Improved Angular Resolution with GQI2: a new Diffusion Imaging Q-Space Cartesian Lattice Reconstruction Method

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Introduction

A simple analytic transform exists which can generate sharp and smooth real ODFs. This work concentrates on comparing GQI2[1] an extension of GQI[2] with DSI[3].

Methods

DSI real ODF

$$\psi_{DSI}(\hat{\mathbf{u}}) = \int_0^\infty P(r\hat{\mathbf{u}}) r^2 dr$$

Signal to Propagator relationship

$$S(\mathbf{q}) = S_0 \int P(\mathbf{r}) \exp(i2\pi \mathbf{q}\cdot\mathbf{r}) d\mathbf{r}$$

$$\Downarrow \quad Q(\mathbf{r}) = S_0 P(\mathbf{r})$$

$$S(\mathbf{q}) = \int Q(\mathbf{r}) \exp(i2\pi \mathbf{q}\cdot\mathbf{r}) d\mathbf{r}$$

$$\Downarrow \quad S(\mathbf{q}) = S(-\mathbf{q})$$

$$Q(\mathbf{r}) = \int S(\mathbf{q}) \exp(-2\pi \mathbf{q}\cdot\mathbf{r}) d\mathbf{q}$$

$$\Downarrow \quad \text{cosine transform}$$

$$Q(\mathbf{r}) = \int S(\mathbf{q}) \cos(2\pi \mathbf{q}\cdot\mathbf{r}) \mathbf{q}$$

GQI2 real ODF

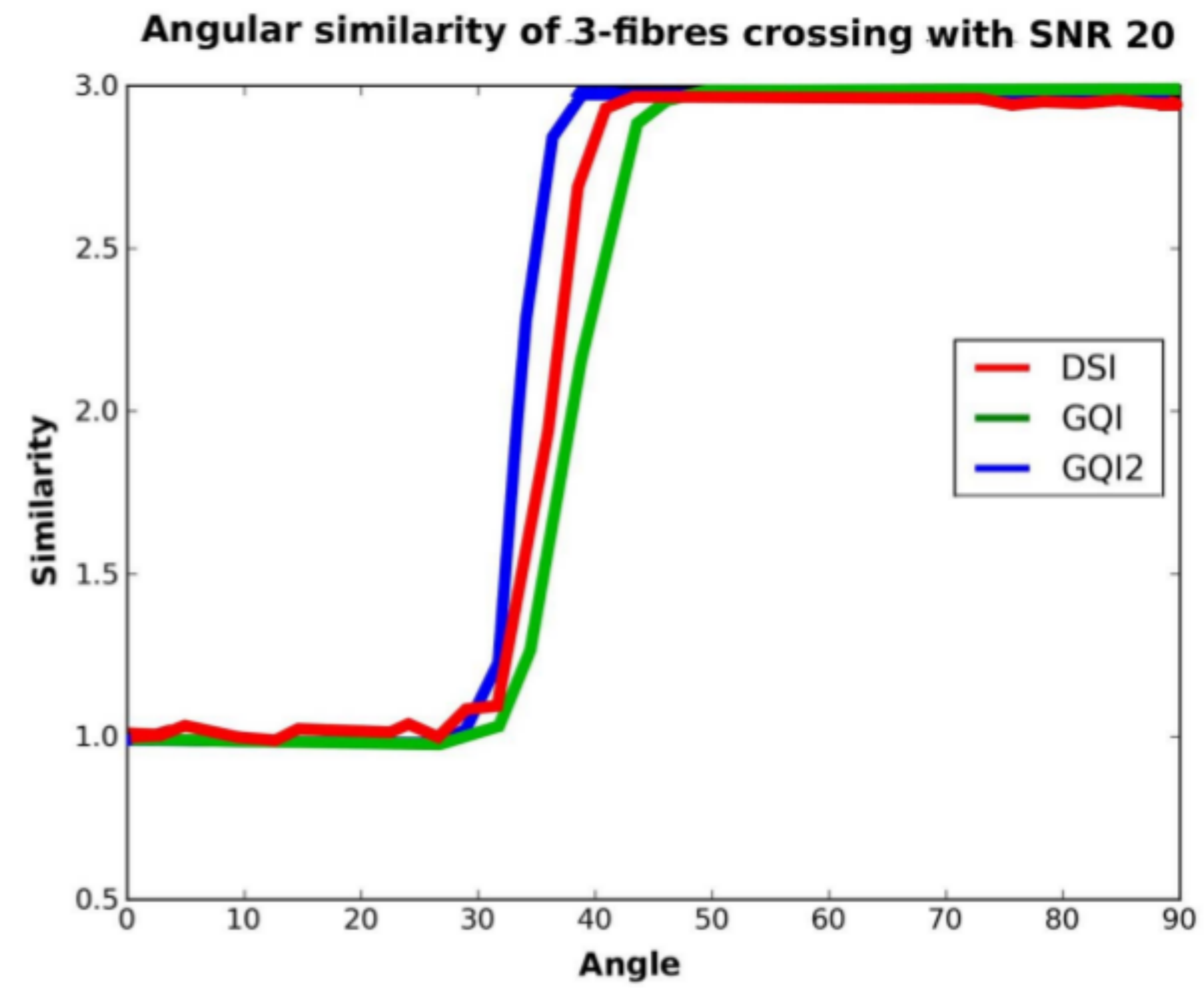
$$\psi_{GQI2}(\hat{\mathbf{u}}) = \int_0^\lambda Q(r\hat{\mathbf{u}}) r^2 dr$$

