Reconstructing Low Radiation CT Scans using Transformer and UNet Res Based Neural Networks

Presentation by Mihiran Piyarathna

Research Problem and Real World impact

- 6.7 million CT scans performed in the year ending March 2022. (NHS, England)
- 375 million CT scans, worldwide each year. (UNSCEAR)(Wojcik, 2022)
- ~10% of medical imaging procedures, but
- ~60% of Human medical **radiation exposure (UNSCEAR)(Wojcik, 2022)**
- **Alternative,** Low radiation scans are noisy and often lead to misdiagnosis.
- Our Research Problem is compiling a hybrid NN to reconstruct a clear CT image that can be reasonable alternative to a HDCT from Low Radiation DICOM X-ray projections.

Method, Implementation

Phase 1

Design backed by Literature

- Literature that inspired:
  - Learned Primal-Dual
  - iRadonMap
  - DTSGD
  - CTformer (Transformer)
  - Encoder Decoder CNN
- Design:
  - Hybrid with DRUnet
  - Hybr. with Restormer

Phase 2

Experimentation & Implem.

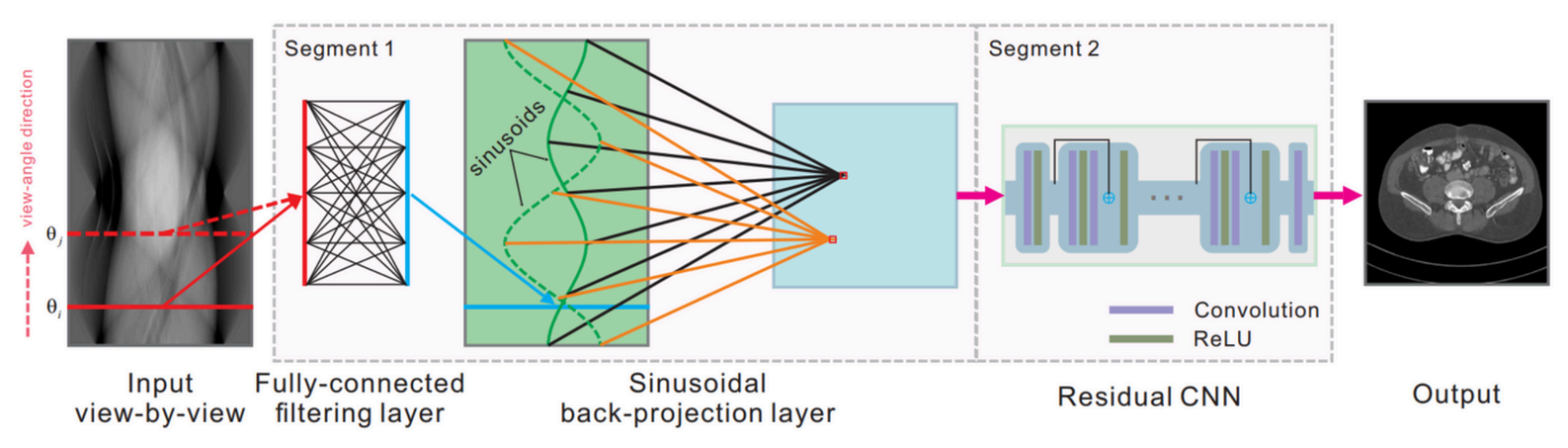
- Experimentations:
  - Learned Primal-Dual
  - DeepImagePrior
  - IRadonMap
- Implementations:
  - Filtered Back Project
  - Transition Layer
  - Layer up UNetRes for CT
  - Retrain Transformr. onCT

