

COMPRESSED SENSING MRI RECONSTRUCTION USING WEIGHTED THRESHOLDING OF WAVELET TREE STRUCTURE

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ABSTRACT

Magnetic resonance imaging is a medical imaging technique used to examine the anatomy and physiological processes of the human body. The primary drawback of this technique is the long scan times required to acquire images, which may make examinations uncomfortable for patients and renders this modality susceptible to motion artifacts. Compressed sensing (CS) enables signal acquisition using measurements substantially less than is required based on the Nyquist criterion, and therefore this approach has been shown to decrease the scan time required for an MRI scan. Model-based CS methods seek to improve on the performance of standard CS methods by exploiting prior information, such as wavelet coefficient structure, in the reconstruction algorithm. Some model-based CS methods use the structural dependence that exists between parent-child wavelet coefficients to improve performance. In this paper, we improve upon the approach that leverages the structural dependence of parent-child wavelet coefficients by applying weight thresholds to the entire wavelet tree structure. Using a three-level hierarchical structure (Grandparent-Parent-Child) eliminates the redundancy of parent-child relationships and contributes towards a more efficient acquisition of data. Experimental results reveal that this innovation speeds up the image reconstruction process by approximately 10% with consistent improvement in quality of image compared to a prior model-based algorithm.
Keywords: compressed sensing of MRI, wavelet tree sparsity, weighted thresholding

INTRODUCTION

One of the core challenges of magnetic resonance imaging (MRI) reconstruction is the significant duration required to acquire the images. MRI examinations require patients to remain stationary for the duration of a scan, which is typically 20–60 minutes. The length of an examination not only makes the patient uncomfortable, but can result in motion-based artifacts, which has a negative impact on the diagnostic quality of the images. In the case of MRI, considerable attention has been paid to utilizing compressed sensing (CS) as a method to reduce scanning time, because it enables signal acquisition at a sub-Nyquist rate, based on the sparsity of the signal in some domain.

In the CS approach, there are two stages of data processing: the acquisition stage and the reconstruction stage. During the acquisition stage, an N-dimensional signal y is sampled at sub-Nyquist rate to give M measurements ($M << N$). According to CS theory [1], the lower bound for these M measurements so as to enable signal reconstruction is $O(K + KlogN)$, where the signal y is known to be K-sparse in some domain. During the reconstruction stage, the M measurements are used to recover y (or a transformed version of y) by applying an optimization method. A key to understanding the application of CS reconstruction to MRI is to recognize that the MRI data are represented in 3 distinct domains. Firstly, the MRI signals are acquired in the k-space or Fourier domain, which is also the domain used to assess CS reconstruction error. Secondly, as established via the research of Lustig and Donoho [2], there must be a domain (Φ) in which MRI data have a sparse representation. Φ is typically the wavelet domain. Finally, we need to visualize MRI data as an image x in the spatial domain for diagnostic purposes. The relationship between y and x is given by $y = Fx$, where F represents the Fourier transform matrix. The basic reconstruction model for CS-MRI is expressed in equation (1):