Performance Comparison of Direct Fourier Sum and Regridding Reconstructions of Sodium TPI

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INTRODUCTION

The quantification of MR signals in biochemical MR imaging has important clinical applications. Quantitative sodium imaging is an example of a measurement that can be used for assessing tissue viability in the setting of stroke and tumor treatment [1]. Many non-proton MR nuclei, including sodium, have short transverse relaxation times and therefore require special acquisition strategies. Twisted projection imaging (TPI) is an important example of an acquisition scheme that enables clinically useful tissue sodium concentration maps with 5 mm isotropic resolution to be acquired in less than 9 minutes [2]. Such a non-Cartesian k-space acquisition can be processed into images by regridding the data to a Cartesian grid and using the Fast Fourier Transform (FFT) [3] or by more the computationally intensive direct Fourier sum (DFS) of the sampled data. The signal-to-noise ratio (SNR) and spatial resolution of the two reconstruction methods are compared for sodium imaging of a high-resolution phantom at 9.4T.

DIRECT FOURIER SUM (DFS) RECONSTRUCTION

Any function can be reconstructed from its continuous Fourier transform (FT). A support-limited function can be periodically extended and represented by a discrete Fourier series, which means it can be perfectly reconstructed from samples of its Fourier transform. However, if the samples do not lie on a Cartesian grid no perfect reconstruction is possible. A common approach to the reconstruction of such data is to first interpolate the known non-Cartesian data on to a uniform grid and then utilize the perfect reconstruction from the grid. This is known as regridding [3]. Since perfect reconstruction is achieved from Cartesian samples, inaccuracies in regridding-based reconstructions are introduced during the interpolation step.

As an alternative to a regridding reconstruction, one can approximate the continuous inverse FT (iFT) as a summation of the measured (non-Cartesian) Fourier components with proper weights, which we term the DFS. The most obvious choice of weights is the inverse of the sampling density. For a TPI acquisition these weights will increase as $|k|^2$ for the radial portion of the trajectory and will be constant for the twist portion [2]. This weighting leads to the approximation of the iFT integral as the Riemann sum (rectangular integration).

METHODS

Sodium imaging was performed on a resolution phantom using the 9.4T 80 cm MR scanner described in [4] and a TPI acquisition scheme (TR/TE=150/0.76 ms, 0.2 radial fraction, 5mm isotropic resolution, 4mT/m max. gradient, 50 KHz readout bandwidth, 1028 total trajectories, 946 points per trajectory). The data were reconstructed using the regridding (Kaiser-Bessel kernel) [3,4] and DFS reconstructions. Reconstructions of the resolution phantom were generated using from 100 to 900 points of the k-space trajectories in 20-point intervals. The regridding reconstruction for the maximum number of points is shown in figure 1. As a measure of resolution, we focus on the region of interest (ROI), which contains 4 features with 5 mm spacing and define our resolution measure as feature visibility evaluated as the average difference between the mean of the ROI and the minima of the ROI. To alleviate the issue of pixel registration, only the well-registered point minima are used. The measure of SNR is taken to be the mean inside a homogeneous region divided by the standard deviation of the background. To evaluate the point spread function of regridding and DFS reconstructions, TPI data from a point source was generated using a forward model and was reconstructed with the two methods.

RESULTS

The evolution of feature visibility and SNR are plotted in figure 2. It can be seen that for both reconstruction methods the feature visibility increases with acquisition time, but starts leveling off around 15 ms. The improvement comes at the expense of lower SNR due to more noise being included in the reconstruction. The DFS has lower feature visibility than the regridding reconstruction, but higher SNR. The point spread functions from the reconstructions of simulated point TPI data had the full-width half-maxima of 7.2 mm for regridding and FFT and 8.1 mm for the DFS reconstruction, confirming the superior resolution of the regridding-based approach. In principle, it may be possible to optimize DFS utilizing more accurate integration methods.

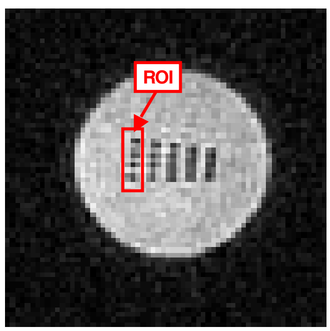

Fig.1: A reconstruction of a central slice of the reconstruction of a resolution phantom showing the resolution feature.

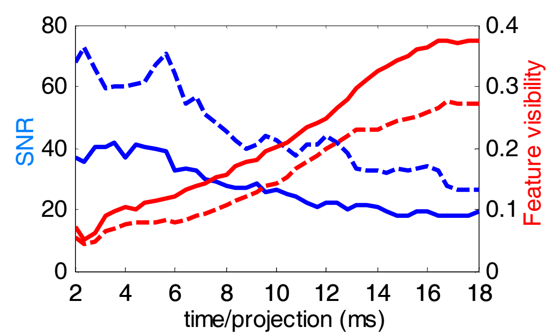

Fig. 2: Feature visibility measure (red) and a signal to noise ratio measure (blue) as a function of acquisition time for points contributing to the regridding (solid line) and DFS (dashed line) reconstructions.

CONCLUSION

The spatial resolution is higher while the SNR is lower for the image reconstruction performed with regridding and the FFT than for DFS. This result reflects the narrower point spread function of the regridding and FFT reconstruction as compared to the DFS process and justifies the use of the computationally simple approach of regridding and FFT in for clinical sodium imaging.

REFERENCES

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