A SEDCNN Machine Learning Model for Textured SAXS/WAXD Image Denoising

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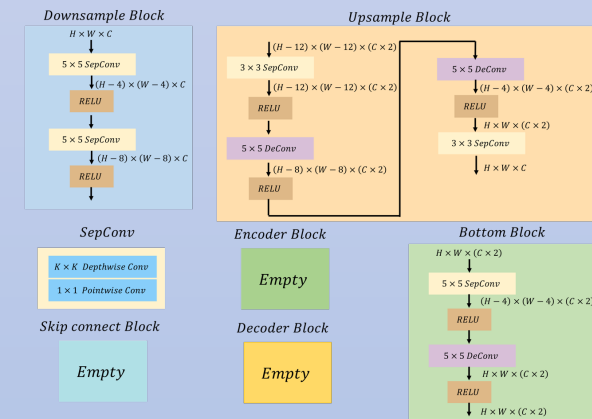
Introduction

- Experiments on next-generation beamlines are evolving into multi-modal, multi-scale, time-resolved, in-situ characterization.
- To maintain high signal-to-noise ratio (SNR), prolonged exposure and excessive dose occurring in SAXS/WAXD experiments remains a serious concern.
- This work algorithmically improves the SNR of SAXS/WAXD images, allowing more redundancy in exposure time and dose reduction during experiments.
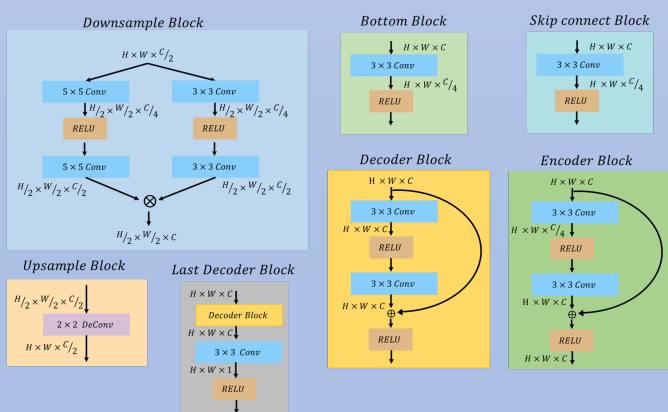
Network Design
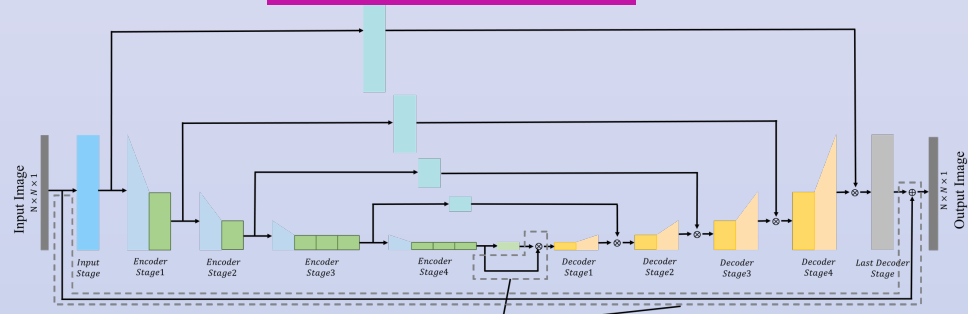
SAXS Size: $N^2 \times 48$ $(N-8)^2 \times 48$ $(N-16)^2 \times 48$ $(N-24)^2 \times 48$ $(N-32)^2 \times 48$ $(N-32)^2 \times 48$ $(N-32)^2 \times 48$ $(N-24)^2 \times 48$ $(N-16)^2 \times 48$ $(N-8)^2 \times 48$ $N^2 \times 1$

