Phantom based geometric evaluation of cortical surface model

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Background

The surface of the human cerebral cortex is a highly folded sheet with the majority of its surface area buried within folds. The importance of the cortical surface lies primarily in their relation to the cytoarchitectonic and functional organization of the underlying cortex and in their utilization as features in non rigid registration methods. Therefore, it is important to represent faithfully cortical surface in both topology and geometry of the true cortical surface. Since the geometry is variable across individuals and is not known a priori, validation of the model is very difficult. Therefore, there has been no explicit method except visual inspection, which could not certify the accuracy of the surface model objectively and quantitatively, to evaluate cortical surface model. In this study, we present a novel method validating the geometry of the cortical surface model quantitatively using MRI phantom.

Method

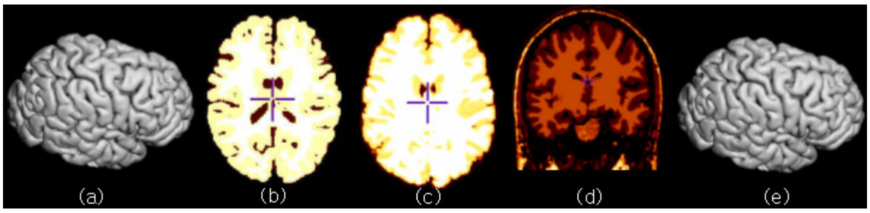

Fig. 1 Evaluation using phantom

(a) created cortical surface (b) surface masked volume (c) digital brain phantom (d) phantom including skull (e) recreated cortical surface from phantom

For the phantom based evaluation, we used an MRI simulator which was developed for simulating MR images with a classified phantom volume [3]. Our propsed evaluation consists of 6 procedures: 1) pial and WM surfaces were first reconstructed from MRI (Fig. 1 (a)). 2) A phantom including 4 labeled tissues (GM, WM, CSF, and background) was created from the surfaces. WM voxels were defined inside of the WM surface, and GM voxels were set between the pial and WM surfaces. To create partial volume effects, voxels on the pial surface were given probabilities of 70% for GM and 30% for CSF. CSF voxels were also defined in the voxels between inside of the exterior brain mask and outside of pial surface to simulate extra-pial CSF. All other voxels were set to a background label (Fig. 1 (b)). 3) The MRI simulator was given parameters of TR=18ms, TE=10ms, slice thickness=1mm, the same resolution and volume size as the original image, and then a T1 MR image was simulated from the phantom (Fig. 1 (c)). 4) Additional substructures including skull were added from original MRI to brain phantom (Fig. 1 (d)). 5) With the simulated MRI, pial and white surfaces were reconstructed again. 6) Finally, we measured the differences between the two surfaces resulting from 1) and 4).

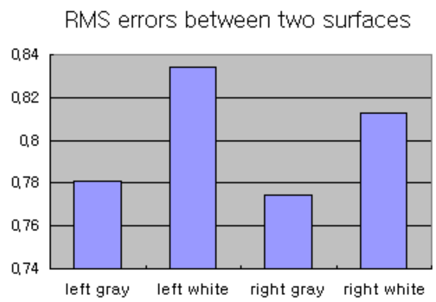

Fig. 2 RMS errors

Mean rms errors(mm) measured between original surface and recreated surface from phantom

Results

We used Freesurfer[1] developed in MGH as a cortical surface reconstruction method. To evaluate the algorithm, we used 4 subjects randomly selected from MNI ICBM MRI data base, which were T1-weighted images of 1.0mm×1.0mm×1.0mm resolution and 181×217 ×181 voxel dimension. The evaluation was performed comparing original surface (Fig. 1 (a)) representing ground truth and recreated surface (Fig. 1 (e)) from phantom image. We used two kinds of measure to evaluate surface model. First, we measured the euclidean distance between the two surfaces resulting from 1) and 4). Second, the surface areas were compared between two surfaces. See (Fig. 2) and (Fig. 3).

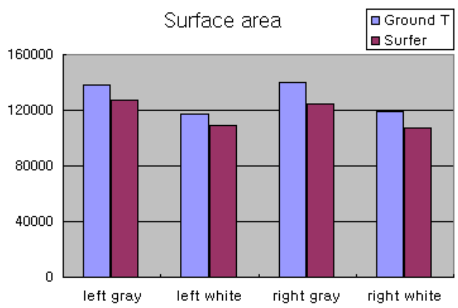

Fig. 3 Surface area

Total surface area(mm^2) measured with original surface and recreated surface from phantom

Discussion

Our proposed evaluation using MRI phantom provides "ground truth" which evaluates directly the geometric accuracy of cortical surface model. While the bias related to cortical surface reconstruction method could be induced to MRI phantom, this evaluation can be used as a quantitative evaluation of cortical surface model.

Reference

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