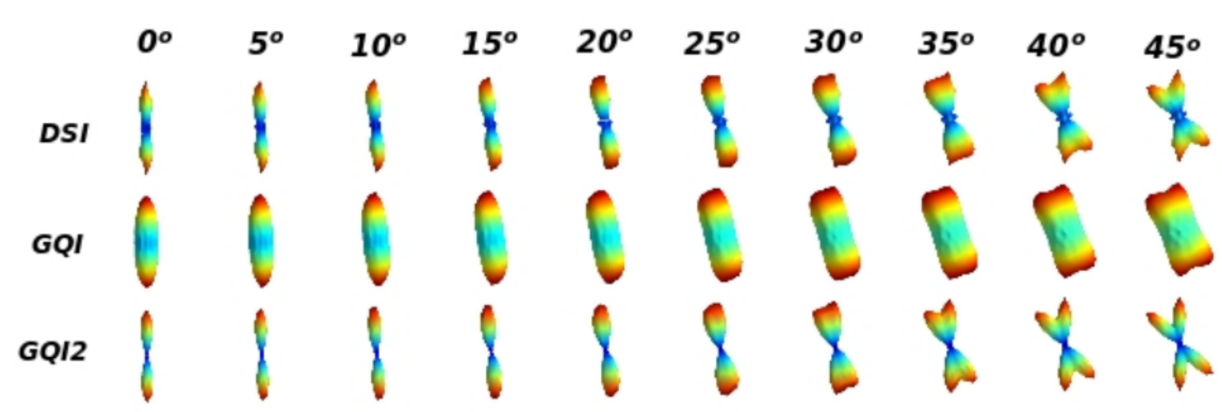
$$\psi_{GQI2}(\hat{\mathbf{u}}) = \lambda^3 \int S(\mathbf{q}) H(2\pi\lambda \mathbf{q}\cdot\hat{\mathbf{u}}) d\mathbf{q}$$

$$H(x) = \begin{cases} \dfrac{2\cos(x)}{x^2} + \dfrac{(x^2-2)\sin(x)}{x^3}, & x \neq 0 \\ 1/3, & x = 0 \end{cases}$$

