DnLUT: Ultra-Efficient Color Image Denoising via Channel-Aware Lookup Tables

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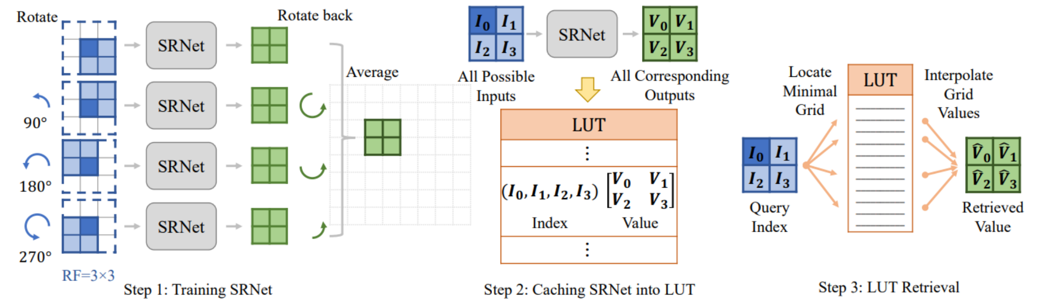
Codes: https://github.com/Stephen0808/DnLUT

Introduction of the LUT-based method

- **Training:** Stacking 2×2 & 1×1 convolutional kernels for **one channel**.
- **Transferring:** Traversing all the possible input and store the results.
- **Inference:** Indexing and interpolating the retrieved values.

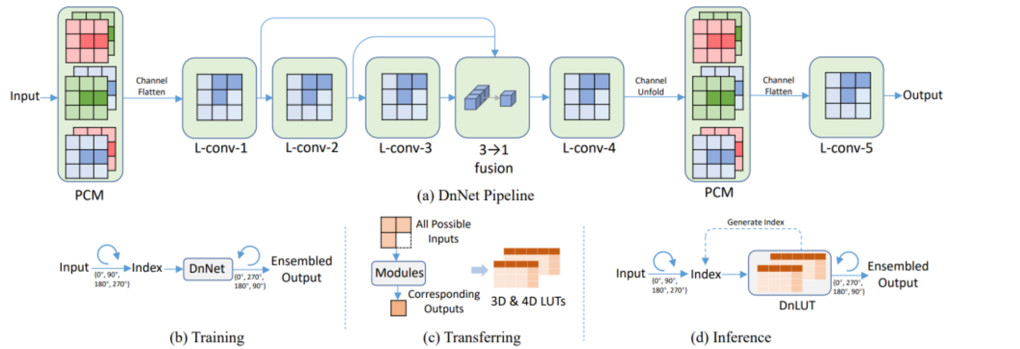


Generalize to multi-channel?

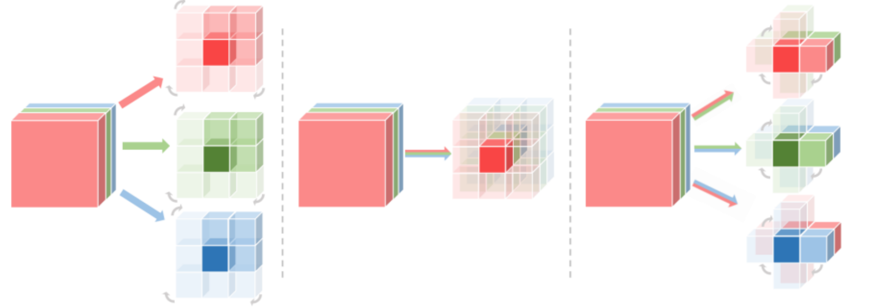
RF	Depth	LUT Dim.	LUT Size*
1×1	1	1D	17 B
1×1	3	3D	4.9 KB
2×2	1	4D	83.5 KB
1×2	3	6D	24.1 MB
2×2	3	12D	582.6 TB
$k \times k$	c	$k \times k \times cD$	$(2^4+1)^{k \times k \times C}$ B

- Spatial-wise kernels are hard to generalize to channel-aware network for their explosive storage.
- When aiming to capture more spatial information, do we have to sacrifice the richness of channel information?

