Emerging Clinical Techniques / Temporal Acceleration Methods

Daniel K. Sodickson, MD, PhD Daniel.Sodickson@med.nyu.edu

Highlights: Recent approaches to accelerated dynamic imaging have the potential to change the way imaging is performed and interpreted in everyday practice.

Title: ***Temporal Acceleration Methods***

Target audience: Clinicians and basic scientists interested in rapid imaging approaches

OUTCOME/Objectives: To review the fundamental principles of and explore the recent renaissance in accelerated imaging techniques taking advantage of dynamic information

PURPOSE: In our field of magnetic resonance, we stand at the brink of a new understanding of the role of time in imaging. According to long tradition, we have tended to view our images as temporal snapshots, or else as temporal frames with temporal resolution defined by a nominal start time and a nominal end time. We recognize, of course, that evolution continues to occur (both in spin space and in coordinate space) throughout the duration of image acquisition, but we typically aim to minimize the effects of that evolution through judicious use of pulse sequences and acceleration techniques. Recently, however, we have experienced the beginnings of a change of paradigm in our treatment of the time domain. Rather than viewing temporal variation as a nuisance or a challenge to be overcome, an increasing number of investigators are developing techniques which embrace temporal variability in order to increase information content, improve efficiency, and ultimately change the workflow of biomedical imaging.

METHODS: Throughout the history of MRI, numerous approaches have been devised for accelerating individual time frames, including fast pulse sequences, rapidly-switching magnetic field gradients, constrained reconstructions (such as partial Fourier reconstruction), and parallel imaging. Meanwhile, it has long been appreciated that temporal variations are often sufficiently slow that nearby time points have highly correlated spatial information. Keyhole methods, sliding window approaches, and other tools in our collective bag of tricks take advantage of this property by sharing information between multiple temporal frames. Other so-called "k-t" acceleration techniques (1) aim to recover full image information from undersampled datasets through the removal of carefully-arranged spatiotemporal aliasing. The recent advent of compressed sensing approaches (2), taking advantage of the sparsity of image information, has highlighted the advantages of incoherent sampling, resulting in a resurgence of interest in non-Cartesian acquisition trajectories. A growing body of experience with compressed sensing has confirmed that the greatest current opportunities for acceleration lie in datasets with a temporal dimension. The prospect of highly-accelerated dynamic datasets, meanwhile, has spurred interest in continuous image acquisition approaches which support flexible and tailored reconstruction (3, 4). Even when the desired output is static images, continuous acquisition can result in robustness to motion, reduced artifact, and improved image quality. Beyond improved images, however, continuous acquisition can offer enriched information content. One noteworthy example of an information-rich imaging approach rooted in the time domain is MR fingerprinting (5), in which (incoherent and non-steady-state) temporal evolution takes over much of the burden of spatial encoding, and which enables diverse contrast-determining tissue and system parameters to be characterized in a single acquisition.

RESULTS: It is important to note that, for all their great promise, temporal acceleration techniques are not without their challenges. Failure modes can be subtle – for example involving temporal blurring, and loss of fine details or small image components. Caution is required both in the levels of acceleration attempted and in the interpretation of accelerated image sets.

DISCUSSION: Despite ongoing challenges, an increasingly rich body of work is being devoted to temporal acceleration methods. Indeed, many attendees of the recent ISMRM workshop on Data Sampling & Image Reconstruction emerged with a sense that a sea-change is underway – that the task of image acquisition and reconstruction is increasing aimed not merely at generating a series of frozen time-frames, but rather at extracting diverse information from complex time-ordered data.

CONCLUSION: Temporal acceleration methods, and the new perspective about time that they are increasingly coming to represent, are not only practical tools for clinical and research applications, but have the potential to lead to fundamental changes in imaging workflow. We may even be approaching an era in which the burden of imaging protocols is shifted from acquisition to reconstruction; in which comprehensive image datasets with multifaceted information content are acquired rapidly and continuously, and are reconstructed after the fact to meet the specific needs of clinicians and scientists.

REFERENCES:

1. Tsao J, Boesiger P, Pruessmann KP. k-t BLAST and k-t SENSE: Dynamic MRI with high frame rate exploiting spatiotemporal correlations. Magn Reson Med. 2003;50(5):1031-42.
2. Lustig M, Donoho D, Pauly JM. Sparse MRI: The application of compressed sensing for rapid MR imaging. Magn Reson Med. 2007;58(6):1182-95.
3. Mistretta CA, Wieben O, Velikina J, Block W, Perry J, Wu Y, Johnson K. Highly constrained backprojection for time-resolved MRI. Magn Reson Med. 2006;55(1):30-40. PMCID: 2366054.
4. Chandarana H, Feng L, Block TK, Rosenkrantz AB, Lim RP, Babb JS, Sodickson DK, Otazo R. Free-breathing contrast-enhanced multiphase MRI of the liver using a combination of compressed sensing, parallel imaging, and golden-angle radial sampling. Invest Radiol. 2013;48(1):10-6.
5. Ma D, Gulani V, Seiberlich N, Duerk J, Griswold M. MR Fingerprinting (MRF): A Novel Quantitative Approach to MRI. Proceedings 20th Scientific Meeting, International Society for Magnetic Resonance in Medicine; 2012 May; Melbourne, Australia; *Nature* 2013, in press.