Offline Open Source Data Reconstruction

Educational course: *Surfing School: Hands-On Open-Source MR: From Pulse Sequence Programming to Reconstruction & Analysis*

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Declaration of Financial Interests or Relationships

Speaker Name: Maxim Zaitsev

I have the following financial interest or relationship to disclose with regard to the subject matter of this presentation:

Company Name: Siemens Healthineers (Erlangen, Germany)
Type of Relationship: Research collaboration

Motivation

Open science and open innovation

- To foster collaboration, accelerate scientific discovery, and streamline clinical translation.

Figure created with ChatGPT

Motivation

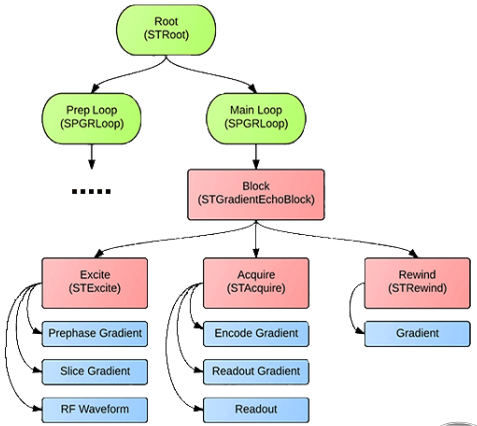
Open science and open innovation

- To foster collaboration, accelerate scientific discovery, and streamline clinical translation.
- Various open-source sequence development tools, such as Pulseq, gammaSTAR, and SequenceTree.

Figure created with ChatGPT

Pulseq

gammaSTAR



SequenceTree

Motivation

Challenges for data reconstruction

- **Limited integration with vendor-provided online reconstruction**
  - ➢ Time-consuming, complex, or even infeasible.

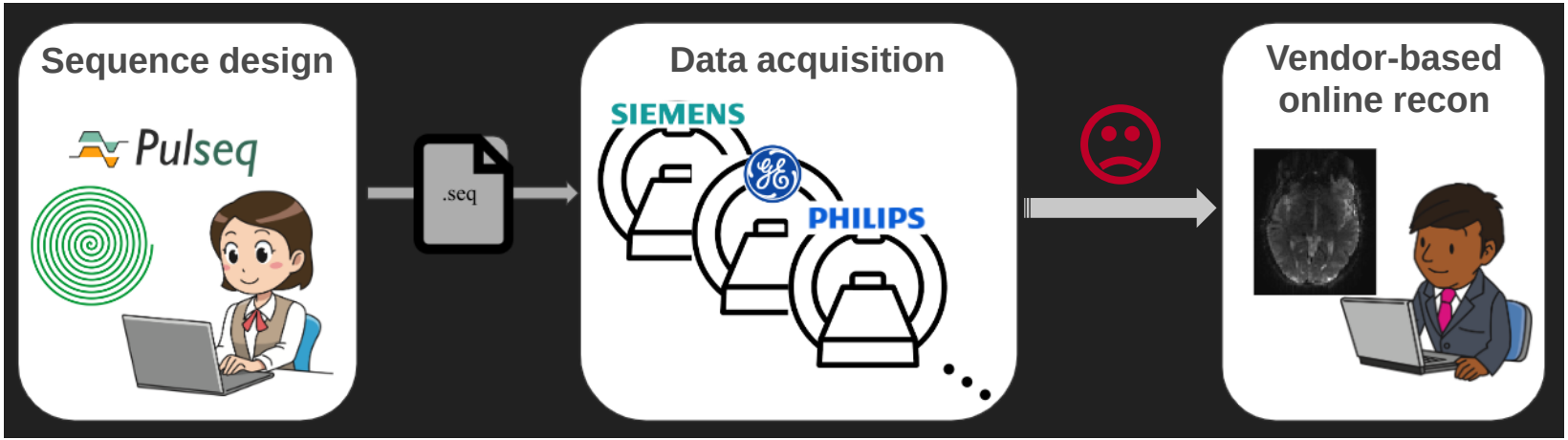


Figure adapted from https://harmonizedmri.github.io/

Motivation

Challenges for data reconstruction

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- **Closed-source vendor-integrated reconstruction environments**
  - ➢ Often operate as a black box → difficulty in debugging and optimization.
  - ➢ Limited support for novel pulse sequences.

