Diffusion-based Thermal Infrared Image Denoising via Latent and Wavelet Domain Optimization

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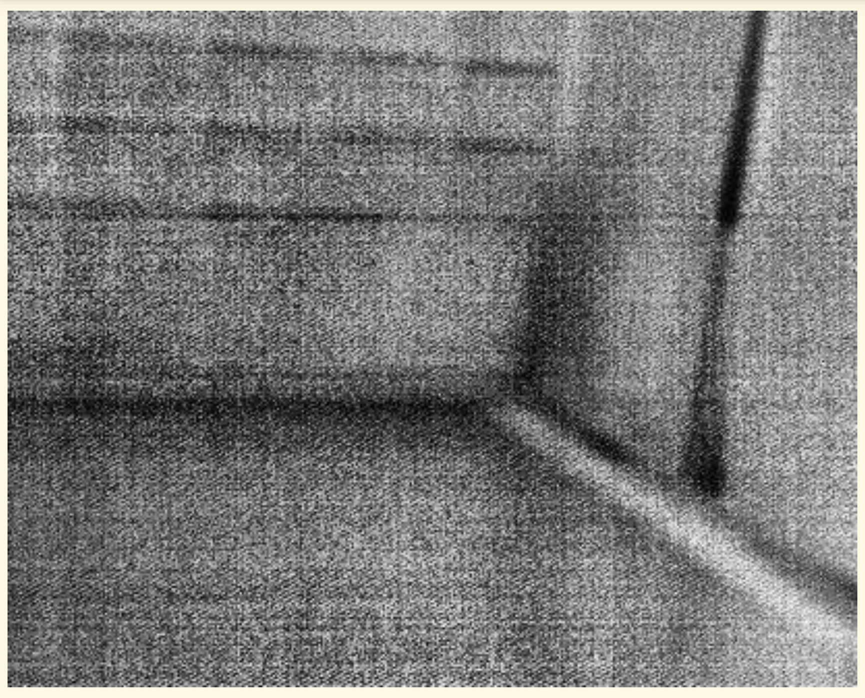
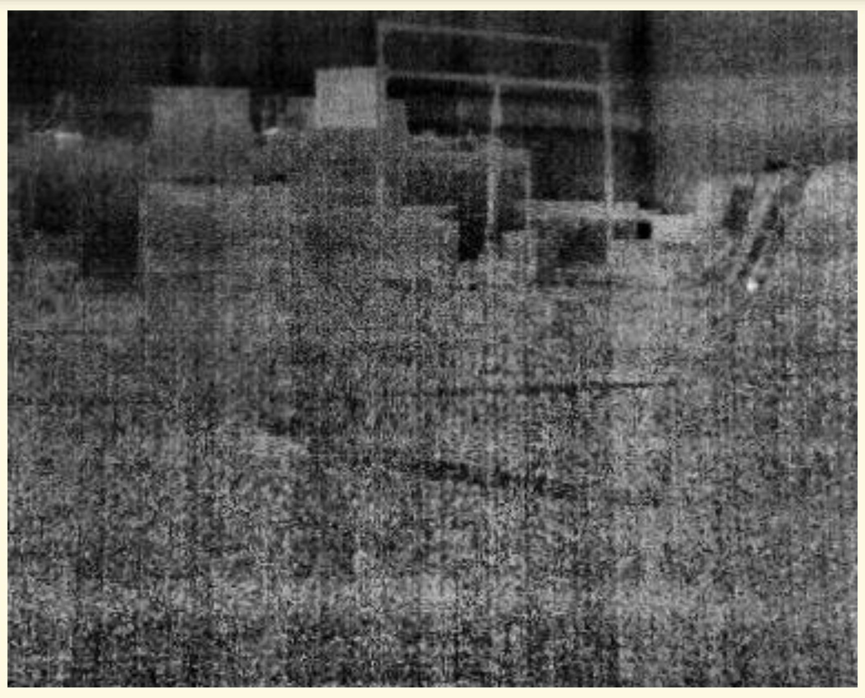
Problem Statement



