Tradeoffs in Supersampling of DTI Metrics

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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 naive 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?

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 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


Please see the abstract for further references as well as further details about acquisition and processing.

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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.

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 magnification of values (Figure A). Our "gold standard" technique, to which all others are compared, is supersampling the DWIs 16x with no further supersampling.

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.

Discussion

• Our "gold standard" technique is equivalent to the standard practice of zero-padding k-space data before DWI 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 [1] as many for wx-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.

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