Phase 3

Testing & Valuation

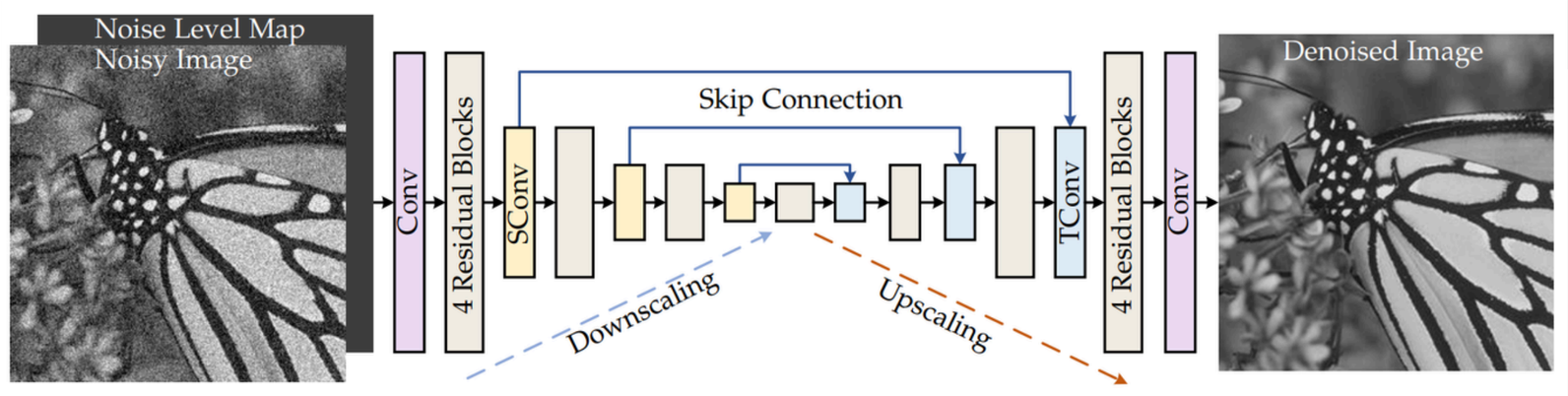
- Evaluation - PSNR: Peak Signal to Noise Ratio
- Evaluation - SSIM: Structural Similarity Index Measure

Inspired by Literature



Inverse Radon Map (iRadonMap): deep learning framework for CT reconstruction that replaces the traditional multi-stage Radon inversion pipeline with a unified neural network. It first uses learnable layers to mimic filtering and sinusoidal back-projection, then applies a residual CNN to refine the image.
(He, Wang and Ma, 2020).

Inspired by Literature



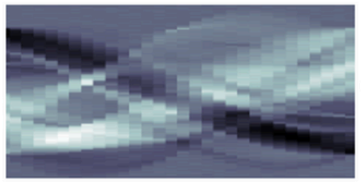
DRUnet: achieves denoising by combining U-Net's multi-scale encoder–decoder structure with ResNet-style residual blocks, enabling both global context capture and local detail refinement.

Conditioned to adaptively handle different noise strengths within a single framework (Zhang et al., 2022).

