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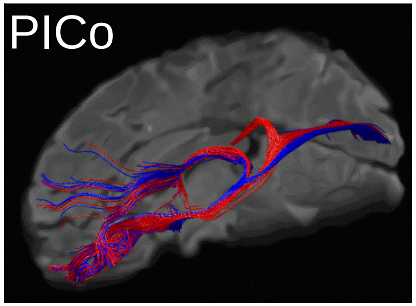

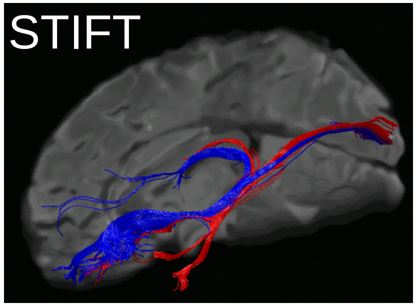

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SWI-informed Diffusion Tensor Tractography

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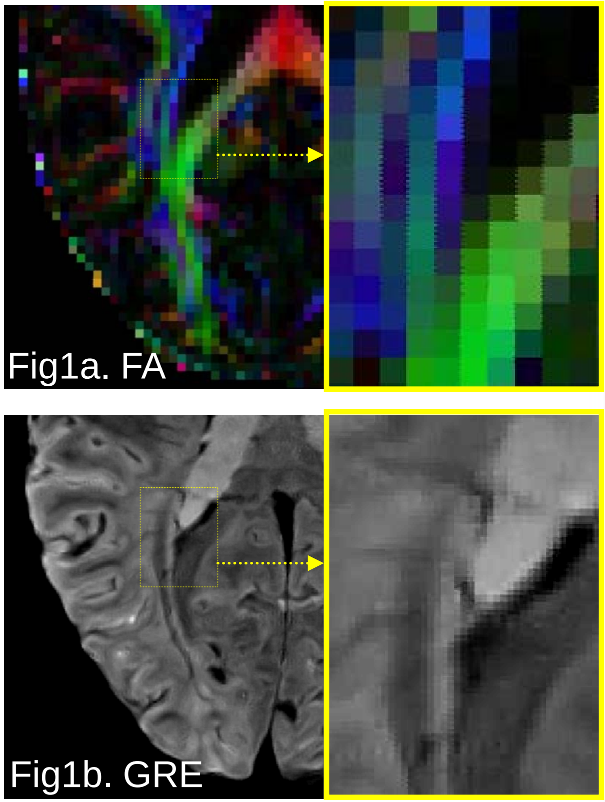
Problem description

Fibre tractography in diffusion weighted images (DWI) suffers from partial volume effects

- Typical DWI voxels (8 ml) contain multiple tracts at e.g. tract borders (Fig.1a)
- High resolution (0.125 ml) long TE gradient echo images (GRE) also show contrast within the white matter at high field[1] (Fig.1b)

Tractography can benefit from combining the diffusion tensor with information from high resolution volumes



[1] Li et al., NI 2006

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Structure Tensor Informed Fibre Tractography (STIFT)

The structure tensor (ST) is a suitable representation of scalar images to incorporate in tractography algorithms

- The ST captures local image features; the principal structure direction (PSD) is given by the first eigenvector of the ST (Fig.2)
- In anisotropic diffusion filtering the ST is used to enhance certain features of the image
- The ST calculated by edge-enhancing diffusion[1] is most useful for enhancing the sheet-like fiber bundles in the GRE image

The PSD at tract borders in GRE images is expected to be orthogonal to the principal diffusion direction (PDD) (Fig.2)

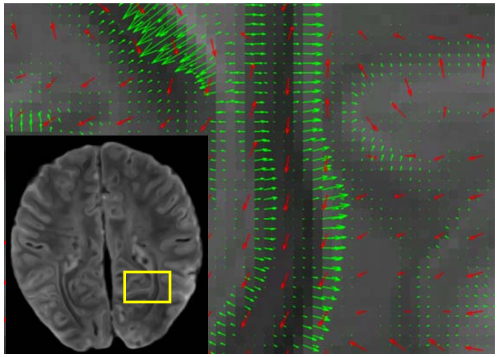

Fig2. PDD (red) & PSD (green)

[1] Weickert, PhD thesis 1996

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Fibre tracking with Camino PICo[1] and STIFT

- Adapted PICo informed by the structure tensor
  - Tracking direction (TD) is found by rotating the PDD towards the plane orthogonal to the PSD proportional to its normalized first eigenvalue λ_1^{ST}

$$TD = \left\| \lambda_1^{ST} \left\| PSD \times (PDD \times PSD) \right\| + (1 - \lambda_1^{ST}) PDD \right\| \qquad \text{(Eq.1)}$$

