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Pierrick Coupé[1], Olivier Periot[2,5], José V. Manjón[3], Bassem Hiba[4], Michèle Allard[2,5]

[1] Laboratoire Bordelais de Recherche en Informatique, Unité Mixte de Recherche CNRS (UMR 5800), PICTURA Research Group, Bordeaux, France

[2] Univ. Bordeaux, INCIA, UMR 5287, F-33400 Talence, France.
CNRS, INCIA, UMR 5287, F-33400 Talence, France.

[3] Instituto de Aplicaciones de las Tecnologías de la Información y de las Comunicaciones Avanzadas (ITACA), Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain

[4] Centre de Résonance Magnétique des Systèmes Biologiques, UMR 5536 CNRS, Université Bordeaux Segalen, F-33076 Bordeaux, France

[5] CHU de Bordeaux, F-33076 Bordeaux, France

Introduction

Track-Density Imaging (TDI) [1] has been proposed as super-resolution method for diffusion-weighted images (DWI). Based on fiber-tracking (FT), TDI enables to produce high-resolution white matter images. However, the sensitivity to noise of FT negatively impacts TDI accuracy and reproducibility [3]. In this study, we analyzed whether the use of DWI denoising is able to improve TDI robustness and reproducibility.

Methods

Data: 10 DWI acquisitions of a human brain were acquired using a 3T MR scanner (Achieva, Philips Medical Systems). A standard spin-echo EPI pulse sequence with sensitivity encoding was used (b-value: 700 s/mm2; 21 diffusion directions) with the following parameters: TE/TR ~ 60/8000 ms; FOV = 215x215x85 mm^3; matrix size = 172x172 with 68 slices and an isotropic spatial resolution of 1.2x1.2x1.2 mm^3.

Image Processing: To compensate for inter-acquisition motion and intra-acquisition eddy current distortion, all the DWI (i.e., 220 images) were linearly registered to the b0 image of the first acquisition. As shown in [2], trilinear interpolation of FSL eddy current correction tends to overblur the corrected images. Therefore, the FSL script was modified to use nearest neighbor interpolation to better preserve structures and noise patterns. Finally, the b-matrixes of the 10 acquisitions were adjusted to account for head rotation.

Noisy and Denoised testing datasets: To investigate the impact of denoising on TDI, two testing datasets were used. First, the *noisy dataset* was composed of the 10 motion-corrected original acquisitions. Second, the *denoised dataset* was based on the same 10 acquisitions but denoised using the LPCA denoising filter [4].

Gold-Standard (GS): The 10 acquisitions of the *noisy dataset* were averaged in order to estimate the GS. This resulted in a high SNR GS used as reference during experiments.

TDI: TDI [1] was estimated from the GS, the noisy and the denoised datasets. The diffusion tensors and FA maps were obtained by using FSL. Whole brain tractography was obtained with MRtrix by using constrained spherical deconvolution [5] and probabilistic streamlines tractography. The default tracking parameters were used (seed = whole brain, step-size = 0.2 mm, maximum harmonics order = 6, 10 000 000 tracks). Finally, a super-resolution TDI map was created at 0.3 mm isotropic resolution.

Results

To investigate the impact of LPCA denoising on TDI, PSNR was estimated between TDI of both testing datasets and TDI of the GS. This quality metrics was computed over a mask where TDI of the GS was higher than 0. Higher values of PSNR indicate higher similarity compared to GS. The average PSNR was 24.14dB (+/- 0.28) for the *noisy dataset* and 27.30dB (+/- 0.14) for the *denoised dataset.* Figure 1 shows TDI maps calculated from GS, noisy and denoised datasets. The structures are visually more distinct and less noisy in the denoised TDI map. Figure 2 shows the maps of coefficient of variation (CoV)=$100*\sigma/\mu$ and of coefficient of dispersion (CoD)=σ^2/μ estimated over the 10 acquisitions for both datasets. CoV and CoD maps of the *noisy dataset* demonstrate a more pronounced speckled appearance with high values in GM and at the level of the ventricles.

