Prototypic Setup for Evaluation of a Compressed-Sensing Technique in Clinical Patient Studies

K.T. Block[1], R. Grimm[2], L. Feng[1], R. Otazo[1], H. Chandarana[1], D.K. Sodickson[1]

1) Center for Biomedical Imaging, NYU School of Medicine, New York, USA
2) Pattern Recognition Lab, University of Erlangen, Erlangen, Germany

Introduction: Iterative image reconstruction techniques, including L1-regularized techniques like Compressed Sensing (CS), have gained strong interest in the research community over the past years because they promise significant acceleration of the MRI scan speed [1]. However, very limited experience exists whether these methods are robust enough for clinical routine use and whether they deliver consistent and trustable results in patient exams. A major problem is that the techniques have very high computational requirements, which make it impossible to implement the algorithms on the reconstruction hardware of current MR systems.

Recently, a CS-based reconstruction technique for dynamic contrast-enhanced (DCE) imaging with a radial stack-of-stars 3D GRE sequence has been presented [2], which offers significantly higher motion robustness compared to conventional DCE-MRI exams and enables obtaining dynamic information during free breathing. The approach promises a viable solution for dynamic MRI of patients that are incapable of suspending respiration during the data acquisition, including sick, elderly, as well as pediatric patients which are often sedated. However, the achievable sensitivity for detection of lesions still needs careful assessment before it can be used as primary diagnostic method for clinical patients. Here, we describe our prototypic setup and the software tools that we are using to integrate the method into our clinical workflow for evaluating it in routine exams, which may serve as model for clinical evaluation of other CS-based techniques.

Methods: In the CS-based DCE-MRI approach, data is collected with a radial stack-of-stars sequence over several minutes while the contrast agent is injected 20 sec after the start of the acquisition. After the exam, a gridding reconstruction is performed online on the MR system using all acquired data, which gives the technicians feedback regarding the overall quality of the exam. This time-averaged reconstruction has similar contrast to conventional T1-weighted post-contrast exams and is sent to PACS along with the routine exams. Because of the high computational requirement, the dynamic CS reconstruction has to be performed offline on an external server. To transport the data to the server, a software client has been developed that runs as background service on all our MR systems. Once every night, the raw data from all protocols that have been tagged for offline reconstruction is exported and transferred to a central reconstruction server. If reconstructions are needed more urgently, the transfer can be triggered manually with a single mouse click (Fig 1). Using this fully automated mechanism, performing the dynamic CS exams does not create significant additional workload for the technicians, which is important in view of the tight patient scheduling in routine practice.

When new data arrives on the reconstruction server, the CS-based reconstruction is started which has been implemented as performance-optimized stand-alone program written in the C++ programming language. A version with command-line interface for batch processing as well as a version with graphical user interface (GUI) exists, which is mainly used for optimizing reconstruction parameters (Fig 2). To achieve sufficient reconstruction speed, the algorithm has been parallelized across slices using the OpenMP interface, which is possible for stack-of-stars trajectories after running a FFT along the slice direction. Using a Linux server with 64 cores (AMD Opteron 6272) and 128 Gb memory, processing of complete 4D datasets with high temporal resolution takes on average between 5 – 45 min, depending on the number of slices, base resolution, and desired temporal resolution. After running the iterations for all slices, images are saved in the DICOM format where relevant patient information for the DICOM tags is extracted from the header of the raw data file. Finally, the DICOM images are sent to the PACS archive. The radiologists can then read the images along with the routine exams using the standard PACS workstation software, or using DICOM viewers with PACS integration like OsiriX [3] or ClearCanvas workstation (Fig 3) [4].

Conclusion: The setup described here enabled us to acquire DCE-MRI datasets in over 360 patient exams conducted over the past months, including abdominopelvic, breast, neck, orbits, brain, and spine exams. For these patients, standard clinical protocols included post-contrast but not dynamic imaging, which made it possible to run the radial stack-of-stars sequence during the injection without interfering with clinical imaging. This helps us evaluating the performance of the CS-based dynamic reconstruction technique in a large number of realistic patient cases to identify and address remaining problems for routine use of the technique. The software tools developed for this purpose could be used for testing other CS reconstruction techniques as well.

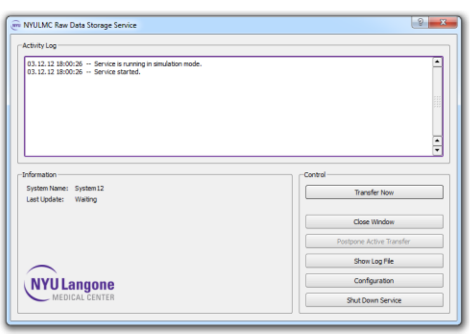

Fig 1: User interface of the data transfer service running as background task on the clinical MR systems.

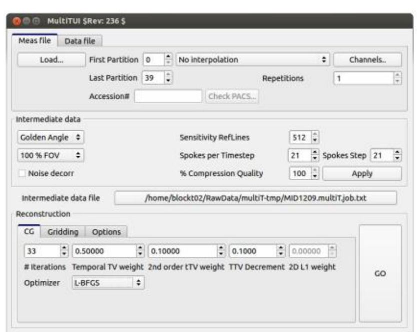

Fig 2: User interface of the C++ implementation of the CS-based DCE-MRI reconstruction running on Linux.

Fig 3: Dynamic images reconstructed using the CS approach of a patient with optical nerve sheath meningioma, loaded into the MPR viewer of the ClearCanvas workstation software.

References: [1] Lustig et al, MRM 2007:58 [2] Chandarana et al, Inv Radiol 2012:Epub
[3] www.osirix-viewer.com [4] www.clearcanvas.ca