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# MainConcept HEVC Hybrid GPU Acceleration Modes for NVIDIA NVENC

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## INTRODUCTION

Modern encoders are complex products. Usually, they contain more components than those required or described in encoding standards or implemented in reference encoders. Implementation of these components is vendor-specific and can have a significant impact on the overall quality of the product. The most common example of such a component is Rate Control.

Rate Control is a complex component by itself. Rate Control is responsible for not only keeping to the target bit rate but also for ensuring bit distribution across a stream to smoothen the drops in quality and improve the overall quality at the same bit rate. To redistribute bits, Rate Control needs to know the type, complexity and other parameters of the upcoming frames. The more it knows about these frames – the more efficiently bits can be redistributed.

Another custom component is Preliminary Analysis, which

processes each incoming frame and determines a coding scheme for it. The coding scheme defines a set of coding tools for optimal performance and quality. Preliminary Analysis estimates the number of bits per frame for Rate Control. Mistakes in determining the coding scheme or number of bits may cause significant drops in quality during encoding. Therefore, a deep preliminary analysis is an important part of encoders. A typical component relationship is shown in Figure 1.



FIG. 1: A typical encoder diagram



**NVIDIA has supported HEVC encoding on its graphics processor (NVENC HEVC), since the second generation of the Maxwell architecture. Well-known advantages of NVENC include:**

- It provides good subjective quality for mid-complexity sequences.
- It is fast, producing more than 100 frames per second at 4K resolution.
- It is an energy-efficient way to encode HEVC compliant streams.
- It offloads CPU from computing-intensive encoding tasks and allows users to run other tasks more efficiently.



**However, NVENC is not widely used for broadcast OTT encoding due to several reasons:**

- Analysis and Rate Control are not good enough to use in the professional market, especially for low bit rates. The main concerns of customers are noticeable local drops in quality, pulsing quality on film-grain content and low bit rate accuracy.
- It does not support popular options like Constant Rate Factor (CRF), two-pass encoding, Hypothetical Reference Decoder model (HRD), etc.

For HEVC SDK 11, MainConcept introduced “Driven” and “Hybrid” acceleration modes in addition to the existing “Full” mode for NVENC acceleration encoding. These three acceleration modes become available when an NVIDIA video card is installed in a user’s PC or server. Full acceleration mode wraps NVIDIA’s NVENC into common MainConcept API and offloads the complete processing to the hardware. This feature allows for the best encoding speed, however the hardware encoder lacks some features which may result in lower visual quality on complex video content.

Driven and Hybrid acceleration modes combine the features of the MainConcept software encoder with the performance of NVENC. The Driven mode uses MainConcept Analysis and MainConcept Rate Control but NVENC as the HEVC coder, as shown in Figure 2. Since all encoding is done by NVENC, the encoder performance remains almost independent of the CPU. Driven mode is thus a good choice for an average power PC. Because NVENC only supports two performance levels (High Performance – HP and High Quality – HQ), the more fine-grained performance adjustments normally possible via the MainConcept Performance API are not possible in Driven mode.

In Hybrid mode, the MainConcept HEVC and NVIDIA NVENC coders are used simultaneously, as shown in Figure 3. In this mode, the encoder delegates some of the work to NVENC. NVENC operates at the HQ performance level, while the performance of the MainConcept Coder can be smoothly adjusted using the Performance API. Since the coders run simultaneously, Hybrid can be faster than Driven mode for low performance levels (0-8). However, it is not recommended to use these levels due to possible pulsing of quality between frames encoded by different coders. Because of the intense computations of the MainConcept Coder, Hybrid mode has a higher CPU load and is more sensitive to CPU performance than Driven mode. This mode is recommended for high-end PCs and servers.



FIG. 2: Driven mode diagram

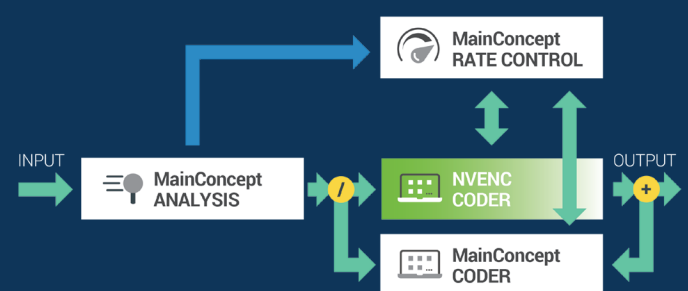


FIG. 3: Hybrid mode diagram

# PERFORMANCE EVALUATION

The pack of 4K video sequences from the MSU “HEVC Video Codecs Comparison 2018” was used for the performance evaluation of the pure software encoder, Full mode with its default limit of 5 B-pictures, Driven and Hybrid modes. The speed vs. quality trade-off plot for the “Egypt” clip (15 Mbps) is shown in Figure 4.

