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Enhanced Rectangle Transformer for Hyperspectral Image Denoising

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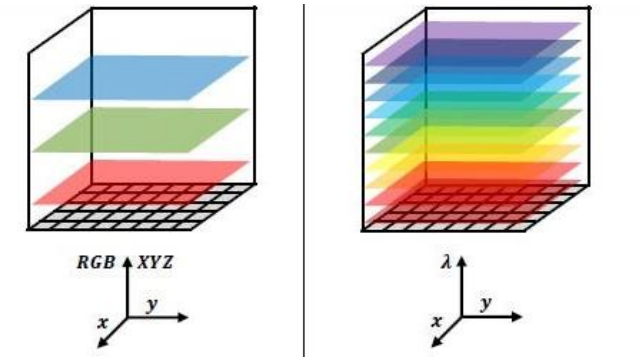
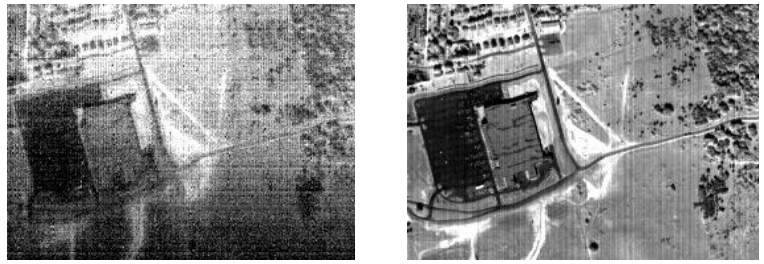
Background

Introduction to Hyperspectral Image



- 3D Cube
- Rich spectral information

Hyperspectral Image Denoising

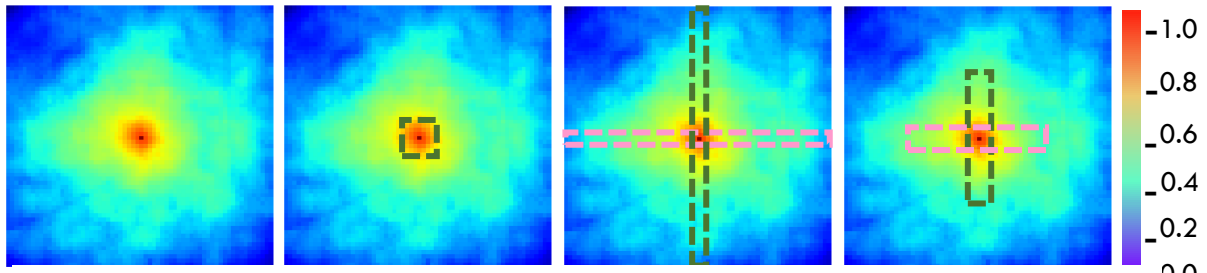


Noisy hyperspectral images in different bands

How to **effectively** denoise a **HSI** while **preserving** critical information?

Background

Motivation



(a) similarity to central pixel | (b) window self-attention | (c) cross-shaped self-attention | (d) rectangle self-attention (ours)

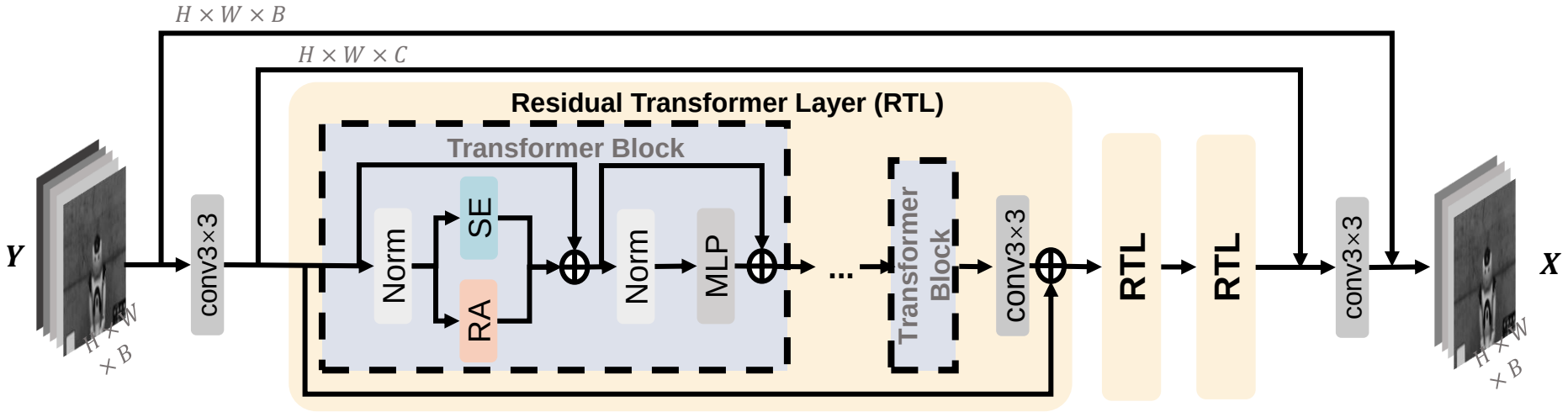
In spatial domain, as the distance between pixels becomes longer, the similarity decreases.

