Detail-Revealing Deep Low-Dose CT Reconstruction

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Abstract

Low dose CT Reconstruction

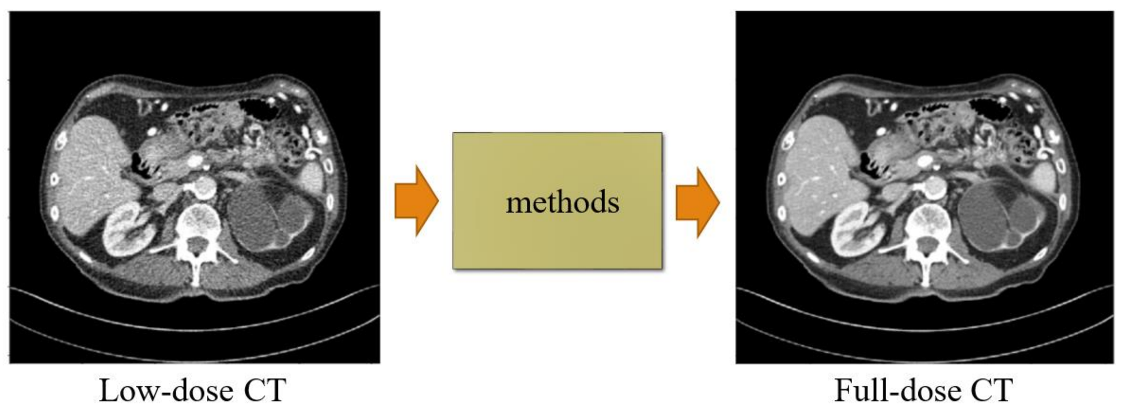


Figure 1: CT reconstruction

- Existing methods & weaknesses :

(1) Raw data filtered reconstruction, e.g., Filtered Back Projection (FBP). Hand-designed filters.

(2) Iterative reconstruction: Recasts the reconstruction as a iterative optimization process. Objective functions based on naive assumptions.

(3) CNN-based methods: Learn the mapping between low-dose CT image and normal dose CT image with deep networks. Details damage.

Motivation

(1) No hand-designed filters and not rely on raw data.

(2) Learn better mapping between low-dose CT and full-dose CT.

(3) Suppressing the noise effectively and retaining the structures well simultaneously.

