HEVC Results from MC Noise Reduction of HDR Content

April 2016

1 Introduction

This paper presents the latest comprehensive HEVC results from isovideo's motion-compensated (MC) noise reduction of HDR clips. Significant improvements have been made due to improved motion processing and very rubust noise modelling over the past year. A new feature of Viarte noise reduction provides two settings, one for *distribution* and one for *archive*. The "*archive*" mode is really intended for very high quality processing, and compromises on the side of zealously preserving detail under any circumstances. The "*distribution*" setting attempts to preserve all detail at viewing distances of 1 picture height, while providing as much noise reduction and bitrate/PSNR improvement as possible. Both *distribution* and *archive* settings preserve lower level details better than previously obtained, and gains in HEVC compression are observed for all test sequences over the useful range of CQP settings in the set: 7,12,17,22,27,32,37.

The sources used in this study are professional quality BT2020 PQ40 graded clips available from https://hdr-2014.hdm-stuttgart.de/. Each clip is then:

- i) further rounded to 10-bit PQ40 for HEVC original encoding, and
- ii) noised reduced using 16-bit I/O and 32 bit internal processing, and then rounded to 10-bit PQ40 for HEVC denoise encoding.

The PQ40 OETF (SMPTE ST 2084) preserves up to 4000 nits without saturation. A total of 15 clips were used in this group. Since 4:2:0 and 4:4:4 results are very similar from our previous study, only 4:2:0 is presented for the current HEVC results.

To get a reliable overall estimate of the HEVC gains obtained via MC noise reduction prior to encoding, we first present a parametric plot of *averaged* results, shown in section **3 Table and Figure**. The bitrates and PSNRs are separately averaged over the 15 clips in the set, and for each of the set of CQP values. Then results from a selected few individual clips are shown as well in this short paper. If you are interested in seeing all of the individual tables and figures, they are included in the corresponding **long** paper, which is available upon request.

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The names of the clips used in the averaging are given below. All clips from the 10 scenes in the graded BT2020 PQ40 set are included. They represent a very wide variety of contrasting and challenging lighting conditions.

- Beerfest_lightshow (composite clip: including Beerfest_lightshow_01 to Beerfest_lightshow_09)
- Bistro (composite clip: including Bistro_01 to Bistro_03)
- Car_closeshot, Car_fullshot, Car_longshot
- Carousel_fireworks (composite clip: including Carousel_fireworks_1 to Carousel_fireworks_09)
- Fishing_longshot Fishing_closeshot
- Fireplace (composite clip: including Fireplace_01, Fireplace_02)
- Poker_travelling, Poker_fullshot
- ShowGirl_01, ShowGirl_02
- Smith_Hammering
- Smith_Welding

2 Discussion

Averaged Results of Graded BT2020 PQ40 Clips

The following discussion refers only to averaged results, not individual clips results in the test group. The averaged results should carry more statistical significance in terms of what could be expected in bitrate savings for a given PSNR, or the PSNR gains at a given bit rate, when using MC noise reduction prior to HEVC compression. The details for individual clips are also shown as an example.

As can be seen from the parametric plot in Section 3 below, for a PSNR of **55**dB, average bitrate gains are around **6.5:1** reduction for distribution (red), and over **4:1** for archive (yellow). At **50**dB, the bitrate gains increase to around **8:1** for distribution, and around **6:1** for archive. At a PSNR of 45dB, they reduce again to a 4:1 gain.

Considering bitrates, the PSNR improves by 6dB or more above 5Mbps, rising to 8dB at over 20Mbps. The PSNR gain at 3Mbps is about 5dB for distribution and 4dB for archive; even at the lowest quality level tested, the PSNR gain is still 1.5dB. These results show considerable improvement, particularly at the high quality end, over what may be expected from the next generation of encoder following HEVC.

