

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)

$$\text{MSE} = \text{bias}^2 + \text{variance}$$

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

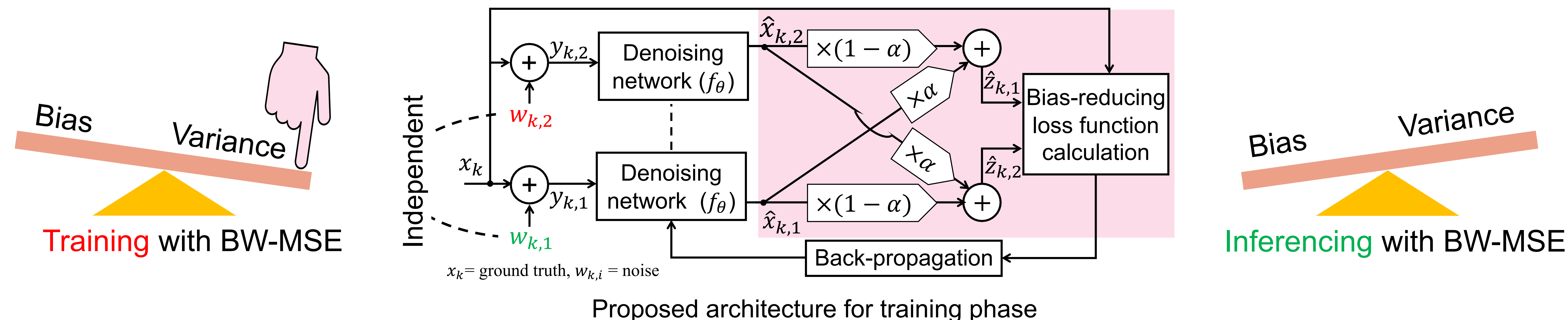
Bias Variance

Training with MSE

Our solution

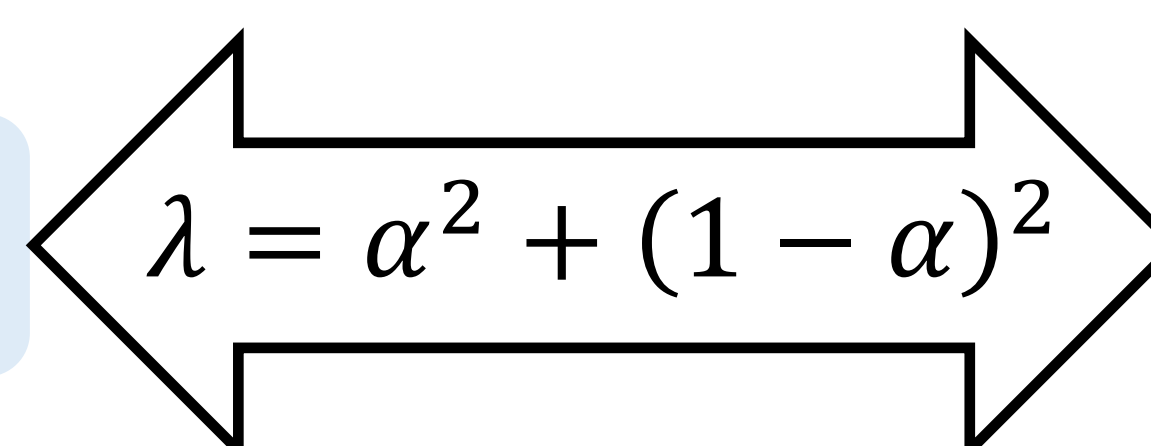
Weight variance less during training

Get reduced bias during inference



Bias Weighted MSE (BW-MSE)