  - The adapted tracking direction is used in white matter only

- Seed point pairs were placed in the GRE image in adjacent voxels within and outside conspicuous fiber bundles

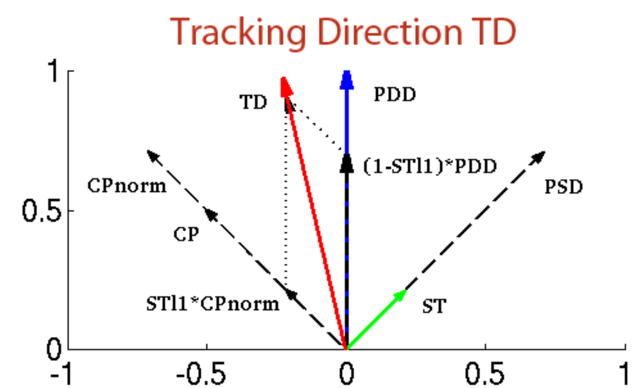

Fig3. Tracking Direction

[1] Parker et al., JMRI 2003

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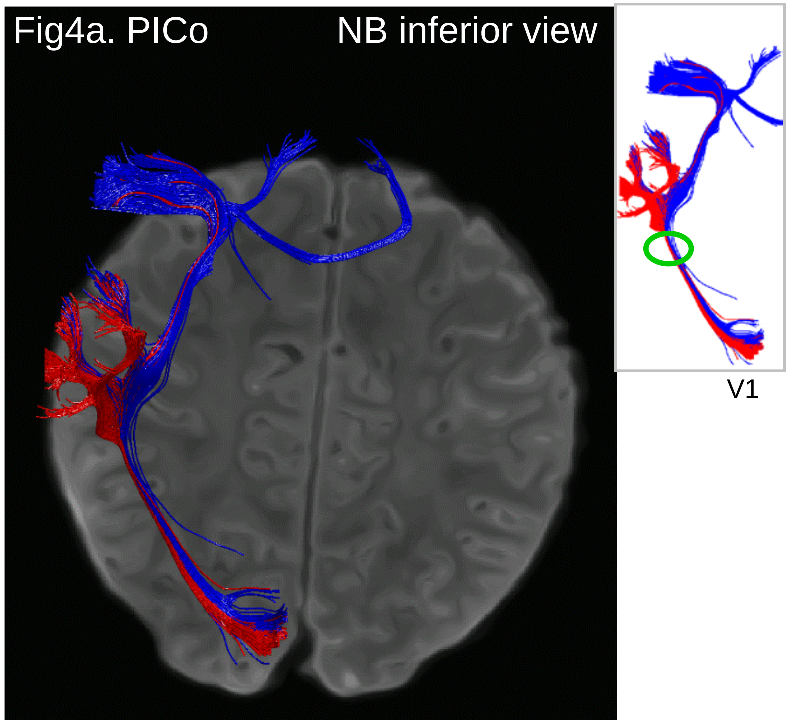
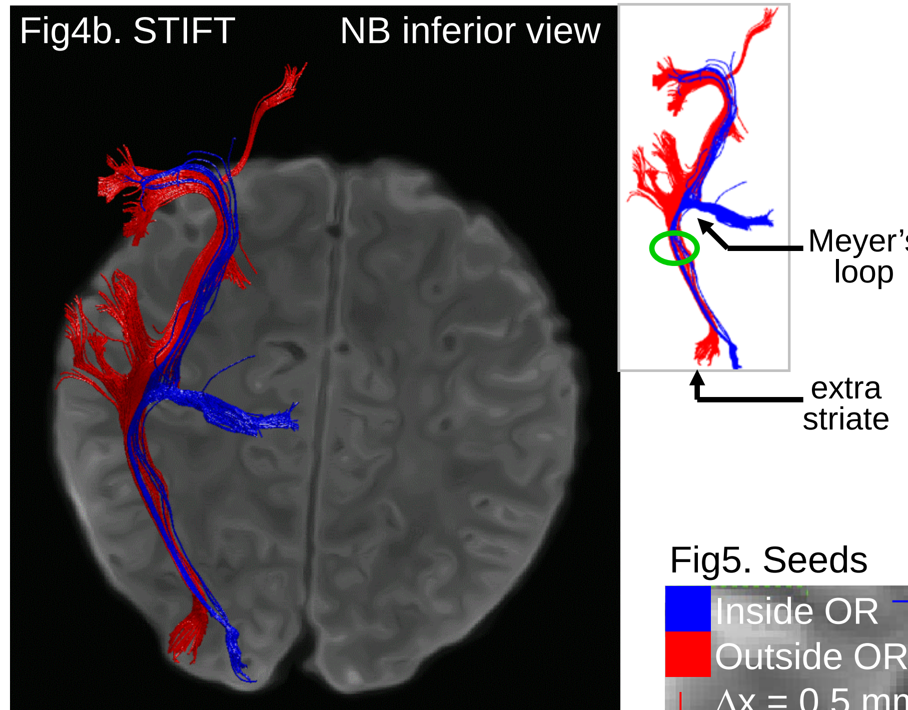
Optic radiation (OR)





