Contextual Enhancements on DW-MRI

Rutger Fick

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Where innovation starts

Categories and Approach

DTI Category

b-value = 1200, 32 gradients

HARDI Category

b-value = 3000, 64 gradients

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DTI Category

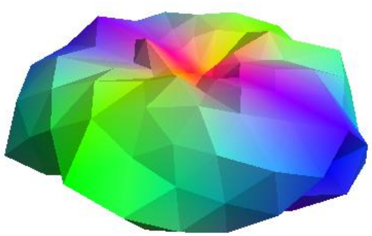
B-value = 1200, 32 gradients

HARDI Category

B-value = 3000, 64 gradients

Two-Step Approach

Raw Data



Constrained Spherical Deconvolution

→

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fODF

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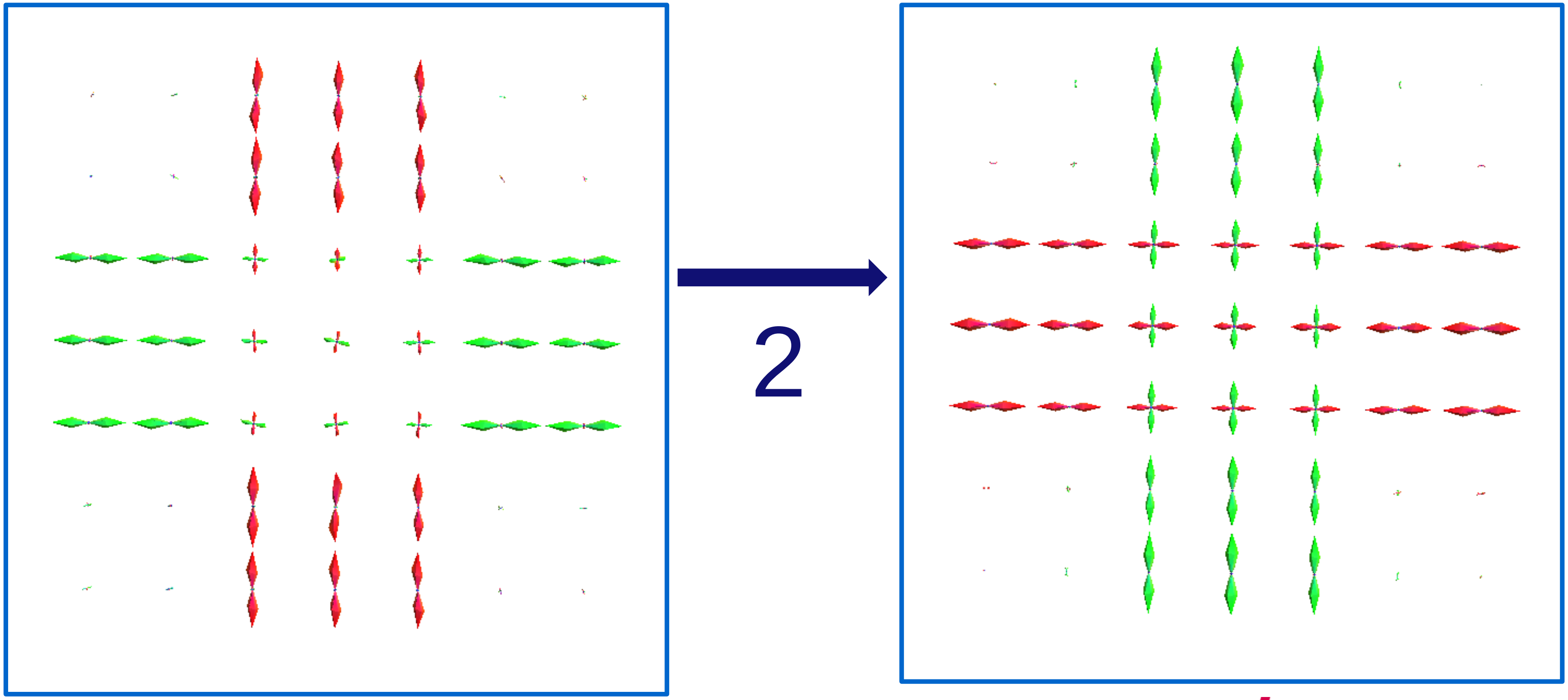
Enhancement of fODF Field

Artificial Fiber Crossing
B-value=1200, 32 gradients

Glyphs are aligned with surrounding!