Furthermore, an average improvement of around a 20-30% in HEVC encoding speed is observed, and up to 100% speedup has been found for very noisy sequences. The noise reduction is implemented on

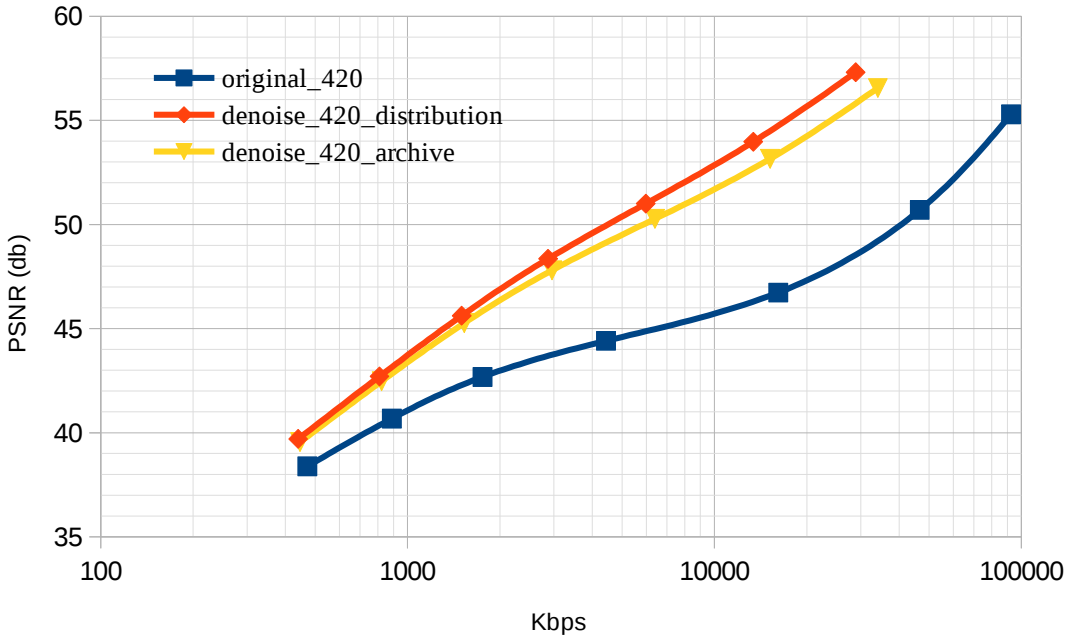
GPUs and can easily exceed the HEVC encoding throughput on a 6-dual-core CPU for presets “medium” through “veryslow”, allowing a genuine increase in throughput for most encoding situations.

3 Detailed Results of Averaged HDR Clips

3 Table & Figure Average (15 clips) of 12-bit Graded BT2020 PQ40 CQP 420 10-bit x265 (veryslow)

CQP	Original Kbps	Original Y-PSNR	Distribution Kbps	Distribution Y-PSNR	Archive Kbps	Archive Y-PSNR
7	92596.63	55.29	28848.08	57.31	34066.2	56.55
12	46664.58	50.7	13381.01	53.97	15167.37	53.15
17	16146	46.73	5972.95	51	6400.37	50.27
22	4430.82	44.41	2867.76	48.35	2958.17	47.8
27	1754.59	42.68	1500.57	45.62	1529.23	45.26
32	889.27	40.68	809.78	42.7	822.88	42.47
37	471.51	38.39	440.09	39.7	446.36	39.55

Average of 15 Graded Clips PQ40 BT2020 CQP 420 10-bit x265 (veryslow)