PICo:

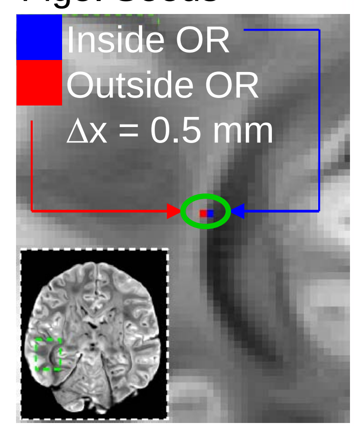
Frontal[1] and temporal[2] to V1

[1] Inferior occipito-frontal fasciculus (IOFF))
[2] Inferior longitudinal fasciculus (ILF)
[3] Optic radiation (OR)

STIFT:

- Meyer's loop to V1[3]
- Frontal[1] and temporal[2] to *extrastriate* areas

Fig5. Seeds



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Tapetum (TM)

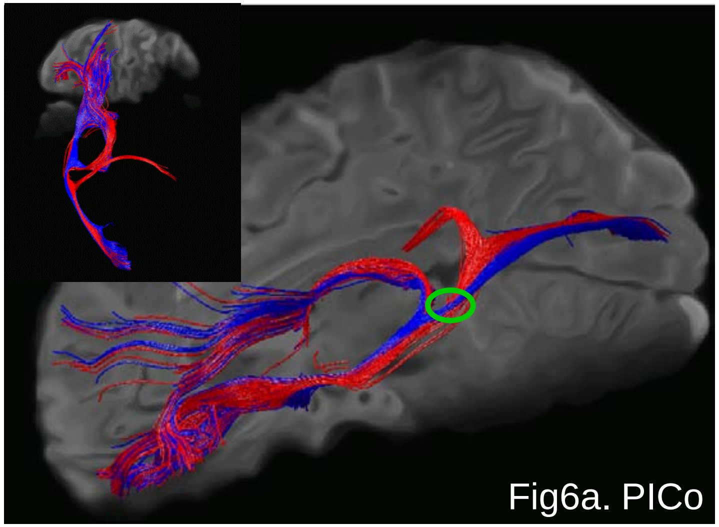


Fig6a. PICo

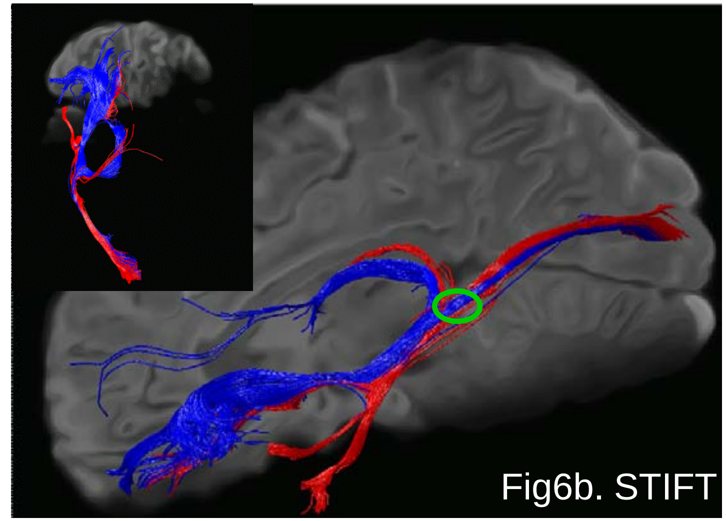


Fig6b. STIFT

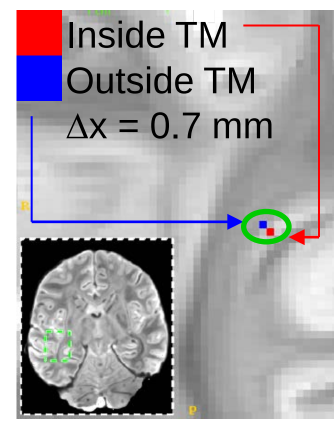
PICo:

