Structure-Preserving Deraining with Residue Channel Prior Guidance

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https://github.com/Joyies/SPDNet

2021 ICCV OCTOBER 11-17 VIRTUAL

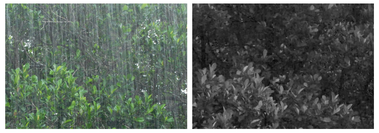
Problem

The current deraining methods are difficult to remove all rain streaks and recover the structural information of images in complex scenarios.

- Most methods predict rain streaks and then subtract rain streaks from rainy images to get the final output. However, the density of rain streaks varies, which leads to excessive or insufficient removal of rain streaks.
- These methods focus on learning the structure of rain streaks, but they pay less attention to learning the structure of objects and ignore the importance of image prior.

Motivation

- Compared with other prior, Residue Channel Prior (RCP) show clear structures even extracted from the rainy image. Moreover, RCP is the residual result of the maximum channel value and minimum channel value of the rainy image, calculated without any additional parameters.



A. Rainy Image B. RCP of A

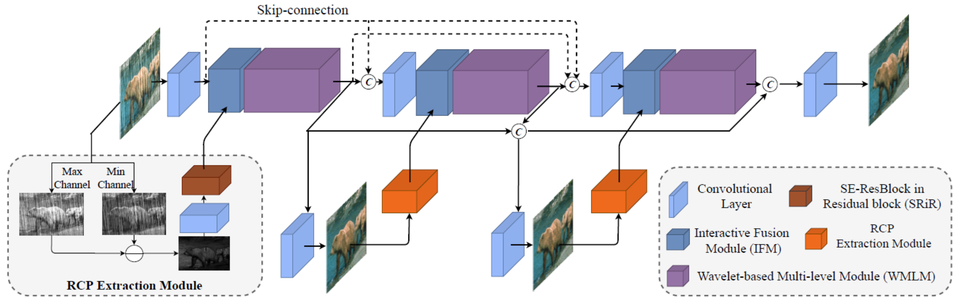
- Compared with deconvolution and down-sampling operation, wavelet transform may be helpful in preserving detailed textures.

Contributions

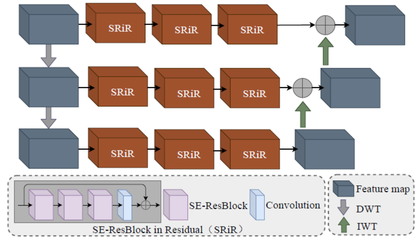
- We explore the importance of residue channel prior (RCP) for rain removal and propose a Structure-Preserving Deraining Network (SPDNet) with RCP guidance. Extensive experimental results show that SPDNet achieves new state-of-the-art results.
- We propose an RCP extraction module and an Interactive Fusion Module (IFM) for RCP extraction and guidance, respectively. Meanwhile, an iterative guidance strategy is designed for progressive image reconstruction.
- We design a Wavelet-based Multi-Level Module (WMLM) as the backbone of SPDNet to learn the background of the area covered by the rain streak.

Method

- The overall architecture of the proposed Structure-Preserving Deraining Network



- Wavelet-based multi-level module

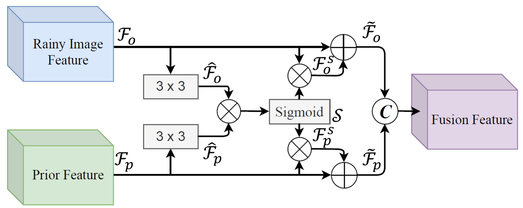


$$\begin{cases}\tilde{\mathcal{F}}_i = \tilde{\mathcal{F}}, & \text{if } i = 0,\\ \tilde{\mathcal{F}}_i = Conv\left(DWT(\tilde{\mathcal{F}}_{i-1})\right), & \text{if } i > 0,\end{cases}$$

$$\tilde{\mathcal{F}}_i^s = SRiR(\tilde{\mathcal{F}}_i), i = 0,1,2.$$

$$\tilde{\mathcal{F}}_{i-1}^s = IWT\left(Conv(\tilde{\mathcal{F}}_i^s)\right) + \tilde{\mathcal{F}}_{i-1}^s, i = 2,1$$

- Interactive Fusion Module



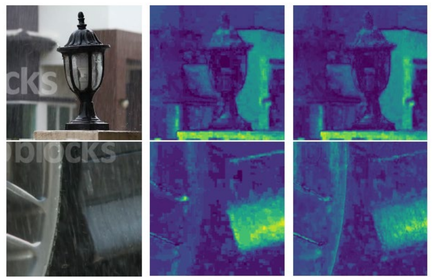
$$\hat{\mathcal{F}}_o = Conv(\mathcal{F}_o) \qquad \mathcal{F}_p^s = \mathcal{S} \otimes \mathcal{F}_p$$

$$\hat{\mathcal{F}}_p = Conv(\mathcal{F}_p) \qquad \tilde{\mathcal{F}}_o = \mathcal{F}_o^s + \mathcal{F}_o$$

$$\mathcal{S} = Sigmoid(\hat{\mathcal{F}}_o \otimes \hat{\mathcal{F}}_p) \qquad \tilde{\mathcal{F}}_p = \mathcal{F}_p^s + \mathcal{F}_p$$

$$\mathcal{F}_o^s = \mathcal{S} \otimes \mathcal{F}_o \qquad \tilde{\mathcal{F}} = Concat(\tilde{\mathcal{F}}_o, \tilde{\mathcal{F}}_p)$$

- Iterative Guidance Strategy



(a) (b) (c)

(a) is rainy images, (b) is the RCP of rainy images, and (c) is the RCP of output results. It is observed that the structure of RCP of output results is more obvious than rainy images. Based on this observation, we propose an iterative guidance strategy to obtain a clearer RCP and replace the RCP of rainy images.

