CARE: Coil-based Artifact Reduction

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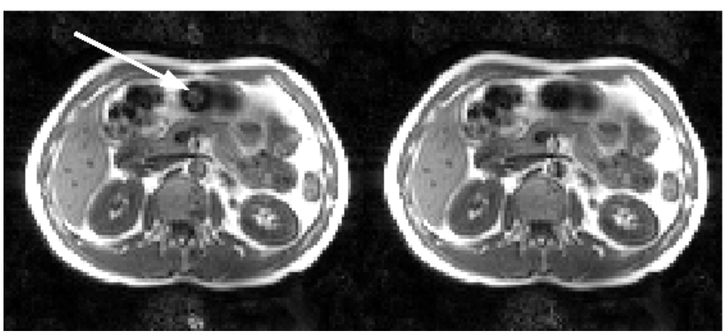
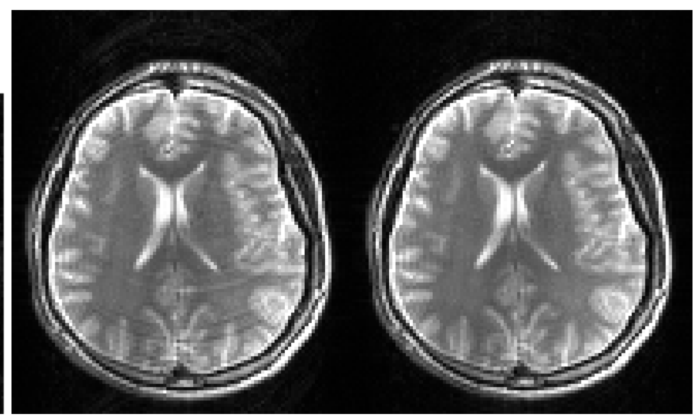
Introduction Multiple receive coils with differing spatial sensitivities provide complementary information about an object. This data can be used to correct image artifacts that arise from object changes such as motion or flowing blood. A key feature of our new method, unlike [1], is that object changes are represented as changes to the coil profiles. When an optimisation routine is used to find the artifact parameters, the object no longer needs to be treated as unknown, greatly reducing the number of unknowns .

Theory The image s_j obtained from coil j with sensitivity c_j is given by $s_j = c_j r$ where r is the underlying object. In k-space this is the convolution $S_j = C_j \otimes R$. If the object R changes during acquisition to R', then acquired data becomes $S_j' = C_j \otimes R'$. Expressing the artifact cause as a change to the coil sensitivity profiles, rather than a change to the object, we can write $S_j' = C_j' \otimes R$. For example, the unstable signal fluctuations from flowing blood can be represented as a local change in the sensitivity of all the coils. If J represents a group of one or more coils, and the data from these coils are stacked, the convolution can be written as matrix equations $\mathbf{S}_J' = \mathbf{C}_J'\mathbf{R}$. By varying the coils in the group J, we can obtain multiple estimates for $\mathbf{R}$. When the changes in $\mathbf{C}_J'$ are correct, these estimates of $\mathbf{R}$ will be self-consistent. We use a non-linear least squares optimisation routine with the unknowns being the parameterised changes to the coils and the cost function $\sum_j \left|\mathbf{R}_j - \mathbf{R}_g\right|^2$. Here $\mathbf{R}_j$ is the solution using one coil (J={j}) and $\mathbf{R}_g$ is the generalised SMASH solution using all coils (J={1,2,3,…}) [2]. Once the corrected (time-varying) coil profiles have been determined, the object can be solved for using the standard generalised SMASH method.

Method Fully sampled data were acquired on Philips 1.5T scanners. For a motion example, a volunteer was asked to move his head in approximately the phase encoding direction (vertical) whilst being scanned using a turbo spin echo sequence and using a fixed, 6-channel head coil. In the optimisation, the coil positions in the phase encode direction were treated as unknowns. The motion for one column of data was found and applied to all columns. For a flow example, a non-turbo spin-echo sequence was used with 128 phase encodes and a 4-channel body coil. In this case, the optimisation unknowns were complex multiples to the coil sensitivity profiles over the region of the aorta (selected manually). Corrupted image columns were processed separately and replaced in the artifacted image.

Results





Flow artifact (arrowed) from aorta. Algorithm corrected. Motion corrupted. Algorithm corrected.

The figures above demonstrate the artifact corrections. We have also reduced artifacts caused by motion of the eyeball and, in simulations, ghosting due to some motion in multi-shot diffusion weighted images (not shown).

Conclusion When an artifact cause is expressed as an equivalent change to coil sensitivity profiles, reconstruction of the object from different coils is consistent only when correct modifications are made to the coil profiles. Regions with low coil sensitivity enhance the ghosts compared to the reconstruction using all coils. This helps drive the optimisation to the correct solution. Unlike previous work [1], the underlying object is no longer treated as an optimisation unknown, significantly reducing the number of unknowns and making the algorithm faster and more robust. The present method also corrects a wider class of image artifacts.

References [1] Atkinson et al. ISMRM 2003 p. 1063. [2] Bydder et al. Magn. Reson. Med. 2002:47;160-170.
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