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Enhancement of fODF Field

Detection of alignment requires coupling of position and orientation!

$$U : \mathbb{R}^3 \rtimes S^2 \to \mathbb{R}^+ : (\underline{\mathbf{y}}, \underline{\mathbf{n}}) \to U(\underline{\mathbf{y}}, \underline{\mathbf{n}})$$

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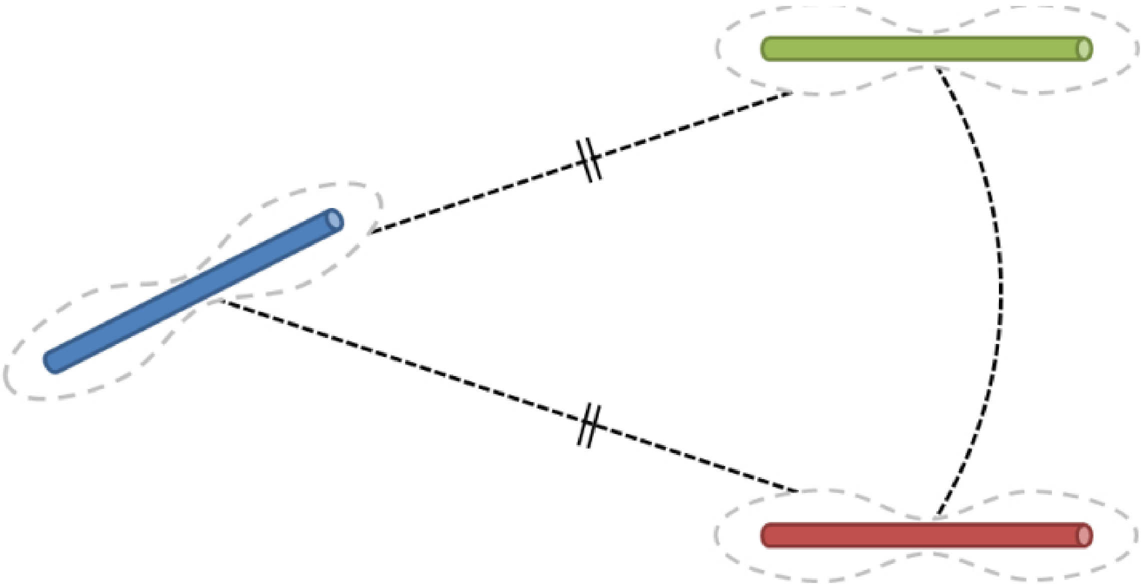

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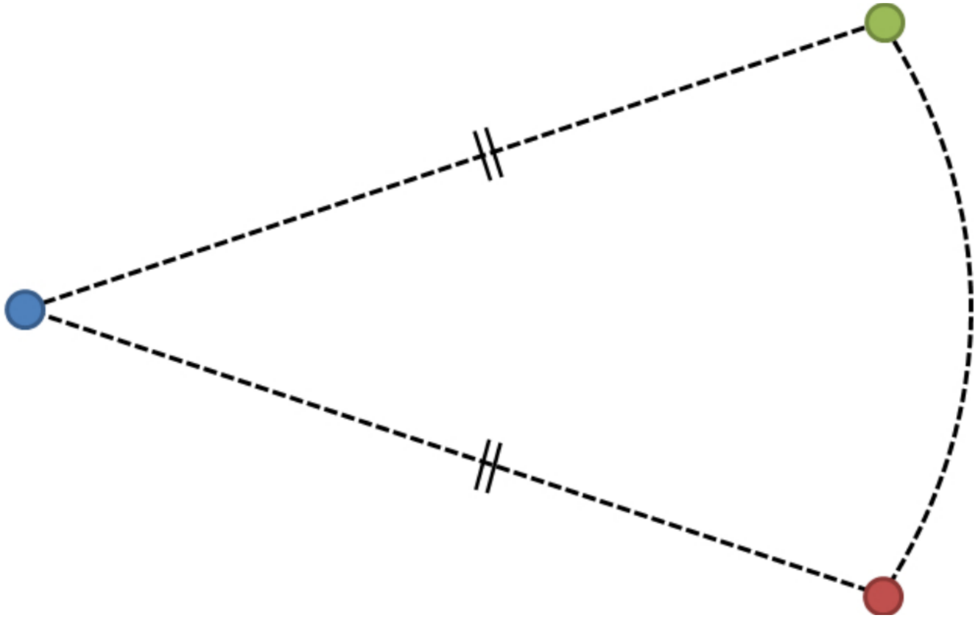

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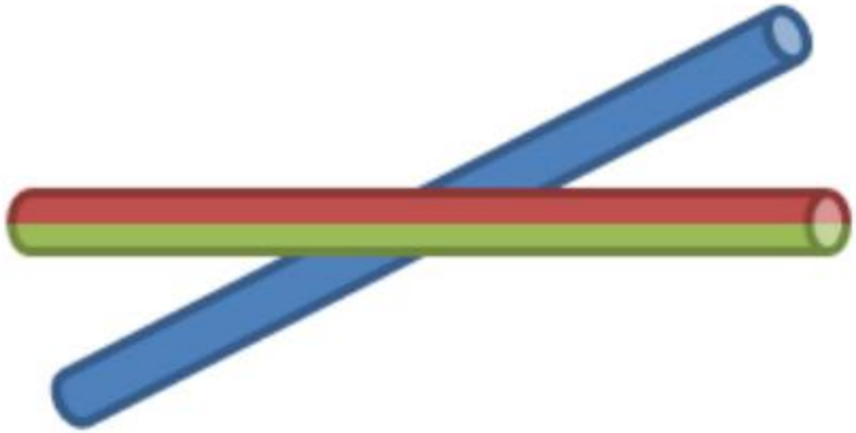