WAXD Size: $N^2 \times 16$ $(N/2)^2 \times 32$ $(N/4)^2 \times 64$ $(N/8)^2 \times 128$ $(N/16)^2 \times 256$ $(N/16)^2 \times 64$ $(N/8)^2 \times 64$ $(N/4)^2 \times 32$ $(N/2)^2 \times 32$ $(N)^2 \times 16$ $N^2 \times 1$
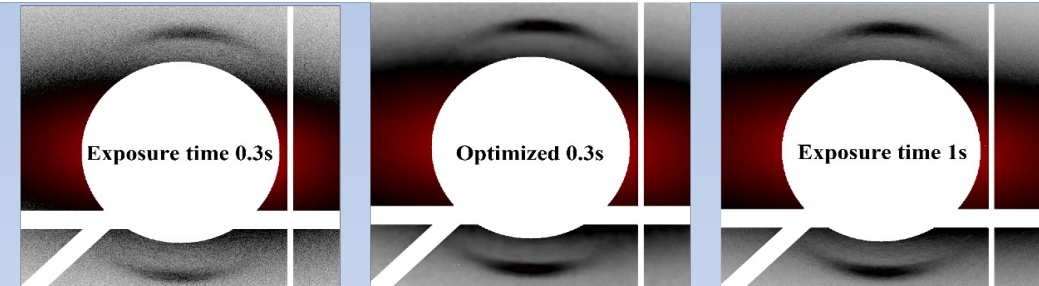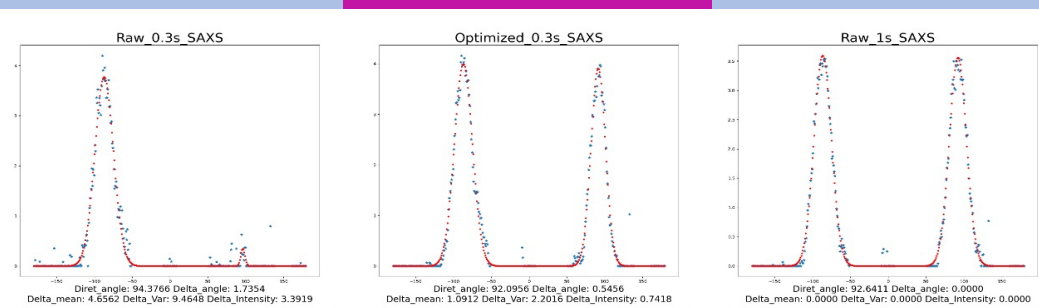
Conv | Downsample Block | Encoder Block | Bottom Block | Skip connect Block
SepConv | upsample Block | Decoder Block | Last Decoder Block | ⊗ Catenate | ⊕ Elemwise add

SAXS Part

WAXD Part

SAXS

Raw_0.3s_SAXS — Diret_angle: 94.3766 Delta_angle: 1.7354; Delta_mean: 4.6562 Delta_Var: 9.4648 Delta_Intensity: 3.3919

Optimized_0.3s_SAXS — Diret_angle: 92.0956 Delta_angle: 0.5456; Delta_mean: 1.0912 Delta_Var: 2.2016 Delta_Intensity: 0.7418

Raw_1s_SAXS — Diret_angle: 92.6411 Delta_angle: 0.0000; Delta_mean: 0.0000 Delta_Var: 0.0000 Delta_Intensity: 0.0000

Exposure time 0.3s   Optimized 0.3s   Exposure time 1s
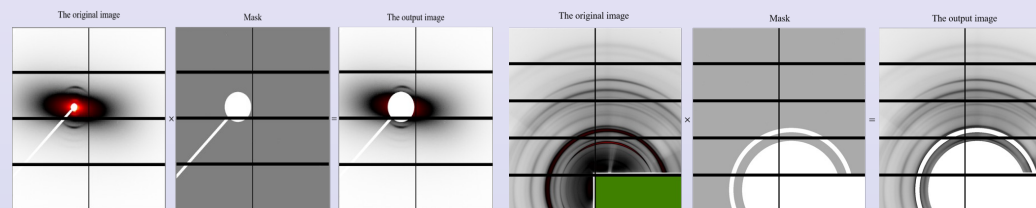
Methods