Method

Dual-Branch Network Architecture

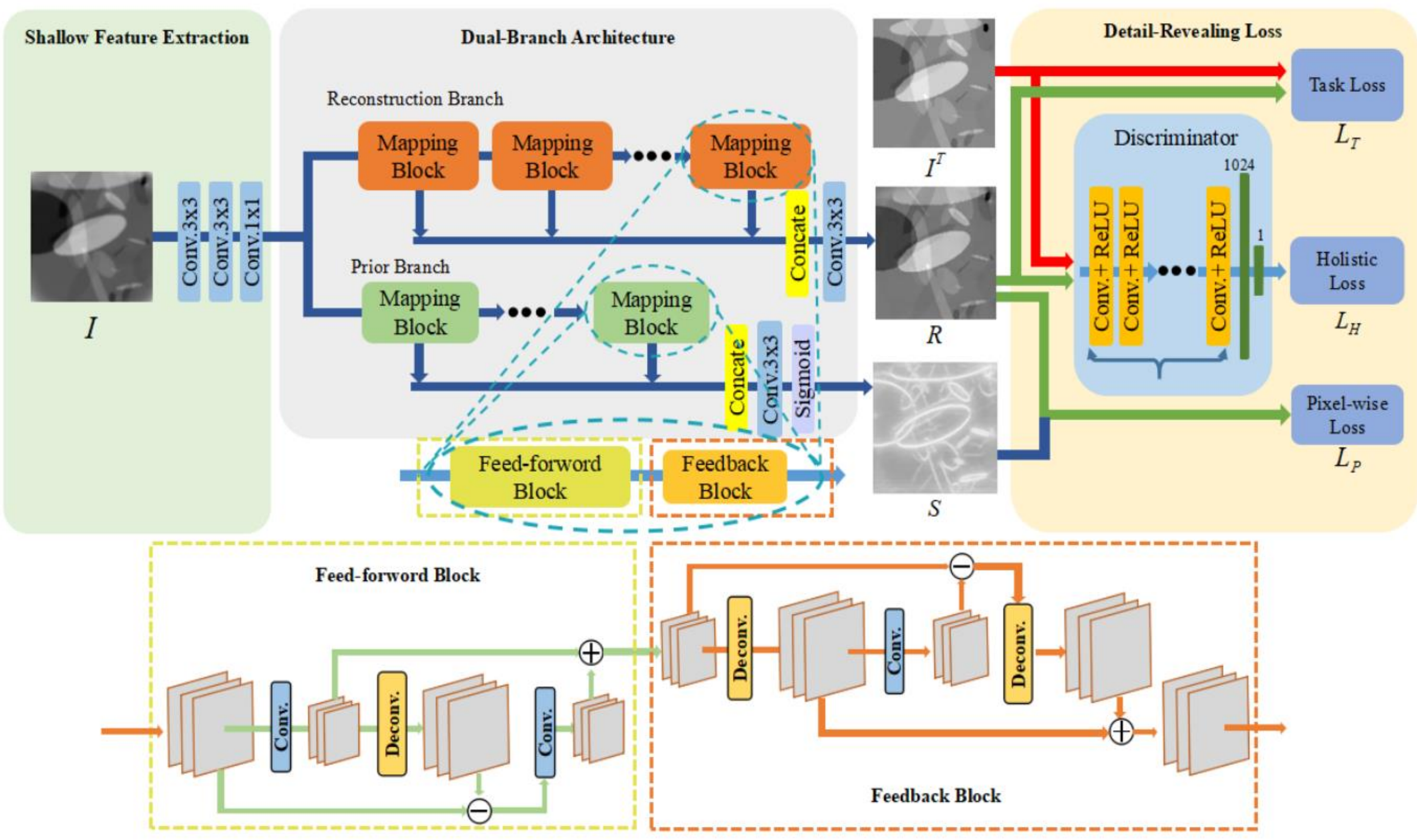


Figure 2: An overview of the proposed method.

Detail-Revealing Loss

- Pixel-wise Loss L_P:

$$L_p = \frac{1}{N}\sum_{t=1}^{N}\sum_{p_t}(||\nabla_x^2 R(p_t)||e^{-\gamma|S(p_t)|} + ||\nabla_y^2 R(p_t)||e^{-\gamma|S(p_t)|}),$$

where N is the total number of training samples. P_t means a given pixel at *t-th* sample. R and S are the refined CT image and the structure image obtained from reconstruction branch and prior branch, respectively. γ is a empirical parameter.

an extra regularization term L_r is imposed on the structure map to encourage invalid predictions.

$$L_r = \frac{1}{N}\sum_{t=1}^{N}\sum_{p_t}|S_t(p_t)|^2. \quad L_P = \alpha_1 L_p + \alpha_2 L_r.$$

- Holistic Loss L_H: LDCT image I, and produces refined CT image R (‘fake sample’), NDCT image I^T.

$$L_H = \frac{1}{N}\sum_{t=1}^{N}\{\mathbb{E}_{I^T\sim\mathcal{P}(I^T)}[D(I^T)] - \mathbb{E}_{R\sim\mathcal{P}(R)}[D(R|I)]\}$$

- Total Loss L:

$$L = L_P + \alpha_3 L_T + \alpha_4 L_H. \quad L_T = \frac{1}{N}\sum_{t=1}^{N}\sum_{p_t}|R(p_t) - I^T(p_t)|$$

