High speed magnetic resonance spectroscopic imaging using wavelet encoding and parallel imaging

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Introduction: It has been shown that wavelet encoding (WE) can reduce acquisition time in magnetic resonance spectroscopic imaging (MRSI) to $T=N^3.T_{eff}+(7.N^2/3-4/3).(TR-T_{eff})$ [1,2]. To further reduce acquisition time, we report its combination with Parallel Imaging (PI, WEPI). In PI multiple receiver coils covering independent and fixed object regions are used to collect MR signals [3]. In wavelet encoding, wavelet domain is filled by using shaped RF pulses with profiles resembling Haar scale, and dilated and translated wavelet functions to acquire amplitude modulated MR signals from sub-spaces with variable sizes and positions [1]. Similar to Fourier encoding with PI where a number of k-space lines determined by the speed factor R are not acquired and reconstructed from MR signals previously acquired, a set of wavelet domain lines are also skipped and reconstructed from the previously acquired ones. The first line of the wavelet domain corresponding to Haar scale function is always acquired. The subsequent wavelet domain lines are either acquired or reconstructed depending on coil region versus sub-space. If the excited sub-spaces are larger than the coil regions, wavelet domain lines are reconstructed from the previous acquisition. If the excited sub-spaces are equal or smaller in size than the coil regions, the corresponding wavelet domain lines are simultaneously acquired using composite RF pulses (Fig.1). This combination reduces acquisition time and minimizes inherent loss of signal-to-noise ratio (SNR) in parallel imaging. (T_{eff} = sequence time-length, TR =repetition time)

Material and Method: The usefulness of WEPI is tested by simulating 4 birdcages receiver coils which accomplish spatial localization similar to the shaped RF pulses in wavelet encoding. Assuming that R=4 and the desired spatial resolution N=16, an RF pulse excitation with a boxcar profile resembling Haar scale function covering the FOV is applied and 4 MR signals are collected from the 4 receiver coils (Line 1 Fig. 1). Using the product of the coil sensitivities and RF pulse profiles (Fig. 2) these MR signals are modulated to fill the first line of the wavelet domain (solid brown line Fig. 1). The following three wavelet domain lines are reconstructed from amplitude signal modulations of the previous acquisition, since the size of the excited sub-space is bigger than the coil region (brown dashed lines Figure. 1). The remaining N-R lines, where the sub-space sizes are equal or smaller than the coil regions, are simultaneously acquired in series of R signal acquisitions using a composite RF pulse containing R sub-pulses with dual-band profiles resembling dilated and translated Haar wavelets (red and blue lines in Figure 1). Inverse wavelet transform is performed on the wavelet domain data to obtain the MRSI image. Acquisition time is reduced to $T=(N^3/R)T_{eff}+[3N^2/R-2(N/R)^2/3-4/3](TR-T_{eff})$.With an undersampling degree = N-R, the SNR in WEPI $SNR_{WEPI}=\sqrt{\frac{(N^2+2).(\log 2(N)-\log 2(R)+1)}{g.(N^2-R^2+3).(\log 2(N)+1)}}.SNR_{WE}$ [4] is higher than Fourier $SNR_{FE|PI}=SNR_{FE}/\sqrt{R}.g$ [3].

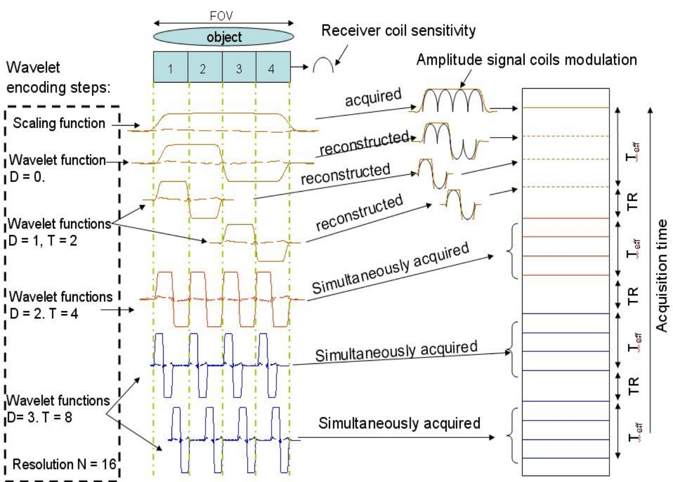

Figure 1: Acquired and reconstructed wavelet domain lines and acquisition time reduction in WEPI for a speed factor R = 4.

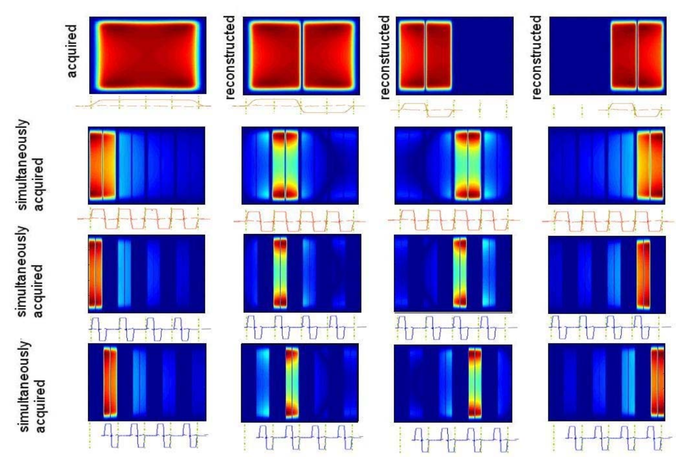

Figure 2: Acquired and reconstructed wavelet lines as a result of RF profiles and coil sensitivities.

Result/Conclusion: Figure 2 displays simulated results of the acquired and reconstructed wavelet domain lines as a result of RF pulse product profiles and the coil sensitivity maps. Using these calculated shapes, we applied the WEPI method on an in-vivo brain tumor choline MRSI image (Figure 3 left). The results show that the WEPI image (Figure 3 centre) is similar to the standard input image. The mean value of the difference in pixel intensity between the two images is 1.46%±, 3.24%. The amount of SNR loss in WEPI ranges between 0.7 and 0.9 as function of R and N. Combining parallel imaging with wavelet encoding further reduces acquisition time with minimum SNR loss compared to Fourier encoding.

Acknowledgement: Sponsored by NSERC-Discovery Grant. RGPIN 327593-06

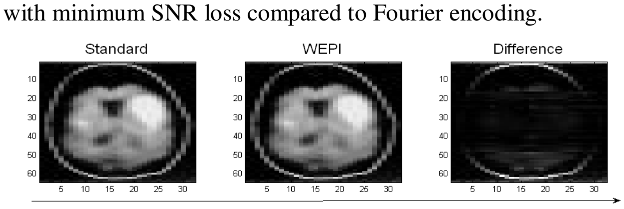

Figure 3: Simulation results of WEPI on brain choline MRSI image.

Reference:
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