Using BCP Index to Evaluate Coregistration Methods in Existing SPM2

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Introduction:

Correcting echo-planar diffusion weighted imaging distortion is a critical procedure for reconstruction of white matter fiber pathways. Although various coregistration approaches have been previously proposed, evaluation based on the quality of white matter fiber pathways has not been reported before. We propose two quantitative indices in this study, bundle curvature profile (BCP) and coherence index (CI) to compare the difference of fiber shape formalism among four build-in coregistration methods in SPM2.

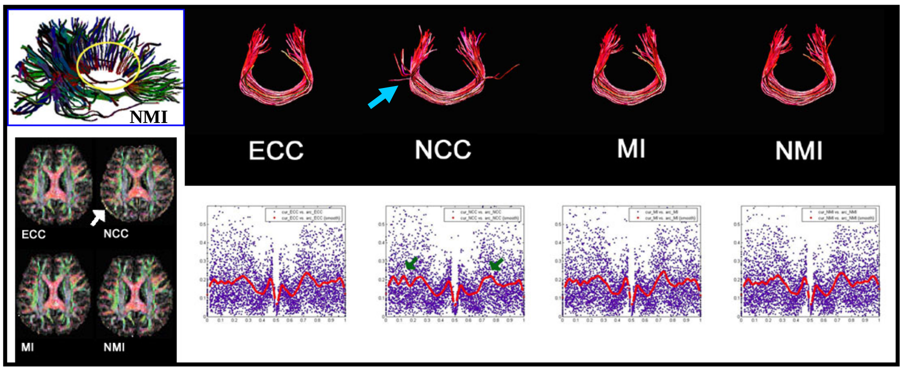
Materials & Methods:

A healthy volunteer were scanned on a 1.5T MRI system (Sonata, Siemens, Erlangen, Germany). A diffusion SE EPI sequence was used to acquire transaxial brain images. Isotropic spatial resolution was obtained by setting FOV = 280 mm × 280 mm, matrix size = 128 × 128 and slice thickness = 2.2 mm. Diffusion-weighted images using the diffusion sensitivity (b-value) = 1000 s/mm^2 were acquired with TR/TE = 8900/95 ms. Diffusion DTI encoding schemes used 13 icosahedrally-oriented steps to acquire 55 transaxial slices covering the whole brain. The scan time for two DTI data sets were about 13 minutes.

SPM2 provided four different coregistration functions, i.e., entropy correlation coefficient (ECC), normalized correlation coefficient (NCC), mutual-information(MI) and normalized mutual-information(NMI) for data correction. In this study, four correction methods were first conducted on a raw DTI data to obtain four corrected DTI data sets. Fiber tracking was performed by using the TENsor Deflection tractography [2] with fixed step size, and the seed points were located at the Corpus Callosum. In this study, CI was used to assess the similarity of an individual fiber tract with respect to the gold standard tractography; here the NMI model was used, and the seed points were put at the central region of Corpus Callosum. To characterize the bundle shape formalism of the traced fiber tracts, Bundle Curvature Profile (BCP), was proposed to capture the mean curvatures [3] of all fibers to represent the 3D fiber bundle shape. For each bundle, the BCP was computed by using a Loess regression method with a quadratic function on the curvature profile of fiber tracts. The Wilcoxon Rank Sum test was then used to assess their similarity differences.

Results:

The upper-left panel of Fig. 1 showed the fiber tracts of corpus callosum by NMI method as golden standard. CI was analyzed in 267 fiber tracts of the corpus callosum and compared between different coregistration methods. We found that CI in NCC was 673.451(654.902), which were significantly higher than CI in ECC, 20.317(28.401), and MI, 20.284(27.583) [3]. The lower-left panel showed the colored vector-overlaid FA maps from four different coregistration methods. Artifacts caused by geometric distortion were clearly seen in NCC method (white arrows). Erroneous tracts (blue arrows) were observed in NCC method as shown in the upper-right panel. The curvatures along the 56 fiber tracts (purple dots) and the BCPs (red curves) were given in the lower-right panel. The mean (standard deviation) of the BCP values in ECC, NCC, MI and NMI were 0.176(0.033), 0.170(0.034), 0.175(0.035) and 0.176(0.034), respectively. Among four BCP values, six pairs Wilcoxon Rank Sum tests were performed. The Family-wise and individual significance levels were set at 0.05 and 0.008. No significant differences were found among the BCPs of ECC, MI and NMI. However, the BCP of NCC was significantly different from the other three (p <0.008), suggesting that ECC, MI and NMI are superior to NCC in correcting DTI data.



Conclusion:

A novel index, BCP, was proposed as the basis to quantify the similarity between two fiber bundles. In this study, the coregistration methods provided by SPM2 were evaluated based on BCP index, and the results suggested that ECC, MI and NMI methods are more suitable for DTI data correction. With the accumulation of more cases in the future studies, we will apply this robust BCP index to find located nearly across the middle point of cingulum bundle in sagittal plane which is known an important role of white matter fiber tracts of the limbic system [4]. Decreased errors from the manual selective this point for asymmetry analysis of cingulum will be expected by using this method. It is because that BCP index denotes realistic cingulum bundle shape for different subject brain size, and is prone to find the center of the cingulum to automatically extract the quantitative anisotropy properties along the cingulum bundle from tractography. We believe that this future work will be one of the most prominent studies for establishing across subjects to cingulum tracks statistical analysis.

References:

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