Correction of susceptibility distortion in EPI: A semi-supervised approach with deep learning.

- MIML workshop -

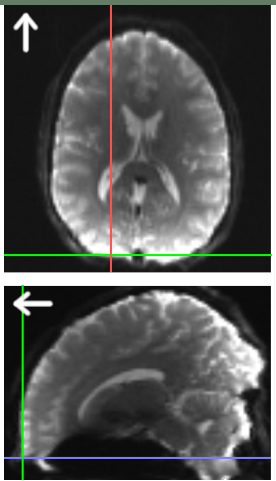
Antoine Legouhy

13 May 2022

EPI images

Echo planar imaging (EPI):

Most common approach for diffusion MRI.



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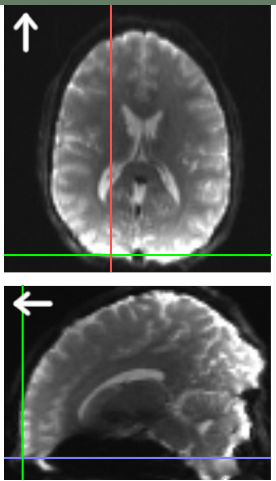

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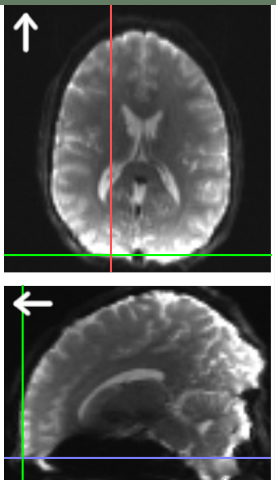

EPI

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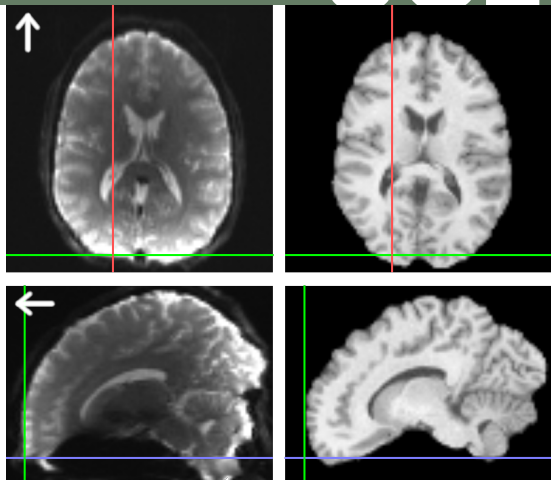
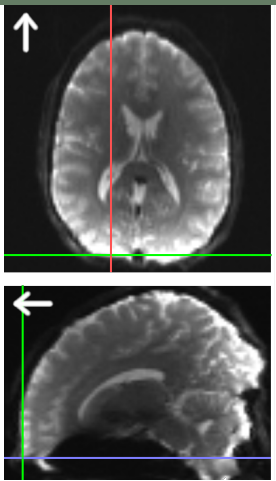
− Severe **geometric distortions**.
Caused by susceptibility-induced B0 field inhomogeneities.
→ Breaks correspondence with anatomical images.



EPI anatomical

Susceptibility distortion

Susceptibility distortion:

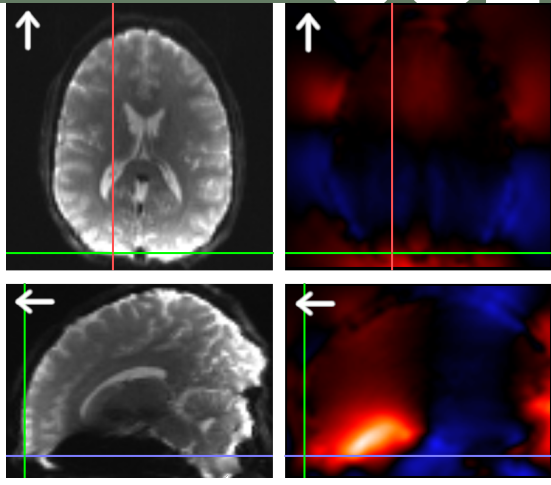


EPI

Susceptibility distortion

Susceptibility distortion:

- Only along PED.