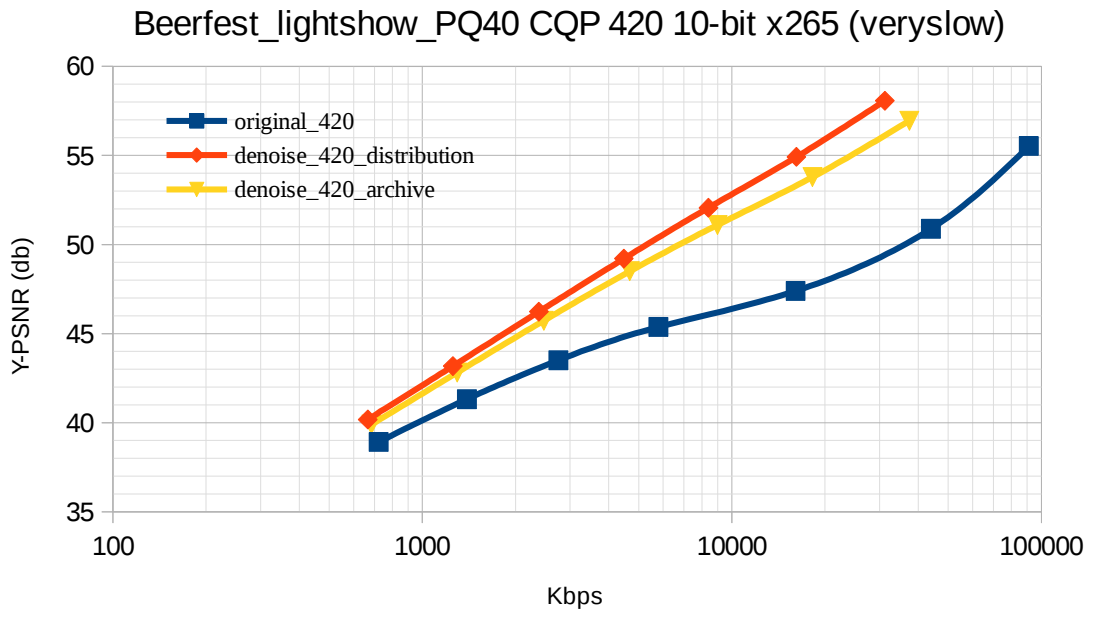


4 Detailed Results from Selected Individual Graded PQ40 BT2020 Clips

4.1 Table & Figure Beerfest_lightshow 16-bit PQ40 CQP 420 10-bit x265 (veryslow)

CQP 420		Original					Denoised	Distribution			
Beerfest_lightshow	CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
	7	91186.96	55.527	54.521	54.099	55.223	31210.19	58.07	56.779	56.349	57.693
	12	43976.06	50.875	51.25	50.621	50.89	16169.61	54.918	54.032	53.572	54.639
	17	16067.79	47.392	48.967	48.426	47.718	8401.95	52.061	51.523	51.069	51.87
	22	5791.86	45.371	46.997	46.543	45.721	4478.23	49.208	48.999	48.549	49.1
	27	2751.07	43.502	44.914	44.512	43.805	2378.61	46.23	46.357	45.961	46.212
	32	1391.76	41.318	43.008	42.671	41.698	1254.13	43.177	44.104	43.759	43.366
	37	721.78	38.915	41.585	41.299	39.546	666.32	40.181	42.467	42.172	40.716

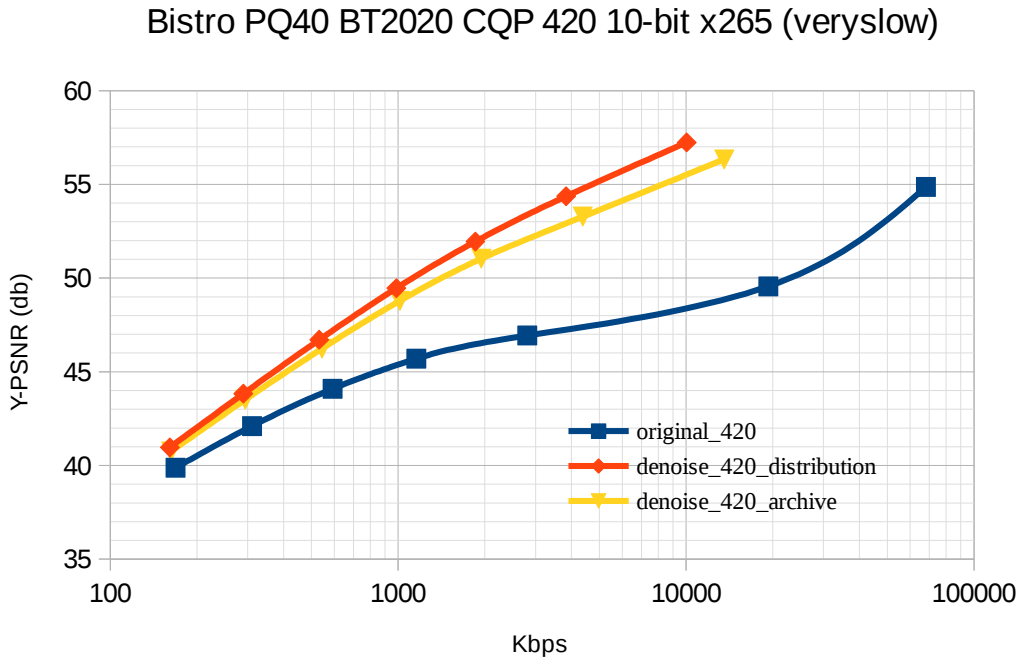
CQP 420		Original					Denoised	Archive			
Beerfest_lightshow	CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
	7	91186.96	55.527	54.521	54.099	55.223	37482.73	56.944	56.042	55.583	56.661
	12	43976.06	50.875	51.25	50.621	50.89	18221.87	53.785	53.34	52.875	53.615
	17	16067.79	47.392	48.967	48.426	47.718	8988.53	51.097	50.974	50.529	51.01
	22	5791.86	45.371	46.997	46.543	45.721	4681.85	48.496	48.594	48.15	48.465
	27	2751.07	43.502	44.914	44.512	43.805	2466.56	45.724	46.056	45.659	45.758
	32	1391.76	41.318	43.008	42.671	41.698	1294.9	42.814	43.847	43.524	43.032
	37	721.78	38.915	41.585	41.299	39.546	684.63	39.894	42.234	41.961	40.445



