Finding the optimal sampling pattern in 2D parallel imaging for a given receiver coil configuration

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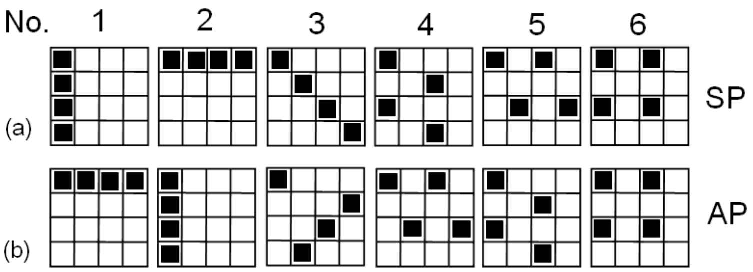
Introduction:

One dimensional parallel imaging is limited to reduction factors of approximately R=4, due to intrinsic limitations on the sensitivity variations in one spatial dimension. Besides the high intrinsic SNR in 2D parallel imaging, due to the volume excitation, scan time reduction can be performed in two spatial dimensions simultaneously, thereby exploiting the sensitivity variations more efficiently, which results in significantly higher reduction factors. It has recently been shown that besides standard 2D SENSE reductions [1], 2D CAIPIRINHA–type [2] reductions are also applicable, which use sampling patterns with sample positions shifted from their normal positions. Thus, there are multiple 2D sampling patterns conceivable given a specific reduction factor. One central question to answer is which sampling pattern exploits the sensitivity variations provided by the underlying coil configuration most efficiently and therefore provides the best image quality after parallel imaging reconstruction. In this work, we show one simple but efficient possibility for finding this optimal 2D sampling pattern for a given sample and coil geometry.

Methods:

In order to find all possible 2D Cartesian sampling patterns given a specific reduction factor R, it is useful to consider an $R\times R$ section of the sampling scheme [3]. In this elementary *RxR* cell, *R* sampling points must be placed in such a way that they satisfy the periodicity of lattices. A 2D Fourier transformation of these binary cells directly yields the corresponding 2D aliasing pattern. In Figure 1a, the complete set of allowed elementary sampling patterns (SP) for a reduction factor of R=4 are displayed (2D-SENSE-type: No 1, 2, 6; 2D CAIPIRINHA-type: No 3, 4, 5). Figure 1b shows the corresponding elementary 2D aliasing patterns (AP), which allow one to immediately anticipate the sensitivities in the 2D FOV which are involved in the aliasing procedure. By calculating and comparing the mean and maximum geometry factor, as well as the corresponding standard deviation for every sampling pattern, the best suited sampling pattern can be extracted. For this calculation, it is adequate to consult extremely low resolution sensitivity maps (matrix 20x20) which correspond in this R=4 case to just 100 matrix inversions for each sampling pattern.

Figure 1:



Results:

Figure 2 shows (a) the final images after parallel imaging reconstruction (SENSE), the corresponding (b) high resolution g-factor maps and the (c) low resolution g-factor maps for all (R=4) sampling patterns given in Figure 1a. In Table 1, the corresponding mean g-factor values and their standard deviations are listed for the high resolution (top row) and low resolution (bottom row) case. For both cases the 2D CAIPIRINHA-type sampling pattern, shown in No. 5, provides the best g-factor performance. In addition, the low resolution estimation matches the high resolution results very well.

Figure 2:

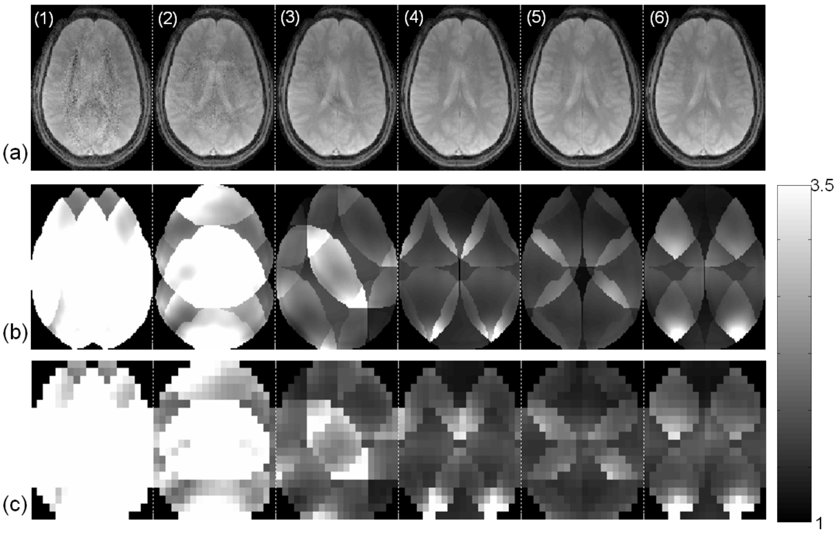


Table 1:

1	2	3	4	5	6	
7.70 ± 4.77	4.30 ± 2.36	2.06 ± 0.57	1.74 ± 0.40	1.66 ± 0.29	1.80 ± 0.50	HR
8.2 ± 4.5	4.4 ± 2.1	2.1 ± 0.6	1.9 ± 0.7	1.7 ± 0.3	1.9 ± 0.7	LR

Conclusion:

The results shown here indicate that a low resolution g-factor analysis of all 2D sampling patterns provides a fast and efficient way to extract the best 2D sampling pattern given a specific reduction factor and coil configuration. This strategy is fast enough that it can potentially be used for real time optimization of the sampling patterns for 2D CAIPIRINHA-type experiments.

References:

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[2] Breuer F et al. Proceedings ISMRM 2004, 326
[3] Tsao J.et al. Proceedings ISMRM 2004, 261

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