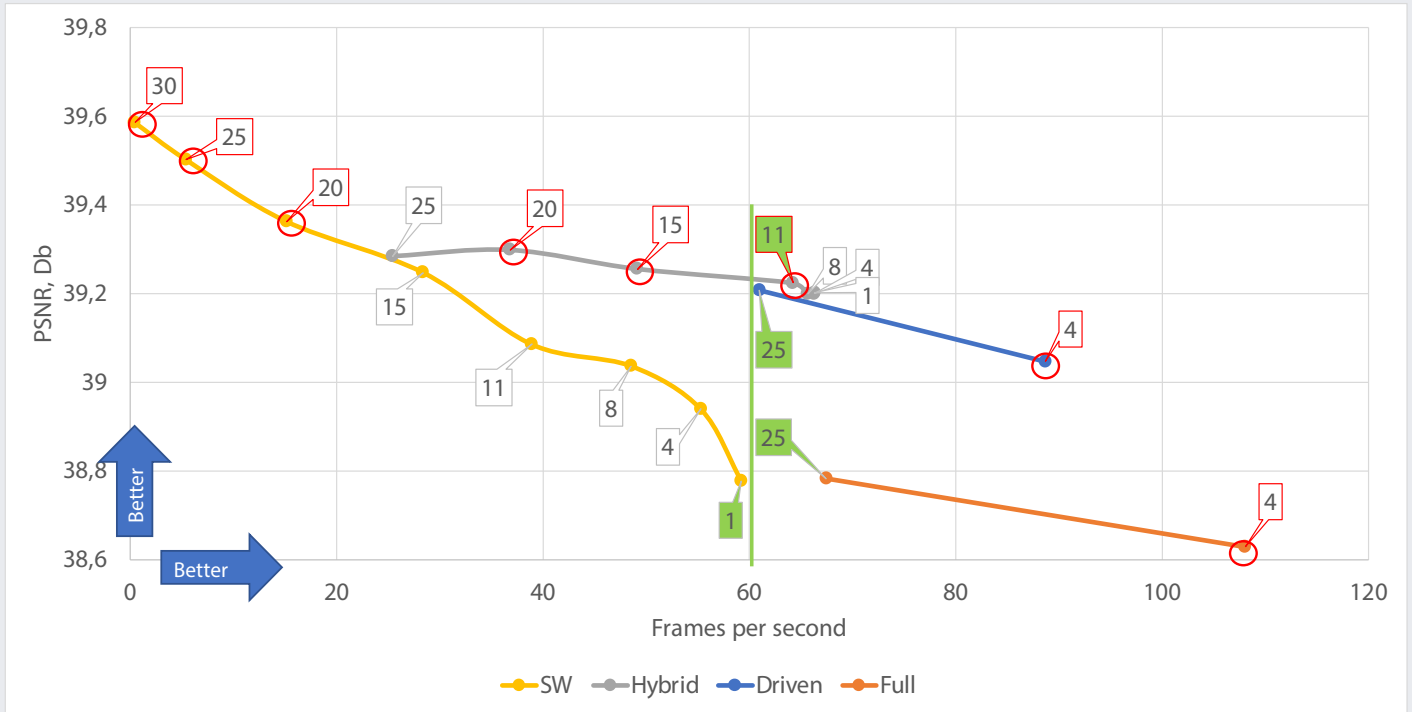


FIG. 4: Egypt speed vs. quality trade-off

The points above and to the right are better. This means the best possible points for the sequence are Full (4), Driven (4), Hybrid (11), Hybrid (15), Hybrid (20), SW (20), SW (25), SW (30). Quality provided by Driven (25) and Hybrid (11) are close to the Balanced preset of the software encoder – i.e. SW (15). They are however at least twice as fast. To estimate the increase in quality at a speed of about 60 frames per second, the following performance levels were chosen: SW (1), Full (25), Driven (25), Hybrid (11). Results using the “Egypt” clip are shown in Figure 5.

