White Matter Structure Assessment from Reduced HARDI Data using Low-Rank Polynomial Approximations

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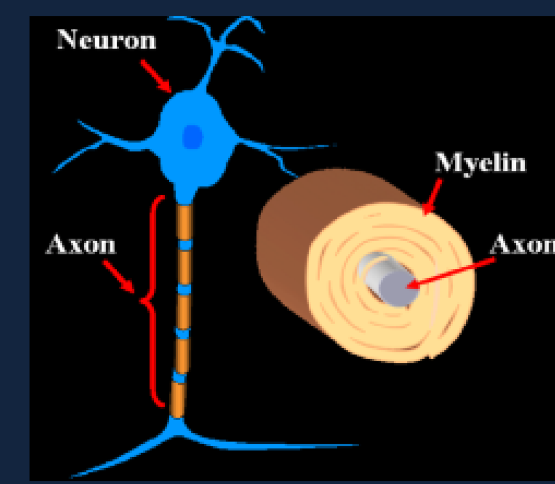
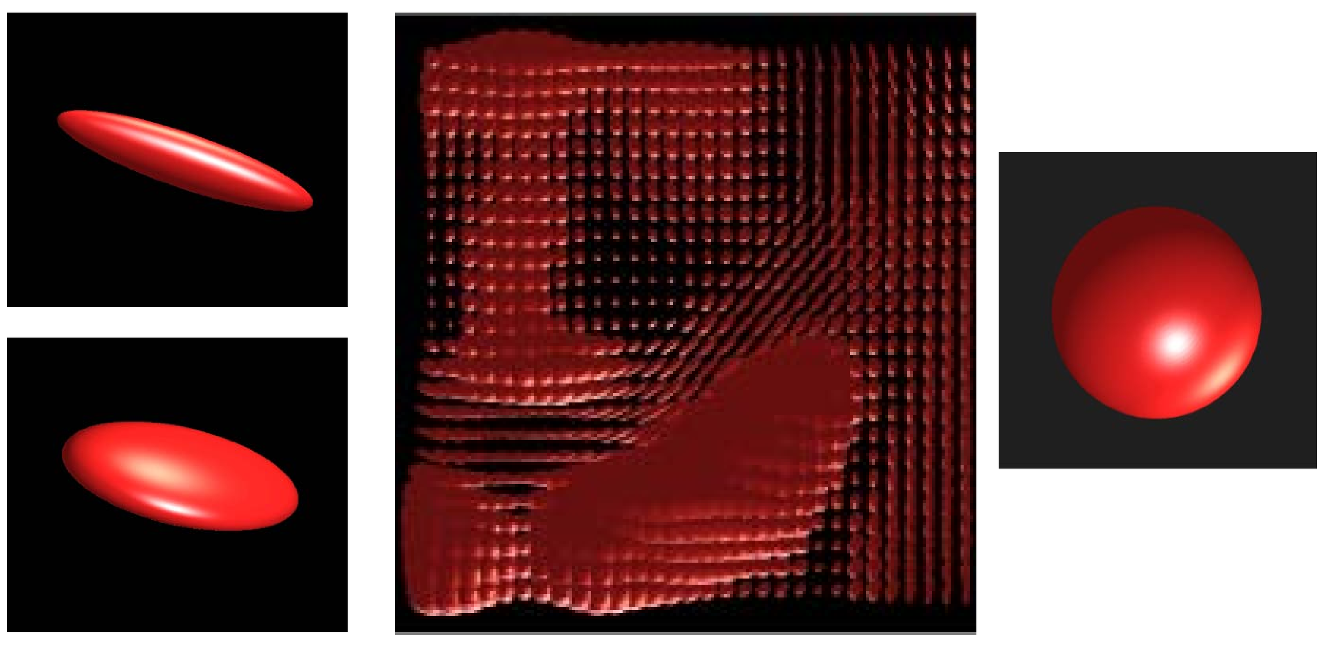
• Diffusion MRI is an imaging modality that measures Brownian motion of water molecules ("diffusion") in brain or heart tissue.
• In fibrous tissue the motion of the molecules is anisotropic.
• We use different modeling techniques to describe the anisotropy at a voxel level (locally) as well as globally, by extracting white matter connectivity maps of the brain.
• In this work, we present a novel mathematical model that accurately estimates white matter fiber orientations using less measurements than are typically available.