Experimental

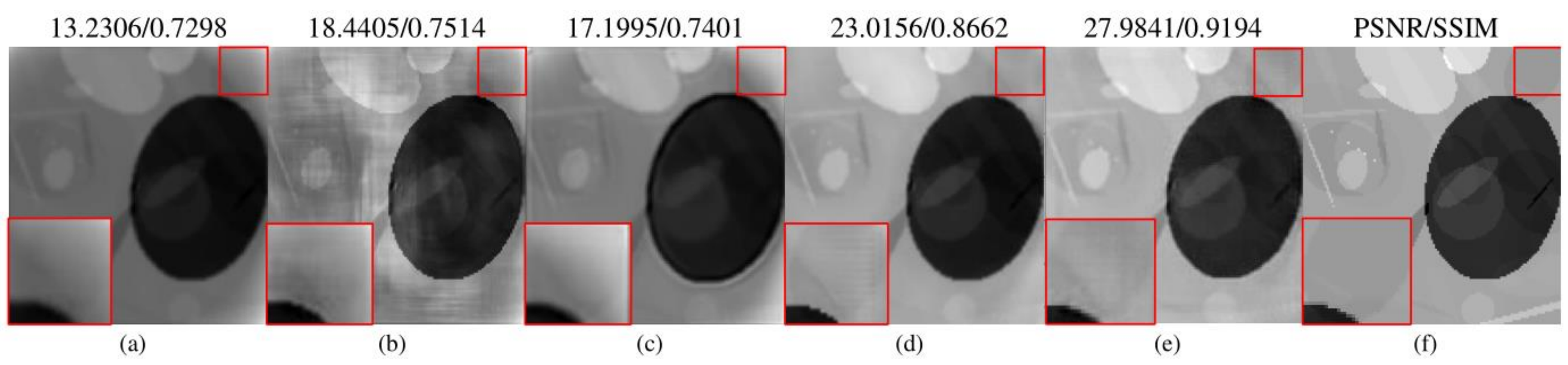


Figure 3: Reconstruction results on ellipse phantom dataset. (a) to (f) indicate FBP, RED-CNN, WGAN-VGG, MAP-NN, ours and GT.