$$\text{BW-MSE} \triangleq \text{bias}^2 + \lambda \times \text{variance}$$

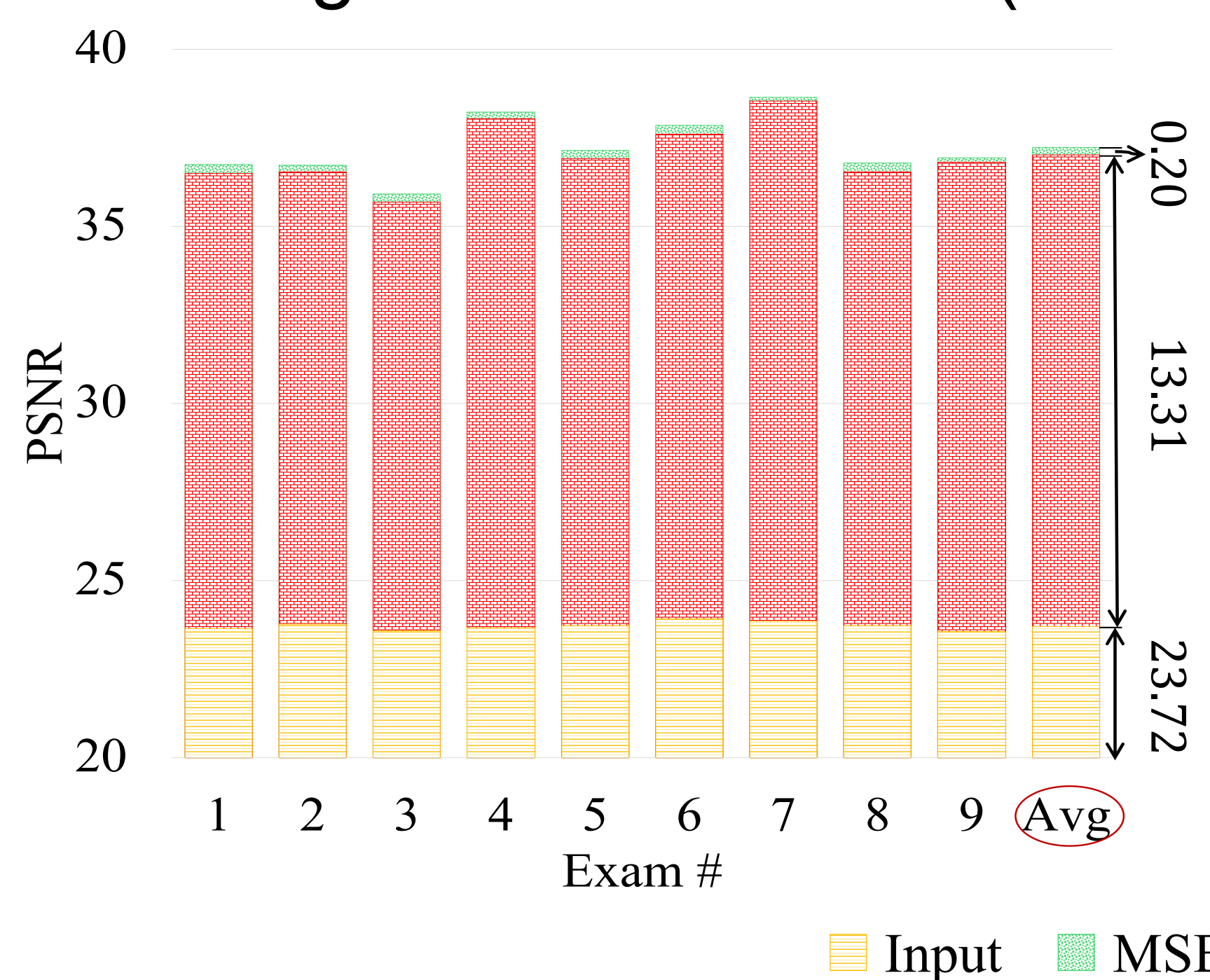


Bias-Reducing Loss Function

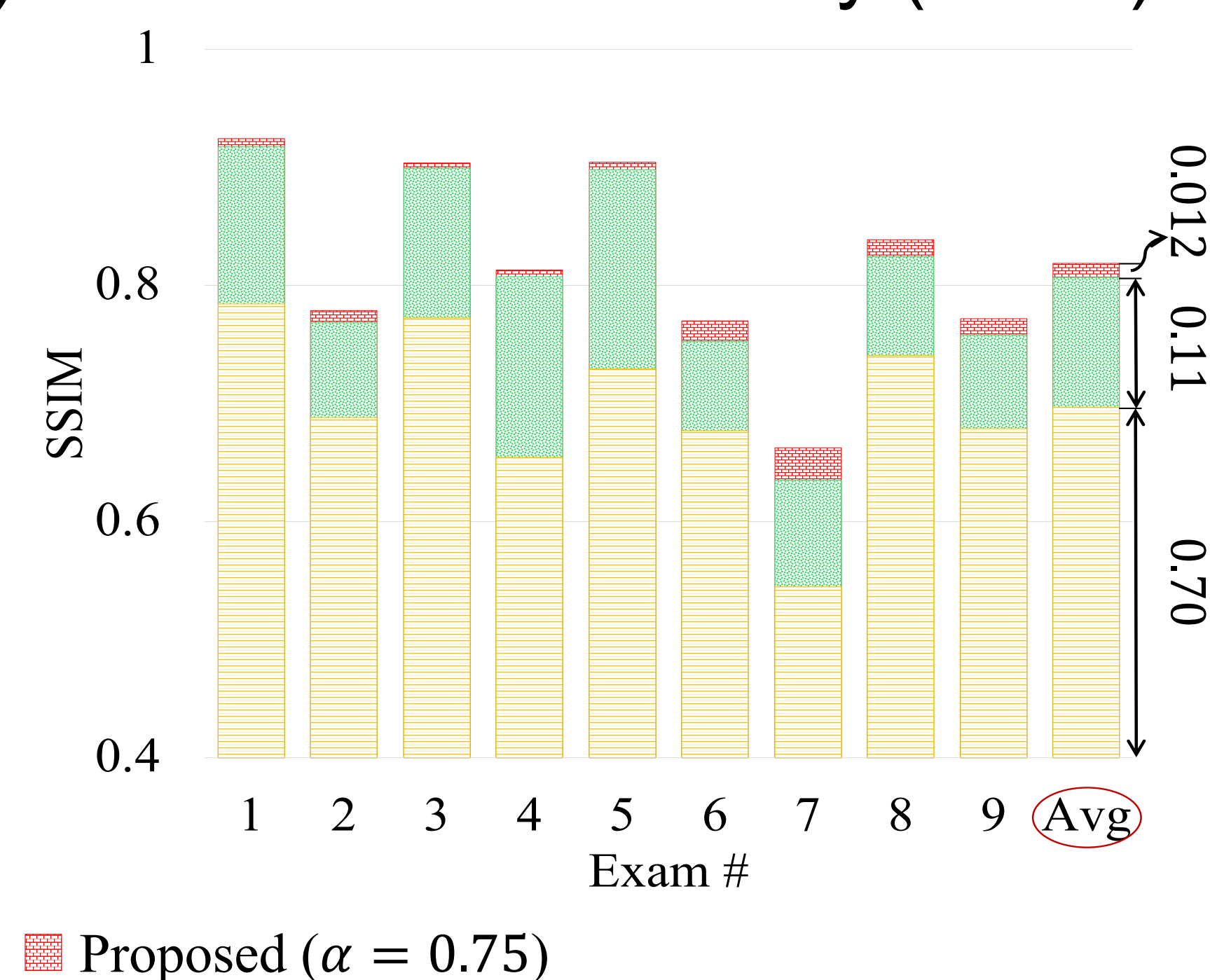
$$\mathcal{L}_{\theta, \alpha}^{(BR)} = \frac{1}{2K} \left\{ \sum_{k=1}^K \left\| \hat{z}_{k,1} - x_k \right\|^2 + \left\| \hat{z}_{k,2} - x_k \right\|^2 \right\}$$

Evaluation

Peak signal-to-noise ratio (PSNR)