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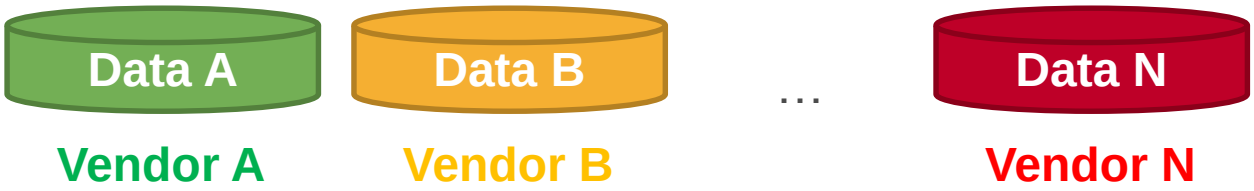

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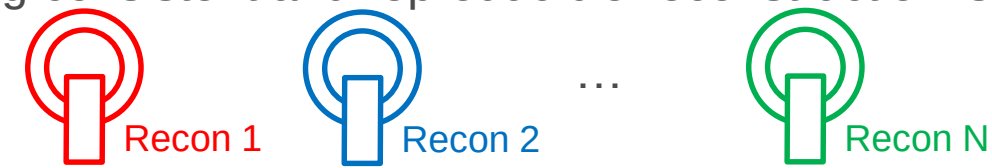
- **Inconsistent data formats across vendors**
  - ➢ Depend on proprietary, vendor-specific knowledge.
- **Lack of harmonization across platforms**
  - ➢ Achieving consistent and reproducible reconstruction is challenging.



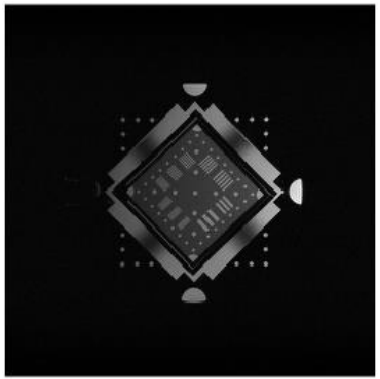
Offline open-source data reconstruction

Overview

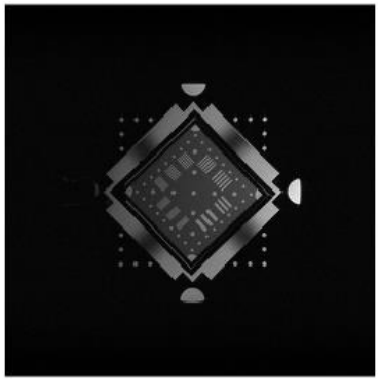
- Manual reconstruction with Matlab, Python, etc
- Semi-automatic demo reconstruction provided by, e.g., Pulseq
- Open-source reconstruction software
  - Berkeley Advanced Reconstruction Toolbox (**BART**)
  - Michigan image reconstruction toolbox (**MIRT**)
  - **Gadgetron** with **ISMRMRD** data fortmat
  - …

Offline open-source data reconstruction

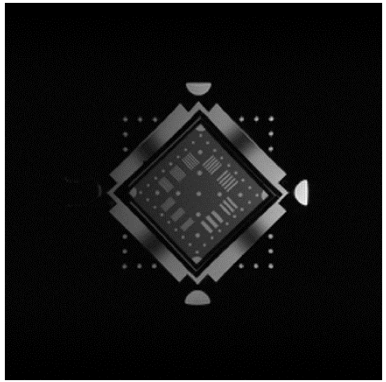
Example recon: 2D GRE



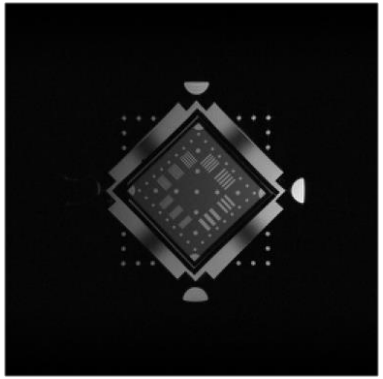
Manual recon



Pulseq demo recon



Gadgetron



BART

All materials are available online:

- Gadgetron installation
- Scripts
- Example data
- ISMRMRD conversion
- …

Tutorial

Prerequisites

- Jupyter Notebooks in the Google Colab environment
  - ➢ No additional software installation is required.
- Prerequisites:
  - ➢ Basic prior knowledge of MR physics and image reconstruction.
  - ➢ A **Google account** to access Google Colab.
  - ➢ A **laptop or tablet** with an active internet connection to run the Jupyter Notebooks.

