A Bias-Reducing Loss Function for CT Image Denoising

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Goal: To denoise X-ray CT images while maintaining textural and structural details

Peek into literature

State-of-the-art

Convolutional neural networks with loss function as

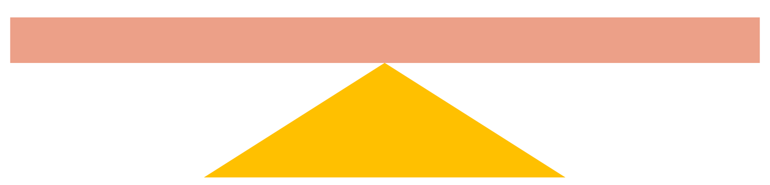
- Mean squared error
  - Produces overly smooth results lacking texture
- Adversarial cost
  - \+ Retains textural details
  - \- Could introduce artifacts

Mean squared error (MSE)

MSE = bias^2 + variance

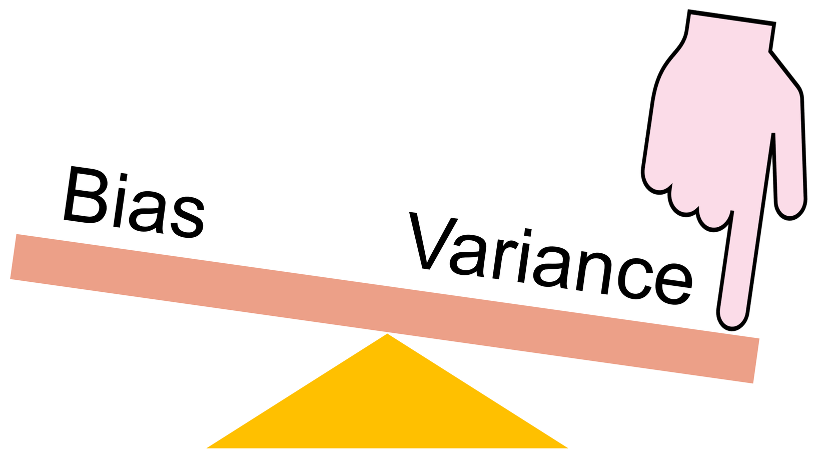
Systematic errors — Noisy variations

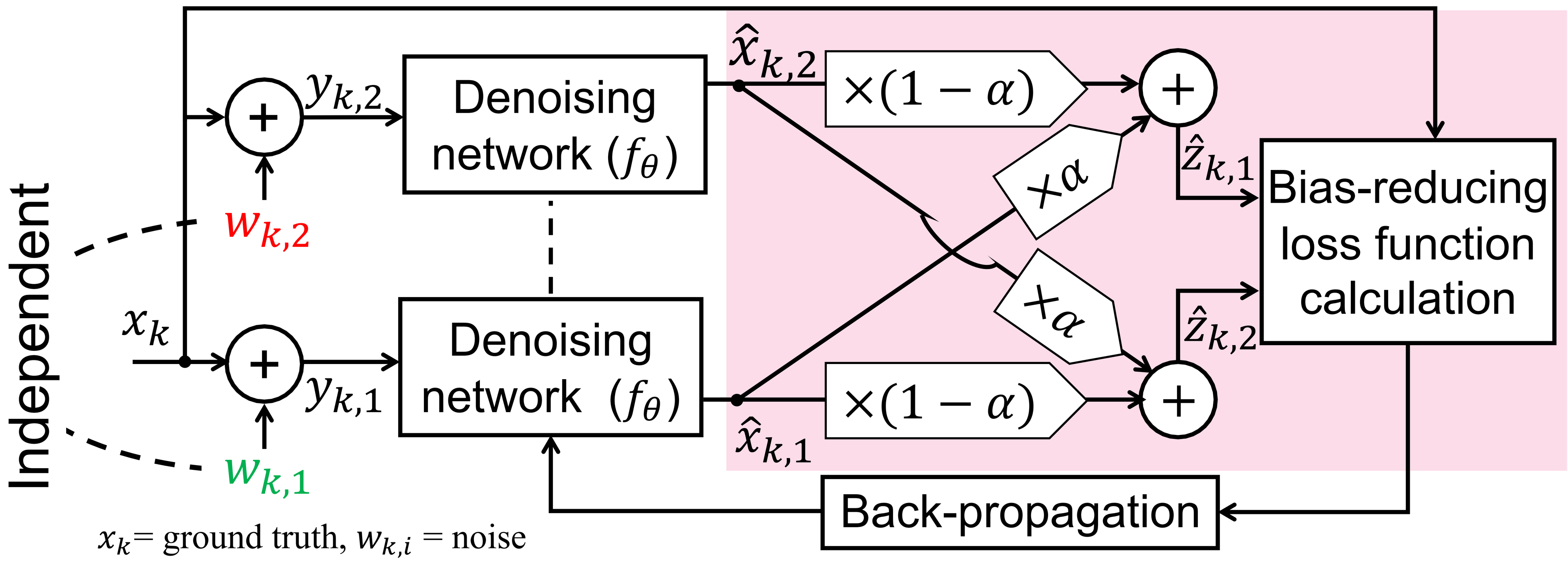
- The error due to bias is less desirable as it results in loss of textural and structural details
- However, MSE weights both errors equally