4.2 Table & Figure **Bistro** 16-bit PQ40 BT2020 CQP 420 10-bit x265 (veryslow)

CQP 420		Original					Denoised	Distribution			
Bistro_pq40	CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
	7	68103.41	54.865	53.897	54.104	54.649	10047.93	57.233	57.136	57.191	57.216
	12	19291.4	49.557	51.382	51.501	50.028	3833.01	54.364	55.548	55.555	54.661
	17	2809.15	46.932	50.432	50.513	47.817	1853.98	51.946	53.819	53.78	52.41
	22	1156.43	45.697	49.334	49.369	46.611	985.29	49.456	51.76	51.673	50.021
	27	591.7	44.086	47.817	47.822	45.019	531.86	46.702	49.423	49.363	47.375
	32	310.94	42.102	46.164	46.109	43.111	289.87	43.828	47.201	47.141	44.664
	37	168.59	39.877	44.858	44.822	41.118	161.03	40.96	45.54	45.508	42.101

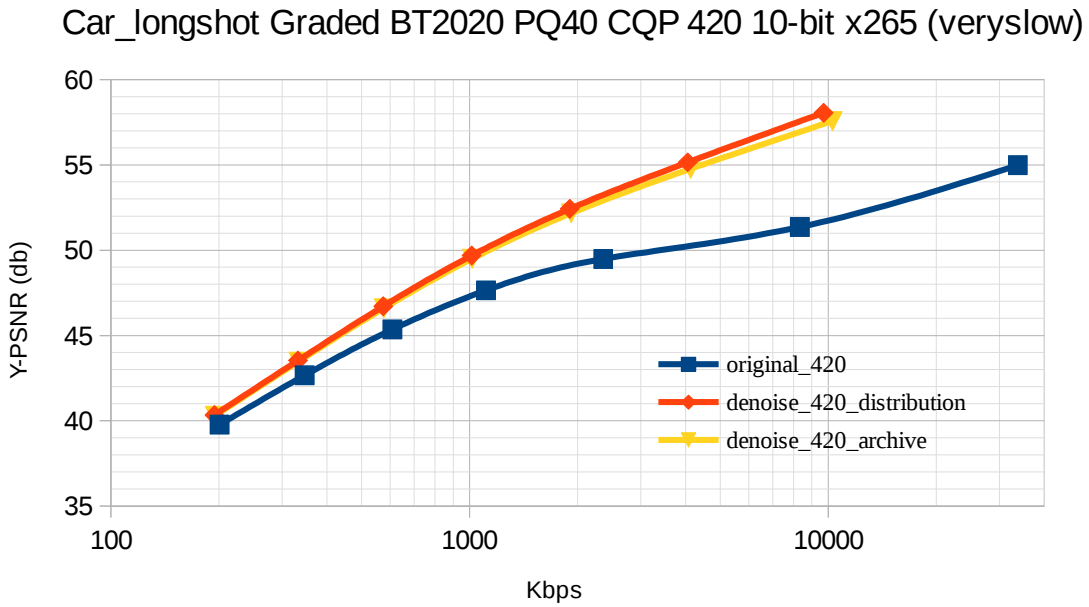
CQP 420		Original					Denoised	Archive			
Bistro_pq40	CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
	7	68103.41	54.865	53.897	54.104	54.649	13574.49	56.334	56.226	56.292	56.315
	12	19291.4	49.557	51.382	51.501	50.028	4377.18	53.276	54.675	54.697	53.629
	17	2809.15	46.932	50.432	50.513	47.817	1943.5	51.032	53.157	53.14	51.561
	22	1156.43	45.697	49.334	49.369	46.611	1013.44	48.781	51.301	51.233	49.403
	27	591.7	44.086	47.817	47.822	45.019	543.6	46.233	49.101	49.037	46.942
	32	310.94	42.102	46.164	46.109	43.111	294.18	43.507	47.025	46.93	44.375
	37	168.59	39.877	44.858	44.822	41.118	162.73	40.753	45.423	45.398	41.917