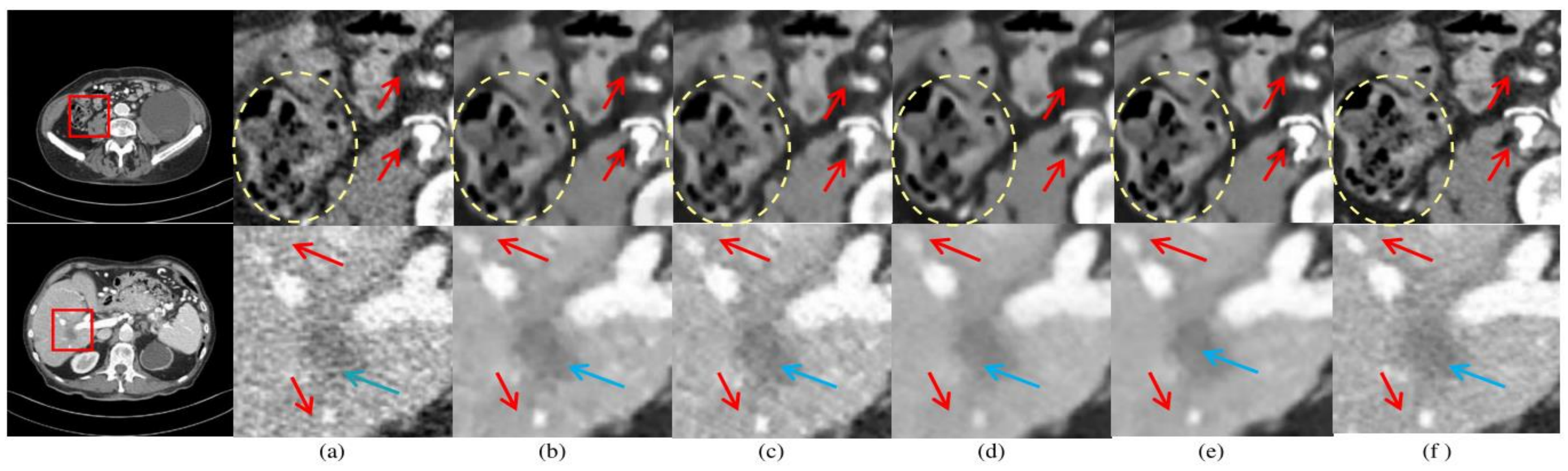


Figure 4: Clinic Mayo dataset: reconstruction results

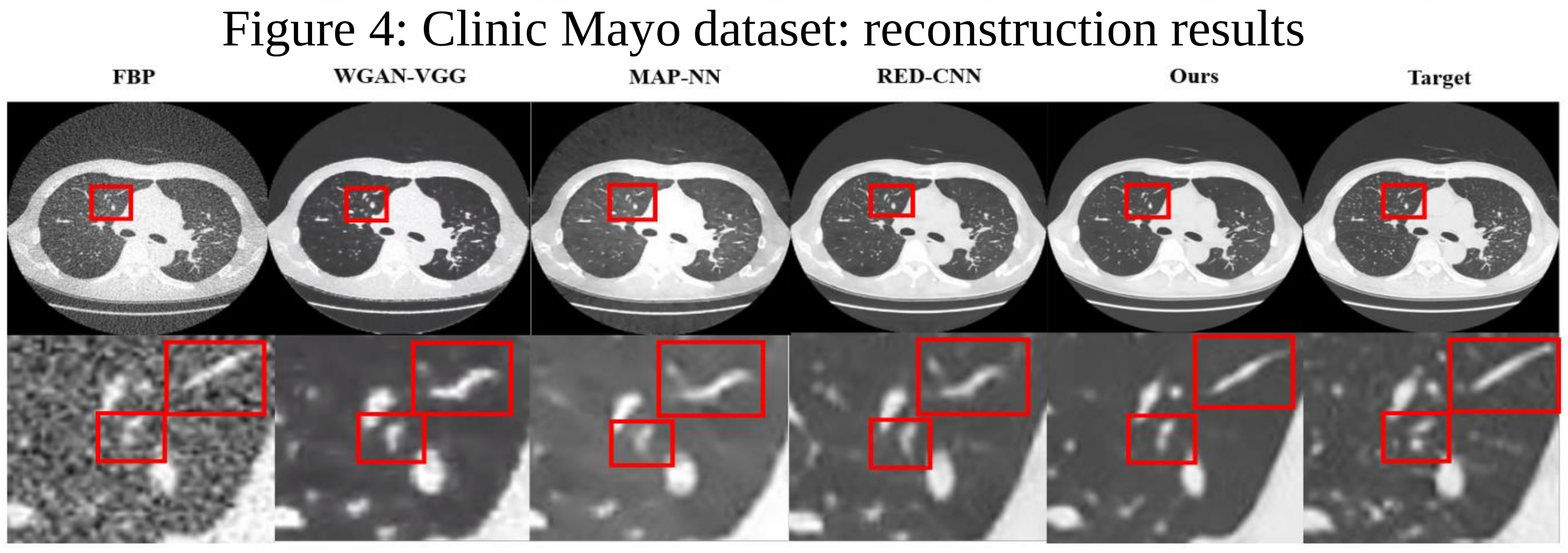
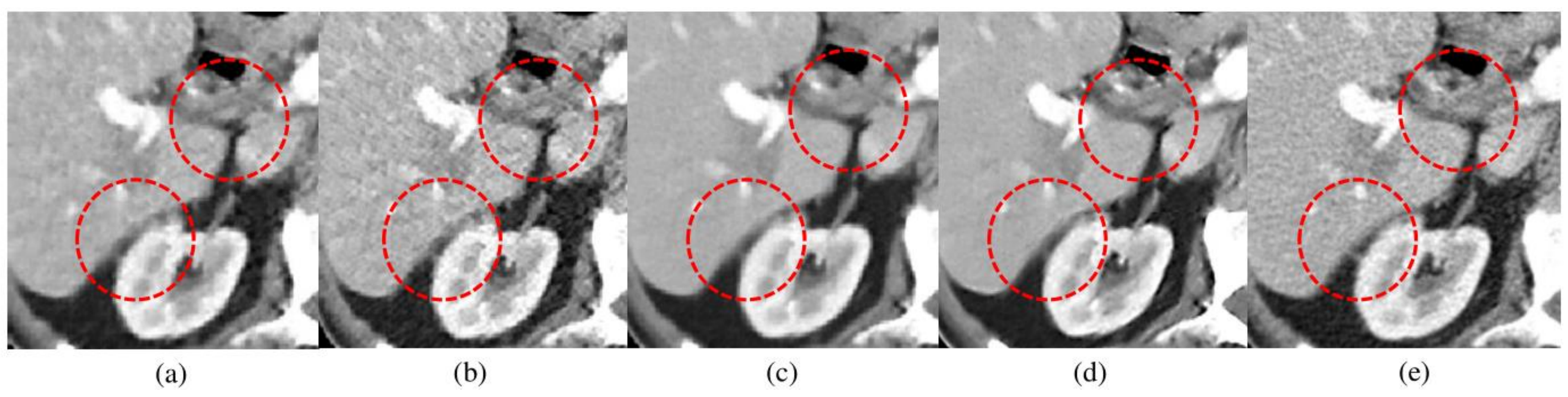


