Inflation and Flattening Algorithm to Reduce the Self-intersection

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Abstract:

Inflation to 3D smooth surface and flattening to 3D sphere or 2D plane are widely used to view the buried sulci of cerebral cortex. Conventional parametric deformable models usually result in self-intersection at thin and deep concave region because of the external forces. Although some algorithms solve that, they require heavy computation. This paper proposes a method that reduces self-intersections with reasonable computation time. The sphere model is deformed to the segmented white matter(WM) and gray matter(GM) boundary. The proposed method has two-step approach. Step1 generates smoothed WM/GM boundaries. In Step2, vertices of sphere are deformed to the smoothed WM/GM boundaries in inverse order. The Step2 uses multi-resolution approach for deep concave region to be considered as shallow region in low-resolution.

Introduction:

Cerebral cortex grows into highly folded and curved 2D sheet and the amount of 60-70% of the sulci is buried[1]. Parametric deformable model is generally used for inflation into 3D smooth surface and for flattening into sphere or 2D plane by iteration processes. The vertices of deformable model are preserved by the internal force and are moved to the desired position by the external force. The external force is modeled to reduce the distance distortion in inflation[1] and to expand the vertices to the corresponding positions on sphere in the direction of normal vector in flattening to sphere[2]. In the thin and deep concave region such as sulci, the vertex of one side of the region can be intersected with the opposite side in flattening. MacDonald solved this problem completely[3], however, it requires heavy computation. In this study, we reduce the self-intersection with low computation amount.

Material and methods:

Self-intersection rarely happens when the deformation is performed smoothly and in the broad and shallow concave region. The proposed flattening is performed inversely from the sphere to the inflated WM/GM boundary. Deformation processes are performed smoothly from the deformed sphere to the smoothed WM/GM boundaries orderly for the one-to-one mapping of the structure information such as curvature between the WM/GM boundary, inflated surface, and flattened sphere. Figure 1 shows overall block diagram of the proposed inflation and flattening method. In Step1, the reconstructed surface[5] of the WM/GM boundary from T_1-weighted image[4] is smoothed and ten intermediate results of the smoothing are stored, which are used in Step2. In Step2, the vertices on sphere are deformed to the acquired WM/GM boundaries in inverse order with preserving the vertex structure. Deformation in Step2 is performed from sphere to the inflated surface, to the intermediate smoothed surfaces from Step1, and finally to the segmented WM/GM boundary. The external force is modeled to be in the normal vector direction if the vertex of deformed sphere is inside of the deformed WM/GM boundary, so that the force push the vertex to the outside of the boundary. Some concave regions are still deep in the inflated surface. Some vertices are stuck to the edge while some vertices do not so that they continue to move and make self-intersection. Thus, multi-resolution approach[6] is used at the first deformation in Step2 to make the deep concave region to be considered as shallow region. The sphere model with 320 triangles and 162 vertices grows with the scale by subdivision of triangles.

Results and Discussions:

Brain MR images were obtained from 3 Tesla MRI system at the KAIST fMRI center, Korea. They are acquired by MP-RAGE with 10ms TR, 4ms TE, and 256×256×256 matrix. The experiment was performed at 2GHz Pentinum IV with 512 MB memory using Visual C++. Figure 3 shows the deformed surfaces from the sphere model to the segmented WM/GM boundary. The self-intersection is not shown in the result, and the computation time is 334 sec.

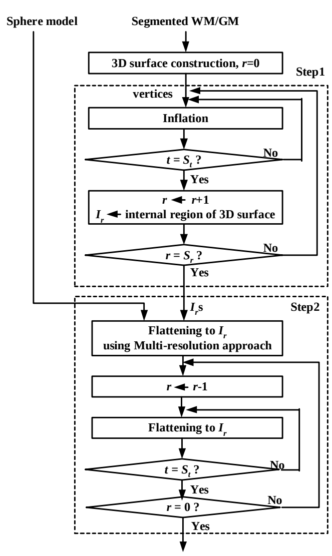

Figure 1. The proposed algorithm

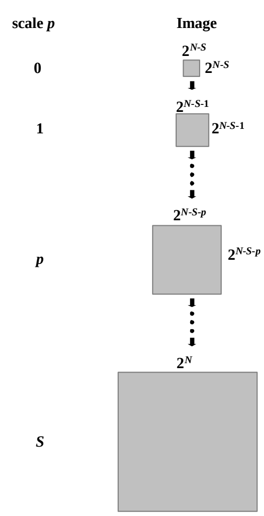

Figure 2. Multi-resolution approach in 2D image

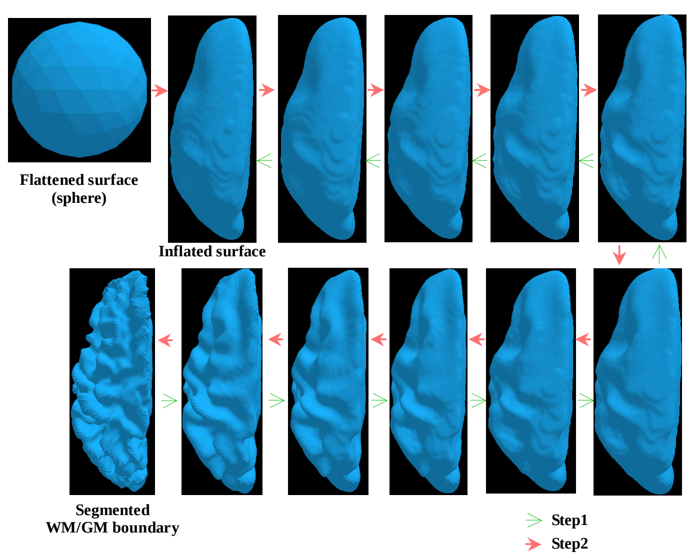

Figure 3. The experimental results

Conclusions:

The proposed method by two-step approach reduces the self-intersection with reasonable computation amount. This algorithm can be improved by considering the minimization of distortion and complete solution of the self-intersection.

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