Adaptive Motion Correction Applied to Clinical Neuroimaging

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Objectives

The objective of this presentation is to give an understanding of the advantages, limitations and challenges of adaptive correction methods applied to clinical neuroimaging. The presentation is aimed at scientists and clinicians interested in understanding the impact patient motion can have on the diagnostic process in clinical neuroimaging and how adaptive correction methods can help to improve diagnosis.

Summary

In medical imaging, patient motion remains a serious challenge. MRI leverages a wide range of contrast mechanisms and offers clinicians excellent soft tissue contrast, however the sequential and rather lengthy acquisition process of k-space data to form an image renders MRI also extremely sensitive to patient motion. While quantitative neuroimaging methods, such as DTI, fMRI or any other method that computes parameters on a per-pixel basis, is super sensitive to motion, over time, physicians have developed skills to read through motion artifacts of minor degree. That said, diagnostic confidence, sensitivity and specificity are clearly impaired in such cases. With increasing severity of motion, MRI scans become non-diagnostic and warrant studies to be repeated, patients to be sedated or in worst cases entire patient exams need to be rescheduled. In our experience, the smaller a lesion and the less conspicuous the lesion is, the earlier even small scale motion can challenge the radiologist's ability to detect and render a diagnosis. With an ever increasing demand on increased patient throughput and shorter exam times, patient motion can be one of the unpredictable factors in a busy radiology practice. While patient motion is a well recognized problem for body MRI, it has been vastly underestimated in neuro MRI. Recent studies have shown however that patient motion can also impair a considerable portion of clinical neuro exams (typically 1-2 per scanner per day), which poses a considerable economical burden for patients and healthcare providers.

For brain imaging one can assume that motion is predominantly rigid and correction approaches are relatively straightforward when compared to body application where physiologic motion and associated organ deformations are elastic and a greater challenge to fix. While there are several quite sophisticated methods that have been presented over the years to correct motion artifacts after imaging data had been acquired, retrospective methods will always be challenged by sparsely or excessively sampled regions of k-space and spin history effects.

A more practical solution is to adapt continuously to patient motion as scan data come in. The shorter the latency between measuring patient motion and adapting to these pose changes the less likely motion artifacts will occur. Note that the way how motion is measured (e.g. MR navigators, self-navigating trajectories, RF tracking coils, ultrasound, optical, etc.) is mostly irrelevant as long as the positional changes can be provided to the pulse sequence fast enough. The term "prospective" is often used in this context but this is a misnomer as it implies that the motion pattern is known in advance. Even with adaptive methods, one lags always behind the true motion. Only the latency is much shorter and the main differentiator is that the correction happens while the data are still acquired.

Based on the encoding hardware principles, to date only rigid body adaptive corrections are available, which are sufficient for brain studies. However, this does not imply that at some point in time also elastic, adaptive methods will be introduced.

In order to be clinically useful, motion correction methods need to be applicable to all MR pulse sequences and should not disrupt normal workflow. If motion is corrected for only a subset of pulse sequences but not for the “money shot”, motion correction is a relief but not a remedy.

Take-home messages

- Motion in neuroimaging is underestimated: 1-2 patients per day/neuro scanner
- Motion correction needs to work for all pulse sequences
- Real-time tracking can be performed with different modalities as long as they are fast enough.
- Setup cannot be disruptive to regular patient workflow