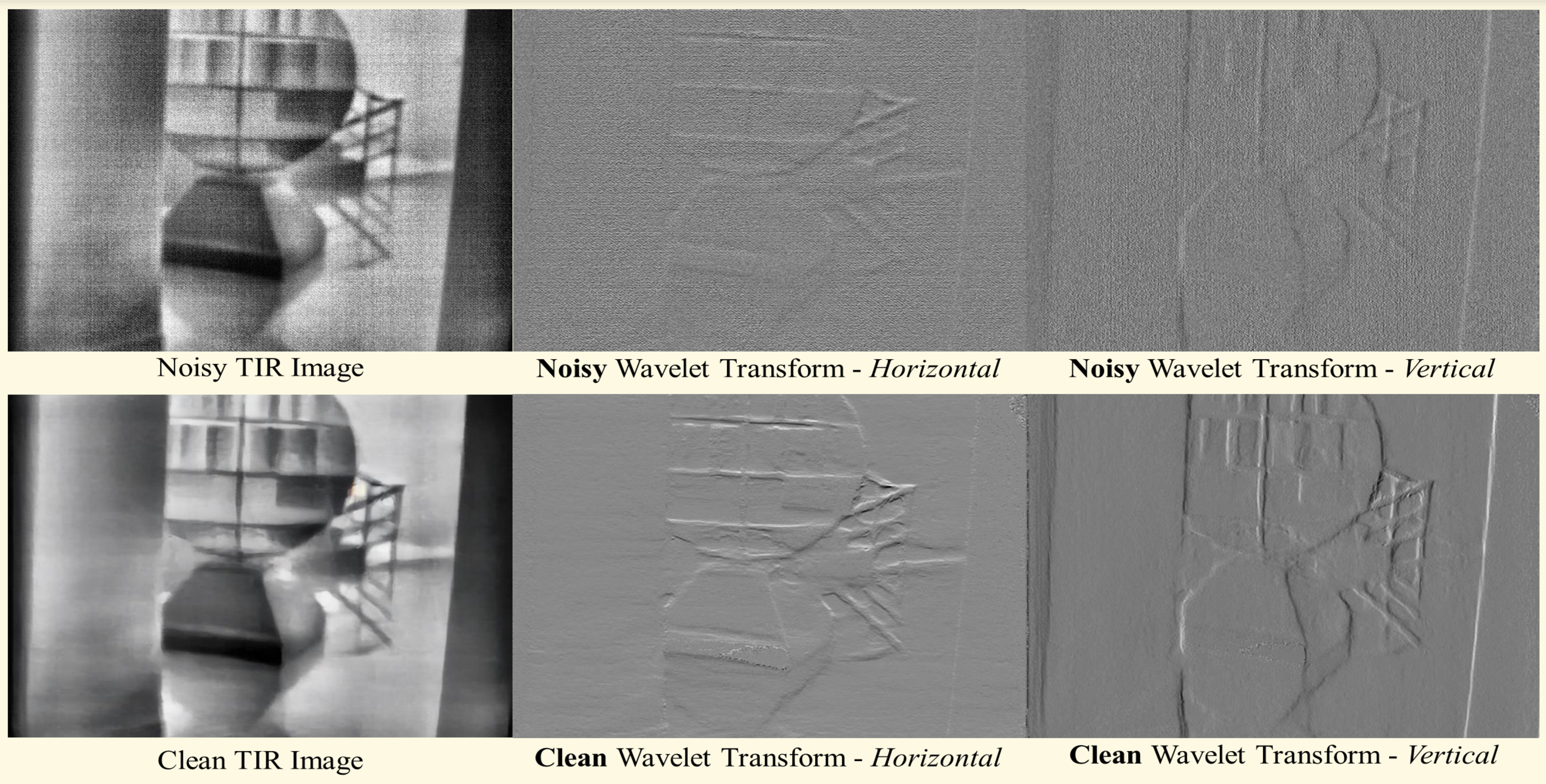
Multispectral Motion Dataset[1]



