MPEG-4 AVC/H.264 Video Codecs Comparison

Video group head: Dr. Dmitriy Vatolin
Project head: Dr. Dmitriy Kulikov
Measurements, analysis: Marat Arsaev

Codecs:

- **H.264**
  - DivX H.264
  - Elecard H.264
  - Intel Ivy Bridge QuickSync (GPU encoder)
  - MainConcept H.264 (software)
  - MainConcept H.264 (CUDA based encoder)
  - MainConcept H.264 (OpenCL based encoder)
  - DiscretePhoton
  - x264
- **Non H.264**
  - XviD (MPEG-4 ASP codec)

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CS MSU Graphics&Media Lab, Video Group

http://www.compression.ru/video/codec_comparison/index_en.html

videocodec-testing@graphics.cs.msu.ru

This is **Free version** of report – it contains mainly average Y-SSIM graphs and few graphs for separate video sequences. It is for video codec users.

Enterprise version contains up to 2000 graphs for all the video sequences, metrics, color-planes and much more. It is for video codec professional users and developers.

Contents

1 Acknowledgments

The Graphics & Media Lab Video Group would like to express its gratitude to the following companies for providing the codecs and settings used in this report:

- Elecard Ltd
- Intel Corporation
- MainConcept GmbH
- x264 Development Team
- DiscretePhoton team

The Video Group would also like to thank these companies for their help and technical support during the tests.

2 Overview

2.1 Sequences

Table 1. Summary of video sequences.

Sequence	Number of frames	Frame rate	Resolution
Video Conferences			
1. Deadline	1374	30	352x288
2. Developers 4CIF	3600	30	640x480
3. Developers 720p	1500	30	1280x720
4. Presentation	548	30	720x480
5. Business	493	30	1920x1080
Movies (SD sequences)			
1. Ice Age	2014	24	720x480
2. City	600	60	704x576
3. Crew	600	60	704x576
4. Indiana Jones	5000	30	704x288
5. Harbour	600	60	704x576
6. Ice Skating	480	60	704x576
7. Soccer	600	60	704x576
8. Race Horses	300	30	832x480
9. State Enemy	6500	24	720x304
10. Party Scene	500	50	832x480
HDTV sequences			
1. Park Joy	500	50	1280x720
2. Riverbed	250	25	1920x1080
3. Rush Hour	500	25	1920x1080
4. Blue Sky	217	25	1920x1080
5. Station	313	25	1920x1080
6. Stockholm	604	50	1280x720
7. Sunflower	500	25	1920x1080
8. Tractor	690	25	1920x1080
9. Big Buck Bunny	600	24	1920x1080
10. Elephants Dream	600	24	1920x1080
11. Troy	300	24	1920x1072
12. Water Drops	535	30	1920x1080
13. Capitol	600	30	1920x1080
14. Parrots	600	30	1920x1080
15. Citybus	600	30	1920x1080
16. Underwater	600	30	1920x1080

Brief descriptions of the sequences used in our comparison are given in Table 1. More detailed descriptions of these sequences can be found in Appendix 1. Test Set of Video Sequences.

2.2 Codecs

Table 2. Short codec descriptions

	Codec	Developer	Version
1.	DivX AVC/H.264 Video Encoder	DivX, Inc.	1.1.1.9
2.	Elecard AVC Video Encoder 8-bit edition,	Elecard Ltd	2.1.032820.120220
3.	MainConcept AVC/H.264 Video Encoder Console Application	MainConcept GmbH	9.2 (for software encoder)
4.	x264	x264 Development Team	core:120 r2146 bcd41dbwas
5.	XviD raw mpeg4 bitstream encoder	XviD Development Team	xvid-1.3.0-dev
6.	Discrete Photon	Discrete Photon Development Team	1.1.0.4
7.	Intel® Quick Sync Video 3rd Generation Intel® Core™ i5/i7 Processors	Intel/SSG/VCSD/CIP	–

Brief descriptions of the codecs used in our comparison are given in Table 2. XviD was used as a good quality MPEG-4 ASP reference codec for comparison purposes. Detailed descriptions of all codecs used in our comparison can be found in Appendix 2. Tested Codecs.

3 Objectives and Testing Rules

3.1 H.264 Codec Testing Objectives

The main goal of this report is the presentation of a comparative evaluation of the quality of new H.264 codecs using objective measures of assessment. The comparison was done using settings provided by the developers of each codec.

The main task of the comparison is to analyze different H.264 encoders for the task of transcoding video—e.g., compressing video for personal use. Speed requirements are given for a sufficiently fast PC; fast presets are analogous to real-time encoding for a typical home-use PC.

3.2 Testing Rules

- The entire test set was divided into two primary types of applications. These applications differ by resolution, bitrate and encoding speed requirements:
  - VideoConference (one pass only)
  - Movies (bitrates of 500-2000 kbps)
  - High-definition television (“HDTV”; bitrates of 0.7-10 mbps)
- There are special presets and speed limitations for every type of application:
  - Video Conference (one pass only, good local bitrate handling)
    - Minimum 60 fps at 4CIF sequence
  - Movies (speed requirements for 750 kbps 4CIF sequences):
    - Minimum 120 fps for "High Speed" preset
    - Minimum 80 fps for "Normal" preset Minimum 40 fps for "High Quality" preset
  - HDTV (speed requirements for 3 mbps 1280x720 sequences):
    - Minimum 100 fps for "High Speed" preset
    - Minimum 50 fps for "Normal" preset
    - Minimum 20 fps for "High Quality" preset
- Each codec’s developer provided settings for each type of application. Each setting’s individual parameters were, to a large extent, chosen by the developers, except the following:
  - DivX H.264
  - XviD (last year presets were used)
- Each codec was tested for speed three times; the minimum score was then used as the representative time.
- During the testing process, source video sequences were in the YV12 format (.yuv file extension) for all codecs.
- For all measurements the PRO version of the YUVsoft Video Codec Scoring System was used (http://vicos.yuvsoft.com/).

- The following computer configuration was used for the main tests:
    - Sugar Bay platform, 3rd Generation Core i7 3770(IVB), 4 Cores CPU @3.4 GHz,
    - Integrated GPU: Intel HD Graphics 4000
    - GPU: NVIDIA GeForce GTX 580
    - Total Physical Memory: 2x2 Gb RAM (1600 MHz)
    - HDD: SSD160G
    - Operation System: Windows 7

During the evaluation the following measures were used:

- SSIM (Y component)
- PSNR (Y component)

Enterprise version of report contains:

- SSIM, Y-SSIM, U-SSIM, V-SSIM
- PSNR, Y-PSNR, U-PSNR, V-PSNR
- MSE
- 3-SSIM
- MS-SSIM

More detailed information about these measures may be found on the Internet at the following URL:

http://www.compression.ru/video/quality_measure/info.html

4 Comparison Results

4.1 Video Conferences

4.1.1 RD Curves

Next figures show RD curves for five video conference sequences. The leader by quality is x264. MainConcept is typically second.

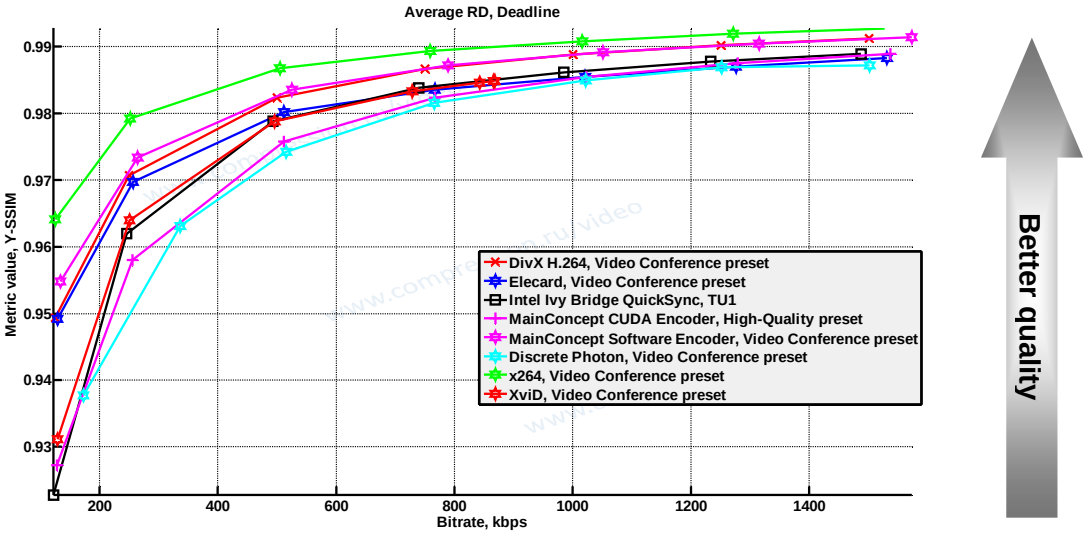

Figure 1. Bitrate/quality—usage area "Video Conference," Deadline sequence, Y-SSIM metric

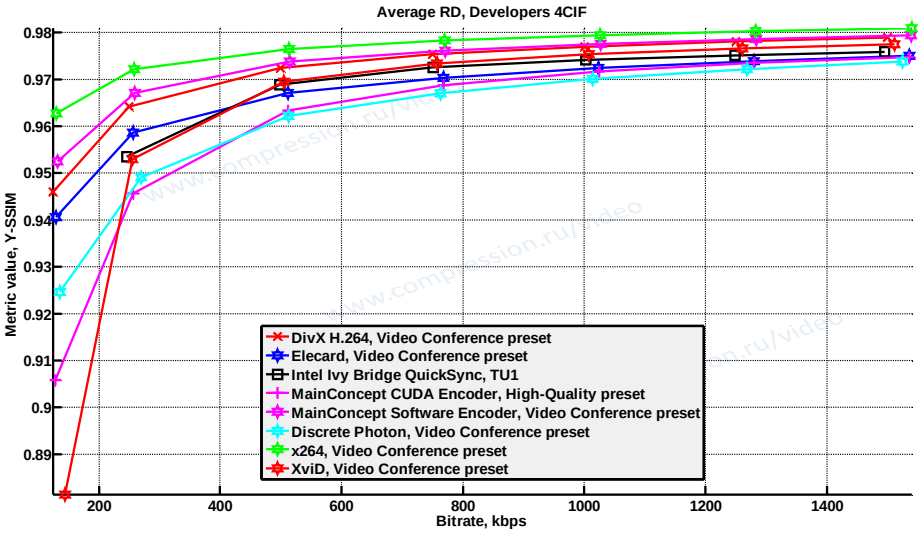

Figure 2. Bitrate/quality—usage area "Video Conference," Developers 4CIF sequence, Y-SSIM metric

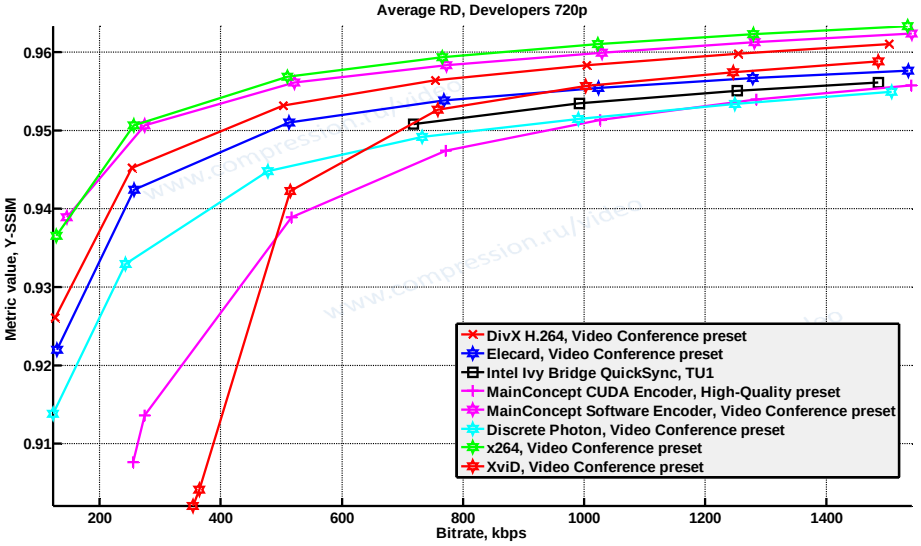

Figure 3. Bitrate/quality—usage area "Video Conference," Developers 720p sequence, Y-SSIM metric

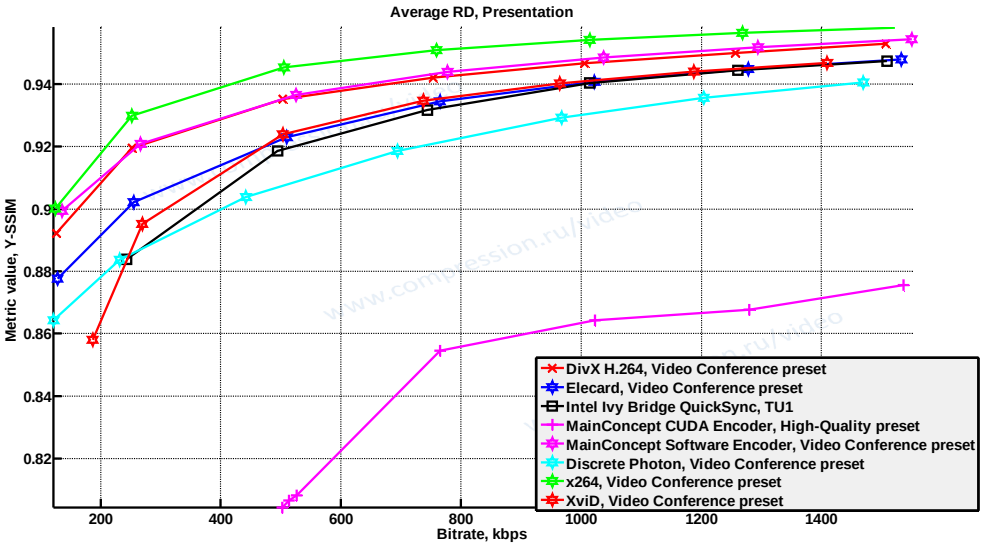

Figure 4. Bitrate/quality—usage area "Video Conference," Presentation sequence, Y-SSIM metric

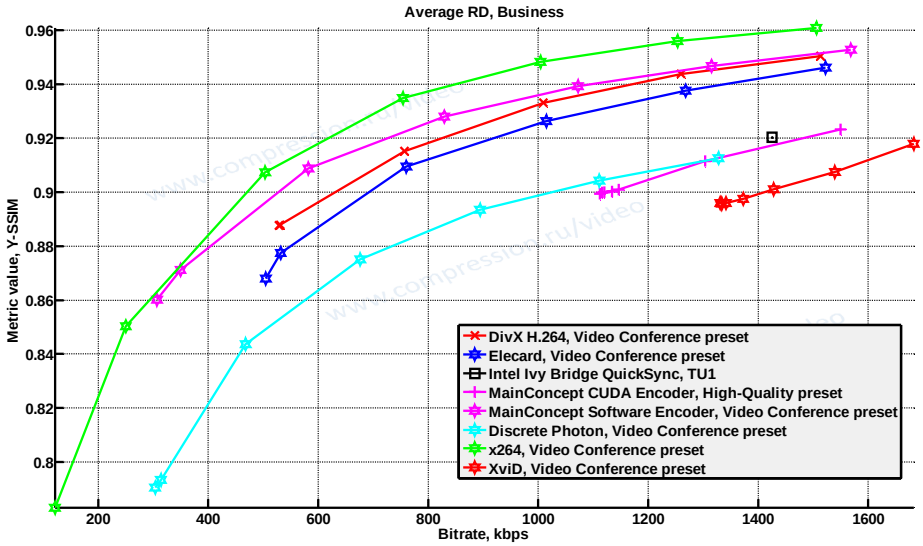

Figure 5. Bitrate/quality—usage area "Video Conference," Business sequence, Y-SSIM metric

4.1.2 Encoding Speed

Absolute speed results are presented in Figure 6 through Figure 8. All the encoders have a similar growth rate for encoding time as the bitrate is increased. Intel Ivy Bridge QuickSync is fastest. Discrete Photon, MainConcept CUDA and Elecard are nest by encoding speed: MainConcept are faster for high resolution sequences and DiscretePhoton – for low resolution.