$$\underset{m \times n}{M} \approx \underset{m \times k}{L_k} \times \underset{\mathrm{k} \times n}{R_k^T}$$

HSI lies in a global spectral low-rank subspace.

Method

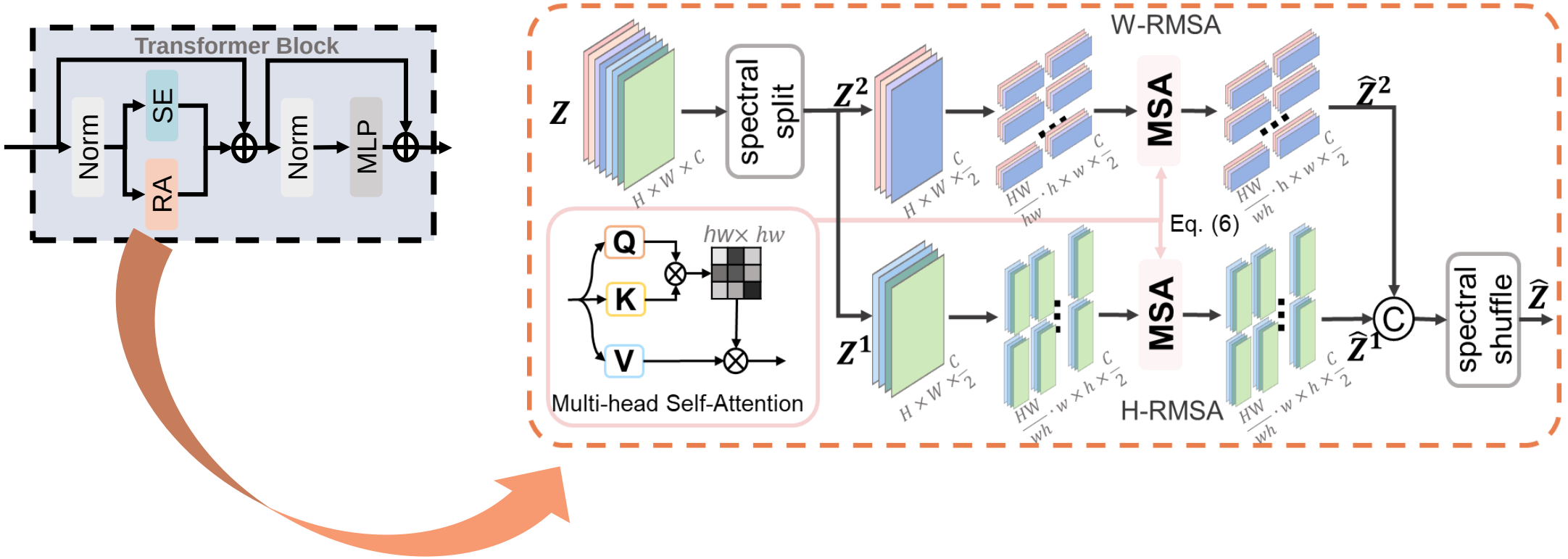
Overall Architecture



Spectral-Enhanced Rectangle Transformer (SERT)

