EPI Distortion Correction using Log-Demons Method in MR Diffusion Tensor Imaging

T. ARSENAULT [1], F YIN [1], J CHINO [1], O. CRACIUNESCU [1], and Z. CHANG[1]
1 Duke University, Durham United States

JULY 12–16 2020 VIRTUAL
JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

Clinical Diffusion Weighted Images (DWI) typically use single-shot EPI acquisitions that are sensitive to static magnetic field inhomogeneities, resulting in geometric distortions.

Previous correction methods require additional acquisitions and potentially lengthen scan time. In this study, we will be investigating the feasibility of the log-demons deformable image registration (DIR) method to correct eddy current and EPI distortions without the need for additional acquisitions.

AIM

To investigate the feasibility of the Log-Demons deformable image registration (DIR) method to correct Echo Planar Imaging (EPI) distortions while preserving diffusion tensor information.

METHOD

- Phantom MR scan was conducted using a diffusion phantom scan (Diffusion Phantom Model 128, High Precision Devices, Inc) on a clinical 3T scanner.
- The scan includes a standard T1-weighted scan and a 20-direction diffusion tensor imaging (DTI) scan, which consists of one data set with b=0s/mm^2 and twenty diffusion-weighted data sets with b=1,000s/mm^2.
- Before EPI distortion correction, the affine method is first used to correct Eddy current distortion of the diffusion-weighted data sets
- Log-Demons DIR algorithm was applied to the DTI images for EPI distortion correction based on the T1-weighted data set and compared to EPI distortion corrections by affine and demons DIR algorithms
- The registered images were analyzed using mutual information (MI) and Cross-correlation (CC)
- Quantitative deviations from the original data after correction were also evaluated using the mean, and root mean square error (RMSE) for thirteen regions of interest in the Apparent Diffusion Coefficient (ADC) and Fractional Anisotropy (FA) maps.

RESULTS

MI and CC were improved by 3.80%, 8.96%, and 4.38% compared to no correction, and affine, and demons algorithm respectively. Analysis of the tensor metrics using percent difference and the RMS of the ADC and FA found that the Log-Demons algorithm outperforms the other algorithms in terms of preserving diffusion information.

Figure 1: ADC and FA maps by Log Demons show reduced spatial distortions as measured by MI and decreased percent difference. Because the phantom is filled with water, we expect the diffusion to be isotropic, which is why there is little signal from the FA maps.

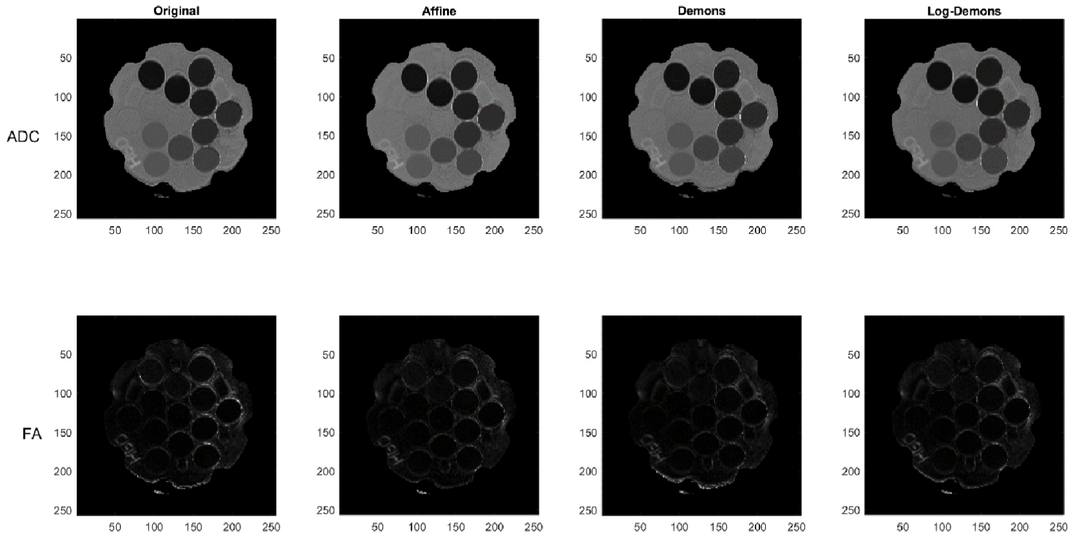

Table 3. Percent difference of the ADC value from each of the 13 cylinders within the diffusion phantom, as compared against the original data

	Affine	Demons	Log-Demons
Average	2.14%	0.42%	0.13%
STD Dev	3.31%	1.03%	0.16%
RMS	3.83%	1.04%	0.17%

Table 4. The percent difference of the FA values from each of the 13 cylinders within the diffusion phantom, as compared against the reference FA value of 0.

	Affine	Demons	Log-Demons
Average	10.82%	3.02%	2.30%
STD Dev	9.07%	3.97%	3.78%
RMS	0.06%	0.01%	0.01%

CONCLUSIONS

This work indicates that the Log-Demons DIR algorithm is feasible to reduce EPI distortion while preserving quantitative diffusion information. Although demonstrated with a DTI phantom study, this method could be extended for areas in which diffusion-weighted imaging is beneficial.

ACKNOWLEDGEMENTS

Thank you to the The Duke Cancer Institute for funding this research.

REFERENCES

[1] QalibreMD. Diffusion Standard Model 128 Diffusion Standard Model 128.(303):1–18, 2016.

[2] Zheng Chang, John P. Kirkpatrick, Zhiheng Wang, Jing Cai, Justus Adamson, and Fang Fang Yin. Evaluating radiation-induced white matter changes in patients treated with stereotactic radiosurgery using diffusion tensor imaging: A pilot study. Technology in Cancer Research and Treatment, 13(1):21–28, 2014.

[3]Tom Vercauteren, Xavier Pennec, Aymeric Perchant, and Nicholas Ayache.Symmetric Log-Domain Diffeomorphic Registration. pages 1–8.

[4] Herve Lombaert, Leo Grady, Xavier Pennec, Nicholas Ayache, and FaridaCheriet. Spectral log-demons: Diffeomorphic image registration with very large deformations.International Journal of Computer Vision, 107(3):254–271, 2014.

[5] J. P. Thirion. Image matching as a diffusion process: An analogy with Maxwell'sdemons.Medical Image Analysis, 2(3):243–260, 1998.

CONTACT INFORMATION

Email: theodore.arsenault@duke.edu