Our solution

Weight variance less during training





Proposed architecture for training phase

Get reduced bias during inference

Bias Weighted MSE (BW-MSE)

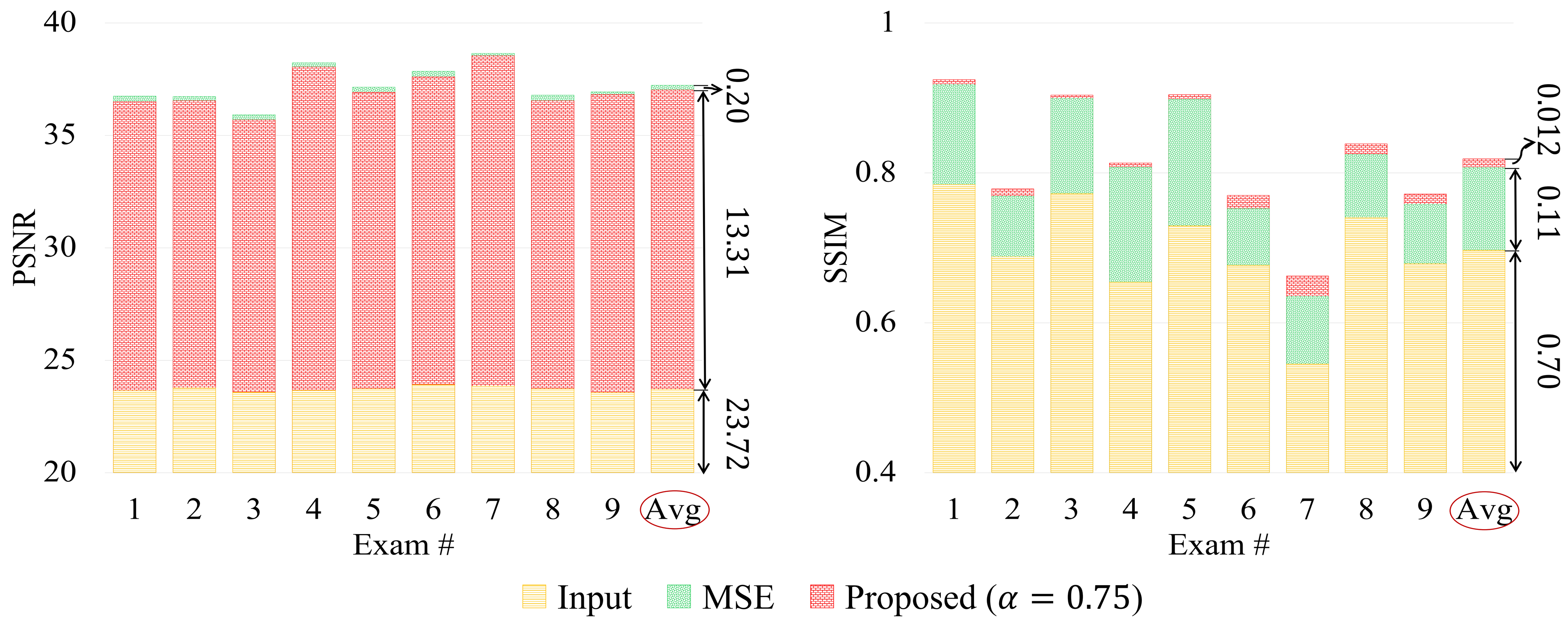
BW−MSE $\triangleq$ bias^2 + λ×variance

$$\lambda = \alpha^2 + (1-\alpha)^2$$

Bias-Reducing Loss Function

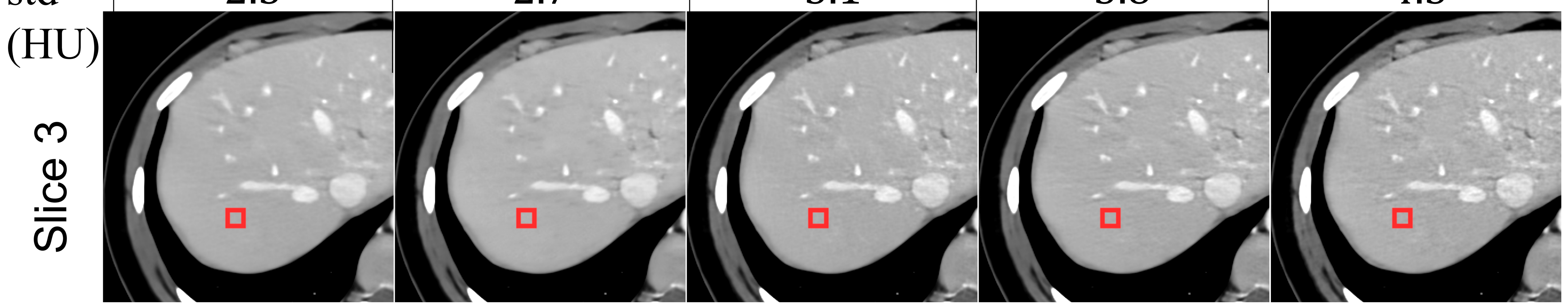
$$\mathcal{L}^{(BR)}_{\theta,\alpha} = \frac{1}{2K}\left\{\sum_{k=1}^{K} \left\|\hat{z}_{k,1} - x_k\right\|^2 + \left\|\hat{z}_{k,2} - x_k\right\|^2\right\}$$