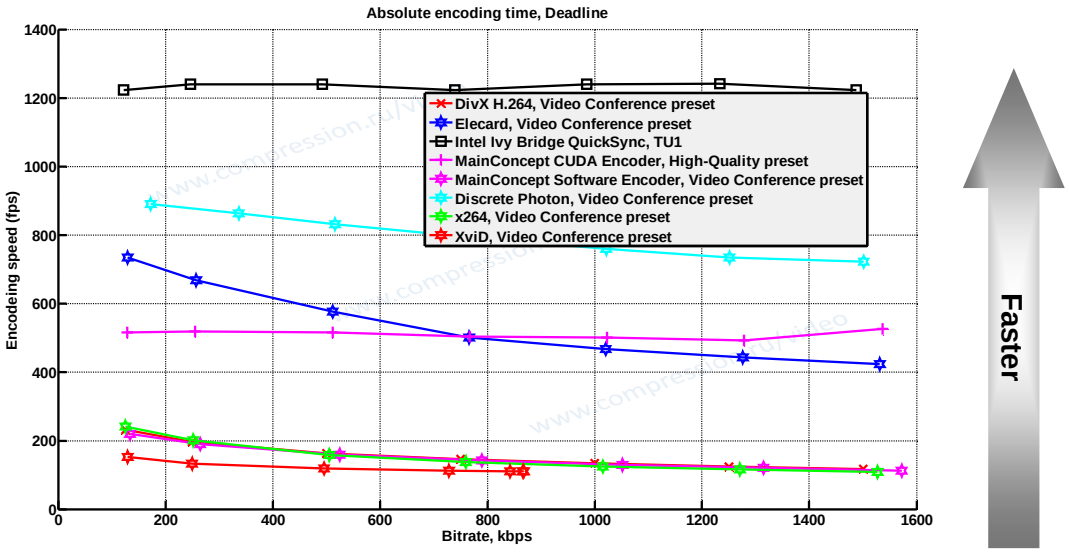

Figure 6. Encoding speed—usage area "Video Conference" Deadline sequence

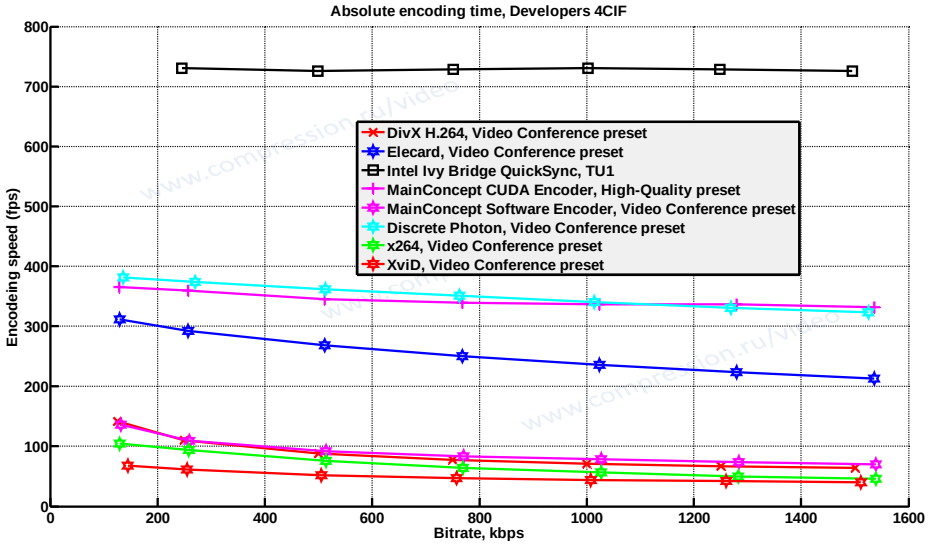

Figure 7. Encoding speed—usage area "Video Conference" Developers 4CIF sequence

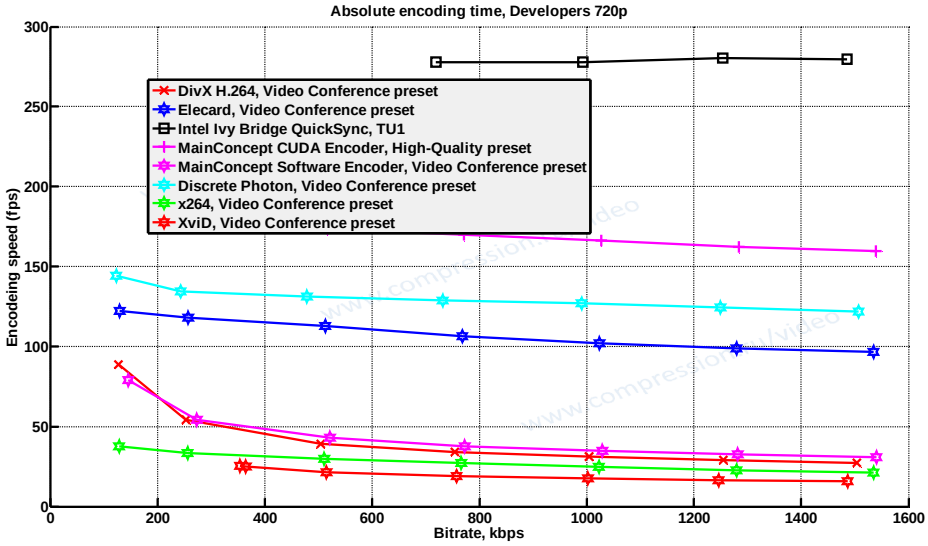

Figure 8. Encoding speed—usage area "Video Conference" Developers 720p sequence

4.1.3 Speed/Quality Trade-Off

Detailed descriptions of the speed/quality trade-off graphs can be found in Appendix 3. Figures Explanation. Sometimes, codec results are not present in the particular graph owing to the codec's extremely poor performance. The codec's RD curve has no intersection with the reference's RD curve.

The speed/quality trade-off graphs simultaneously show relative quality and encoding speed for the encoders tested in this comparison. XviD is the reference codec, for which both quality and speed are normalized to unity for all of the graphs. The terms "better" and "worse" are used to compare codecs in the same manner as in previous portions of this comparison.

Please note that the method of averaging among all sequences assumes that all codecs produced results for each sequence. When this is not the case, only existing results are taken into account.

The four best codecs (no codec performs faster with higher quality) in terms of speed/quality are Intel Ivy Bridge QuickSync, MainConcept, Elecard and x264 at average.

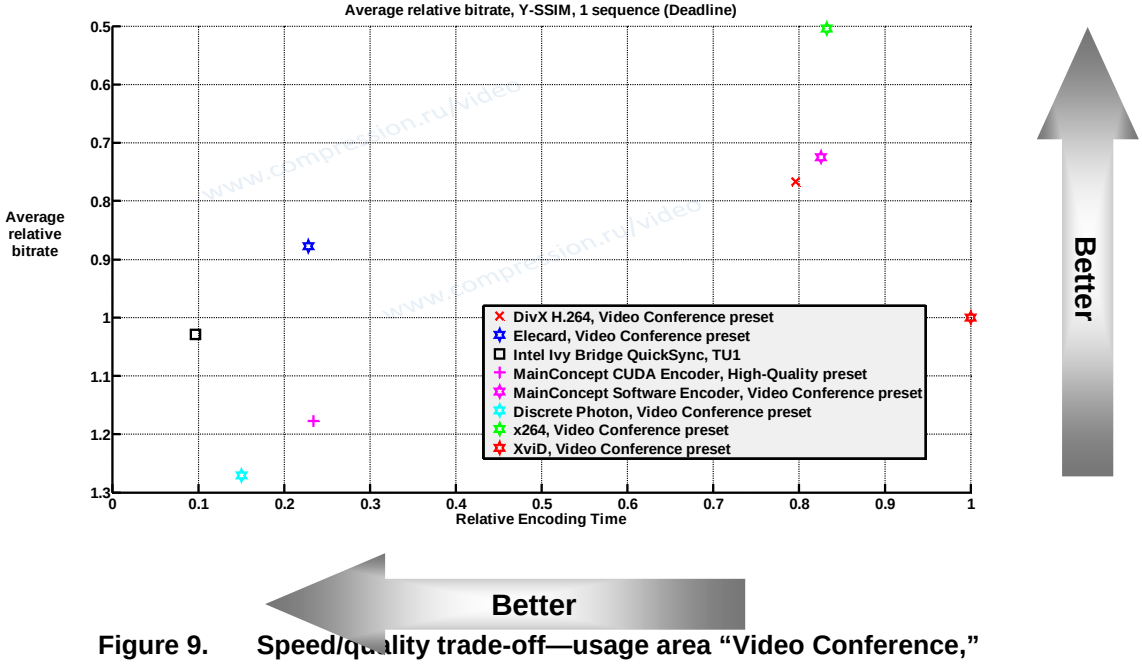

Figure 9. Speed/quality trade-off—usage area "Video Conference," Deadline sequence, Y-SSIM metric

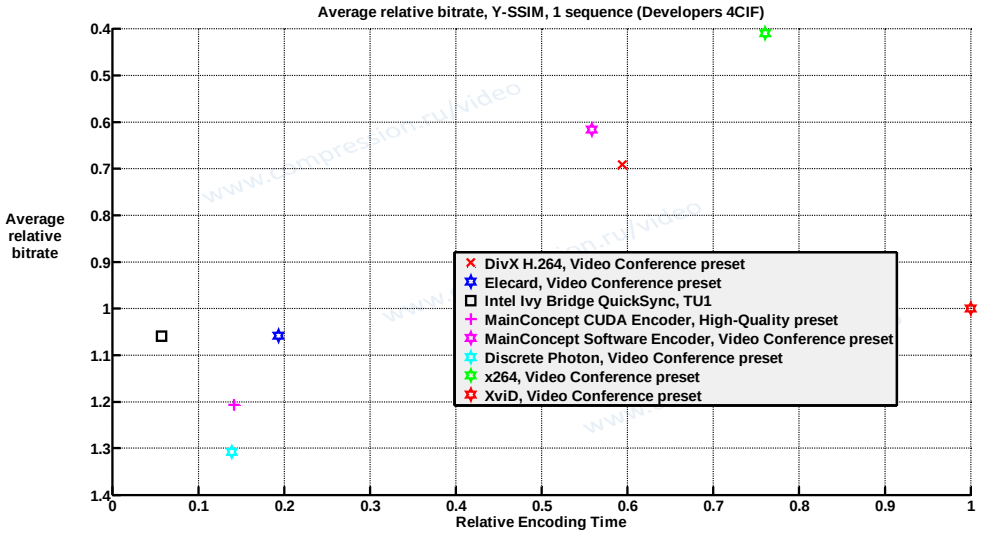

Figure 10. Speed/quality trade-off—usage area "Video Conference," Developers 4CIF sequence, Y-SSIM metric

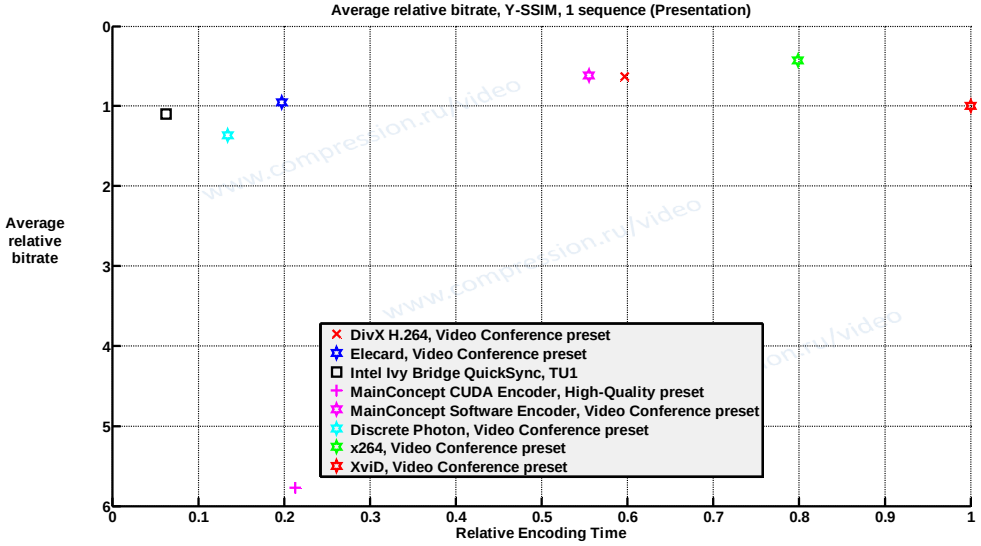

Figure 11. Speed/quality trade-off—usage area "Video Conference," Presentation sequence, Y-SSIM metric

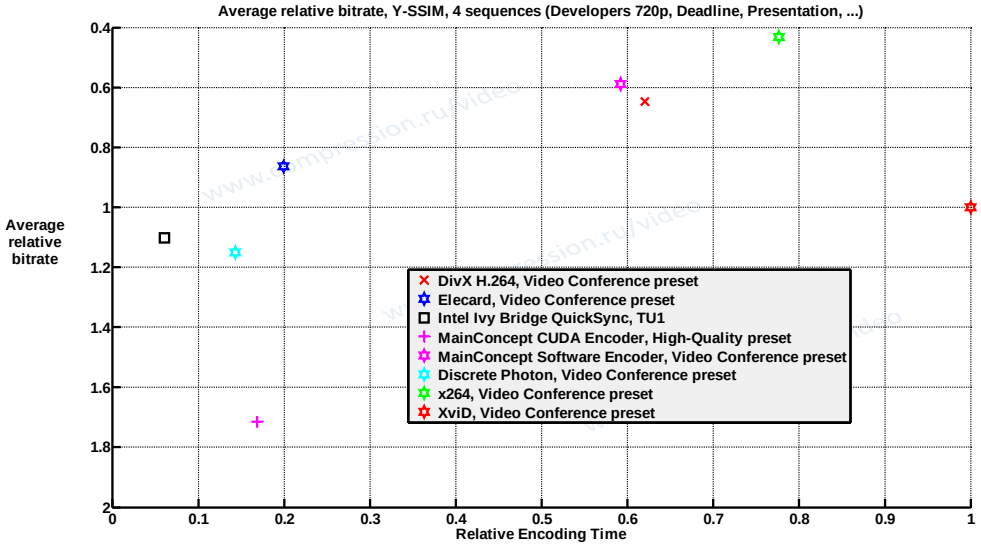

Figure 12. Speed/quality trade-off—usage area "Video Conference," all sequences, Y-SSIM metric

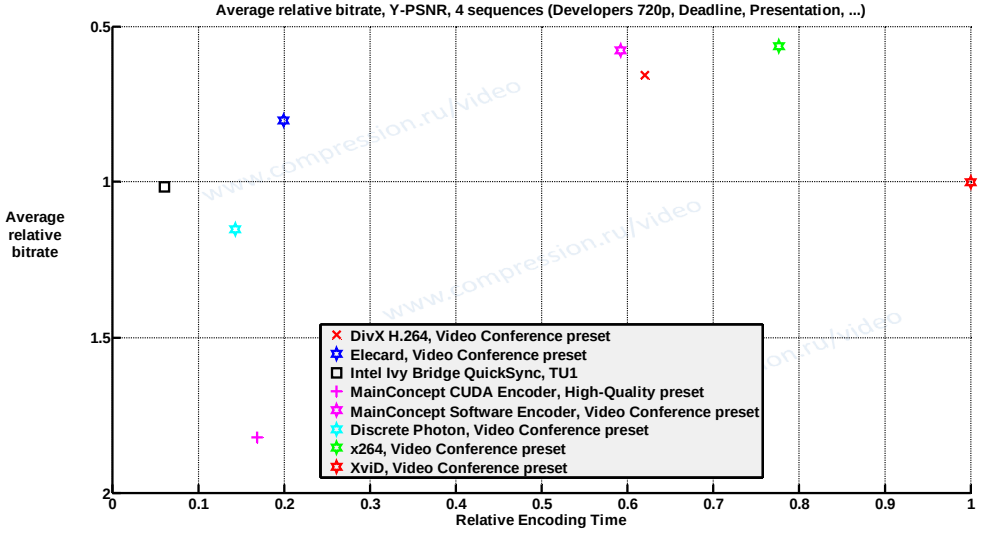

Figure 13. Speed/quality trade-off—usage area "Video Conference,"

4.1.4 Bitrate Handling

Encoders with High Speed presets, except the XviD encoder, demonstrate good bitrate handling for all sequences. There are some issues with bitrate handling for DiscretePhoton encoder for CIF sequence. For high resolution sequences MainConcept CUDA and XviD increase low bitrates and Intel QuickSync does not encode low bitrates.

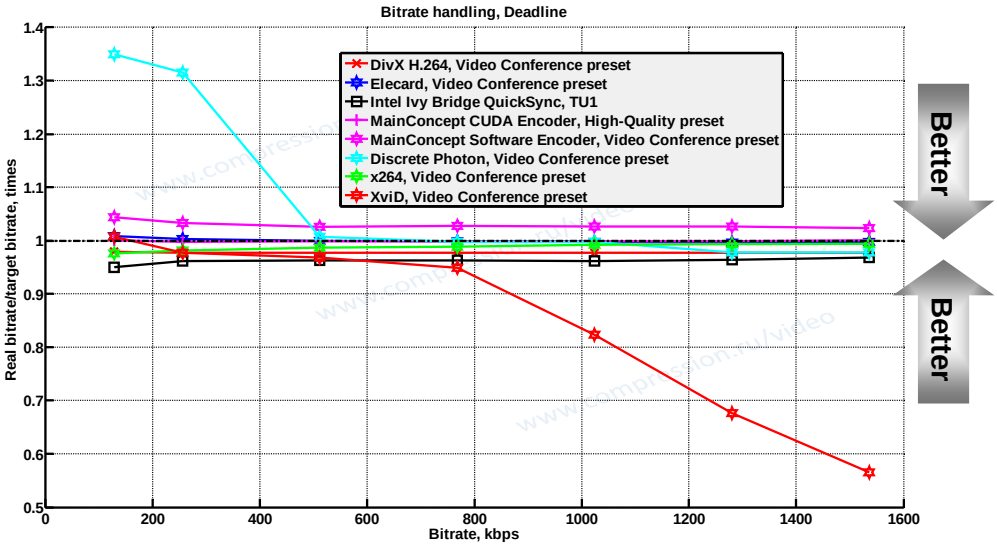

Figure 14. Bitrate handling—usage area "Video Conference," Deadline sequence

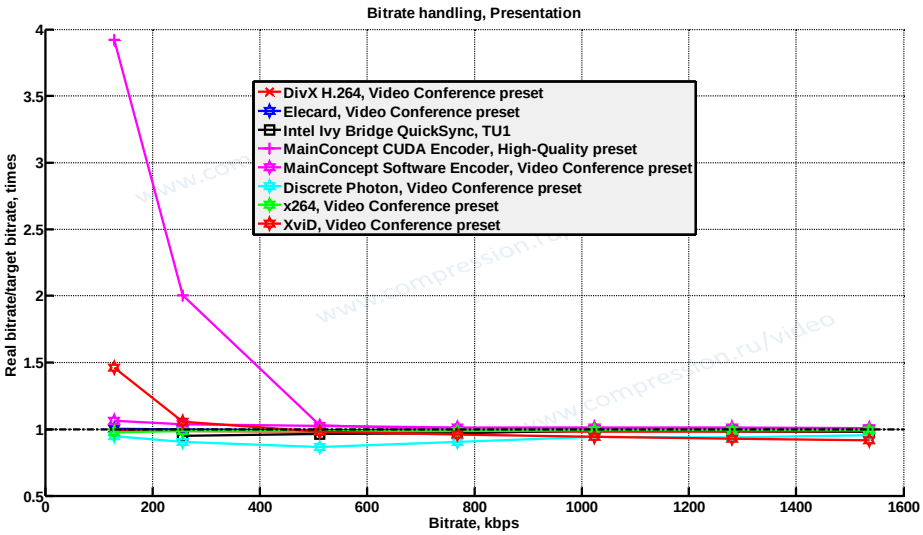

Figure 15. Bitrate handling—usage area "Video Conference," Presentation sequence

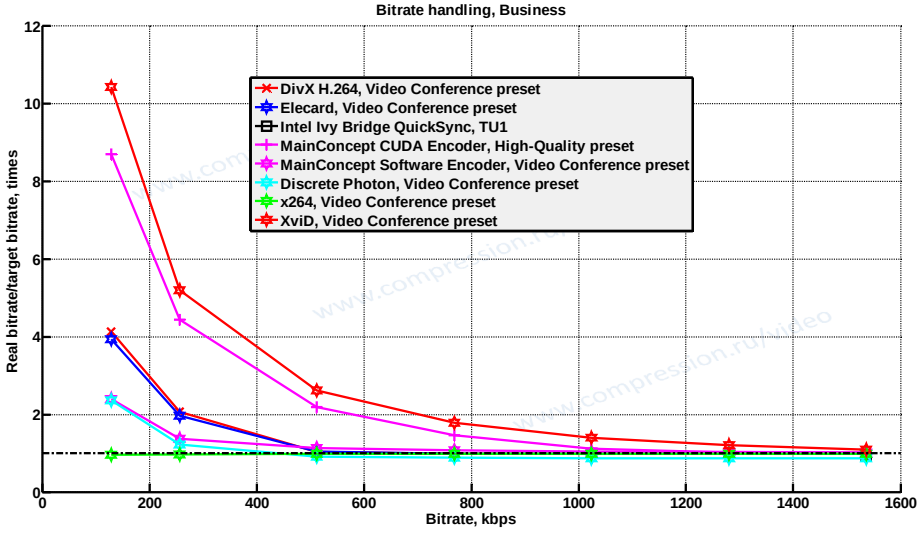

Figure 16. Bitrate handling—usage area "Video Conference," Business sequence

4.1.5 Local Bitrate Handling

For video conference encoding is very important not only keep average bitrate for all the sequence but keep local bitrate for example for 1 second window. In this part of comparison we analyze local bitrate handling by next formula

$$LBH = \frac{\max(mfps) \cdot 8 \cdot fps}{1024 \cdot \text{target\_bitrate}},$$

where *mfps* – average frame size in 1 sec (fps) window

And overall results is maximal value of LBH for sequence.