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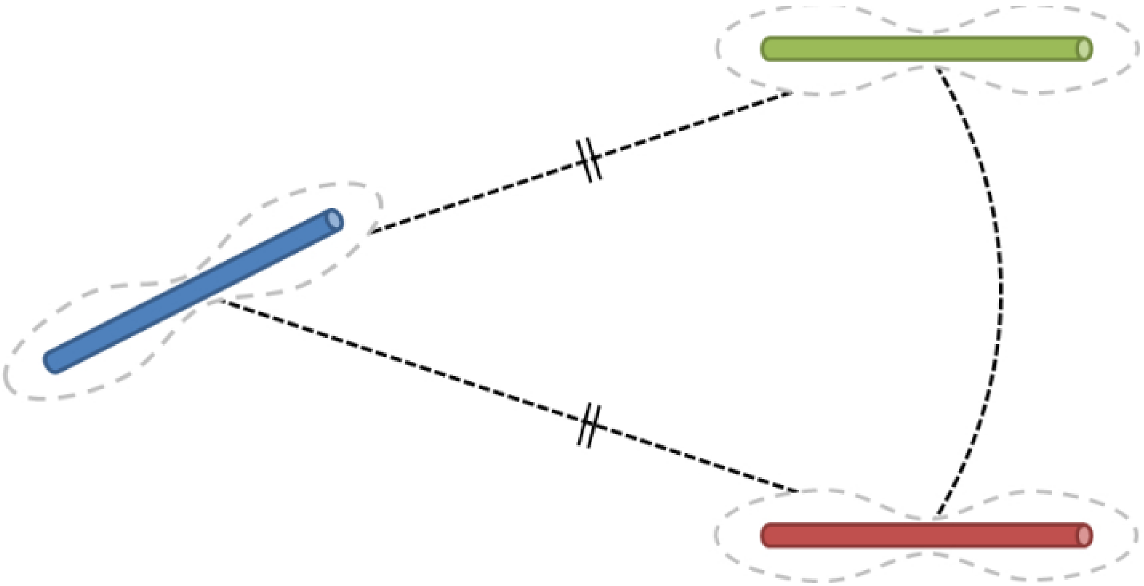
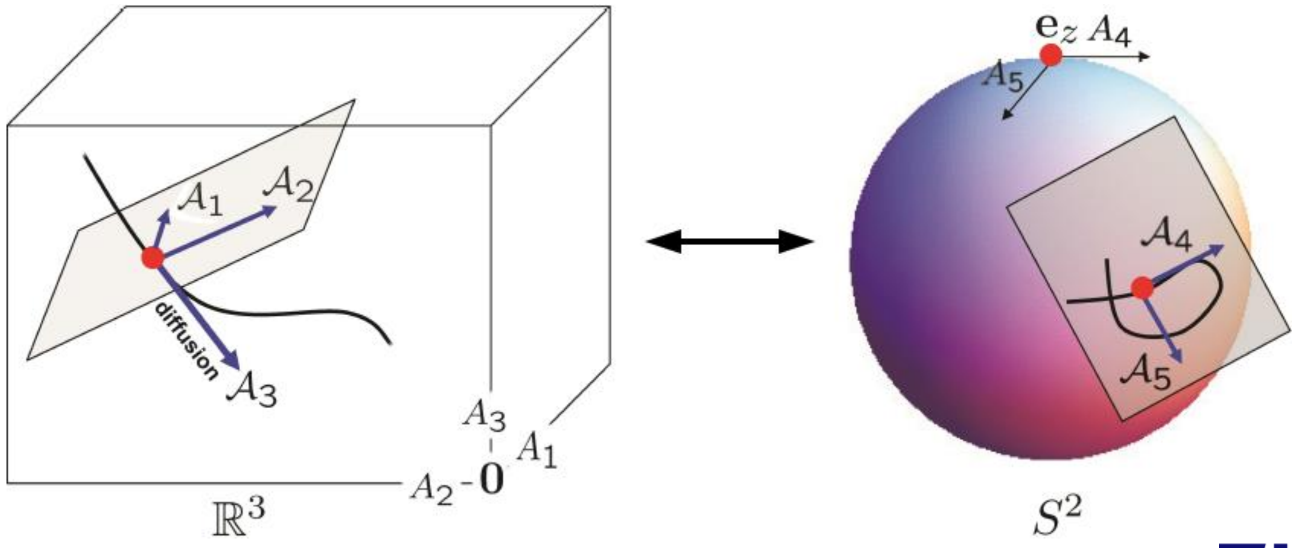


Enhancement of fODF Field

We define directional derivatives in this 5-dimensional space

$$U : \mathbb{R}^3 \rtimes S^2 \to \mathbb{R}^+ : (\underline{\mathbf{y}}, \underline{\mathbf{n}}) \to U(\underline{\mathbf{y}}, \underline{\mathbf{n}})$$

