NeRP: Implicit Neural Representation Learning with Prior Embedding for Sparsely Sampled Image Reconstruction

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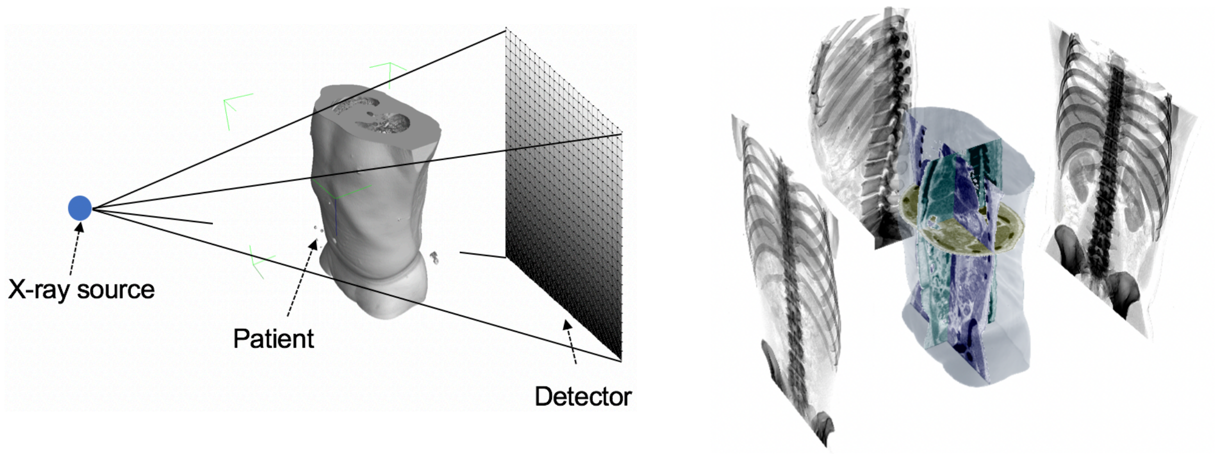
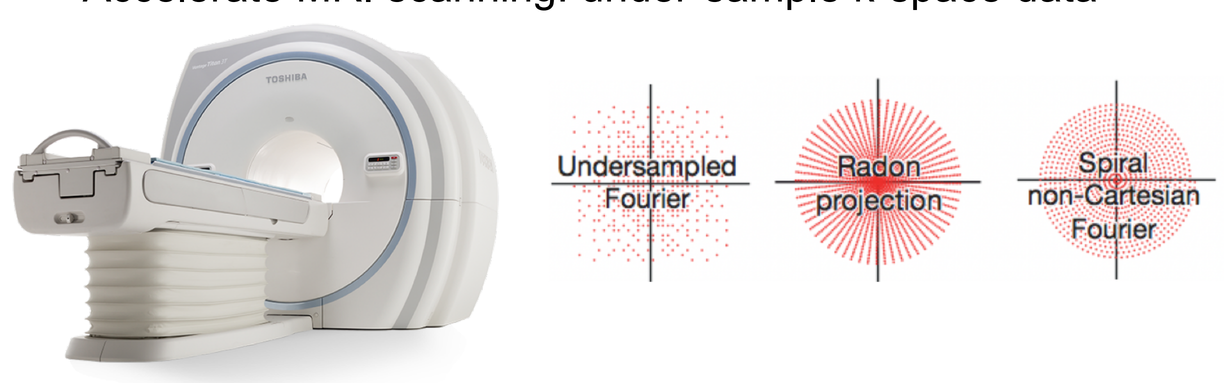
Background and Motivation

Why care sparse-sampling medical imaging?

- X-ray Computed Tomography (CT) imaging
- Reduce radiation injury in CT: sample sparse projection

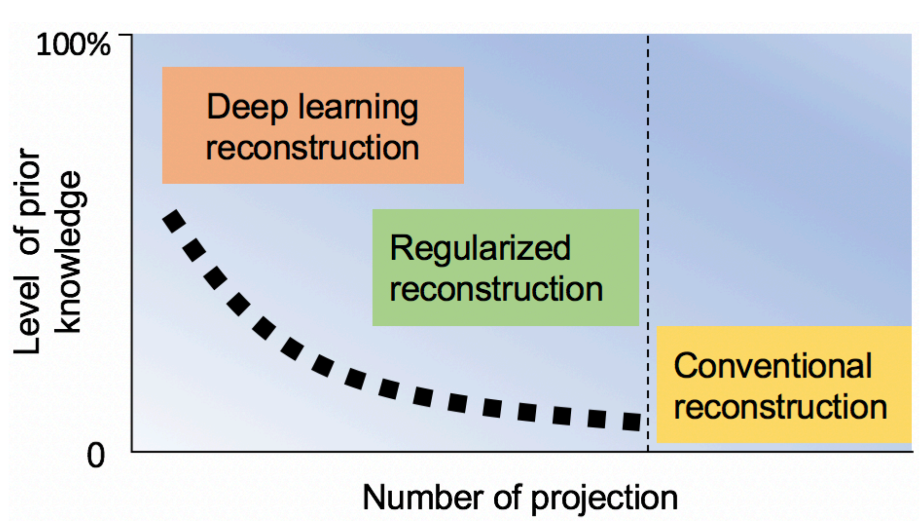


- Magnetic Resonance Imaging (MRI)
- Accelerate MRI scanning: under-sample k-space data



