Unsupervised Motion-Compensated Decomposition for Cardiac MRI Reconstruction via Neural Representation

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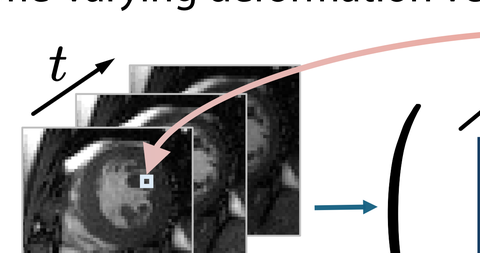
Introduction

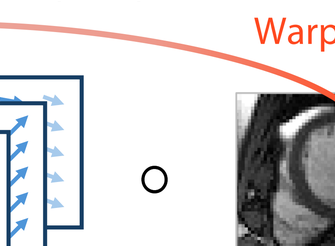
- Clinical Protocol (Cine Imaging) Limitations:

1. ECG Signal Gating



- Increase scan time
- Not feasible to Arrhythmia

2. Breath-Hold



Motion Artifacts

- Susceptible to motion
- Not feasible to Children/Elders

- Real-Time Free-Breathing Cardiac MRI Scans Challenges:
  - Real Time (<50ms) → Severe ill-posedness
  - Respiratory & Cardiac Motion → Complex non-rigid/periodic motions
- Proposed: MoCo-INR
  - Integrate motion-compensation and INR with new designs
  - Flexible with diverse sampling with ultra-high acceleration

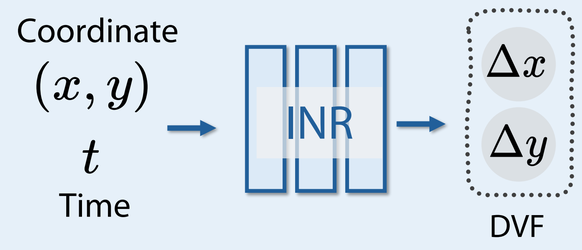
Motion-Compensated Method

- Decompose dynamic sequences into a canonical image and time-varying deformation vector fields (DVF)

Implicit Neural Representation

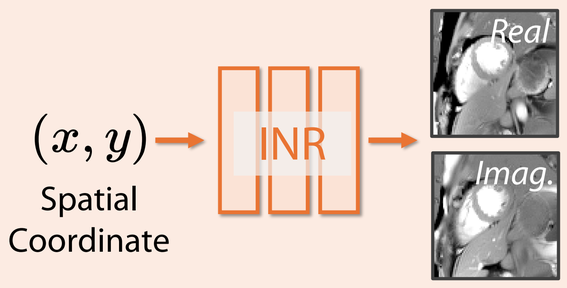
- Using a coordinate-based neural network to represent continuous canonical images and DVFs

DVF Network



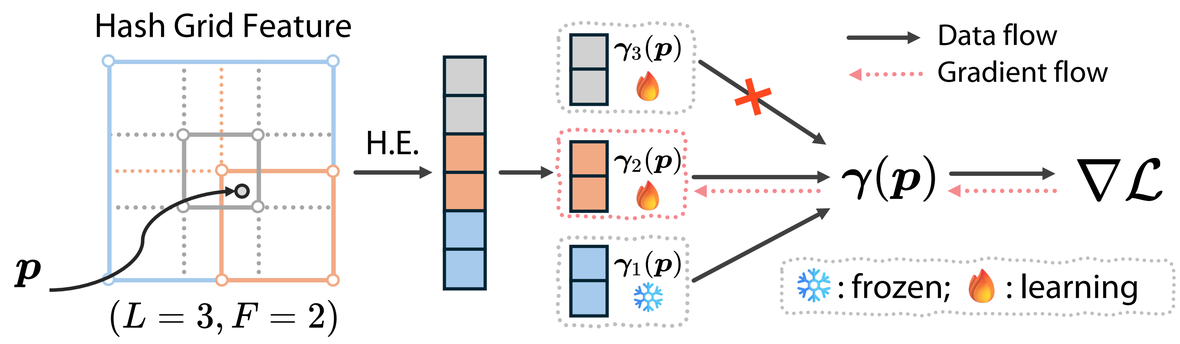
$\mathcal{F}_{\Phi} : \mathbb{R}^3 \rightarrow \mathbb{R}^2$

Canonical Network

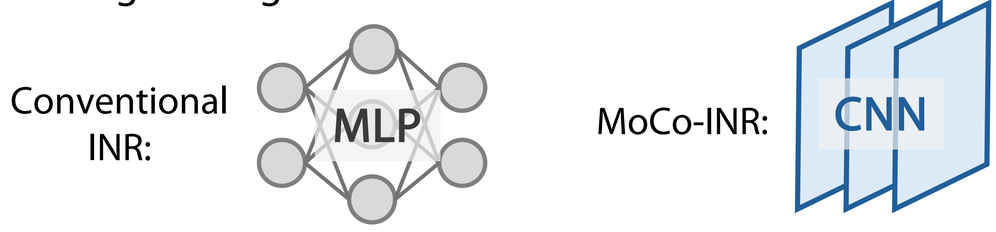


$\mathcal{G}_{\Psi} : \mathbb{R}^2 \rightarrow \mathbb{R}^2$

- **New INR Network Designs:**
  - Coarse-to-Fine Hash-Encoding (C2F H.E.) strategy:



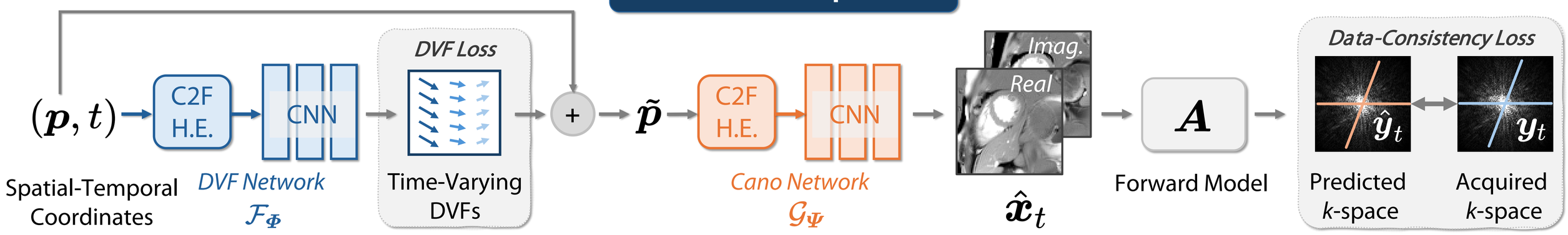
  - Light-Weighted CNN-based Decoder:



- Prone to overfitting noise/artifacts
- Unstable unsupervised optimization

- Local consistency & Inductive bias
- Stable & robust optimization

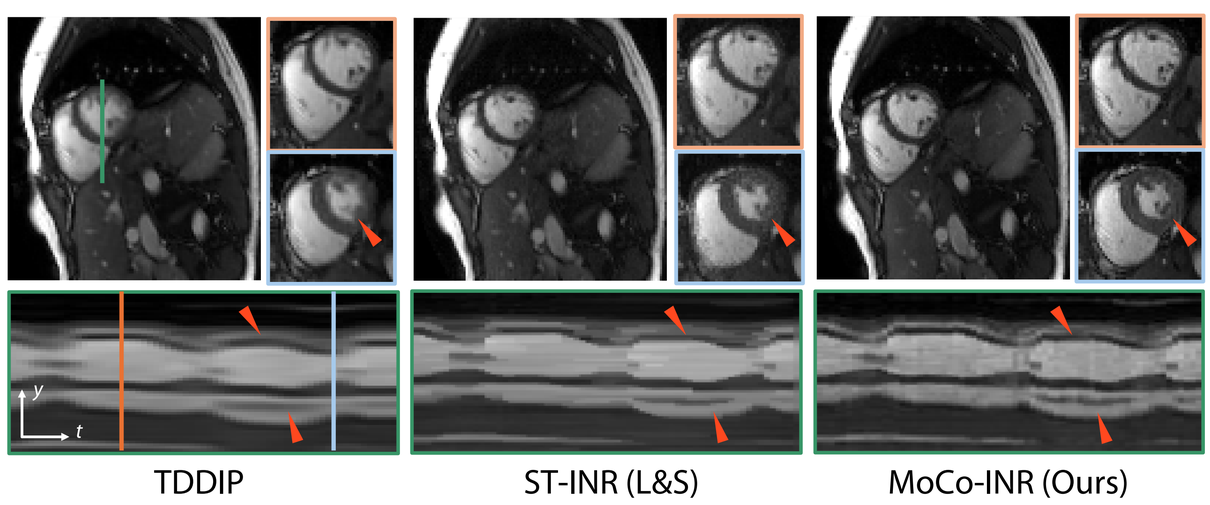
MoCo-INR Pipeline



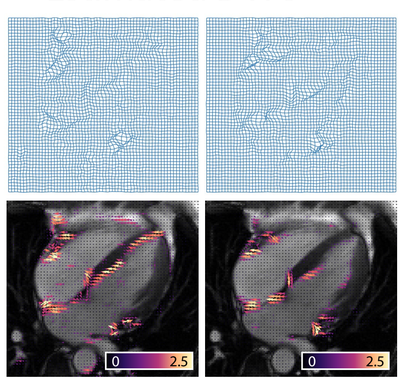
Experimental Results

- Retrospective Studies (Diverse Samplings)

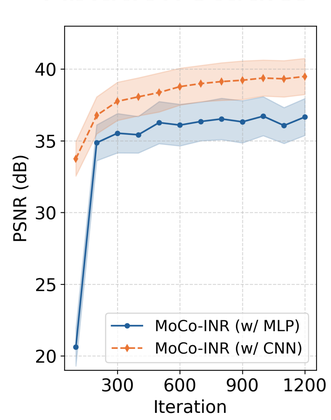
- Prospective Real-Time Free-Breathing Scans



- Estimated DVFs



- Ablation Studies



Model	PSNR	SSIM
w/o $\mathcal{L}_{\text{DVF}}$	34.42±2.73	0.895±0.031
w/o C2F	35.51±2.84	0.926±0.026
Full	**37.75±2.53**	**0.940±0.024**

Paper

Code