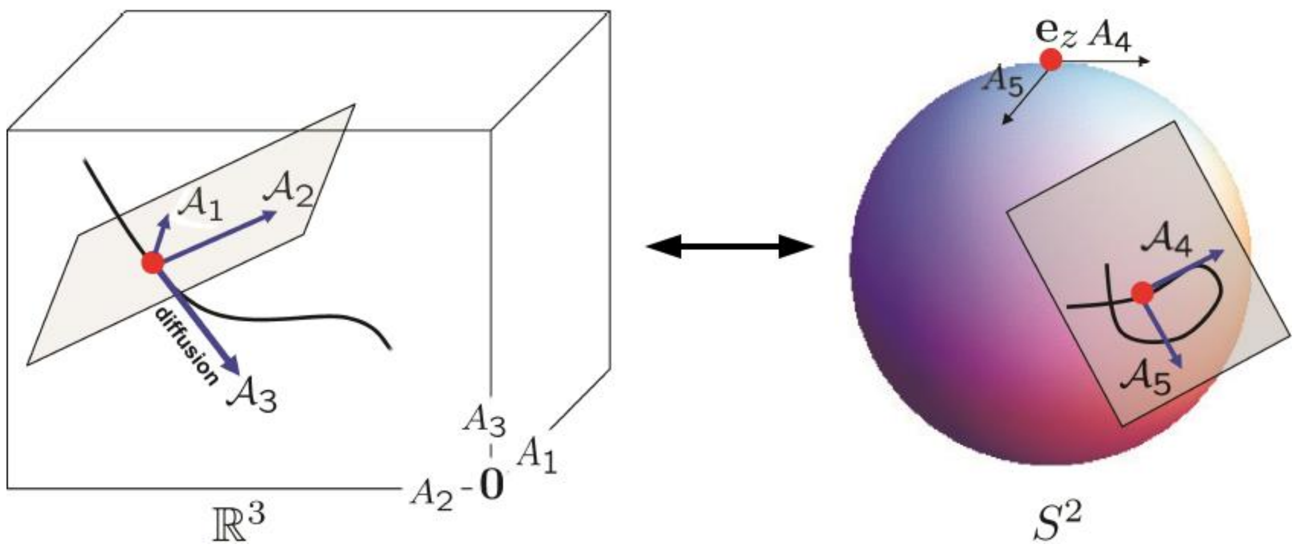


Diffusion Equation

Diffusion equation on $\mathbb{R}^3 \rtimes S^2$

$$\begin{cases} \partial_t W(\mathbf{y},\mathbf{n};t) = \left(\alpha\,(\mathcal{A}_3)^2 + \beta\left((\mathcal{A}_4)^2 + (\mathcal{A}_5)^2\right)\right) W(\mathbf{y},\mathbf{n};t) \\ W(\mathbf{y},\mathbf{n};0) = U(\mathbf{y},\mathbf{n}) \end{cases}$$

