

Tradeoffs in Supersampling of DTI Metrics



Recommendations

- For tractography, supersample DWIs so that inter-voxel distance is at most twice the integration step size. This can be computationally expensive, but prevents eigenvector orientation errors that may accumulate over the length of each tract.
- For voxelwise and tractwise derived-value statistics, be aware that not supersampling the DWIs adds uncertainty to the results. One may trade off tighter error bounds for faster computation.

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Problem Statement

- To compute a field of values derived from diffusion tensors (e.g. FA or principal eigenvectors) at high resolution from low-resolution diffusion-weighted images (DWIs), images may be supersampled to increase their resolution at three stages (see Figure A).
- A naïve approach computes the tensor-derived values (henceforth just called "values") at the source resolution and then supersamples. The optimal but expensive "gold standard" approach supersamples the DWIs at the beginning. These are not equivalent since values are nonlinear functions of the DWIs.
- There are combinatorial options between these extremes (Figure A). What are the tradeoffs?

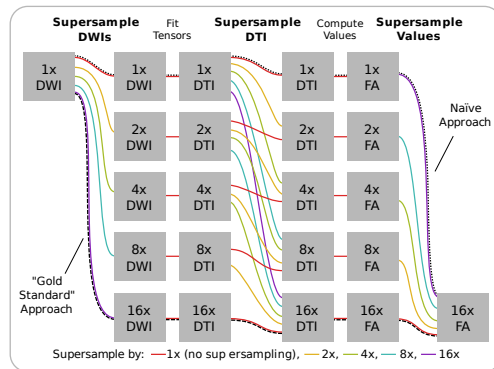


Figure A. Combinatorial possibilities of supersampling at different stages in the process of generating a 16x-magnified FA field.

Motivation

- Diffusion MRI acquisitions generate DWIs at a lower resolution than may be required for the inputs to tractography [1] or tractwise metric techniques [2].
- The initial DWIs represent the diffusion response at all points on a coarse lattice. To compute values between lattice points, one may interpolate from this lattice.
- Alternately, one may use efficient supersampling techniques to cheaply increase the resolution of the lattice, so that interpolation happens between more closely-spaced lattice points, giving higher accuracy.

References

- [1] S. Mori and P. van Zijl, NMR Biomed 15(7-8), p. 468-480, 2002.
 - [2] Z. Ding et al, MRM 49(4), p. 716-721, 2003.
- Please see the abstract for further references as well as further details about acquisition and processing.

Acknowledgment

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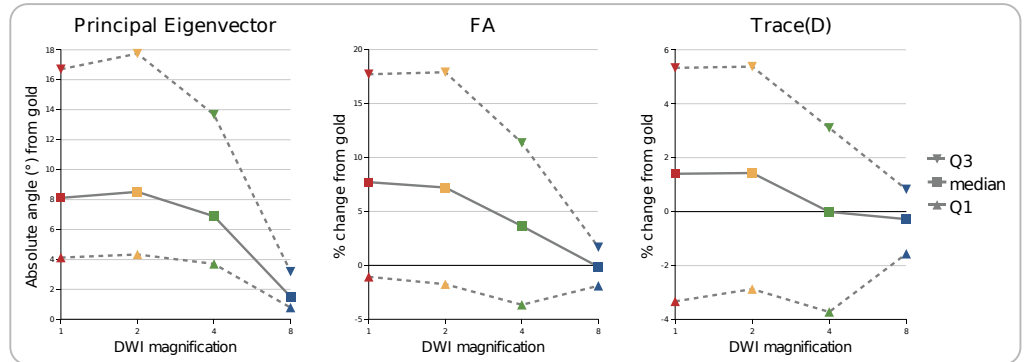


Figure B. First and third quartiles around median deviations from the gold standard for selected techniques marked in Figure C. In the 1x DTI magnification case, DTIs are magnified 2x; in all others there is no DTI supersampling. The remaining magnification to bring the fields of values to 16x is performed on those fields. Note that not only does median accuracy increase with increasing DTI magnification, the variation tightens as well.

Method

- Source DWIs are an 8x8x8-voxel cube from a dw-MRI acquisition with 64 directions at $b=1000$ s/mm² and 10 $b=0$ volumes.
- We restrict supersampling to factors that are powers of 2 and use a sinc convolution kernel. We may supersample the DWIs, the DTI, or the field of values.
- We compare all 15 combinations that result in a 16x magnified lattice of values (Figure A). Our "gold standard" technique, to which all others are compared, is supersampling the DWIs 16x with no further supersampling.

Discussion

- Our "gold standard" technique is equivalent to the standard practice of zero-padding k -space data before DTI reconstruction.
- The computational cost of convolution-based supersampling is dominated by that of tensor fitting.
- Greater supersampling of the DWIs gives better results, but requires more tensor-fitting operations to compute the DTI: w^3 as many for w x-magnified DWIs.
- Supersampling the DTI gives no appreciable benefit unless the DWIs are not supersampled at all.
- In tractography, orientation errors of the principle eigenvector will accumulate over the length of each integral curve.

Results

- Figure B shows, for selected techniques, medians and interquartile ranges of deviation from the gold standard result across all voxels of the 16x magnified field of values. IQRs are representative of those not shown. Figure B shows the median deviation for all techniques.

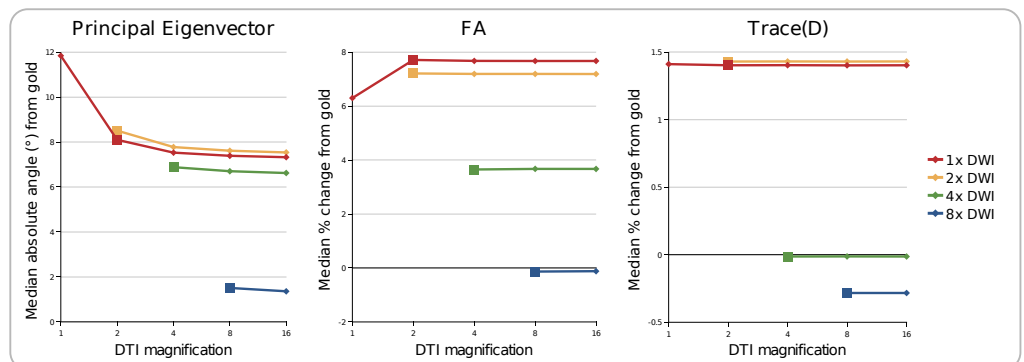


Figure C. Median deviations from the gold standard for three different values for all supersampling techniques. The X-axis, "DTI magnification", indicates the magnification level that results from supersampling the DTI, if at all. Note that supersampling the DTI has almost no effect unless the DWI is not supersampled. Data points marked with large squares are reproduced with error bars in Figure B.