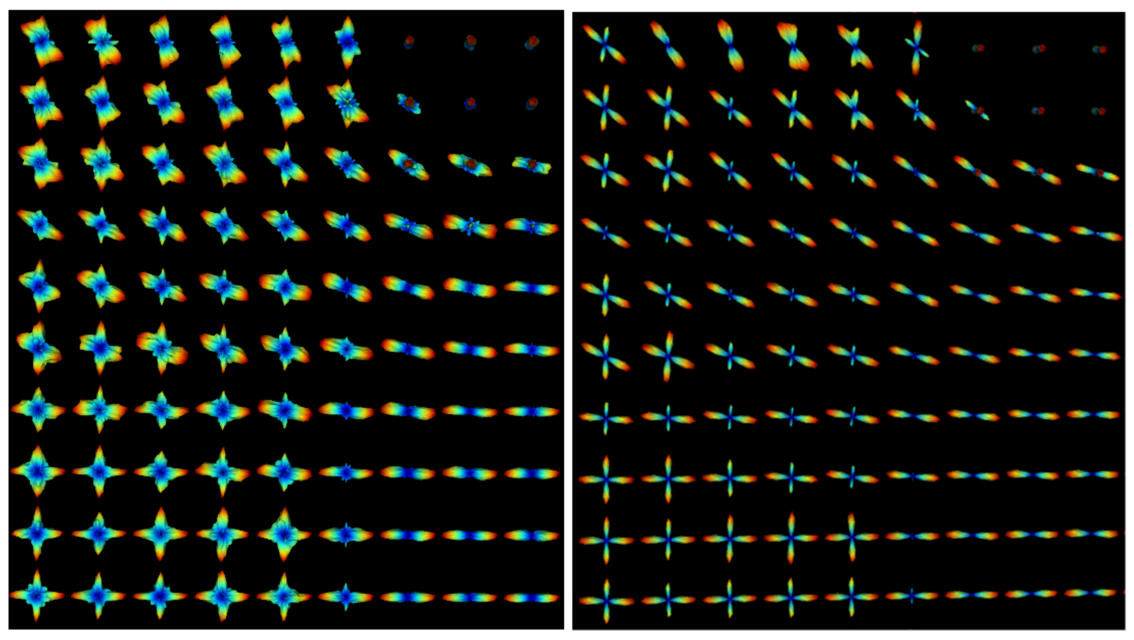
References

[1] Garyfallidis, 2012, PhD thesis
[2] Yeh, et. al, 2010, TMI
[3] Wedeen et. al, 2005, MRM
[4] Descoteaux et. al, 2009, TMI



