Surface Mutual Information for Brain Mapping

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Objective: To avoid the need for a large set of manually-defined landmarks to constrain these surface correspondences, we developed an algorithm to automate the matching of surface features. It extends the mutual information method to automatically match general 3D surfaces (including surfaces with a branching topology).

Methods: Suppose S_1 is an oriented surface. The map from S_1 to a local coordinate (x_1, x_2) plane is a *conformal map* when the first fundamental form scales at each point. All oriented surfaces have global conformal parameterization. A closed surface is uniquely determined by its *conformal representation*, a tuple of *conformal factor* and *mean curvature.* We solve the surface registration problem by computing these intrinsic geometric features from the conformal mesh, and aligning them in the parameterization domain.

To align these scalar fields, we use a fluid registration technique in the parameter domain that is driven by mutual information (MI). The MI method measures the statistical dependence of the voxel intensities between two images and is especially advantageous for image registration problem. With conformal mapping, we essentially convert the surface registration problem into an image registration problem, which is solved by MI methods.

Using the chain rule, we express the gradient of the mutual information between surfaces in the conformal basis of the source surface. This finite-dimensional linear space generates all conformal reparameterizations of the surface.

Results: Illustrative experiments apply the method to the registration of brain structures, such as the hippocampus in 3D MRI scans, a key step in understanding brain shape alterations in Alzheimer's disease and schizophrenia..

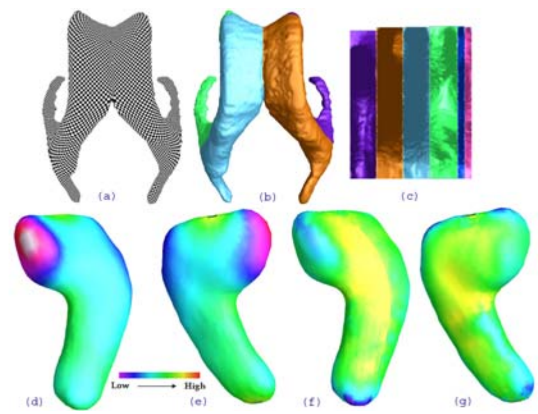

Figure 1. Illustrates conformal surface parameterization. (a) - (c) illustrate conformal parameterizations of ventricular surfaces in the brain for a 65-year-old HIV/AIDS patient. (d)-(g) show the computed conformal factor and mean curvature on a hippocampal surface, (d)-(e) are two views of the hippocampal surface, colored according to conformal factor; (f)-(g) are two views of the hippocampal surface, colored according to mean curvature.

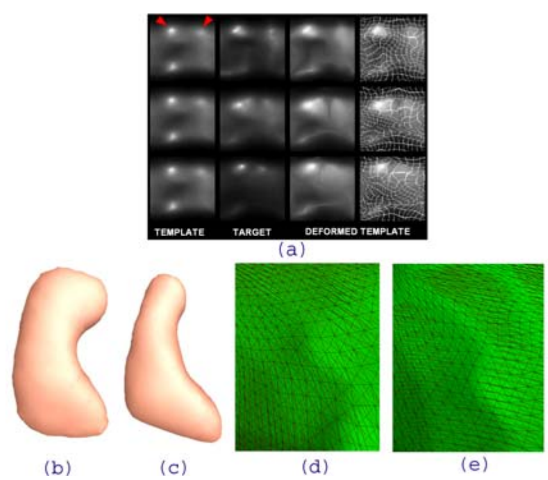

Figure (a) Geometric features on 3D hippocampal surfaces were computed and compound scalar fields were conformally flattened to a 2D square. In the 2D parameter domain, data from a healthy control subject (the template) was registered to data from several Alzheimer's disease patients (target images). (b)-(c) show the two 3D hippocampal surfaces being matched, for (b) a control subject and (c) an Alzheimer's disease patient. We flow the surface from (b) to (c). (d)-(e) show the 3D vector displacement map, connecting corresponding points on the two surfaces, (d) before and (e) after reparameterization of the source surface using a fluid flow in the parameter domain. These 3D vector fields store information on geometrical feature correspondences between the surfaces.

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