OdomBeyondVision[2]

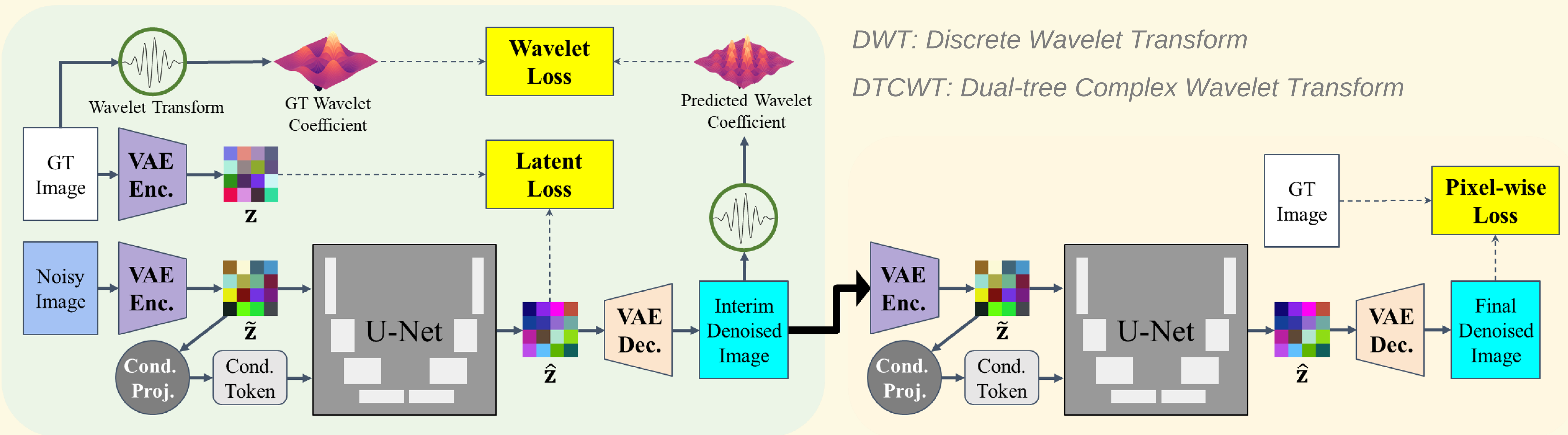
- **Severe non-uniform fixed pattern noise** is present for challenging cases, e.g. indoor sequences
- Causes various complications for downstream tasks

Thermal Imaging in Wavelet Domain



Wavelet transform can effectively separate noise!

