Simulation-based evaluation of susceptibility distortion correction methods in dMRI

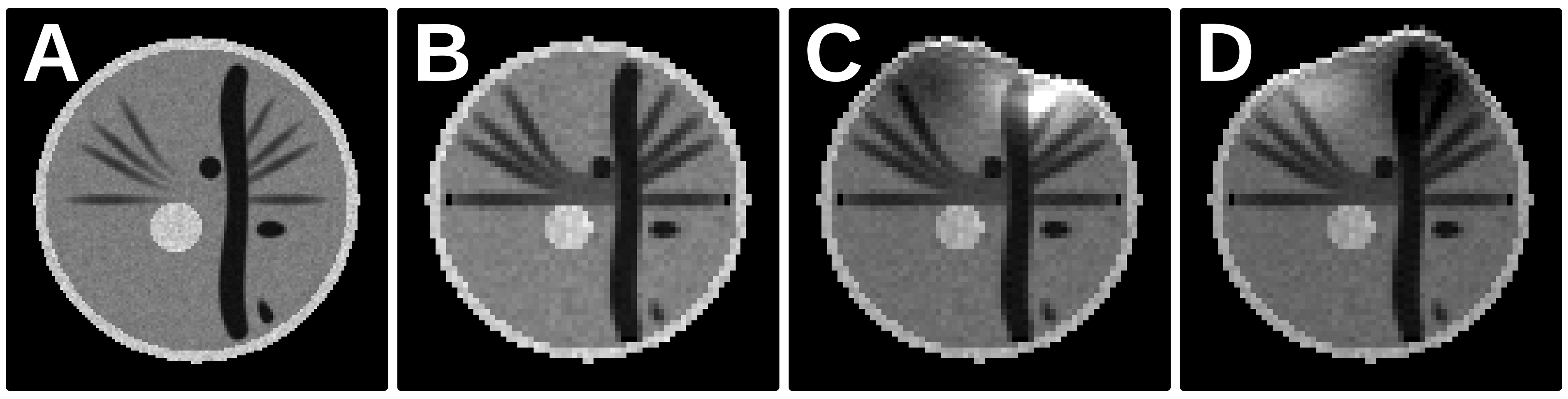
O. Esteban[1,2] A. Daducci[2] E. Caruyer[3] K. O'Brien[4] MJ. Ledesma-Carbayo[1] M. Bach-Cuadra[5,2] A. Santos[1]

1 BIT POLITÉCNICA 2 LTS EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE 3 SBIA Penn UNIVERSITY of PENNSYLVANIA 4 CIBM UNIVERSITÉ DE GENÈVE 5 CHUV Unil UNIL | Université de Lausanne

- Connectivity analyses rely on complex workflows to extract the network from dMRI datasets.
- One important pitfall that potentially bias the extracted connectome is susceptibility distortion, a typical artifact on dMRI [Irfanoglu et al. 2012].
- In this work, we evaluate three widely used methodologies for bias correction, originally proposed for fMRI data: fieldmap-based method (FMB, [Jezzard et al 1995]), reverse-encoding method (REB, [Cordes et al. 2000, Chiou et al. 2000]), and T2-weighted intensity-based registration (T2B, [Kybic et al. 2000]).
- Benchmarking includes geometrical accuracy scores, signal recovery scores, and a preliminary study of impact on the extracted tractography and connectivity matrices.

Digital dMRI phantom & theory-based warping

We generated a test set using low-resolution dMRI phantoms (online available[1]) with corresponding T1-weighted and T2-weighted images at high-resolution.
We simulate the artifact (geometrical distortion and signal dropout) using a synthetic fieldmap.

