Brief Result of Relaxed Projected Gradient Descent CT Reconstruction

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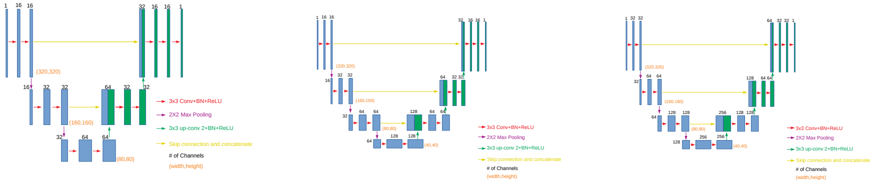
U-NET training

- Basic structure of UNET is stated in [1]
- Due to lack of VRAM of the graphics card, the fowllowing proposed variants can cope up with a rather small batch size for training

Propoased U-NET structure



(a) 2 up/down layers (b) 3 up/down layers (c) (b) w/ 2X depth

Figure: 1

U-NET training

Sequential training stages:

- stage 1: Initialize a model and define a loss function

$$\begin{aligned} \hat{y} &= model(x) \\ loss &= \|\hat{y} - y_{true}\|_2 \end{aligned} \tag{1}$$

- stage 2 : load model(stage 1) and change the loss function

$$\begin{aligned} \hat{y} = model(x), y' &= model(\hat{y}) \\ loss = mean(\|\hat{y} - y_{true}\|_2 &+ \|y' - y_{true}\|_2) \end{aligned} \tag{2}$$

- stage 3: load model(stage 2) and change the loss function

$$\begin{aligned} \hat{y} = model(x), y' = model(\hat{y}), \widetilde{y} &= model(y_{true}) \\ loss = mean(\|\hat{y} - y_{true}\|_2 + \|y' - y_{true}\|_2 &+ \|\widetilde{y} - y_{true}\|_2) \end{aligned} \tag{3}$$

Relaxed Projected Gradient Descent

Algorithm 1: Relaxed Projected Gradient Descent

Input: backprojection operator $\mathbf{H}$, backprojection operator $\mathbf{H}^T$, filtering operator $\mathbf{A}$, noisy measurement(sinogram) $\mathbf{y}$, a pre-trained *CNN* model, stepsize $\gamma > 0$, positive sequence $\{c_n\}_{n\geq 1}$, $\alpha \in [0,1)$.

$k \leftarrow 0$

$\mathbf{x_0} = \mathbf{Ay} \in \mathbb{R}^N$

while *not converge* **do**

  $\mathbf{z}_k = CNN(\mathbf{x}_k - \gamma \mathbf{H^T H x}_k + \gamma \mathbf{H^T y})$

  if $k \geq 1$ **then**

    if $\|\mathbf{z}_k - \mathbf{x}_k\|_2 > c_k \|\mathbf{z}_{k-1} - \mathbf{x}_{k-1}\|_2$ **then**

      $\alpha_k = c_k(\|\mathbf{z}_{k-1} - \mathbf{x}_{k-1}\|_2 / \|\alpha_{k-1}\|\mathbf{z}_k - \mathbf{x}_k\|_2)\alpha_{k-1}$

    else

      $\alpha_k = \alpha_{k-1}$

    end

  end

  $\mathbf{x}_{k+1} = (1-\alpha_k)\mathbf{x}_k + \alpha_k \mathbf{z}_k$

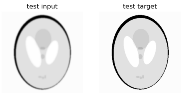
  $k \leftarrow k+1$

end

Artificial dataset[2]

Data formation

- Schepp-Logan Phantom from MATLAB
- Adjusting the intensity value, center, angle and lengths in x- and y -axis
- blurr with 2D spatial filter in size of 5 ($\frac{1}{25}$np.ones((5,5))
- Reconstruction w/o sinogram
- Not a meaningful experiment setup



Artificial Dataset Simulation

Avg. SNR Original CT: 9.55 *dB*

	2layer	3layer	3layer & 2X
MSE	21.4	21.5	...
MLSE	21.2	24.0	24.3

Table: Avg. SNR Reconstructed CT(*dB*)

	2layer	3layer	3layer & 2X
MSE	11.9	12.0	...
MLSE	11.7	14.4	14.8

Table: Avg. SNR increase(*dB*)