Results change depending on sequences – sometimes Elecard is best, sometimes – Intel, sometimes – DivX.

Due to stable low result for XviD – this codec is not shown on some graphs.

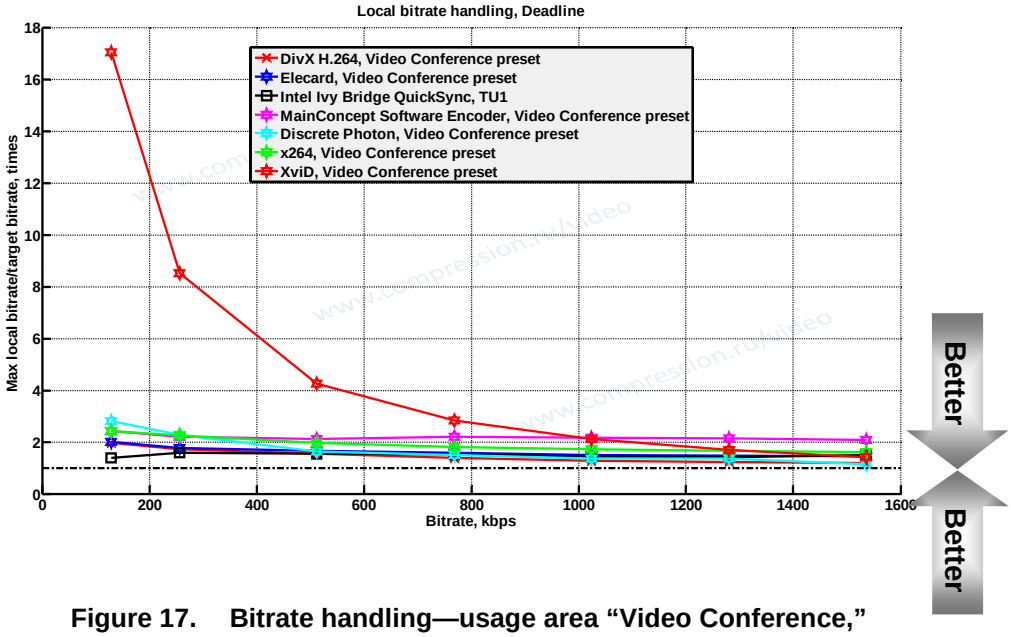

Figure 17. Bitrate handling—usage area "Video Conference," Deadline sequence

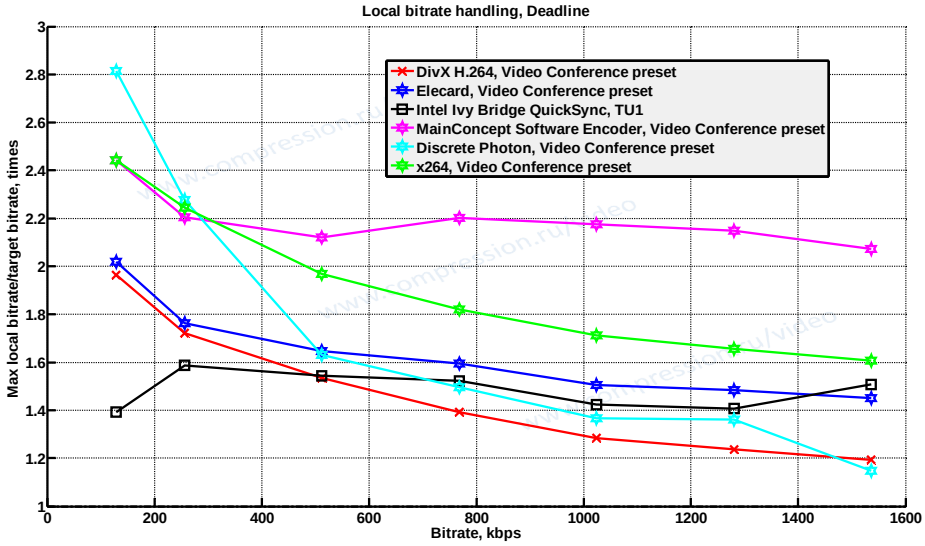

Figure 18. Bitrate handling—usage area "Video Conference," Deadline sequence without XviD

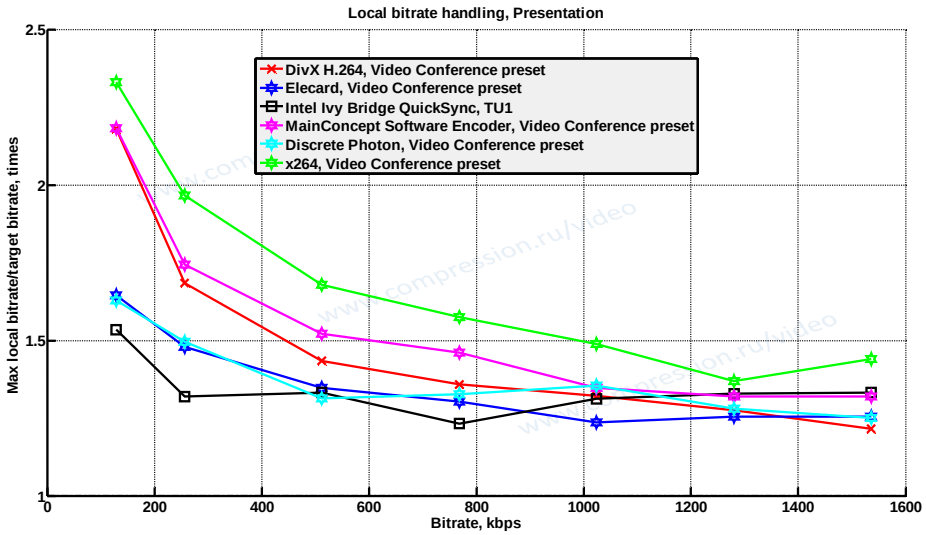

Figure 19. Bitrate handling—usage area "Video Conference," Presentation sequence

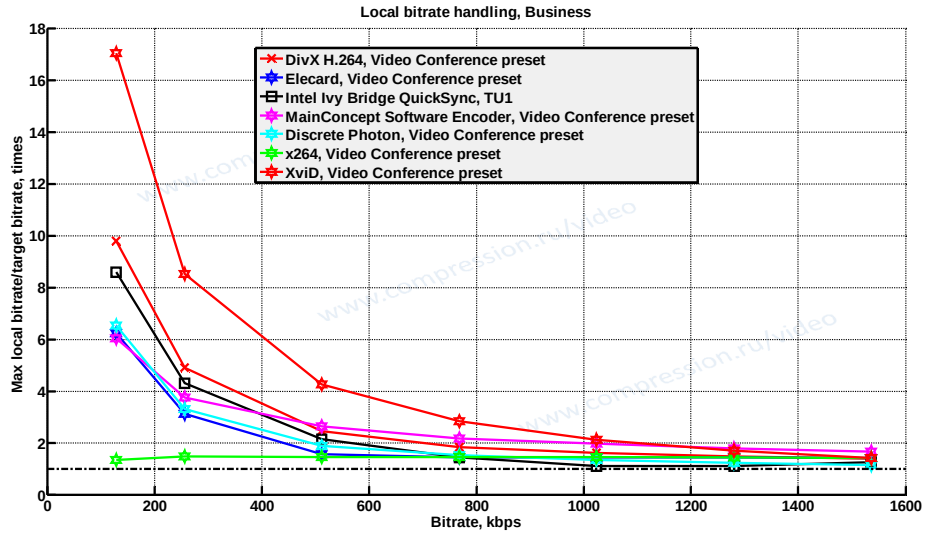

Figure 20. Bitrate handling—usage area "Video Conference," Business sequence

4.1.6 Relative Quality Analysis

Table 3 and Table 4 show relative bitrates for a fixed quality output for all codecs and presets. Note that these tables do not include information about the speed of the encoder.

Note that each number in the tables below corresponds to some range of bitrates (see Appendix 3. Figures Explanation). Unfortunately, these ranges can differ significantly because of differences in the quality of compared encoders. This situation can lead to some inadequate results when three or more codecs are compared.

Consider the Y-SSIM results in Table 3 and Y-PSNR results in Table 4. On average, the leader is the x264 encoder followed by MainConcept encoder.

Table 3. Average bitrate ratio for the same quality. Usage area "Video Conference". Y-SSIM.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	142%	161%	201%	88%	205%	64%	155%
Elecard	70%	100%	110%	150%	60%	147%	43%	116%
Intel QuickSync	62%	91%	100%	125%	55%	133%	40%	91%
MainConcept CUDA	50%	67%	80%	100%	43%	55%	32%	58%
MainConcept	113%	166%	183%	235%	100%	240%	72%	170%
Discrete Photon	49%	68%	75%	182%	42%	100%	31%	87%
x264	156%	233%	250%	313%	139%	324%	100%	232%
XviD	65%	86%	110%	171%	59%	115%	43%	100%

Table 4. Average bitrate ratio for the same quality. Usage area "Video Conference". Y-PSNR.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	127%	146%	191%	87%	190%	89%	152%
Elecard	79%	100%	113%	157%	67%	155%	66%	125%
Intel QuickSync	68%	89%	100%	129%	59%	136%	59%	99%
MainConcept CUDA	52%	64%	78%	100%	44%	54%	42%	55%
MainConcept	115%	150%	170%	226%	100%	228%	102%	173%
Discrete Photon	53%	64%	74%	185%	44%	100%	43%	87%
x264	112%	150%	170%	236%	98%	231%	100%	177%
XviD	66%	80%	102%	182%	58%	115%	56%	100%

Figure 21 and Figure 22 depict the data from the tables above. Each line in the figures corresponds to one codec. Values on the vertical axis are the average relative bitrates compared with the codecs along the horizontal axis. A lower bitrate indicates better relative results.

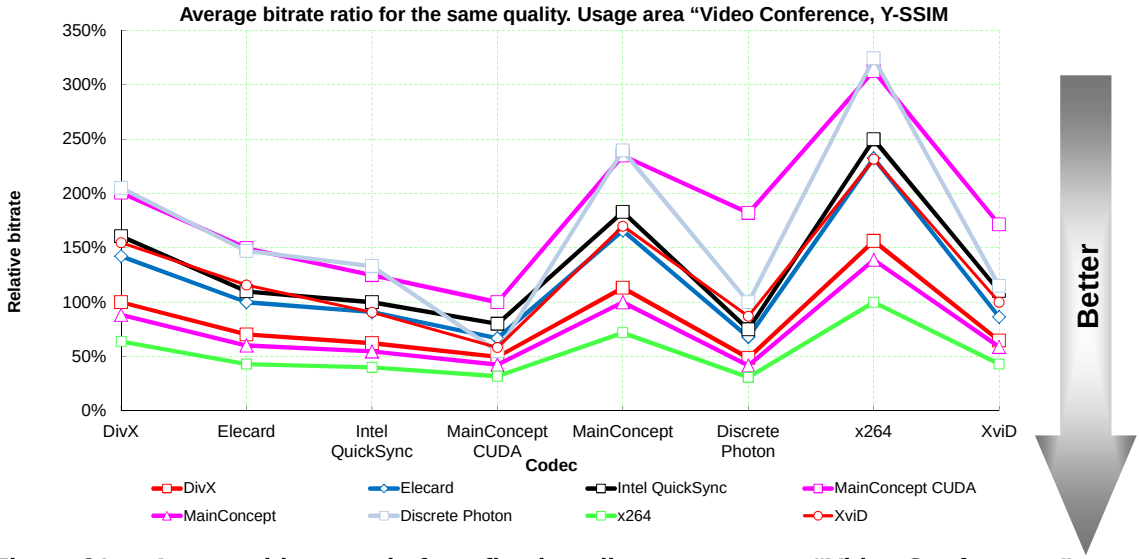

Figure 21. Average bitrate ratio for a fixed quality—usage area "Video Conference," Y-SSIM metric

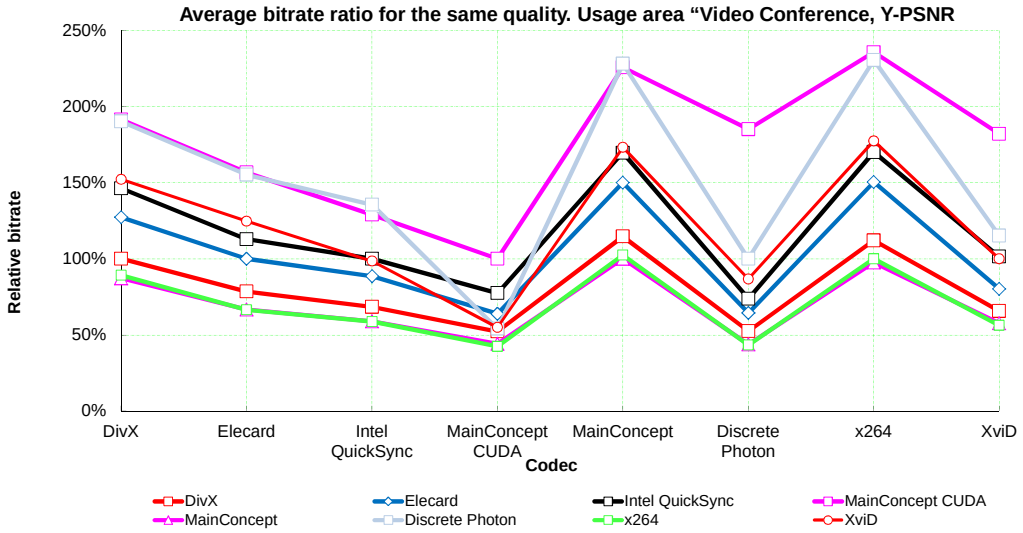

Figure 22. Average bitrate ratio for a fixed quality—usage area "Video Conference," Y-PSNR metric

4.2 Movies

4.2.1 RD Curves

4.2.1.1 High Speed Preset

Figure 23 to Figure 25 show typical situation for all encoders (except some sequences). The leader for almost all video sequences (except Crew and Harbour) is x264. MainConcept is typically second. Third place is for Elecard. MainConcept CUDA exhibited the poorest result (even lower than XviD sometimes).

