Two-Step Approach for Flattening of Brain Surface onto Sphere

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Abstract:

Flattening of the brain surface onto 3D sphere is widely used to view the buried sulci of cerebral cortex. Conventional parametric deformable models usually result in self-intersection during deformation and the resultant triangles may overlap each other at thin and deep concave region because of the external forces. Although some algorithms solve the overlap problem, they require heavy computation and the resultant triangles on sphere do not guarantee non-overlapping. This paper proposes a method that flattens the brain surface onto sphere, where the triangles of the surface do not overlap during and after deformation with reasonable computation time. The proposed method has two-step approach. In step 1, the evaluation whether triangles of the brain surface are overlapped on the sphere or not and the deformation of the vertices of triangles are processed iteratively until all vertices of the brain surface are mapped onto sphere without overlapping. In step 2, the vertices are readjusted on the sphere to minimize the metric distortion.

Introduction:

Cerebral cortex grows into highly folded and curved 2D sheet and the amount of 60-70% of the sulci is buried[1]. Flattening the cerebral cortex onto sphere is a method to visualize the inside of the sulci without topological change. Conformal mapping is used to preserve the angles between vertices, however, it has large metric distortion[2]. Parametric deformable models are used to minimize the metric distortion by iteration processes[1][3][4]. Fischl tried to reduce the metric distortion after mapping vertices of a 3D surface onto sphere[1]. However, in the thin and deep concave region such as sulci, the vertex of a region can be intersected with those of other regions and the triangles on sphere can be overlapped. Kwon tried to reduce intersection by deforming sphere to the 3D surface and using multi-resolutional approach[3]. MacDonald solved intersection problem completely[4], however, it required heavy computation. In this study, we flatten the brain surface onto sphere, where the triangles of the brain surface do not overlap during and after deformation with low computation amount.

Material and methods:

Figure 1 shows overall block diagram of the proposed flattening method. In step 1, the evaluation whether triangles of the brain surface are overlapped on the sphere or not and the deformation of the vertices of triangles are processed iteratively until all vertices of the brain surface are mapped onto sphere without overlapping. The triangles mapped on sphere are evaluated whether they are overlapped or not to the tri-pyramid made of the triangle on sphere and center of the sphere. The evaluation is performed fast by checking the nearby triangles of the tri-pyramid. The non-overlapped triangles are mapped onto sphere once and the vertices of triangles are deformed with some number of iteration. The forces for deforming vertices of the non-overlapped triangles are the smoothing force to preserve the characteristics of vertices and the radial force to push the vertices to the points on sphere[1]. The force for deforming vertices of the overlapped triangles is only the smoothing force to be deformed quickly by the vertices of non-overlapped triangles. The number of iteration is varied from 1000 to 100 with decrement of 100 to control the deformation and the evaluation of overlap. In step 2, the metric distortion is minimized until the mean metric distortion is under the threshold value ε_D after scaling the vertices. The forces for deforming vertices are the distortion minimization force and the radial force[1].

Results and Discussions:

Brain MR images were obtained from 3 Tesla (ISOL Forte) MRI system at the KAIST fMRI center, Korea. They were acquired by MPRAGE with 10ms TR, 4ms TE, and 256×256×256 matrix. The experiment was performed at 2GHz Pentium IV with 512 MB memory using Visual C++ under Windows 2000. Figure 2 shows the original boundary surface between the white matter and gray matter of the left brain and the flattened surfaces after step 1 and step 2. The number of triangles and vertices are 111,104 and 55,554, respectively. Overlapping between triangles is not shown during deformation. The computation time was 186 sec for step 1 and 3 sec and 15 sec for step 2, where ε_D is 20% and 17%, respectively.

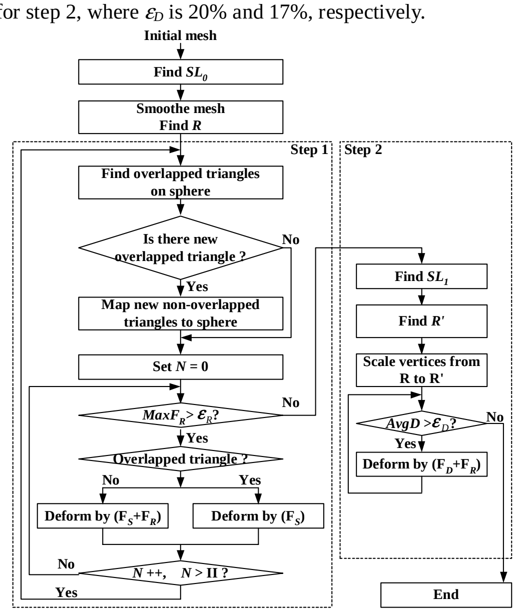

Figure 1. The proposed algorithm

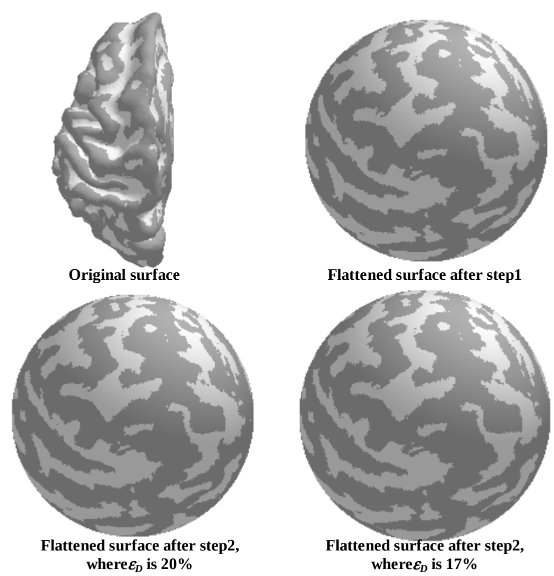

Figure 2. The experimental results

Conclusions:

The proposed two-step approach provides flattening of the surface-rendered brain image without overlapping between triangles, which is performed in a reasonable computation time.

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References:

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