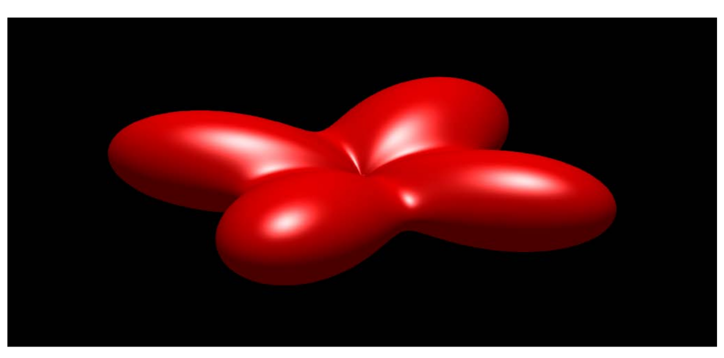


Diffusion MRI modalities

Diffusion Tensor Imaging (DTI):
Each image voxel is represented by a diffusion tensor



High Angular Resolution Diffusion Imaging (HARDI):
Each image voxel is represented by an orientation distribution function (ODF) or a higher-order tensor.

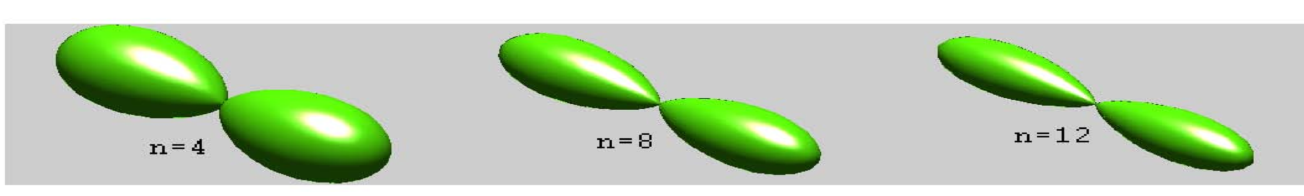


White matter fibers as rank-one tensors

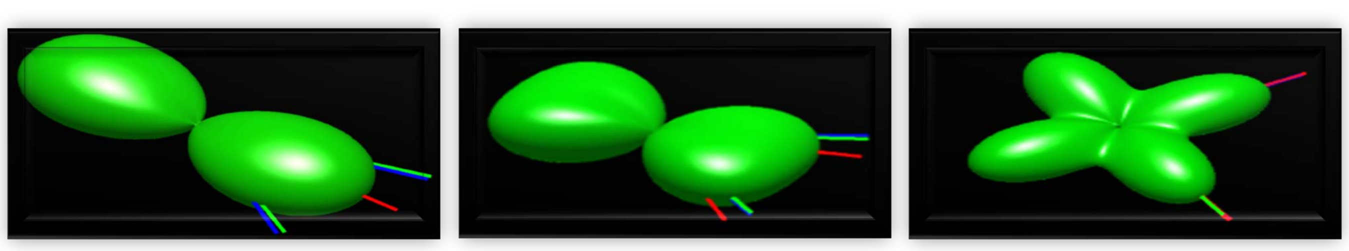
White matter fibers may be represented as linear-forms :

$$f(x) = (v \cdot x)^n, \;\; x \in S^2, \; v \in \mathbb{R}^3$$

where *v* specifies the fiber orientation.

