Why Less can be More: A Dynamic Coil Selection Algorithm for Real-Time Interactive MRI

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Introduction

With the advent of parallel MRI techniques, phased array coil systems with a large number of elements have been introduced. Array coils combine the high local sensitivity with a high global SNR. In conventional diagnostic MRI only those rf coils are selected for imaging that contribute significantly to the MR signal in a selected field-of-view (FOV). In interactive real-time MRI, however, the slice orientation and FOV is continuously changing, and the optimal choice of coils for the initial slice orientation might later lead to foldover artifacts and suboptimal SNR. In this work an algorithm is presented that dynamically selects coil elements depending on their position relative to the current FOV using prior information about the coils such as relative SNR and center of sensitivity.

Methods

$$x_{CM}^{n} := \frac{\int P^n(x)\cdot x\,\mathrm{d}x}{\int P^n(x)\,\mathrm{d}x} \quad \text{with} \quad P(x) := \iint \left|S(x,y,z)\right| \mathrm{d}y\mathrm{d}z \qquad \text{(Eq. 1)}$$

$$SNR = \frac{\int_{k-space\,-centre} \left|S(k_x,k_y)\right| d^2k}{\int_{k-space\,periphery} S\left|(k_x,k_y)\right| d^2k} \qquad \text{(Eq. 2)}$$

In the dynamic algorithm, coil elements are selected for imaging depending on their distance to the selected slice. To compute a distance, a center-of-sensitivity position is assigned to each coil. Therefore, a reference measurement is performed with all coil elements in the MR scanner prior to the interactive scan. Since coil positions need only be determined with a resolution of several millimeters, a fast low-resolution interleaved multi-slice 2D gradient echo sequence was used that provides a spin-density weighted contrast. Equation 1 describes the computation of the x-coordinate x_{CM} of the center-of-sensitivity position from the signal $S(x,y,z)$ with the intermediate calculation of a projection $P(x)$. Note, that for $n = 1$ Eq. 1 reduces to a center-of-mass calculation. To avoid aliasing, the dynamic coil selection algorithm used only those coils whose projected center of sensitivity coincided with the current FOV.
To suppress coils which do not significantly contribute to the overall MR signal, a second SNR-based selection criterion was introduced. Here, the SNR of an individual coil is approximated in k-space from Eq. 2, where it is assumed, the predominant signal energy is found in the k-space center and the noise can be estimated by integrating over the k-space periphery. In initial experiments it was verified, that this SNR estimation correlates well with SNR-values determined from *in vivo* MR images.

Measurements

The dynamic algorithm was tested on volunteer images of the abdomen acquired at a 1.5T clinical MR scanner (Siemens Magnetom Symphony) using a 6-element spine coil (SP1,…,SP6) and 2-element body coil array (BA1, BA2). For reference measurements the following parameters were used: FOV = 500 mm × 500 mm, matrix 64×64, TE = 2.14 ms, TR = 200 ms, 64 slices, slice thickness = 7.8 mm. TrueFISP raw data were acquired separately for all coil elements at different slice orientations and positions using the following parameters: TR = 30 ms, TE = 4.3 ms, $\alpha = 70°$, FOV = 300 mm × 300 mm, slice thickness = 5 mm and matrix 256 × 256. Different parameters in the coil selection criteria (n = 1,2,3; size or integration regions in SNR-calculation) were evaluated. Finally, selected image data were combined with the sum-of-squares algorithm and compared to conventional reconstruction with all coil elements.

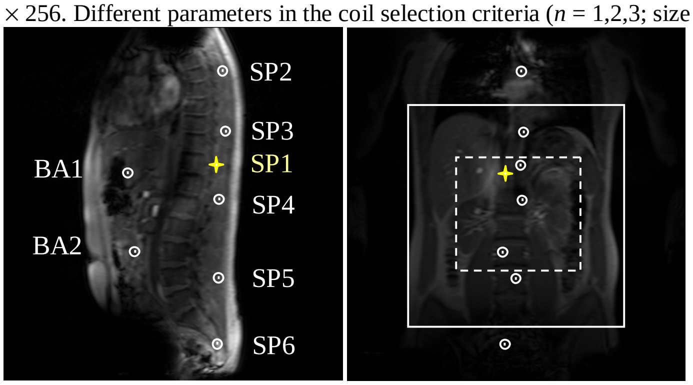

Fig 1:. Saggital and coronal localizer images with the center-of-sensitivity positions. The outlined white box marks the FOV of the trueFISP image acquisition, and the dashed box denotes the FOV used for geometric coil selection.

Results and Discussion

In Fig. 1 the center-of-sensitivity position of Eq. 1 is shown for all coil elements. Here, a weighting factor of $n = 3$ was used. Coil element SP1 was located outside the sensitive imaging volume and only noise was acquired through its receiver channel, which led to the arbitrary co-ordinates shown. The subsequent SNR criterion automatically removed this coil from reconstruction. Geometric coil selection further removed coil elements SP2, SP3, SP5 and SP6.
Fig. 2. compares the result of dynamic coil selection (b) with the image reconstructed from all 8 coil elements (a). In Fig. 2a an SNR of 3.6 is measured in the kidney, however, foldover artifacts are seen, that render major parts of the image uninterpretable. Geometric coil selection (Fig. 2b) eliminates these artifacts, and SNR increases to 4.3. Final application of the SNR criterion (Fig. 2c) further increases SNR to 4.6.
Apart from artifact and noise reduction the algorithm offers the possibility to adjust the number of separate coils to the numeric capabilities of existing image reconstruction hardware. This would allow to limit the number of reconstructed coil elements to a fixed value to account for reconstruction computer limitations and, simultaneously, acquiring real-time interactive images with high SNR. Dynamic coil selection is independent of the actual data acquisition scheme and can readily be combined with other post-processing methods (e.g. parallel MRI) to shorten reconstruction times.

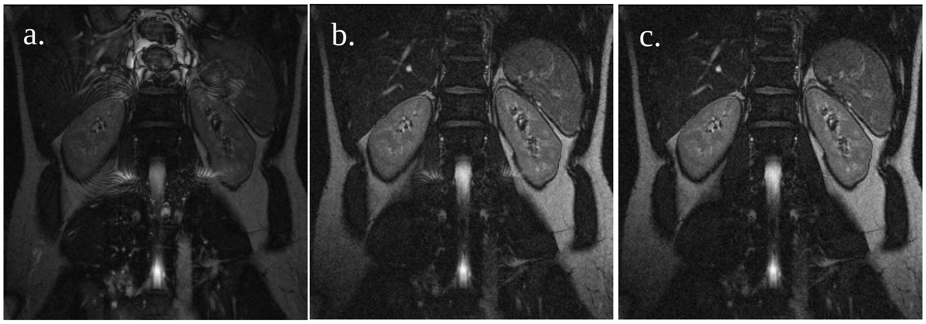

Fig 2: (a) Conventional sum-of-squares image reconstructed from all coil elements. (b) Image after geometrical coil selection (BA1, BA2, SP1, SP4). (c) Final image after SNR selection reconstructed from SP4 and BA1 and BA2 only.