α and β set balance between spatial and angular diffusion



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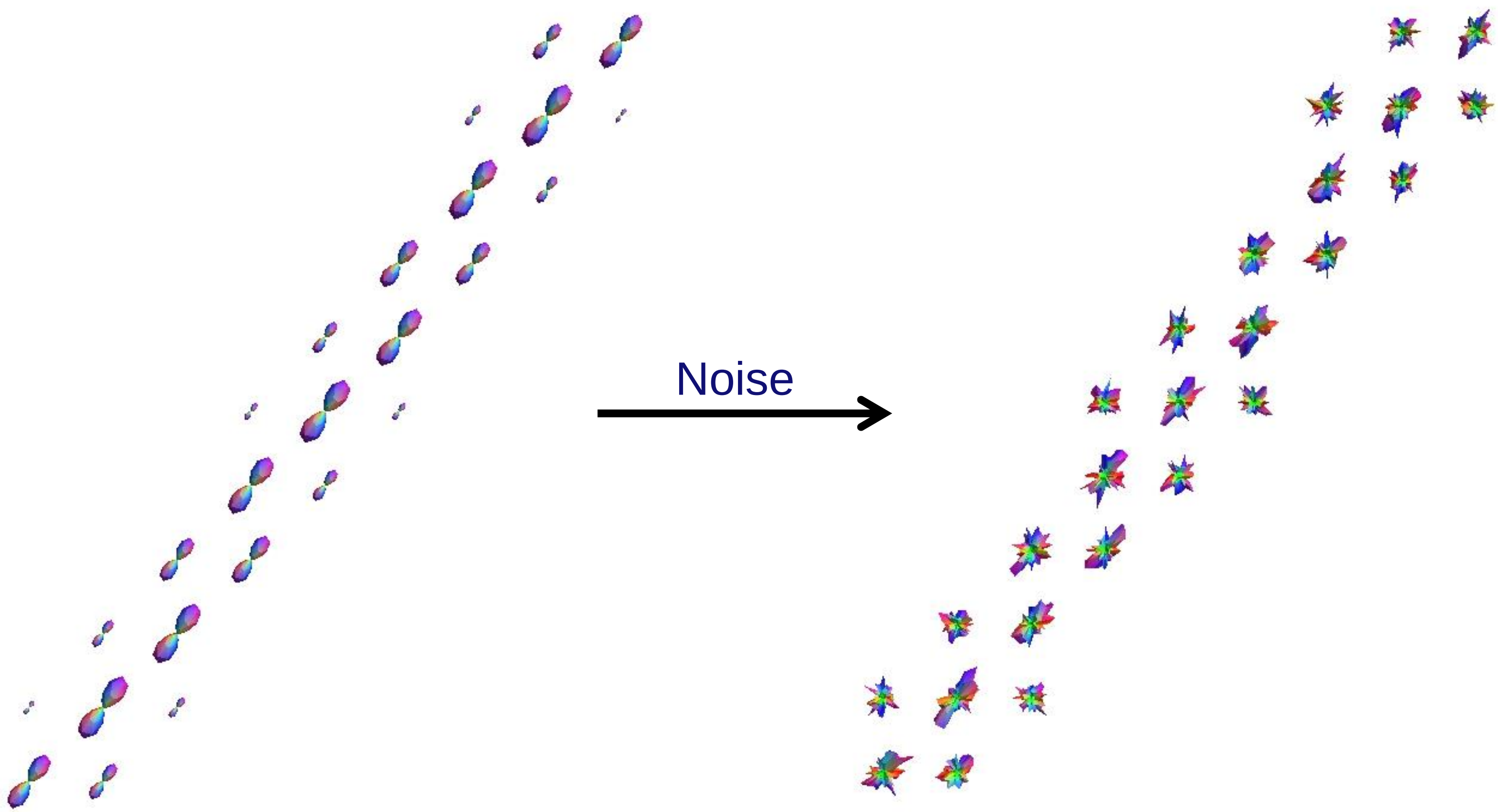
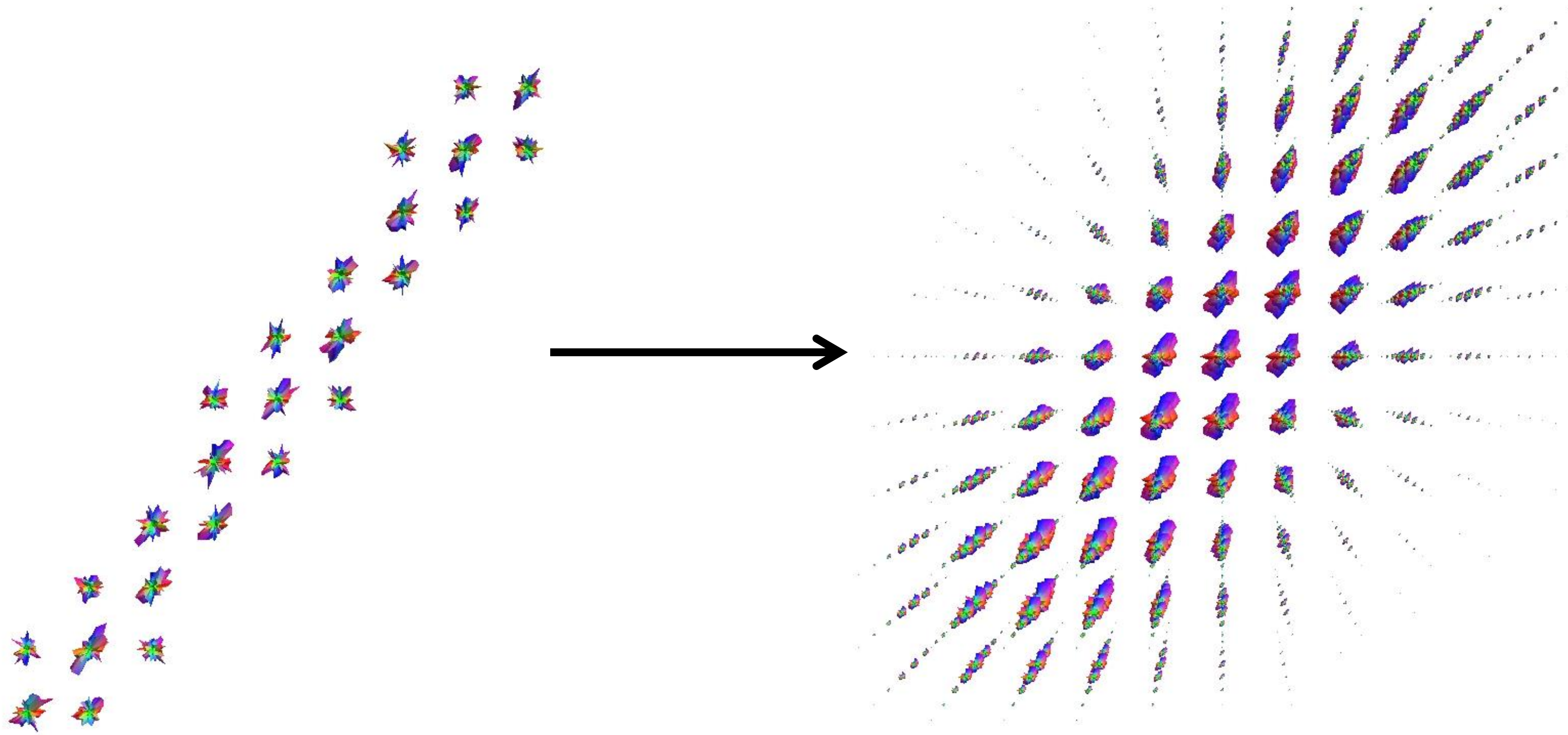
A Simple Example