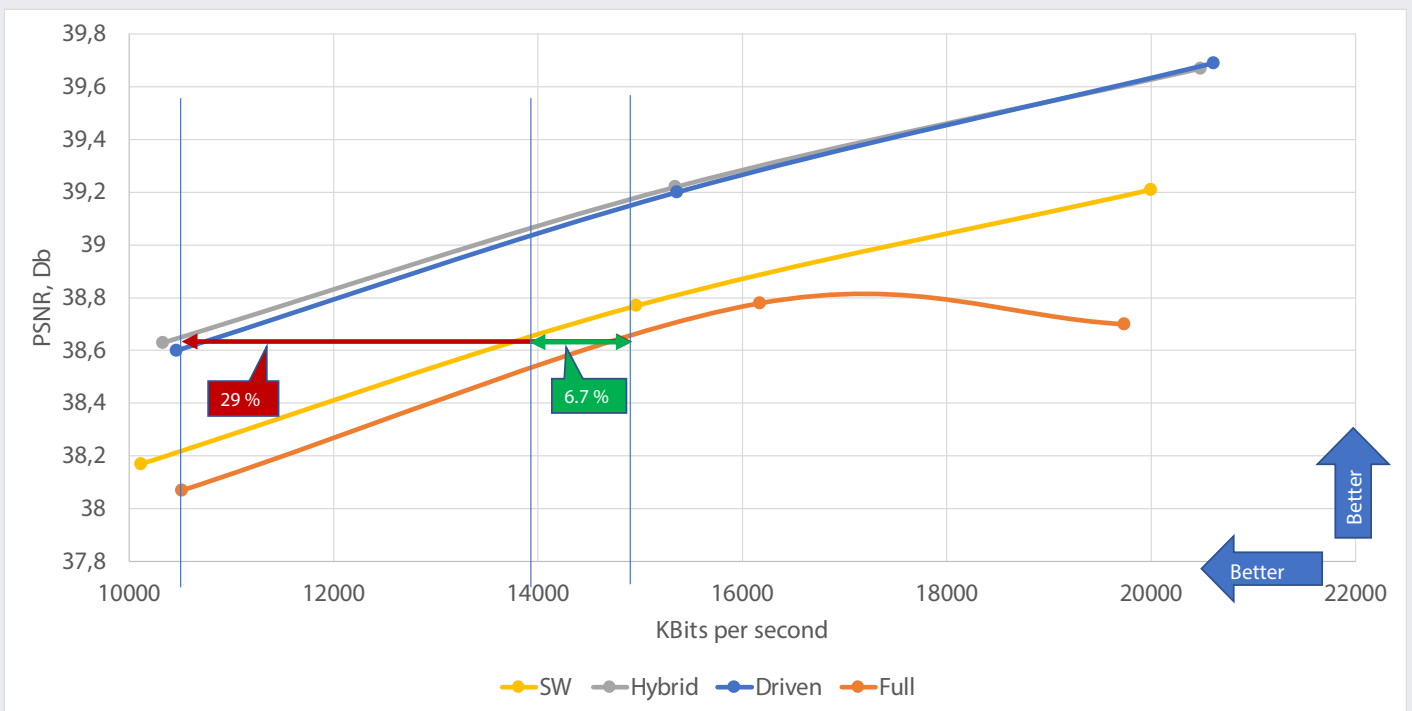


FIG. 5: Egypt bitrate vs. quality trade-off

Figure 5 is a quality plot based on three bitrates: 10, 15 and 20 Mbit per second. Bit rate savings can be estimated by comparing the curves at a fixed quality (Y-axis/PSNR). Full acceleration mode has the worst compression using the “Egypt” clip, and additionally does not improve compression quality as the bit rate increases to 20000 Kbit/s. Switching from Full mode to the software encoder reduces the bitrate by about 7%, and by about 30% when switching from Full to Hybrid/Driven mode.

Figures 6, 7 and 8 are heat maps that compare the average quality and speed gains of the three acceleration modes against the software encoder by the performance levels. In the charts, a speed value is obtained from the speed-quality plots. A quality value is obtained from the bitrate-quality plots. Figures 4, 5 demonstrate the approaches, while the charts show what gains customers should expect on average.

