Flattened Anatomy for Interactive Segmentation & Measurement

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1 Introduction

Anatomical surfaces can be extracted from a volume of medical imagery through segmentation, which is the process of labeling image voxels according to the tissue type represented. Many anatomical surfaces can be described as 2-D manifolds embedded within 3-D space. The manifolds could be linear, such as a plane, or non-linear, such as a curved sheet. In some applications, it would be desirable for the user to be able to interact with the manifold by drawing upon it in some way. The purpose of this drawing could be to perform quantitative measurements such as to measure distances, surface areas, or volumes. The purpose could also be to analyze local properties of the 3-D surface at specific locations, where these properties include thickness and curvature.

A problem arises from the fact that the surfaces, although intrinsically 2-D in nature, are actually 3-D. A user who needs to draw on the surface, could somehow maneuver a 3-D drawing device while viewing a 3-D rendering for feedback. However, this seems cumbersome because a user would need to navigate the 3-D view in addition to drawing, because some portions of the surface would usually be occluded from view.

If the surface could be flattened onto a plane, then a user could draw on it more easily and more accurately. While methods exist for flattening certain anatomies for simple viewing [Bartoli], we propose enabling the user to interact with the flattened manifold. Furthermore, we augment the flattened surface to be a map of surface properties, such as thickness, curvature, or abnormality.

2 Method

The flattening process can be accomplished by projecting the anatomical surface toward a simpler geometric shape. For example, [Bartroli] maps the surface of the colon to a cylinder to facilitate virtual colonoscopy. The flattening process introduces some amount of distortion because it is mathematically impossible to perform a mapping between two surfaces, preserving angles and area at the same time, if the two surfaces do not share the same Gaussian curvature.

To facilitate controlling distortion, we describe a method that performs flattening based not on one cylinder, but on a stack of ellipses, one per slice of the MRI scan. Consider articular knee cartilage as a flat sheet that is rolled and stretched into position around the end of the femur bone. The two surfaces between which to measure thickness are the femoral and joint surfaces. Process a segmented dataset as follows to reconstruct these two surfaces, and “unroll” and “un-stretch” them:

1. Fit an elliptical cylinder to the segmented points using the method of [Halir], as shown in Figure 1.
2. On each slice, fit a slice-specific ellipse by altering only the linear terms of the global ellipse (controlling position and uniform scaling of the radii, but not orientation and aspect ratio).
3. Cast rays oriented not from the ellipse center, but along the vectors normal to the ellipse at a given contour point. The rays are spaced at equal distances along the ellipse perimeter, as computed using elliptic integrals.
4. Observe the contact made between the rays and the segmented object when entering the cartilage (femoral surface) and exiting the cartilage (joint surface).

Thickness can then be computed by using either Iterated Closest Points (ICP) or ray-casting between the opposing contours. As shown in Figure 1, a triangle mesh is wrapped around the segmented volume using the method of Marching Cubes, and each vertex is colored according to the thickness measured at that point. The flattened manifold is texture-mapped onto a plane and added to the 3-D scene. Figure 2 illustrates interacting with the flatted surface by drawing an ROI for measuring statistics.

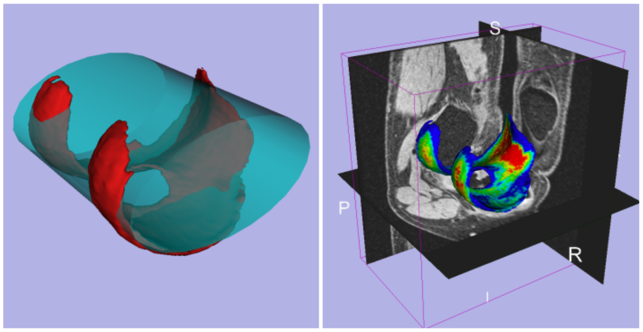

Figure 1: Left: Blue cylinder (step #1 of 4) fit to red cartilage surface. Right: The surface, now colored according to thickness (rather than red everywhere), is rendered in a 3-D scene along with a Multi-Plane Reformat (MPR) of the original MRI scan.

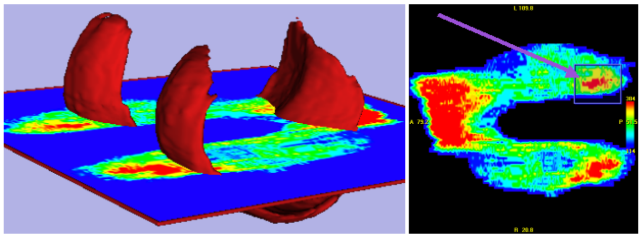

Figure 2: Left: The 3-D surface (red) is rendered relative to the flattened surface (colored by thickness). Right: The user has drawn an ROI (pointed to by purple arrow) on the flattened manifold in order to measure statistical properties within the ROI.

References

Bartroli, A.V., Wegenkittl, R., Konig, A., Groller, E., Sorantin, E. Virtual Colon Flattening. *VisSym 2001*, p. 127-136.

Halir, R., Flussr, J. Numerically Stable Direct Least Squares Fitting Of Ellipses. Proc. 6th *WCSG*, 1998.

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