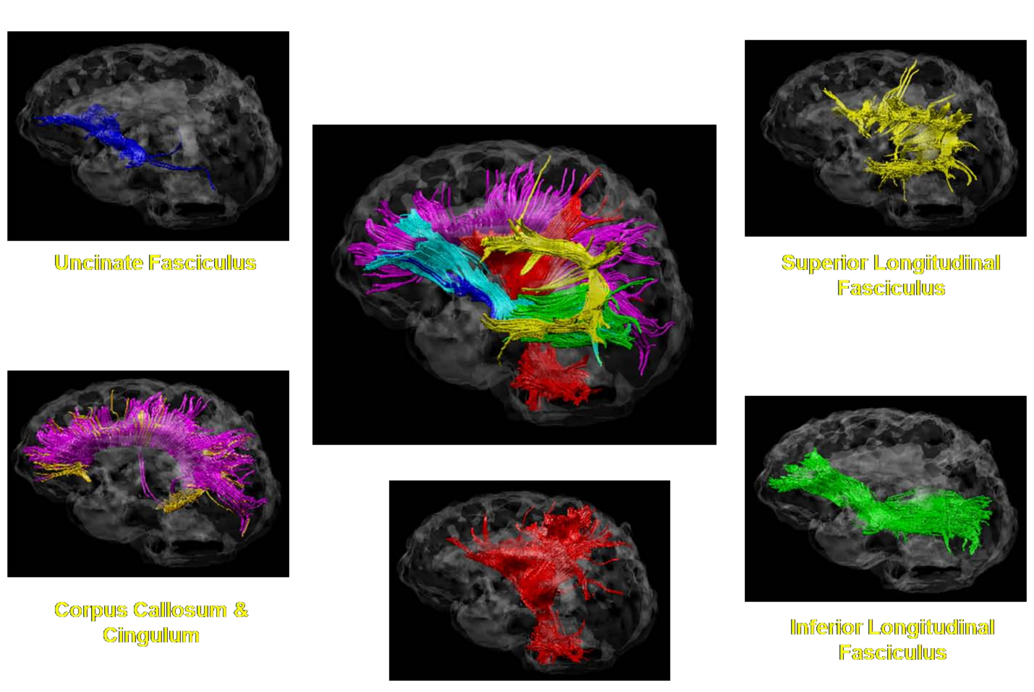


$$ODF(x) = \sum_{i=1}^{N} (v_i \cdot x)^n$$



Fiber tracking

By tracking the principal directions of the tensors (or the ODFs) we obtain a white matter connectivity map of the brain



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Results

• Simulated data

The signal was simulated using a two-tensor model (prolate tensor model) and corrupted by Rician noise.