QUALITY (%)	4K MSU (10, 15, 20 Mbit)			
SPEED (%)	Full mode with 5 B-pictures			
		4	25	FPS
SW	1	2.52	9.85	61.69
		91.75	10.51	
	4	1.66	4.07	57.37
		106.16	18.82	
	8	-5.96	2.18	50.29
		135.18	35.54	
	11	-12.85	-4.35	42.08
		181.07	61.99	
	15	-20.64	-17.67	32.37
		265.46	110.63	
	20	-30.62	-24.89	17.78
		565.30	283.44	
	25	-45.35	-33.46	7.31
		1517.07	831.98	
	30	-56.89	-46.27	0.56
		20926.60	12018.38	
	FPS	118.28	68.17	

FIG. 6: Full vs. SW mode comparison

QUALITY (%)	4K MSU (10, 15, 20 Mbit)			
SPEED (%)	Driven mode			
		4	25	FPS
SW	1	10.21	18.38	61.69
		61.60	7.17	
	4	5.24	14.04	57.37
		73.74	15.22	
	8	3.36	12.60	50.29
		98.20	31.44	
	11	-3.02	6.85	42.08
		136.88	57.09	
	15	-16.33	-4.84	32.37
		208.00	104.26	
	20	-25.14	-12.48	17.78
		460.69	271.84	
	25	-38.49	-24.02	7.31
		1262.80	803.79	
	30	-52.67	-37.17	0.56
		17620.34	11651.84	
	FPS	99.68	66.11	

FIG. 7: Driven vs. SW mode comparison

QUALITY (%)		4K MSU (10, 15, 20 Mbit)								
SPEED (%)		Hybrid mode								
		1	4	8	11	15	20	25	FPS	
SW	1	13,27	16,56	16,48	18,49	19,48	21,98	23,12	61.69	
		23,54	15,15	11,40	5,00	-5,04	-33,49	-51,77		
	4	8,25	11,88	11,77	13,98	15,04	17,66	18,91	57.37	
		32,82	23,80	19,77	12,89	2,09	-28,49	-48,15		
	8	5,76	9,53	9,38	11,81	12,92	15,97	17,45	50.29	
		51,52	41,23	36,64	28,79	16,47	-18,43	-40,85		
	11	-0,62	3,33	3,17	5,81	7,04	10,42	12,02	42.08	
		81,09	68,79	63,30	53,92	39,19	-2,51	-29,31		
	15	-14,49	-9,92	-10,17	-6,83	-5,37	-1,36	0,62	32.37	
		135,46	119,47	112,33	100,13	80,98	26,76	-8,08		
	20	-23,73	-18,70	-19,02	-15,20	-13,57	-9,08	-6,84	17.78	
		328,63	299,52	286,53	264,33	229,47	130,76	67,33		
	25	-37,54	-31,78	-32,21	-27,64	-25,80	-20,61	-17,98	7.31	
		941,83	871,08	839,48	785,52	700,81	460,89	306,71		
	30	-47,88	-42,45	-42,54	-37,51	-35,85	-31,42	-28,97	0.56	
		13559,37	12631,74	12217,54	11510,06	10399,32	7253,79	5232,31		
	FPS		76,21	71,03	68,72	64,77	58,58	41,03	29,75	

FIG. 8: Hybrid vs. SW mode comparison

The charts compare the speed and quality of different modes and performance levels. Each cell contains quality and speed values. Quality value is in the top half of the cell. A positive value means how much bit rate is saved compared to the software encoder, measured in percent. In the same way, a negative value means how much better the software encoder is. The Speed value in the bottom half of the cell represents how much the current mode is faster or slower compared to the software encoder, measured in percent.

For example, in the Full (4) vs SW (4) comparison, Full mode provides better speed and quality. It encodes as good as the software encoder but at a lower bit rate (98.34% of the software encoder bit rate). At the same time, it is two times faster than the software encoder (+106.16%).

The best cases for acceleration modes occur when coding is possible without sacrificing neither speed nor quality. According to the charts, each mode has a limit, after which there is a compromise in speed or quality. The limits are different for different modes, Figure 9 shows the scope of the acceleration modes.