Pipeline for building DnLUT



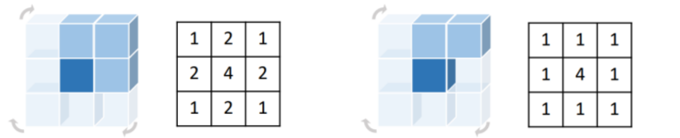
Pairwise Channel Mixer



(a) Spatial-wise (b) Channel-wise (c) Spatial-Channel-wise

- Splitting RGB channels into three pairs: RG, GB, and BR. Processed by 1×2 kernel with depth equals to 2.

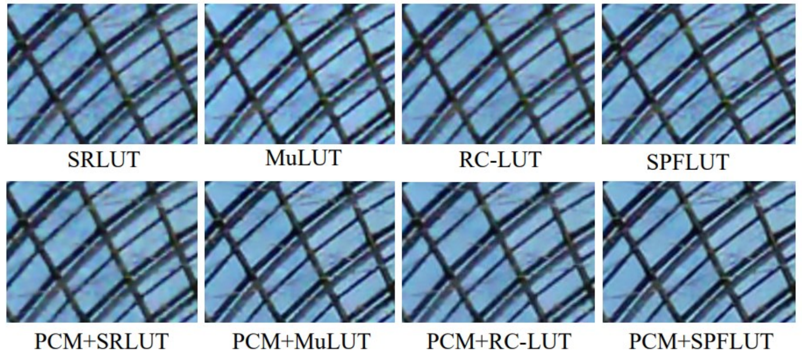
Rotation Non-overlapping Kernel



(a) SR-LUT Kernel (b) DnLUT Kernel (Ours)

- Avoid redundant pixel and reduce ×17 storage.

PCM works for all LUT-based methods



Method	CBSD68	Kodak24	Urban100	McMaster	SIDD
SR-LUT[10]	26.71	27.16	26.04	28.01	29.38
PCM+SR-LUT	28.04(+1.33)	28.55(+1.39)	27.33(+1.29)	28.78(+0.77)	32.33(+2.96)
MuLUT[12]	28.11	29.01	27.67	29.88	33.24
PCM+MuLUT	29.17(+1.05)	29.92(+0.91)	28.74(+1.07)	30.33(+0.44)	34.33(+1.09)
RC-LUT[16]	28.12	29.07	27.80	29.89	33.88
PCM+RC-LUT	29.22(+1.10)	30.09(+1.02)	28.77(+0.97)	30.54(+0.65)	34.67(+0.79)
SPF-LUT[14]	28.56	29.58	28.26	30.44	34.91
PCM+SPF-LUT	29.72(+1.16)	30.63(+1.05)	29.43(+1.17)	30.96(+0.52)	35.56(+0.65)

Real-world Denoising

Datasets	Method	SR-LUT[10]	MuLUT[12]	RC-LUT[16]	SPF-LUT[14]	DnLUT(Ours)	CBM3D[3]	MC-WNNM[24]	DnCNN[30]
SIDD	CPSNR	29.38	33.24	33.88	34.91	35.44	30.14	29.45	36.45
	SSIM	0.634	0.830	0.839	0.865	0.875	0.702	0.682	0.900
DnD	PSNR*	33.69	35.11	35.43	36.22	36.67	33.12	32.34	37.11
	SSIM	0.839	0.868	0.875	0.911	0.922	0.823	0.817	0.932

Efficiency

Category	Method	Platform	Runtime(ms) 256×256	Runtime(ms) 512×512	Energy Cost (pJ)	Storage (KB)
LUT-based	SR-LUT[10]	Mobile	6	19	149.98M	82
	MuLUT[12]	Mobile	21	80	899.88M	489
	RC-LUT[6]	Mobile	18	78	612.92M	326
	SPF-LUT[14]	Mobile	72	257	2.32G	30,178
	DnLUT(ours)	Mobile	23	88	687.34M	518
Classical	CBM3D[29]	PC	3,189	14,343	4.82G	-
	MC-WNNM[24]	PC	74,290	293,424	89.23G	-
DNN	DnCNN[30]	Mobile	543	1,923	542.53G	2,239
	SwinIR[15]	Mobile	73,234	274,453	12.03T	45,499

- 500KB storage, 0.1% energy cost and up to 20× faster inference compared to DnCNN.