A MATLAB Toolbox for Parallel Imaging using Multiple Phased-Array Coils

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INTRODUCTION: Rapid growth of MRI applications calls for continuous development of faster imaging techniques. A number of partially parallel acquisition (PPA) techniques such as SENSE, PILS, SMASH, GRAPPA, and SPACE RIP [1-5] have been developed and have achieved considerable acceleration factors. Though all these methods use multiple receiver channels and k-space subsampling to reduce scan time, each technique has its own k-space coverage and reconstruction strategy. For a given imaging environment (receiver coil array configuration, pulse sequence and imaging time), it is gainful to know which method would provide optimal performance. A parallel imaging toolbox has been developed in MATLAB to implement the afore-mentioned PPA methods, and to simulate and compare them so that an appropriate and reliable method can be chosen for a particular experiment.

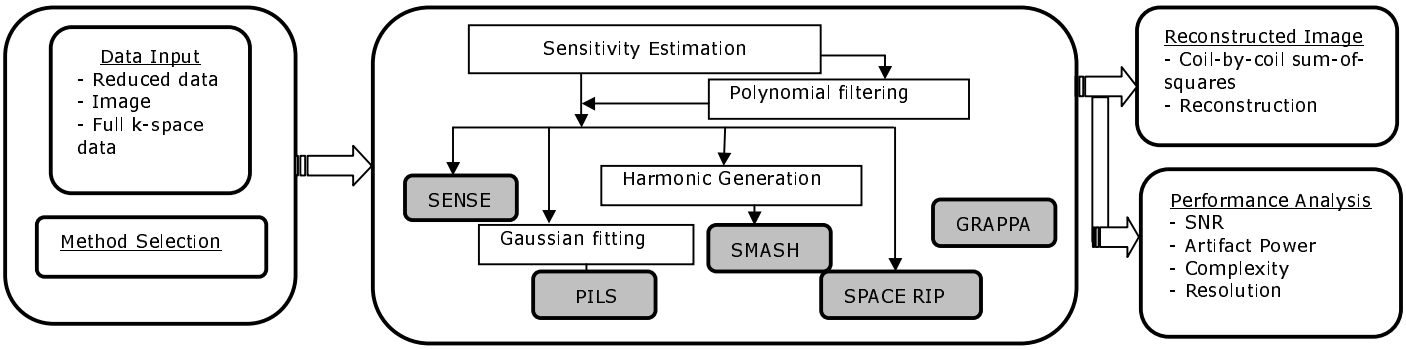
METHOD: This toolbox provides a graphical user interface (GUI) for data input, image reconstruction, and visualization of results. It also allows the user to analyze the parallel imaging techniques for their performance under particular imaging conditions. The MATLAB source codes can also run separately as scripts and are available upon request from Jim Ji (`jimji@tamu.edu`).

Basic functions and input/output specifications: The software reconstructs images from reduced k-space data using the five methods mentioned. It accepts raw k-space data (reduced or full) in MATLAB '.mat' data format. Multiple-channel data is organized linearly with the leading dimension as frequency encoding dimension, followed by phase encoding dimension, and channel dimension. For variable density k-space data required by GRAPPA, auto-calibrated SMASH/ SENSE, and SPACE RIP, a phase encoding index table will also be required. The toolbox can also simulate the subsampled data from a full k-space data set, or an image together with the Gaussian-distributed sensitivity specified. The image size, reduction factor and the variable density sampling can be adjusted to fit the needs of different methods. After reconstruction, performance parameters like SNR, resolution, and artifact power can be evaluated using the tool. The final reconstruction is available at the GUI interface or in the form of a '.mat' file.

Sensitivity estimation: Several methods require prior knowledge of coil sensitivities. The estimation method as in the SENSE method with optional polynomial fitting is implemented [1]**.** The program also provides Gaussian fitting in order to estimate the coil centers for PILS and SMASH reconstructions. For simulated coil sensitivity, the coil configuration and the coil localization can be user-defined.

Image reconstruction: The detailed description of individual reconstruction methods can be found in the references. In addition, several improvements over the original reconstruction methods are also provided: (a) sum-of-squares coil-by-coil reconstruction using the extra center lines, (b) auto-calibration SMASH and SENSE, and (c) regularized SENSE.

Performance analysis: SNR is evaluated on a pixel by pixel basis using two or multiple image acquisitions [6]. Artifact power is calculated based on a reference image [2]. Computational complexity is characterized in terms of complex additions and subtractions required. Resolution due to a particular acquisition technique is characterized by a simulation using a specially designed resolution phantom image.



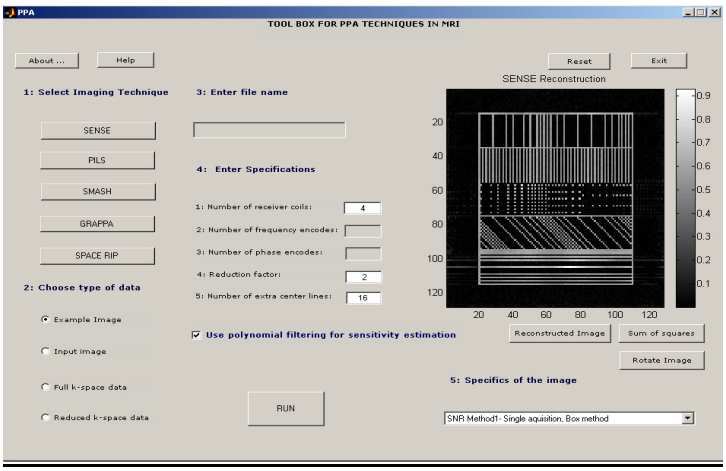


Figure 1. Structure of parallel imaging toolbox (above); and Snapshot of the user interface (left).

CONCLUSION: A MATLAB toolbox for partially parallel acquisition techniques in MRI is designed. It allows the user to study and analyze 2D parallel imaging techniques on the basis of several performance parameters such as SNR, resolution, artifact power and computational complexity. Extension to 3D imaging methods and non-Cartesian k-space coverage is under development and is expected to be available at the time of the conference.

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