*Results for all the sequences, all metrics and all encoders are available in **Enterprise version** report only.*

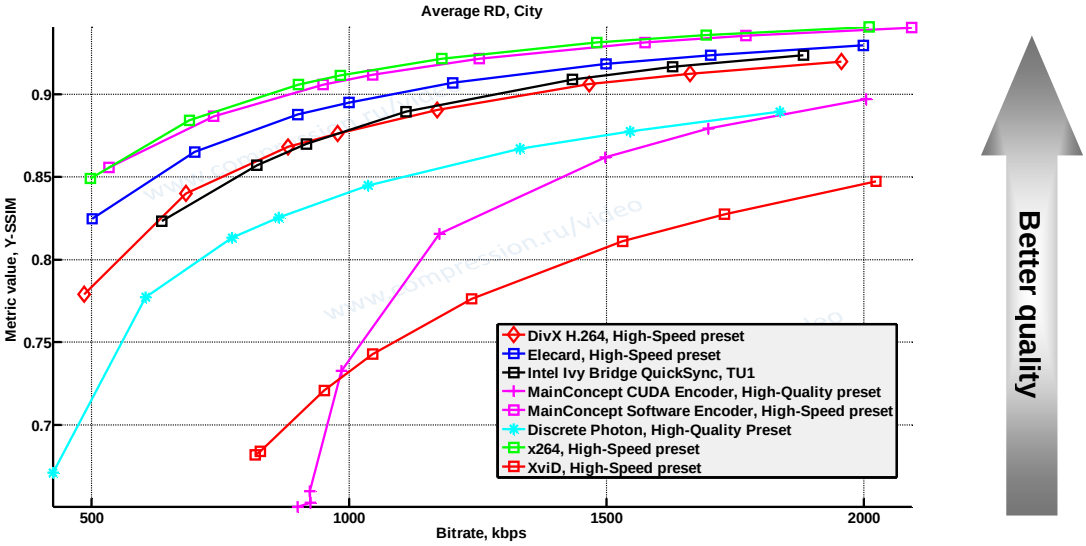

Figure 23. Bitrate/quality—usage area "Movies," "City" sequence, High Speed preset, Y-SSIM metric

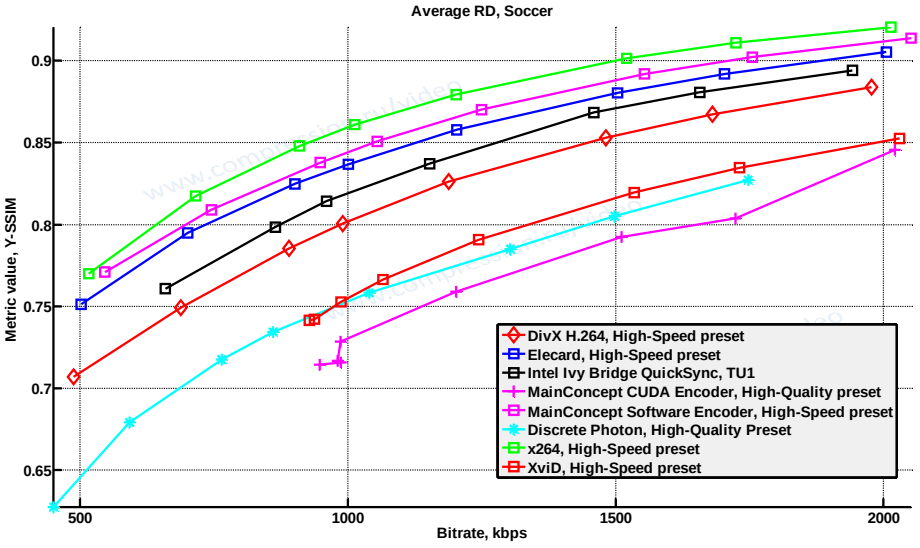

Figure 24. Bitrate/quality—usage area "Movies," "Soccer" sequence, High Speed preset, Y-SSIM metric

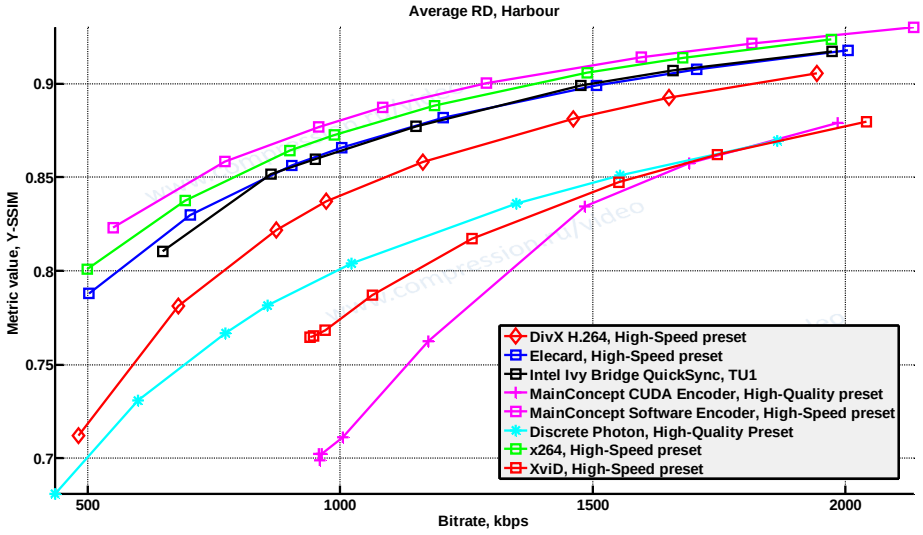

Figure 25. Bitrate/quality—usage area "Movies," "Harbour" sequence, High Speed preset, Y-SSIM metric

4.2.1.2 Normal Preset

The Normal preset results for each sequence are presented in Figure 26 through Figure 28. The figures show the Y-SSIM results. The results slightly depend on the metric used.

SSIM metric: The leader is x264; MainConcept and DivX H.264 placed second – the position depends on sequence tested.

*Results for all the sequences, all metrics and all encoders are available in **Enterprise version** report only.*

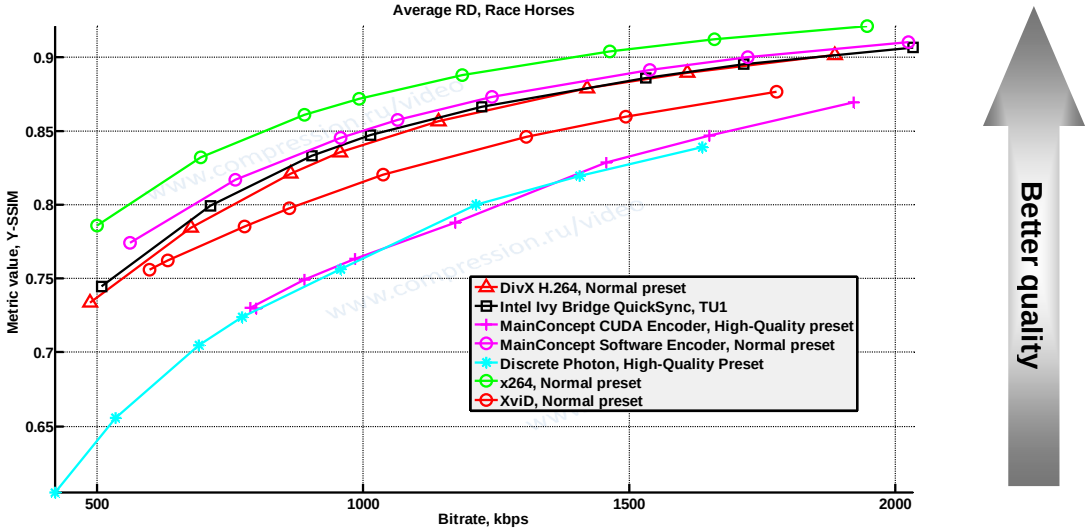

Figure 26. Bitrate/quality—usage area "Movies," "Race Horses" sequence, Normal preset, Y-SSIM metric

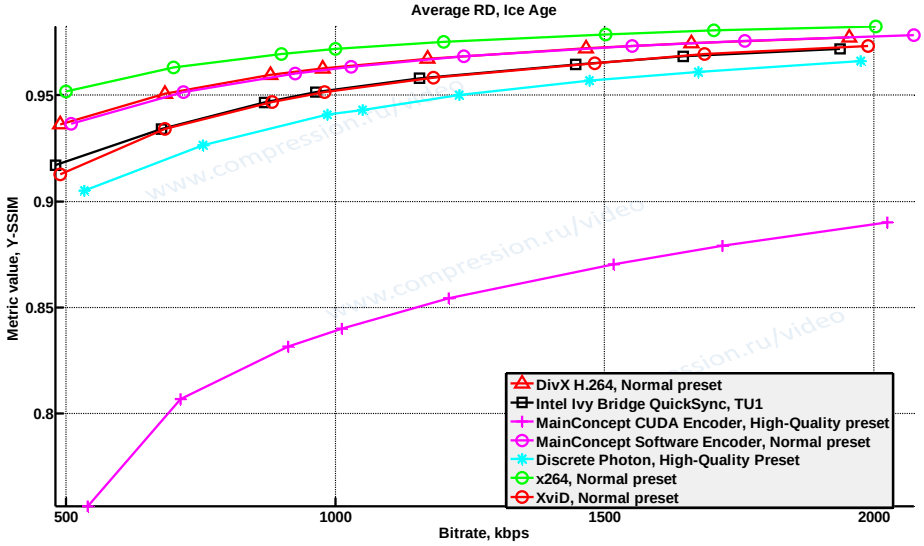

Figure 27. Bitrate/quality—usage area "Movies," "Ice Age" sequence, Normal preset, Y-SSIM metric

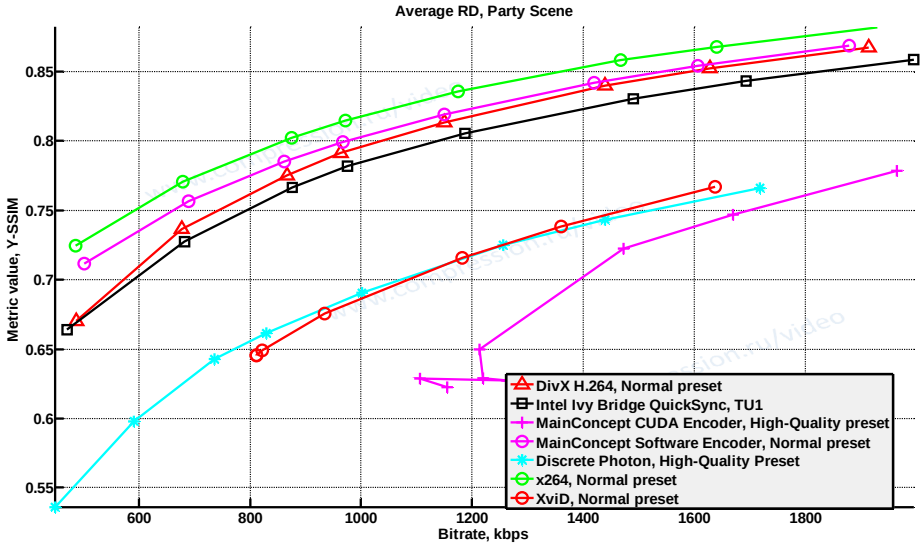

Figure 28. Bitrate/quality—usage area "Movies," "Party Scene" sequence, Normal preset, Y-SSIM metric

4.2.1.3 High Quality Preset

The High Quality preset results for each sequence are presented in Figure 29 through Figure 32. The graphs show the Y-SSIM results. The results change depending on the metric used.

SSIM metric: The leader is x264, followed by MainConcept in second place and the DivX H.264. And these encoders show close results that vary on different sequences. DiscretePhoton and MainConcept CUDA show the lowest results.

*Results for all the sequences, all metrics and all encoders are available in **Enterprise version** report only.*

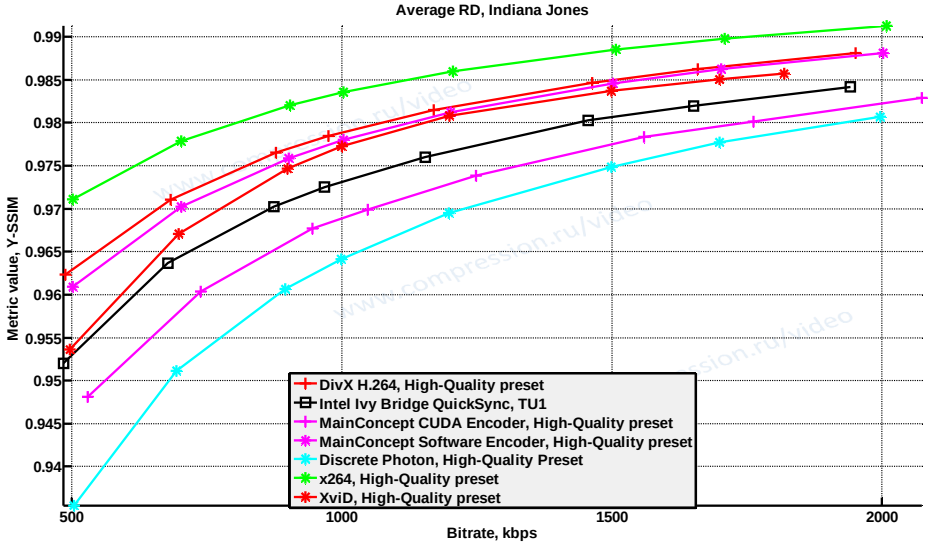

Figure 29. Bitrate/quality—usage area "Movies," "Indiana Jones" sequence, High Quality preset, Y-SSIM metric

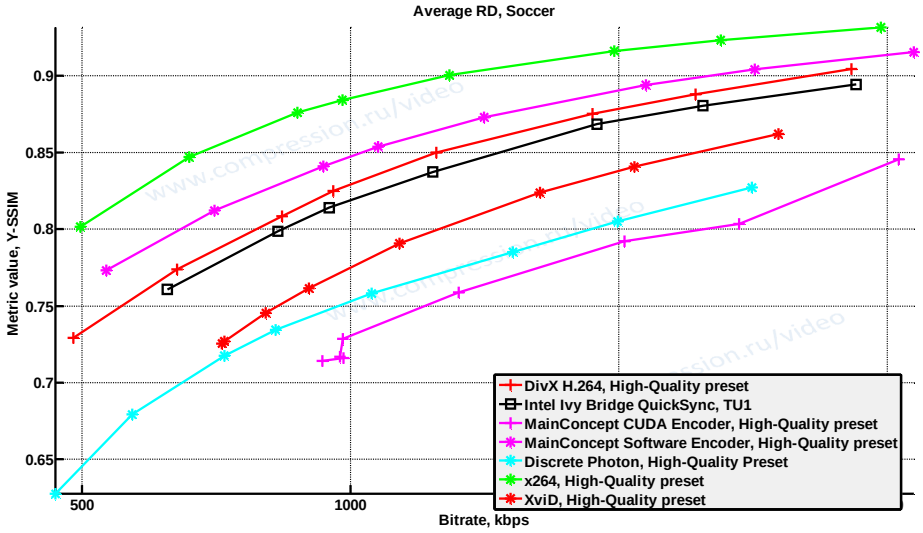

Figure 30. Bitrate/quality—usage area "Movies," "Soccer" sequence, High Quality preset, Y-SSIM metric

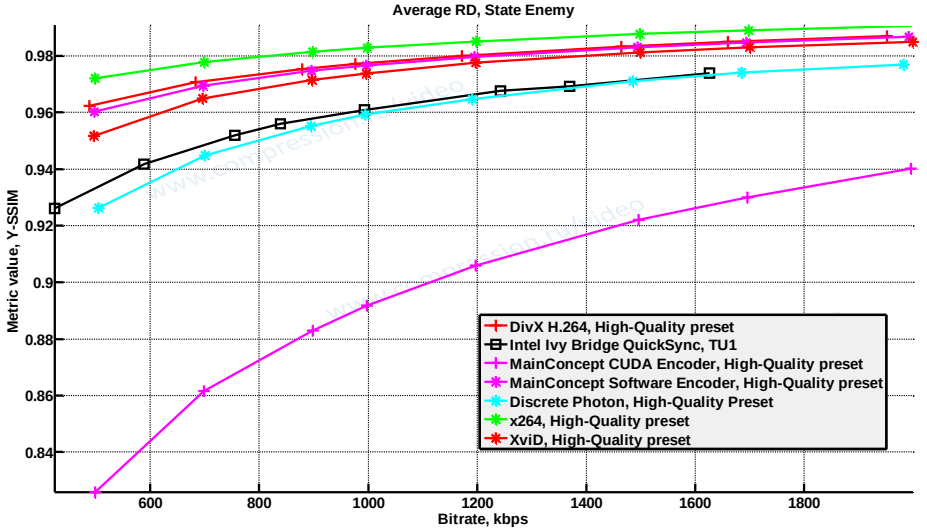

Figure 31. Bitrate/quality—usage area "Movies," "State Enemy" sequence, High Quality preset, Y-SSIM metric

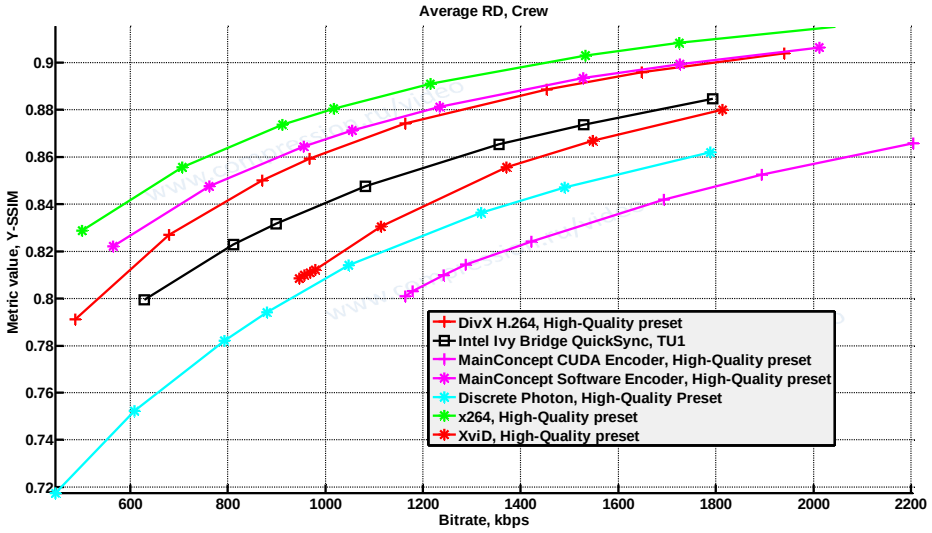

Figure 32. Bitrate/quality—usage area "Movies," "Crew" sequence, High Quality preset, Y-SSIM metric

4.2.2 Encoding Speed

4.2.2.1 High Speed Preset

Absolute speed results are presented in Figure 33 and Figure 34. All the encoders except hardware–based (Intel QuickSync and MainConcept CUDA) have a similar growth rate for encoding time as the bitrate is increased. Intel Ivy Bridge QuickSync is the fastest, followed by DivX H.264.

