# Motion Correction in MRI:

## Optical Prospective Correction Applied to High-Resolution Brain Imaging

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### Highlights

- Prospective motion correction can correct rigid body motion. The MR-representation of an object can depend on its pose. Thus, the signal intensity distribution and the image geometry may not be consistent between motion poses and result in residual artifacts.
- Higher order effects, such as gradient linearity deviations, received coil sensitivities, transmit inhomogeneities or local magnetic field variations need to be considered.

### Problem summary

For very high resolution acquisitions or large motion, artefacts can remain even with highly accurate prospective pose correction. Non-linear effects of motion on the object and its MR signal need to be considered.

### Body

Tackling motion artifacts has been a very active field of research and three categories of strategies that reduce motion artifacts can be distinguished: (i) Fast imaging to “freeze” the motion is efficient but limited in its applications. (ii) Retrospective motion correction is based on either data self-consistency or on motion information detected by MRI methods (navigator techniques) or external sensors. These methods try to reverse the effects of motion on the raw data during the reconstruction process. (iii) Prospective methods also use information about the object pose. However, these methods adapt the measurement method, such that the acquisition volume follows the object motion during the scan to yield consistent data. The main advantage of prospective approaches is the reduction of spin history effects together with the fact that the desired imaging volume is fully covered throughout the scan.
The geometric adjustment of the scan volume according to the object motion prior to each excitation (e.g. every k-space line) effectively reduces motion-related artefacts. The resulting image quality, however, depends on the accuracy and reproducibility of the motion detection mechanism has to approx. 5 to 10 times better than the image resolution. Thus, for very high resolution acquisition, “noise” of the tracking system can reduce image quality. Accurate and fast tracking or effective filter mechanisms are required to avoid such artefacts. Even with perfect position tracking (accurate and fast), residual motion artefacts can occur in the resulting data if the MR-representation of the object differs between different poses. Examples causing such variations are gradient non-linearities, coil sensitivity variations, changes in the RF-transmit field or magnetic field homogeneity.
When multi-channel receiver coil arrays are used for signal reception, motion of an object within a stationary RF-coil during prospective motion correction scans will result apparent motion of the coil around the object leading to temporal variations of the receiver coil sensitivity profiles. Again inconsistent k-space data are the consequence. Bammer et al. proposed an augmented iterative SENSE reconstruction that accounts for such variations of coil sensitivities (1).

Gradient non-linearities result in geometrically different representations of the object depending on its pose in the magnet and thus violate the assumption of object rigidity leading to inconsistent k-space data. The gradient properties are, however, known and the position error can be calibrated. The corresponding effect on image data without motion is commonly corrected by image stretching and compression according to the known gradient fields. Similarly, the effect on each k-space line can be considered by reversal of the position-dependent gradient distortion field (2).
Other known causes for residual artefacts include transmit field variations and magnetic field variations. No solution for varying transmit field distributions has been proposed yet. Dynamic adaptation seems feasible with the emerging technology of parallel transmission. Changes of the magnetic field distribution during an MR-acquisition have been addressed by various groups. Solutions may include retrospective correction during reconstruction if dynamic field mapping is included in the acquisition. A promising approach without additional scan time is the use of field cameras (3). Alternatively, dynamic changes of shim settings may prevent inconsistencies in the raw data.

**Summary**

- Residual artefacts in data acquired with prospective motion correction can be addressed by retrospective correction of receiver coil sensitivity variations and gradient non-linearities.
- Further research and development is needed to correct effects of varying RF and magnetic field distributions due to object motion.

References


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(3) Wilm BJ, Barmet C, Pavan M, Pruessmann KP. Higher order reconstruction for MRI in the presence of spatiotemporal field perturbations. Magn Reson Med. 65(6):1690-701 (2011).