ECCV'20 ONLINE
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中国科学技术大学
University of Science and Technology of China

Learning to Restore ssTEM Images from Deformation and Corruption

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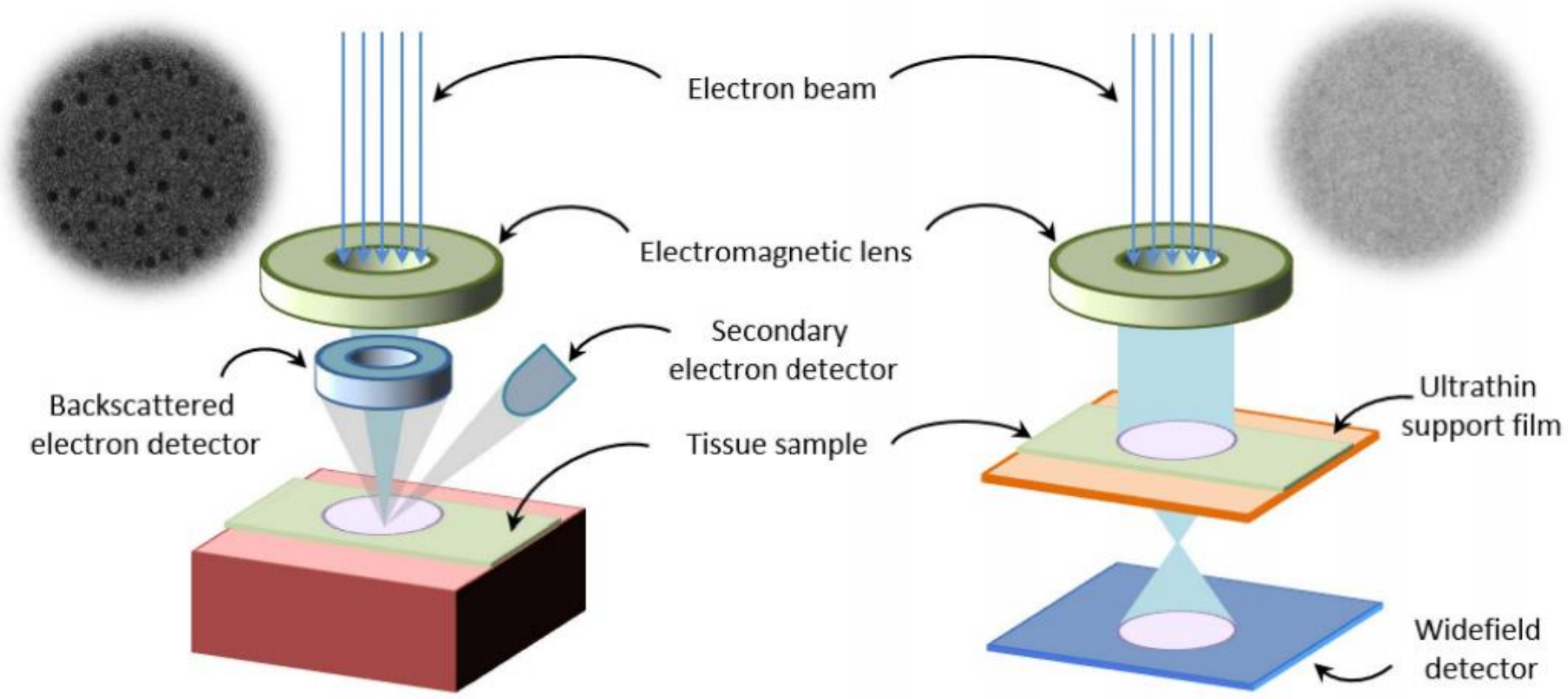
VIDAR
Visual Information Discovery And Recovery

NEL-BITA
National Engineering Laboratory for Brain-Inspired Intelligence Technology and Application

Introduction

- Scanning EM (SEM) & Transmission EM (TEM)

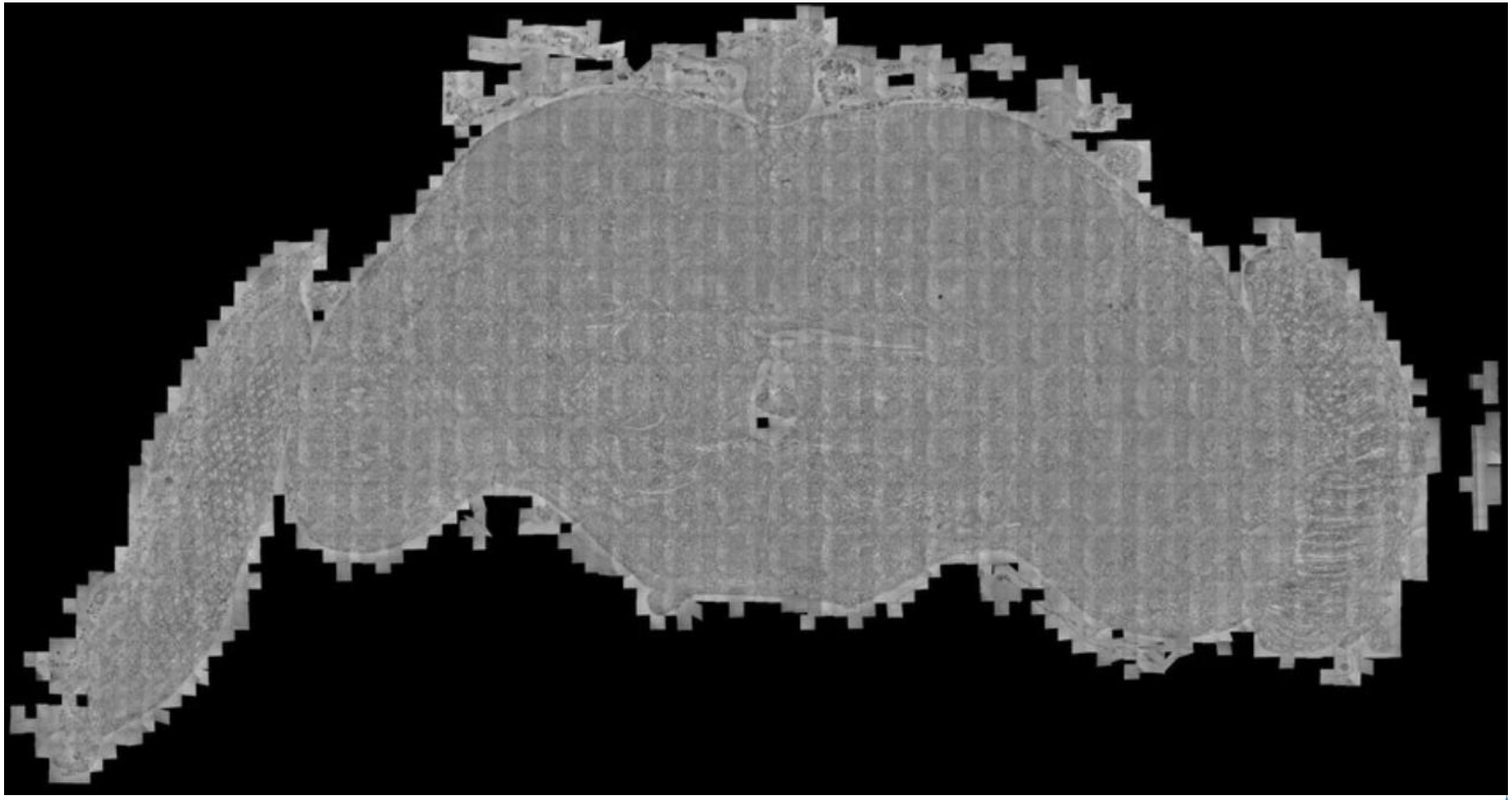


SEM TEM

Minh Quan T., et al. Removing Imaging Artifacts in Electron Microscopy using an Asymmetrically Cyclic Adversarial Network without Paired Training Data. ICCVW 2019.

