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Real-time Motion Correction Using Octant Navigators

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Introduction

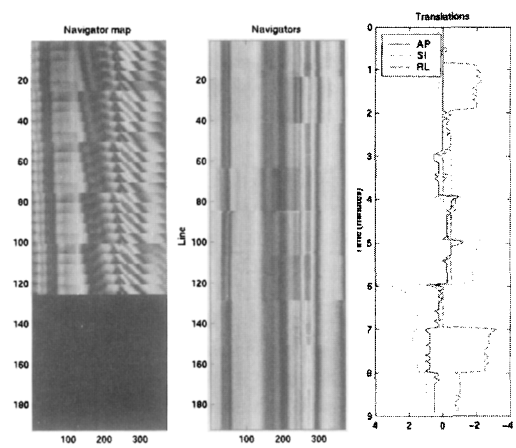
Head motion is a significant contributor both to degradation of image quality in structural scans, and noise in fMRI studies. Retrospective motion correction techniques without navigators cannot be applied to motion within 3D acquisitions. We have developed a method for tracking head motion during a 3D structural or functional scan and compensating for the motion by correcting the gradients during the scan. The method improves on existing prospective motion correction techniques (1) by using an octant navigator that gauges rigid body rotation and translation in a single short read-out, a navigator premap for exact rotational mapping, and navigator preoptimization for choosing the most feature-rich region of k-space for the navigator.

Methods

Our approach uses octant navigators, which are navigators that trace the outline of an octant on the surface of a sphere in k-space. The octant navigator enables a measurement of rotation about the three cardinal axes and translations in all three directions to be achieved in a single short read-out of a few milliseconds. Such navigators may be interleaved between the partitions of a 3D sequence with minimal effect on the total length of the sequence. Even quite rapid subject motions may be characterized in this way.

The first few seconds of a scan are dedicated to the navigator premap. During this time, the region of k-space is mapped over a small number of degrees in each direction from the octant navigator. By comparing the subsequent navigator with this map, the angles of rotation are calculated. Translations are then calculated from the phase difference between the navigator and its match on the map.

A navigator preoptimization scan consists of a series of blocks of navigators. The blocks are collected for various base angles and radii and each block consists of the minimal number of small rotational perturbations sufficient to calculate the Hessian of the error function for the rotational matching. The base angles and radius corresponding to the block for which the determinant of the Hessian (reflecting the expected accuracy of the angle estimate) is maximal is the optimal choice of navigator for the subject.



Results and Discussion

Preliminary data suggest that the approach is feasible. The preoptimization significantly improves the quality of the rotational matching and may allow for shorter navigators to yield acceptable results. The premapping results in a robust calculation of the rotations that previously published approaches achieve with relatively lengthy iterative techniques. Figure 1 shows the navigator map, and a series of navigators collected in a human subject during an MP-RAGE scan, along with the calculated translations.

Reference

1. Ward HA, Riederer SJ, Grimm RC, Ehman RL, Felmlee JP, Jack CR, Jr. Prospective multiaxial motion correction for fMRI. Magn Reson Med 2000;43(3):459-69.