Direct Painting Software for Tracing on 3D Brain Surfaces with Global Conformal Parameterization

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Abstract

After extracting anatomical surface models from 3D magnetic resonance images (MRI), a common requirement in surface-based analysis is the interactive specification of 3D curves or regions of interest on the resulting surfaces (tracing sulci on the cortex, for example). As well as assisting in computational morphometry projects, convenient tools to visualize and trace on 3D brain surfaces may assist in communicating brain data and results, and in teaching anatomy. Since cortical geometry is convoluted and complex, interactive manipulation of high-resolution models proves difficult, and often requires expensive visualization or animation software. We therefore developed a convenient software toolkit that enables users to draw curves and label surface subregions directly on a given brain surface. The software is also designed to work with any Riemannian surfaces.

With surface reconstruction tools such as deformable models, level set techniques, or Marching Cubes, geometric models of brain surfaces are frequently extracted from MRI volumes. These geometric surfaces are commonly represented as triangle meshes in the medical imaging field. In our work, we treat these surfaces as complex manifolds and compute their holomorphic differentials (conformal structures). This essentially induces a parameterization of the surface by mapping it onto a sphere, or, in the non-zero genus case, onto a connected set of rectangular subdomains. For example, the closed surface of the cortex can be mapped conformally onto a set of rectangles. This mapping, a conformal equivalence, is one-to-one, onto, and angle-preserving. In our tracing software, we use the fact that since the parameterization domain is a rectangle it is straightforward to build a one-to-one map between computer screen and the visible portion of the surface. In other words, the global conformal parameterization helps us to convert the mouse position on the screen to a unique position on the brain surface. The software is written with OpenGL in C++, and works on a PC running the Windows XP operating system. The geometry of the traced 3D curves is recorded by saving them as a list of vertices on the surface mesh. A labeled region is stored by recording the set of ordered vertices on its boundary. Currently, the software can read our internal mesh format, but work is underway on modules to read data formats written by FreeSurfer, BrainVoyager, and BrainVISA. Once the software toolkit is complete, it will be made freely available for research and education purposes.

Figure 1 demonstrates the use of our software. Figure 1 (a) shows the result of inducing a global conformal parameterization on the cortex. The parameterization is visualized by a checker-board image, by backprojecting a rectilinear grid in the parameter domain onto the 3D brain surface. Figure 1 (b) shows the tracing process. The software captures the mouse positions and connects a list of vertices to approximate the curve drawn on the surface. During this stage, new vertices may be generated on edges using mesh operations (e.g. edge splitting). Figure 1 (c) shows several 3D sulcal curves traced on the brain surface. The software can be used to interactively label all the landmarks on brain surfaces, or specify regions of interest for subsequent computations (e.g., of surface area, complexity, etc.). Besides drawing curves on the brain surface, one can also use the software to carve out subregions of the surface and store these edited subregions. Figure 1 (d) shows a region labeling example.
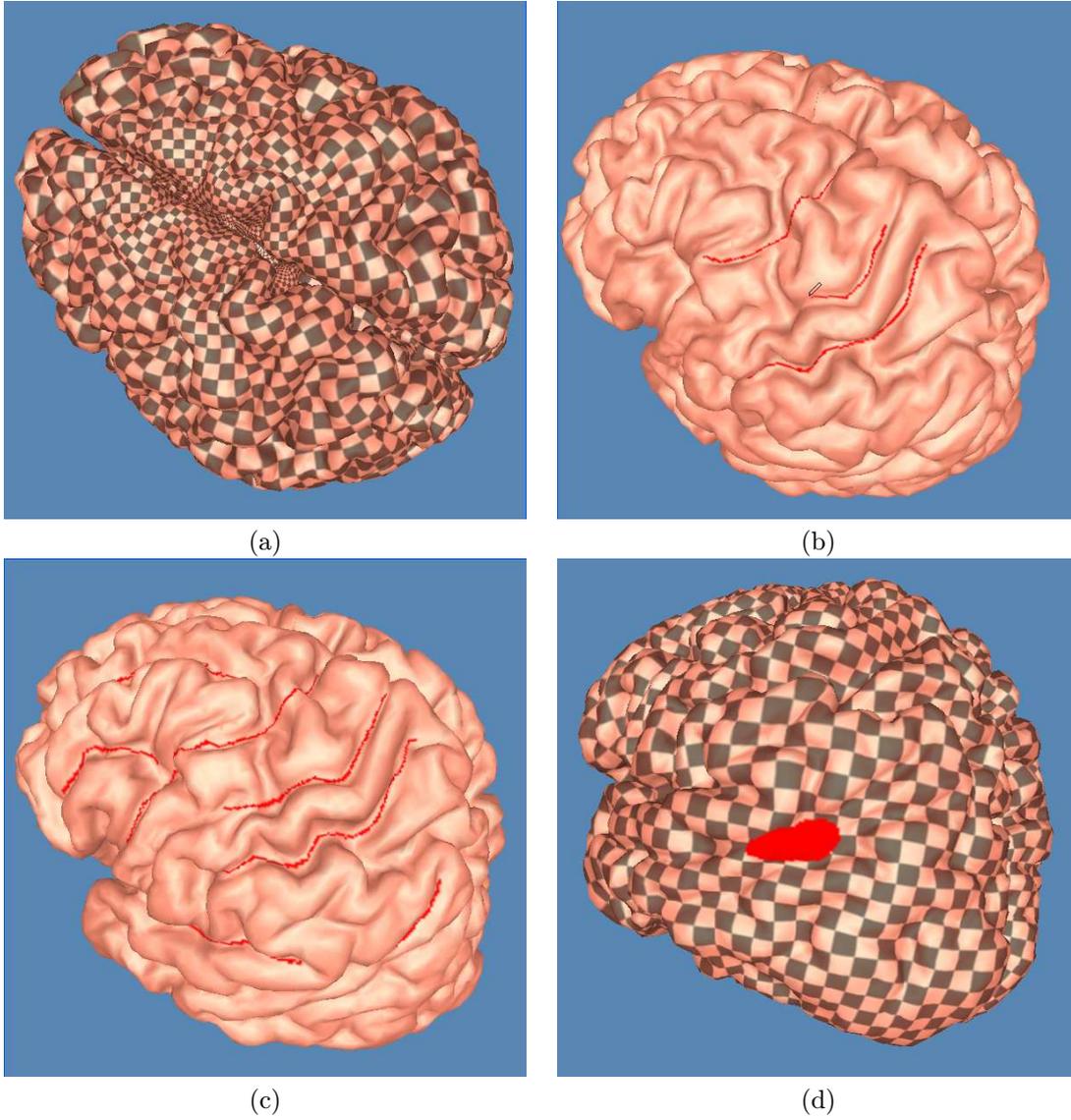
Figure 1. Illustrates tracing on the brain surface with the direct painting software. (a) shows the global conformal parameterization of the surface; (b) shows the curve drawing process; (c) shows a set of sulcal curves drawn on brain surface; (d) shows the region labeling function; a specified region of interest is labeled in red.