Figure 5: NOD test data sample of Osaka dataset.

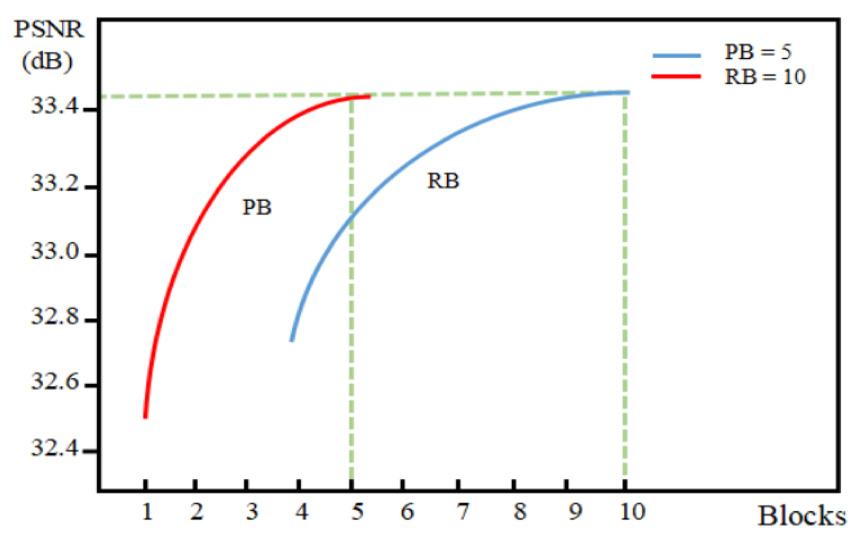
Method	*MGGO*	*HCM*	*NOD*	*EMP*	*RGGO*	*CON*
FBP	17.5520/0.3218	17.4272/0.3312	17.8473/0.3294	17.5908/0.3258	17.8630/0.3174	17.6867/0.3292
RED-CNN	25.4023/0.5334	26.1479/0.5634	27.2621/0.6036	27.3236/0.6110	28.0048/0.6458	26.9475/0.5966
WGAN-VGG	21.4565/0.4304	21.0871/0.4275	22.1383/0.4797	22.0226/0.4803	22.7123/0.5201	21.9261/0.4783
MAP-NN	22.8305/0.4715	22.9790/0.4814	23.9418/0.5271	23.5418/0.5250	24.3455/0.5564	23.7720/0.5252
Ours	25.6587/0.5464	26.3172/0.5764	27.6888/0.6182	27.9948/0.6349	28.4401/0.6584	27.3671/0.6092

Table 1: Objective results of Osaka dataset.

Ablation



Ablation	*PSNR*	*SSIM*
only RB (feed-forward)	32.5246	0.8873
only RB (ours)	32.8656	0.8924
RB + Holistic	32.8775	0.8913
RB + PB	33.4323	0.9436
Ensemble	33.4088	0.9431



Ablations on branches and numbers of mapping blocks.