AAPM Low Dose CT Image and Projection Data [4]

Case Study

- Patient: C002
- BodyPartExamined: Chest
- 278 slices Full dose CT images in size (512,512)
- Online DICOM viewer link
- First 200 slices for training and 20 slices for testing
- Carry out the experiment like Experiment 1. in [3]

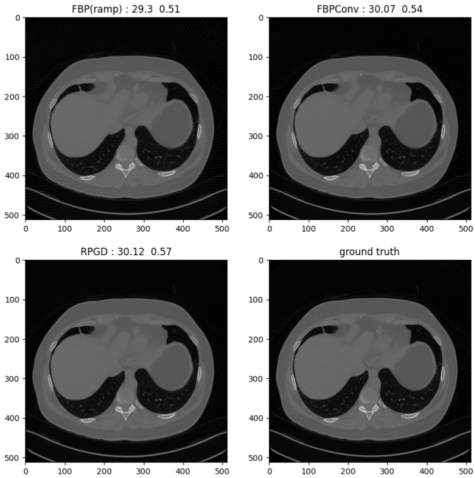
Experiment Setup & Hyper-parameter configuration

parameter	quantity	parameter	quantity
UNET training			
train samples	200	test samples	20
batch size(train)	5	batch size(test)	20
optimizer	ADAM	LR(stage 1)	1.0e-3
LR(stage 2)	1.0e-3	LR(stage 3)	1.0e-3
train epoch(1)	40	train epoch(2)	20
train epoch(3)	100	momemetum(BN)	0.99
RPGD for reconstruction		obervation window	0 HU - 2621 HU
α	1.0	γ	1.0e-2
c_k	0.5	# of iterations	24

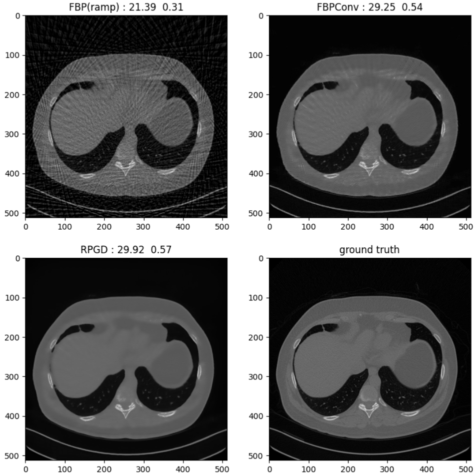
Table: list of parameters

- Only 1b is used to train the netwotk. 1c causes "OOM" problem due to lack of VRAM.
- Neither noise nor read-out error is added.(Input image SNR = ∞)
- Recontruct CT images with differnet views of sinogram
- Confined observation window [0 HU, 2621 HU]
- Full result of reconstruction from 144 views sinogram link
- Full result of reconstruction from 45 views sinogram link

Reconstruction from 144 views sinogram



Reconstruction from 45 views sinogram



Conclusion & Further works

- Atrificial dataset will not be used any more.
- RPGD method outperforms quite slightly in all cases, which is similar to the result in [3].
- RPGD method has significant boost in image quality index when sinogram with fewer views is used.
- I will try the dataset from you later, which consists of 18 patients, later in this week

References

[1] K. H. Jin, M. T. McCann, E. Froustey, and M. Unser, "Deep convolutional neural network for inverse problems in imaging", IEEE Transactions on Image Processing **26**, 4509–4522 (2017) 10.1109/TIP.2017.2713099.

[2] *Deep-learning-based projected gradient descent for image reconstruction*, https://github.com/PhanHuyThong/Image-Reconstruction-by-CNN-based-PGD, Accessed: 2019-11-25.

[3] H. Gupta, K. H. Jin, H. Q. Nguyen, M. T. McCann, and M. Unser, "Cnn-based projected gradient descent for consistent ct image reconstruction", IEEE Transactions on Medical Imaging **37**, 1440–1453 (2018) 10.1109/TMI.2018.2832656.

[4] Moen, Chen, Holmes 3rd, Duan, Yu, Yu, Leng, Fletcher, and McCollough, *Data from low dose ct image and projection data [data set]. the cancer imaging archive.* https://doi.org/10.7937/9npb-2637, Accessed: 2019-11-25.