Proposed Method



DWT/DTCWT Model

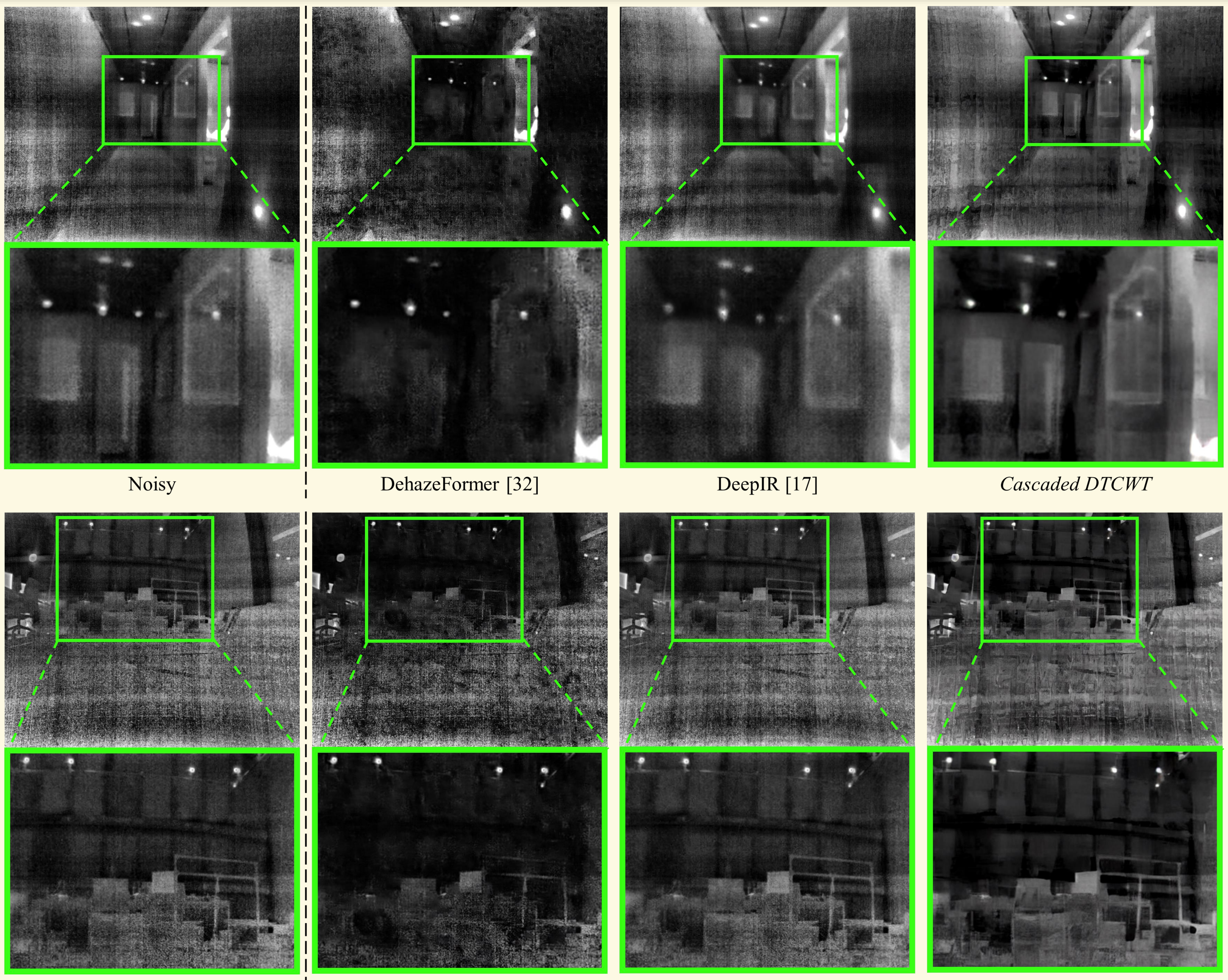
Cascaded Model

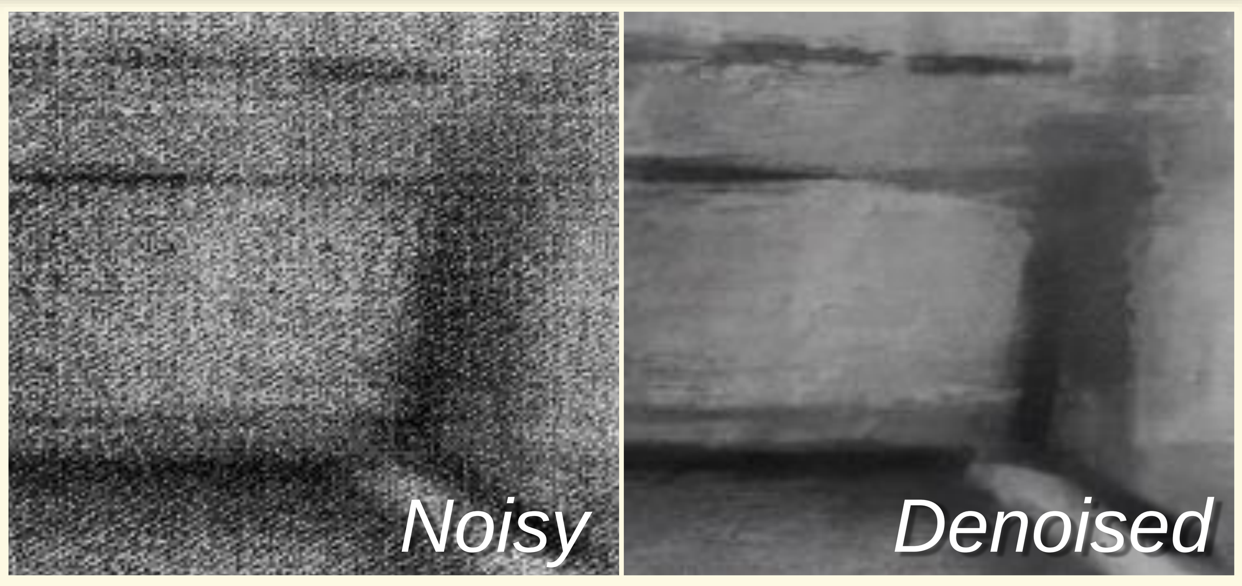
DWT: Discrete Wavelet Transform

DTCWT: Dual-tree Complex Wavelet Transform

- Utilize `Stable Diffusion`, large pretrained diffusion model to **mitigate data scarcity** and **enhance diversity**
- **Fine-tune U-Net** in **Latent + Wavelet domain** for robust denoising
- **Cascade** the identical model tuned on **pixel domain** for enhanced fidelity

Results





- Qualitative **zero-shot results** on indoor sequences[1,2] with heavy fixed pattern noise
- First model to effectively denoise in such challenging conditions

Quantitative Results

Method	PSNR (dB) ↑	SSIM ↑
CLAHE	17.23	0.3205
NB2NB	17.59	0.5552
Cycle-Dehaze	13.77	0.7358
FFDNet	17.61	0.5162
DehazeFormer	18.18	0.5134
U^2D^2Net	23.63	<u>0.7358</u>
Liu et al.	<u>24.53</u>	0.5335
Proposed	**27.97**	**0.8594**

All methods trained using 5570 clean-noisy paired TIR images, provided by Liu et al.[3]

- Ablation Study on various architectures

Model	Loss				Evaluation Metric			
