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A Method for Automatic Demarcation of Sulcal and Gyral Regions on the Cortical Surface

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Abstract

- The human cerebrum is characterized by a complex folding pattern of sulci and gyri characterized by a set of prominent sulcal and gyral folds that can be consistently identified on typical brains. However, there is also a large degree of variability in curvature from subject to subject.
- Since sulcal and gyral boundaries form surrogates for the brain's cytoarchitecture, labeling sulcal and gyral anatomy on cortical surfaces from T1-weighted brain images can add an additional layer of information for neuroanatomical studies. Most existing methods for labeling the cortex do not explicitly demarcate sulcal and gyral regions and even fewer will make this delineation based on an individual's own anatomy.
- Starting from T1-weighted images, we present a method for automatic delineation of sulcal and gyral regions on the cortex. The method first uses registration to an atlas to delineate sulcal curves on the subject's cortical surface representation. The sulcal and gyral regions are then demarcated using a combination of mean curvature information and the locations of a set of labelled sulcal curves.

Materials and Methods

- We previously described a USCBrain atlas [5] that is integrated into the BrainSuite software [1]. The USCBrain atlas contains 26 named sulcal curves on each hemisphere defined using a prescribed cortical delineation protocol [2]. These sulci can be found consistently in brains with typical anatomy.
- We first process T1-weight images using BrainSuite to generate a cortical surface mesh representation.
- The mid-cortical surface is then smoothed and mean curvature computed. For this purpose, first, principal curvatures are computed by fitting a quadratic polynomial in each of the vertex neighborhoods. The mean of the two principal curvatures defines the mean curvature [4]. The zero level-set of the mean curvature is defined as the boundary between sulcal and gyral regions (Fig1a).
- We next use BrainSuite to register to the cortical surface of the atlas to the subject [3,6]. The atlases 52 sulcal curves are transferred to the subject cortex and refined using the subject's local geometric information (Fig1b).
- Next, the sulcal curves are used to correct interruptions in the thresholded mean-curvature maps (Fig1c). Finally, the sulcal regions are identified using nearest neighbor labelling (Fig1d) and the topology of the labels corrected using connected component analysis (Fig1e) resulting in Fig1f.