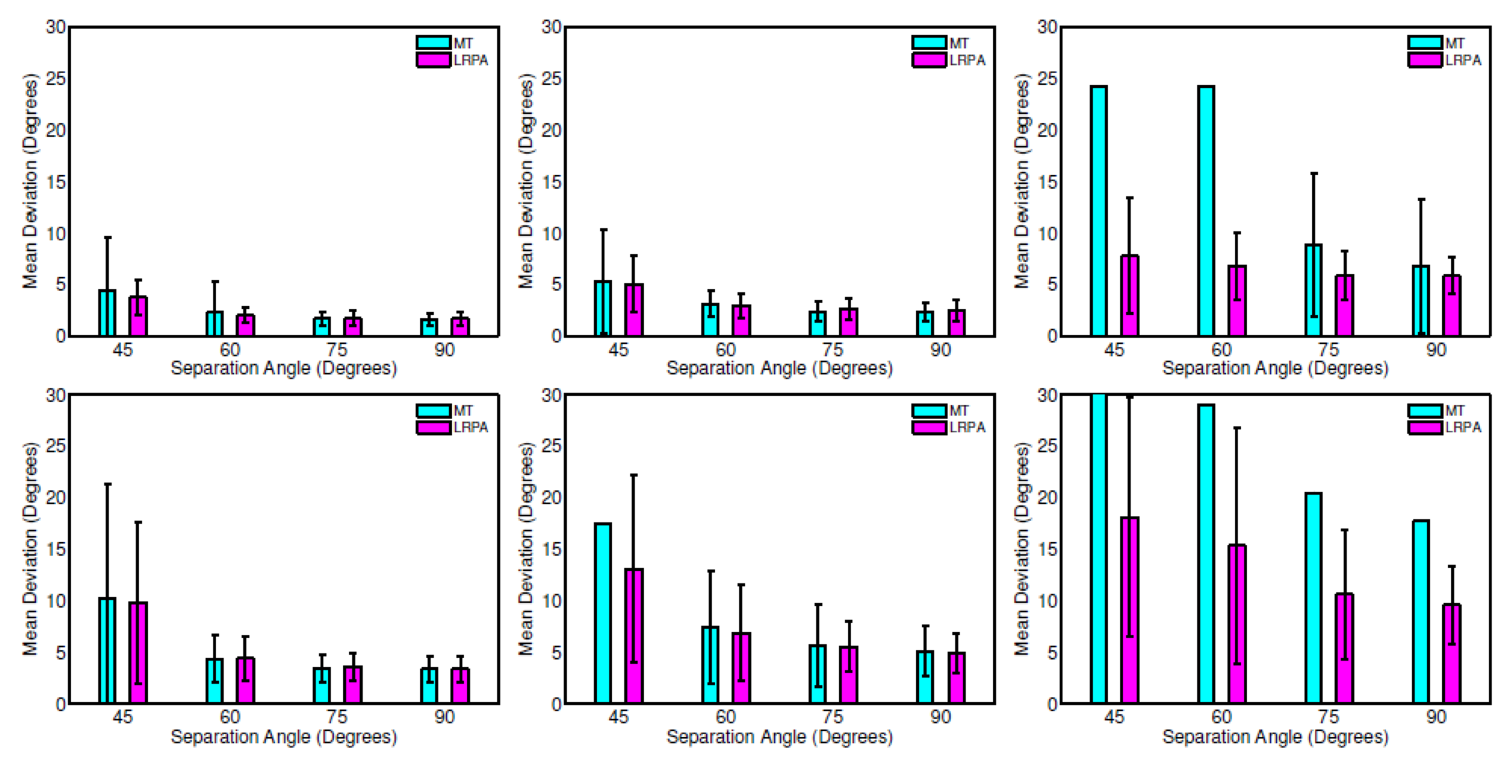


Fig. 1: Top to bottom: SNR 40 and 20. Left to right: 64, 32 and 12 gradient directions.

• Comparisons on synthetic 3D phantom (ISBI challenge, May 2012)

