

BART Toolbox for Computational MRI

- ▶ **For research use**
- ▶ Available for Linux, MacOS X, (Windows), ...
- ▶ BSD license (free for commercial use)
- ▶ <https://mrirecon.github.io/bart/>

Contributors:

Jon Tamir, Christian Holme, Moritz Blumenthal, Nick Scholand, Philip Schaten, ... many more (see ACKNOWLEDGMENTS)

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Motivation

- ▶ **Rapid prototyping**
(similar to Matlab, octave, ...)
- ▶ **Reproducible research**
(i.e. scripts to reproduce experiments)
- ▶ **Robustness and clinically feasible runtime**
(C/C++, OpenMP, GPU programming)
- ▶ Educational tool
- ▶ Platform for collaboration

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Programming library

- ▶ Consistent API based on multi-dimensional arrays
- ▶ Fast transforms: FFT, nuFFT, wavelet
- ▶ Generic iterative (matrix-free) algorithms (conjugate gradients, FISTA, IRGNM, ADMM, iPALM, ...)
- ▶ Composable operators / algorithms
- ▶ Transparent GPU acceleration of most functions
- ▶ Neural networks

Command-line tools

- ▶ Simple file format
- ▶ **Looping, parallelization, streaming**
- ▶ Interoperability with Matlab, Python
- ▶ Basic operations: fft, resize, slice, ...
- ▶ Sensitivity calibration and image reconstruction

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Generic Tools

fft	FFT
slice	extract slice
extract	extract block
resize	crop / zeropad
flip	reverse dimensions
join	merge files
zeros/ones	create files
circshift	circular shift
conv	convolution
scale	scale
conj	complex conjugate
fmac	fused multiply-add
saxpy	scalar mult. and add
sdot	dot product
rss	root-sum-of-squares
repmat	repmat
svd	singular-value d.

MRI Tools

cc	channel compression
walsh	Walsh method
caldir	Direct calibration
ecalib	ESPIRiT calibration
ncalib	non-linear calibration
pics	ℓ_1 -SENSE/ESPIRiT
moba	model-based recon
nlinv	non-linear inversion
nufft	non-uniform FFT
pocsense	POCSense
fovshift	Retrospectively shift FOV
pattern	extract pattern
poisson	Poisson-disc pattern
signal	create signal curves

Low field?

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pics: Parallel Imaging Compressed Sensing

> bart pics -RA:B:C:D -R ... [-t trj] [-B basis] kspace sens image

- ▶ parallel imaging and compressed sensing
- ▶ non-Cartesian k-space trajectories
- ▶ subspace reconstruction
- ▶ multiple regularization terms
- ▶ A: different types of regularization:
 ℓ_2 , ℓ_1 , total variation, ℓ_1 -wavelet, (multi-scale) low-rank
- ▶ B: transforms along arbitrary dimensions (space, time, etc.)
- ▶ C: joint-thresholding along arbitrary dimensions
- ▶ D: regularization parameter

Note: Depending on the algorithm additional parameters (step size, number of iterations, etc.) must be set for optimal results.

moba: Model-Based Reconstruction

```
> bart moba - model -r ... [-t trj] kspace enc output [sens]
```

- ▶ signal model (T_1 , T_2 , T_2^* , $T_2^* + \delta B_0$, Bloch)
- ▶ parallel imaging and compressed sensing
- ▶ non-Cartesian k-space trajectories
- ▶ A, B, C, D: regularization

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Resources

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3. Source code: <https://github.com/mrirecon/bart>
4. Mailing list with public archive (see website)
5. Workshops:
<https://github.com/mrirecon/bart-workshop>
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<https://github.com/mrirecon/bart-webinars>
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Educational Track 2 (ET2): Reconstruction of Images and Parameter Maps

[https:](https://github.com/mritogether/ESMRMB2024_Hardware_to_Map)

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Schedule

- ▶ Image Reconstruction: Compressed Sensing, Model-Based Reconstruction, Machine Learning (Efrat Shimron)
- ▶ Introduction to the BART Toolbox (Martin Uecker)
- ▶ Parameter Mapping for Low-Field MRI (Julia Pfitzer)