NIBIB Plenary Session on Innovations in Imaging: How Compressed Sensing will Change the World of MR

Compressed Sensing in MRI

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Magnetic Resonance Imaging (MRI) is a non-invasive imaging modality. Unlike Computed Tomography (CT), MRI does not use ionizing radiation. In addition, MRI provides a large number of flexible contrast parameters. These provide excellent soft tissue contrast. Since its invention more than 30 years ago, MRI has improved dramatically both in imaging quality and speed. This has revolutionized the field of diagnostic medicine. Imaging speed is a major part of this revolution as it is essential in many MRI applications. Improvements in MRI hardware and imaging techniques have enabled faster data collection, and hence faster imaging. However, we are currently at the point where fundamental physical and physiological effects limit our ability to simply encode data more quickly.

This fundamental limit has led many researchers to look for methods to reduce the amount of acquired data without degrading the image quality. These reduced sampling methods are based on the fact that MRI data is redundant, so the underlying information may be extracted from less data than traditionally considered necessary. One of the most significant clinical impacts of reduced sampling methods has been accomplished by parallel imaging with multiple receiver channels. Imaging with multiple channels provides more useful data per MRI acquisition, so fewer acquisitions are needed per scan. Another source of redundancy that has been gaining significant attention is the sparsity and compressibility of various MR signals. This effort has been motivated by the recent introduction of the theory of compressed sensing (CS).

Medical images, much like natural images taken by digital cameras can be compressed many folds (for example using the popular JPEG compression). The typical paradigm of compression is to first collect all the necessary data and then compress it. The question that arises is why is it necessary to collect so many measurements if most of the data is non-important? Compressed sensing provides a way to address this question. It is a new sampling theory for compressible signals that allows sampling at rates much lower than the Nyquist-rate. CS implicitly compresses data within the signal acquisition process by obtaining fewer so-called "incoherent measurements". This is accomplished through various non-uniform and pseudo-random k-space sampling schemes. Images can be accurately reconstructed from these measurements using non-linear recovery processes that enforce data consistency with the measurements and compressibility of the reconstruction. The practical result of CS in the context of MRI is that MR images require much less data for reconstruction, and hence can be scanned much faster.

The talk will cover the basics of compressed sensing theory in the context of MRI. It will also survey current status and trends in using compressed sensing for clinical applications. Results of significant scan-time accelerations will be presented from a variety of applications including angiography, hyperpolarized 13C MRSI, dynamic imaging, cardiac imaging \and many others.