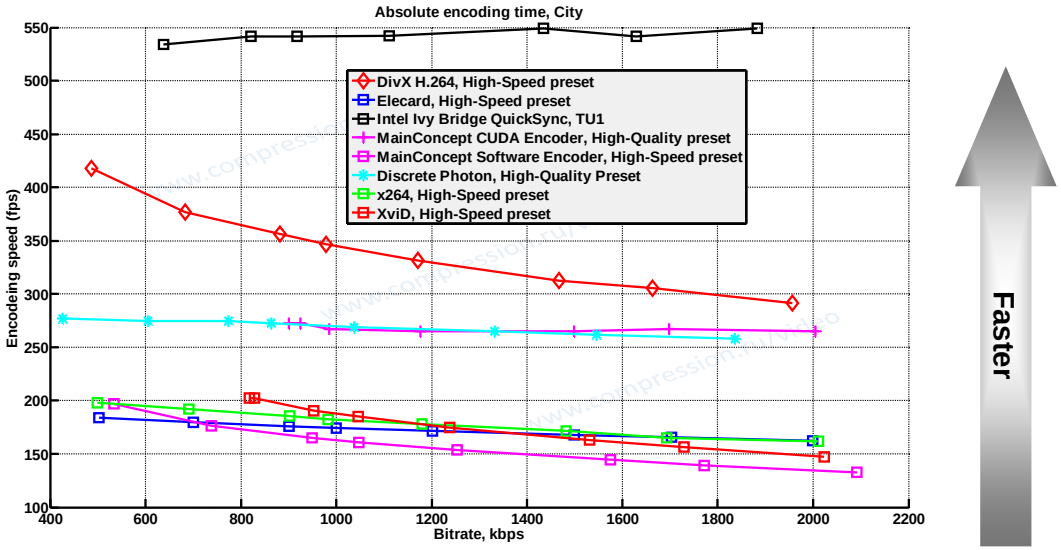

Figure 33. Encoding speed—usage area "Movie" "City" sequence, "High Speed" preset

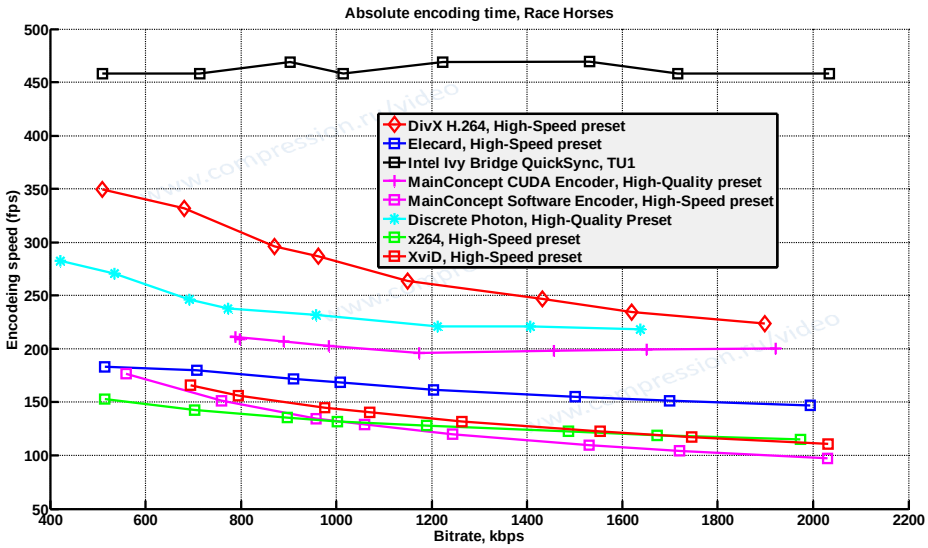

Figure 34. Encoding speed—usage area "Movies" "Race Horses" sequence, High Speed preset

4.2.2.2 Normal Preset

Absolute speed results are presented in Figure 35 through Figure 37. All the encoders hardware-based have a similar growth rate for encoding time versus increasing bitrate. Intel Ivy Bridge QuickSync is the fastest encoder at all the sequences followed by MainConcept CUDA and DiscretePhoton.

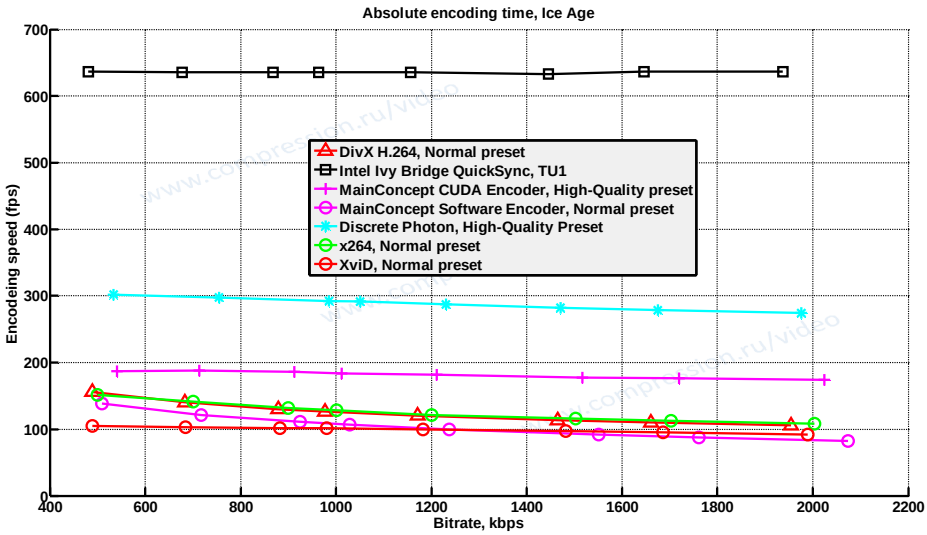

Figure 35. Encoding speed—usage area "Movies"
"Ice Age" sequence, Normal preset

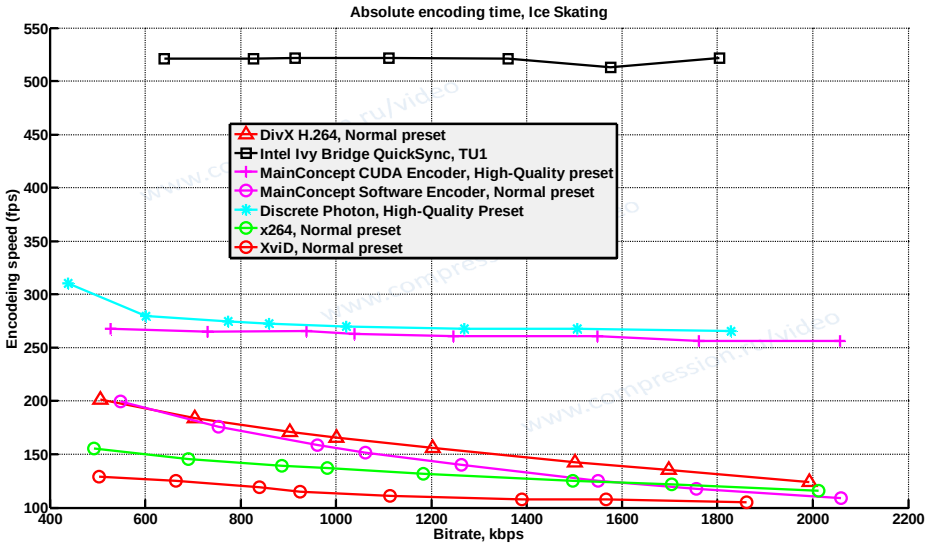

Figure 36. Encoding speed—usage area "Movies"
"Ice Skating" sequence, Normal preset

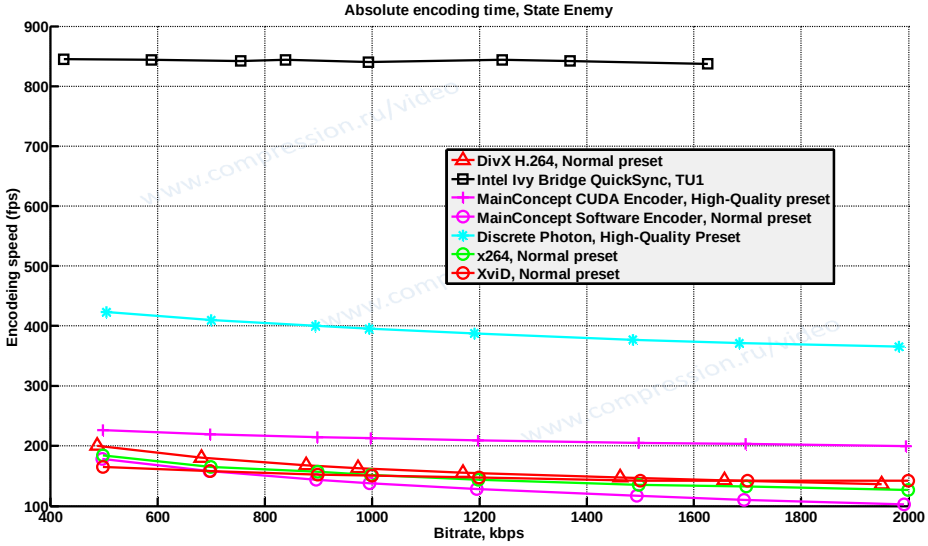

Figure 37. Encoding speed—usage area "Movies"
"State Enemy" sequence, Normal preset

4.2.2.3 High Quality Preset

Absolute speed results are presented in Figure 38 through Figure 39. The situation is close to Normal Speed preset at average.

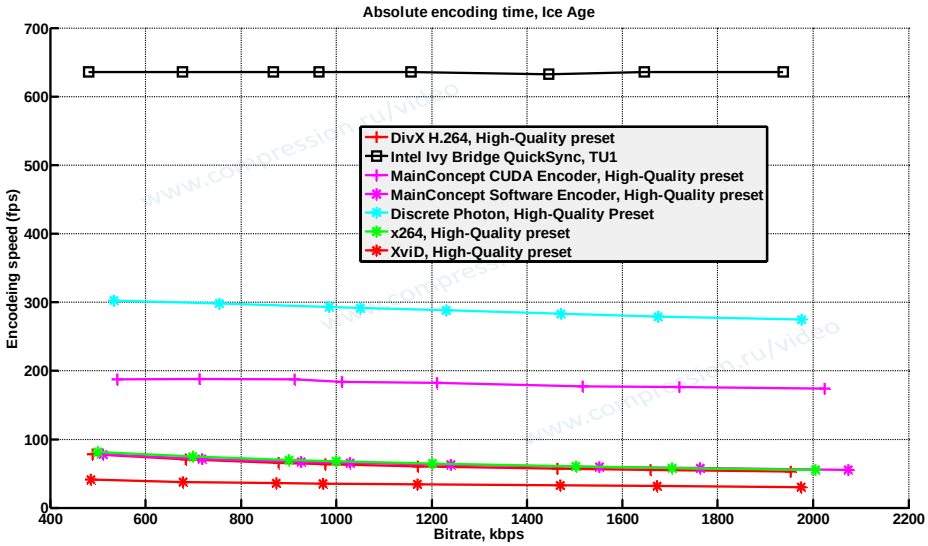

Figure 38. Encoding speed—usage area "Movies"
"Ice Age" sequence, High Quality preset

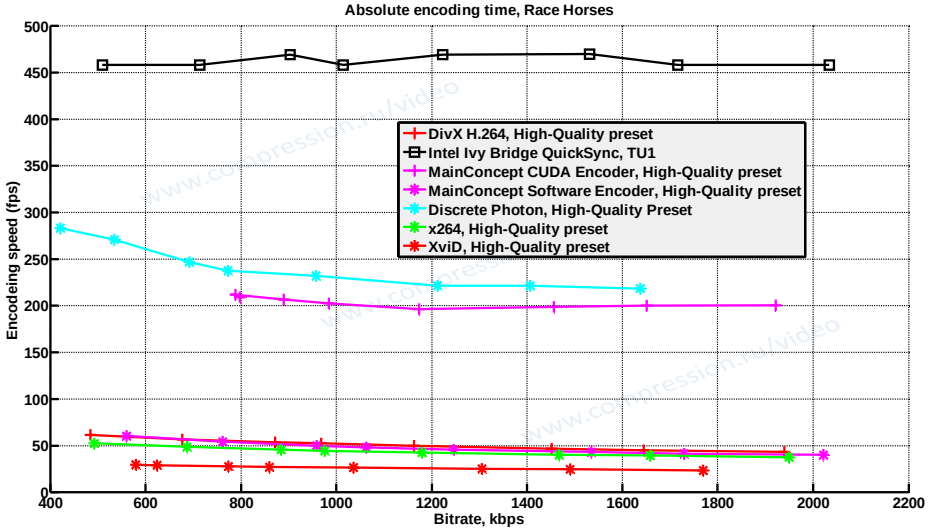

Figure 39. Encoding speed—usage area "Movies"
"Race Horses" sequence, High Quality preset

4.2.3 Speed/Quality Trade-Off

Detailed descriptions of the speed/quality trade-off graphs can be found in Appendix 3. Figures Explanation. Sometimes, codec results are not present in the particular graph owing to the codec's extremely poor performance. The codec's RD curve has no intersection with the reference's RD curve.

The speed/quality trade-off graphs simultaneously show relative quality and encoding speed for the encoders tested in this comparison. XviD is the reference codec, for which both quality and speed are normalized to unity for all of the graphs. The terms "better" and "worse" are used to compare codecs in the same manner as in previous portions of this comparison.

Please note that the method of averaging among all sequences assumes that all codecs produced results for each sequence. When this is not the case, only existing results are taken into account.

4.2.3.1 High Speed Preset

Figure 40 through Figure 43 show results for the High Speed preset. The chosen metric has an influence on results.

The three best codecs (no codec performs faster with higher quality) in terms of speed/quality are x264, Elecard and Intel Ivy Bridge QuickSync at average. But there are sequences where it is not true, for example at Crew sequence MainConcept is better than x264. PSNR metric usage does not change the result strongly.

Results for all the sequences, all metrics and all encoders are available in ***Enterprise version*** *report only.*

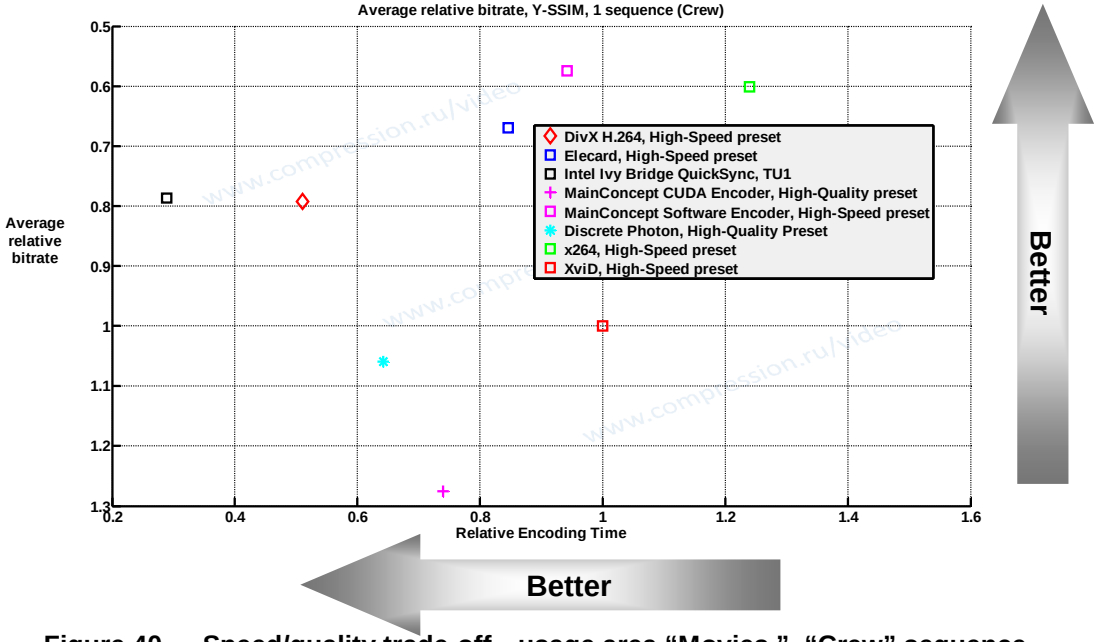

Figure 40. Speed/quality trade-off—usage area "Movies," "Crew" sequence, High Speed preset, Y-SSIM metric

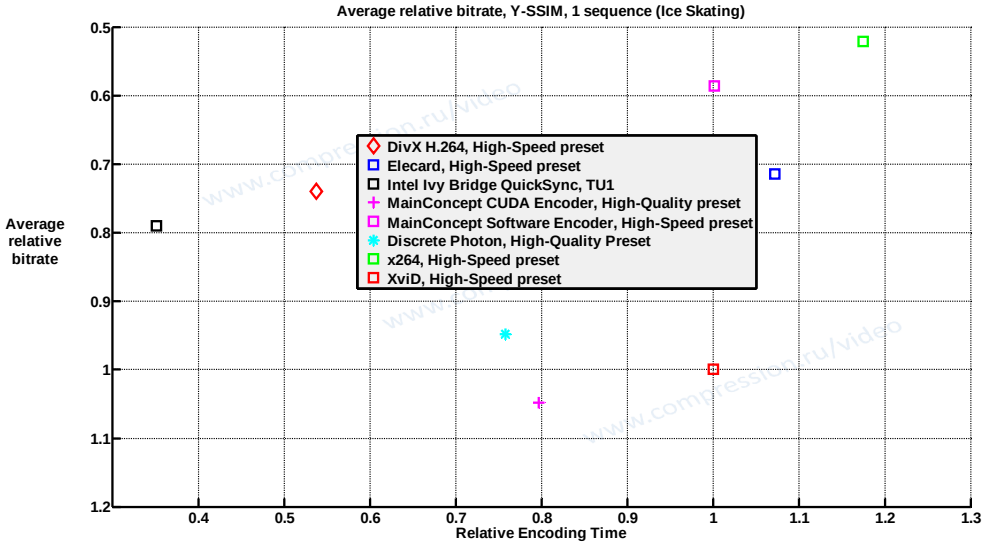

Figure 41. Speed/quality trade-off—usage area "Movies," "Ice Skating" sequence, High Speed preset, Y-SSIM metric