Introduction

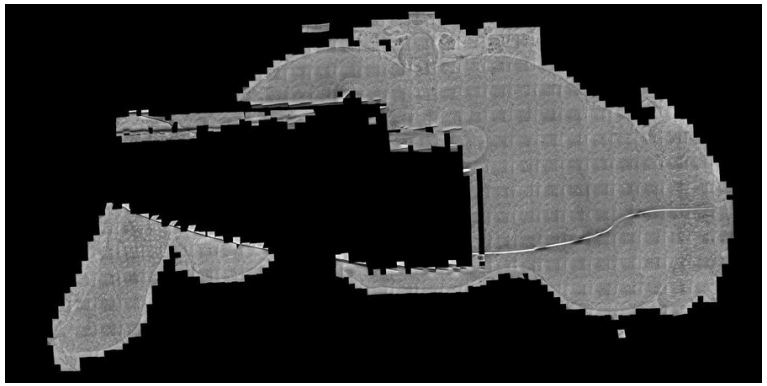
- Full Adult Fly Brain (FAFB)



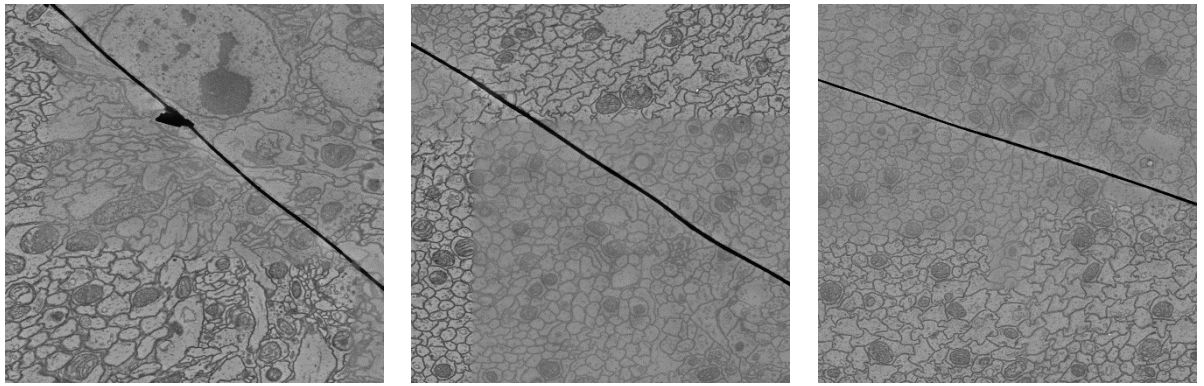
Zheng, Z., et al. A complete electron microscopy volume of the brain of adult drosophila melanogaster. Cell 2018.

Introduction

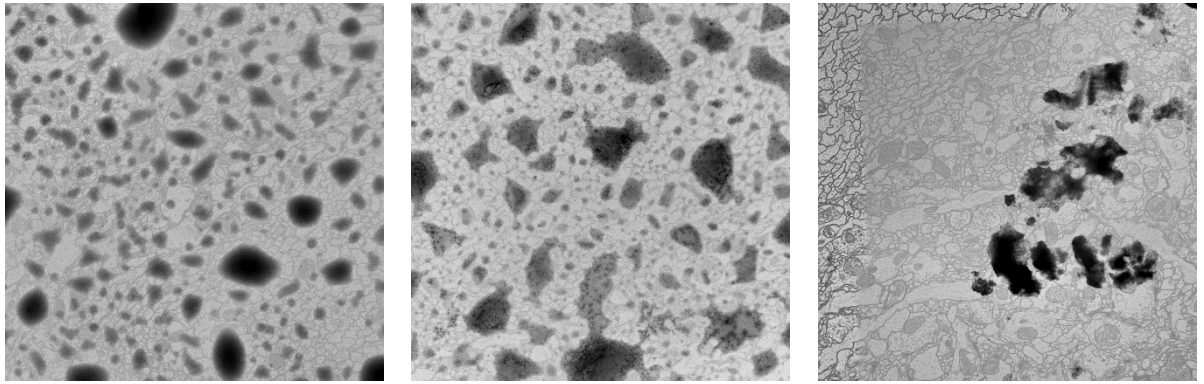
- Main artifacts in FAFB



Miss sections (MS, 4.4%)



Support Film Folds (SFF, 3.2%)

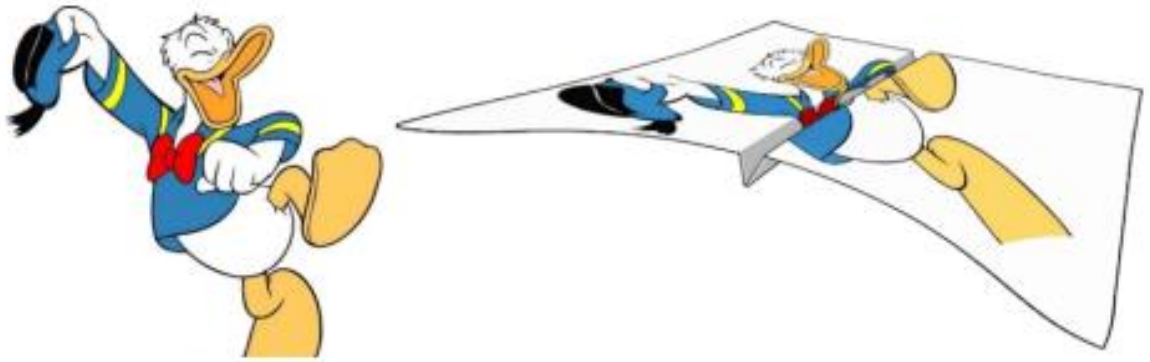


Staining Precipitates (SP, 2.6%)

Jan Funke. Automatic Neuron Reconstruction from Anisotropic Electron Microscopy Volumes. PhD thesis, ETH Zurich, 2014.

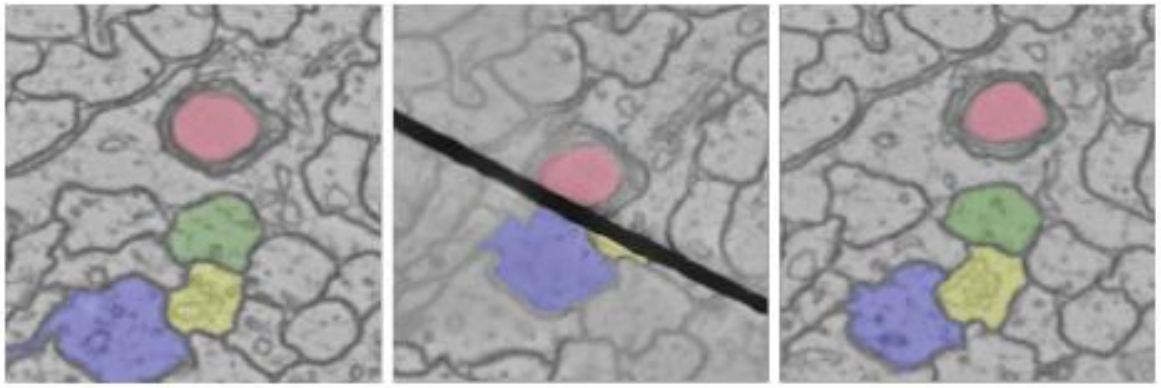
Introduction

- The characteristic of Support Film Folds (SFF) degradation
  - Deformation
  - Corruption



(a)

A cartoon image as an intuitive example to demonstrate SFF degradation.

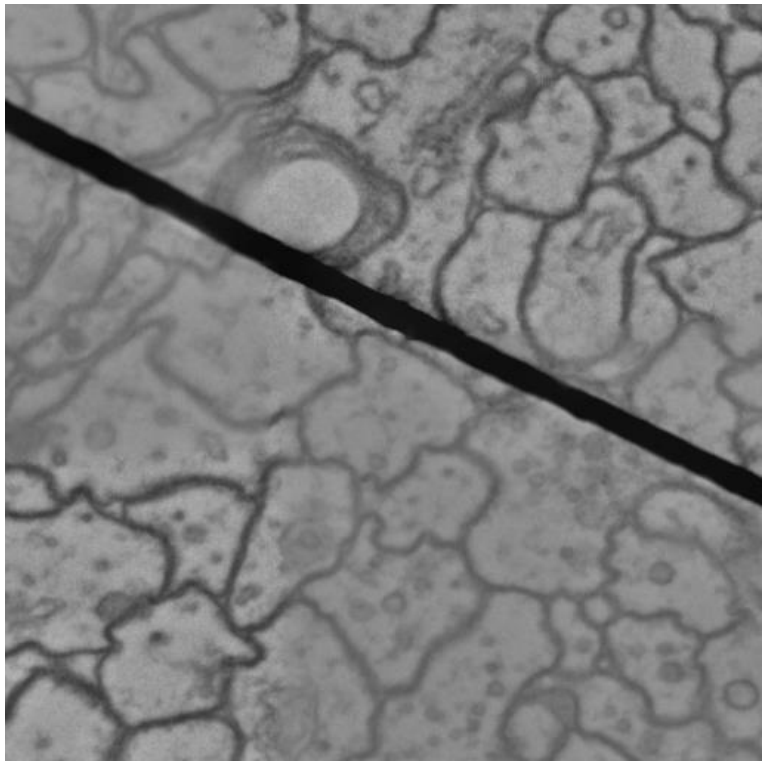


(b)

Three consecutive ssTEM images where the middle one is with SFF artifacts.

