The use of principal component analysis (PCA) for estimation of the maximum reduction factor in 2D parallel imaging

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Introduction:

With today's trend towards large coil arrays, the problem of determining a maximum acceleration is becoming increasingly relevant. This is especially true in 3D imaging. In this abstract we demonstrate that this problem can in large part solved using principal component analysis (PCA). Additionally, by applying the PCA in multiple dimensions separately, the maximum possible reduction factor in each dimension can be estimated.

Methods:

Principal component analysis (PCA) is a mathematical procedure that transforms a number of correlated variables into a number of uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. The PCA basically consists of an eigendecomposition of the covariance matrix C, which is calculated from the coil sensitivity matrix S as $C=S*S'$. The principal coil components are then calculated by multiplying the sensitivity matrix S with the calculated eigenvectors sorted by the corresponding eigenvalues, which represent the degree of remaining variability.

Experiments were performed on a SIEMENS Avanto clinical scanner equipped with a cylindrical two-ring 12 channel head array. For demonstration purposes, one axial plane of a volunteer's head was chosen to investigate the encoding efficiency in LR and AP direction.

Results:

In Figure 1 (a) the eigenvalues (normalized to one) and (b) the cumulative sum of the eigenvalues are shown after principal component analysis of the 2D calculated sensitivity maps. It can be seen that only 5 or 6 of the 12 principal coil components are uncorrelated and therefore give contribution to the parallel imaging encoding. This limits the maximum possible reduction factor in two spatial dimensions to R=5-6 with this coil array.

Figure 1: *2D principal component analysis of coil sensitivities*

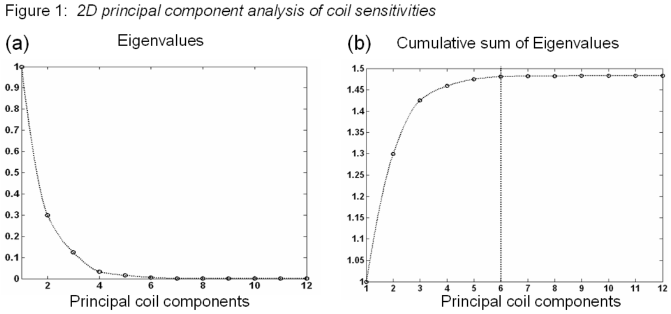
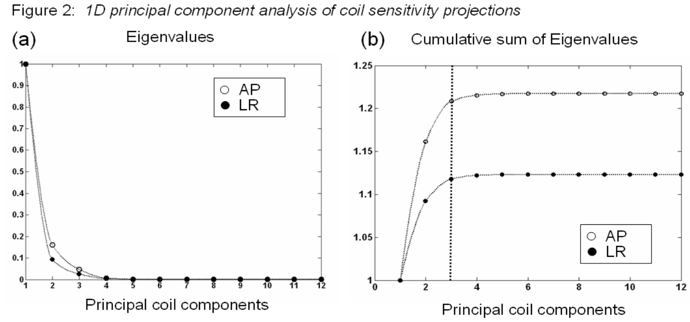
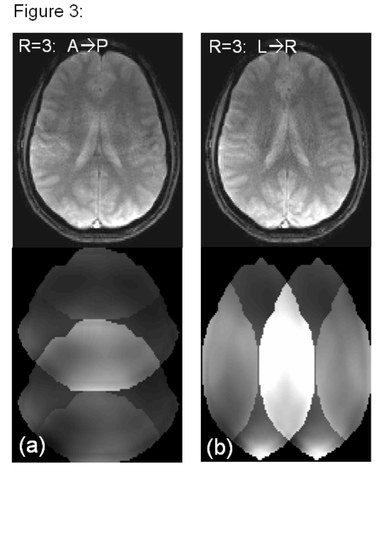


Figure 2: *1D principal component analysis of coil sensitivity projections*



Similarly, Figure 2a displays the eigenvalues of the PCA, which was now applied separately in the LR and in the AP directions using simple projections. In Figure 2b, the cumulative sum of these eigenvalues is plotted for both projections. This illustration allows one to compare qualitatively the encoding efficiency in these two directions. The position where the curve reaches saturation gives an estimation of the maximum possible reduction factor in this direction. Additionally, the saturation value itself (integral) contains information which can be used to determine the more efficient encoding direction, which is the AP direction. To emphasize this fact, Figure 3 shows geometry-factor maps and SENSE reconstructions with a reduction factor of R=3 applied (a) only in the AP and (b) only in the LR direction.

Figure 3:



Conclusion:

In this work we have shown that principal component analysis of coil sensitivities allows one to estimate the maximum possible reduction factor in multiple dimensions separately. This could be instrumental in choosing the optimal phase encoding direction in 1D parallel imaging. Additionally, the maximum possible 2D reduction factor can be established. In particular, this analysis could provide a way to find the optimal 2D sampling pattern in 2D parallel imaging (2D-SENSE [1], 2D CAIPIRINHA [2]).

References:

[1] Weiger M et al. MAGMA 2002; 14:10-19
[2] Breuer F et al. Proceedings ISMRM 2004, 326

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