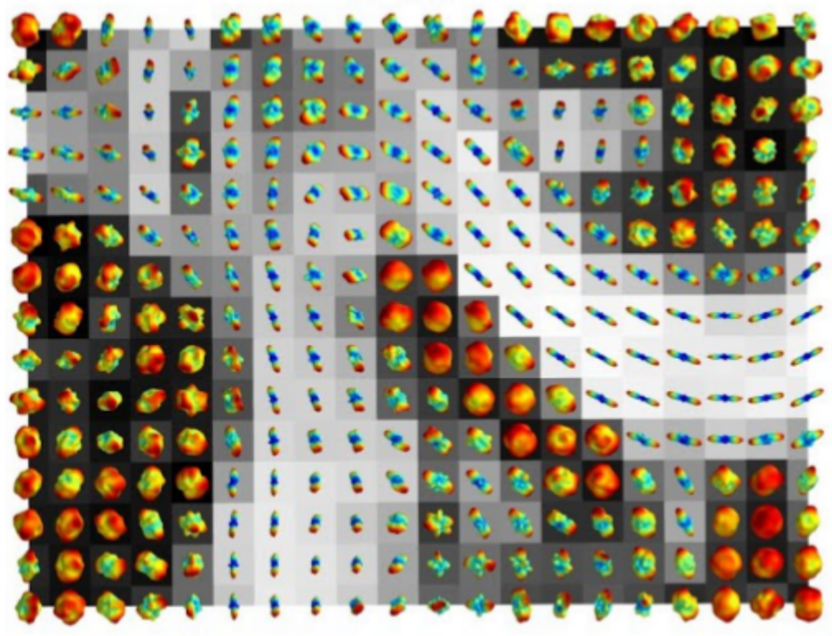


GQI2 GQID

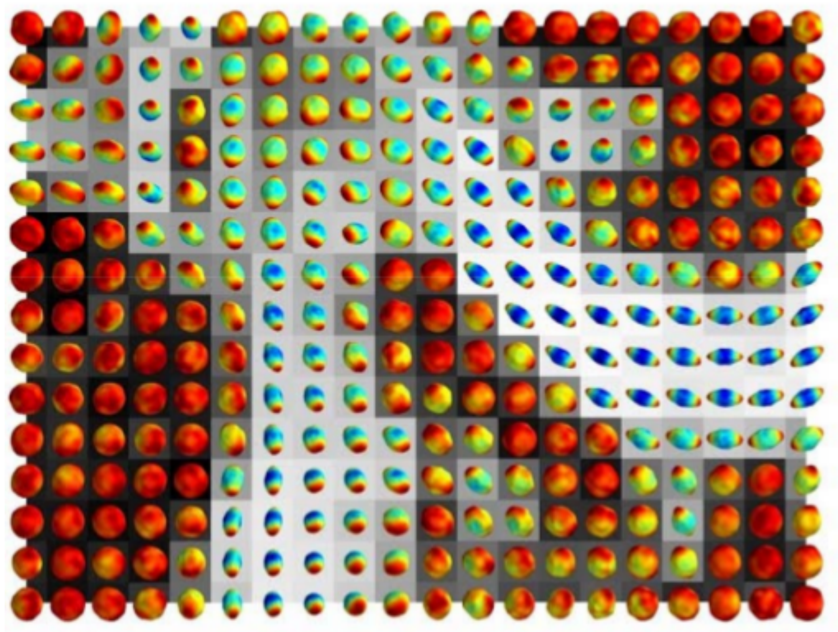


Results

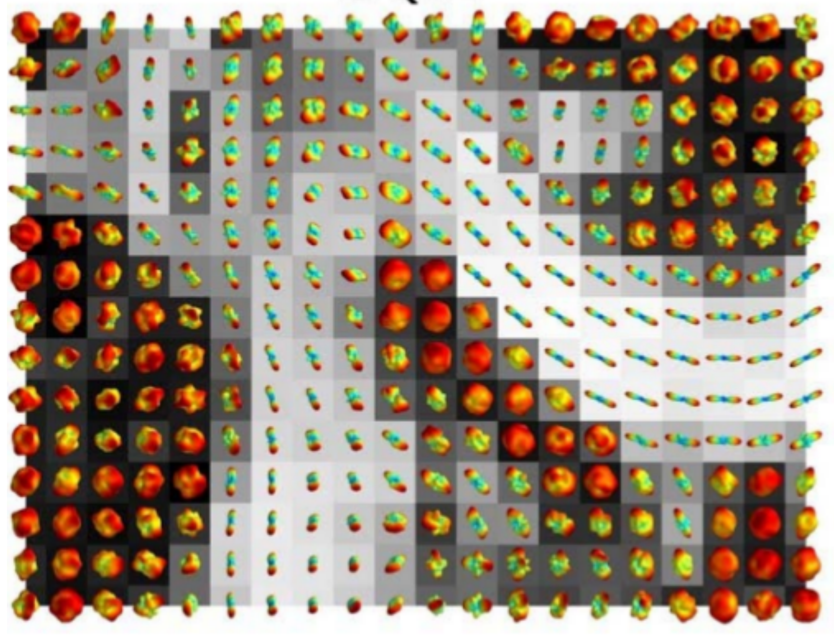
DSI



GQI



GQI2



Discussion/Conclusions

GQI2 has superior performance over DSI and GQI concerning angular resolution. It also generates smoother ODFs and it is faster to calculate than DSI. Any resulting tractography based on GQI2 will more accurately reflect complexity of underlying fiber structure with multiple crossings than GQI or DSI.

It is even possible to extend the GQI2 ODFs with SDT deconvolution (GQID)[4] which allows to recover an even sharper ODF at lower crossing angles. We are currently working on testing GQI2 and GQID with a number of different simulations, acquisition schemes and real datasets.

In summary, GQI2 is very fast to compute, it does not necessarily depend on a Cartesian lattice, but more work is needed to establish which types of grids are the best for this reconstruction method. Furthermore, it has high angular resolution and a solid theoretical basis.

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