- Frontal to V1; mixed for both seeds
- Tapetum corpus callosum specific to seed in TM

STIFT:

- Separation of frontal fibers
- Temporal tapetum specific to seed in TM

Fig7. Seeds



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Anatomical specificity increased with STIFT

Closely spaced seed points in neighbouring tracts result in well separated tracts using STIFT

- From the seedpoint within the OR[3], the geniculostriate pathway was tracked, while seeding just outside the OR reconstructed the associative fibers of the IOFF[1] and ILF[2]; PICo tracked the IOFF and ILF to V1
- Different parts of the tapetum were tracked by PICo and STIFT; STIFT showed clearly separate fiber tracts for both seeds

Large veins and iron-rich subcortical structures can affect STIFT results negatively

At specific locations STIFT can be a valuable tool to increase specificity and accuracy of fiber tracking

[1] Inferior occipito-frontal fasciculus (IOFF)
[2] Inferior longitudinal fasciculus (ILF)
[3] Optic radiation (OR)

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Additional material

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Methods: acquisition

DWI, GRE, and T1-weighted images in two healthy volunteers:

Table 1. Acquisition parameters * subj1/subj2

	DWI	GRE	T1
sequence	SE-EPI	3D FLASH	MPRAGE
field strength	3T	7T	3T
coil	32-ch array	8-ch array	32-ch array
TR/TE/TI	8300/95/- ms	36/25/- ms	2300/3.03/1100 ms
matrix size	110 x 110	448 x 336	256 x 256
FOV [mm]	220 x 220	224 x 168	256 x 256
slice thickness [mm]	2.0	0.5	1.0
Resolution [mm]	2.0 x 2.0 x 2.0	0.5 x 0.5 x 0.5	1.0 x 1.0 x 1.0
no of slices	64	208/240*	192
Bandwidth		120 Hz/px	
flip angle [°]		15	
diffusion volumes	7 @ b = 0 s/mm2	x	x
	61 @ b = 1000 s/mm2	x	x
acquisition time	~10 min	~20 min	~10 min

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Methods: preprocessing (1)

1. DWI artefact detection & realignment with PATCH[1]
2. Brain extraction with FSL
3. Bias field correction with FSL
4. Coregistration
   a) GRE ➔ T1; with FSL using FAST-based weighting volumes
   b) Mean b=0 DWI ➔ T1; with constrained warping[2]
5. GRE image structure tensor with edge-enhancing diffusion[3]
6. Vessel enhancing diffusion with VED[4]
7. WM-GM Segmentation with FSL

[1] Zwiers, ISMRM 2009
[2] Visser, ISMRM 2010; Poster #3459
[3] Kroon & Slump, IEEE-EMBS Benelux 2009
[4] Koopmans, MRMP 2008

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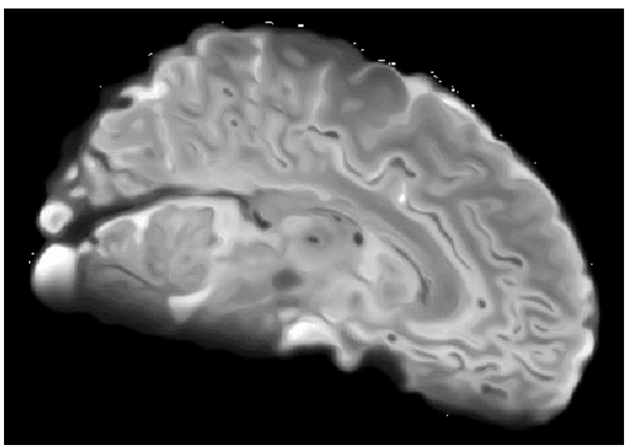
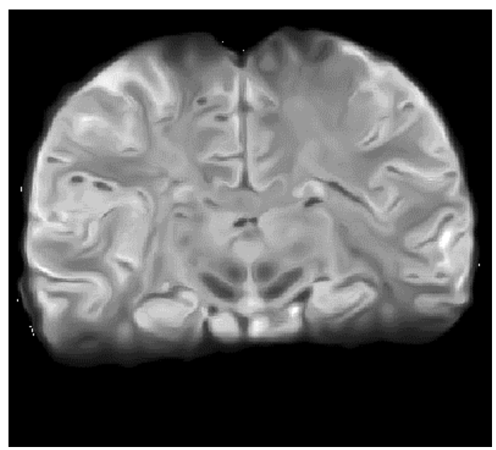
Methods: preprocessing (2)