Novel Proposed Method

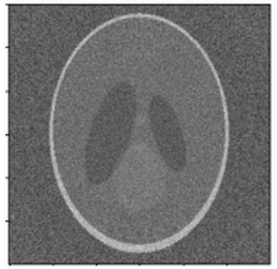
Hybrid Transformer Pipeline

Low photon Sinogram

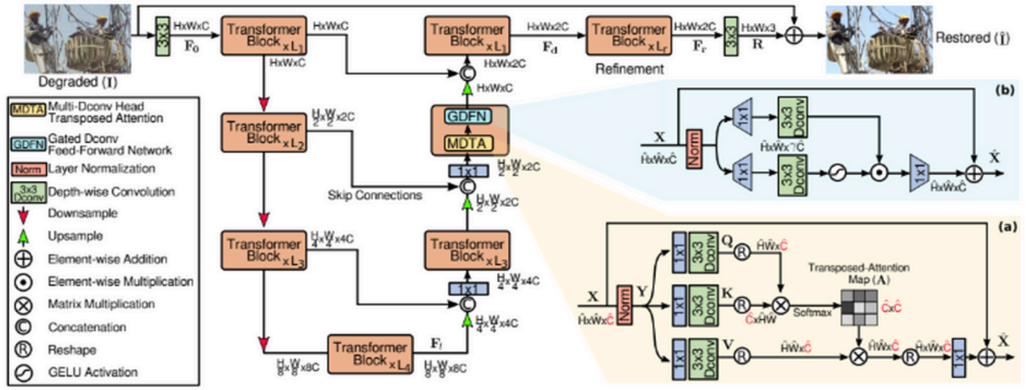


FBP

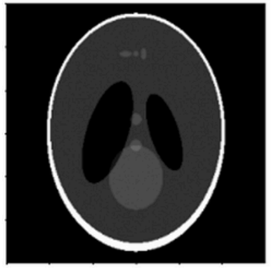
Inverse Radon Transformed Image



Inferencing through fine-tuned Restormer NN



Reconstructed Image

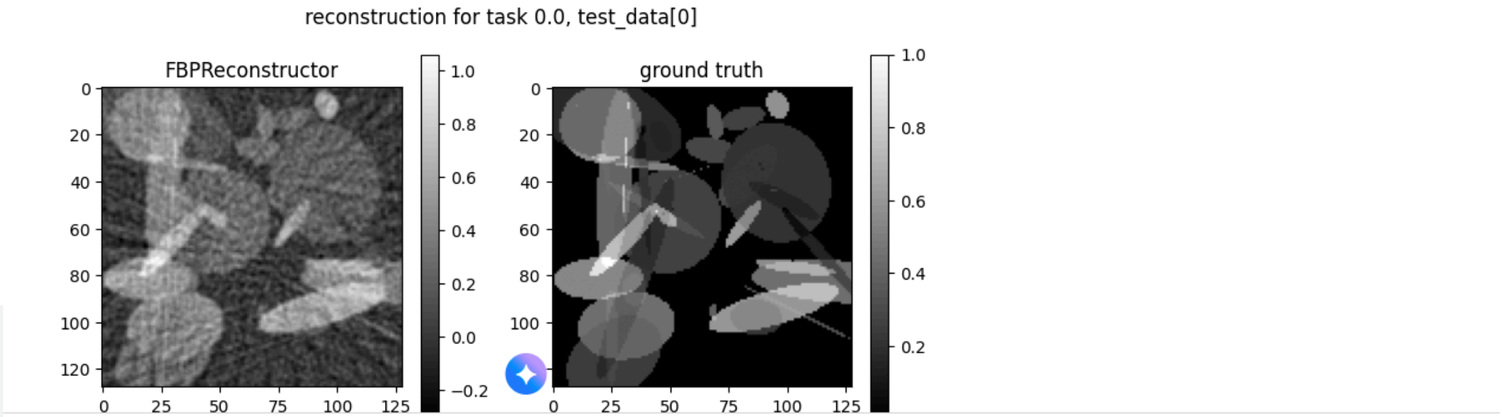


Method - FBP Expanded

Fine Tuning and Retrained for the Purpose of our Problem

Fine - tuned Filtered Back Projection model through an enumeration of hyper Parameters ...
executed the cross validation throughout the main dataset and 2 experimental datapair sets

```
running task 0/1 ...
sub-task 0/6 ...
sub-task 1/6 ...
sub-task 2/6 ...
sub-task 3/6 ...
sub-task 4/6 ...
sub-task 5/6 ...
ResultTable(results=
                        reconstructor       test_data                    measure_values                                                                                misc
task_ind sub_task_ind
0        0            FBPReconstructor  test part 0:10  mean: {psnr: 22.16, ssim: 0.4689}  {'hp_choice': {'filter_type': 'Ram-Lak', 'frequency_scaling': 0.8}}
         1            FBPReconstructor  test part 0:10  mean: {psnr: 21.78, ssim: 0.4536}  {'hp_choice': {'filter_type': 'Ram-Lak', 'frequency_scaling': 0.9}}
         2            FBPReconstructor  test part 0:10  mean: {psnr: 21.36, ssim: 0.4381}  {'hp_choice': {'filter_type': 'Ram-Lak', 'frequency_scaling': 1.0}}
         3            FBPReconstructor  test part 0:10  mean: {psnr: 24.57, ssim: 0.5963}     {'hp_choice': {'filter_type': 'Hann', 'frequency_scaling': 0.8}}
         4            FBPReconstructor  test part 0:10  mean: {psnr: 24.47, ssim: 0.5831}     {'hp_choice': {'filter_type': 'Hann', 'frequency_scaling': 0.9}}
         5            FBPReconstructor  test part 0:10  mean: {psnr: 24.33, ssim: 0.5705}     {'hp_choice': {'filter_type': 'Hann', 'frequency_scaling': 1.0}}
)
```



