# Moner: Motion Correction in Undersampled Radial MRI with Unsupervised Neural Representation


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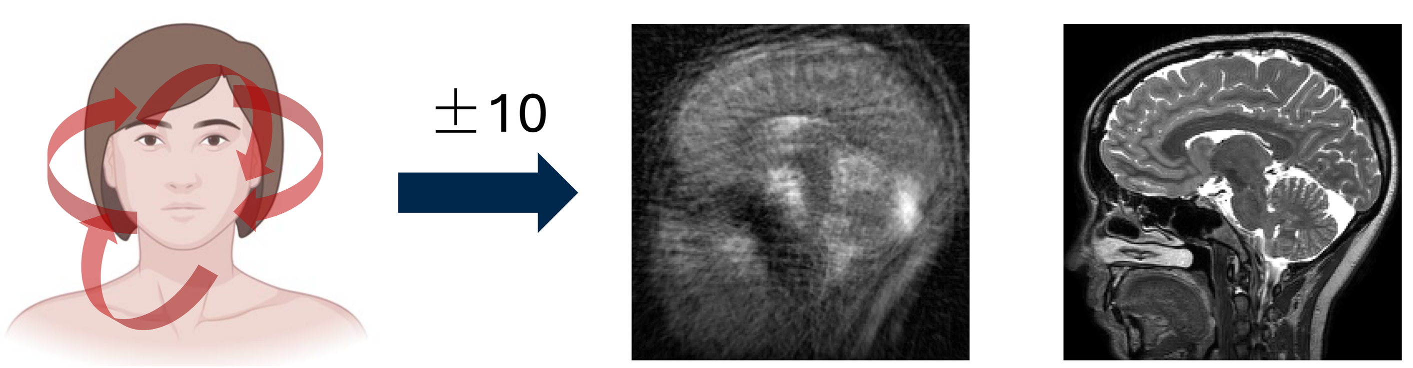
## Overview

- **Goal:** Reconstruct motion-free MR images from rigid motion-corrupted *k*-data without using external data.
- **Solution:** Jointly estimate motion and images by integrating a quasi-static motion model into neural representation.
- **Results**: Our unsupervised approach outperforms SOTA supervised techniques on in- & out-of-domain data.

## Background

- **Radial Magnetic Resonance Imaging (MRI)**
  - A medical imaging technique to image human anatomy.

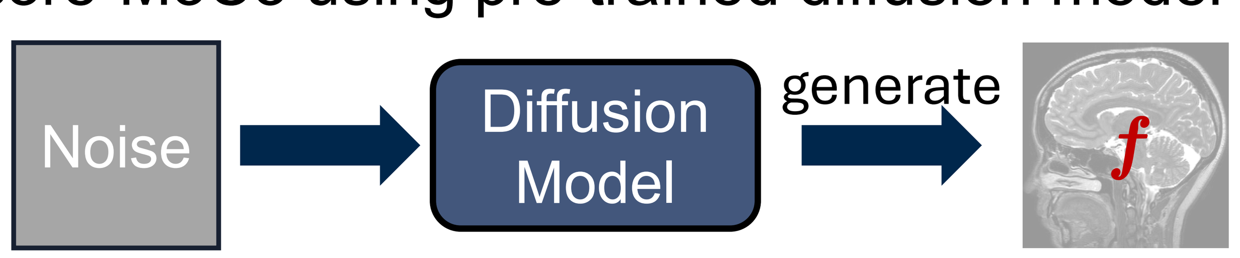

- **Why is Motion Correction (MoCo) necessary in MRI?**
  - Subject inevitably moves due to long scanning duration, which leads to severe motion artifacts in MR images.




- **The SOTA framework for MRI MoCo**
  - Combines MRI forward model (i.e., Fourier transform), a rigid motion model, and pre-trained neural networks.
  - Jointly estimates motion and reconstructs MR images.