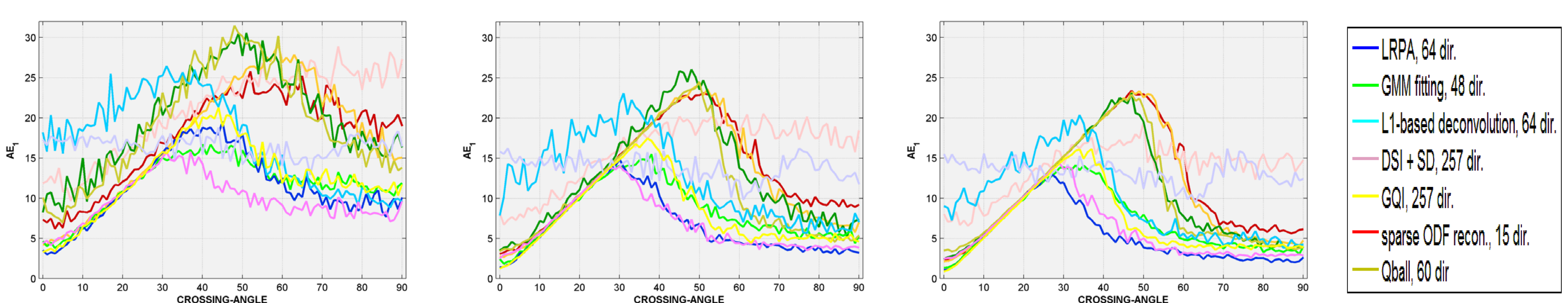
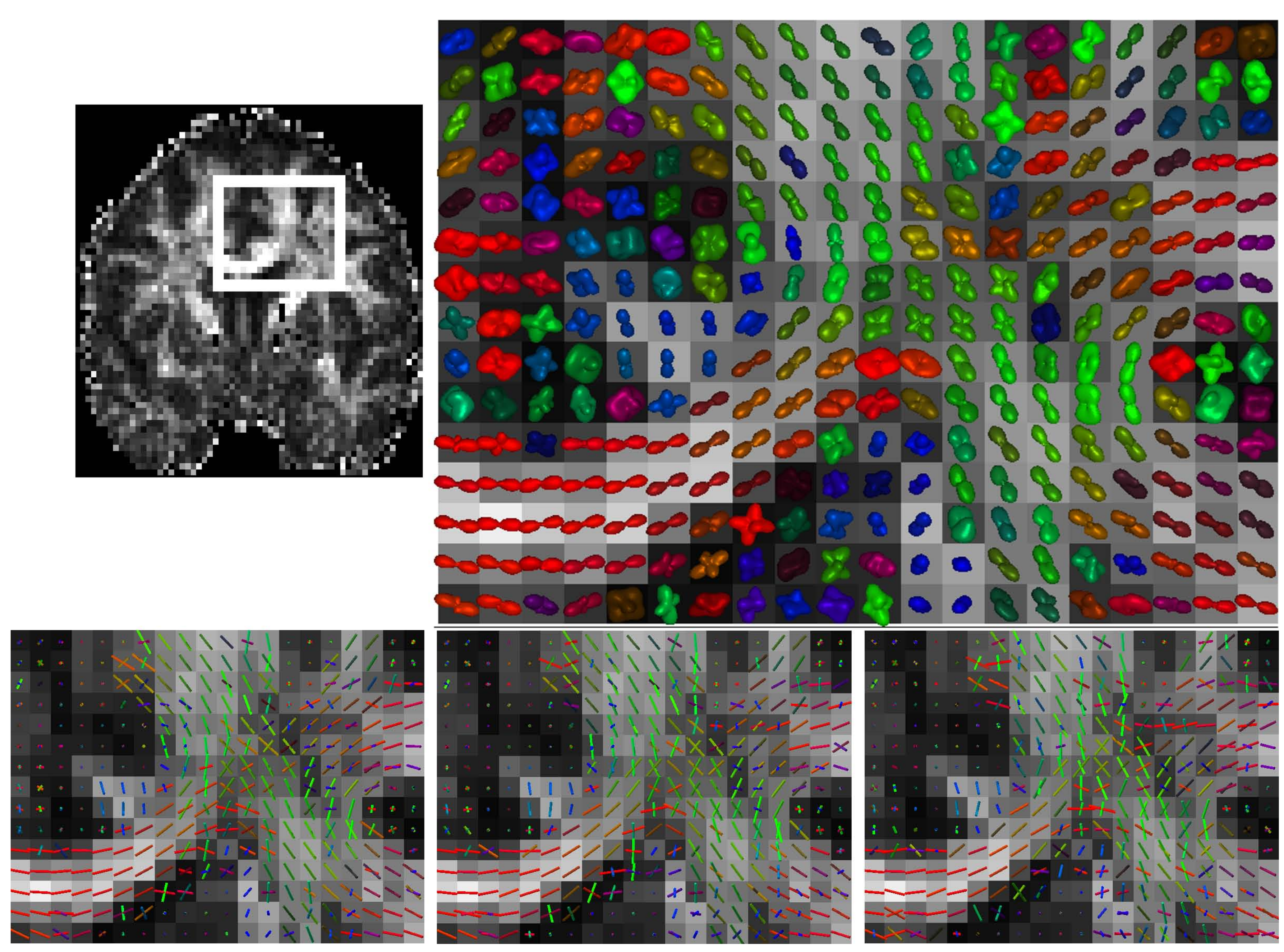


Fig. 2: From left to right: SNR 10, 20 and 30.

• In vivo brain data



References

1. Gur, Y., Jiao, F., Zhu, S.X., Johnson, C.R.: White matter structure assessment from reduced HARDI data using low-rank polynomial approximations. In proceedings of CDMRI'12, Nice, France, October 2012.
2. Gur, Y., Jiao, F., Zhu, S.X., Johnson, C.R.: Fiber orientations assessment via symmetric tensor decomposition. In: ISBI Workshop on HARDI reconstruction, Barcelona, Spain (May 2012) http://hardi.epfl.ch/
3. Jiao, F., Gur, Y., Johnson, C.R., Joshi, S.: Detection of crossing white matter fibers with high-order tensors and rank-k decompositions. In: IPMI'11. Volume 6801 of LNCS. (2011) 538–549.