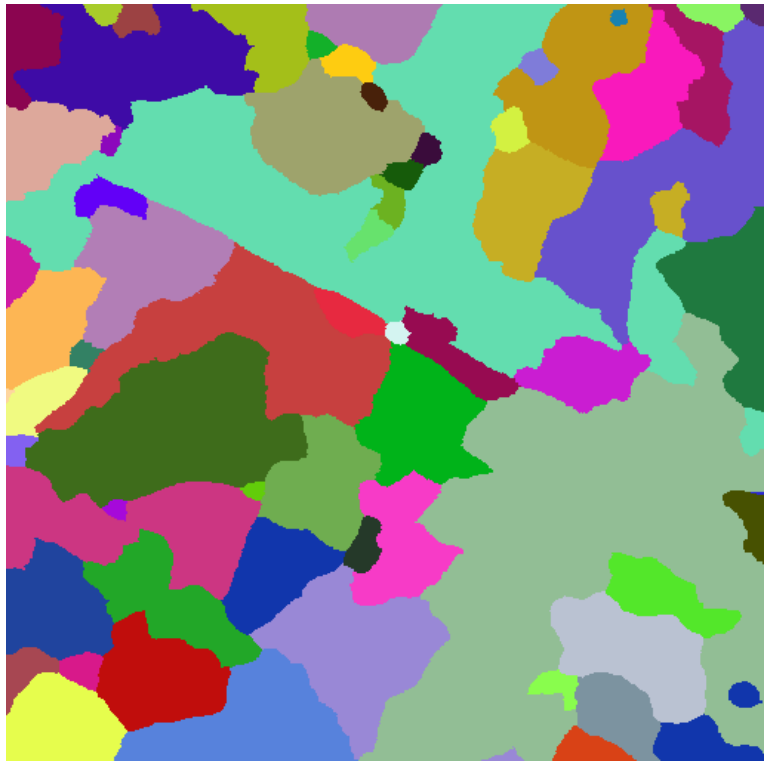
Introduction

- The influence of SFF degradation
  - Image quality
  - Subsequent tasks: alignment, segmentation and so on



One ssTEM image with SFF degradation

segmentation



The corresponding segmentation result

Related Work

- EM image restoration
  - Denoising [1]
  - Axial deformation [2]
  - Axial slice thickness artifacts [3]

[1]. Roels, J., et al. An overview of state-of-the-art image restoration in electron microscopy. Journal of Microscopy 2018.
[2]. Saalfeld, S., et al. Elastic volume reconstruction from series of ultra-thin microscopy sections. Nature Methods 2012.
[3]. Hanslovsky, P., et al. Image-based correction of continuous and discontinuous non-planar axial distortion in serial section microscopy. Bioinformatics 2017.

Related Work

- EM image restoration
  - Denoising [1]
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- Image inpainting
  - Partial Convolution (PC) [4]

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  - Denoising [1]
  - Axial deformation [2]
  - Axial slice thickness artifacts [3]
- Image inpainting
  - Partial Convolution (PC) [4]
- Substitution/Interpolation
  - Substitution [5]
  - Video frame interpolation [6]

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[4]. Liu, G., et al. Image inpainting for irregular holes using partial convolutions. ECCV 2018.
[5]. Li, P.H., et al. Automated reconstruction of a serial-section em drosophila brain with flood-filling networks and local realignment. bioRxiv 2019.
[6]. Niklaus, S., et al. Video frame interpolation via adaptive separable convolution. ICCV 2017.

Contributions

- Challenges
  - SFF exhibits drastically different characteristics
  - There is no corresponding groundtruth for the degraded ssTEM image

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  - SFF modeling
  - Deep restoration network

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- Motivation
  - SFF modeling
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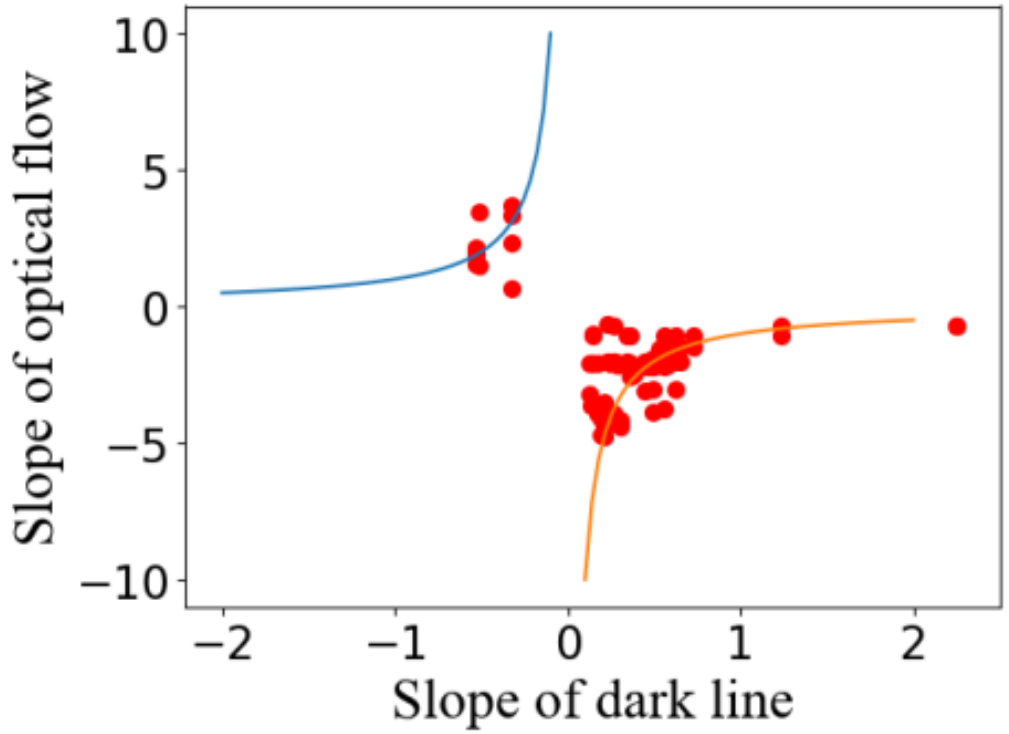
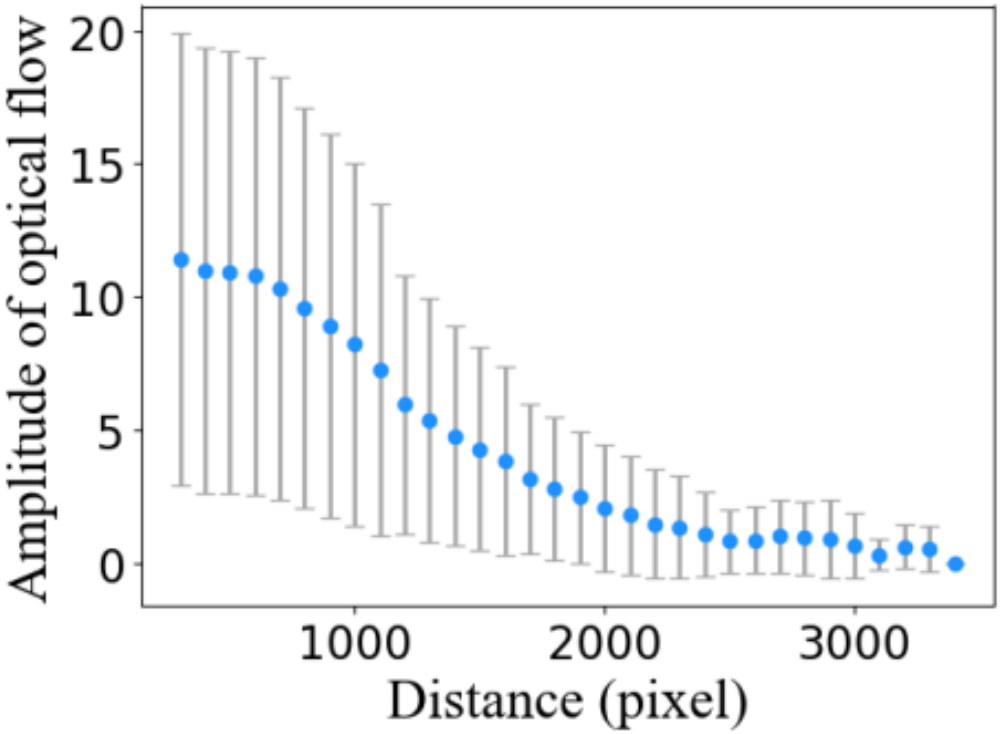
- Contributions
  - Comprehensive analysis on the statistics of SFF
  - Synthesis algorithm to generate degraded/groundtruth image pairs
  - The first learning-based framework for ssTEM image restoration from SFF artifacts
  - Experiments on both image restoration quality and neuron segmentation accuracy