	Pixel	Latent	DWT	DTCWT	PSNR (dB) ↑	SSIM ↑	LPIPS ↓	FID ↓
Pixel-wise Loss	✓				23.65	0.7800	0.1769	69.8716
Latent-Only		✓			26.28	0.8472	0.1767	46.4288
Bior. DWT		✓	✓		26.49	**0.8594**	0.1748	45.7763
DTCWT		✓		✓	**27.97**	0.8382	<u>0.1560</u>	40.4746
Bior. Cascaded	✓	✓	✓		26.32	0.8507	0.1602	<u>38.7875</u>
DTCWT Cascaded	✓	✓		✓	<u>26.53</u>	<u>0.8556</u>	**0.1529**	**38.1301**

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Lab Homepage

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Reference

[1] W. Dai, Y. Zhang, S. Chen, D. Sun, and D. Kong, “A multi-spectral dataset for evaluating motion estimation systems,” inProc. IEEE Intl. Conf. on Robot. and Automat. IEEE, 2021,pp. 5560–5566.

[2] P. Li, K. Cai, M. R. U. Saputra, Z. Dai, and C. X. Lu,“Odombeyondvision: An indoor multi-modal multi-platform odometry dataset beyond the visible spectrum,” in Proc.IEEE/RSJ Intl. Conf. on Intell. Robots and Sys. 2022

[3] G. Liu, J. Xu, Y. Cheng, Y. Su, and B. Yang, “A two-stageapproach for single thermal image restoration,” ElectronicsLetters, vol. 61, no. 1, p. e70111, 2025.