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LensNet: An End-to-End Learning Framework for Empirical Point Spread Function Modeling and Lensless Imaging Reconstruction

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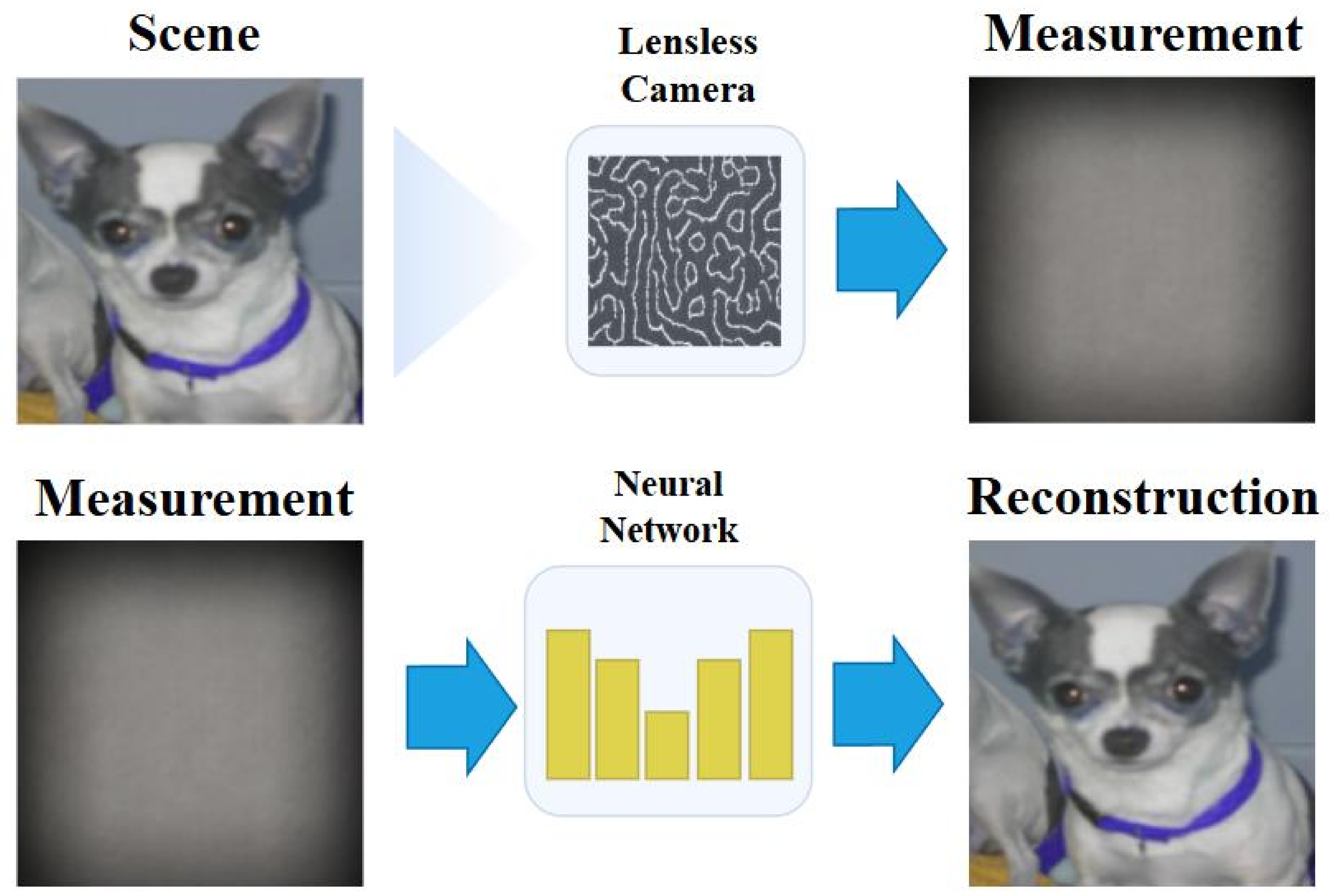
Introduction

❖ **Lensless imaging** avoids the use of lenses altogether and instead uses computational algorithms to reconstruct scenes. **However**,

➢ **Adaptability of the PSF** (Point Spread Function): Traditional methods rely on static or pre-calibrated PSF models, making them difficult to adapt to real-world imaging conditions such as illumination variations, sensor noise, resulting in degraded reconstruction quality.

➢ **High-frequency recovery bottlenecks**: While existing deep learning-based reconstruction methods have made progress, they still suffer from blurring or loss of high-frequency information.



❖ **Our method:** We propose a novel end-to-end deep learning framework (**LensNet**) for lensless imaging that dynamically captures multi-scale features in both spatial and frequency domains, substantially improving the fidelity and accuracy of image reconstructions over conventional methods.

Results

❖ **Dataset**

➢ **DiffuserCam, MWDNs.** Both datasets undergo a standard preprocessing pipeline to ensure consistent input dimensionality, facilitating a robust and fair comparison of lensless imaging strategies.

