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Wave-LORAKS for highly accelerated MRI: Structured low-rank matrix reconstruction for Wave-encoded MRI

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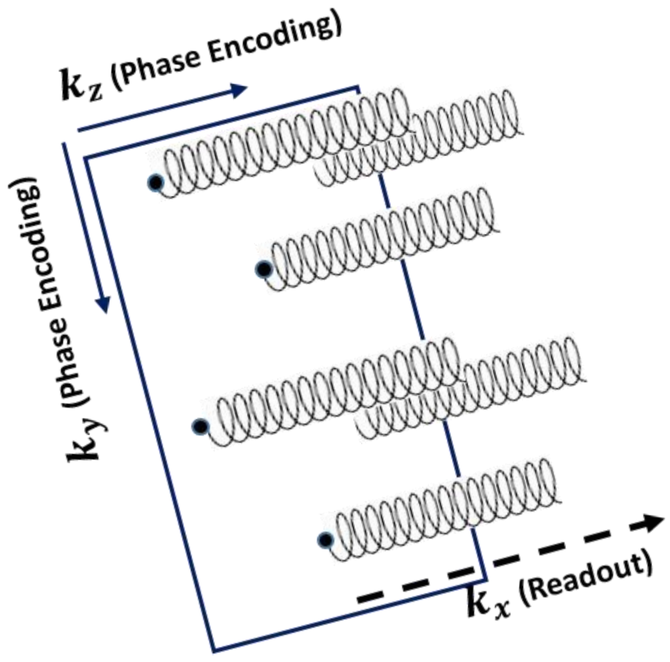
Motivation & Introduction

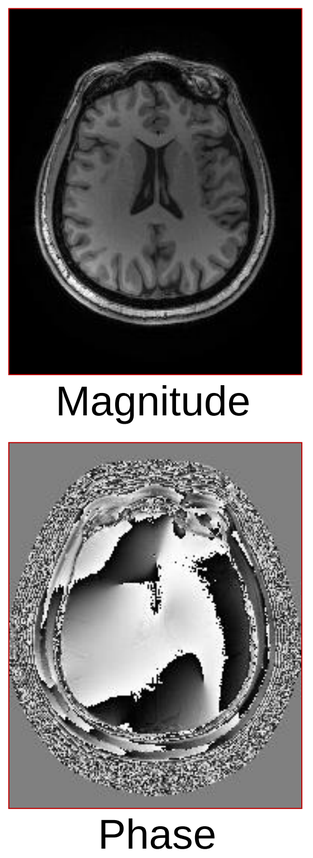
- MRI is a useful tool for imaging inside the body
- Slow data acquisition is a big barrier
- MRI data is discrete samples in Fourier domain (called k-space). So, signal processing techniques can be applied.
- Can design sampling trajectories: Cartesian grid (general) spiral, radial, random, variable density, or etc.
- Acquiring more data samples = Longer scan time
  - Goal: less samples & lower reconstruction error by designing proper acquisition and reconstruction

Our approach

- Wave-CAIPI is an MRI data acquisition method using corkscrew sampling trajectories, leading to better reconstruction through reduced aliasing. However, this only relies on simple least-square solution.
- LORAKS is a powerful reconstruction method employing low-rank constraints of the structured matrices, when MR Images have small support and slowly varying phase.
- We propose Wave-LORAKS that combines Wave-CAIPI data acquisition and LORAKS reconstruction, enabling higher acceleration and more flexible sampling.

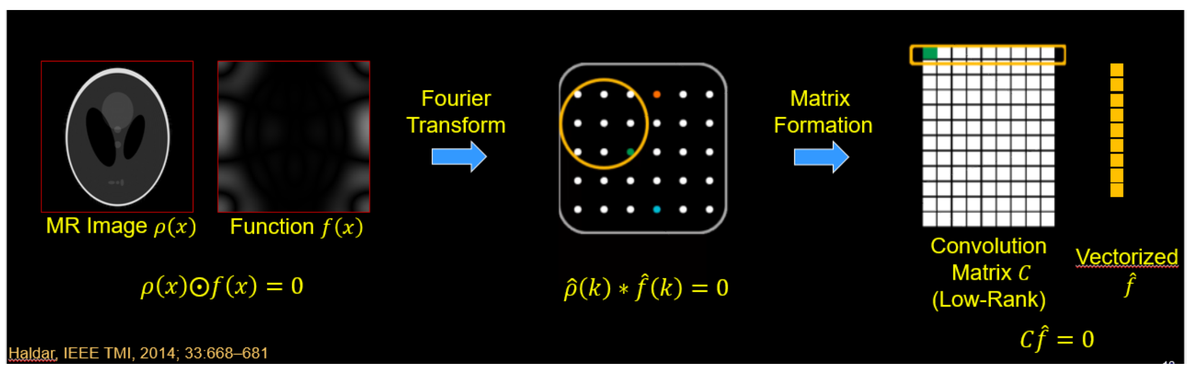


Wave-CAIPI MRI data acquisition



Wave-LORAKS

- LORAKS low-rank constraints



- Objective Function

$$\min_{\boldsymbol{\rho}} \|\mathbf{E}\boldsymbol{\rho} - \mathbf{d}\|_{\ell_2}^2 + \lambda \left(\sum_{k_x} \mathbf{J}(\boldsymbol{\rho}_{k_x}) + \sum_{k_y} \mathbf{J}(\boldsymbol{\rho}_{k_y}) + \sum_{k_x} \mathbf{J}(\boldsymbol{\rho}_{k_z}) \right)$$