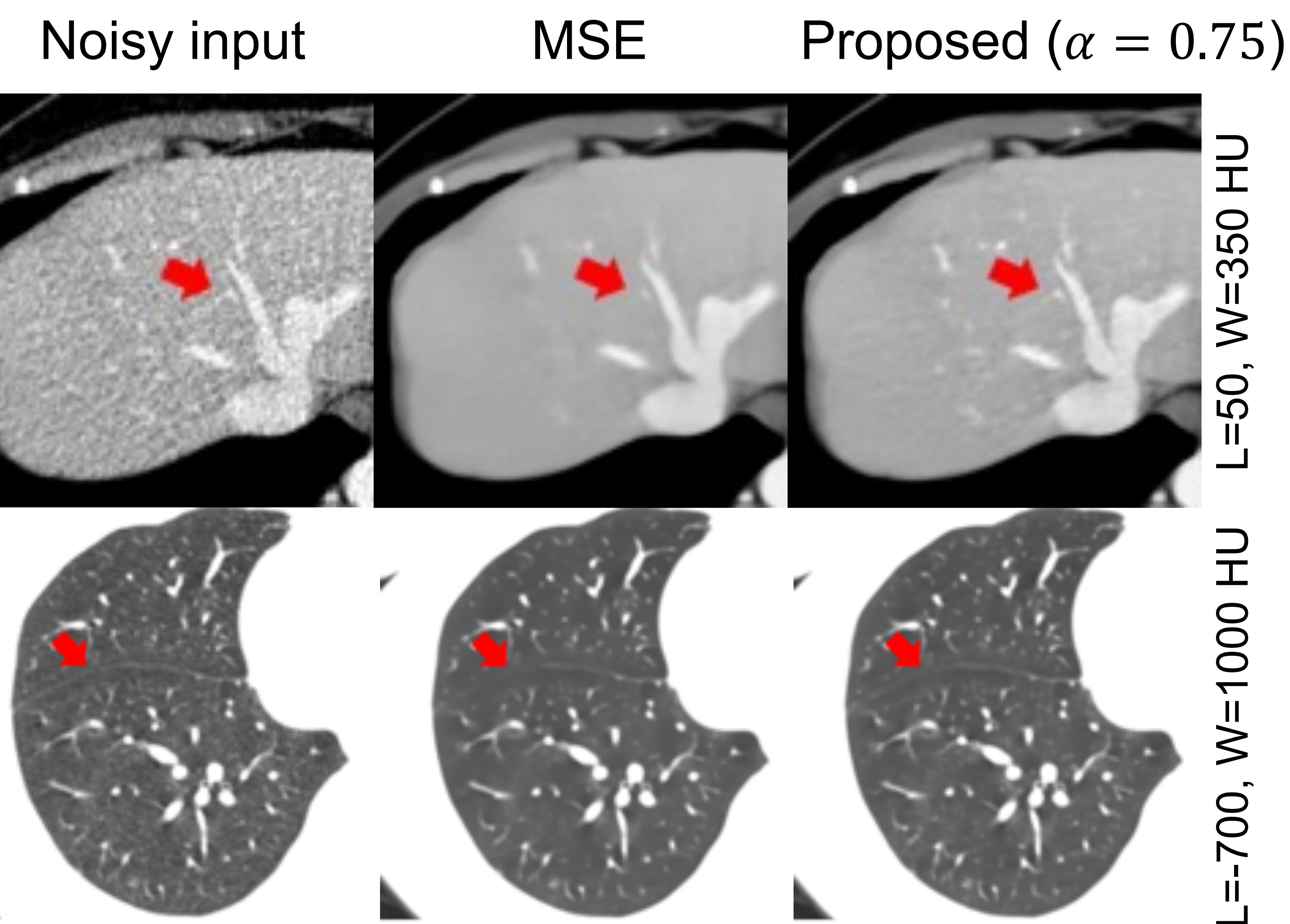
Structural similarity (SSIM)



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
Slice 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.