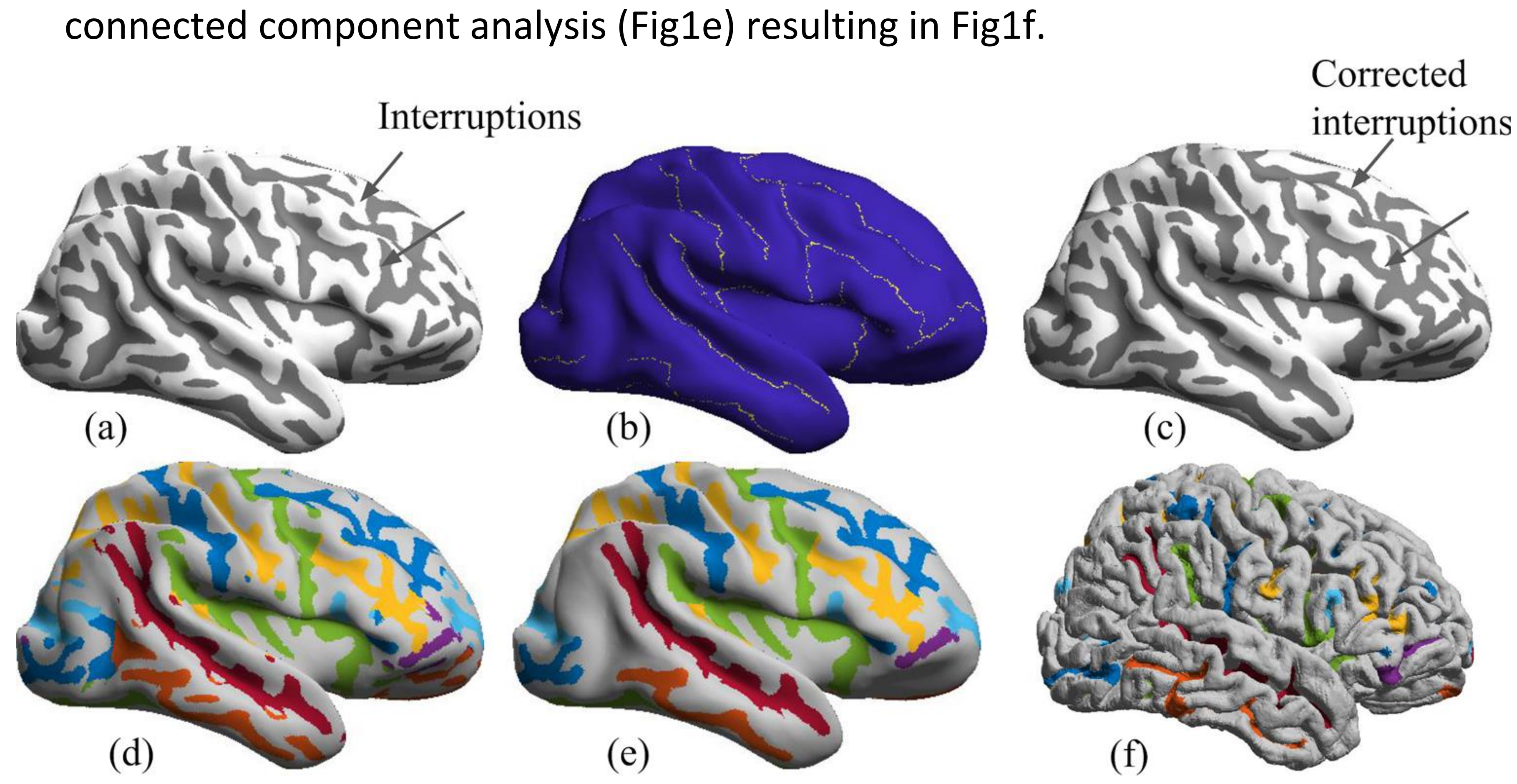

Figure 1: The procedure for automatic delineation of sulcal and gyral regions: (a,b,c,) identification of regions based on mean curvature (d,e,f) labeling based on transferred sulci.

BrainSuite Software: http://brainsuite.org

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Results

- MATLAB implementation takes ~5mins per subject in addition to the standard surface extraction and registration steps in BrainSuite. These sulcal delineations may be overlaid onto the other two atlas labellings to delineate a larger number of ROIs (Fig 2). Users who may want to examine multiple delineation schemas for their project would only be required to register their subjects to the atlas once since the brain template is the same for each of these labellings.
- The software is implemented and integrated into the BrainSuite and is available for download from the BrainSuite website.
- As a result, BrainSuite can now generate a more detailed delineation of the subject's cortical anatomy which will facilitate more specificity in ROI-based studies of cortical anatomy and function.