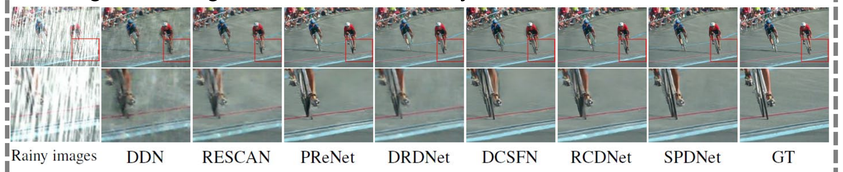
$$\begin{cases}\mathcal{F}_n = WMLM(\hat{\mathcal{F}}_n, \mathcal{P}_n; \theta_n),\\ \mathcal{B}_n = Conv(\mathcal{F}_n),\\ \mathcal{P}_{n+1} = REM(\mathcal{B}_n), & \text{if } n = 1,2.\end{cases}$$

Results

Methods	Param.	Time 128 × 128	Rain200L		Rain200H		Rain800		Rain1200		SPA-Data	
			PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM	PSNR	SSIM
GMM[24]	——	27.961s	28.66	0.8652	14.50	0.4164	25.71	0.8020	25.81	0.8344	34.30	0.9428
DSC[27]	——	7.947s	27.16	0.8663	14.73	0.3815	22.61	0.7530	24.24	0.8279	34.95	0.9416
DDN[8]	0.06M	0.278s	34.68	0.9671	26.05	0.8056	25.87	0.8018	30.97	0.9116	36.16	0.9463
RESCAN[23]	0.15M	0.016s	36.09	0.9697	26.75	0.8353	26.58	0.8726	33.38	0.9417	38.11	0.9707
PReNet[31]	0.17M	0.012s	37.70	0.9842	29.04	0.8991	27.06	0.9026	33.17	0.9481	40.16	0.9816
DCSFN[34]	6.45M	0.253s	39.37	0.9854	29.25	0.9075	28.38	0.9072	34.31	0.9545	——	——
DRDNet[6]	2.72M	0.069s	39.05	0.9862	29.15	0.8921	28.21	0.9012	34.02	0.9515	40.89	0.9784
RCDNet[37]	3.17M	0.068s	39.87	0.9875	30.24	0.9098	28.59	0.9137	34.08	0.9532	41.47	0.9834
SPDNet(Ours)	3.04M	0.055s	**40.59**	**0.9880**	**31.30**	**0.9217**	**30.21**	**0.9152**	**34.57**	**0.9561**	**43.55**	**0.9875**

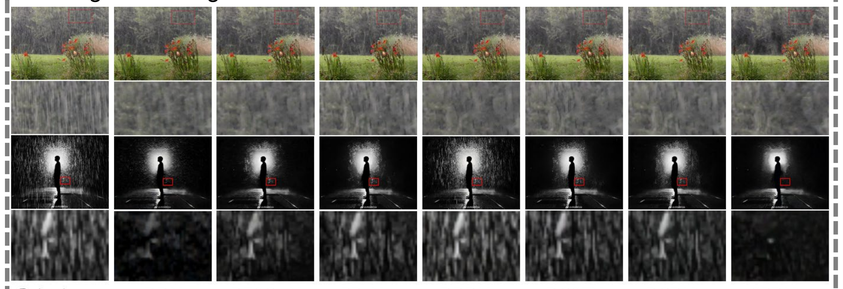
Visual Comparison

- Image deraining results tested on the synthetic datasets.



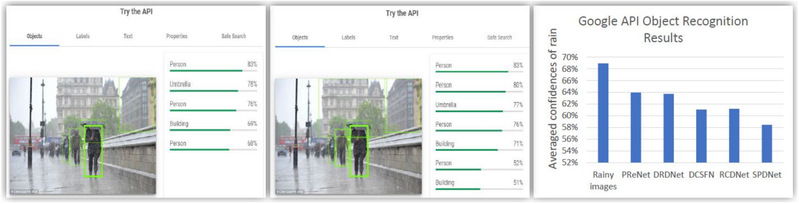
Rainy images DDN RESCAN PReNet DRDNet DCSFN RCDNet SPDNet GT

- Image deraining results tested on the real-world datasets.



Rainy image DDN RESCAN PReNet DRDNet DCSFN RCDNet SPDNet

Application



	Rainy	DRDNet	DCSFN	RCDNet	SPDNet
mAP-50↑	0.551	0.652	0.665	0.658	**0.692**