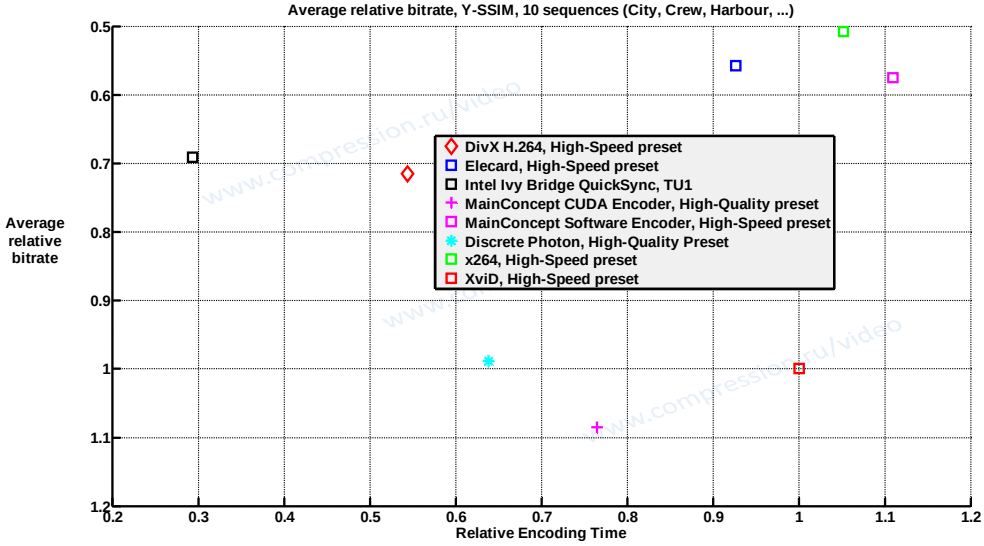

Figure 42. Speed/quality trade-off—usage area "Movies," All "Movie" sequences, High Speed preset, Y-SSIM metric

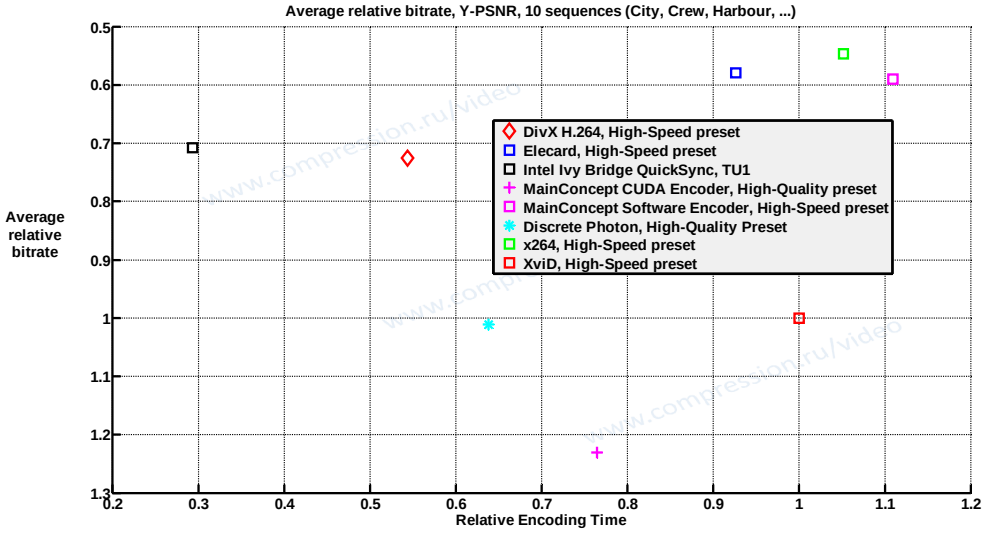

Figure 43. Speed/quality trade-off—usage area "Movies," All "Movie" sequences, High Speed preset, Y-PSNR metric

4.2.3.2 Normal Preset

Figure 44 through Figure 47 show results for the Normal preset. The results differ slightly depending on the chosen metric.

Three encoders (x264, DivX H.264 and Intel QuickSync) are best (no codec performs faster with higher quality) in terms of speed/quality at average. But there are sequences where it is not true, for example at Crew sequence codecs change their places.

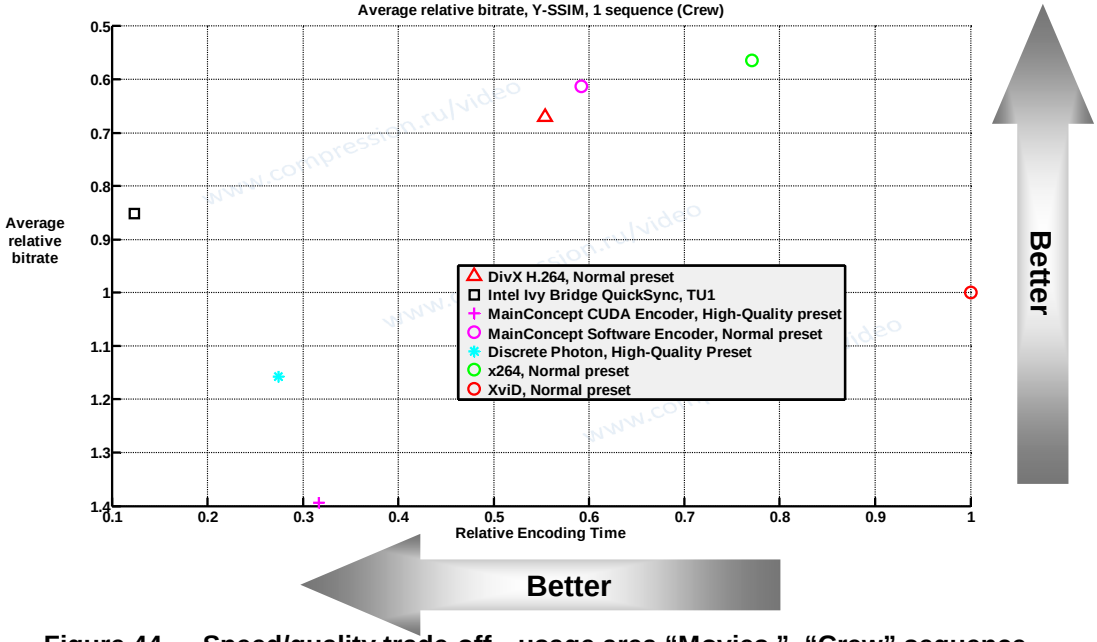

Figure 44. Speed/quality trade-off—usage area "Movies," "Crew" sequence, Normal preset, Y-SSIM metric

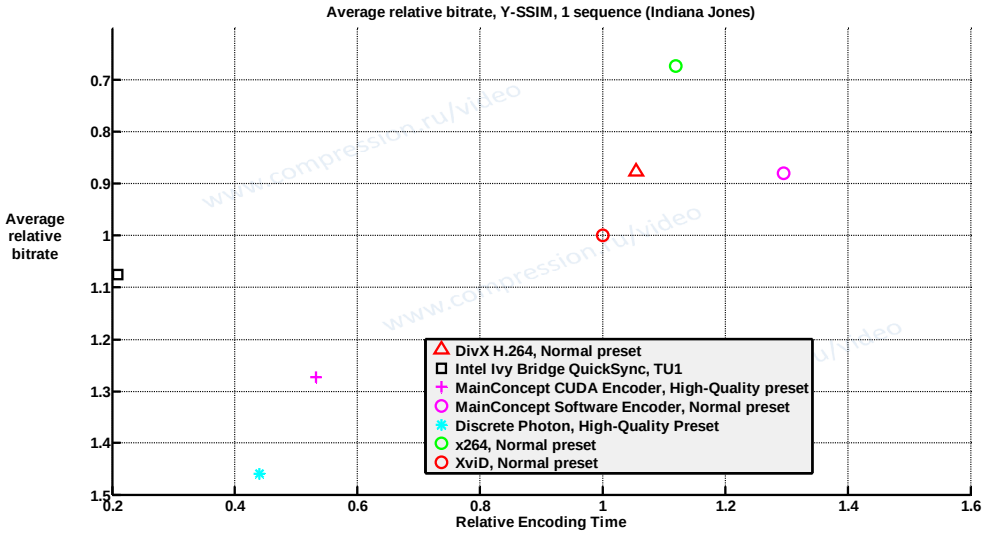

Figure 45. Speed/quality trade-off—usage area "Movies," "Indiana Jones" sequence, Normal preset, Y-SSIM metric

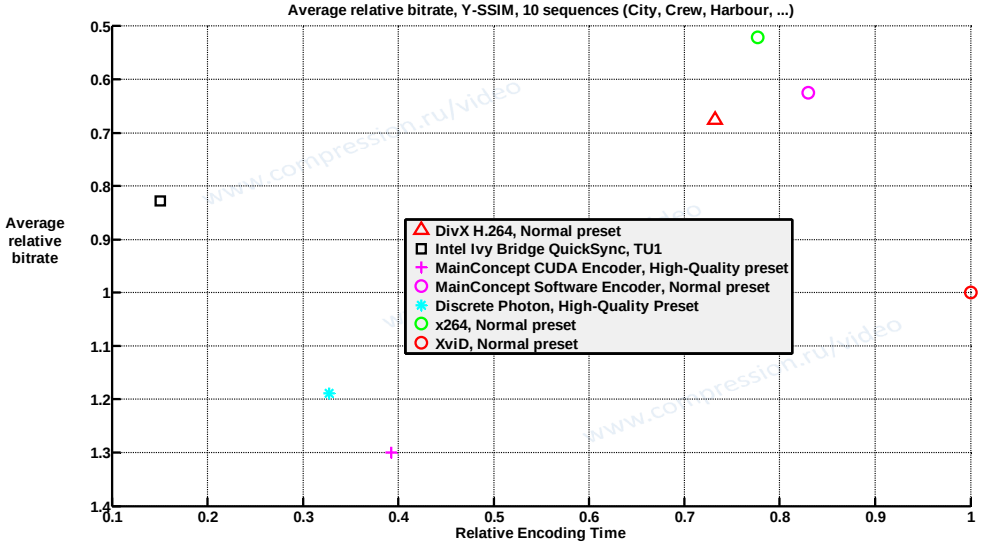

Figure 46. Speed/quality trade-off—usage area "Movies," All "Movie" sequences, Normal preset, Y-SSIM metric

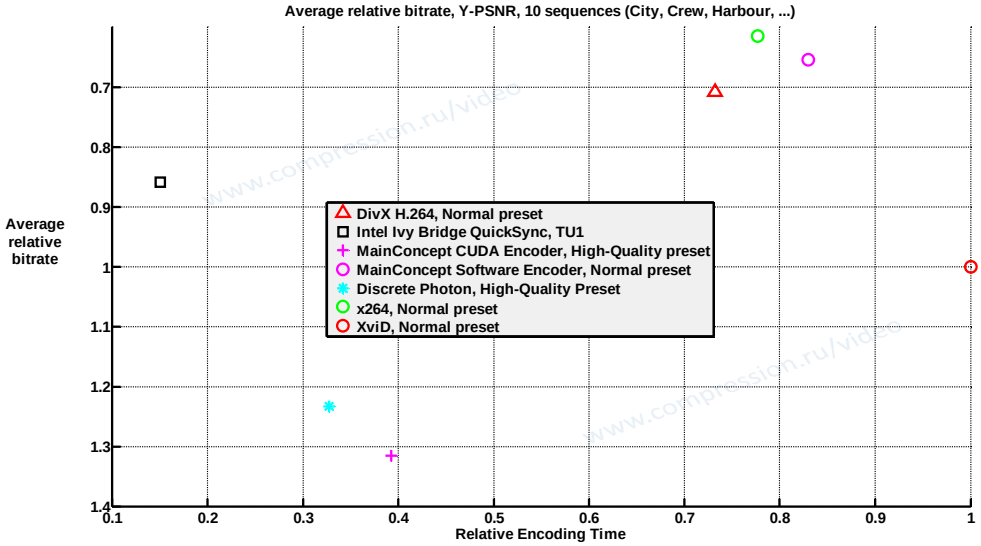

Figure 47. Speed/quality trade-off—usage area "Movies," All "Movie" sequences, Normal preset, Y-PSNR metric

4.2.3.3 High Quality Preset

Figure 48 through Figure 51 show results for the High Quality preset. The results slightly depend on the chosen metric.

The four best codecs (no codec performs faster with higher quality) in terms of speed/quality are Intel Ivy Bridge QuickSync, DivX H.264, MainConcept and x264 at average (DivX H.264 and MainConcept results are very close) But there are sequences where results differ to average.

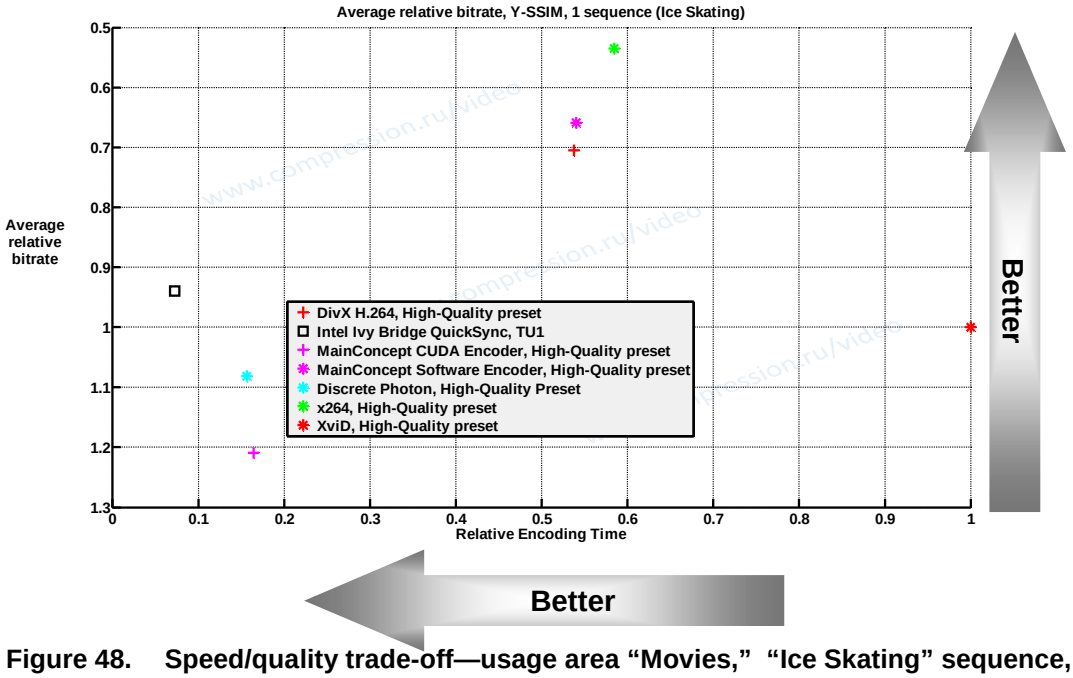

Figure 48. Speed/quality trade-off—usage area "Movies," "Ice Skating" sequence, High Quality preset, Y-SSIM metric

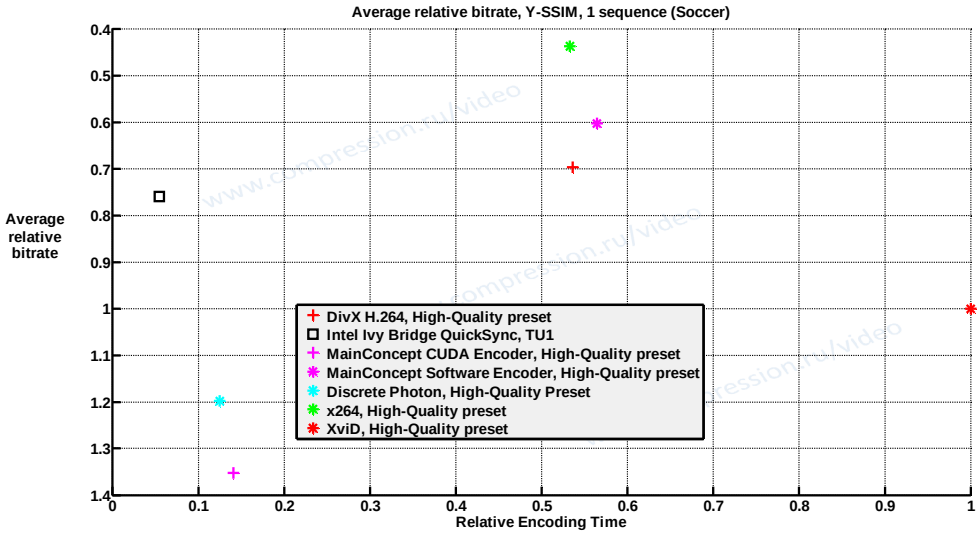

Figure 49. Speed/quality trade-off—usage area "Movies," "Soccer" sequence, High Quality preset, Y-SSIM metric

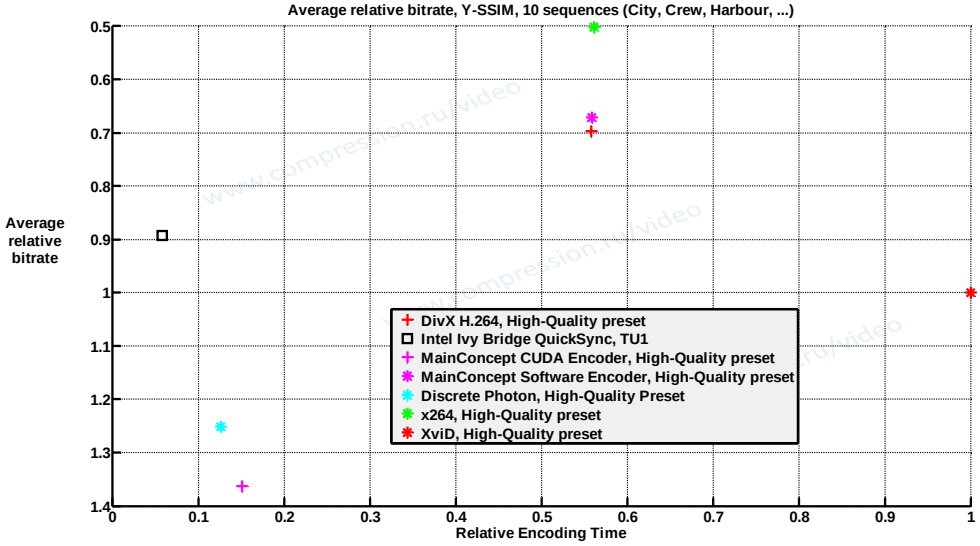

Figure 50. Speed/quality trade-off—usage area "Movies," All "Movie" sequences, High Quality preset, Y-SSIM metric