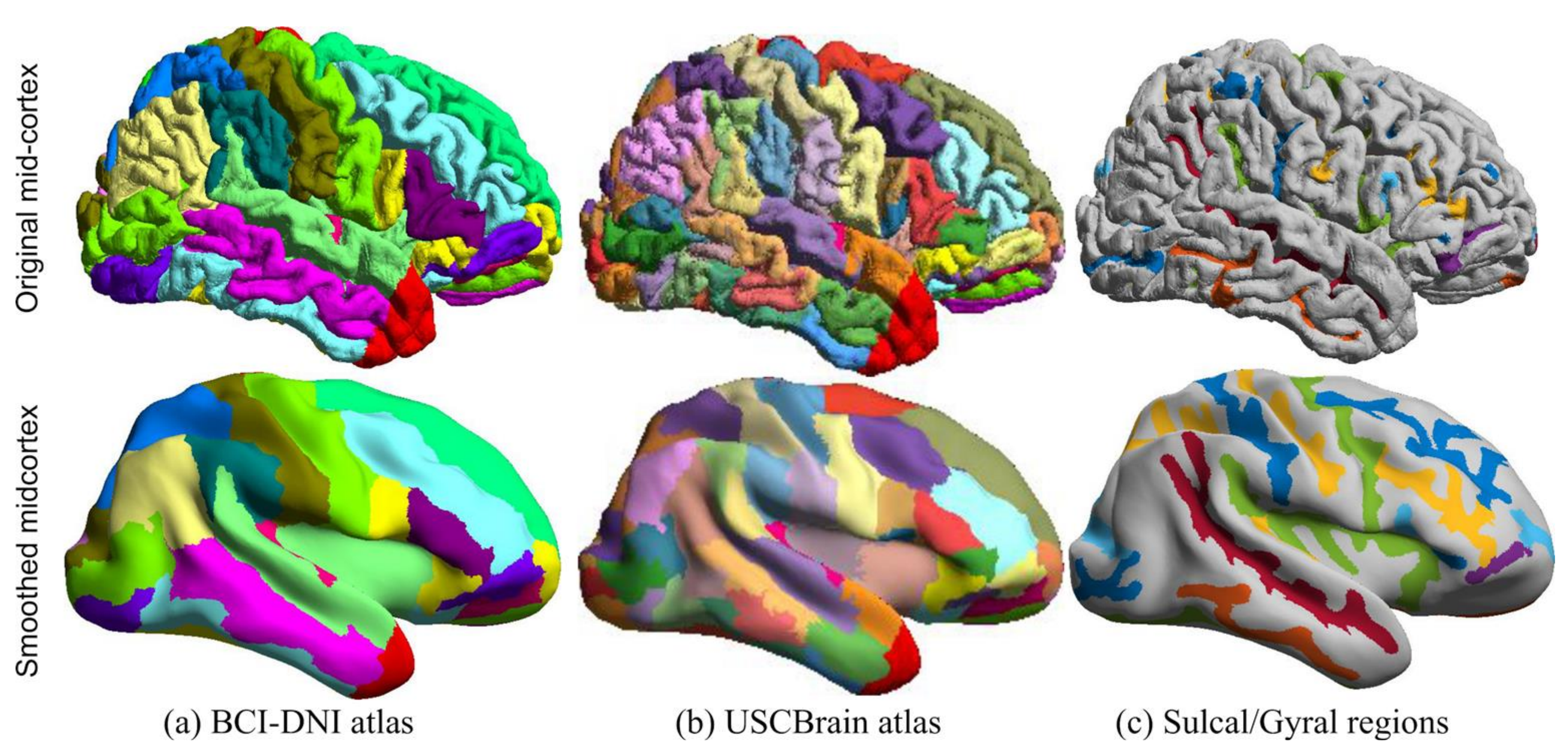

Figure 2: Different region delineations options for cortical labeling using the USCBrain atlas in conjunction with BrainSuite and the new sulcal/gyral delineation method. (a) BCI-DNI atlas with anatomical labels: sulcally-delineated gyral labels (the BCI-DNI atlas); (b) USCBrain atlas with anatomical labels refined by functional data: subdivisions of gyral regions delineated using resting-state functional connecticity (c) cortical folding based sulcal-gyral region labeling: the new labeling of cortical folding patterns identifying sulcal regions surrounding each of the 26 labeled sulci.

