ResoNet: Noise-Trained Physics-Informed MRI Off-Resonance Correction

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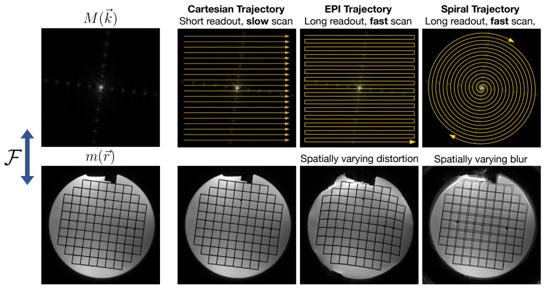
Project Page

Introduction

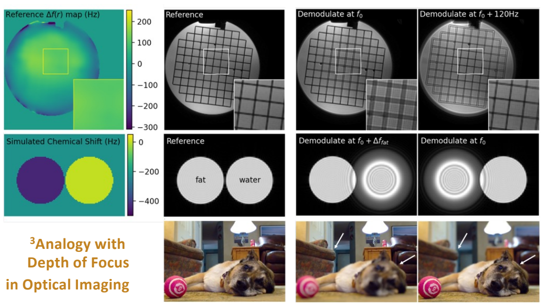
- Magnetic Resonance Imaging (MRI) collects samples in the spatial Fourier domain (*k*-space) in many shots, called *readouts*.
- Non-Cartesian trajectories provide rapid imaging[1] and robustness to patient motion[2], but are more susceptible to *off-resonance* artifacts.



- **Goal: develop a physics-informed deep learning-based reconstruction framework to correct off-resonance in MRI.**

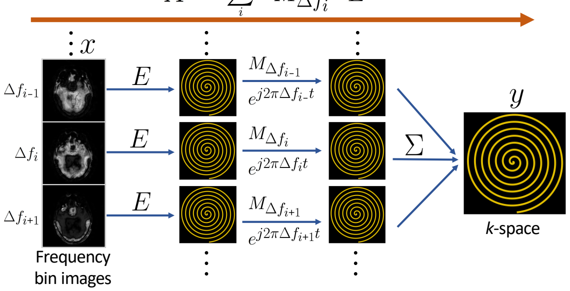
Off-Resonance Blurring

- Artifacts due to **main magnetic field inhomogeneities** and **tissue properties**.



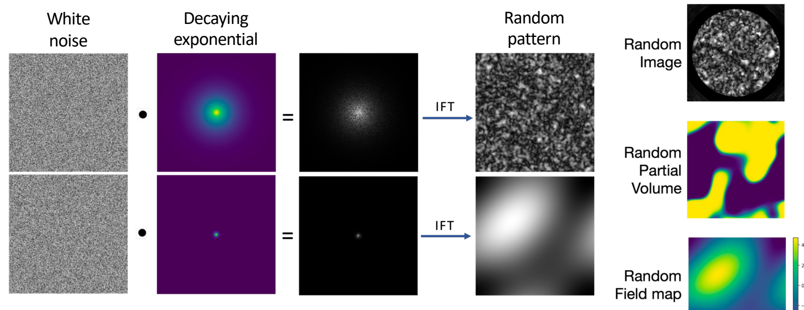
Physics-Informed Forward Model *A*

$$A = \sum_i M_{\Delta f_i} E$$



- Model the object as a **stack of sharp images at multiple frequency bins**. **E**: encode (e.g., Non-Uniform FFT). $\mathbf{M}_{\Delta f}$: phase modulate. **Σ**: sum across bins.

Synthetic Noise-Like Training Data

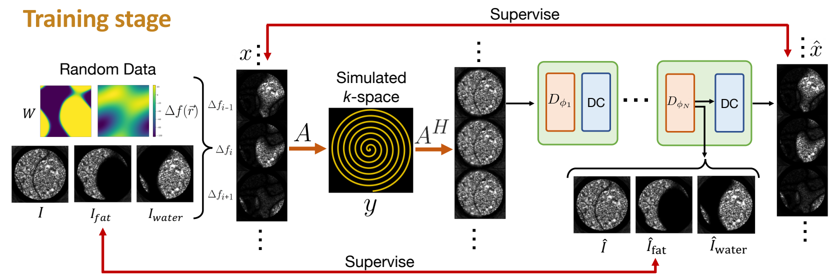


- Mimic Power Spectral Density (PSD) of real data.

Physics-Informed Deep Learning Framework

- Previous works aim to deblur images directly[4-6] or require/estimate field maps[7-8].
  - ✗ Neglect the physics during reconstruction[4,6-7]
  - ✗ Do not handle fat/water partial volume effects[4-8]
  - ✗ Rely on training datasets collection[6-8]
  - ✗ Require extra scans[5]
- Our approach:
  - ✓ Model **leverages physics model *A*** and deep learning to reconstruct images.
  - ✓ Correct **off-resonance and handle fat/water separation** from a **single** echo-time Spiral **scan**.