Conclusion

The gain of 3dB in term of PSNR demonstrates the higher similarity between TDI of denoised acquisitions and TDI of the GS. Moreover, the lower standard deviation of this metric highlights the better consistency of TDI estimation after denoising. Visual assessment of RGB TDI maps demonstrates a better contrast and conspicuity of boundaries between GM, WM and ventricles on the denoised images. Moreover, in CoV and CoD maps, high values indicate regions where TDI measurements are the less consistent over the 10 acquisitions. By using LPCA filter, it appears that TDI reproducibility is globally improved. Finally, DWI denoising enables to limit false positive TDI values in GM and CSF.

References

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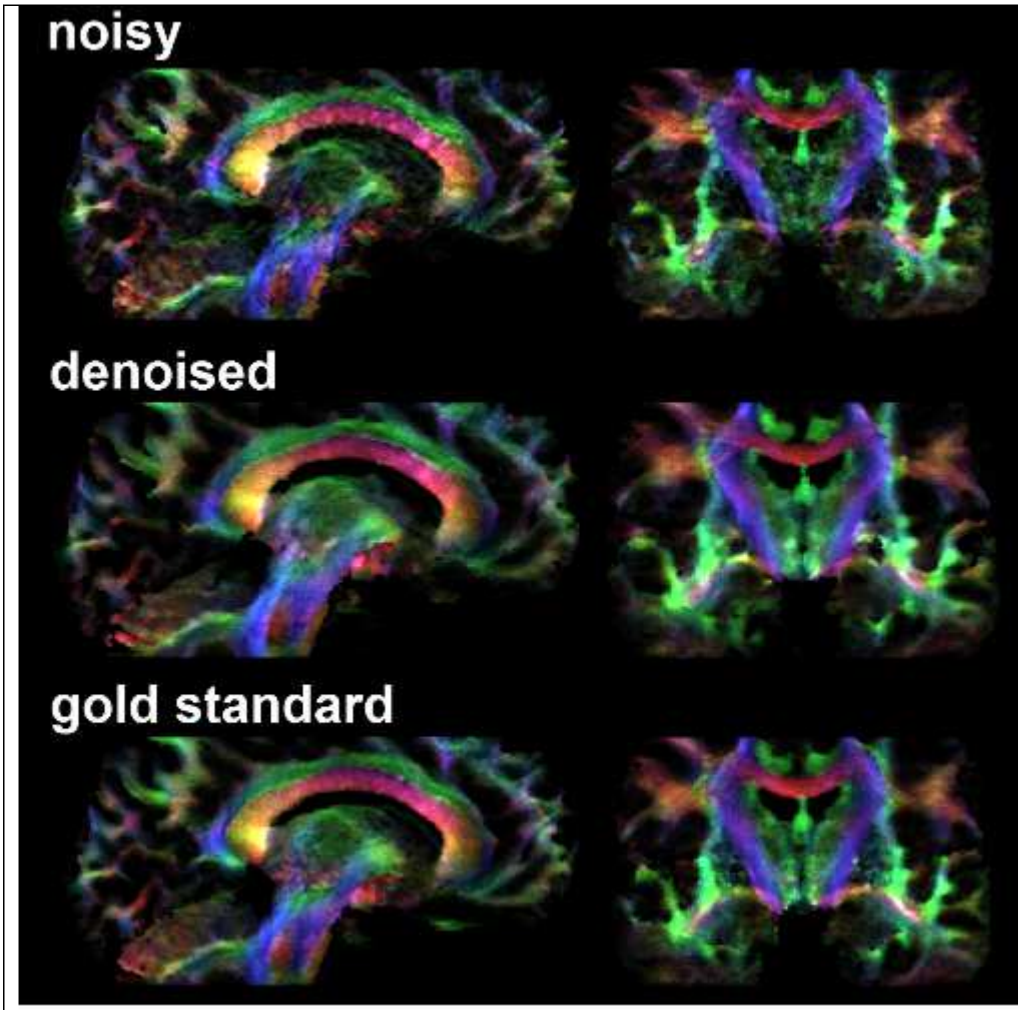

Figure 1: from top to bottom, RGB TDI maps estimated from a noisy acquisition, a denoised acquisition and from the gold standard.