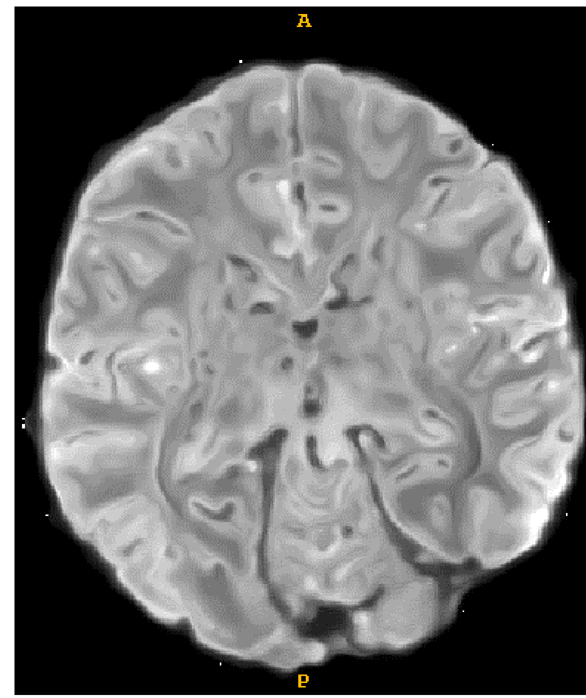
Coregistration

a) GRE ➔ T1; with FSL using FAST-based weighting volumes

b) Mean b=0 DWI ➔ T1; with constrained warping in PE direction[2]







[2] Visser, ISMRM 2010; Poster #3459

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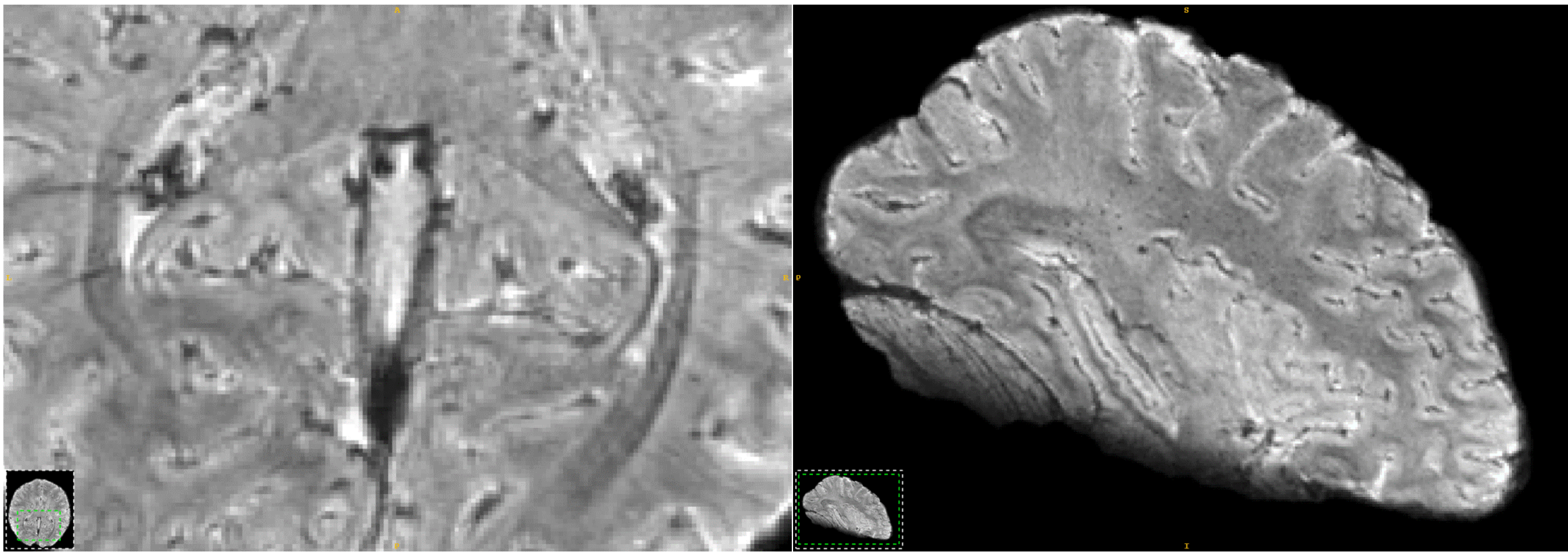
Methods: preprocessing (3)

GRE image structure tensor with edge-enhancing diffusion[3]



[3] Kroon & Slump, IEEE-EMBS Benelux 2009