Link to Google Colab

https://github.com/pulseq/ISMRM-2025-Surfing-School-Hands-On-Open-Source-MR

Tutorial

1_GRE2D_manual_BART_reconstruction

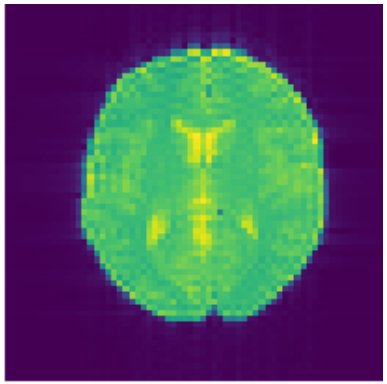
- Pulseq-based 2D fully-sampled GRE
- Simulation with MRzero
- Manual reconstruction
- **Detailed instructions for BART**

BART command structure:

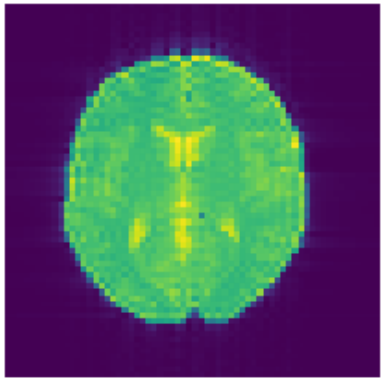
```
bart + command + options + input/output
```

2D inverse (-i) unitary (-u) FFT:

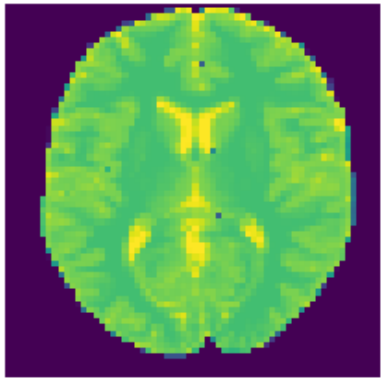
```
bart fft -u -i $(bart bitmask 0 1) ksp img
```



Manual recon (2D FFT)



BART recon (2D FFT)



Digital phantom for simulation

Tutorial

2_GRE2D_PICS_BART_Cartesian_undersampling

- Nx = 256, Ny = 256, #coil = 18
- 2-fold undersampling, 32 auto-calibration lines

