Automatic Landmark Tracking and the Optimization of Brain Conformal Mapping

[1]Lok Ming Lui , [1,2]Yalin Wang, [1]Tony F. Chan, [2]Paul M. Thompson

[1]Department of Mathemtics, UCLA.

[2]Laboratory of Neuro Imaging, Brain Mapping Division, Department of Neurology, UCLA School of Medicine, Los Angeles, CA ,USA.

Objective: Important anatomical features on the cortical surface are usually represented by landmark curves, called sulcal/gyral curves. (Figure 1) It is extremely time-consuming to label these landmark curves manually, especially when large dataset must be analyzed. We present algorithms to automatically detect and match landmarks curves on cortical surfaces to get an optimized brain conformal parameterization.

Methods: We propose an automatic landmark curve tracing method based on the principal directions of the local Weingarten matrix. Our algorithm obtains a hypothesized landmark curves using the Chan-Vese segmentation method, which solves a Partial Differential Equation (PDE) on a manifold with global conformal parameterization. Based on the global conformal parametrization of a cortical surface, our method adjusts the landmark curves iteratively on the spherical or rectangular parameter domain of the cortical surface along its principal direction field, using umbilic points of the surface as anchors. The landmark curves can then be mapped back onto the cortical surface. (Figure 2)

Sulci region extraction using CV model on surfaces:

(by considering the mean curvature as the intensity)

$$F_{CV}(c_1,c_2,\psi)=\int_M (u_0-c_1)^2 H(\psi)dS+\int_M (u_0-c_2)^2(1-H(\psi))dS+\nu\int_M |\nabla_M H(\psi)|_M \, dS$$

Iterative scheme to obtain the sulci curve by minimizing:

$$E_{principal}(\vec{c}) = \int_0^1 \left| \frac{\vec{c}\,'}{\sqrt{<\vec{c}\,',\vec{c}\,'>_M}} - \vec{V}\circ\vec{c}\right|_M^2 dt$$

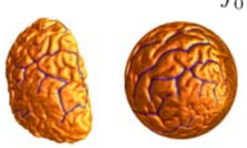

Figure 1:
Sulci landmarks on the brain surface. The original surface is on the left. Its conformal mapping result to a sphere is on the right.

Results: We tested our automatic landmark tracking algorithm on a set of left hemisphere cortical surfaces extracted from brain MRI scans, acquired from normal subjects at 1.5T (on a GE Signa scanner). In our experiments, 6 landmarks were automatically located on cortical surfaces, which closely resemble these manually labeled curves. Next, we applied these automatically labeled landmark curves to effectively generate an optimized conformal parametrization of the cortical surface, in the sense that homologous features across subjects are caused to lie at the same parameter locations in a conformal grid.

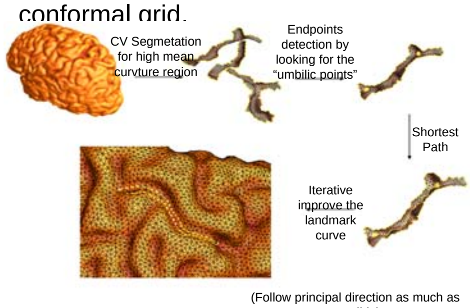

Figure 2.
Diagram showing the basic idea of our automatic landmark tracking algorithm. Sulci region is found using the CV Segmentation model. The sulci landmark curve is obtained by using an iterative scheme.

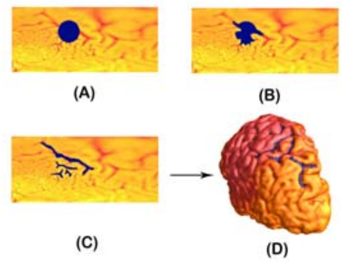

Figure 3.
Sulcal curve extraction on the cortical surface by Chan-Vese segmentation. With suitable initial contour, major sulci landmarks can be effectively extracted at the same time.

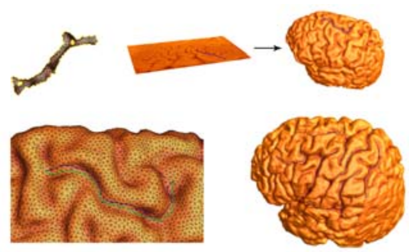

Figure 4.
Automatic landmark tracking using a variational approach. We trace the landmark curves on the parameter domain along the edges whose directions are closest to the principal direction field. The corresponding landmark curves on the cortical surface is shown. This gives a good initialization for our variational method to locate landmarks. Landmarks curve evolved to a deeper region using our variational approach. Ten sulci landmarks are automatically traced using our algorithm. Ten sulci landmarks are automatically traced using our algorithm.

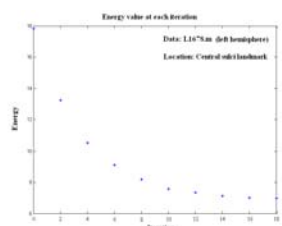

Table 1:
The value of $E_{principal}$ at each iteration is shown. Energy is decreasing, meaning that the curve follows the principal direction more and more. Energy reached its steady state with 25 iterations, meaning that our algorithm is efficient using the CV model as the initialization..

Figure 5:
Optimized Conformal Mapping using the automatically traced sulci landmark curves.

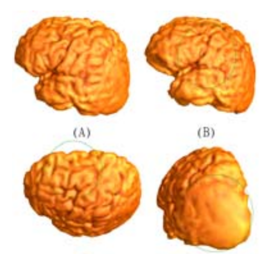

Figure 6:
We take the average of the optimized conformal maps. Thenfigure shows the average of the optimized conformal maps with 10 automatic traced sulci landmarks added. Observe that the sulci landmarks are clearly shown, meaning that the alignment of the important landmarks is consistent. Note that more anatomical features will be preserved with more landmarks added, but more conformality will be lost.

Conclusions: we proposed a variational method to automatically trace landmark curves on cortical surfaces, based on the principal directions. To accelerate the iterative scheme, we initialized the curves by extracting high curvature regions using Chan-Vese segmentation. This involves solving a PDE on the cortical manifold. The landmark curves detected by our algorithm closely resembled those labeled manually. Finally, we used the automatically labeled landmark curves to create an optimized brain conformal mapping.

Acknowledgement: This work is supported by grants from NIH under contracts MH65166 and U54 RR021813. It is also supported by the University of California at Los Angeles under the VIGRE summer research internship program.