		SW performance level							
		1	4	8	11	15	20	25	30
Mode	Full (0-14)	good	good	good	bad	bad	bad	bad	bad
	Full (15-31)	good	good	good	good	bad	bad	bad	bad
	Driven (0-14)	good	good	good	good	bad	bad	bad	bad
	Driven (15-31)	good	good	good	good	good	bad	bad	bad
	Hybrid	good	good	good	good	good	bad	bad	bad

FIG. 9: Scope of the acceleration modes

## CONCLUSION

Since Full mode is the fastest, it makes sense to use it if the encoding speed is critical.

Balanced speed and quality encoding can be done using any acceleration mode (Full, Driven, Hybrid). However, Driven and Hybrid modes offer the best combination of these parameters. They are superior to both pure software and hardware encoders in this performance range. But how is this possible? NVENC provides coding tools that are disabled at low performance levels for the software encoder. The MainConcept encoder provides more sophisticated Rate Control and Analysis that are unavailable for the pure NVENC. The combination of the strengths improves the performance of the encoders taken separately.

Driven and Hybrid modes have several other advantages over Full mode: better subjective quality for low bitrates, better subjective quality for high complexity content, better subjective quality for film grain content, better bitrate accuracy, and a wider set of Coder, Analysis and Rate Control options.

Nevertheless, if encoding speed is no concern, the pure software encoder is still the best choice for superior quality in the performance range (25 – 30).

## Appendix A – System Configuration

- CPU: I9-9900K
- RAM: 64 GB
- GPU: NVIDIA RTX 2070
- OS: Windows x64
- Driver version: 419.67





SAVE UP TO  
**2.5<sup>X</sup>** encoding  
time

## Appendix B – Video Sequences Information

For evaluation purpose, MainConcept used the video sequences pack introduced by the MSU for “HEVC Video Codecs Comparison 2018”. The complete description of the sequences and the criteria for their selection can be found at [http://compression.ru/video/codec\\_comparison/hevc\\_2018/](http://compression.ru/video/codec_comparison/hevc_2018/)

Title	Source
Crowd Run	<a href="https://media.xiph.org/video/derf/">https://media.xiph.org/video/derf/</a>
Ducks Take Off	<a href="https://media.xiph.org/video/derf/">https://media.xiph.org/video/derf/</a>
Egypt	<a href="https://vimeo.com/242603763">https://vimeo.com/242603763</a>
House Demolition	<a href="https://vimeo.com/209252001#t=37">https://vimeo.com/209252001#t=37</a>
Old Car	
Sea Lions	<a href="https://vimeo.com/170666745">https://vimeo.com/170666745</a>
Snowboarding	<a href="https://vimeo.com/202605482#t=1m41s">https://vimeo.com/202605482#t=1m41s</a>
Star Sky	<a href="https://vimeo.com/129462933">https://vimeo.com/129462933</a>
Surfing	<a href="https://vimeo.com/229222461">https://vimeo.com/229222461</a>
TV News	<a href="https://vimeo.com/83846065">https://vimeo.com/83846065</a>

## Appendix C – Encoder Command Line Parameters

Mode	Parameters
Software	<code>sample_enc_hevc -I420 -w 3840 -h 2160 -bitrate &lt;BITRATE&gt; -f &lt;FPS&gt; -perf &lt;LEVEL&gt; -v &lt;SOURCE_FILE&gt; -o &lt;TARGET_FILE&gt;</code>
Full	<code>sample_enc_hevc -I420 -w 3840 -h 2160 -bitrate &lt;BITRATE&gt; -f &lt;FPS&gt; -perf &lt;LEVEL&gt; -v &lt;SOURCE_FILE&gt; -o &lt;TARGET_FILE&gt; -hw_acceleration 2</code>
Driven	<code>sample_enc_hevc -I420 -w 3840 -h 2160 -bitrate &lt;BITRATE&gt; -f &lt;FPS&gt; -perf &lt;LEVEL&gt; -v &lt;SOURCE_FILE&gt; -o &lt;TARGET_FILE&gt; -hw_acceleration 2 -hw_acc_mode 1</code>
Hybrid	<code>sample_enc_hevc -I420 -w 3840 -h 2160 -bitrate &lt;BITRATE&gt; -f &lt;FPS&gt; -perf &lt;LEVEL&gt; -v &lt;SOURCE_FILE&gt; -o &lt;TARGET_FILE&gt; -hw_acceleration 2 -hw_acc_mode 2</code>

## REQUEST A DEMO:



MAINCONCEPT HEVC SDK

Free evaluation downloads are available for testing.

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