SFF Modeling

- Statistical analysis
  - Slope
  - Amplitude



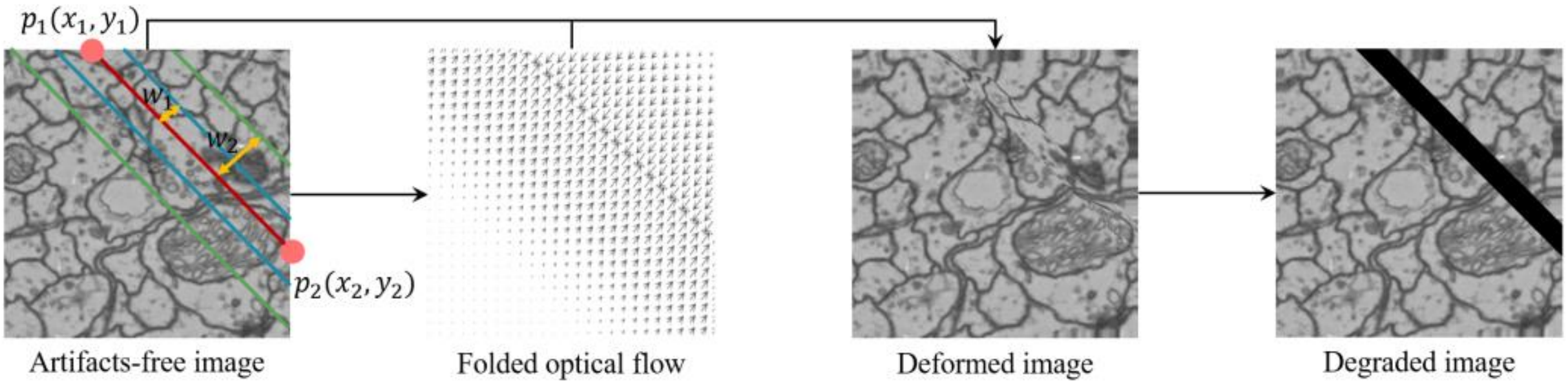
(a)



(b)

