Prospective motion correction: the benefits and the challenges

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Purpose

This work reviews recent developments in prospective motion correction for MR imaging of the brain. The aim is to explain why prospective motion correction has great potential for clinical MRI and to identify the obstacles that must be overcome to make the technique truly useful. It is hoped that this review will give those new to the field insight into future research directions and motivate the development of solutions to the present challenges.

Outline of Content

Motivation Artifacts caused by head motion during MR imaging of the brain remain a largely unsolved problem. This comes at a significant financial cost, due to repeated scans and the need for anesthesia in some cases. Furthermore, if good-quality images cannot be obtained, patient outcome can be adversely affected. Numerous motion correction techniques exist, but these are generally sequence specific. Prospective motion correction is a general approach that can be applied to most imaging sequences. It could therefore have major implications for clinical practice.

Method Tracking data representing the pose (position and orientation) of the head are obtained during MR imaging. Various methods have been used for this purpose, including stereo camera systems [1], in-bore single camera systems [2], small coils known as 'active markers' [3], or the MR image data itself [4]. Head pose information is passed to the scanner during imaging and the gradient fields and the RF phases and frequencies are adjusted so that the imaging volume follows the motion of the subject; hence, the term 'prospective' motion correction (Fig. 1).

Advantages Prospective motion correction has several major advantages over methods that first collect *k*-space data and then correct for the effects of motion retrospectively. Retrospective correction does not compensate for spin history effects and, in the presence of large rotations, does not guarantee sufficient sampling of *k*-space (Fig. 2). In the worst case, the object can move out of the image volume. Prospective correction solves these problems, as the imaging volume is adjusted to follow the object, resulting in a image free of motion artifacts (Fig. 3).

Challenges Many practical challenges must be addressed before the technique will be suitable for regular clinical use. For high-resolution imaging, the accuracy and precision of tracking is critical [5] (Fig. 4). Any external tracking marker must be securely attached to the subject and must move rigidly with the skull. Delays in the feedback of pose data must be minimized. Any external tracking system used must be fully MR compatible and also must be calibrated, so that the resulting pose information is expressed in the coordinates of the MR scanner. The development of reliable and convenient solutions to these issues is a current area of research.

If the above requirements are met, prospective motion correction is likely to be a clinically-useful technique; however, there are numerous effects that will then limit the quality of the result in some cases. Higher order motion (e.g., velocity, rather than displacement) is typically not accounted for. Magnetic susceptibility boundaries in the body produce inhomogeneities in the B0 field. This means that although the imaging volume may follow the brain closely, the images in an EPI time series may be distorted relative to each other, due to changes in the B0 field. Receive coil sensitivity profiles are also an issue, as with perfect prospective motion correction the coil sensitivity profiles will move relative to the apparently-stationary object. This effect will be more important when imaging with a high number of small coils. In this case, it appears likely that a retrospective correction step, such as [6], may need to be applied after prospective correction. At high fields, spatial variation of the transmit (B1+) field will complicate matters further. Gradient non-linearities mean that deformations of the object may change with its pose, which may cause residual artifacts after prospective correction. Finally, correcting for Nyquist ghosting in EPI when using a mixture of gradients for the readout direction may be problematic. For many of these examples, it is unclear exactly how severely they will affect the limits of the technique; this remains an area for future work.

Summary

Prospective motion correction is not without its share of challenges: these must be overcome if it is to become a useful tool for routine clinical imaging. However, the potential of the technique suggests that the benefits justify the effort required to solve these problems.

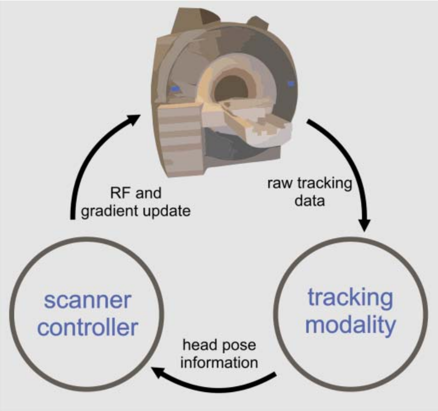

Fig. 1: The prospective motion correction feedback loop.

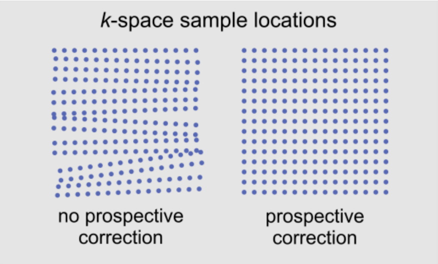

Fig. 2: Unlike retrospective techniques, uniform sampling in *k*-space is maintained even if rotations occur.

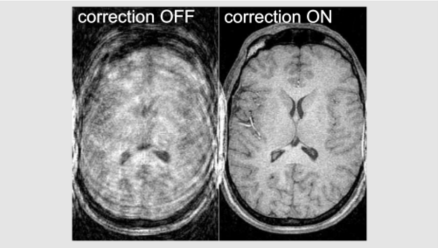

Fig. 3: Results obtained when using prospective correction from two scans with equivalent motion [1].

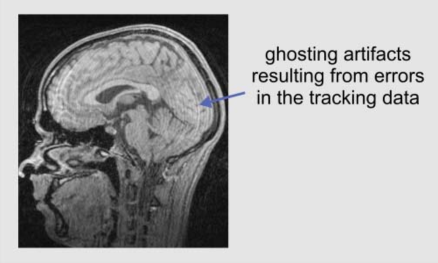

Fig. 4: The accuracy and precision of tracking data is critical for effective prospective motion correction.

References

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