3D EXTRACT (Extrapolation and Correlation) for Rapid Correction of 3D Rotation and Translation

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Introduction

A rapid post-processing technique is described for the compensation of rotational and translational motion in 3D imaging. The technique is an extension of the EXTRACT (extrapolation and correlation) method previously described for 2D in-plane translational motion correction [1]. The technique does not require acquisition of additional data, and is based on correlation of motion-corrupted data with extrapolated data. It is demonstrated that the 3D EXTRACT technique is capable of correcting arbitrary 3D rotational and translational motion.

Theory

In 2D EXTRACT, motion estimation and correction for in-plane translational motion are performed in a center-out fashion, starting from a small number of base views near the center of k-space (assumed to be motion-free) and growing outward. In each correction step, a few phase-encoding lines adjacent on either side of the base are first extrapolated to estimate a “motion-free” reference. The extrapolated data are subsequently correlated with the corresponding k-space lines of the acquired, motion-corrupted data to estimate translation [1-2]. The acquired data could also be rotated to various angles prior to the correlation, and the maximum correlation used to compensate for rotational motion. The detected motion is used to correct the acquired data, which are then incorporated into the expanding motionless base. The algorithm continues until the entire k-space is motion compensated.

3D EXTRACT for correcting rigid-body rotation and translation in a 3D Cartesian dataset works in a similar fashion by partitioning the k-space into thin sections, each consisting of several contiguous phase encoding (k_y) planes. Assuming no motion occurs within each section, 3D EXTRACT begins from an initial base section at k_y=0 and grows outward along $\pm k_y$. Extrapolation of 3D k-space data is more conveniently done by first performing a 1D inverse FT along k_z to separate the slices, then extrapolating in 2D k_x-k_y plane for each slice, followed by a FT back to 3D k-space. 3D correlation yields a 3D vector for both in-plane and through-plane translation. For rotational motion, the motion-corrupted data could be rotated by various angles prior to the correlation; the maximum correlation for all angles subsequently yields 3D rotation as well as translation.

Methods

Compensation for 3D rotational and translational motion was demonstrated in *in vivo* time-of-flight (TOF) angiography experiments: 200x200x52 mm^3 FOV, 256x256x64 matrix, TR/TE 40/6.0 ms. A pair of lateral head constraints was used, and the volunteer was instructed to nod his head back and forth several times during the scan, both abruptly and continuously. Although the proposed technique could correct for full 6 degree of freedom (DOF) rigid-body motion, because of the use of the lateral head restraints and to reduce the computation time, only 4 DOF motion was searched in this particular experiment, including 3D translation and through-plane rotation about the x-axis. A shearing method [3] was used to perform 3D rotations, and correlation was performed on k-space sections consisting of 8 contiguous phase-encoding planes. Between adjacent sections, the x-axis rotation search range was ± 8 degrees (allowing a maximum of 8 degree rotation between contiguous sections). Axial and coronal maximal intensity projection (MIP) images were reconstructed for image quality comparisons.

Results and Discussion

MIP images before and after applying 3D EXTRACT are shown in **Fig. 1**, demonstrating removal of ghosting, reduction of blurring and restoration of small vessels after motion correction. The estimated motion for rotation and translation along z (the two with most deviations) are shown in **Fig. 2**. The processing time was approximately 10 minutes. In addition to the rapid processing time, a major advantage of EXTRACT is the ability to estimate any range of 3D translational motion with a single correlation, without the need to predetermine the range of search, as required by other methods [4]. A systematic comparison with other 3D compensation techniques remains to be carried out to assess the relative performance.

Conclusion

An efficient 3D motion correction technique based on data extrapolation and correlation is proposed and demonstrated in a TOF angiography exam containing both rotation and translation.

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References
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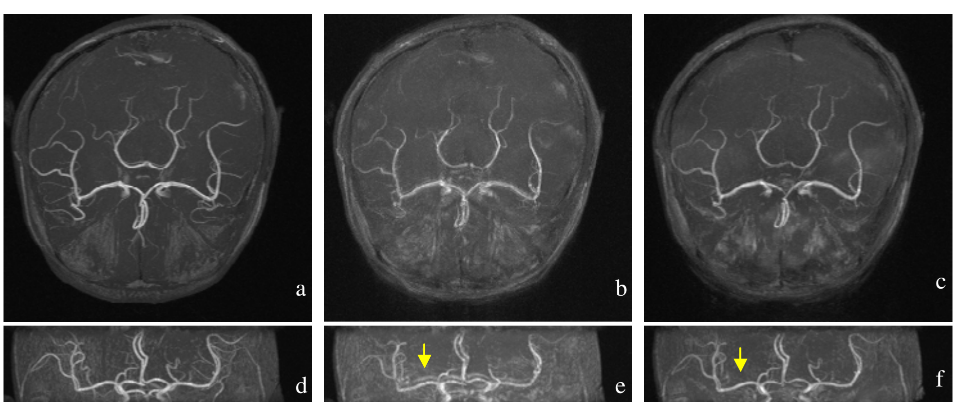

Fig. 1 MIP images from an in vivo TOF angiography scan: (a) Motion-free control; (b) Corrupted; (c) Corrected with 3D EXTRACT. (d)-(f) Corresponding coronal projections. The arrows indicate a region where artifact removal is particularly noticeable.

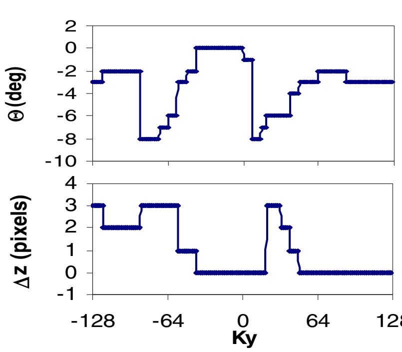

Fig. 2 Through-plane rotation and translation detected for the experiment shown in Fig. 1.