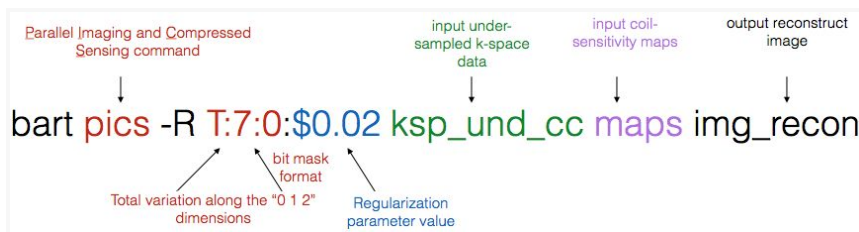


Review of Berkeley Advanced Reconstruction Tool-Box (BART)

The BART tool box is an open source reconstruction tool-box which provides an efficient and flexible framework for rapid prototyping of MRI reconstruction algorithms. BART has an exhaustive programming library which contains several useful functions that are commonly used such as operations on multi-dimensional arrays, handling non-Cartesian data, handling multiple regularization (eg. Tikhonov, Total variation, l1-wavelets, multi-scale low rank), range of iterative numerical optimization methods, calibration based, calibration-less methods for parallel MRI, transparent GPU acceleration for most of these functions. These can be run directly from the command-line or interfaced via Matlab/Octave, and run through Matlab/Octave.

An example usage of the “pics” command, which performs parallel imaging and compressed sensing with total variation regularization is listed below:



The functionality of all of the BART commands can be obtained by using the ‘-h’ help option. For instance below is the functionality of the “pics” command:

```
bart('pics -h')
Usage: pics [-l ...] [-r f] [-c] [-s f] [-i d] [-t <string>] [-n] [-g] [-p
<string>] [-e] [-d d] [-u f] [-C d] [-f f] [-w f] [-S] <kspace> <sensitivities>
<output>
```

Parallel-imaging compressed-sensing reconstruction.

```
-l1/-l2          toggle l1-wavelet or l2 regularization.
-r lambda        regularization parameter
-c              real-value constraint
-s step         iteration stepsize
-i iter         max. number of iterations
-t file         k-space trajectory
-n             disable random wavelet cycle spinning
-g             use GPU
-p file         pattern or weights
-e             set stepsize based on max. eigenvalue
```

```
-d level          debug level
-u rho           ADMM rho
-C iter          ADMM max. CG iterations
-f rfov          restrict FOV
-w val          scaling
-S              Re-scale the image after reconstruction
-h              help
```

Instructions to get started with BART are documented at: <https://mrirecon.github.io/bart/>
The git hub repository is located at: <https://github.com/mrirecon/bart>

The above include installation instructions for linux, mac, and windows. The reviewer was able to easily install BART on the linux and mac platforms based on the instructions provided above.

After installation, the reviewer recommends users to go through the exercises listed at

<https://github.com/mikgroup/bart-workshop>,
<http://mrirecon.github.io/bart/examples.html>

The reviewer found these to be very useful, which are well documented, and systematically introduce to various terminologies within BART and its features. For instance, it gives the users a sense of the input, output data formats, usage of bit-mask terminology, interface with Matlab, displaying the data etc. The reviewer was able to easily run all the demos in the above two links, and was able to use pieces of code provided in these demos to adapt to his own data.

The developers of BART also maintain a mailing list at mrirecon@lists.eecs.berkeley.edu. The reviewer highly recommends joining this mailing list, which gives the users to keep track of solutions being suggested while BART is being adapted to several new reconstruction problems. The responses to users questions are answered on a highly timely fashion by the developers of BART, and also by the general community of BART users. The response time is typically within few hours.

Overall, BART allows for easy to use options of several constrained MRI reconstruction algorithms, and also provides an exhaustive list of commands and tools that can be readily adapted to built new reconstruction algorithms. Its simplicity and structure is attractive for users who wish to efficiently handle large multi-dimensional data, and for efficient use in a clinical setting. Its flexibility allows for advanced reconstruction

developers to borrow inbuilt code to develop new reconstruction code. BART promotes all of its development in an opensource format in timely updates of the code in the git repository, and timely responses and trouble shooting while using BART in the mailing list.

References:

1. Jonathan I Tamir, Frank Ong, Joseph Y Cheng, Martin Uecker, and Michael Lustig, Generalized Magnetic Resonance Image Reconstruction using The Berkeley Advanced Reconstruction Toolbox, ISMRM Workshop on Data Sampling and Image Reconstruction, Sedona 2016
2. Martin Uecker, Frank Ong, Jonathan I Tamir, Dara Bahri, Patrick Virtue, Joseph Y Cheng, Tao Zhang, and Michael Lustig, Berkeley Advanced Reconstruction Toolbox, Annual Meeting ISMRM, Toronto 2015, In Proc. Intl. Soc. Mag. Reson. Med. 23:2486
3. Martin Uecker, Patrick Virtue, Frank Ong, Mark J. Murphy, Marcus T. Alley, Shreyas S. Vasanawala, and Michael Lustig, Software Toolbox and Programming Library for Compressed Sensing and Parallel Imaging, ISMRM Workshop on Data Sampling and Image Reconstruction, Sedona 2013