Method Restormer Expanded

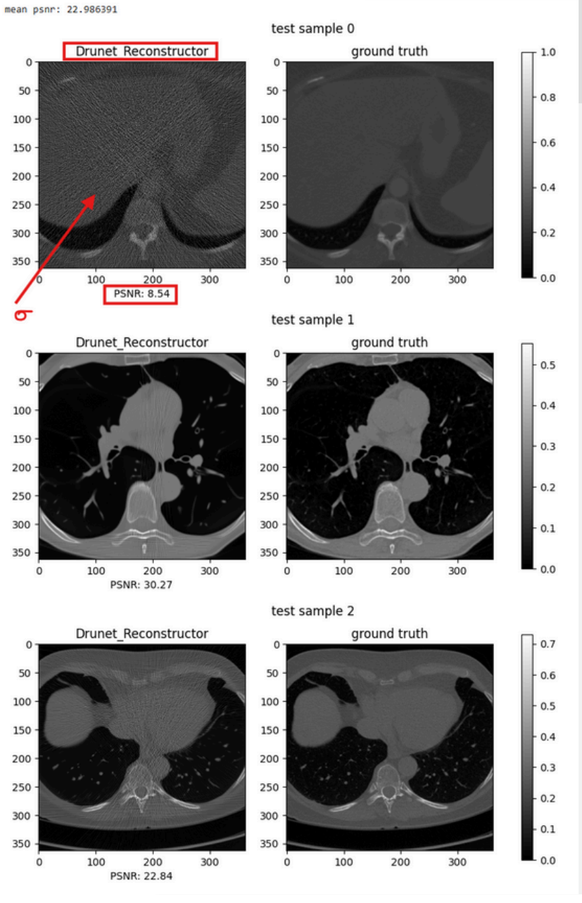
Fine Tuning and Retraining for the Purpose of our Problem

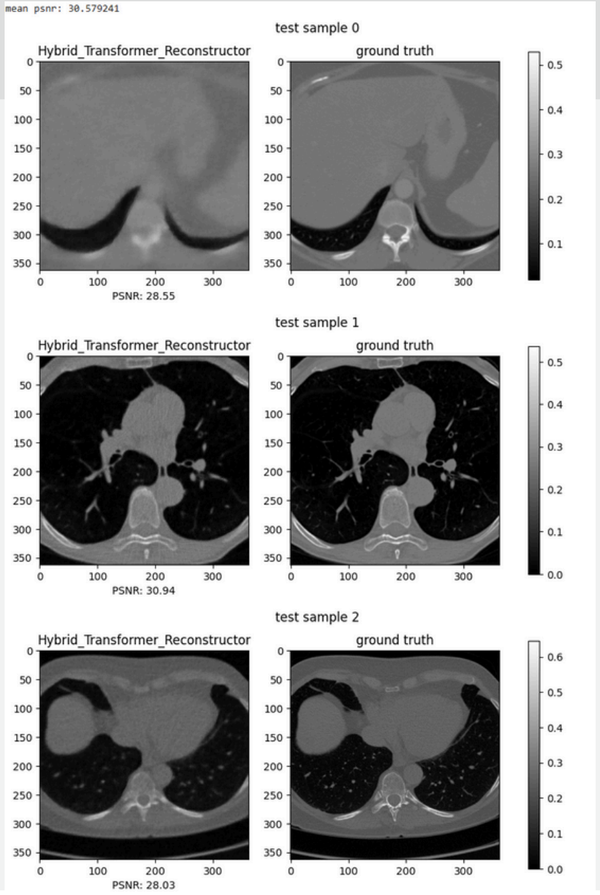
Fine - tuned Restormer model through 4 sets of hyper Params..
Tried hyper params: 1. various image patch size, 2. input channel variations, 3. Fixed iterations, Progressive iterations, 4. dimensions and refinement blocks
Re-trained the model on lq and hq CT scans.