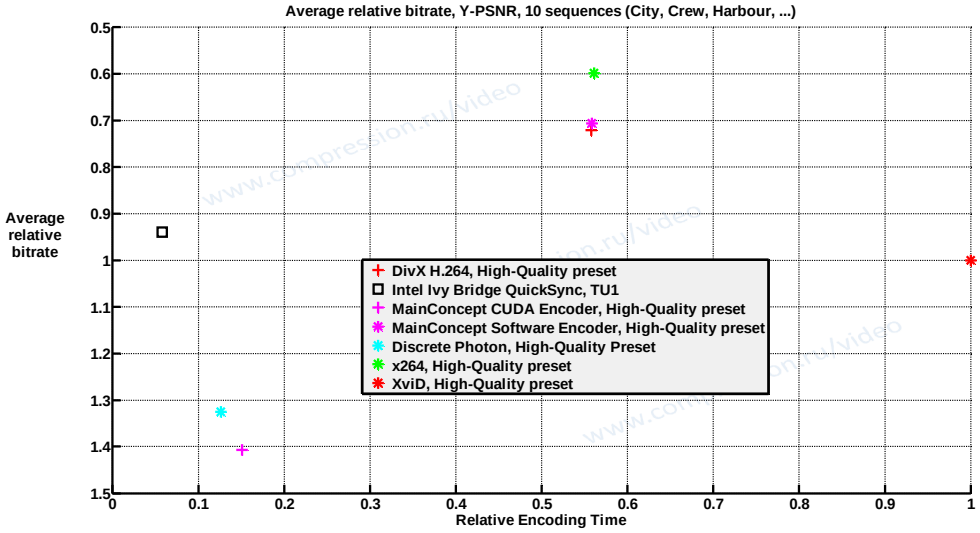

Figure 51. Speed/quality trade-off—usage area "Movies," All "Movie" sequences, High Quality preset, Y-PSNR metric

4.2.4 Bitrate Handling

4.2.4.1 High Speed Preset

Encoders with High Speed presets, except the XviD encoder, demonstrate good bitrate handling for all sequences. There are some issues with bitrate handling for MainConcept CUDA encoder for some sequences (for example City and Race Horses sequences).

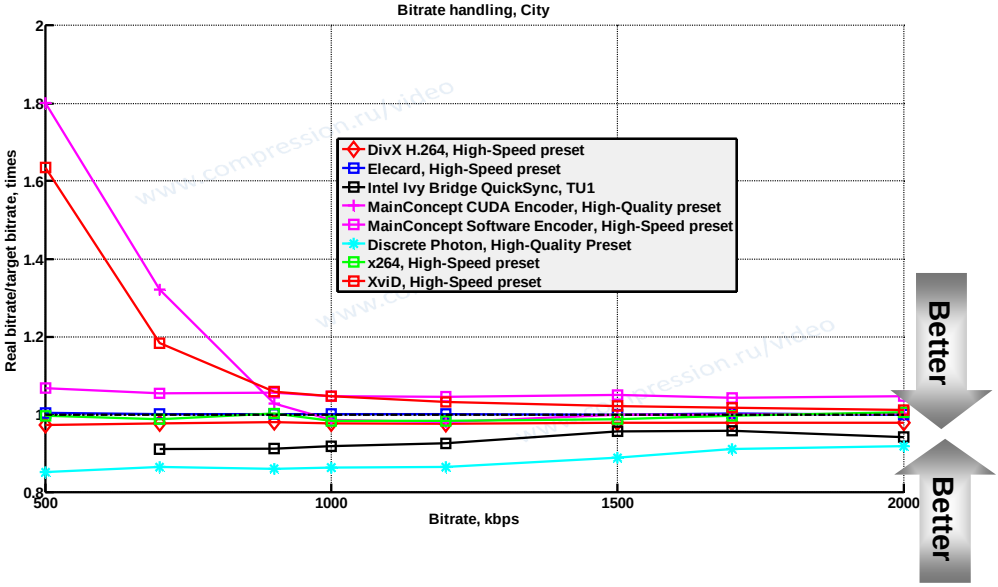

Figure 52. Bitrate handling—usage area "Movies," "City" sequence, High Speed preset

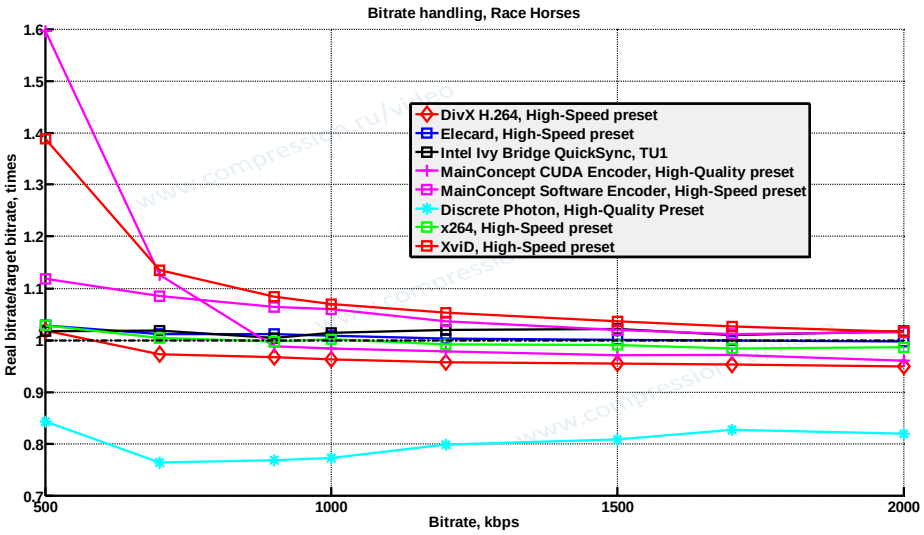

Figure 53. Bitrate handling—usage area "Movies," "Race Horses" sequence, High Speed preset

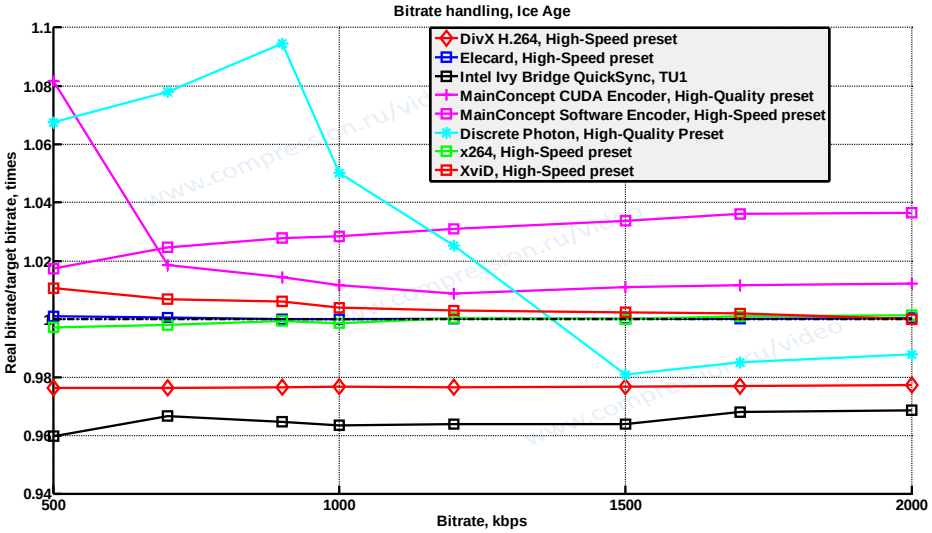

Figure 54. Bitrate handling—usage area "Movies," "Ice Age" sequence, High Speed preset

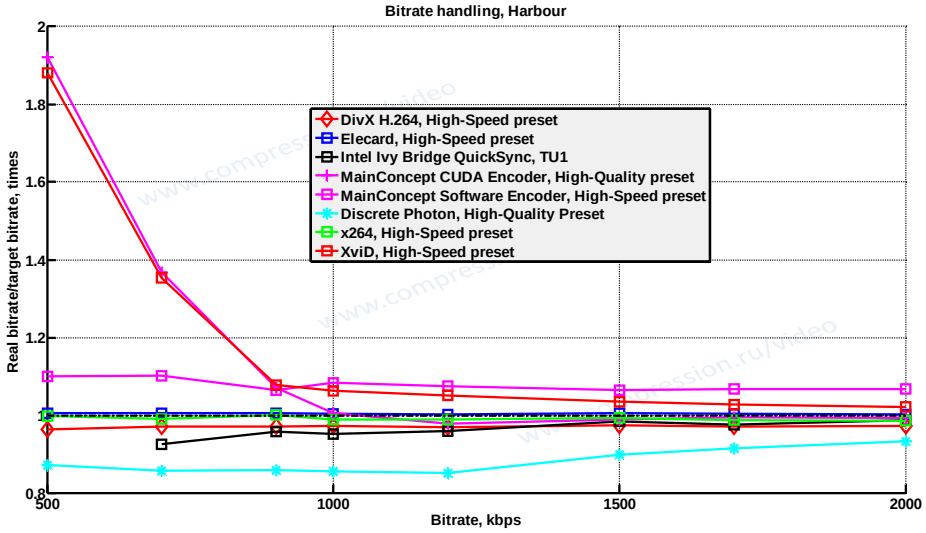

Figure 55. Bitrate handling—usage area "Movies," "Harbour" sequence, High Speed preset

4.2.4.2 Normal Preset

Results are close to HighSpeed results: encoders with High Speed presets, except the XviD encoder and MainConcept CUDA, demonstrate good bitrate handling for all sequences.

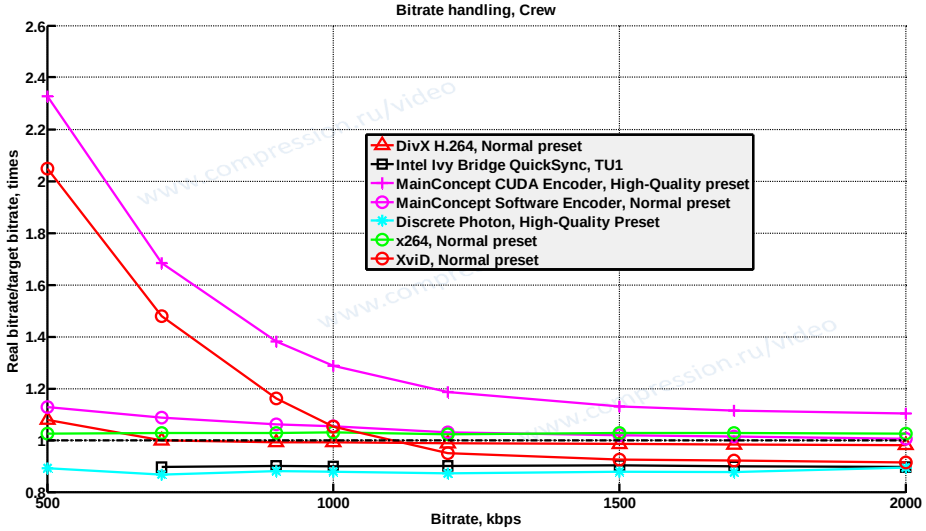

Figure 56. Bitrate handling—usage area "Movies," "Crew" sequence, Normal preset

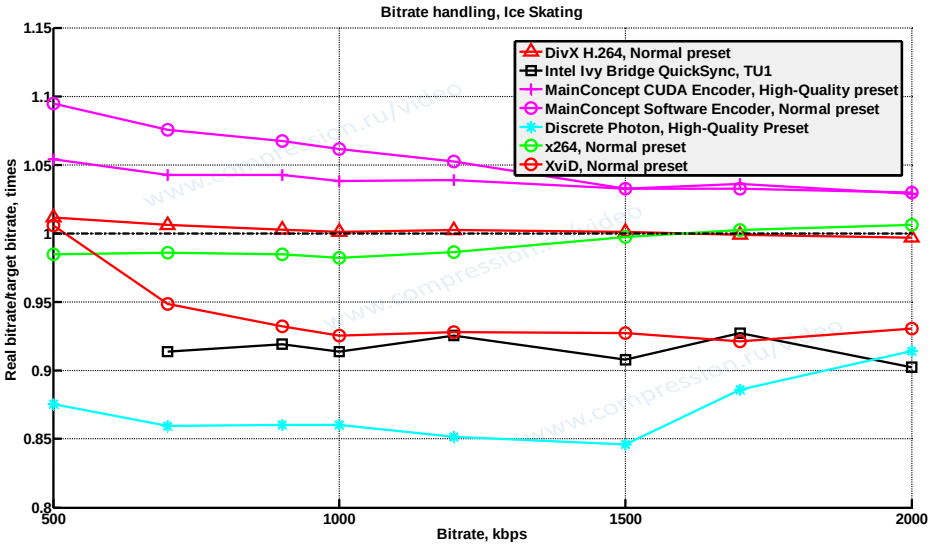

Figure 57. Bitrate handling—usage area "Movies," "Ice Skating" sequence, Normal preset

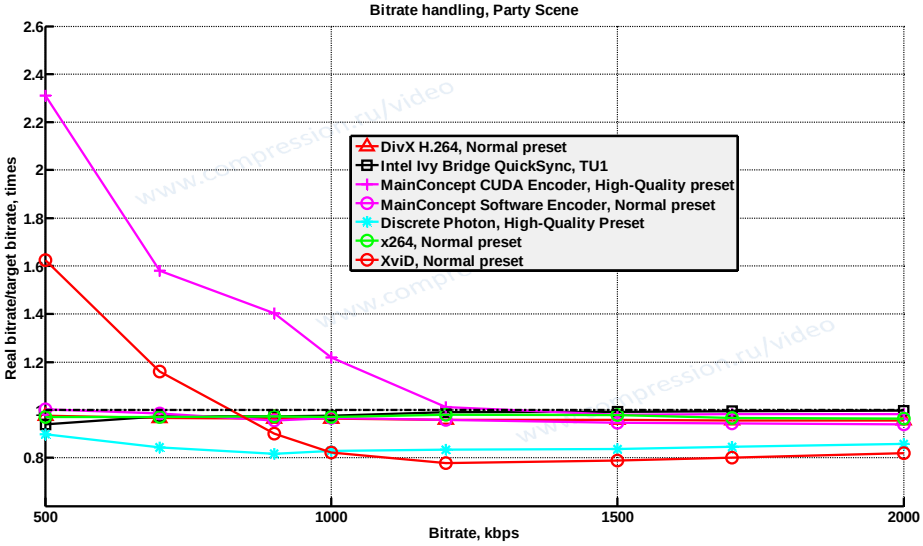

Figure 58. Bitrate handling—usage area "Movies," "Party Scene" sequence, Normal preset

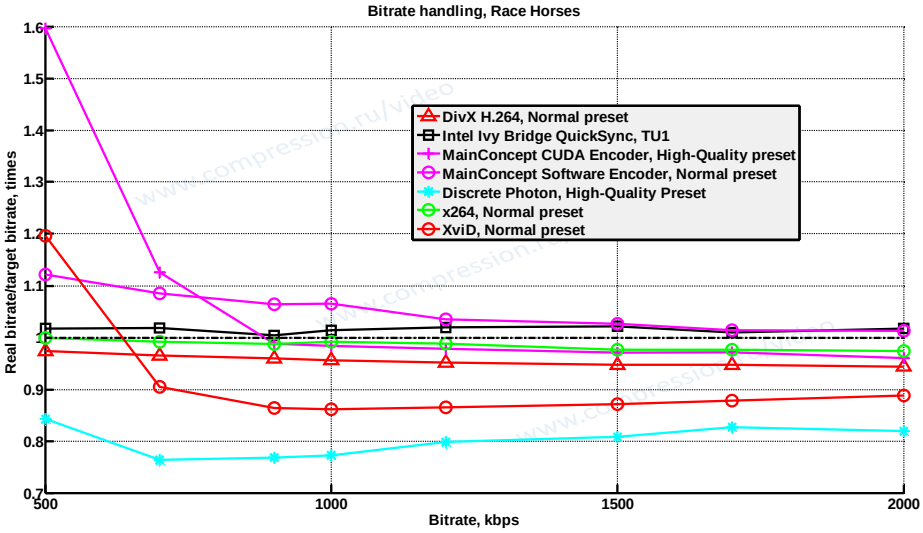

Figure 59. Bitrate handling—usage area "Movies," "Race Horses" sequence, Normal preset

4.2.4.3 High Quality Preset

The results are quite close to HighSpeed and Normal presets: all encoders show good bitrate handling mechanisms except XviD, with some issues for MainConcept and DiscretePhoton.