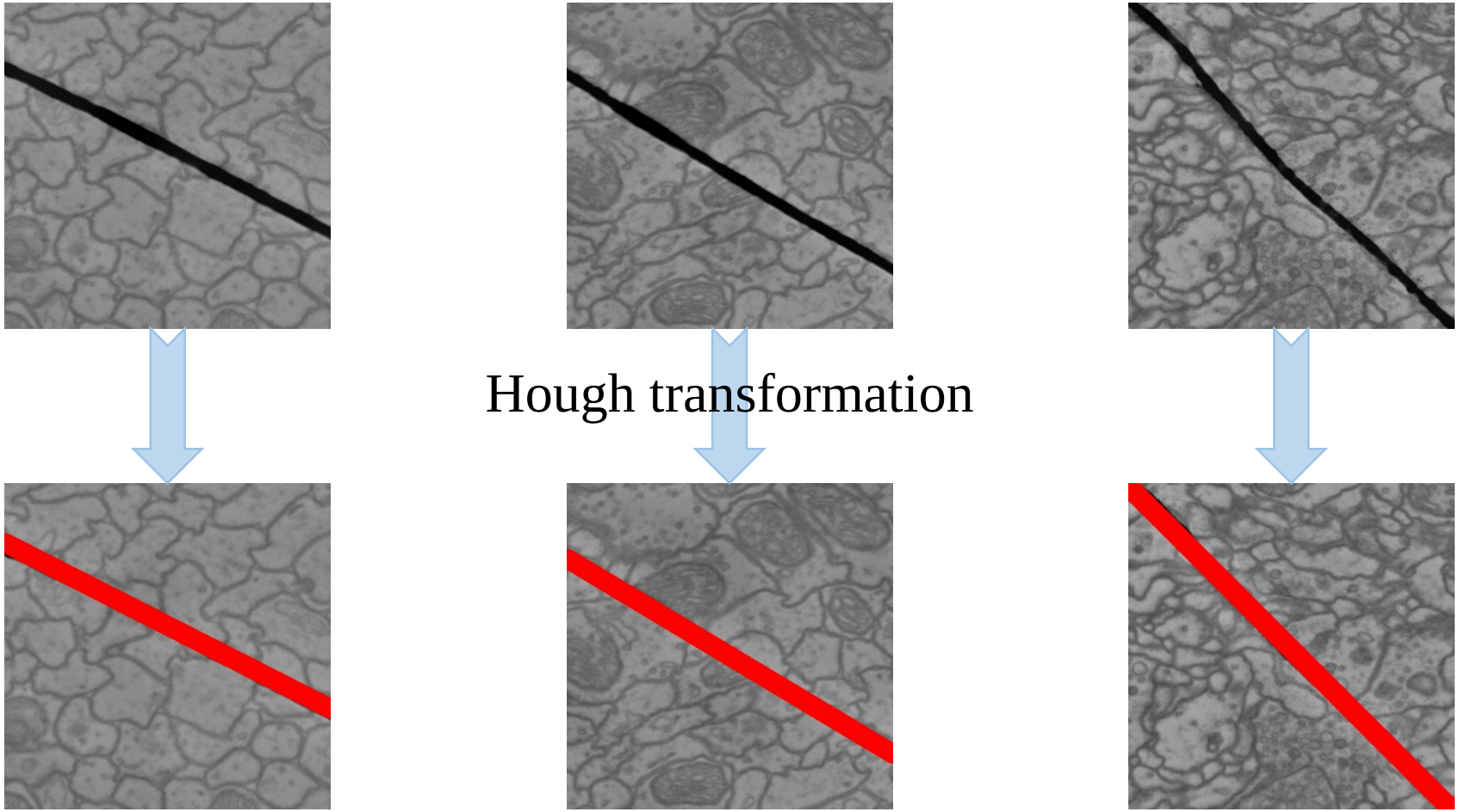
SFF Modeling

- SFF simulation
  - Deformation
  - Corruption



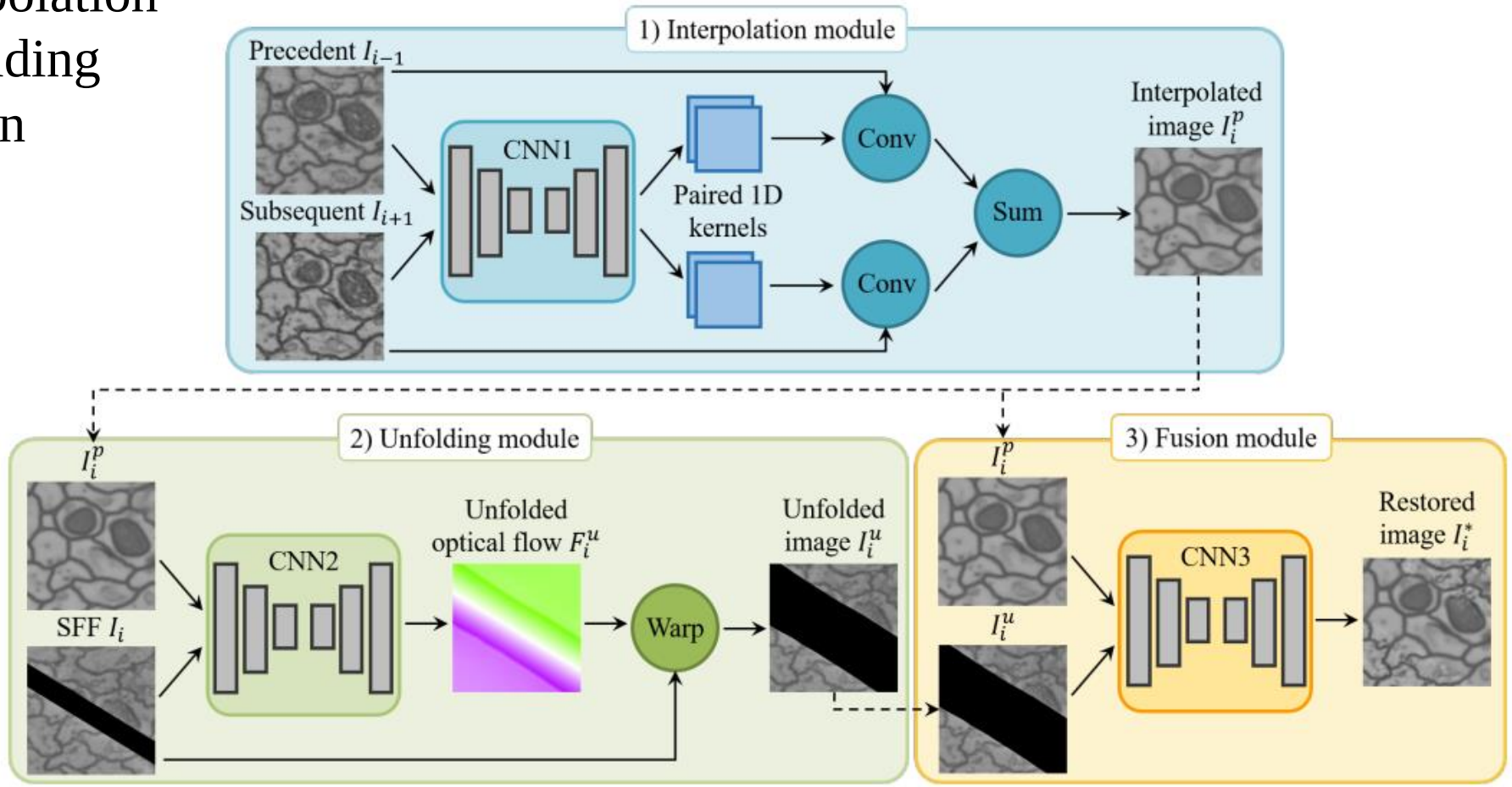
SFF Restoration

- Artifacts detection



SFF Restoration

- Restoration framework
  - Interpolation
  - Unfolding
  - Fusion



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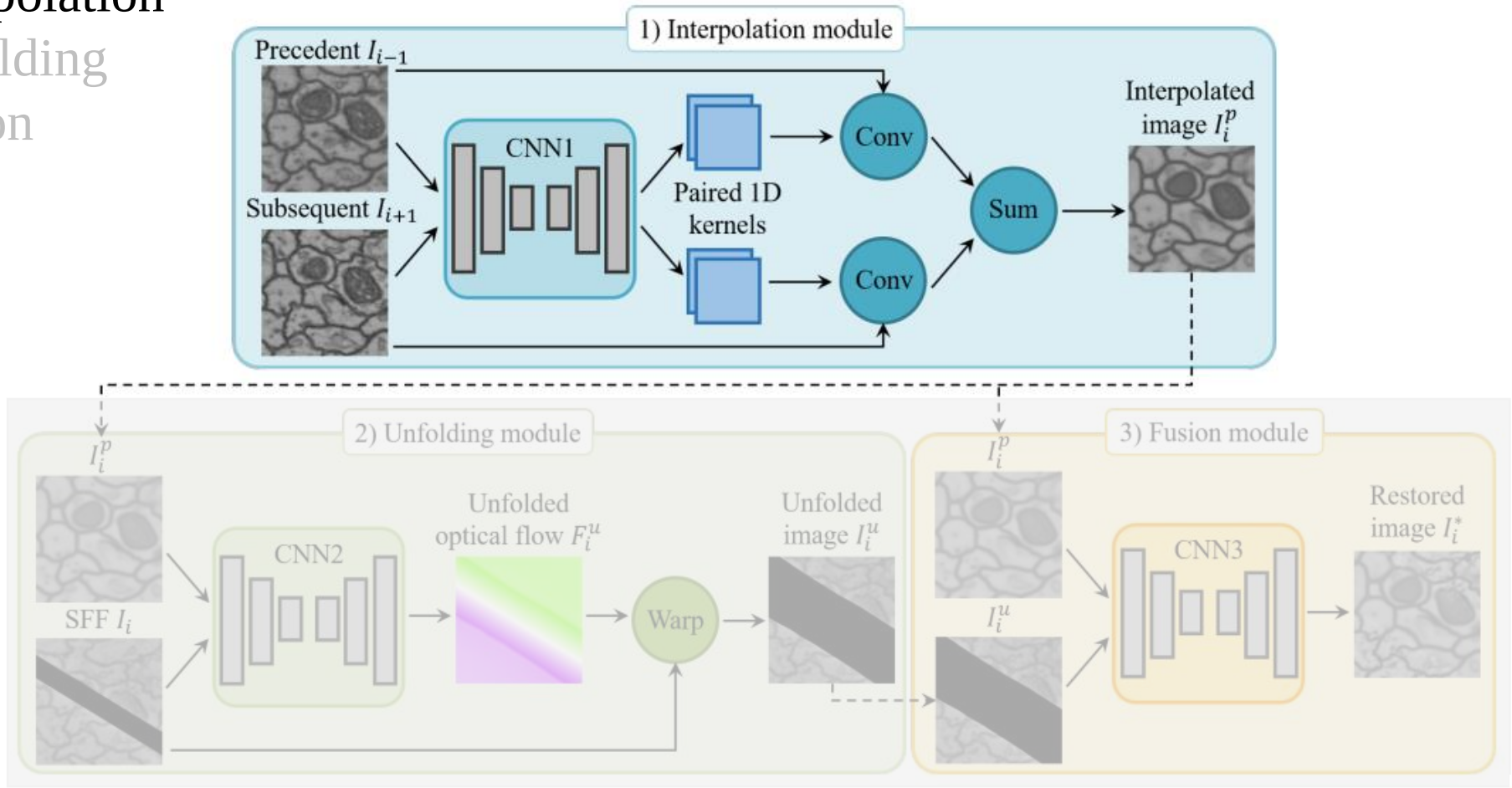

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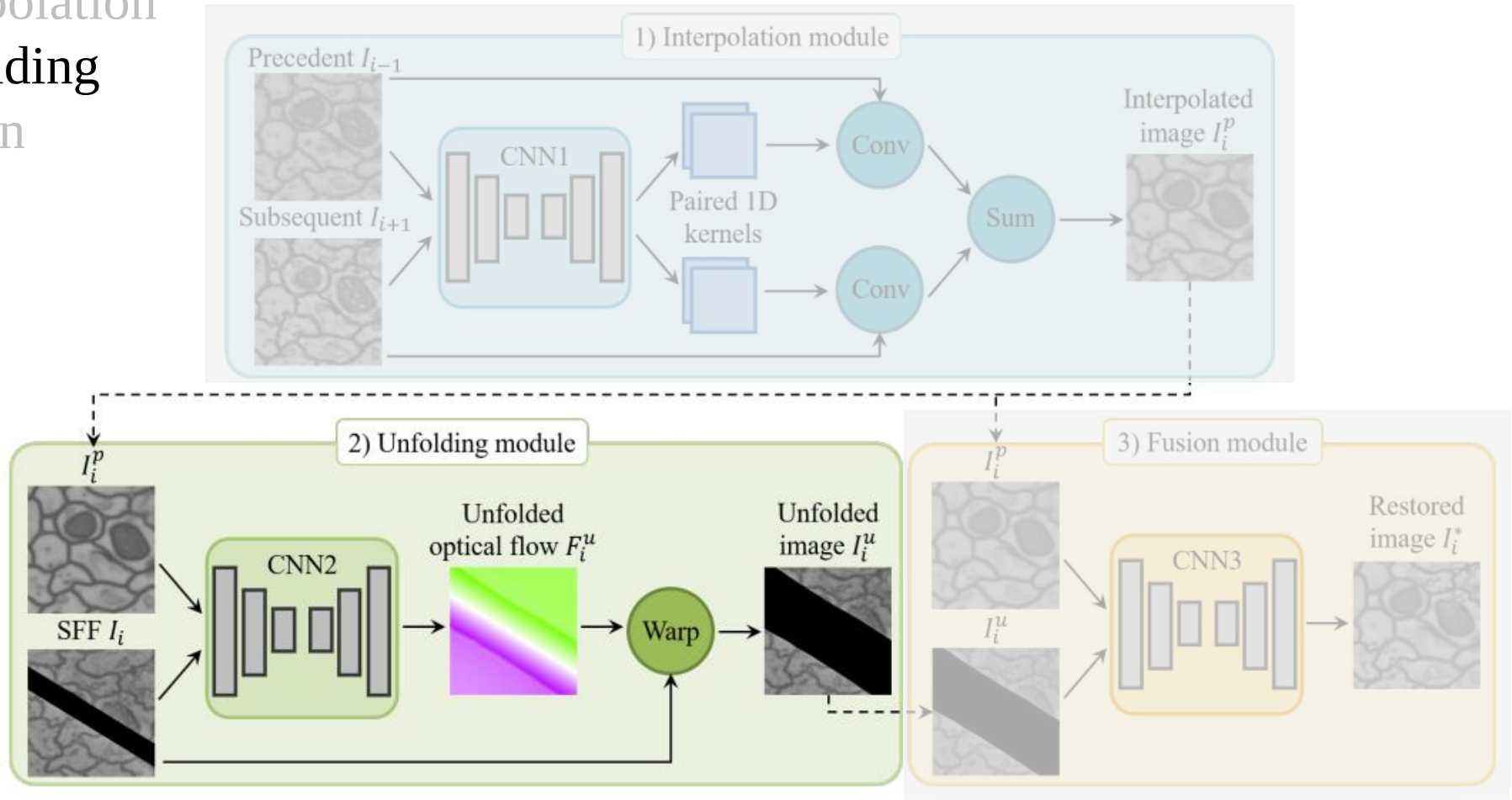