Inverse problem: Sparse-sampling image reconstruction

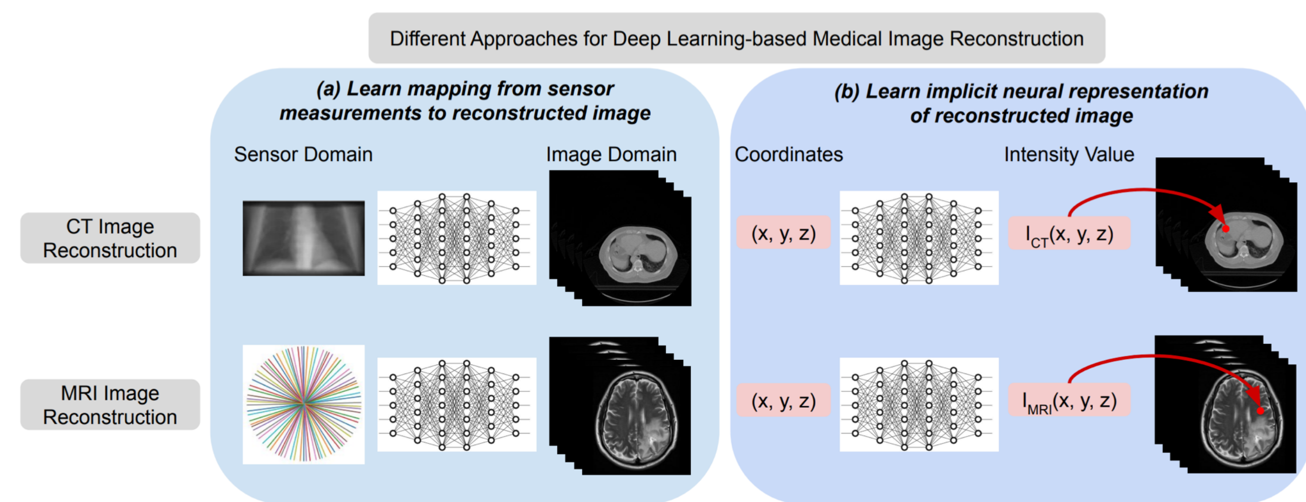
- Leverage prior knowledge for inverse problem solving



Neural Representation Learning

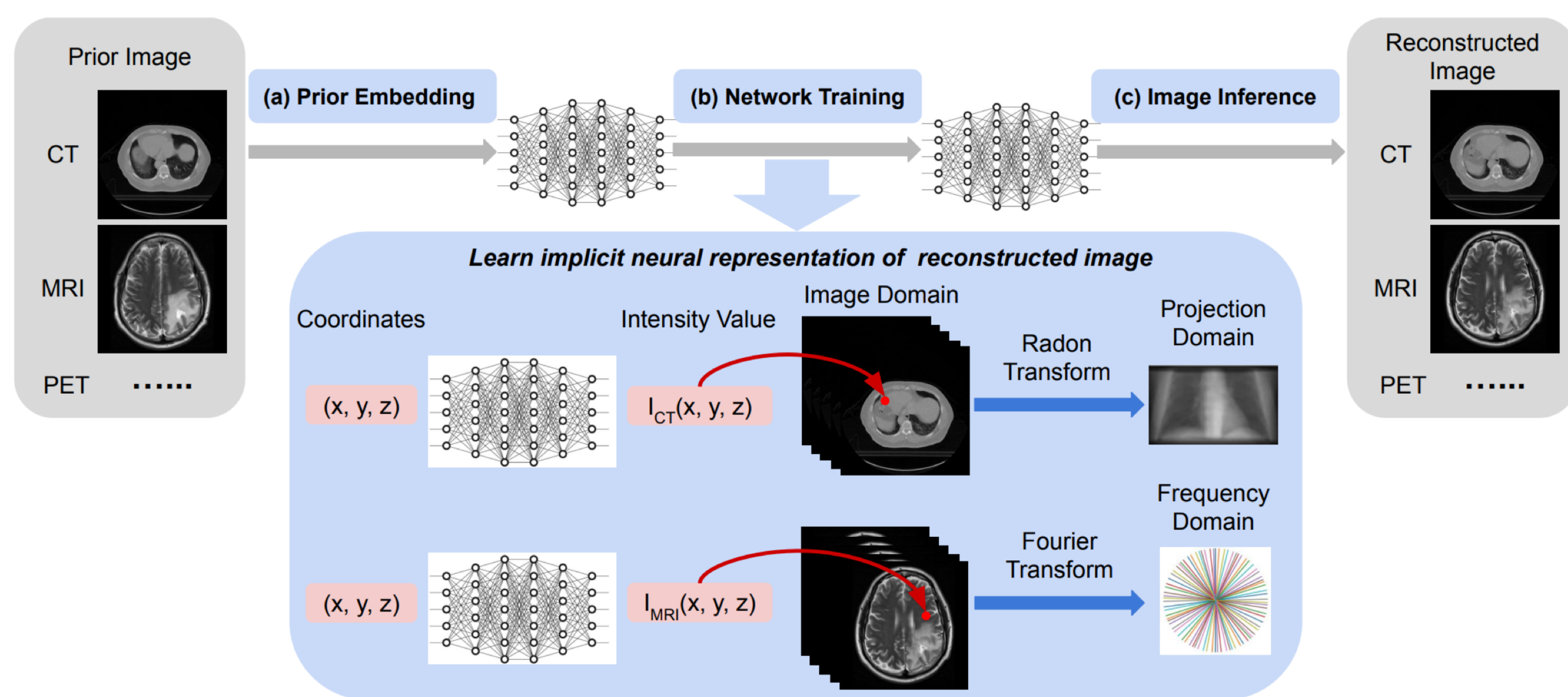
Coordinate-based Continuous Function Optimization:

- Different from previous deep learning-based image reconstruction
- Parametrize an image as a continuous function through Multi-Layer Perceptron (MLP) model



NeRP: Neural representation learning with prior embedding for sparse-sampling image reconstruction

- Exploit internal information from longitudinal prior image and physics of sparse-sampling measurements to learn representation of unknown subject



Unsupervised Image Reconstruction

- No large-scale data from external subjects is required for training
- Easily generalize to different anatomic sites and various imaging modalities
- Robustly capture subtle yet significant structural changes like tumor progression

TABLE I
RESULTS OF 3D CT IMAGE RECONSTRUCTION
USING 5 / 10 / 20 PROJECTIONS ON DIFFERENT ANATOMICAL SITES

Methods	Pancreas CT	HeadNeck CT	Lung CT
Projections = 10			
FBP	17.95 / 0.461	23.05 / 0.653	21.49 / 0.597
GRFF [20]	28.07 / 0.855	29.38 / 0.864	27.80 / 0.835
NeRP w/o prior	28.88 / 0.850	30.40 / 0.858	30.98 / 0.880
NeRP (ours)	**37.66 / 0.981**	**36.92 / 0.976**	**32.73 / 0.941**
Projections = 20			
FBP	18.23 / 0.610	23.42 / 0.750	21.74 / 0.717
GRFF [20]	29.27 / 0.893	32.56 / 0.931	32.75 / 0.935
NeRP w/o prior	32.41 / 0.927	32.59 / 0.920	32.86 / 0.929
NeRP (ours)	**39.06 / 0.986**	**38.81 / 0.985**	**36.52 / 0.972**
Projections = 30			
FBP	18.31 / 0.650	23.54 / 0.773	21.83 / 0.7443
GRFF [20]	31.53 / 0.932	32.34 / 0.927	33.13 / 0.942
NeRP w/o prior	33.88 / 0.953	33.53 / 0.942	33.97 / 0.951
NeRP (ours)	**39.65 / 0.987**	**39.50 / 0.987**	**37.66 / 0.980**

TABLE II
RESULTS OF 3D MRI IMAGE RECONSTRUCTION
USING 30 / 40 / 50 RADIAL SPOKES FOR DIFFERENT IMAGE CONTRASTS

Methods	T1	T1c	T2	FLAIR
Spokes = 30				
Adjoint NUFFT	20.91 / 0.63	21.68 / 0.63	19.55 / 0.57	19.77 / 0.58
GRFF [20]	27.98 / 0.90	27.67 / 0.88	25.66 / 0.85	25.98 / 0.86
NeRP w/o prior	27.49 / 0.85	27.82 / 0.87	25.91 / 0.85	26.87 / 0.88
NeRP (ours)	**28.43 / 0.90**	**29.06 / 0.92**	**26.86 / 0.90**	**27.52 / 0.90**
Spokes = 40				
Adjoint NUFFT	21.30 / 0.66	22.05 / 0.67	20.17 / 0.62	20.23 / 0.61
GRFF [20]	28.18 / 0.90	28.11 / 0.89	25.67 / 0.85	25.99 / 0.86
NeRP w/o prior	29.70 / 0.92	29.29 / 0.91	27.59 / 0.91	27.54 / 0.90
NeRP (ours)	**31.75 / 0.96**	**30.53 / 0.94**	**28.73 / 0.93**	**29.07 / 0.93**
Spokes = 50				
Adjoint NUFFT	21.40 / 0.68	22.26 / 0.69	20.42 / 0.64	20.49 / 0.64
GRFF [20]	28.50 / 0.91	27.59 / 0.88	25.23 / 0.85	25.90 / 0.87
NeRP w/o prior	30.65 / 0.94	29.26 / 0.91	28.40 / 0.92	27.68 / 0.90
NeRP (ours)	**32.55 / 0.96**	**31.37 / 0.95**	**30.13 / 0.95**	**30.02 / 0.94**

NeRP: Embedding Longitudinal Image Prior