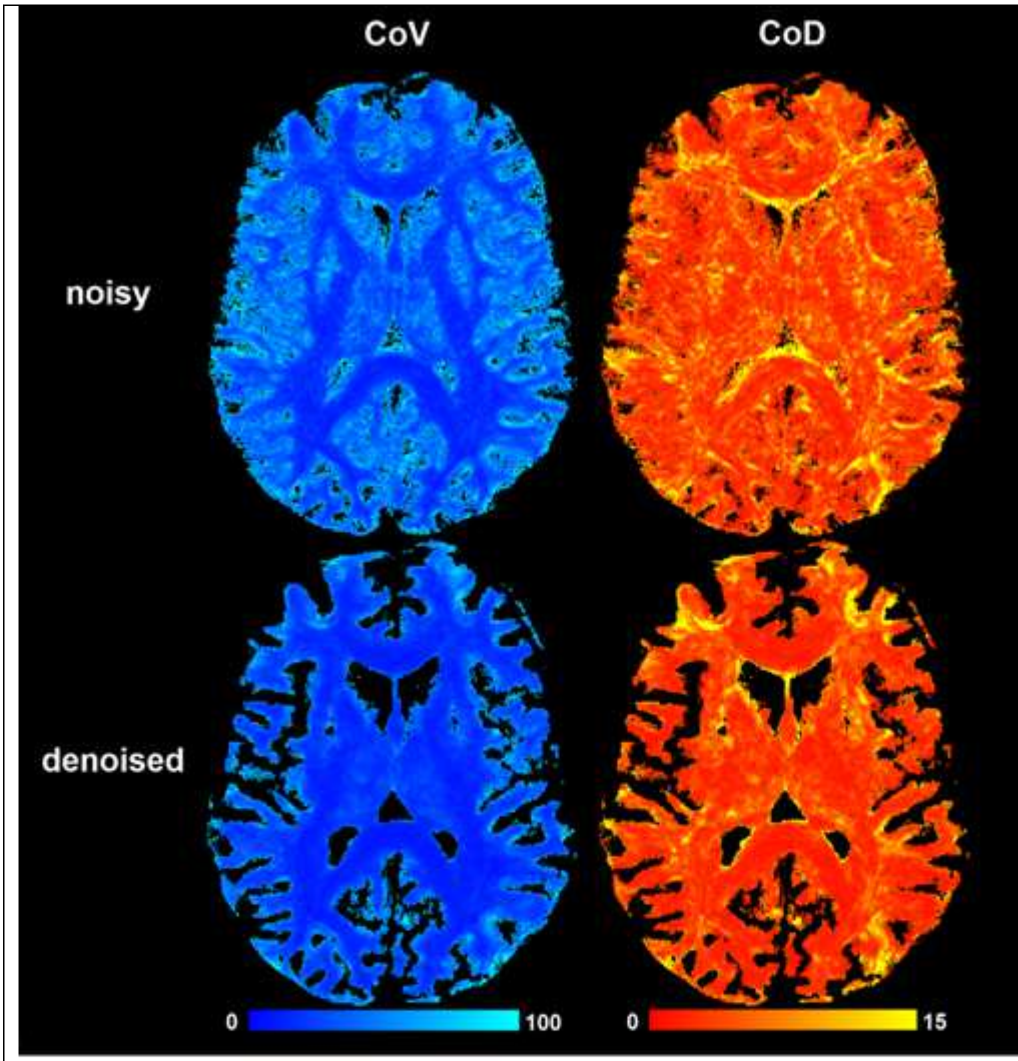

Figure 2: CoV* and CoD** maps computed over the 10 acquisitions of the noisy and denoised datasets.

* *Coefficient of Variation ; ** Coefficient of Dispersion*