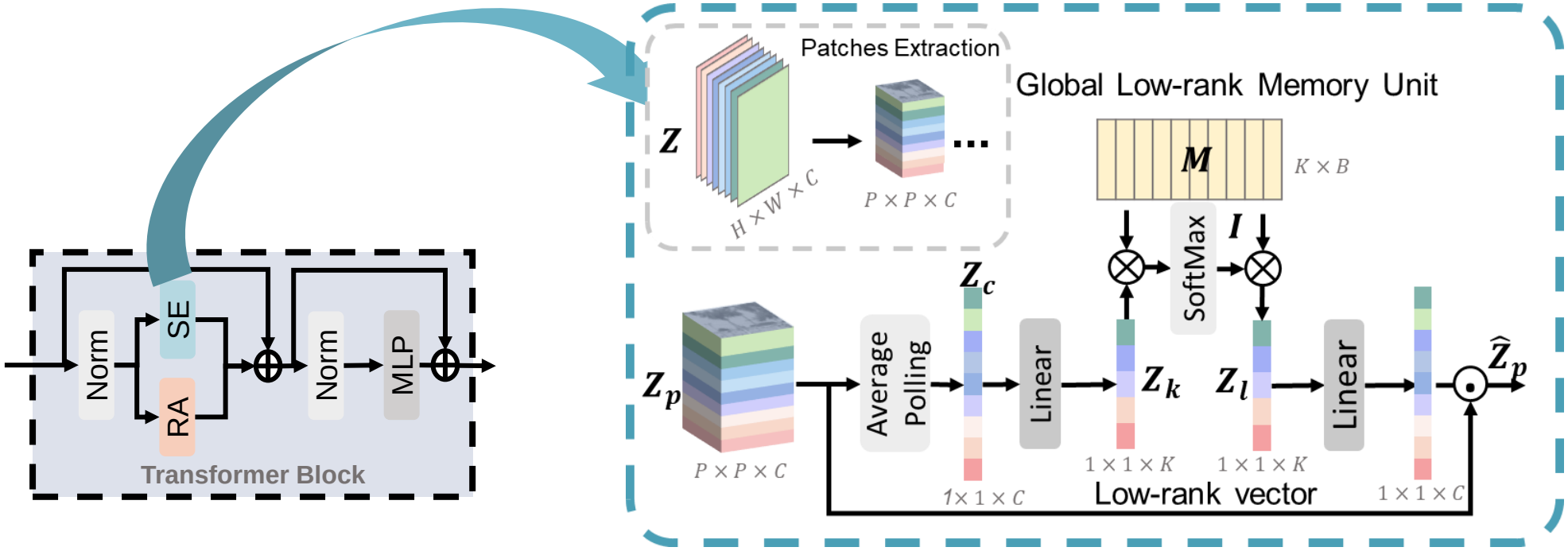
Method

Rectangle self-Attention



Method

Spectral Enhancement



Experiments

Results on Gaussian Noise

Method	10			30			50			70			10-70		
	PSNR	SSIM	SAM	PSNR	SSIM	SAM	PSNR	SSIM	SAM	PSNR	SSIM	SAM	PSNR	SSIM	SAM
Noisy	28.13	0.8792	18.72	18.59	0.5523	37.9	14.15	0.3476	49.01	11.23	0.2301	56.45	17.24	0.4782	41.94
BM4D	40.78	0.9930	2.99	37.69	0.9872	5.02	34.96	0.9850	6.81	33.15	0.9554	8.40	36.62	0.9770	5.51
LLRT	46.72	0.9983	1.60	41.12	0.9920	2.52	38.24	0.9830	3.47	36.23	0.9732	4.46	40.06	0.9860	3.24
NGMeet	**47.90**	0.9988	1.39	42.44	0.9816	2.06	39.69	0.9658	2.49	38.05	0.9531	2.83	41.67	0.9937	2.19
HSID-CNN	43.14	0.9918	2.12	40.30	0.9854	3.14	37.72	0.9746	4.27	34.95	0.9521	5.84	39.04	0.9776	3.71
GRNet	45.25	0.9976	1.83	42.09	0.9957	2.18	40.25	0.9936	2.42	38.95	0.9914	2.63	41.44	0.9944	2.27
QRNN3D	45.61	0.9977	1.80	42.18	0.9955	2.21	40.05	0.9929	2.63	38.09	0.9883	3.42	41.34	0.9938	2.42
T3SC	45.81	0.9979	2.02	42.44	0.9957	2.44	40.39	0.9933	2.85	38.80	0.9904	3.26	41.64	0.9942	2.61
MAC-Net	45.20	0.9974	1.87	42.10	0.9955	2.35	40.09	0.9931	2.79	38.64	0.9905	3.16	41.31	0.9941	2.52
SERT (Ours)	47.72	**0.9988**	**1.36**	**43.56**	**0.9969**	**1.77**	**41.33**	**0.9949**	**2.05**	**39.82**	**0.9929**	**2.30**	**42.82**	**0.9957**	**1.88**

Table 1. Averaged results of different methods under Gaussian noise levels on ICVL dataset. PSNR is in dB.