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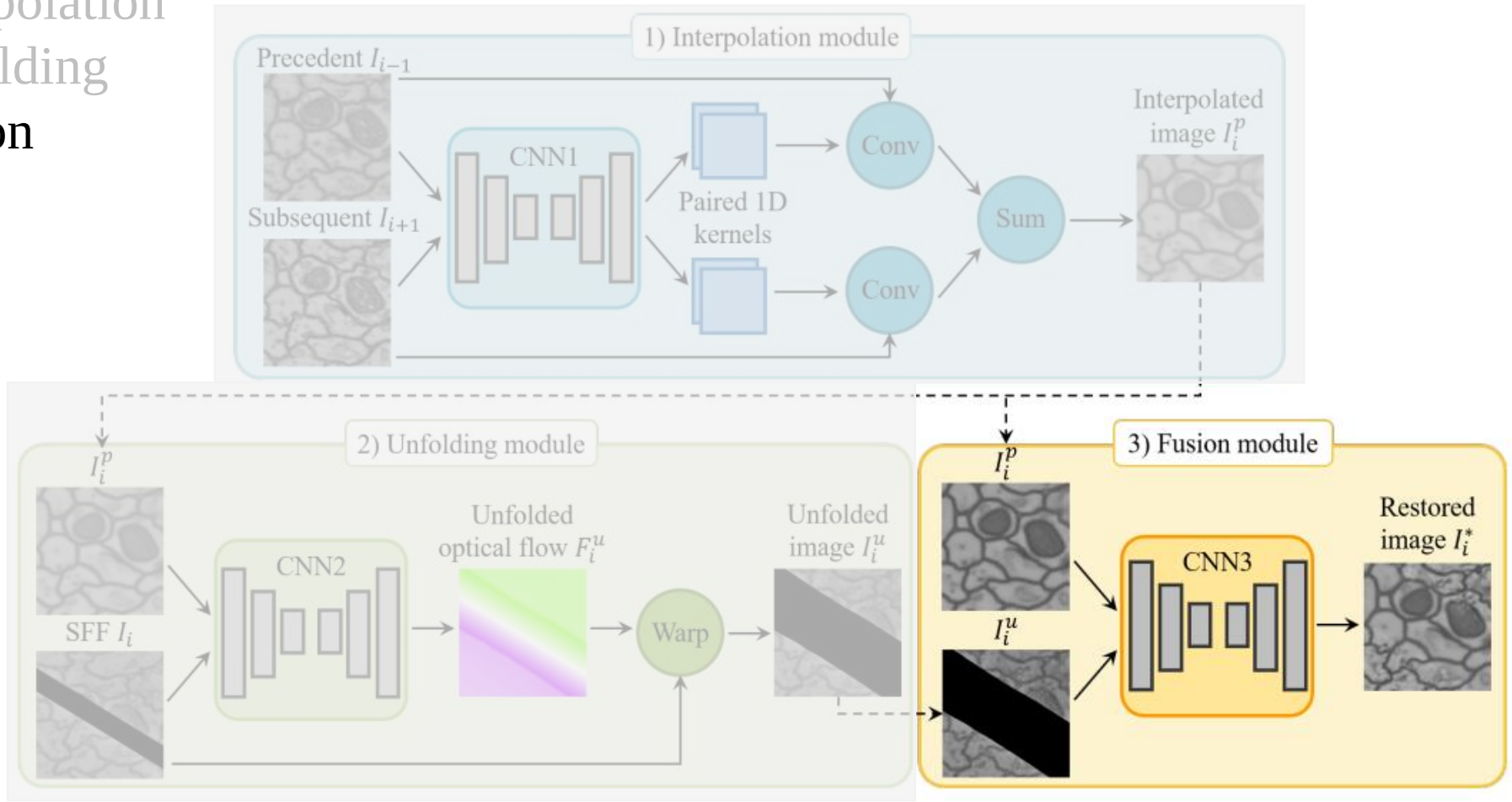

Experiments

- Data preparation
  - Full Adult Fly Brain (FAFB) [1]
  - CREMI Challenge [2]

[1]. https://www.temca2data.org/
[2]. https://cremi.org/

Experiments

- Data preparation
  - Full Adult Fly Brain (FAFB) [1]
  - CREMI Challenge [2]
- Implementation details
  - Training: 512× 512, 4000 samples selected from FAFB
  - Test: 2048× 2048, synthetic data on CREMI and real data on FAFB

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  - Full Adult Fly Brain (FAFB) [1]
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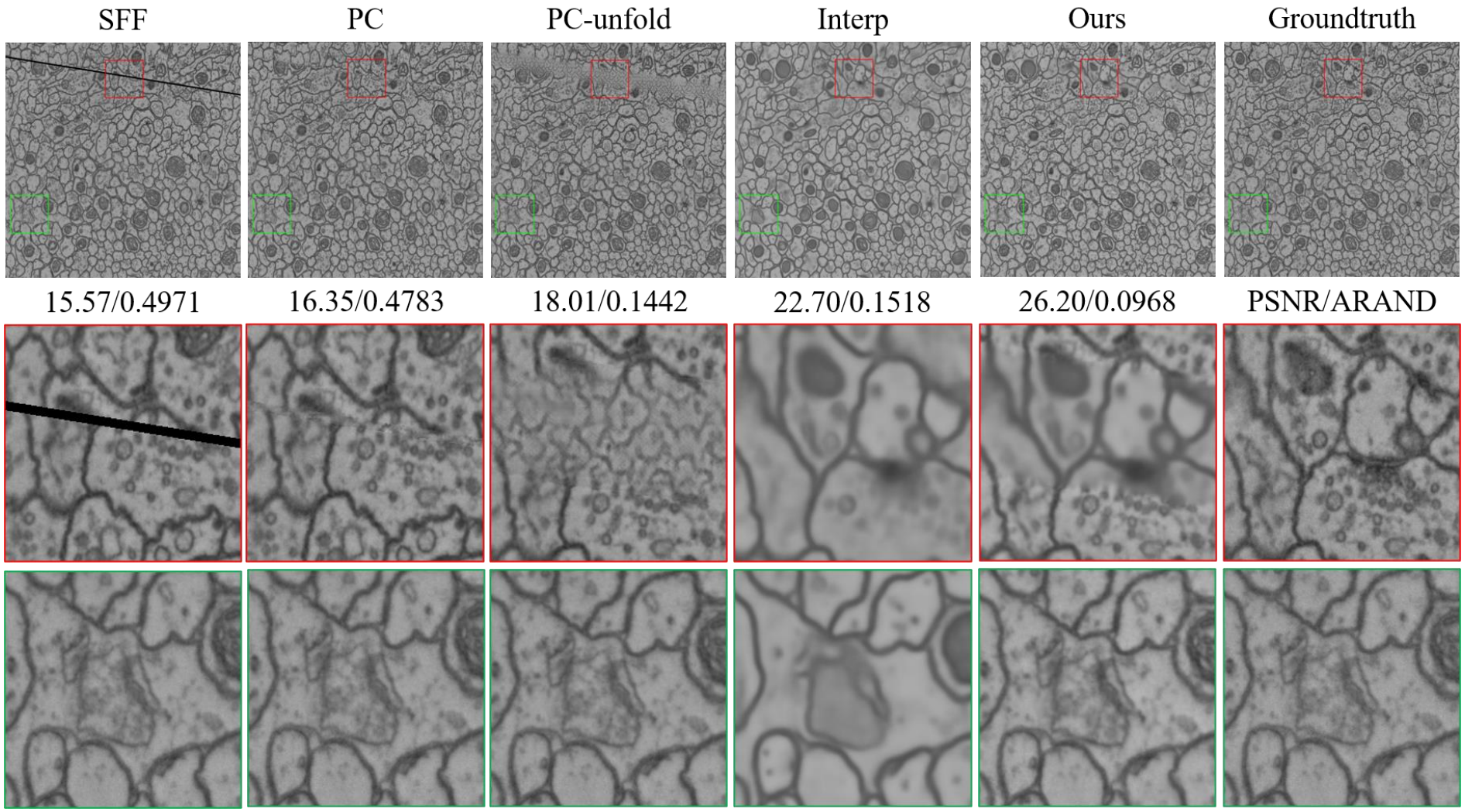
- Implementation details
  - Training: 512× 512, 4000 samples selected from FAFB
  - Test: 2048× 2048, synthetic data on CREMI and real data on FAFB
- Evaluation metric
  - Fidelity metric: PSNR and SSIM
  - Perceptual metric: Frechet Inception Distance (FID)
  - Segmentation metric:
    - Variation of Information (VOI)
    - Adapted Rand Error (ARAND)

[1]. https://www.temca2data.org/
[2]. https://cremi.org/

Synthetic data results

CREMI	Metric \ Method	SFF	Sub. [16]	PC [17]	PC-unfold	Interp [22]	Ours
A	PSNR ↑	15.57	19.57	16.35	18.01	22.70	**26.20**
	SSIM ↑	0.5615	0.4353	0.5665	0.7517	0.6595	**0.8261**
	FID ↓	229.71	33.30	36.83	62.44	144.69	**27.80**
	VOI ↓	2.6780	1.2505	2.6440	0.9507	0.8967	**0.7833**
	ARAND ↓	0.4971	0.2881	0.4783	0.1442	0.1518	**0.0968**
B	PSNR ↑	15.11	18.16	16.43	18.17	22.22	**26.81**
	SSIM ↑	0.5842	0.3586	0.6161	0.7532	0.6041	**0.8202**
	FID ↓	260.27	50.54	41.78	53.57	175.26	**38.17**
	VOI ↓	4.0629	3.8864	3.7147	3.4817	3.1898	**3.0957**
	ARAND ↓	0.5806	0.5855	0.3931	0.4355	0.3680	**0.3517**
C	PSNR ↑	14.52	17.74	15.09	16.97	21.96	**25.74**
	SSIM ↑	0.4988	0.3066	0.5037	0.7257	0.5766	**0.7957**
	FID ↓	335.38	42.70	44.60	73.33	168.13	**42.26**
	VOI ↓	4.5572	3.6755	4.5789	3.4882	3.1606	**3.0825**
	ARAND ↓	0.4244	0.4280	0.4308	0.3309	0.2835	**0.2789**
Inference time (s)		*	*	0.1235	0.5130	0.0075	0.4251

