Accelerated ^{1}H-MRSI: Artifact Reduction by Target-Driven Reconstruction

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Introduction

Magnetic Resonance Spectroscopic Imaging (MRSI) is a powerful technique to gain insight into physiological processes in the human body. Since 2D MRSI examinations typically last excessively long, the use of acceleration techniques is of great importance. Here, we use a SENSE approach [1, 2, 3]. The Spatial Response Function (SRF) indicates which spatial areas contribute to the final voxel content. Ideally, it vanishes outside the voxel of interest (VOI). However, since the SRF is a superposition of the encoding functions used, whose number is finite, it typically exhibits noticeable side lobes. In parallel MRSI, where the number of ***k***-space sampling points is extremely low, this detrimental effect is particularly pronounced. As a result, voxel spectra often contain unwanted contributions by signal originating elsewhere, e.g. subcranial fat signal in brain matter voxels. ***In this work***, we demonstrate a novel reconstruction approach that allows to address this issue by minimizing a cost function that contains the deviation from a predefined SRF target.

Theory and Methods

Algorithm: Reconstruction was performed by applying a reconstruction matrix F to raw ***k***-space data. In our proposed method [4], F is calculated as the minimum of the cost function $\Delta_\pi = (F\Psi F^H)_{\pi,\pi} + \|(FE - T)_\pi\|_2^2$ for each voxel π. Here, E is the encoding matrix and Ψ the noise covariance matrix; H indicates the Hermitean adjoint. The first term optimizes SNR, whereas the second term minimizes the deviation of the resulting SRF FE from an initially chosen target T. Target functions were centered on the VOI and are displayed in Fig. 1. Note that T=Boxcar mimics standard SENSE reconstruction. T=Gaussian is expected to be a more realistic approximation to the actual SRF, while T=|Sinc| was chosen for comparison. No spatial apodization or spectral filtering was applied.

Data acquisition: Transversal slice SELOVS MRSI [5] (FOV: 240 mm x 240 mm, voxel size 10 mm x 10 mm x 12 mm) of a volunteer brain (see Fig. 2) were acquired on a 3T MR system (Philips Medical Systems, Best, The Netherlands) with an 8-channel head coil along with the coil sensitivity information. Outer volume and VAPOR water suppression was employed, and twofold cartesian ***k***-space undersampling was used.

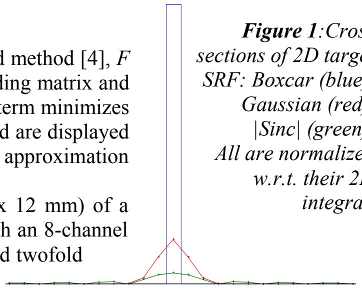


***Figure 1**:Cross sections of 2D target SRF: Boxcar (blue), Gaussian (red), |Sinc| (green). All are normalized w.r.t. their 2D integral.*

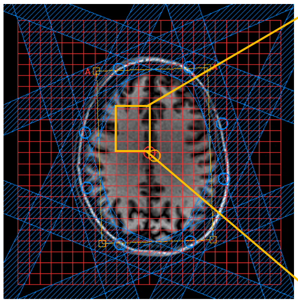


***Figure 2**: 24x24 voxel slice with fat suppression slabs (blue)*

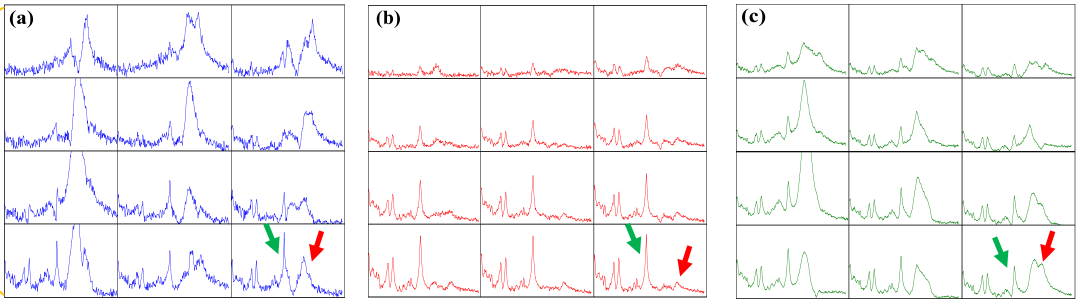


***Figure 3**: A subset of reconstructed spectra with (a) T=Boxcar, (b) T=Gaussian and (c) T=|Sinc|*

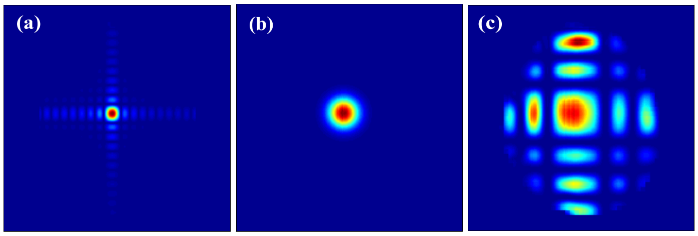
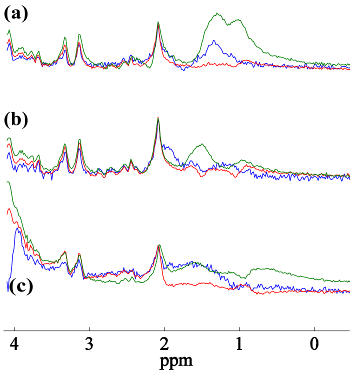


***Figure 4**: Resulting SRF for (a) T=Boxcar, (b) T=Gaussian and (c) T=|Sinc|*

→ ***Figure 5**: Reconstructed spectra with T=Boxcar (blue), T=Gaussian (red) and T=|Sinc| (green) from (a) slice 1 with undersampling in RL direction, (b) slice 1, AP and (c) slice 2, RL. All spectra have been normalized w.r.t. the NAA peak*



Results

Fig. 3 shows a subset of voxel spectra in the range from -0.5 ppm to 4.1 ppm. Despite OVS, fat contamination peaks (red arrows) are clearly visible next to the NAA peak (green arrows). They are partly frequency-shifted due to shim imperfections at their original location. The use of Gaussian-shaped SRF targets results in largely reduced fat artifacts in comparison to the standard reconstruction. Examples of the SRFs resulting from the calculation of the reconstruction matrix are shown in Fig. 4 for a VOI in the center of the brain (lower right in Fig. 3). In the standard SENSE case, considerable side lobes remain. A Gaussian target leads to a somewhat wider, but well-localized single peak, corresponding to the reduced fat fold-over from the edge of the object. With a Sinc target, hefty side lobe aliasing occurs, as is reflected by the solid fat peaks shown in Fig. 3c. These findings are substantiated by the comparison shown in Fig. 5, as the above-stated trends can, to varying extent, be observed in both undersampling directions and are found in various different transversal slices of the volunteer brain. The remaining metabolite peaks can be clearly identified, independent of the chosen target SRF.

Conclusion

SENSE reconstruction in conjunction with a predefined target SRF is used to facilitate accelerated MRSI acquisition. We demonstrate that fine-tuning of reconstruction parameters enables the suppression of residual fat fold-over artifacts. In particular, using Gaussian-shaped SRF targets was found to lead to spectra of superior quality compared to standard reconstruction.

References

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