A robust spherical inflation technique using the method of concentric rings

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Abstract:

Spherical inflation of the brain surface is a kind of surface-based visualization that helps to view the buried sulci of cerebral cortex. Although the three-step approach shows no-overlap between triangles and the minimized linear distortion, computation time depends on smoothness of the initial surface. This requires smoothing of surface as a prerequisite for fast computation. The two-step approach proposed in this paper exploits the method of concentric rings so that it is not necessary to smooth surface in advance. In addition, it performs smoothing on only vertices that cause overlap between triangles, thereby reducing redundant computation to smooth all vertices in the projection-to-sphere step in the three-step approach. The experimental result shows that the surface is projected onto a sphere without overlap between triangles by the proposed method faster than by the three-step approach when the initial surface is obtained by surface rendering from the segmented images.

Introduction:

In conventional parametric deformable models for spherical inflation, the vertex at thin and deep concave region can be intersected with those of other regions, and triangles on sphere can overlap with each other. Although some algorithms solve the overlap problem, they require heavy computation for calculating forces that are not optimal with each other[1][2]. The three-step approach consists of three steps each of which performs deformation just by one force to maximize the effect of the force. Projection-to-sphere step projects the vertices in the initial surface to a sphere in their normal directions initially and smoothes all vertices until there is no overlap between triangles. Distortion-minimization step deforms vertices from the projection-to-sphere step to minimize the linear distortion. However, computation time depends on smoothness of the initial surface in the projection-to-sphere step and there is no criterion for appropriate smoothness.

Material and methods:

Figure 1 shows overall block diagram of the proposed two-step spherical inflation method. In the projection-to-sphere step, vertices are projected onto a sphere initially applying the method of concentric rings[3] as shown in Figure 2. The neighboring vertices of the seed vertex, which has the largest z Cartesian coordinates, are belonged to the 1st level. The neighboring vertices of the vertices in the i^{th} level are belonged to the $(i+1)^{th}$ level if they are not assigned to the lower levels. θ and ϕ in 2D polar coordinates are assigned to the vertices according to each vertex's level and position within the level, respectively. If a triangle is folded thereby causing overlap, at least a polygon that consists of neighboring vertices of a vertex in the triangle is concave. After initial projection, vertices that cause concave polygons among three vertices of the folded triangles are smoothed iteratively from lower to higher levels until there is no overlap between triangles. In the distortion-minimization step, the projected vertices from the projection-to-sphere step are deformed to minimize linear distortion until difference of average distortion between t^{th} and $(t-1)^{th}$ iteration is less than ε, which is 10^{-6} here. Except initial projection to a sphere in the projection-to-sphere step, deformation is performed in 2D (θ,ϕ) polar coordinates for vertices to exist on sphere.

Results and Discussions:

In experiments, brain MR images in the FreeSurfer package[4] were used. The experiment was performed at 3GHz Pentium IV with 1GB memory using Visual C++ under Windows XP for the proposed method and Linux for FreeSurfer released on July 24, 2003. Figure 3 shows the initial and the smooth surfaces of cortex for the left hemisphere after segmentation[5] and surface rendering[6]. The initial surface is projected onto a sphere without overlap between triangles after 88 iterations and 4500 iterations by the proposed method and the previous method[3], respectively, as shown in Figure 4. The inflated surfaces by the proposed method and FreeSurfer are shown as in Figure 5. Distortion of the inflated surface by the proposed method is lower than that by FreeSurfer. Computation time was reduced largely and folding between triangles does not happen in the proposed method.

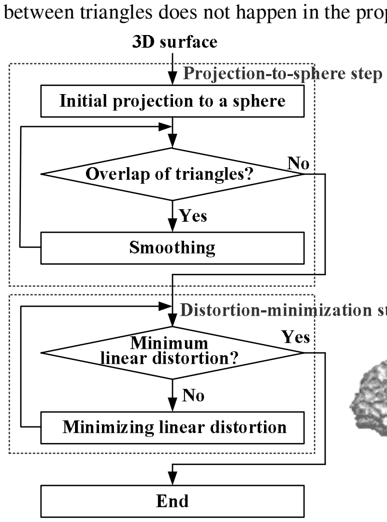

Figure 1. The proposed method

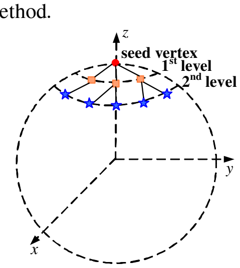

Figure 2. Initial projection to a sphere

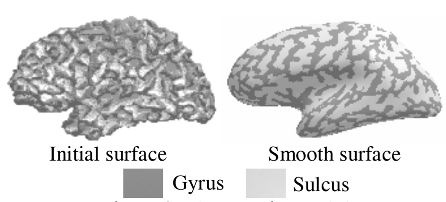

Figure 3. The experimental data

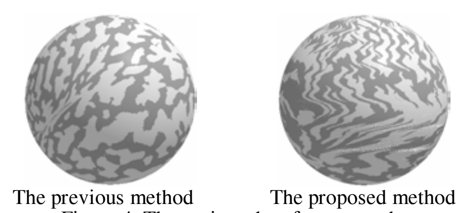

Figure 4. The projected surface to a sphere after projection-to-sphere step

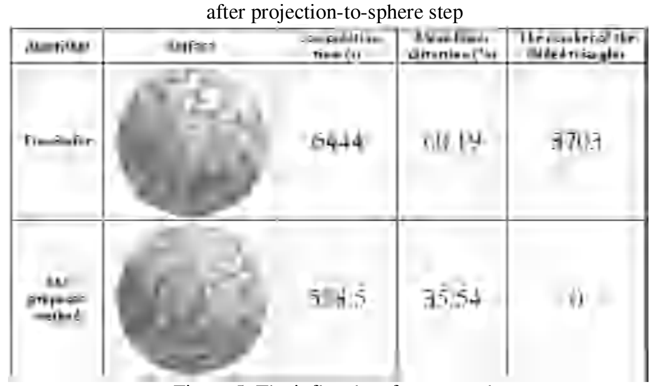

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Figure 5. The inflated surface to a sphere

Conclusions:

The proposed two-step spherical inflation method provides the inflated surface to a sphere without overlap between triangles and with minimized distortion. The initial projection to a sphere by using the method of concentric rings does not require smoothing process as a prerequisite. Deforming only vertices which cause overlapping of triangles reduces computation time.

Acknowledgement:

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References:

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