Isotropic Spatial Diffusion

Isotropic Spatial Diffusion:

$$\begin{cases} \partial_t W(\mathbf{y},\mathbf{n};t) = \left((\mathcal{A}_1)^2 + (\mathcal{A}_2)^2 + (\mathcal{A}_3)^2\right) W(\mathbf{y},\mathbf{n};t) \\ W(\mathbf{y},\mathbf{n};0) = U(\mathbf{y},\mathbf{n}) \end{cases}$$



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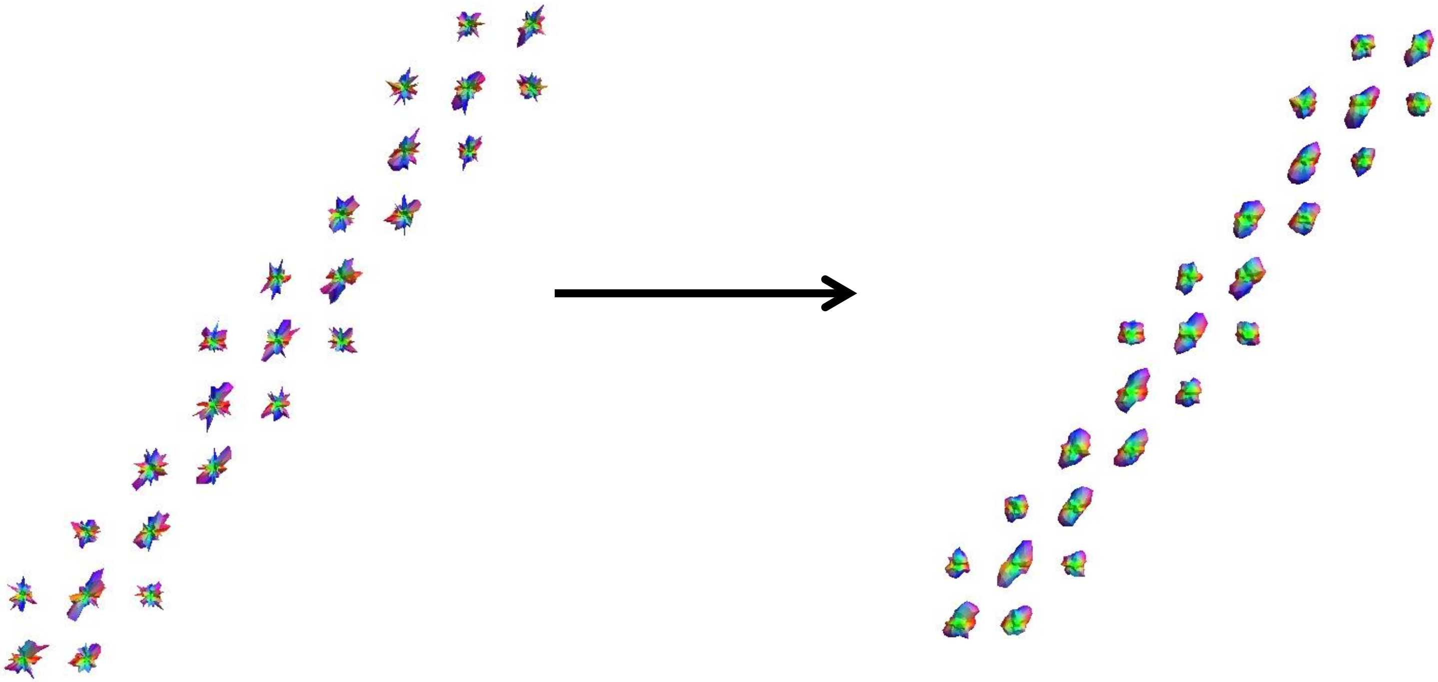
Angular Diffusion

Angular diffusion:

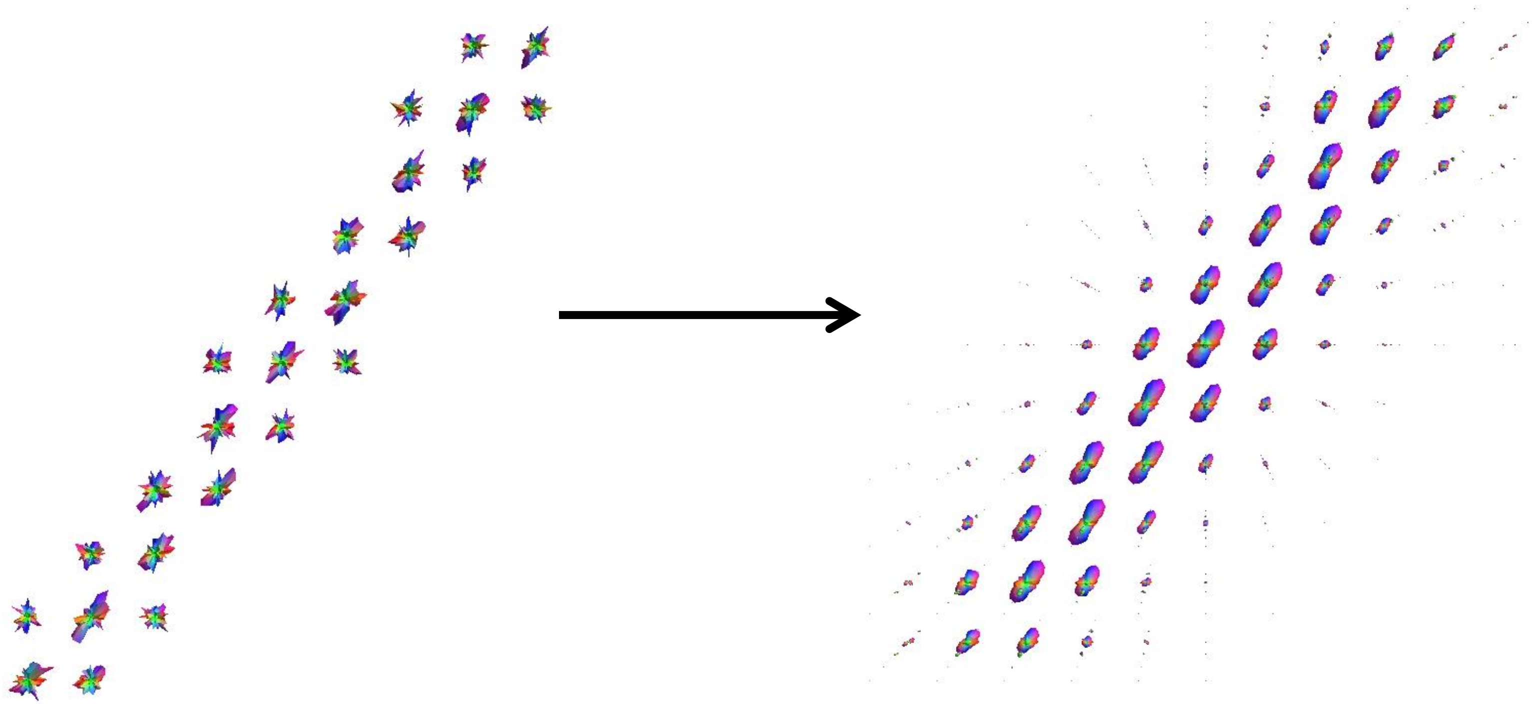
$$\begin{cases} \partial_t W(\mathbf{y},\mathbf{n};t) = \left((\mathcal{A}_4)^2 + (\mathcal{A}_5)^2\right) W(\mathbf{y},\mathbf{n};t) \\ W(\mathbf{y},\mathbf{n};0) = U(\mathbf{y},\mathbf{n}) \end{cases}$$



Contour Enhancement

Coupled diffusion:

$$\begin{cases} \partial_t W(\mathbf{y}, \mathbf{n}; t) = \left(\alpha \left(\mathcal{A}_3\right)^2 + \beta \left(\left(\mathcal{A}_4\right)^2 + \left(\mathcal{A}_5\right)^2\right)\right) W(\mathbf{y}, \mathbf{n}; t) \\ W(\mathbf{y}, \mathbf{n}; 0) = U(\mathbf{y}, \mathbf{n}) \end{cases}$$



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Edge Preserving Diffusion

- **Uses a K parameter which lowers α when the changes along the orientation are large**

- **Effect: Less shooting out of the curve**

$$\begin{cases} \partial_t W(\mathbf{y},\mathbf{n};t) = \left(\mathcal{A}_3 \tilde{\alpha} \mathcal{A}_3 + \beta \left((\mathcal{A}_4)^2 + (\mathcal{A}_5)^2\right)\right) W(\mathbf{y},\mathbf{n};t) \\ W(\mathbf{y},\mathbf{n};0) = U(\mathbf{y},\mathbf{n}) \end{cases}$$

$$\tilde{\alpha}(\mathbf{y},\mathbf{n}) = \alpha e^{-\frac{(\mathcal{A}_3 W(\mathbf{y},\mathbf{n};t))^2}{K^2}}$$