Experiments

Results on Complex Noise

Method	10			30			50			70			10-70		
	PSNR	SSIM	SAM	PSNR	SSIM	SAM	PSNR	SSIM	SAM	PSNR	SSIM	SAM	PSNR	SSIM	SAM
Noisy	28.13	0.8792	18.72	18.59	0.5523	37.9	14.15	0.3476	49.01	11.23	0.2301	56.45	17.24	0.4782	41.94
BM4D	40.78	0.9930	2.99	37.69	0.9872	5.02	34.96	0.9850	6.81	33.15	0.9554	8.40	36.62	0.9770	5.51
LLRT	46.72	0.9983	1.60	41.12	0.9920	2.52	38.24	0.9830	3.47	36.23	0.9732	4.46	40.06	0.9860	3.24
NGMeet	**47.90**	0.9988	1.39	42.44	0.9816	2.06	39.69	0.9658	2.49	38.05	0.9531	2.83	41.67	0.9937	2.19
HSID-CNN	43.14	0.9918	2.12	40.30	0.9854	3.14	37.72	0.9746	4.27	34.95	0.9521	5.84	39.04	0.9776	3.71
GRNet	45.25	0.9976	1.83	42.09	0.9957	2.18	40.25	0.9936	2.42	38.95	0.9914	2.63	41.44	0.9944	2.27
QRNN3D	45.61	0.9977	1.80	42.18	0.9955	2.21	40.05	0.9929	2.63	38.09	0.9883	3.42	41.34	0.9938	2.42
T3SC	45.81	0.9979	2.02	42.44	0.9957	2.44	40.39	0.9933	2.85	38.80	0.9904	3.26	41.64	0.9942	2.61
MAC-Net	45.20	0.9974	1.87	42.10	0.9955	2.35	40.09	0.9931	2.79	38.64	0.9905	3.16	41.31	0.9941	2.52
SERT (Ours)	47.72	**0.9988**	**1.36**	**43.56**	**0.9969**	**1.77**	**41.33**	**0.9949**	**2.05**	**39.82**	**0.9929**	**2.30**	**42.82**	**0.9957**	**1.88**

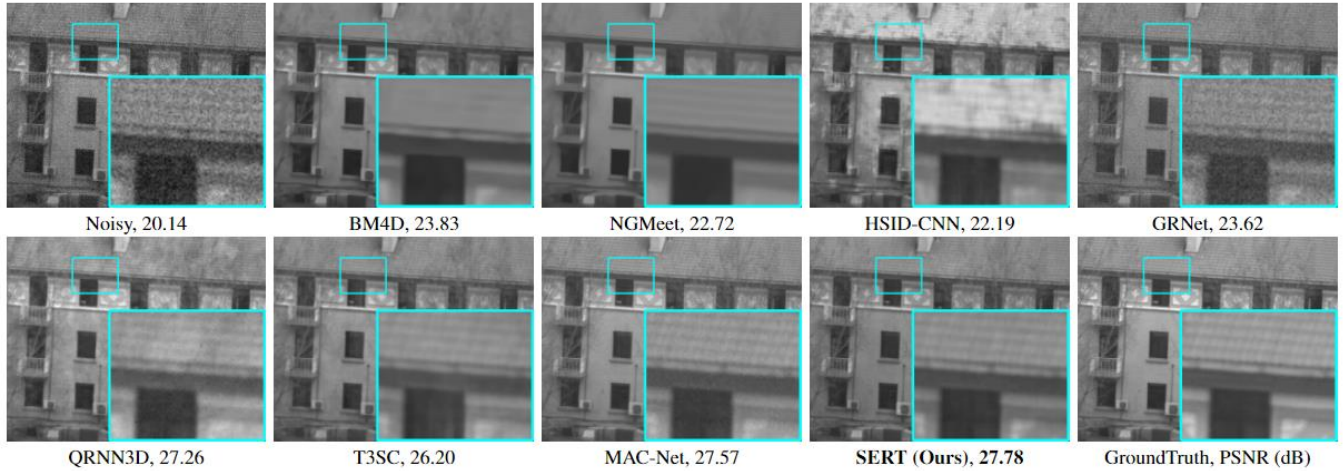
Table 1. Averaged results of different methods under Gaussian noise levels on ICVL dataset. PSNR is in dB.