❖ **Comparison with Other Methods**

Table 1: Performance comparison on two datasets: DiffuserCam and MWDNs. Metrics include PSNR (dB), SSIM, and LPIPS. Best results are highlighted in red and bold.

Method	DiffuserCam			MWDNs		
	PSNR↑	SSIM↑	LPIPS↓	PSNR↑	SSIM↑	LPIPS↓
Wiener [1949]	7.33	0.083	0.770	9.44	0.045	0.731
Vanilla GD	13.27	0.432	0.585	16.70	0.503	0.429
Nesterov GD [1998]	12.16	0.394	0.518	17.06	0.671	0.362
FISTA [2009b]	11.09	0.341	0.554	16.25	0.697	0.368
ADMM [2011]	12.76	0.442	0.541	17.76	0.638	0.343
APGD [2015]	12.13	0.385	0.518	17.34	0.448	0.439
TikNet [2020]	19.75	0.720	0.221	26.57	0.913	0.075
FlatNet [2020]	21.16	0.720	0.231	19.08	0.841	0.178
LenslessGAN [2021]	22.51	0.737	0.193	27.49	0.913	0.077
UDN [2022]	20.00	0.688	0.250	26.98	0.908	0.081
MWDN [2023]	25.74	0.816	0.132	31.74	0.957	0.030
LensNet	**27.46**	**0.863**	**0.099**	**33.22**	**0.960**	**0.024**