EPI distortion field

Susceptibility distortion

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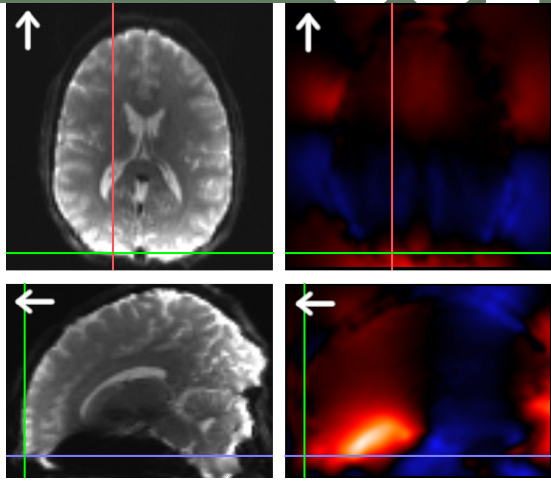
- More severe around medium interfaces: air / tissue or soft tissue / hard tissue.

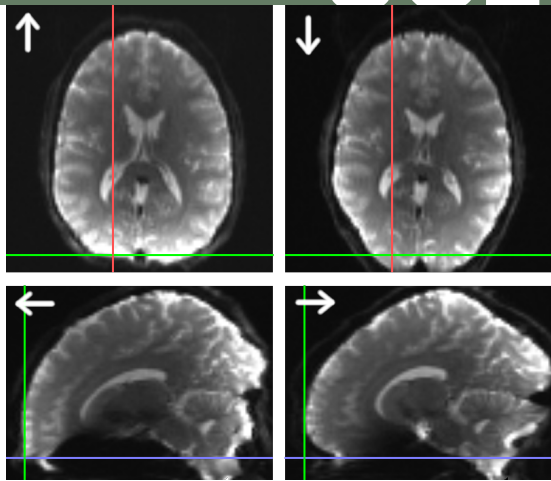


EPI distortion field

Susceptibility distortion

Susceptibility distortion:

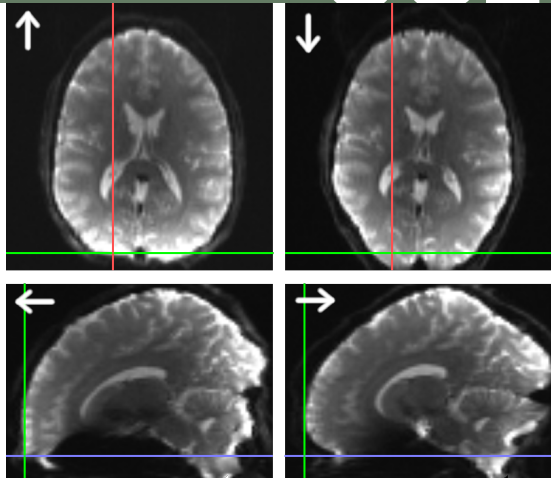
- Only along PED.
- More severe around medium interfaces: air / tissue or soft tissue / hard tissue.
- Reverted for reverted PED: contractions $\leftrightarrow$ expansions.



PA AP

Susceptibility distortion correction

Most effective correction method:



PA AP

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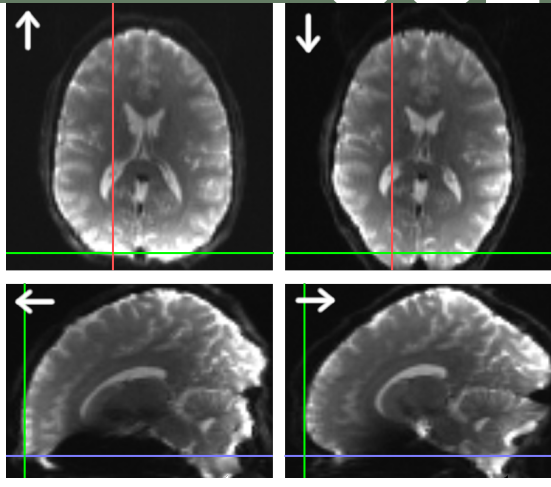
Most effective correction method:

1. Acquire extra data with same settings but opposite PED.

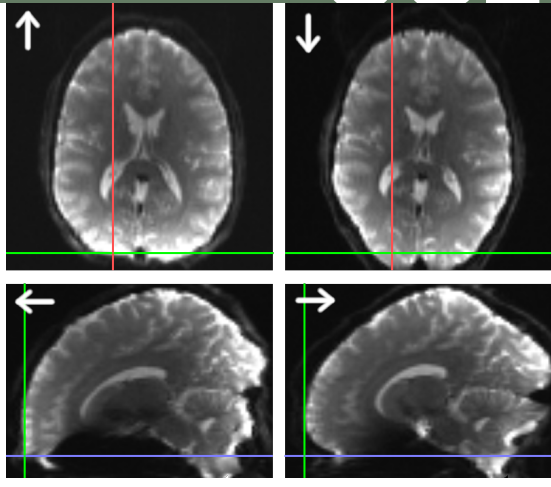


PA AP

Susceptibility distortion correction

Most effective correction method:

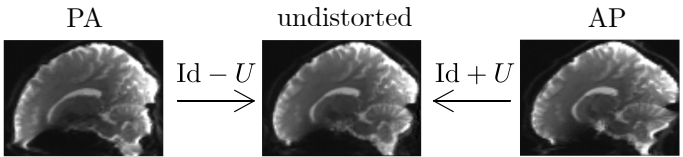
1. Acquire extra data with same settings but opposite PED.
2. Perform non-linear registration constrained along PED.



PA AP

An image registration problem

Optimization problem: find *best* field U such that:



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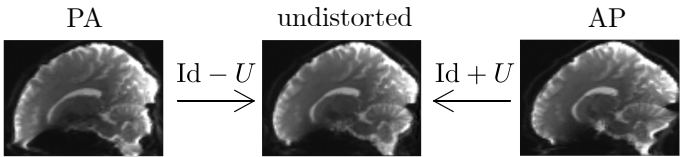

Classic registration

- Usual method.
- Restart from scratch for each new image pair.

  $\rightarrow$ Intensive

An image registration problem

Optimization problem: find *best* field U such that:

Classic registration

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  $\rightarrow$ Intensive

Deep-learning registration

- Big optimization at training.
- One shot registration.

Existing methods

TOPUP

- Classic registration.
- Jacobian intensity modulation.
- Purely intensity-based.

Duong et al. 2020

- Deep-learning registration.
- No Jacobian intensity modulation.
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Existing methods