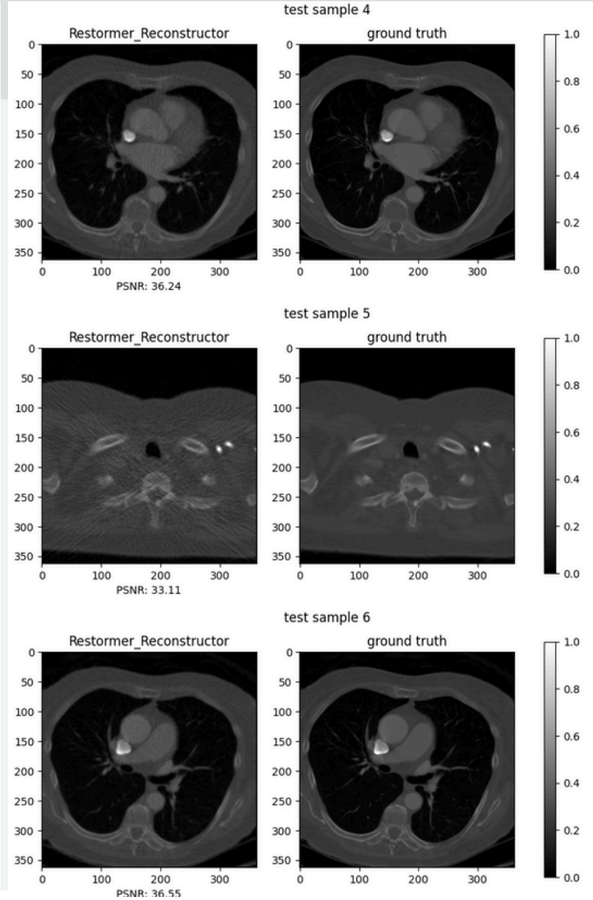
```
  io_backend:
    type: disk

  # data loader
  use_shuffle: true
  num_worker_per_gpu: 4 # 8
  batch_size_per_gpu: 2 # 8

  ### ------------Progressive training------------------------
  mini_batch_sizes: [2,1,1,1,1,1] # [8,5,4,2,1,1]             # Batch size per gpu
  iters: [92000,64000,48000,36000,36000,24000]
  gt_size: 320 # 384   # Max patch size for progressive training
  gt_sizes: [128,160,192,256,320] # [128,160,192,256,320,384]  # Patch sizes for progressive
  training.
  ### ------------------------------------------------------------

  ### ------- Training on single fixed-patch size 128x128---------
  # mini_batch_sizes: [8]
  # iters: [300000]
  # gt_size: 128
  # gt_sizes: [128]
  ### ------------------------------------------------------------

  dataset_enlarge_ratio: 1
  prefetch_mode: ~

val:
  phase: val # added since, missing param for def train dataloader
  name: ValSet
  type: Dataset_GaussianDenoising
  sigma_test: 25
  in_ch: 1  ## Grayscale image
  dataroot_gt: ./Datasets/test/BSD68
  dataroot_lq: none
  io_backend:
    type: disk

# network structures
network_g:
  type: Restormer
  inp_channels: 1
  out_channels: 1
  dim: 48
  num_blocks: [4,6,6,8]
  num_refinement_blocks: 4
  heads: [1,2,4,8]
  ffn_expansion_factor: 2.66
  bias: False
  LayerNorm_type: BiasFree
  dual_pixel_task: False
```