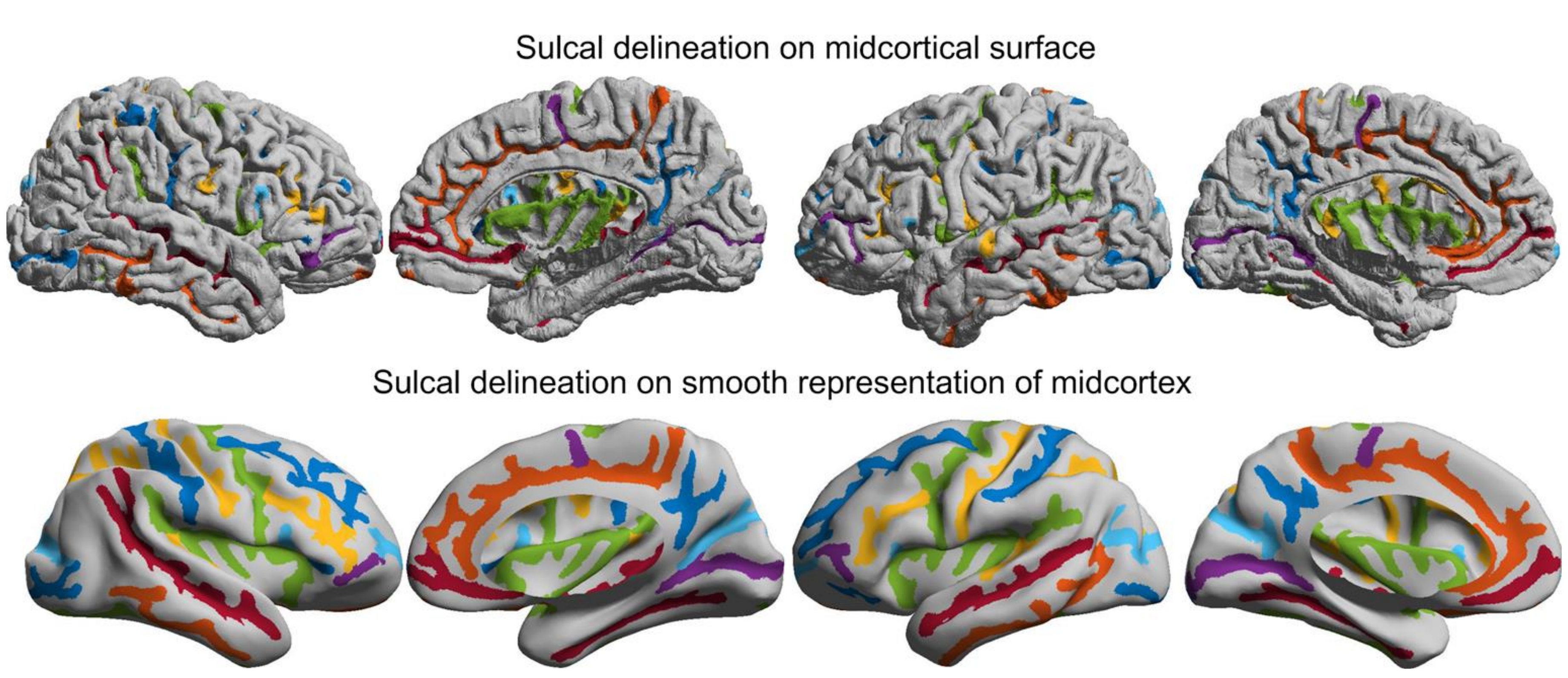

Figure 3: The color-coded sulcal regions shown on the mid-cortical representations of USCBrain atlas. On top, the cortical mesh for midcortical surface is shown, while at the bottom, a smooth representation of the same surface is shown.

Conclusion

- The addition of the ability to delineate gyral and sulcal regions based on an individual's cortical curvature provides greater flexibility within BrainSuite to define regions of interest in cerebral cortex.
- In addition to morphometry, this has particular application in defining the location of implanted stereotatic EEG electrodes in candidates for neurosurgical resection or ablation treatment of epilepsy.
- The USCBrain atlas and new sulcal/gyral delineation method are fully integrated into the BrainSuite software [1].

References

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