Experiments

Results on Real Noise

Metric	Noisy	BM4D	LLRT	NGMeet	HSID-CNN	GRNet	QRNN3D	T3SC	MAC-Net	**SERT (Ours)**
PSNR	23.26	29.04	28.26	28.72	26.44	25.33	28.12	28.51	29.20	**29.68**
SSIM	0.7609	0.9471	0.9417	0.9511	0.8992	0.8381	0.9066	0.9323	0.9489	**0.9533**
SAM	17.329	3.087	3.960	2.735	5.242	9.737	5.590	4.408	4.099	**2.536**

Table 3. Average results of different methods on 15 real noisy HSIs. The PSNR is in dB, and best results are in bold.



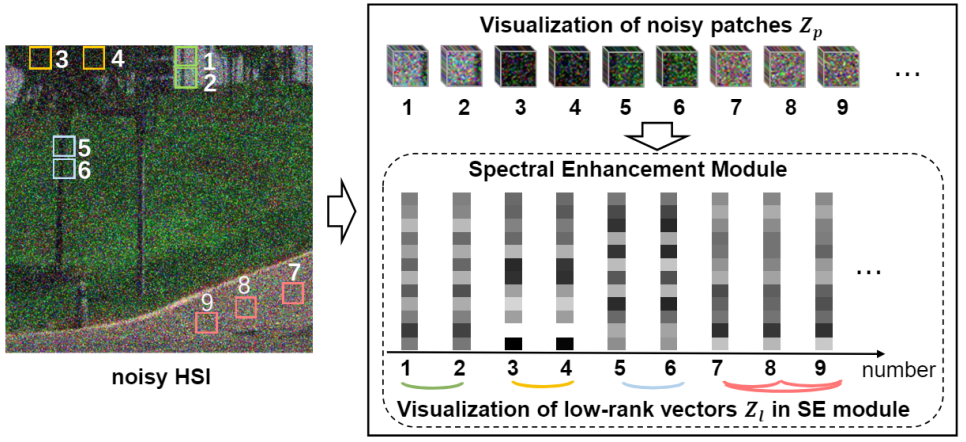
Realistic dataset: Tao Zhang et al. Hyperspectral image denoising with realistic data. In ICCV,2021.

Experiments

Model Complexity

Metric	Synthetic Noise (512×512×31)						Real Noise (512×512×34)					
	HSID-CNN	GRNNet	T3SC	QRNN3D	MAC-Net	**SERT (Ours)**	HSID-CNN	GRNNet	T3SC	QRNN3D	MAC-Net	**SERT (Ours)**
PSNR (dB)	39.04	41.44	41.34	41.64	41.31	42.82	26.439	25.326	26.412	28.396	29.196	29.681
Params (M)	0.40	44.39	0.83	0.83	0.43	1.91	0.40	44.40	0.83	0.83	0.43	1.91
GFLOPS	3249.7	610.7	-	2513.7	-	1018.9	3564.2	611.9	-	2756.9	-	1021.9
Time (s)	1.700	0.361	1.123	0.683	3.627	0.717	1.865	0.407	1.204	0.822	2.992	0.764

Low-rank Module



Conclusion

- We propose a spectral enhanced rectangle Transformer for HSI denoising, which can well exploit both the non-local spatial similarity and global spectral low-rank property of noisy images.
- We present a multi-shape rectangle spatial self-attention module to effectively explore the comprehensive spatial self-similarity in HSI.
- A spectral enhancement module with memory blocks is employed to extract the informative low-rank vectors from HSI cube patches and suppress the noise

Arxiv: http://arxiv.org/abs/2304.00844

Code: https://github.com/MyuLi/SERT

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THANKS