Synthetic data results



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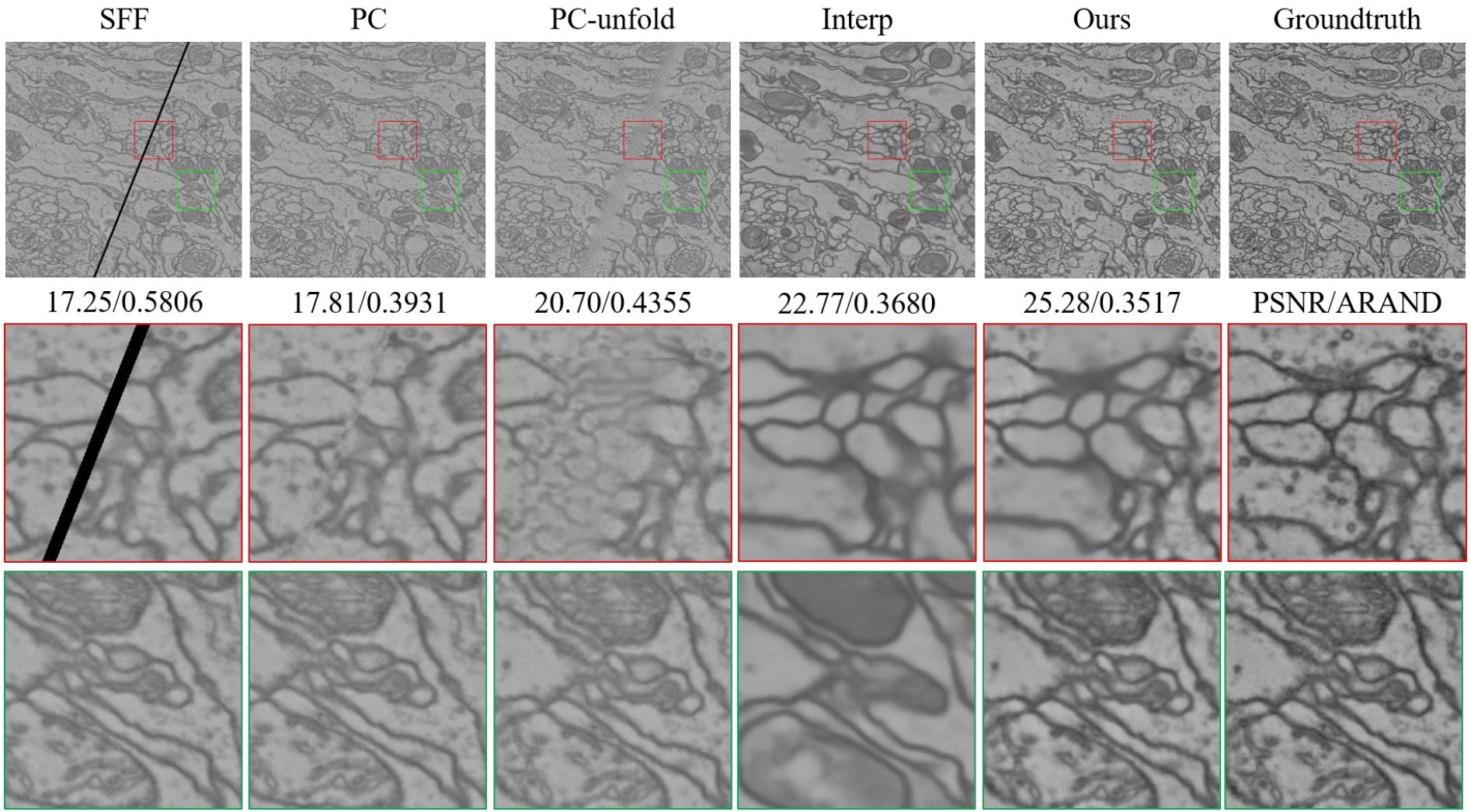
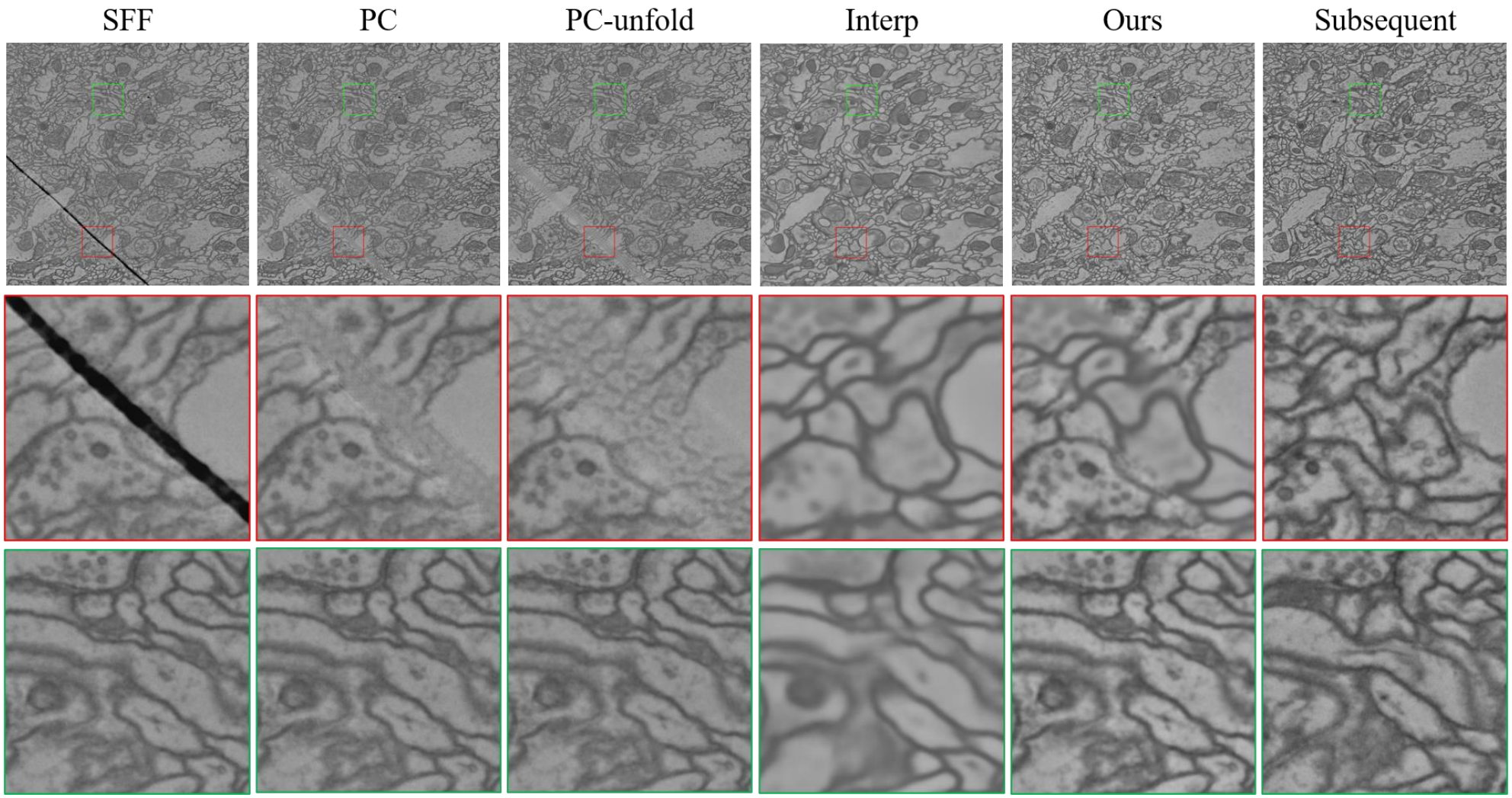
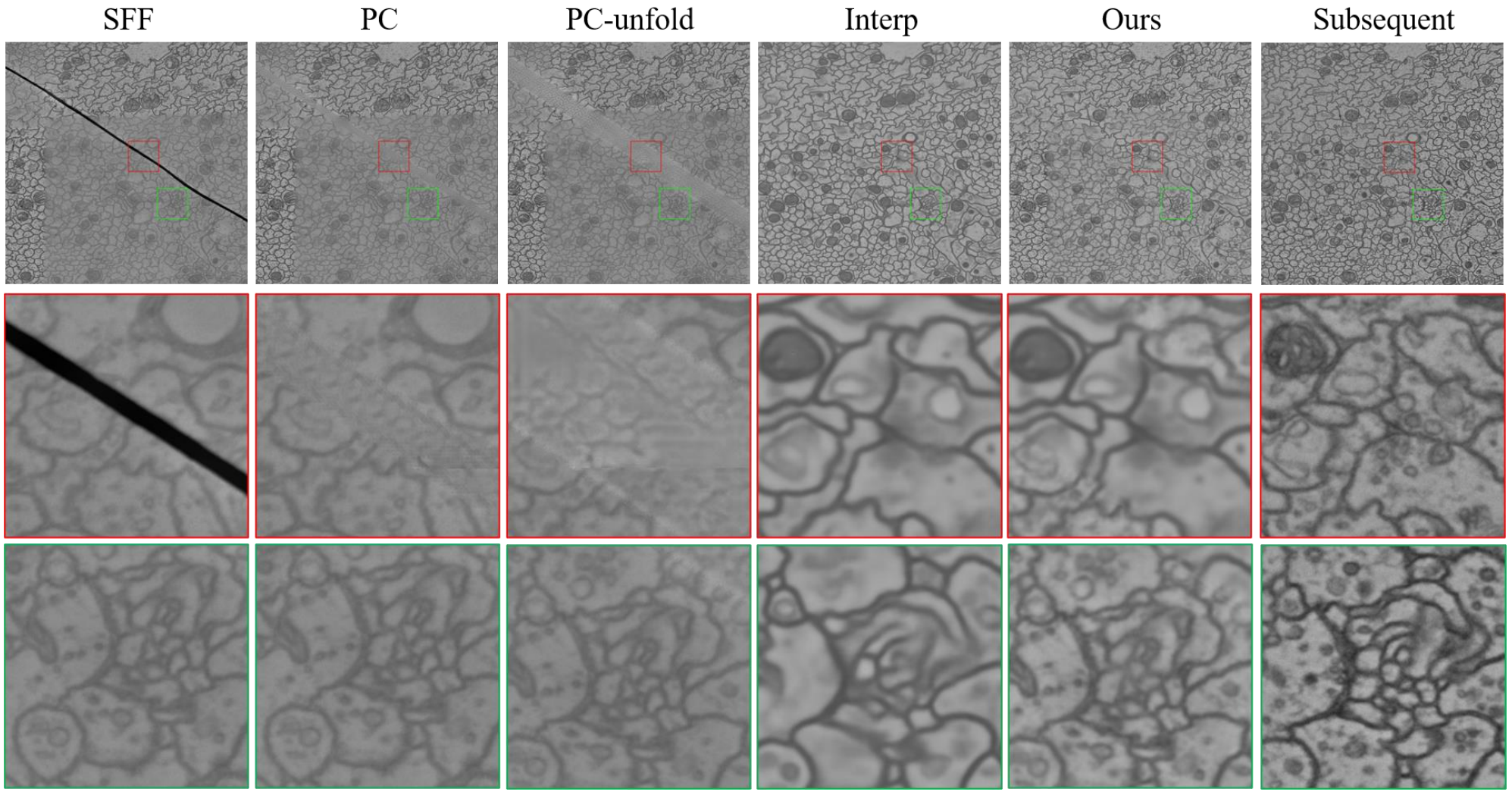


