One-Pot Multi-Frame Denoising

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Introduction

Motivation

Hard to get clean images in real life

Existing MFD methods: KPN, MKPN, BPN, etc.

N2N is closest to what we want

but

Multi-frame noisy images are available in many scenes

All previous MFD methods are supervised

N2N lacks full utilization of the multiple frames

so

Multi-frame denoising (MFD) is necessary!

Unsupervised MFD is necessary!

One-pot multi-frame denoising (OPD) is necessary!

Contributions

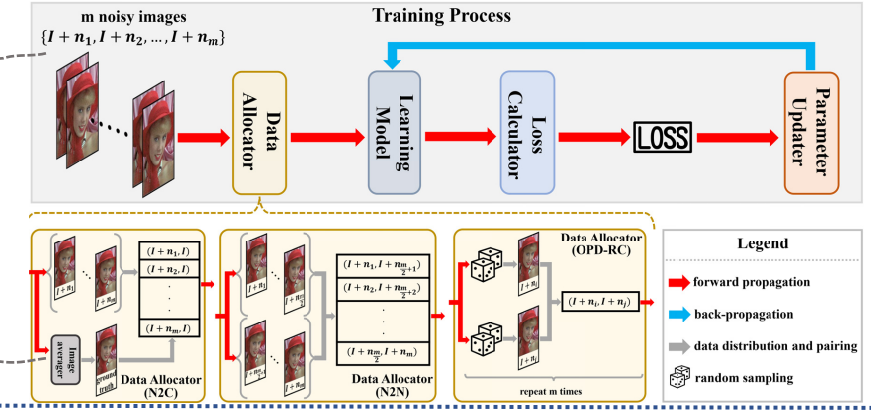
- Propose OPD, **the first unsupervised MFD method** based on an unprecedented mutual supervision paradigm.
- Specifically from the perspectives of data allocation and loss function, **OPD-RC** and **OPD-AL** are presented.
- OPD behaves as **the SOTA unsupervised method** and is **comparable to supervised N2C** methods.

Methods

OPD-RC (Random Coupling)

the common workflow to train a learning-based model

the key difference between OPD-RC and other strategies



OPD-AL (Alienation Loss)

naïve mean square error (MSE), similar to N2N

mean square alienation (MSA), rewarding the inter-frame alienation mined by model training

$$\mathcal{L}_{OPD} = \frac{1}{N_B}\sum_{i=1}^{N_B}\left[(\mathcal{L}^N_{MSE})_i - (\mathcal{L}_{MSA})_i\right],$$

where $(\mathcal{L}^N_{MSE})_i$ and $(\mathcal{L}_{MSA})_i$ are respectively formulated as:

$$(\mathcal{L}^N_{MSE})_i = \frac{1}{m(m-1)}\sum_{j=1}^{m}\sum_{\substack{k=1,\\k\neq j}}^{m}\left\|\boldsymbol{y}_i^j - (\boldsymbol{x}_i + \boldsymbol{n}_i^k)\right\|_2^2$$

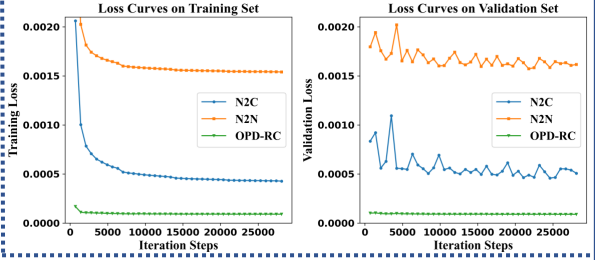
$$(\mathcal{L}_{MSA})_i = \frac{1}{m^2}\sum_{j=1}^{m-1}\sum_{k=j+1}^{m}\left\|\boldsymbol{y}_i^j - \boldsymbol{y}_i^k\right\|_2^2$$