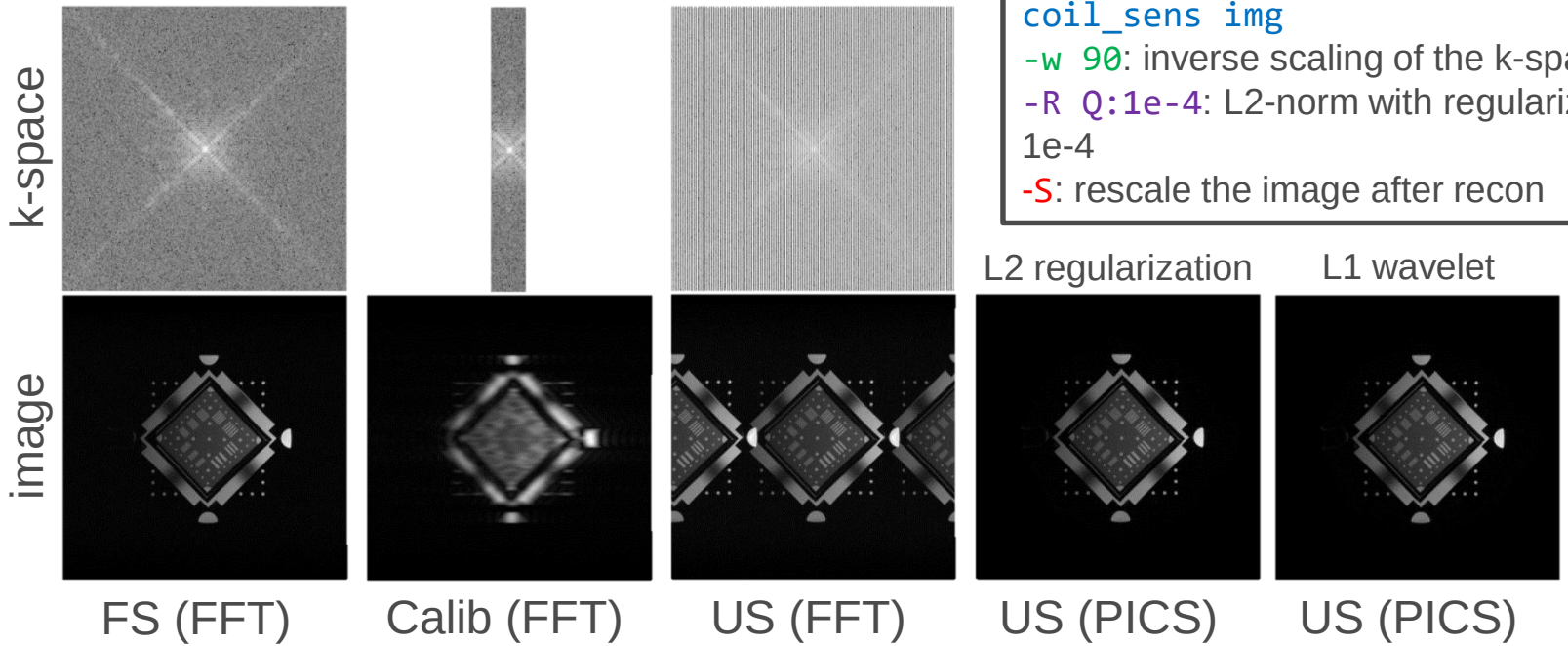
PICS recon with L2 regularization:

```
bart pics -w 90 -R Q:1e-4 -S ksp coil_sens img
```

`-w 90`: inverse scaling of the k-space data

`-R Q:1e-4`: L2-norm with regularization value of 1e-4

`-S`: rescale the image after recon



Tutorial

3_GRE2D_PICS_BART_Poisson_undersampling

- Nx = 256, Ny = 256, #coil = 18
- 2*2 in-plane acceleration, Auto-calibration: 32*32

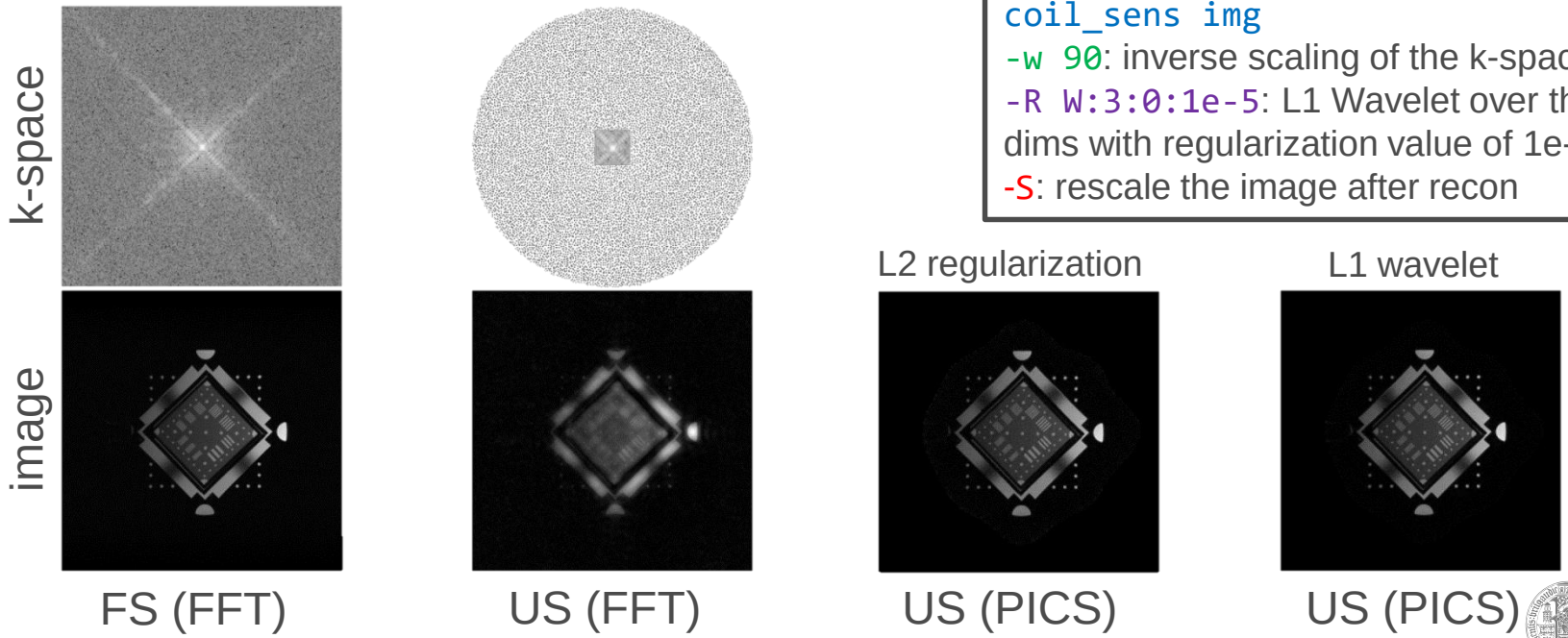
PICS recon with L1 Wavelet regularization:

```
bart pics -w 90 -S -R W:3:0:1e-5 ksp coil_sens img
```