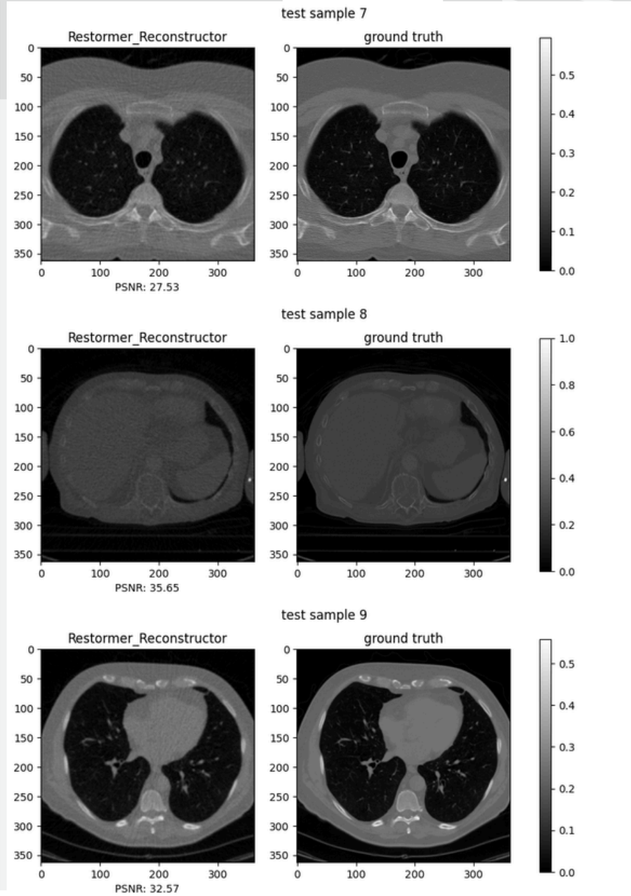
< Colab Link >

EVALUATION SNIPPETS









Performance of the Novel Hybrid Models

	Test Data	PSNR ↑	SSIM ↑	PSNR_Rank	SSIM_Rank
FBPReconstructor	LoDoPab part 'Test'	25.4	0.4552	11	14
BFGSReconstructor	LoDoPab part 'Test'	-45.97	0.0000000542	18	18
ISTAReconstructor	LoDoPab part 'Test'	11.6	0.07372	16	17
ADMMReconstructor	LoDoPab part 'Test'	11.6	0.07373	16	16
MLEMReconstructor	LoDoPab part 'Test'	17.93	0.4488	15	15
GaussNewtonReconstructor	LoDoPab part 'Test'	18.47	0.4831	14	12
Hybrid UNet Residual model sigma 8	LoDoPab part 'Test'	22.99	0.48	13	13
LandweberReconstructor	LoDoPab part 'Test'	23.01	0.5603	12	11
CGReconstructor	LoDoPab part 'Test'	26.43	0.6441	10	9
Hybrid UNet Residual model sigma 15	LoDoPab part 'Test'	27.63	0.618	9	10
Hybrid UNet Residual model sigma 25	LoDoPab part 'Test'	29.35	0.6853	8	8
Hybrid UNet Residual model sigma 42	LoDoPab part 'Test'	29.91	0.7149	7	7
Hybrid UNet Residual model sigma 35	LoDoPab part 'Test'	30.14	0.722	6	3
IRadonMapReconstructor	LoDoPab part 'Test'	30.4	0.7293	5	1
Hbrd Transf_1-CT retrn fixPatch 240K Itr	LoDoPab part 'Test'	31.05	0.7198	4	4
Hbrd Transf_0-GreyImage Progr Training 300K Itr	LoDoPab part 'Test'	31.22	0.7175	3	5
Hbrd Transf_5-Pre_Trained_blind	LoDoPab part 'Test'	31.23	0.7157	2	6
Hbrd Transf_4-CT Progr Training 24K, 12Kth Itr select	LoDoPab part 'Test'	31.4	0.7228	1	2

COLAB & DISCUSSION

Time to Discuss :!

< Colab Link >

THANK YOU

Presentation by Mihiran Piyarathna

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