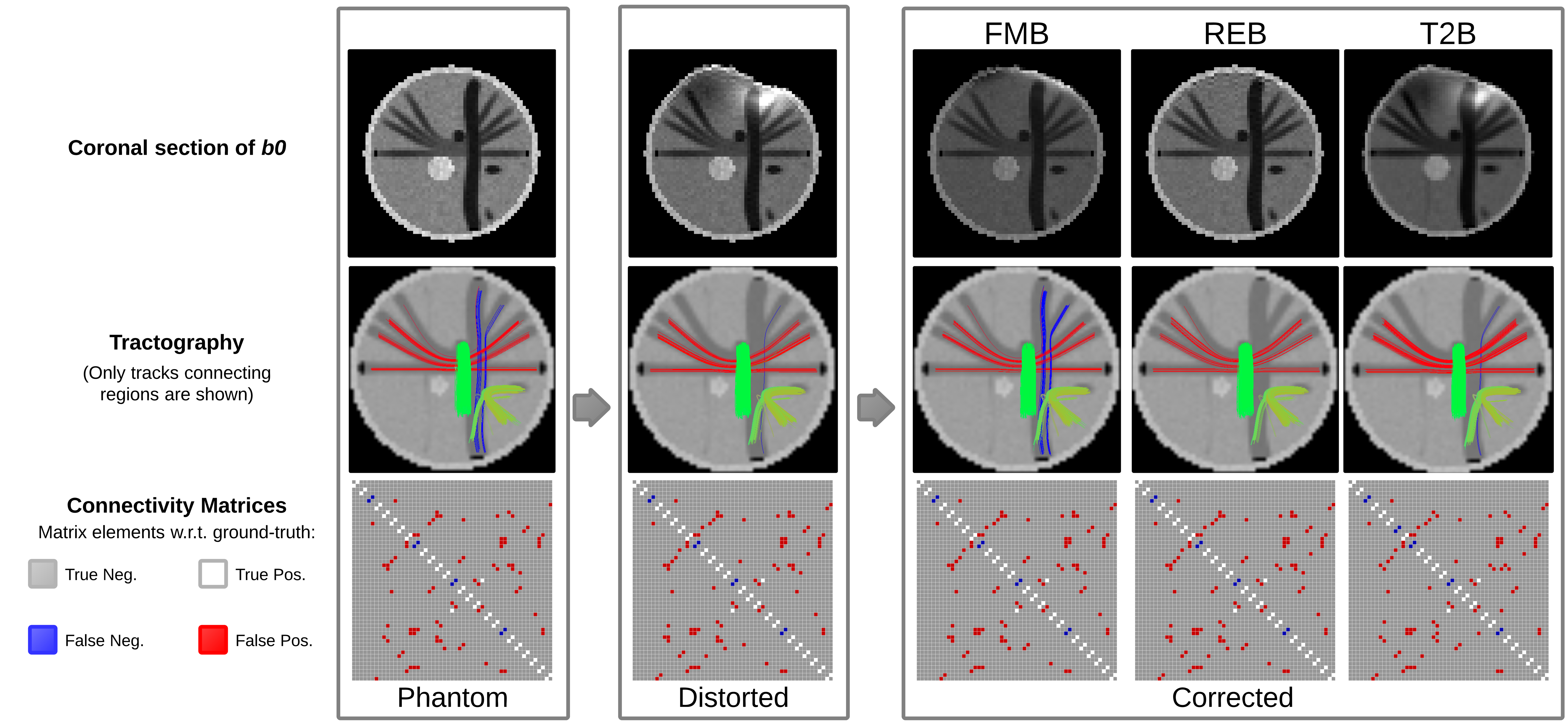


A) T2w; B) undistorted *b0* volume; C, D) distorted *b0* volumes with opposed phase encoding directions, maximum displacement of 3.80 mm.

Evaluation framework

We use *nipype*[2], a powerful tool for building processing pipelines in neuroimaging.
The evaluation framework includes the phantom distortion module, the three correction methodologies, DTI&HARDI reconstruction methodologies, tractography, and a final module to analyse downstream impact on geometry, tractography and connectivity.

Visual results



Quantitative results

Table : Accuracy results

	Overlap (Jaccard Index, %)				Signal Correlation (%)	
	Av.	CSF	WM	GM	*b0*	DWIs
FMB	93.00	88.57	96.74	94.02	80.05	$96.26 \pm .06$
REB	96.64	94.31	98.26	96.75	91.00	$97.65 \pm .03$
T2B	79.19	66.31	89.85	82.14	64.58	$90.10 \pm .13$

Table : Tractography and connectivity results.

	# tracks	length (mm)	FP	FN
Original	735	40.87 ± 13.55	40	4
Distorted	878	40.54 ± 13.73	42	4
FMB	743	40.04 ± 13.60	43	4
REB	830	39.87 ± 13.93	44	4
T2B	825	41.44 ± 12.85	40	5

Conclusions and references

- DTI dataset was rejected in evaluation: extracted connectivity matrices were biased, as the phantom is designed for high angular resolution methods.
- In terms of geometry, the results indicate that REB method ranks first.
- In terms of tractography, visual assessment and quantitative results suggest that FMB could be better.
- Connectivity matrices are evaluated, but a more appropriate phantom is required. A phantom with the connecting interface densely covered by the seeding regions may be the key to characterize the impact on connectivity.
- Connectome analyses demand the standardization of processing techniques and pipelining sofware tools to ensure replicability of experiments and reliability of results.

Links and references

1. emmanuelcaruyer.com/phantomas.php
2. nipy.sourceforge.net/nipype

 oscar.esteban@upm.es