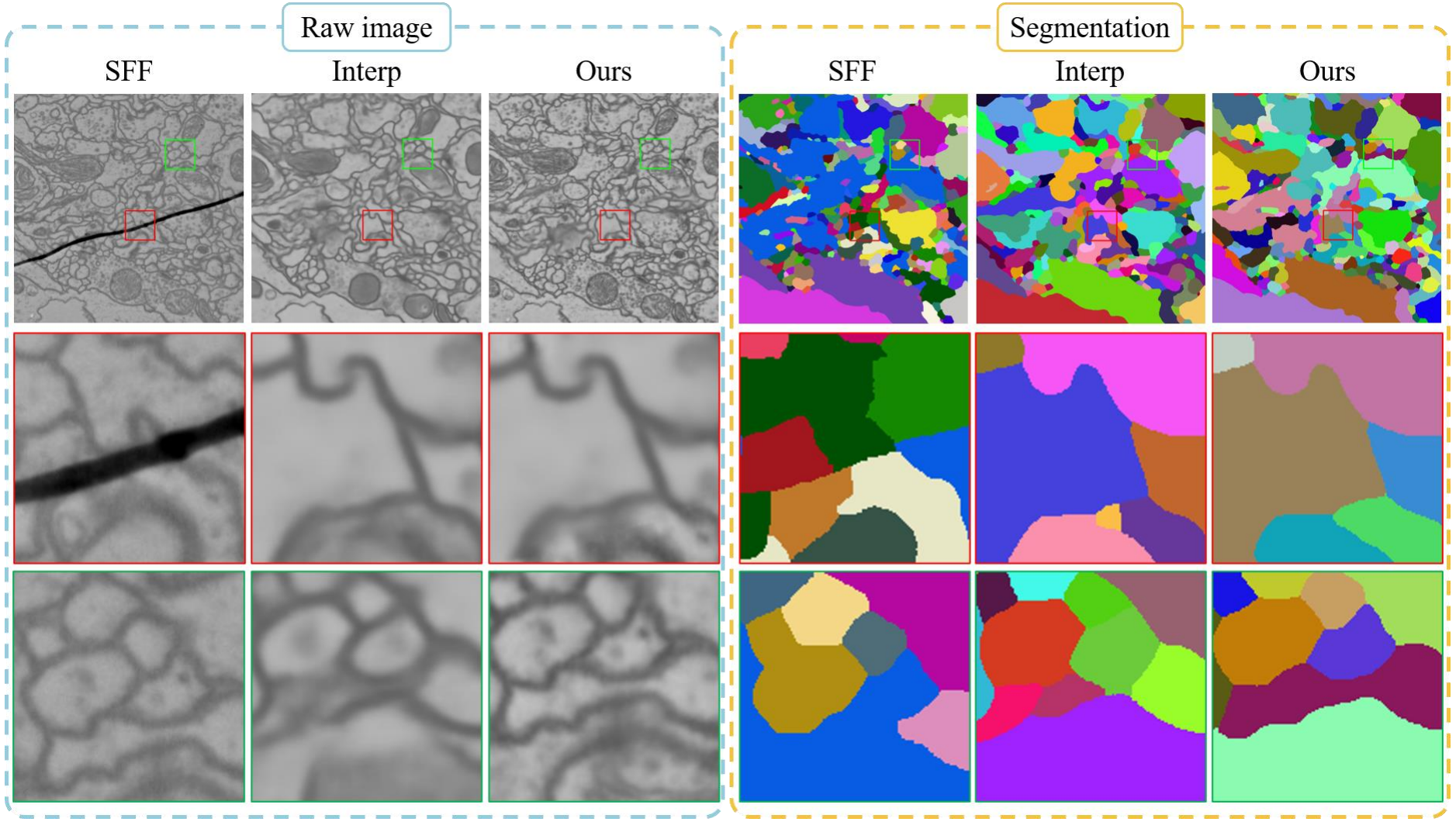
Real data results



Real data results



Segmentation results



Ablation Study

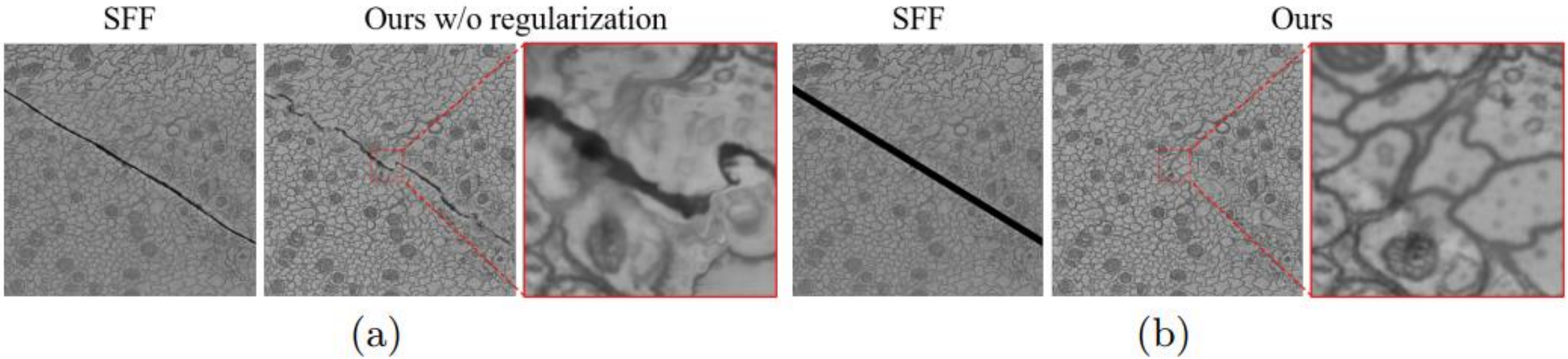
- Function of module

Ablation results for each module in the proposed restoration framework.

Interpolation	Unfolding	Fusion	PSNR	SSIM	FID	VOI	Rand
✓			22.70	0.6595	144.69	0.8967	0.1518
✓	✓		18.30	0.7393	115.55	0.9416	0.1430
✓		✓	24.68	0.7767	80.54	0.8301	0.1254
	✓	✓	25.94	0.8058	39.96	0.8534	0.1259
✓	✓	✓	**26.20**	**0.8261**	**27.80**	**0.7833**	**0.0968**

Ablation Study

- Regularization of corruption



Conclusions

- Analysis and modeling of SFF degradation
- The first learning-based restoration framework
- The superiority of performance on both synthetic and real data
- Benefit for the future research of neuron morphology and connectomics

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Thanks for your listening!

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