Optimizing Spars 3D-MRI using Cubic Compressed Sensing Reconstruction Method

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Introduction:

Using sparse MRI data acquisition and compressed sensing (CS) reconstruction has been demonstrated to be an effective method to reduce the MRI scan time while maintain reasonable image quality [1]. For volumetric or 3D MRI, as there isn't sparsity in frequency direction, it's normally converted into 2D-CS reconstruction problem for easy implementation. However, due to the nature of the sparsity, the 2D-CS reconstructed images suffer from loss of image detail, especially when phase encoding are not very high (less or equal to 128x128) which represent majority of MRI cases. In this work, we compared the true-3D or Cubic-CS reconstruction with Slice-CS method. The results demonstrated that Cubic-CS method not only reduces the reconstruction time by about a factor of 2, but also greatly improves the image quality.

Methods:

Head image of a healthy volunteer was acquired with FSE sequence with 26 cm FOV, 128x128x128 matrix, 2500 ms TR, 84 ms TE, on a 3T GEHC MR750 scanner (GE Healthcare, Waukesha, Wisconsin) using a single channel (birdcage) coil. Sparseness of the k-space data were applied in two phase encoding directions for a total reduction of 10x, 5x and 2.5x corresponding to 10%, 20% and 40% of full sampled data respectively. During the process of argmin{ $\|\Phi m\text{-}k\|_2 + \lambda TV(m)$} using Conjugate Gradient method [2] the sparsed k-space data were treated in two methods: (1) data were transferred into a stack of "slices" through the frequency dimension FFT, all variables and operators were in 2D; (2) data and all variables and operators were in 3D cubic format (Fig. 1) for full 3D-CS reconstruction. The CS reconstruction was performed off-line with MatLab script.

Result and Discussion:

Fig. 2 represents a selected slice from the 3D image set reconstructed with 2D-Slice and 3D-Cubic CS methods. The 3D-Cubic CS reconstructed images shows significantly less loss in details. At the reduction factor R=2.5, the CS reconstructed images are very close to the reference images while the computation time is reduced by about a factor of 2 comparing to slice-CS reconstruction method. It also shows that with 3D-Cubic CS, as the entire data is treated as one unity, the "air-tissue" boundary of the image is well defined (Fig. 3). 3D information helps to maintain the details of the entire subject due to its property of unity. It's also true that 3D non-Cartesian sparse MRI resists better in noise and artifact with 3D-CS method.

References:

[1] Lustig M et al. MRM 2007 58:1182-1195;

[2] Y.H. Dai & Y. Yuan. Journal of Computational Mathematics, Vol.20, No.6, 2002

Acknowledgement:

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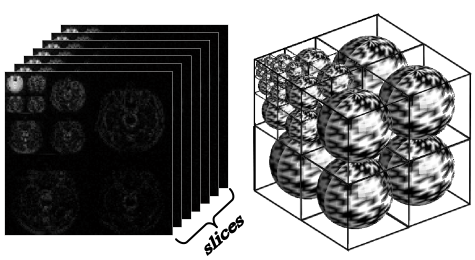

Fig.1 Wavelet component in Slice-CS model (left) and Cubic-CS model (right) for 3D sparsed MRI reconstruction.

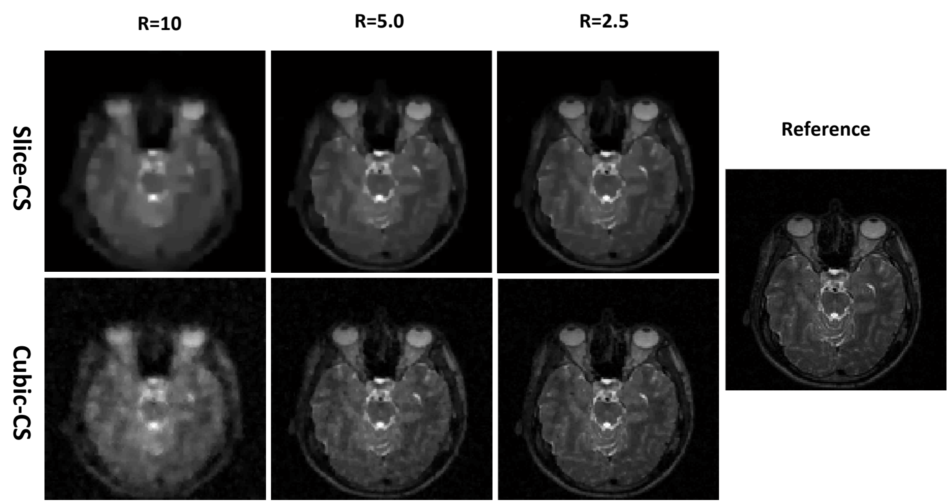

Fig. 2 A selected slice from the 3D image set. Cubic-CS (bottom row) reconstruction method maintains more detail than Slice-CS (top row). Columns from left to right represent sparse reduction factor of 10, 5 and 2.5.

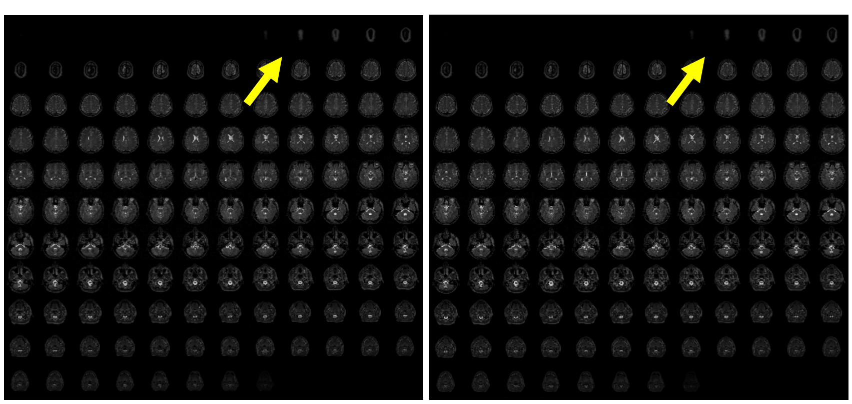

Fig. 3 Cubic-CS maintains better "air-tissue" interfaces with its nature of unity treatment comparing to slice-CS reconstruction method. left: Cubic-CS reconstructed images; Right: Reference images.