Research Solutions: Prospective Correction Overview

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Highlights/Take-home messages

- Prospective motion correction maintains data quality by continuously updating the imaging volume to follow the moving object of interest.
- Head motion is predominantly rigid body and can therefore be accurately compensated for using prospective motion correction on a standard MR system with linear gradients.
- Tracking the motion of the object of interest with sufficient accuracy, precision and temporal resolution is a major challenge in prospective motion correction.
- There are a number of secondary effects that are not compensated for in typical prospective motion correction implementations, including the effects of gradient non-linearities, B0 distortions and RF coil sensitivity profiles.

Objectives

The objective of this presentation is to give an understanding of the advantages, limitations and challenges of prospective correction methods. Neuroimaging will be used as an example, but many of the same principles apply when imaging other organs. The presentation is aimed at scientists and clinicians interested in developing or evaluating motion correction techniques.

Summary

Introduction: Motion artifacts remain a serious problem in MRI. Prospective correction is a general technique that attempts to prevent artifacts from occurring by updating the encoding fields to compensate for motion. It was first used as early as 1986 for the correction of respiratory motion in abdominal imaging [1].

Theory, as applied to neuroimaging: Movements of the head during an MRI examination can be approximated as rigid body motion, comprising three translation terms and three rotation terms. The scanner gradient and RF waveforms can be updated to effectively compensate for this motion, thereby maintaining the consistency of k-space data and preventing artifacts in the reconstructed image.

Method description: Numerous implementations of prospective motion correction have been demonstrated. One major point of difference between these methods is the way in which head tracking data are obtained. Following Ref. [2], tracking methods can be grouped into three distinct categories: MR navigators (e.g. [3, 4]), gradient field detection systems (e.g. [5, 6]), or optical systems [7-9]. Where necessary, tracking data are transformed into the coordinate system of the scanner. At a suitable point in the imaging sequence, the gradient and RF fields are then updated based on the transformed tracking data.

Typical results:
Promising imaging results have been demonstrated for a wide range of field strengths and imaging applications, including fMRI [9-11], DWI [12] and DTI [13], and spectroscopy [14], to name only a few examples.

Advantages: Adaptive correction methods have an inherent advantage over retrospective correction methods in that a uniform k-space sample density is maintained, the imaged object cannot leave the field of view, and spin history effects are avoided. Other advantages include compatibility with most imaging sequences and use of the standard reconstruction chain.

Challenges: The quality (precision, accuracy, latency) of tracking data is critical for successful adaptive correction. If an external tracking system is used, then achieving good MR compatibility and marker fixation are also major challenges. Finally, uncorrected effects, such as B0 inhomogeneities and gradient non-linearities, can lead to residual artifacts after prospective motion correction.

Conclusions: Prospective motion correction shows great promise for neuroimaging applications, due to its ability to maintain k-space data quality and prevent motion artifacts during head motion.

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