`-w 90`: inverse scaling of the k-space data

`-R W:3:0:1e-5`: L1 Wavelet over the first two dims with regularization value of 1e-5

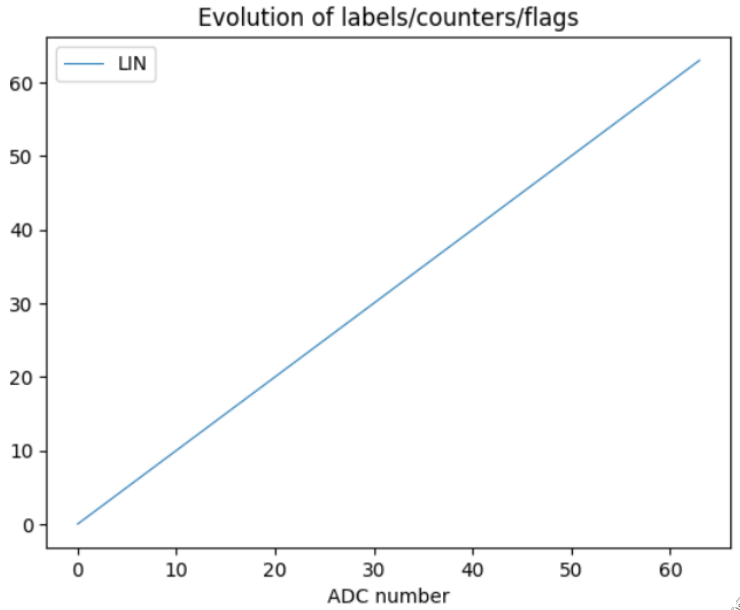
`-S`: rescale the image after recon



Tutorial

4_GRE2D_ISMRMRD_conversion


```
seq.add_block(gxPre, mr.scale_grad(gy,
peScales[i]), gzReph,
mr.make_label(type='SET',label='LIN',
value=PElbl[i]))
```



Labels for the 2D GRE data

Related links

- Pulseq: https://github.com/pulseq
- MRzero: https://mrzero-core.readthedocs.io/en/latest/intro.html
- gammaSTAR: https://gamma-star.mevis.fraunhofer.de/#/
- SequenceTree: https://www.opensourceimaging.org/project/sequencetree/
- BART: https://mrirecon.github.io/bart/
- MIRT: https://github.com/JeffFessler/mirt
- Gadgetron: https://github.com/gadgetron/gadgetron
- ISMRMRD: https://github.com/ismrmrd/ismrmrd

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Pulseq MATLAB

pypulseq Python

TOPPE

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