Building 3D dynamic keyhole library with compressive sensing and parallel imaging reconstruction

Dao Lam, Ben Lewis, H M Gach, Sasa Mutic and Taeho Kim
Department of Radiation Oncology
Washington University in Saint Louis

JULY 12–16 2020 VIRTUAL
JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

Real time tumor tracking in MRI-guided radiotherapy (MRgRT) is difficult due to limitation in time of imaging acquisition and image quality. This study provides a novel method to achieve good image quality while still maintaining the real time constraint of MRgRT. The short time imaging acquisition is achieved by using dynamic keyhole technique and the quality of imaging is improved by making use of compressive sensing total variation (TV) reconstruction.

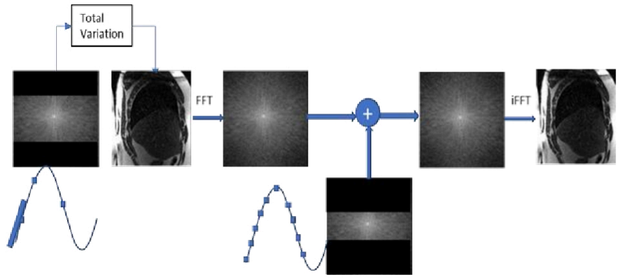
AIM

Motion-free high-spatial resolution library is a key component for real-time 3D dynamic keyhole in MRgRT. The aim of this study is to develop a procedure for motion-free high-spatial resolution library using a compress-sensing approach in image reconstruction and processing for real-time 3D MRgRT. .

METHOD

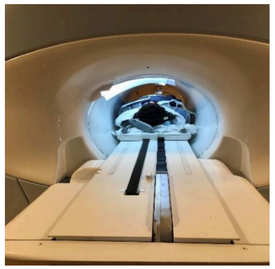
In 0.35T MRgRT systems, 3D MR images were acquired using 3D TrueFISP (FOV: 350 x 350 mm, matrix: 150 x 150 x 8, voxel: 2 x 2 x 2 mm3, acquisition time: 5 s) from a motion phantom and a human subject. To reduce motion during imaging, the phantom was posed at the designated position and the human subject was in breath-hold using respiratory visual guidance system. The keyhole library is reconstructed using compressive sensing with parallel imaging. Specifically, coil sensitivity is estimated by ESPIRiT calibration method, followed by compressive sensing reconstruction from the input k-space and coil sensitivity with total variation constraint to achieve a less noise, high contrast images. In the study, under-sampled data were used to improve temporal resolution of the library such as 10, 20, 30, 50, 70, 100% of the acquired data. The performance of the method was compared with the Fourier-transformed images in terms of SNR, CNR and edge enhancement using SSIMach in image reconstruction and processing for real-time 3D MRgRT. .

METHOD



To reduce the acquisition time in 3D dynamic keyhole, compressive sensing technique is used. A total variation minimization helps recover a less noise, more contrast library

Human scanning set up with anterior and posterior torso RF coils, and a pressure sensor under the antior coil.



Human scanning set up with anterior and posterior torso RF coils, and a pressure sensor under the antior coil.

Image reconstruction with parallel imaging and compressive sensing:

Images are reconstructed through an optimization:

Minimize TV(m)

s.t. $||F_u\ (m)-y||< e$

where m is the reconstructed image, y is the measurement, e controls the fidelity of the measured data. TV() is total variation operation, F_u is under-sampled Fourier transform. When array coils are used, coil sensitivity maps are estimated by ESPIRiT algorithm directedly from autocalibration data.

RESULTS

Quantitative results

SNR	LR+0%HR	LR + 10%HR	LR+ 20%HR	LR+ 40%HR	LR+ 60%HR	LR+ 70%HR	LR+ 80%HR	LR+ 90%HR
FFT	12.1	10.6	11.2	9.8	9.4	8.1	7.6	7.5
Total Variation	49.2	67.9	77.1	77.0	78.0	74.5	67.8	63.6

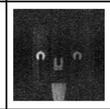
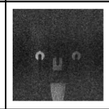
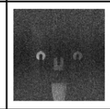
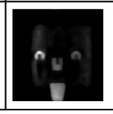
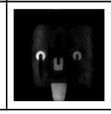
CNR	LR+0%HR	LR + 10%HR	LR+ 20%HR	LR+ 40%HR	LR+ 60%HR	LR+ 70%HR	LR+ 80%HR	LR+ 90%HR
FFT	1.3	5.9	6.3	4.4	3.5	2.8	2.4	2.3
Total Variation	3.4	30.0	52.2	51.6	54.5	52.0	47.7	45.1

SSMI	LR+0%HR	LR + 10%HR	LR+ 20%HR	LR+40%HR	LR+ 60%HR	LR+ 70%HR	LR+ 80%HR	LR+ 90%HR
Total Variation	.72	.87	.92	.94	.96	.97	.99	1

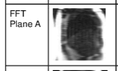
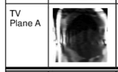
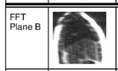
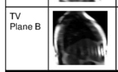
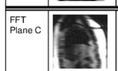
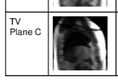
LR: Low resolution data, **HR**: high resolution data, **SSMI**: structural similarity index

Qualitative results

Phantom dataset

Phantom	LR	LR +10%HR	LR +20%HR	LR+60%HR	LR+90%HR
FFT					
TV					

Human dataset

Human	10%HR	20%HR	30%HR	70%HR	100%HR
FFT Plane A					
TV Plane A					
FFT Plane B					
TV Plane B					
FFT Plane C					
TV Plane C					

CONCLUSIONS

3D dynamic keyhole with compressed sensing total variation reconstruction could obtain better image quality in less acquisition time.

REFERENCES

1. Lee, Danny, et al. "Dynamic keyhole: A novel method to improve MR images in the presence of respiratory motion for real-time MRI." Medical physics 41.7 (2014)
2. Lustig, Michael, David Donoho, and John M. Pauly. "Sparse MRI: The application of compressed sensing for rapid MR imaging." Magnetic Resonance in Medicine: An Official Journal of the International Society for Magnetic Resonance in Medicine 58.6 (2007)

CONTACT INFORMATION

Dao Lam: dao.lam@wustl.edu