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**Picture quality evaluation of
non-local means post filtering
by SSIM**

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NON-LOCAL MEANS (NLM) FILTER

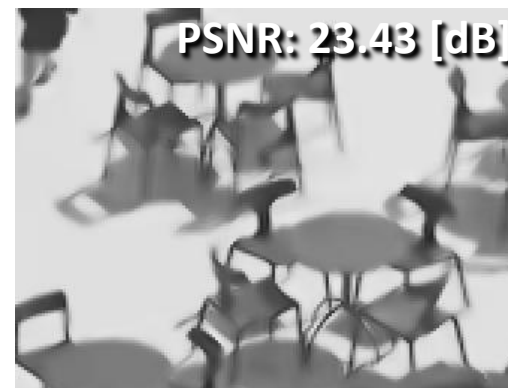
- Suitable for reducing coding artifacts around edges.
 - Improves subjective quality better than PSNR-based RDO.



Decoded picture



Weak NLM filter



Strong NLM filter

← Controlled by single parameter →

- In the experiment,
 - NLM filter is utilized as a **post filter**, and is applied only to luma component.
 - Parameter for filter strength and Quadtree-based filter on/off information are coded.
 - **SSIM-based RDO** is employed.

STRUCTURAL SIMILARITY (SSIM)

- Comparison of 2-D geometrical structure between two pictures (x: original, y: decoded).

- μ : mean intensity
- σ : deviation
- C_1 : $(0.01 \cdot 255)^2$
- C_2 : $(0.03 \cdot 255)^2$

$$\text{SSIM}(\mathbf{x}, \mathbf{y}) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

- Simplified SSIM-based RD-cost minimization.
 - Block by block λ control using variance of original picture.

$$\text{Cost} = \text{SSD} + \lambda \text{Rate}$$

C. Yeo, H. L. Tan, Y. H. Tan, "On Rate Distortion Optimization Using SSIM," in proc. of the IEEE ICASSP-2012, Kyoto, Japan, Mar. 25 - 30, 2012.

OBJECTIVE EVALUATION

			Reference (MainProfile All-Intra)			NLM post filtering				BD-rate (PSNR)	BD-rate (SSIM)
		QP	kbps	Y psnr	SSIM	kbps	Y psnr	SSIM	FltBit/frame	Y	Y
Class A 4K	PeopleOnStreet	22	104595.62	43.24	0.9825	104595.65	43.24	0.9825	1.00	-0.5%	-1.3%
		27	60768.17	39.83	0.9639	60847.34	39.83	0.9641	2639.16		
		32	34760.80	36.72	0.9337	34852.43	36.78	0.9347	3054.52		
		37	20373.29	33.86	0.8966	20460.43	34.00	0.8997	2904.76		
Class B 1080p	Kimono	22	22261.04	42.70	0.9659	22285.29	42.65	0.9660	1010.15	1.2%	-1.8%
		27	12119.17	41.01	0.9546	12155.68	40.95	0.9550	1521.55		
		32	6817.14	38.96	0.9361	6850.46	38.95	0.9371	1388.18		
		37	3795.37	36.51	0.9048	3828.51	36.56	0.9069	1380.79		
Class C WVGA	BasketballDrill	22	20724.66	41.75	0.9692	20730.08	41.75	0.9692	108.55	-0.1%	-1.0%
		27	11201.07	38.37	0.9377	11218.79	38.36	0.9380	354.34		
		32	5982.81	35.41	0.8930	6000.85	35.44	0.8941	360.77		
		37	3302.37	32.78	0.8421	3319.97	32.86	0.8447	352.02		
Class D WQVGA	BQSquare	22	12962.45	41.18	0.9765	12965.20	41.17	0.9766	45.82	-0.3%	-0.5%
		27	8219.97	36.80	0.9420	8224.93	36.81	0.9422	82.53		
		32	5047.25	32.99	0.8935	5052.74	33.03	0.8941	91.46		
		37	2988.97	29.44	0.8388	2994.74	29.50	0.8402	96.12		
Class E 720p	FourPeople	22	30153.57	43.81	0.9790	30186.48	43.76	0.9791	548.46	0.0%	-2.6%
		27	18425.97	41.26	0.9708	18463.14	41.23	0.9712	619.45		
		32	11306.02	38.39	0.9569	11343.52	38.44	0.9581	625.03		
		37	6884.67	35.29	0.9320	6923.28	35.41	0.9348	643.56		
Class F WQVGA	SlideEditing	22	37876.15	46.37	0.9976	37877.00	46.37	0.9976	28.50	-1.9%	-5.1%
		27	28379.30	41.83	0.9950	28393.94	42.16	0.9957	487.89		
		32	21184.69	37.04	0.9880	21200.15	37.40	0.9898	515.37		
		37	15101.99	32.07	0.9681	15118.73	32.47	0.9725	558.07		
	All (24 seq.)									0.0%	-1.1%

CONCLUSION

- Average BD-rate (PSNR) was **0.0 [%]**.
- Average BD-rate (SSIM) was **-1.1 [%]**.
 - Improvements of subjective quality in various regions.
 - Improvements at low-rate (QP: 37) were remarkable.
- SSIM-based RDO might be useful for improving the subjective quality.
- NLM filtering seems to be a promising candidate to be explored.