Correction of Motion Artifacts in Time-Resolved Contrast Enhanced MRA Using Convex Projections

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Abstract

An iterative convex projection method is presented to remove motion artifacts in time-resolved MRA images. Placing constraints on the temporal changes allowed to occur from one image to the next identifies motion corrupted k-space coefficients which can then be replaced by values obtained by iteration. Specifically High-pass phase filtering is combined with convex projections in k-space and image-space successively to remove non-rigid, non-global motion. Preliminary results indicate significant improvement in MRA quality.

Introduction

Patient motion is a major source of error and artifact in MRA, reducing the overall quality and obscuring important anatomic and temporal features. Several motion correction techniques have been proposed [1,2] for limited rigid, global motion in single-frame MR images. Time resolved 2D and 3D Contrast-enhanced MRA however makes available a whole set of temporal data that may be exploited during motion correction! From the temporal series, we obtain a reliable, non-corrupted reference and use it to correct the corrupted frames. The method corrects for motion during k-space acquisition without degrading radiologically important temporal events such as the arrival of the contrast agent.

Proposed Method

Projection Onto Convex Sets (POCS) [3] was used to apply successive constraints to the corrupted frame in an iterative process. Provided these constraints define convex projections, convergence is guaranteed. Figure 1 illustrates our POCS algorithm with four independent projections represented by labeled boxes that nudge the corrupted frame towards better ones. The output of each projection is given by

$$I_k = (1-\lambda_k)I_{k-1} + \lambda_k P_k(I_{k-1}), \quad k = 1,\ldots,4 \qquad (1)$$

where $1 < \lambda_k < 2$ are relaxation parameters, and P_k are the projections as shown in figure 1.

Translational motion causes a smoothly varying phase term in k-space - linear for global motion, and sinusoidally modulated for non-global motion. This phase is removed by a high-pass phase filtering operation denoted by the box **phase-correct**, which acts like a convex projection. This phase filter removes translational motion artifact, whether global or local, without affecting other temporal events. Rotational motion rotates k-space, causing small changes in local k-space values. This is undone by the projection **k-restrict**, which successively restricts corrupted k-values to lie within a small range of the reference k-values. Projections **parenchyma** and **BkGnd** provide additional intensity constraints in image space by forcing the known background and parenchyma regions to have close to reference intensity. Every constraint set defined by these projections is convex, thus guaranteeing convergence. The power of the POCS method derives from these highly independent constraints, applied alternately in two orthogonal spaces (k-space and image space). As a result convergence is fast, typically producing good results in fewer than four iterations.

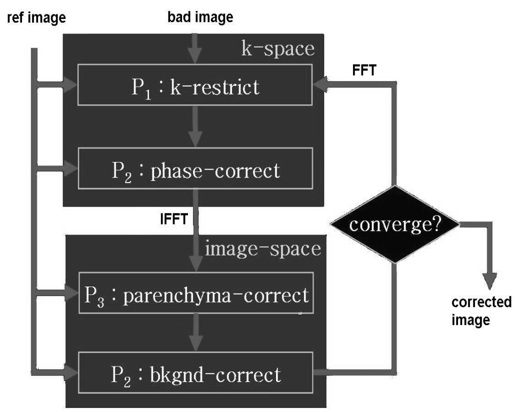

Figure 1: The POCS algorithm

Results

Figure 2(a) shows a difference image obtained from a time-resolved MRA series corrupted with non-global motion. This case is exceedingly difficult to correct by most current algorithms. However, our POCS algorithm has successfully removed spurious vasculature regions caused by motion, without degrading the true arterial phase. Figure 2(b) was obtained after four iterations with relaxation factor of 0.5. Both (a) and (b) are displayed at the same level of contrast and saturation.

A study of 46 MRA cases was undertaken as follows. In each case an experienced radiologist obtained the best difference image manually. These images were presented, along with automatically POCS-corrected images, to another radiologist in a double blind testing situation. The results, shown in table 1, indicate no significant difference in image quality between the manual and the automatically motion corrected images. However we note that the number of much improved cases (6) is higher than the number of much degraded cases (2).

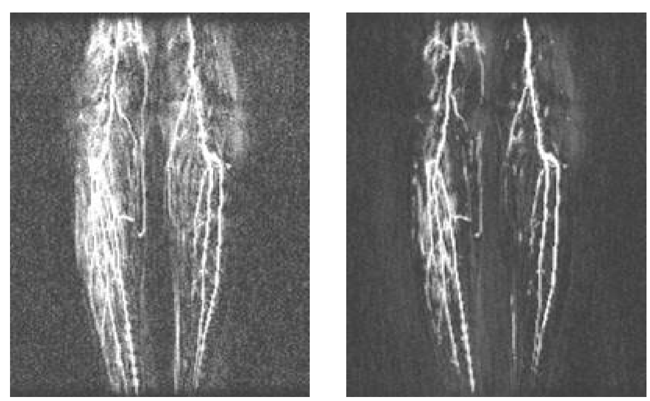

Figure 2: (a) Motion corrupted, and (b) Corrected by POCS

Table 1: Results of a double blind comparison of POCS with manual

POCS much better	POCS slightly better	Same	Manual slightly better	Manual much better
6	11	13	14	2

Conclusion

A convex projection-based algorithm that successively nudges a motion corrupted frame towards a non-corrupted one is able to identify and partially correct corrupted features of k-space and thereby remove artifacts due to complex non-global or non-rigid motion. Radiologically important temporal features are not degraded by the successive projections. The technique has the potential to retrieve corrupted angiography data that would otherwise be unusable due to motion artifacts. Preliminary results suggest significant gains in image quality.

References

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3. K Ratakonda and N Ahuja, "*POCS Based Adaptive Image Magnification*" , Proc ICIP, October 1998.