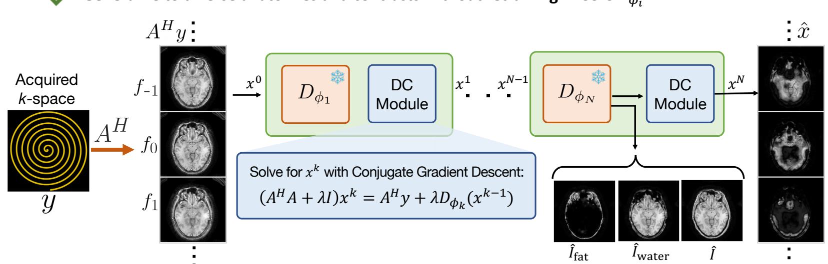
Training stage



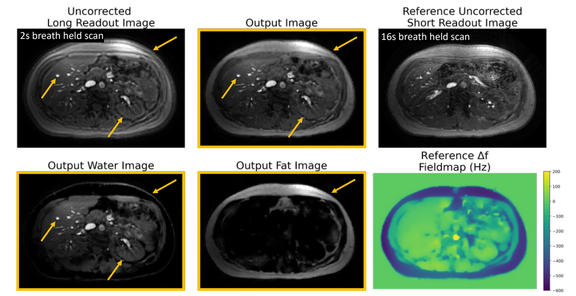
✓ **Train model exclusively on synthetic noise-like data**. Bypass dataset collection challenges.

Inference stage

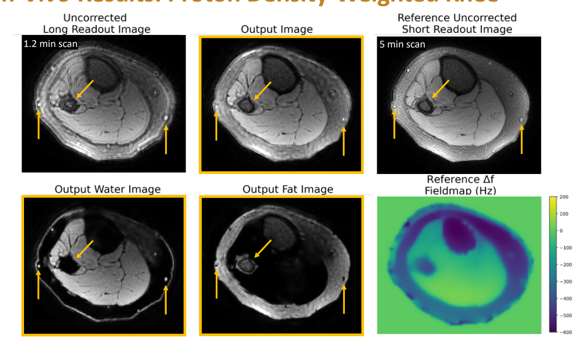
✓ **Generalize to diverse anatomies and contrasts without retraining.** Freeze D_{ϕ_i}.



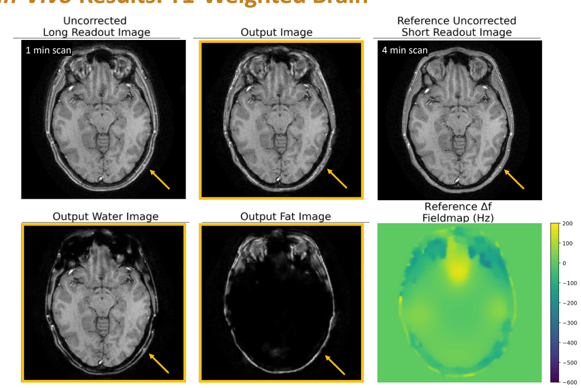
In-Vivo Results: T1-Weighted Abdominal



In-Vivo Results: Proton Density-Weighted Knee



In-Vivo Results: T1-Weighted Brain



References

[1] M. A. Bernstein, K. F. King, X. J. Zhou, Handbook of MRI pulse sequences. Elsevier, 2004. **[2]** Y. Yang et al., "Comparison of fast MR scan techniques for cerebral activation studies at 1.5 Tesla," Magn Reson Med, vol. 39, no. 1, pp. 61–67, Jan 1998. **[3]** Wikimedia Foundation, "Light field camera," Wikipedia, Oct 8, 2022, https://en.wikipedia.org/ wiki/Light_field_camera. **[4]** Noll DC et al. Deblurring for non-2D Fourier transform magnetic resonance imaging. 1992. **[5]** Noll DC et al. Conjugate phase MRI reconstruction with spatially variant sample density correction. 2005. **[6]** Zeng DY et al. Deep residual network for off-resonance artifact correction with application to pediatric body MRA with 3D cones. Magn Reson Med. 2019. **[7]** Lim Y et al. Deblurring for spiral real-time MRI using convolutional neural networks. Magn Reson Med. 2020. **[8]** Haskell MW et al. Deep learning field map estimation with model-based image reconstruction for off-resonance correction of brain images using a spiral acquisition. ISMRM Workshop on Data Sampling and Image Reconstruction. 2020.

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