4.3 Table & Figure Car_longshot 16-bit PQ40 BT2020 CQP 420 10-bit x265 (veryslow)

CQP 420		Original					Denoised	Distribution			
Car_longshot	CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
	7	33782.05	54.984	58.237	57.614	55.719	9708.65	58.054	60.741	60.237	58.663
	12	8334.64	51.36	56.674	55.969	52.601	4053.25	55.148	58.665	58.13	55.96
	17	2357.27	49.486	54.922	54.24	50.759	1902.37	52.425	56.269	55.752	53.321
	22	1110.19	47.646	52.962	52.412	48.906	1013.16	49.688	53.847	53.438	50.677
	27	609.27	45.359	50.716	50.454	46.666	574.17	46.712	51.276	51.139	47.836
	32	346.82	42.664	48.478	48.52	44.123	332.12	43.535	48.806	48.977	44.874
	37	200.81	39.777	46.591	46.969	41.528	194.22	40.337	46.84	47.274	42.017

CQP 420		Original					Denoised	Archive			
Car_longshot	CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
	7	33782.05	54.984	58.237	57.614	55.719	10278.48	57.565	60.538	60.01	58.242
	12	8334.64	51.36	56.674	55.969	52.601	4137.47	54.772	58.529	57.978	55.642
	17	2357.27	49.486	54.922	54.24	50.759	1918.46	52.163	56.201	55.667	53.106
	22	1110.19	47.646	52.962	52.412	48.906	1016.57	49.502	53.773	53.378	50.52
	27	609.27	45.359	50.716	50.454	46.666	576.12	46.596	51.248	51.126	47.744
	32	346.82	42.664	48.478	48.52	44.123	333.12	43.468	48.74	48.972	44.815
	37	200.81	39.777	46.591	46.969	41.528	194.85	40.298	46.875	47.282	41.993



4.4 Table & Figure Fireplace 16-bit PQ40 BT2020 CQP 420 10-bit x265 (veryslow)

CQP 420	Original					Denoised	Distribution			
Fireplace_grad CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
7	110325.65	55.091	53.892	53.508	54.744	31324.91	57	55.637	55.599	56.654
12	55617.54	50.452	49.548	49.222	50.185	14435.52	53.697	52.852	53.202	53.529
17	16652.41	45.766	46.979	47.31	46.111	6720.92	50.868	50.715	51.304	50.904
22	4646.75	43.765	45.597	46.161	44.294	3492.45	48.377	48.733	49.285	48.535
27	2220.67	42.327	44.269	44.813	42.88	1936.42	45.703	46.591	47.079	45.986
32	1213.61	40.481	42.891	43.385	41.145	1095.51	42.75	44.698	45.024	43.278
37	670.28	38.221	41.852	42.245	39.178	616.97	39.68	43.296	43.482	40.608