Evaluation

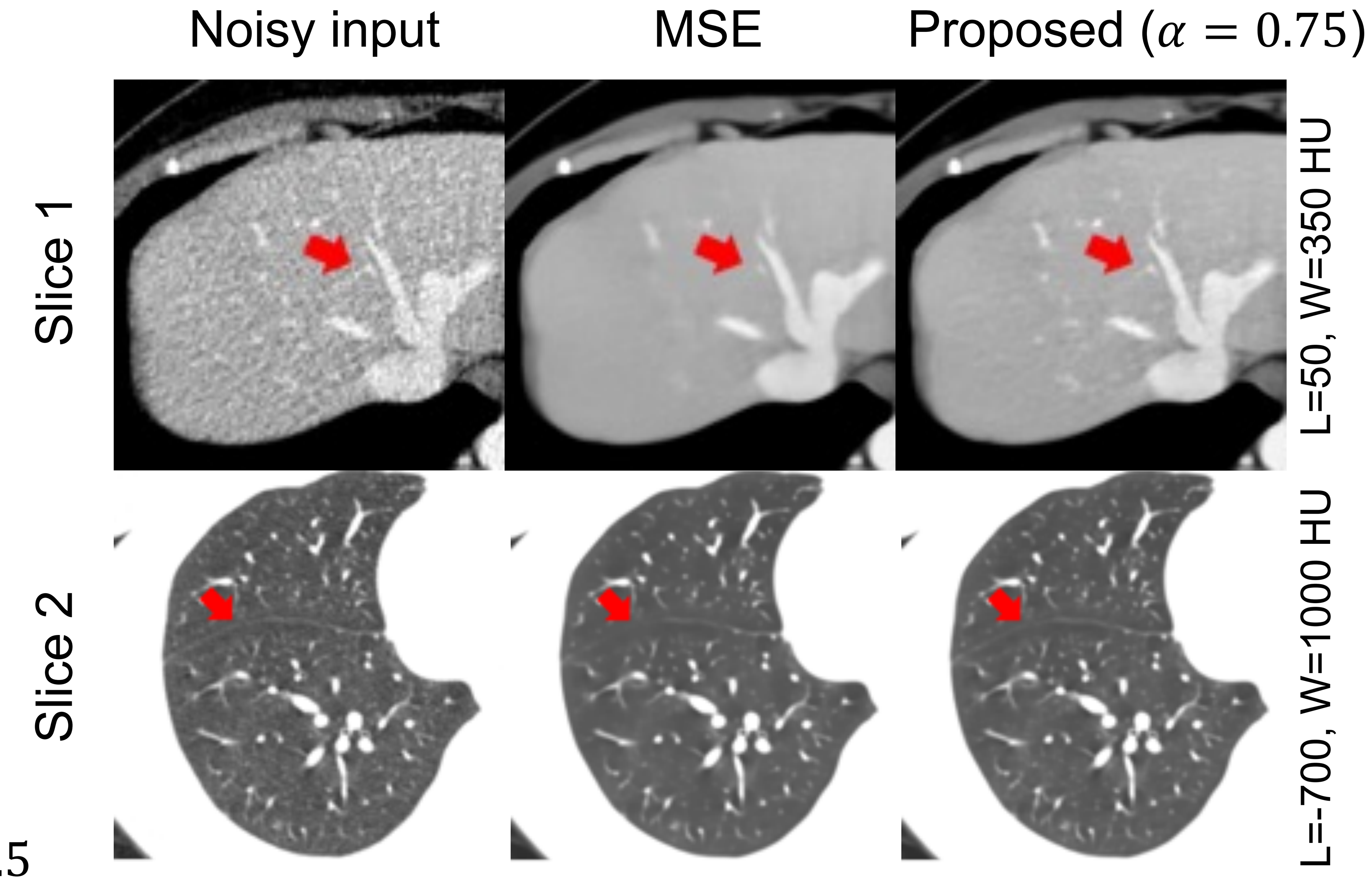


α vs. Bias

α	1.0	0.875	0.75	0.625	0.5
std (HU)	2.5	2.7	3.1	3.8	4.3



Denoised results for low-dose exam



Conclusion: The proposed bias-reducing loss function preserves more textural and structural details in denoised results as compared to MSE. It improves SSIM at the cost of a slight decrease in the PSNR.