Experiments

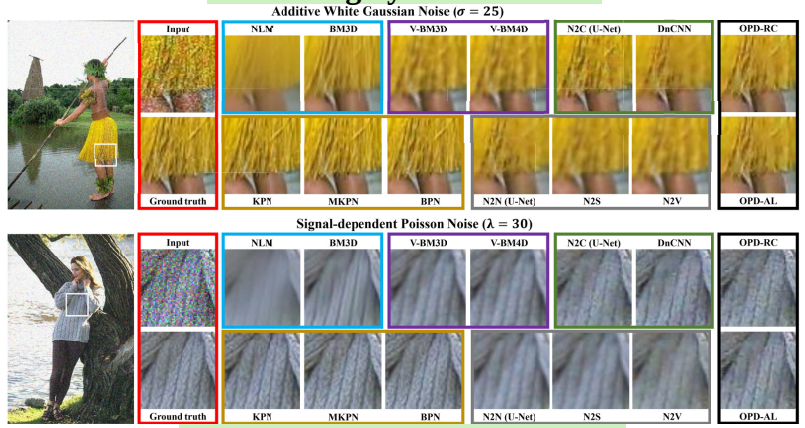
Quantitative Evaluation

Category		Method	Gaussian			Poisson			OCT		
			PSNR	SSIM	RMSE	PSNR	SSIM	RMSE	PSNR	SSIM	RMSE
Input			22.72	0.505	0.074	21.20	0.469	0.088	20.35	0.513	0.096
non-learning	single-image	NLM[5]	24.92	0.670	0.059	24.96	0.676	0.058	26.36	0.600	0.048
		BM3D[9]	25.63	0.774	0.055	23.82	0.684	0.066	26.67	0.612	0.047
	multi-frame	V-BM3D[22]	27.50	0.801	0.051	25.56	0.707	0.062	27.62	0.623	0.044
		V-BM4D[27]	27.86	0.811	0.051	25.79	0.711	0.062	27.87	0.630	0.043
supervised	single-image	N2C	28.04	0.798	0.041	27.92	0.781	0.041	29.79	0.898	0.033
		DnCNN[48]	29.01	0.827	0.036	28.39	0.814	0.039	28.84	**0.871**	0.036
	multi-frame	KPN[31]	32.31	0.917	0.025	32.28	0.916	**0.025**	26.68	0.582	0.047
		MKPN[29]	**32.67**	**0.924**	**0.024**	**32.43**	**0.923**	**0.025**	28.68	0.592	0.037
		BPN[44]	**33.84**	**0.942**	**0.021**	**33.11**	**0.936**	**0.023**	29.00	0.602	0.036
unsupervised	single-image	N2N[26]	27.48	0.787	0.048	27.28	0.775	0.044	28.07	0.817	0.040
		N2S[2]	26.88	0.780	0.049	27.11	0.760	0.045	22.23	0.523	0.089
		N2V[23]	26.29	0.772	0.050	26.95	0.721	0.046	21.90	0.518	0.091
	multi-frame	OPD-RC	**28.15**	**0.805**	**0.040**	**28.22**	**0.789**	**0.040**	**30.69**	**0.900**	**0.029**
		OPD-AL	**28.36**	**0.807**	**0.039**	**28.16**	**0.790**	**0.040**	**30.40**	**0.871**	**0.030**

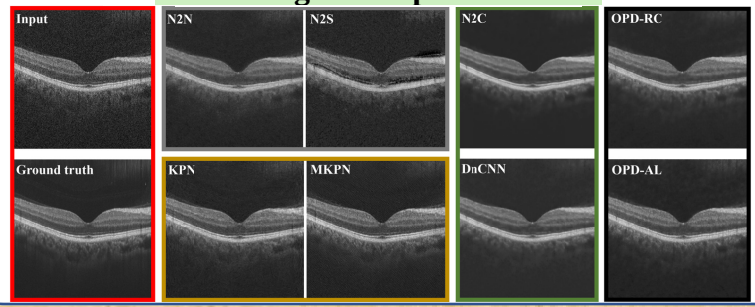
OPD Makes Training More Efficient



Denoising Synthetic Noise



Denoising OCT Speckle Noise



More Frames Bring Better Performance