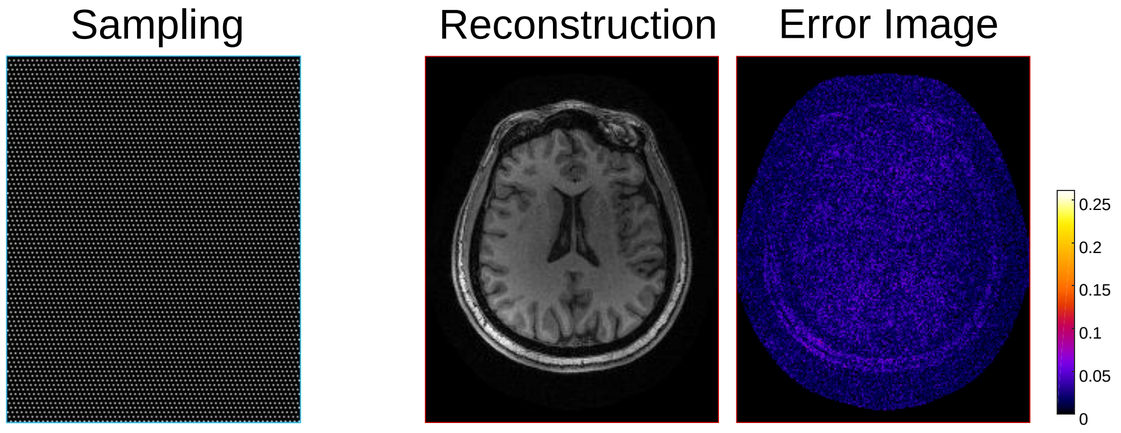
Data Consistency (Wave-CAIPI)

LORAKS low-rank constraints

Conclusion & Future Work

- Proposed and evaluated the new Wave-LORAKS approach for highly accelerated MRI
- Higher acceleration / more flexible sampling
- Easily combined with other constraints (like sparsity)

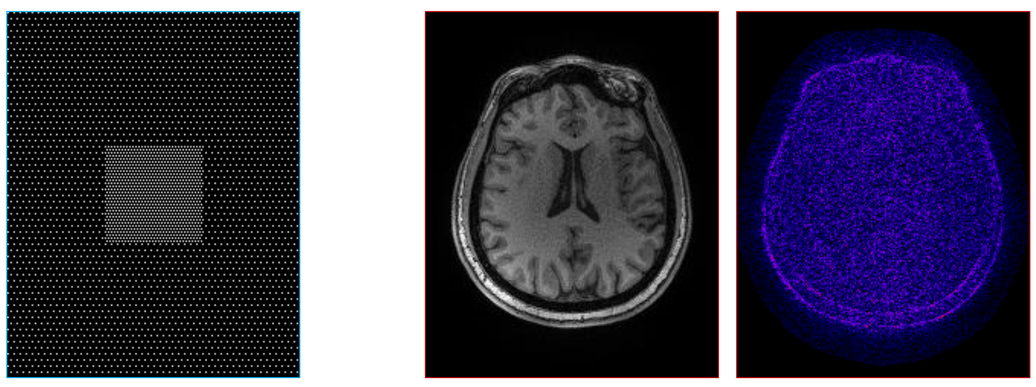
Wave-CAIPI (Conventional least-square solution)



9x CAIPI (Hexagonal/ Quincunx)

NRMSE: 0.13226
HFEN: 0.12348

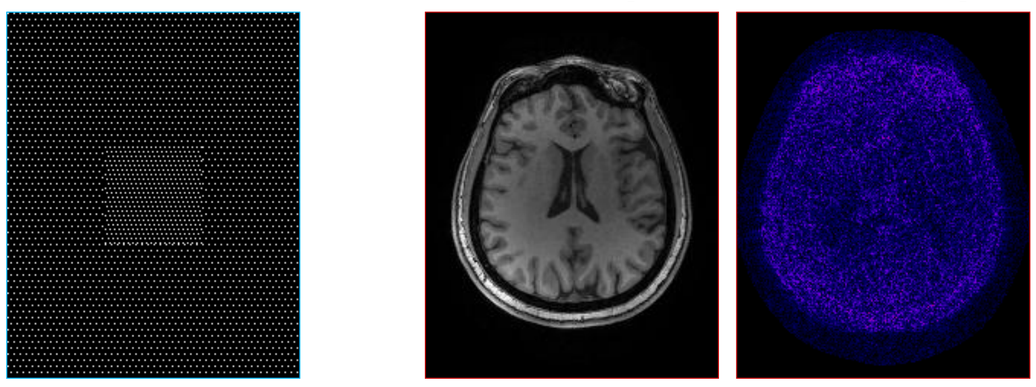
Wave-LORAKS (Proposed)



12.6x Variable density CAIPI

NRMSE: 0.13121
HFEN: 0.11737

Wave-LORAKS + TV (Total Variation)



14.9x Variable density CAIPI

NRMSE: 0.12180
HFEN: 0.11913

References

Haldar. Low-rank modeling of local k-space neighborhoods (LORAKS) for constrained MRI, IEEE TMI, 2014

Bilgic et al., Wave-CAIPI for highly accelerated 3D imaging, MRM, 2015

Kim et. al., LORAKS makes better SENSE: phase-constrained partial Fourier SENSE reconstruction without phase calibration, MRM, 2016

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