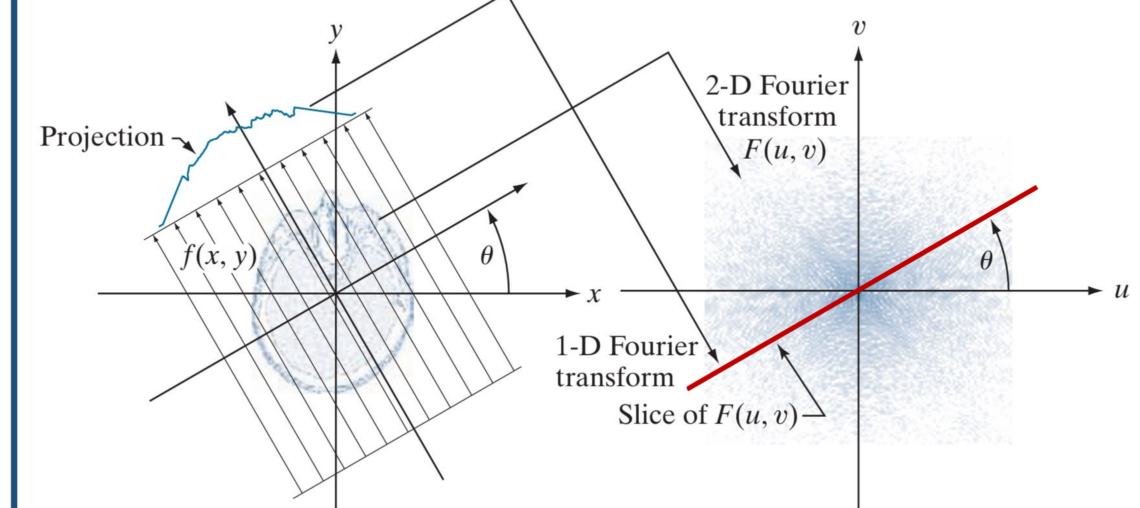
$$\arg\min_{\boldsymbol{f},\,\vartheta,\,\boldsymbol{\tau}} \sum_{\forall(\theta,\omega)} \left\| \mathcal{T}_{\theta,\omega}\{\tilde{\boldsymbol{f}}\} - \boldsymbol{k}(\theta,\omega) \right\|_2^2, \quad \text{with} \;\; \tilde{\boldsymbol{f}} = \mathcal{R}(\boldsymbol{f};\vartheta,\boldsymbol{\tau})$$

  - Score-MoCo using pre-trained diffusion model is SOTA.




## Our Solution

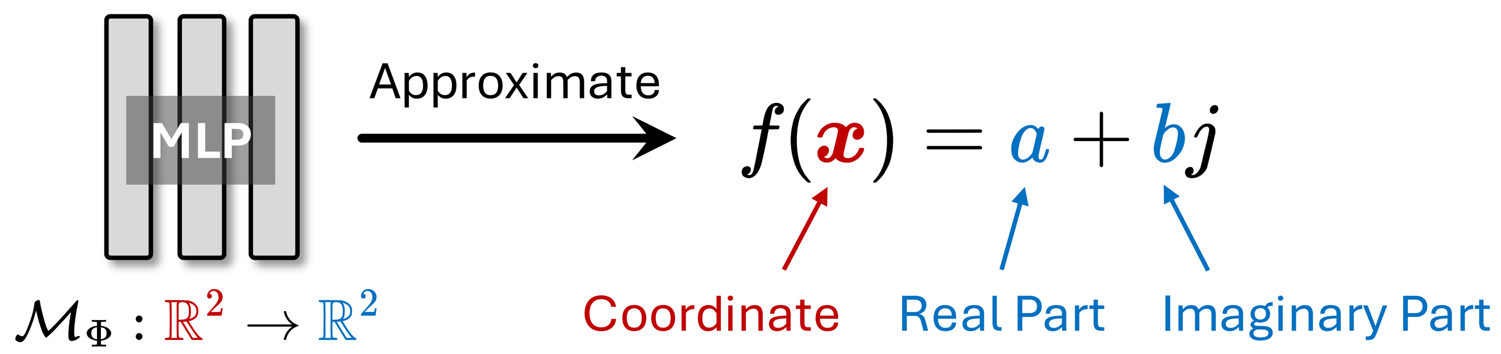
- **Formulation:** Reformulating radial MRI reconstruction as a back-projection problem via the Fourier-slice theorem.




