WS subjects. The first columns shows the right hemisphere and the second column shows the left hemisphere.

Conclusions: Conformal invariants are robust to rigid-body transformations and conformal transformations of the surfaces from which they are derived. Local geometry is well preserved under conformal mapping so conformal invariants are good candidate features for brain research on cortical and subcortical surface morphology.







Category: Modeling and Analysis
Sub-Category: Motion correction/Spatial normalization, atlas construction