Motion Correction Techniques

O. Speck Dept. Biomedical Magnetic Resonance, Otto-von-Guericke University Magdeburg, Germany

Subject or organ motion is one of the main reasons for degraded or even non-diagnostic image quality in MRI and a very relevant number of MRI scans or even entire examinations have to be repeated due to motion artifacts causing a significant financial burden on the health care system. While MR imaging is generally getting faster, and thus seems to be the most obvious solution to the challenge, at the same time, image resolution is ever increasing allowing more detailed anatomical insights but at the same time rendering the measurement more motion sensitive.

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 (1). (ii) Retrospective motion correction is based on either data self consistency or on motion information detected by MRI methods (navigator techniques) or external sensors (2-6). 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 (7,8). 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.

Another dimension that differentiates the different methods is the method to determine motion information either by data self-consistency requirements, MR navigator signals, or external motion sensors. While MR-based methods naturally deliver motion information in the coordinate system of the gradient set, external sensors have to be accurately cross-calibrated to allow coordinate transformation. Furthermore, some methods assume rigid body motion or affine object transformations while others apply more general motion models.

Many limitations and challenges are shared with between the correction methods. In general, the image quality largely depends on the accuracy of motion detection relative to the image resolution (9).

Despite the large body of literature on motion correction and very impressive correction performance in many publications, only very few methods have been introduced into clinical practice. Despite very elaborate methods, for cardiac imaging, perhaps the most challenging MR application, the main solution to fight respiratory motion is still imaging during breath-hold or during end-systole as determined by navigators. Similar methods are applied for abdominal imaging. Very recently, volumetric navigators have been introduced into commercial products. These methods allow correction of rigid body motion without extra hardware requirements but can only be applied to sequences that have sufficient "dead time" to insert the pose detection module. In addition, these methods are currently limited to brain imaging as rigid body motion is assumed.

Although the topic of motion correction has been addressed for many years in research and the number of publications is still growing, the developed methods have only very partially entered any product. One exception are navigators for respiratory motion suppression in abdominal imaging. Many of the results that are reported for new motion correction technologies are limited to very small subject numbers and correct artificial situations in which the subjects are asked to perform motion or hold still. Larger comparative studies on the efficacy of motion correction methods in a realistic clinical setting are scarce but needed to demonstrate the benefits and justify investments.

References:

1. Mansfield P, Maudsley AA. Planar spin imaging by NMR. J Magn Reson 1977;27:101-119.
2. Friston KJ, Ashburner J, Poline JB, Frith CD, Frackowiak RSJ. Spatial realignment and normalization of images. Hum Brain Mapp 1995;2:165-189.
3. Thesen S, Heid O, Mueller E, Schad LR. Prospective acquisition correction for head motion with image-based tracking for real-time fMRI. Magn Reson Med 2000;44(3):457-465.
4. Kim B, Boes JL, Bland PH, Chenevert TL, Meyer CR. Motion correction in fMRI via registration of individual slices into an anatomical volume. Magn Reson Med 1999;41(5):964-972.
5. Welch EB, Manduca A, Grimm RC, Ward HA, Jack CR, Jr. Spherical navigator echoes for full 3D rigid body motion measurement in MRI. Magn Reson Med 2002;47(1):32-41.
6. Atkinson D, Hill DL, Stoyle PN, Summers PE, Clare S, Bowtell R, Keevil SF. Automatic compensation of motion artifacts in MRI. Magn Reson Med 1999;41(1):163-170.
7. Zaitsev M, Dold C, Sakas G, Hennig J, Speck O. Magnetic resonance imaging of freely moving objects: prospective real-time motion correction using an external optical motion tracking system. NeuroImage 2006;31(3):1038-1050.

8. Derbyshire JA, Wright GA, Henkelman RM, Hinks RS. Dynamic scan-plane tracking using MR position monitoring. J Magn Reson Imaging 1998;8(4):924-932
9. Maclaren J, Speck O, Stucht D, Schulze P, Hennig J, Zaitsev M. Navigator accuracy requirements for prospective motion correction. Magn Reson Med 2009.