- Preprocessing: masking and resizing

Fig. 1*: preprocessing procedures, including masking and resizing*

- Customized metrics reflecting physical attributes
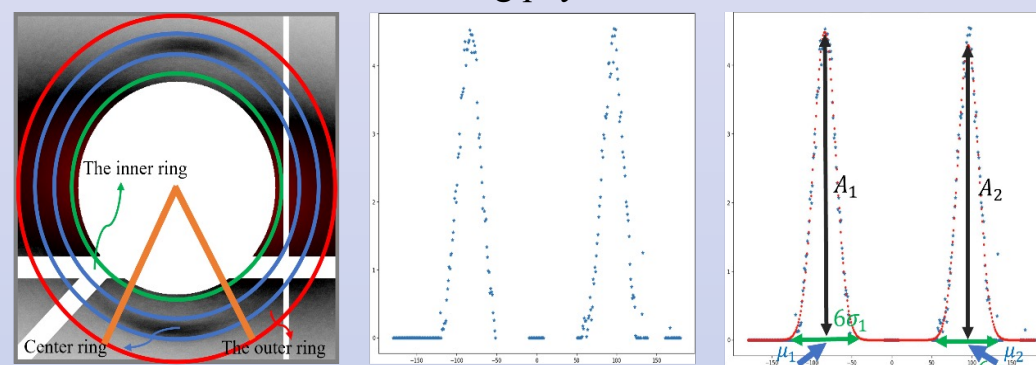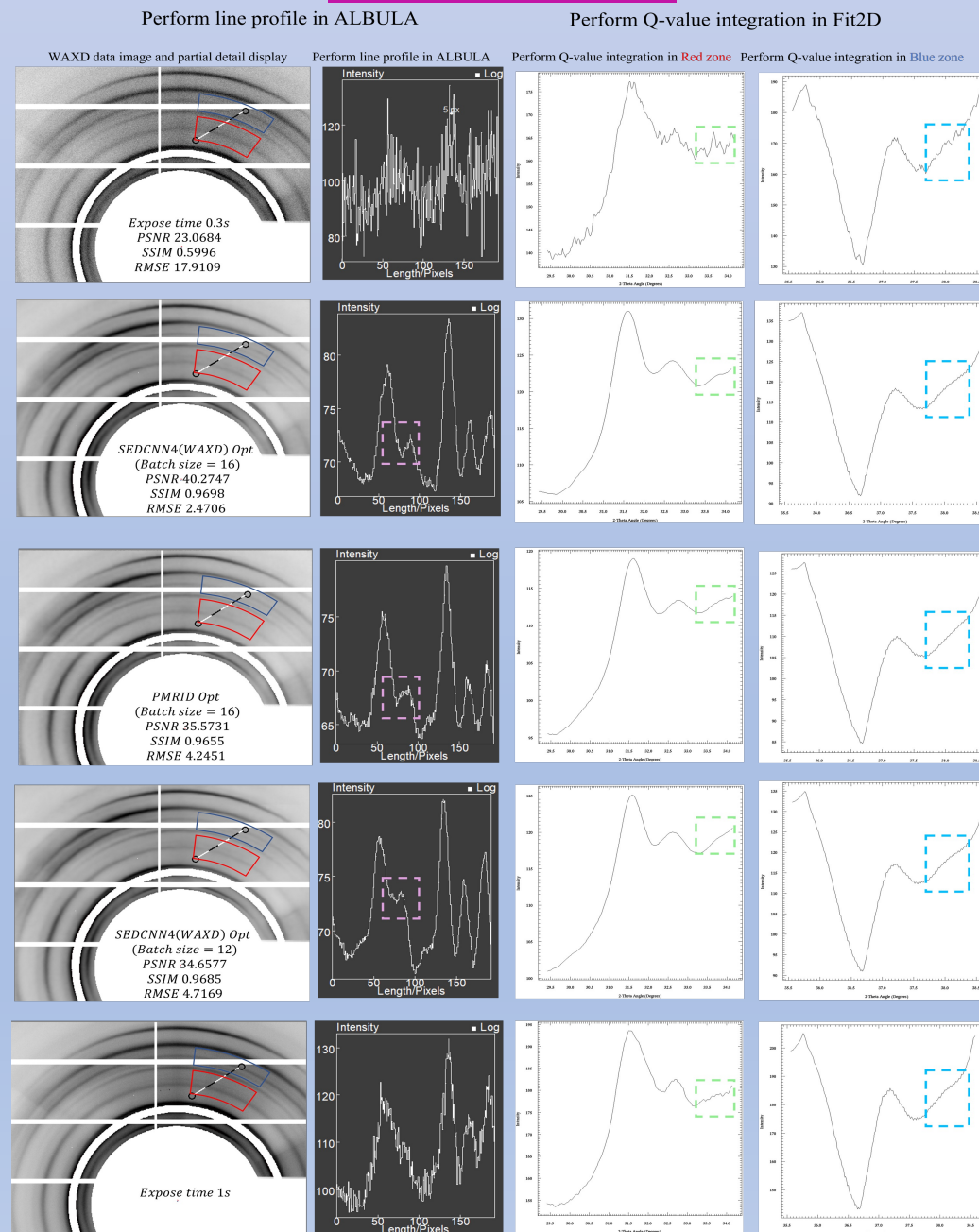

The inner ring   Center ring   The outer ring

Fig. 2*: radial integration, upon which various customized metrics are built*

- Block-based training scheme empowers small network models.
- Fine-tuning hyperparameters to reach optimal performance.

WAXD

Perform line profile in ALBULA   Perform Q-value integration in Fit2D

WAXD data image and partial detail display | Perform line profile in ALBULA | Perform Q-value integration in Red zone | Perform Q-value integration in Blue zone

Expose time 0.3s
PSNR 23.0684
SSIM 0.5996
RMSE 17.9109

SEDCNN4(WAXD) Opt (Batch size = 16)
PSNR 40.2747
SSIM 0.9698
RMSE 2.4706

PMRID Opt (Batch size = 16)
PSNR 35.5731
SSIM 0.9655
RMSE 4.2451

SEDCNN4(WAXD) Opt (Batch size = 12)
PSNR 34.6577
SSIM 0.9685
RMSE 4.7169

Expose time 1s

Conclusions

- The proposed model provides bespoke denoising solution for SAXS/WAXD images, from data preprocessing to network design and to final performance evaluation metrics.
- The model demonstrates superior denoising performance on highly textured SAXS/WAXD images, compared with classic natural image denoisers like U-Net, REDCNN, and PMRID.