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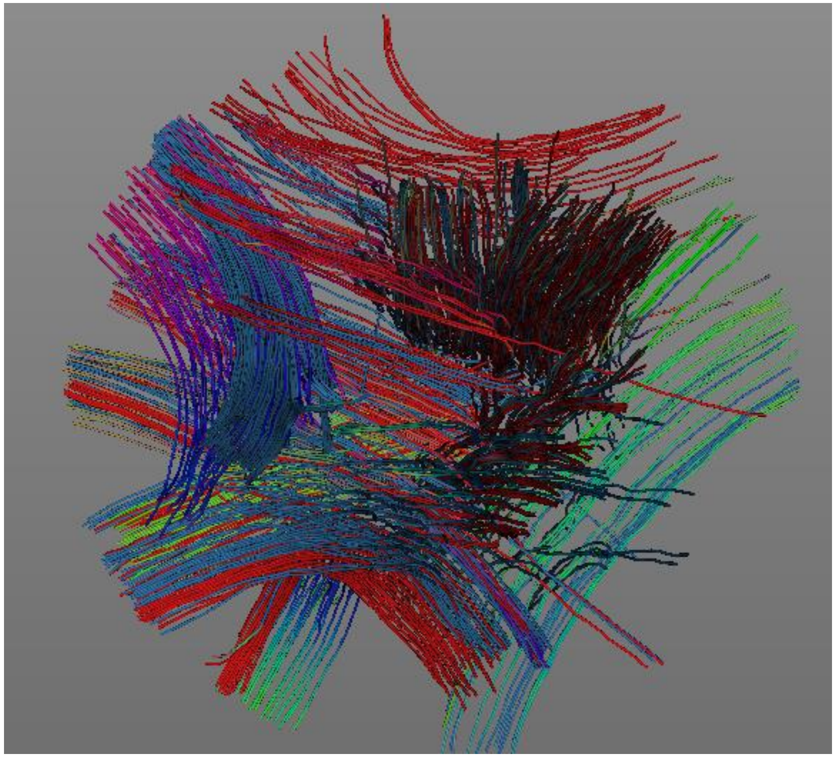
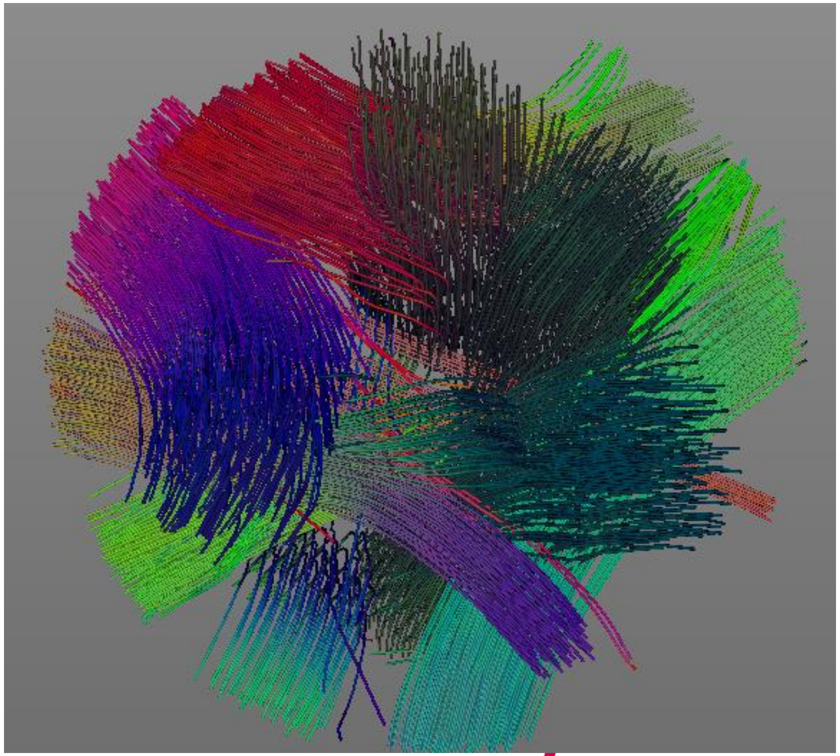
Preliminary Fiber Tracking Results

32 measured orientations, SNR=10

Only CSD



CSD + Enhancements



Summary

We introduce a new contextual enhancement method using a coupled domain of $\mathbb{R}^3 \rtimes S^2$

Aligns fiber fragments according to their surrounding

Allows tracking through crossings when using low number of gradients.

Thank you for your attention

Are there any questions?

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•http://bmia.bmt.tue.nl/people/RDuits/CreusenDuits-NM-TMA2011.pdf

•R. Duits and E. Franken. “Left-invariant diffusions on the space of positions and orientations and their application to crossing-preserving smoothing of HARDI images.” International Journal of Computer Vision, 40, 2010.

•http://bmia.bmt.tue.nl/people/RDuits/IJCV2010fulltext.pdf

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