$$\mathcal{T}_w^{-1}\{\boldsymbol{k}(\theta,\omega)\} = \boldsymbol{g}(\theta,\rho) = \int_{\boldsymbol{r}(\theta,\omega)} \boldsymbol{f}(\boldsymbol{x})\,\mathrm{d}\ell_{\boldsymbol{x}}$$

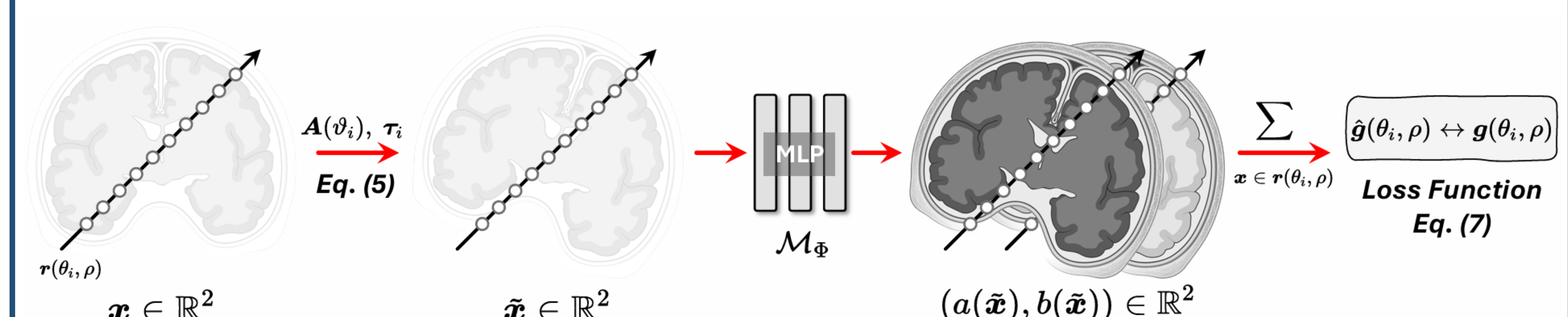
$$\arg\min_{\boldsymbol{f},\,\vartheta,\,\boldsymbol{\tau}} \sum_{\forall(\theta,\rho)} \left\| \int_{\boldsymbol{r}(\theta,\rho)} \tilde{\boldsymbol{f}}(\boldsymbol{x})\ell_{\boldsymbol{x}} - \boldsymbol{g}(\theta,\rho) \right\|_2^2, \quad \text{with} \;\; \tilde{\boldsymbol{f}} = \mathcal{R}(\boldsymbol{f};\vartheta,\boldsymbol{\tau})$$

- **Neural Representation:** Using a coordinate-based neural network to approximate a continuous function of MR images.




- **Coarse-to-fine Image Recovery:** Motion estimation mainly relies on low-frequency structures (e.g., skull), rather than high-frequency details (e.g., cerebellum).