TOPUP

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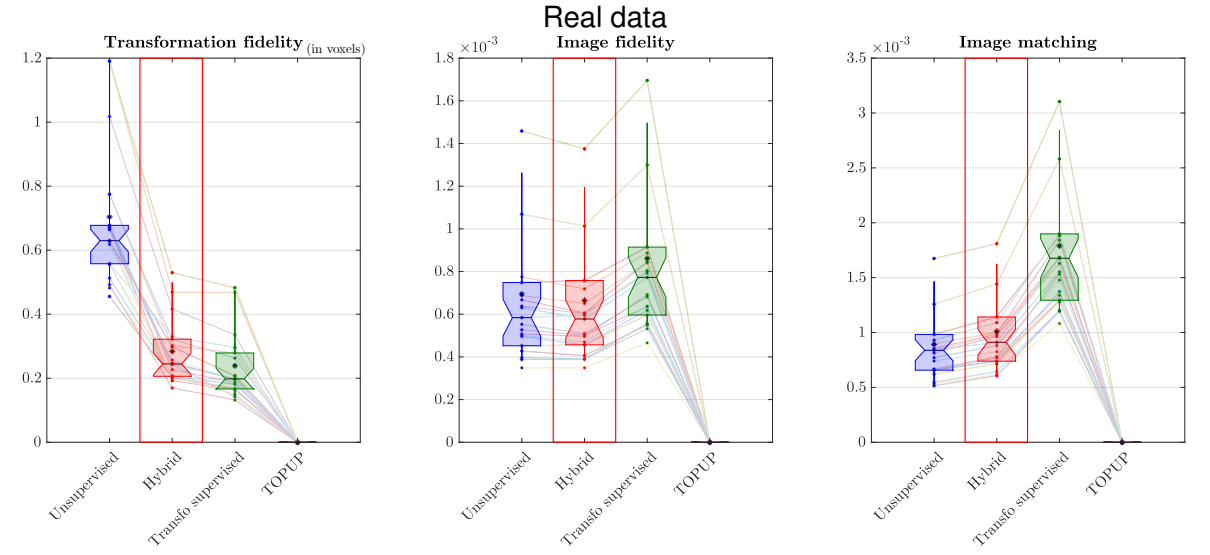
Intensity similarity between transformed images is only a surrogate measure of the goodness of the transformation.

Existing methods

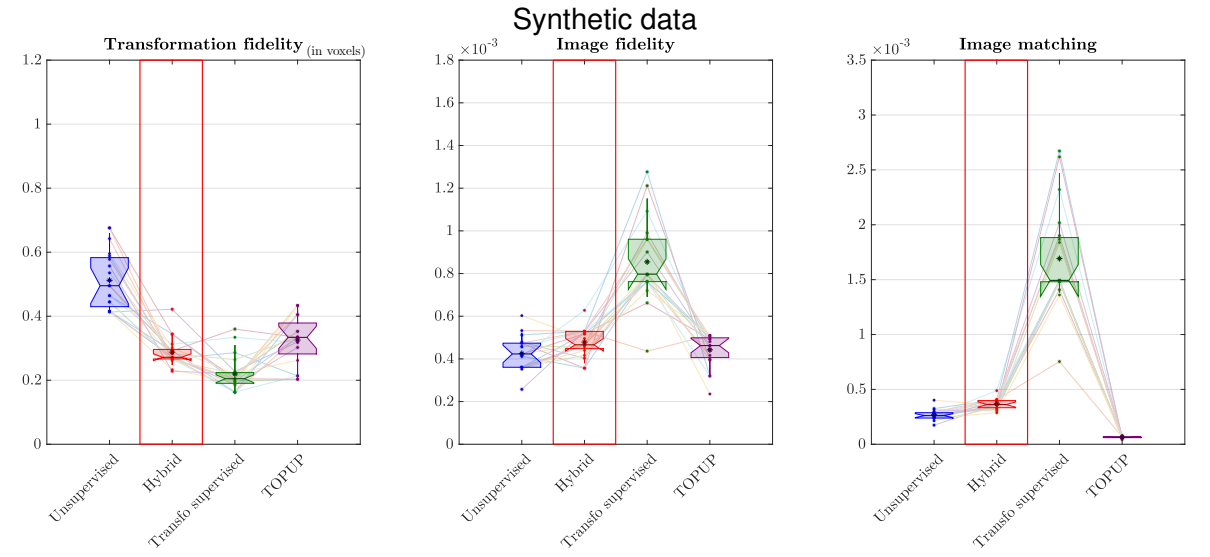
Proposed method:

- Deep-learning architecture.
- Semi-supervised:
  - Image similarity between transformed images (unsupervised).
  - Distance between estimated and ground truth distortion fields (supervised). Ground truth only at training.
- Jacobian intensity modulation.
- Spatially weighted at training.

Results


Real data
Transformation fidelity (in voxels)
Image fidelity
Image matching
×10^-3
×10^-3
Unsupervised
Hybrid
Transfo supervised
TOPUP

Results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