CQP 420	Original					Denoised	Archive			
Fireplace_grad CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
7	110325.65	55.091	53.892	53.508	54.744	39373.86	56.148	55.064	54.901	55.857
12	55617.54	50.452	49.548	49.222	50.185	17129.87	52.711	52.137	52.428	52.604
17	16652.41	45.766	46.979	47.31	46.111	7301.46	49.916	50.075	50.669	50.03
22	4646.75	43.765	45.597	46.161	44.294	3627.01	47.642	48.252	48.832	47.867
27	2220.67	42.327	44.269	44.813	42.88	1987.56	45.185	46.286	46.75	45.518
32	1213.61	40.481	42.891	43.385	41.145	1118.66	42.402	44.423	44.779	42.952
37	670.28	38.221	41.852	42.245	39.178	628	39.442	43.054	43.311	40.377

4.5 Table & Figure Smith_Welding 16-bit PQ40 BT2020 CQP 420 10-bit x265 (veryslow)

Smith_Welding CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
7	157803.73	54.957	53.878	53.855	54.684	46398.19	56.152	54.26	54.024	55.65
12	96538.07	50.856	48.179	48.023	50.167	19087.52	52.484	51.319	50.621	52.106
17	34069.39	44.312	45.07	44.124	44.383	6690.26	49.363	49.639	48.813	49.329
22	5069.18	41.096	44.195	43.21	41.748	2460.96	47.167	48.099	47.436	47.317
27	1426.3	40.291	43.257	42.405	40.926	1180.03	45.263	46.256	45.746	45.447
32	718.19	39.336	42.145	41.419	39.947	634.78	42.987	44.373	43.945	43.28
37	392.04	37.915	41.208	40.54	38.654	354.65	40.399	42.919	42.497	40.976

CQP 420	Original					Denoised	Archive			
Smith_Welding CQP	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined	Kbps	Y-PSNR	Cb-PSNR	Cr-PSNR	Combined
7	157803.73	54.957	53.878	53.855	54.684	58098.4	55.584	53.834	53.695	55.129
12	96538.07	50.856	48.179	48.023	50.167	23698.44	51.646	50.62	49.943	51.305
17	34069.39	44.312	45.07	44.124	44.383	7787.8	48.396	49.018	48.125	48.44
22	5069.18	41.096	44.195	43.21	41.748	2625.27	46.32	47.622	46.883	46.553
27	1426.3	40.291	43.257	42.405	40.926	1227.36	44.644	45.89	45.332	44.886
32	718.19	39.336	42.145	41.419	39.947	658.14	42.572	44.12	43.65	42.9
37	392.04	37.915	41.208	40.54	38.654	367.5	40.127	42.713	42.267	40.717

5 Conclusion

For denoised archive purposes, it is best to process in the 4:4:4 domain for 4:4:4 sources, as color is better preserved, in particularly for the “beerfest” clip which contains many bright colored dots. Viarte noise reduction has been tested with hundreds of hours of material (a majority of SDR content, with some HDR), and has been found effective across a wide variety of noise conditions, including removing:

- film grain
- shot noise,
- residual interlace artifacts
- blocking artifacts.

Furthermore, it works well with any type of lossy or lossless compression, not specifically HEVC.

Accurate true-motion-based NR can be much better at distinguishing features and noise than that achievable in a regular encoder, without adding extreme complexity to the encoding process. As a result, a large PSNR gains at a given bitrate or substantial bitrate reduction for a given PSNR is achivable, while preserving subtle details based on expert viewing. Furthermore, GPUs can be used with separate denoise to achieve higher throughput in a pipeline. AWS and other cloud providers are already supporting GPU instances, allowing much higher throughput.

Benefits and Applications of MC Noise Reduction:

- Reduced storage or network bandwidth for studio archives, with much improved downstream workflow efficiency,
- Significantly lower bit-rates with any lossy encoder in soft realtime IP contribution applications,
- Increased effective capacity for Blu-ray, or portable storage devices,
- High quality OTT distribution of HDR or SDR, particularly for PQ encoded sources,
- Digital remastering of SD to HD, or HD to UHD, particularly where edge-preserving sharpening scaling would otherwise magnify noise,
- Reducing noise to prevent perturbations in digital remastering from SDR to HDR, which further reduces noise visibility in HDR displays, thereby increasing immersiveness.

Note that all noised reduced clips can be viewed at isovideo NAB 2016 exhibition booth #**SU14608**. Please contact isovideo if you are interested further exporation or incorporation NR for your workflow.