❖ **Implementation Study**

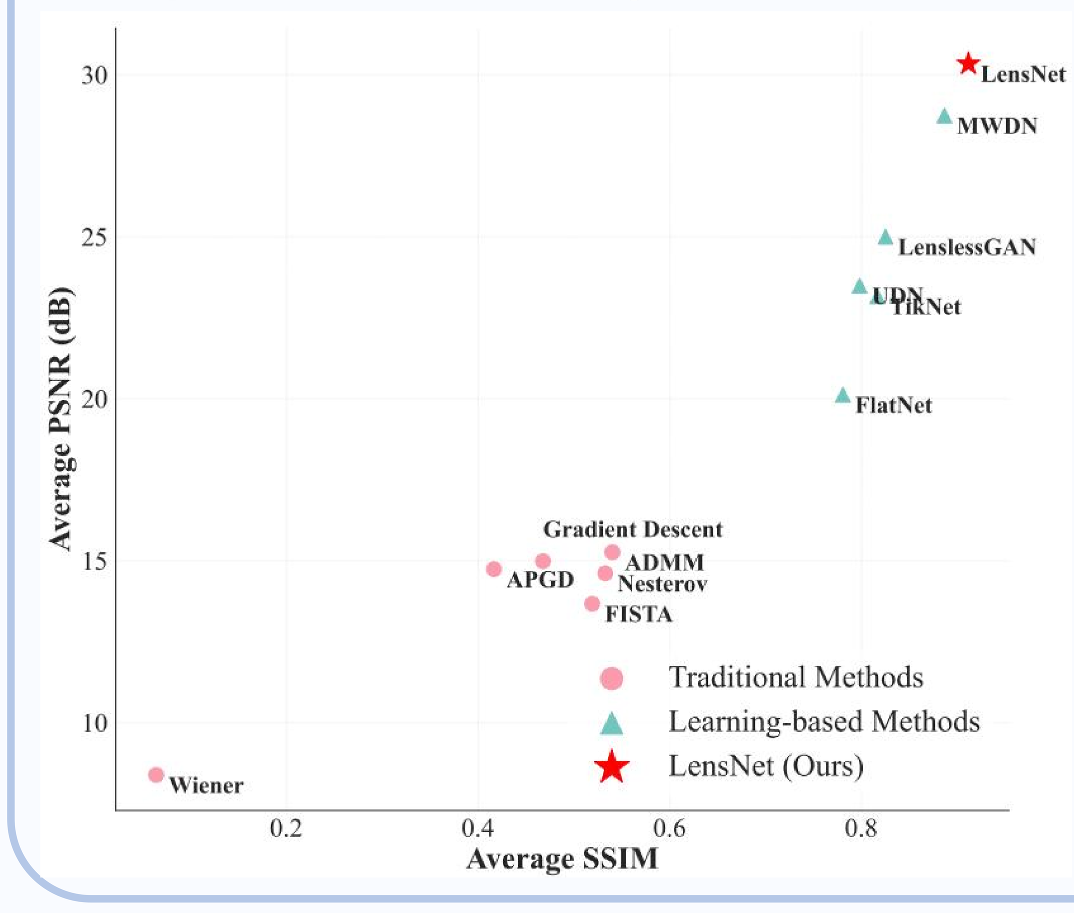


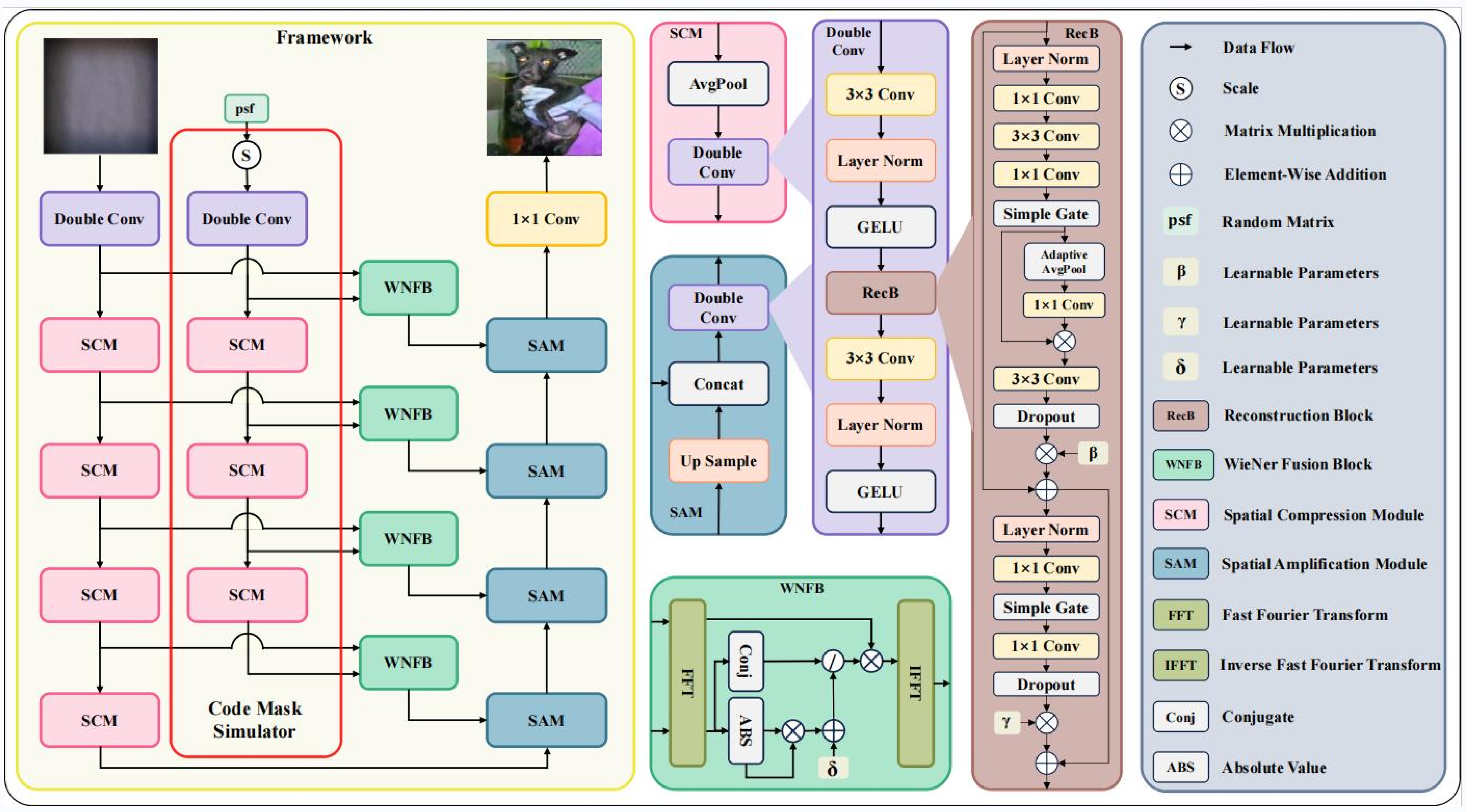
Table 2: Ablation Study on LensNet

Methods	LensNet		
	PSNR↑	SSIM↑	LPIPS↓
ThreeDown	25.68	0.910	0.084
w/o RecB	30.36	0.945	0.044
w original PSF	31.92	0.954	0.031
Ours	**33.22**	**0.960**	**0.024**

Table 4: Comparison of Parameter Count and FLOPs

Method	Params (M)	FLOPs (G)
Ours	31.18	115.10
FlatNet	59.13	220.42
LenslessGAN	11.77	13.82
MWDN	21.96	83.85
TikNet	59.13	220.42
UDN	1.04	2.37

LensNet Framework



❖ **Code Mask Simulator**

The **CMS** captures the intensity distribution features in measurement, which encode the coded mask pattern. Consequently, the system's PSF can be inferred from **these learned mask distributions.**

❖ **Spatial Amplification Module**

The **SAM** could integrate spatial and frequency domain information more comprehensively. Serving as a multi-scale fusion mechanism, the SAM leverages information from both domains to produce high-quality reconstructions, ensuring that critical **spatial details and global consistency** are well-preserved.

Resources

Paper:
https://arxiv.org/pdf/2505.01755
Code:
https://github.com/baijiesong/Lensnet

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Contact

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