- **Joint Motion Correction and MRI Reconstruction**

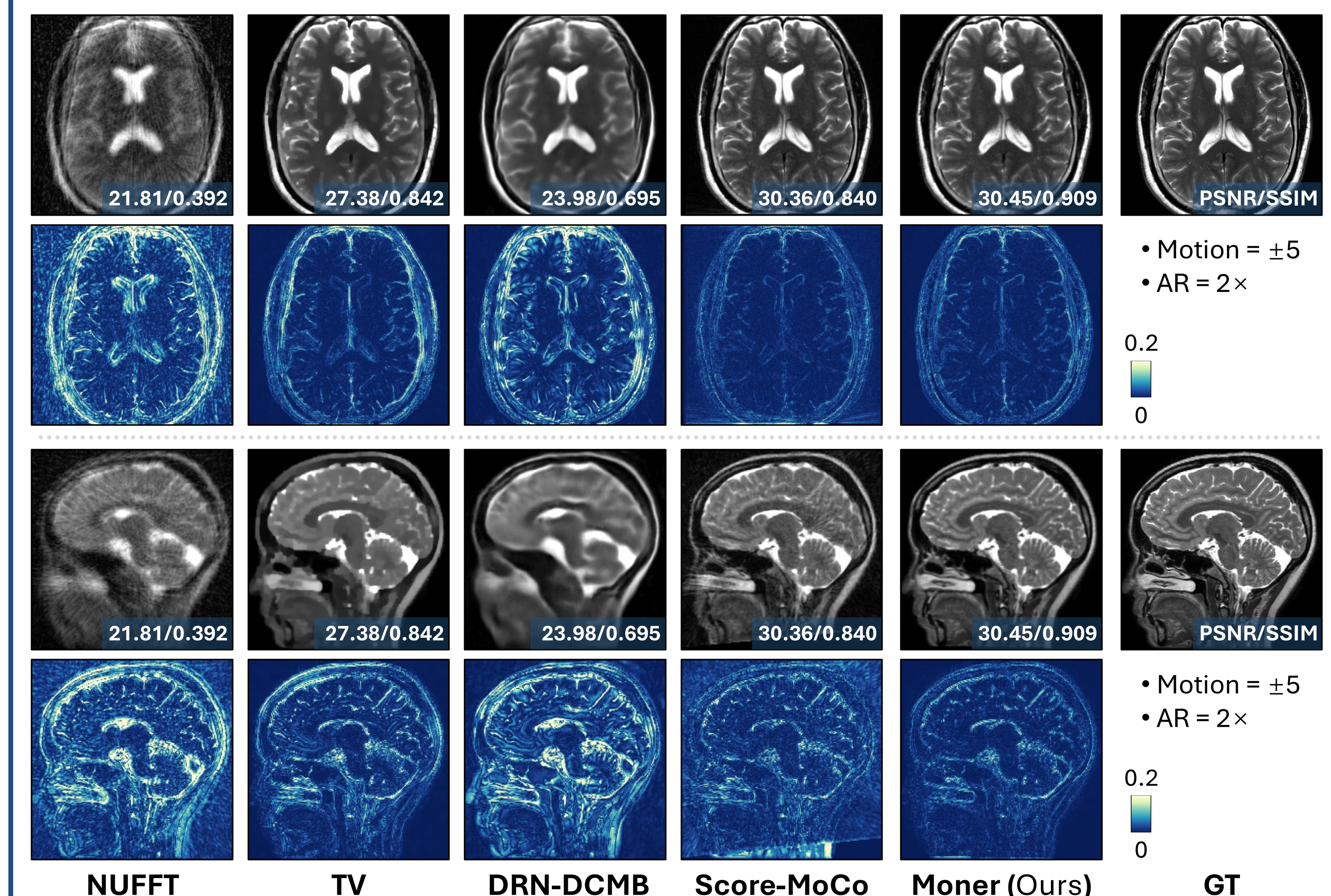



➢ ***Four Steps:***

1. *Sample multiple coordinates along ray paths in the canonical space.*
2. *Transform sampled points to physical space using the motion model.*
3. *Feed the transformed coordinates into the MLP to predict the MR image.*
4. *Generate projection data via a differentiable projection model.*
5. *Optimize MLP and motion parameters minimizing errors on projection data.*

## Experimental Results

- Results on ***simulated*** 2D fastMRI and MoDL datasets




- Results on an ***in-vivo*** 3D sample (scanning time ≈ 8 min.)