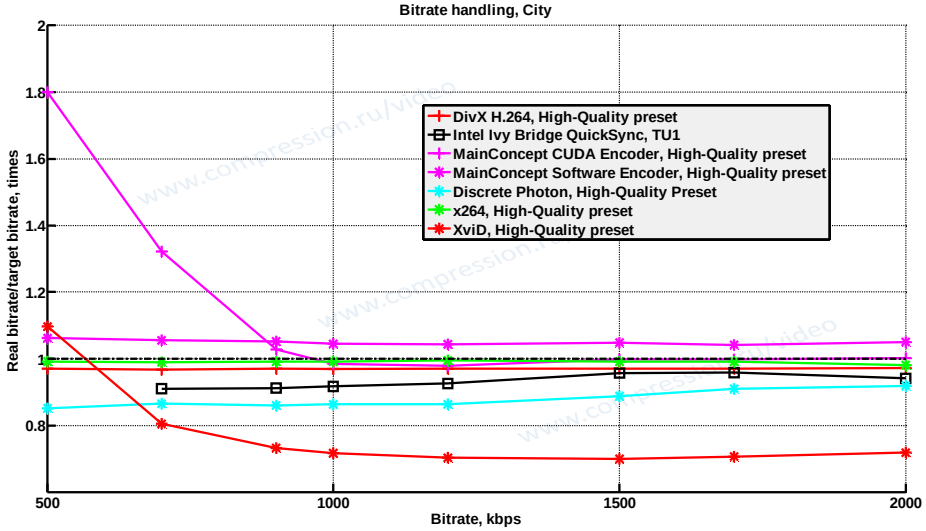

Figure 60. Bitrate handling—usage area "Movies," "City" sequence, High Quality preset

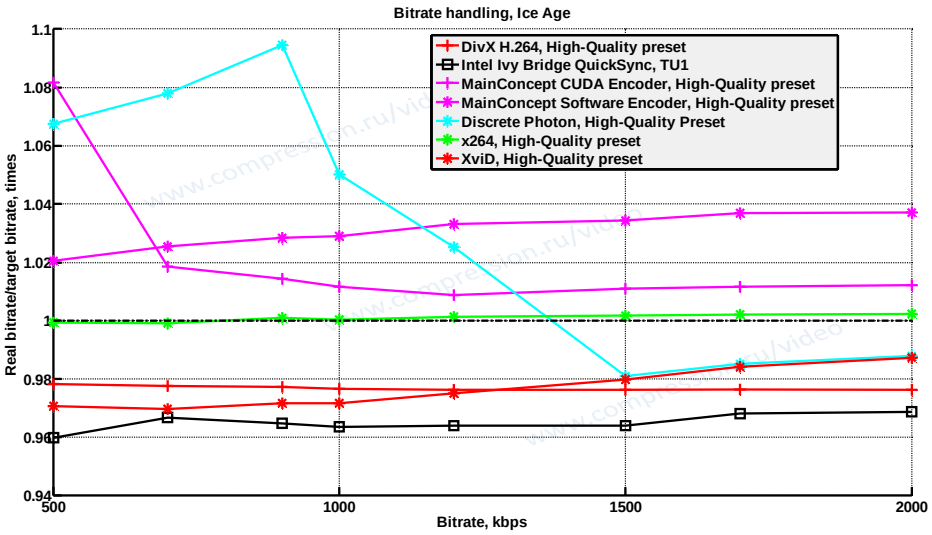

Figure 61. Bitrate handling—usage area "Movies," "Ice Age" sequence, High Quality preset

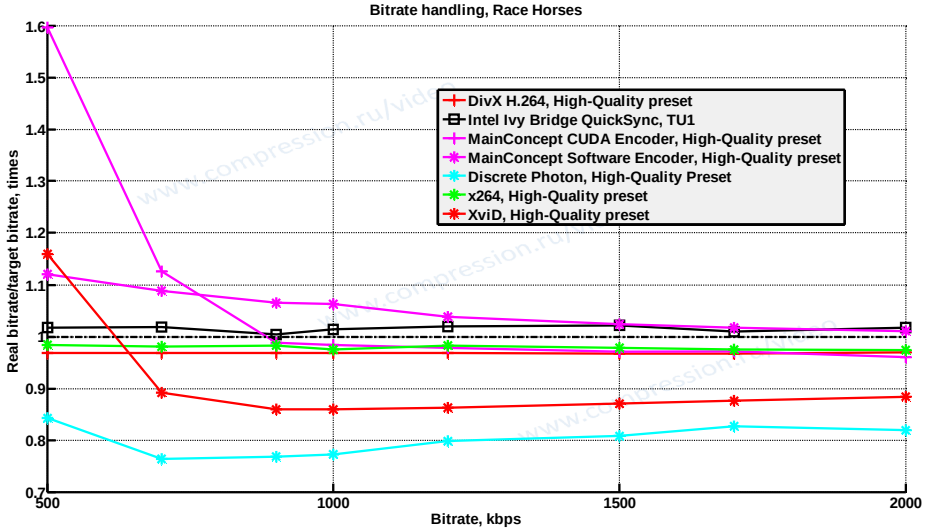

Figure 62. Bitrate handling—usage area "Movies," "Race Horses" sequence, High Quality preset

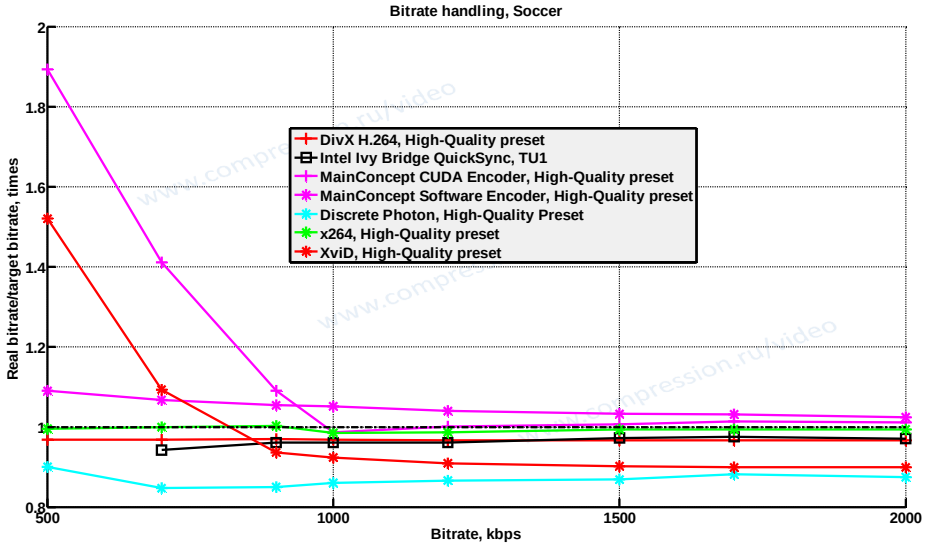

Figure 63. Bitrate handling—usage area "Movies," "Soccer" sequence, High Quality preset

4.2.5 Relative Quality Analysis

Table 5 through Table 10 show relative bitrates for a fixed quality output for all codecs and presets. Note that these tables do not include information about the speed of the encoder.

Note that each number in the tables below corresponds to some range of bitrates (see Appendix 3. Figures Explanation for more details). Unfortunately, these ranges can differ significantly because of differences in the quality of compared encoders. This situation can lead to some inadequate results when three or more codecs are compared.

Consider the High Speed preset (Y-SSIM results in Table 5 and Y-PSNR results in Table 6). On average, the leader is the x264 encoder and MainConcept with Elecard encoders are second (Elecard is better than MainConcept).

Table 7 and Table 8 present the Normal preset results for the Y-SSIM and Y-PSNR quality metrics, respectively. The results are similar to those of the

High Speed preset: the leader is the x264 encoder and MainConcept is second.

Table 9 and Table 10 present the High Quality preset results for the Y-SSIM and Y-PSNR quality metrics, respectively. The results are very similar to those of the Normal preset: the leader is the x264 encoder and MainConcept encoder is second.

Table 5. Average bitrate ratio for the same quality. Usage area "Movie". "High Speed" preset, Y-SSIM.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	80%	97%	155%	74%	140%	65%	140%
Elecard	126%	100%	115%	190%	91%	178%	82%	179%
Intel QuickSync	104%	87%	100%	183%	77%	147%	67%	145%
MainConcept CUDA	65%	53%	55%	100%	48%	77%	45%	92%
MainConcept	135%	110%	130%	208%	100%	194%	88%	174%
Discrete Photon	72%	56%	68%	130%	52%	100%	46%	101%
x264	154%	122%	148%	224%	114%	217%	100%	197%
XviD	72%	56%	69%	108%	58%	99%	51%	100%

Table 6. Average bitrate ratio for the same quality. Usage area "Movie". "High Speed" preset, Y-PSNR.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	81%	97%	154%	75%	141%	75%	138%
Elecard	123%	100%	115%	187%	91%	178%	93%	173%
Intel QuickSync	103%	87%	100%	179%	77%	147%	77%	141%
MainConcept CUDA	65%	53%	56%	100%	49%	80%	50%	81%
MainConcept	133%	109%	130%	205%	100%	192%	100%	169%
Discrete Photon	71%	56%	68%	125%	52%	100%	52%	99%
x264	133%	108%	130%	202%	100%	191%	100%	183%
XviD	73%	58%	71%	123%	59%	101%	55%	100%

Table 7. Average bitrate ratio for the same quality. Usage area "Movie". "Normal" preset, Y-SSIM.

	DivX	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	124%	195%	94%	180%	78%	148%
Intel QuickSync	81%	100%	183%	76%	147%	63%	121%
MainConcept CUDA	51%	55%	100%	48%	77%	41%	77%
MainConcept	106%	132%	210%	100%	197%	83%	160%
Discrete Photon	56%	68%	130%	51%	100%	42%	84%
x264	128%	160%	243%	121%	236%	100%	192%
XviD	68%	83%	130%	62%	119%	52%	100%

Table 8. Average bitrate ratio for the same quality. Usage area "Movie". "Normal" preset, Y-PSNR.

	DivX	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	123%	192%	94%	177%	89%	141%
Intel QuickSync	82%	100%	179%	76%	147%	72%	116%
MainConcept CUDA	52%	56%	100%	48%	80%	46%	76%
MainConcept	107%	131%	207%	100%	194%	95%	153%
Discrete Photon	56%	68%	125%	51%	100%	48%	81%
x264	113%	140%	218%	106%	207%	100%	163%
XviD	71%	86%	132%	65%	123%	61%	100%

Table 9. Average bitrate ratio for the same quality. Usage area "Movie". "High Quality" preset, Y-SSIM.

	DivX	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	129%	201%	96%	189%	71%	144%
Intel QuickSync	77%	100%	183%	74%	147%	54%	112%
MainConcept CUDA	50%	55%	100%	47%	77%	36%	73%
MainConcept	104%	135%	214%	100%	200%	73%	149%
Discrete Photon	53%	68%	130%	50%	100%	37%	80%
x264	142%	184%	277%	137%	272%	100%	199%
XviD	70%	89%	136%	67%	125%	50%	100%

Table 10. Average bitrate ratio for the same quality. Usage area "Movie". "High Quality" preset, Y-PSNR.

	DivX	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	131%	201%	98%	191%	83%	139%
Intel QuickSync	76%	100%	179%	75%	147%	63%	106%
MainConcept CUDA	50%	56%	100%	47%	80%	41%	71%
MainConcept	102%	133%	211%	100%	198%	85%	141%
Discrete Photon	52%	68%	125%	51%	100%	42%	75%
x264	120%	159%	246%	118%	236%	100%	167%
XviD	72%	94%	141%	71%	133%	60%	100%

Figure 64 through Figure 69 depict the data from the tables above. Each line in the figures corresponds to one codec. Values on the vertical axis are the average relative bitrates compared with the codecs along the horizontal axis. A lower bitrate indicates better relative results.

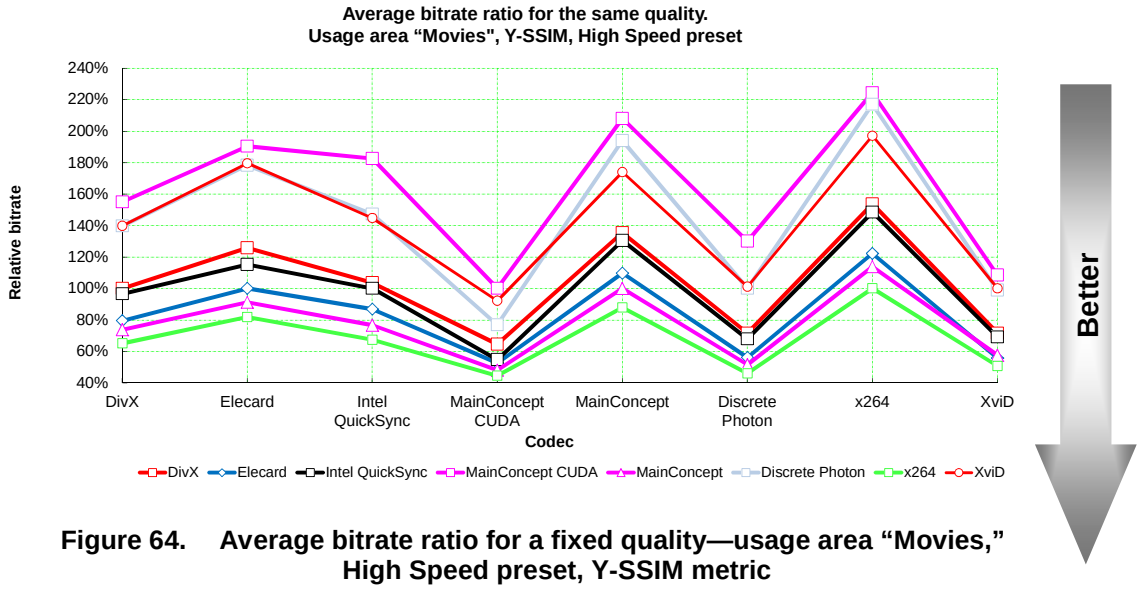

Figure 64. Average bitrate ratio for a fixed quality—usage area "Movies," High Speed preset, Y-SSIM metric

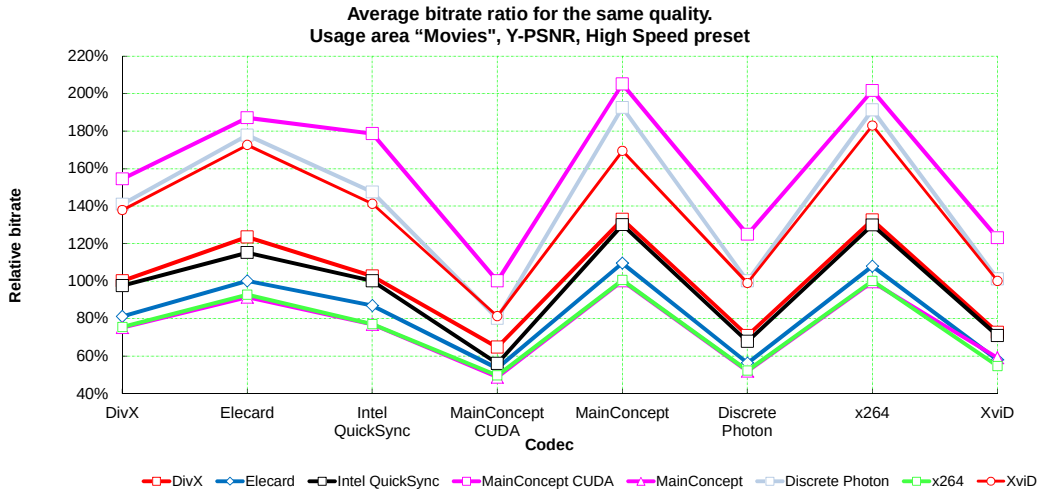

Figure 65. Average bitrate ratio for a fixed quality—usage area "Movies". High Speed preset, Y-PSNR metric.

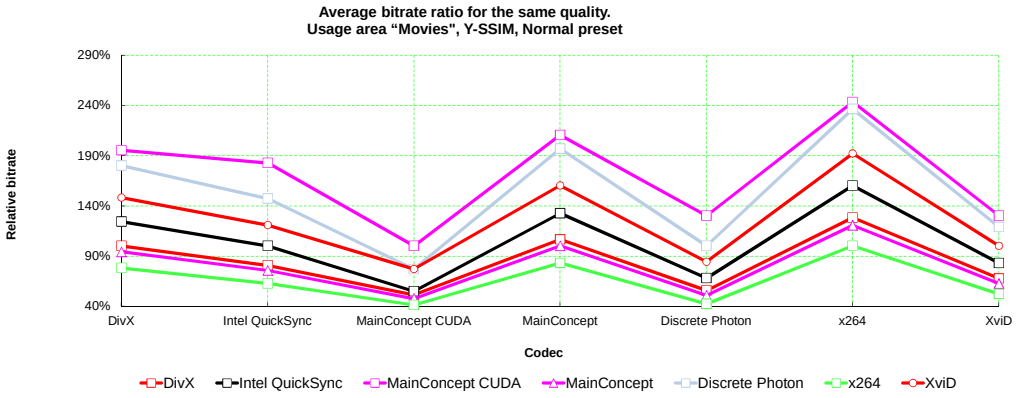

Figure 66. Average bitrate ratio for a fixed quality—usage area "Movies". Normal preset, Y-SSIM metric.

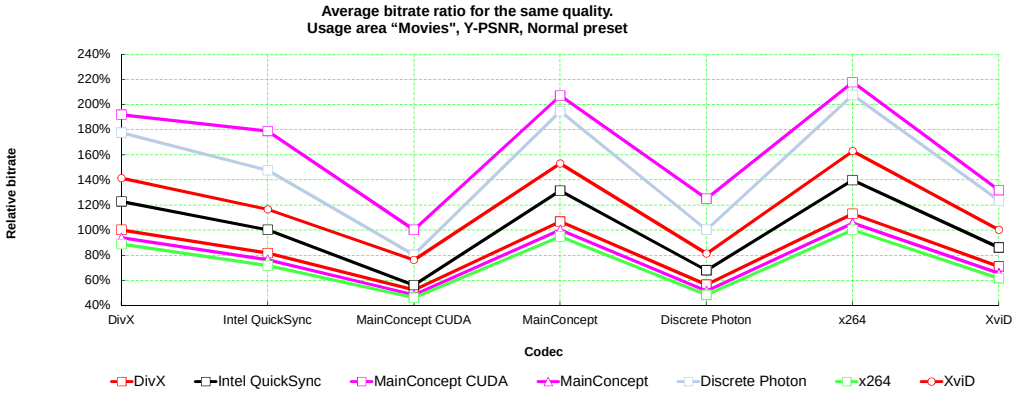

Figure 67. Average bitrate ratio for a fixed quality—usage area "Movies". Normal preset, Y-PSNR metric.

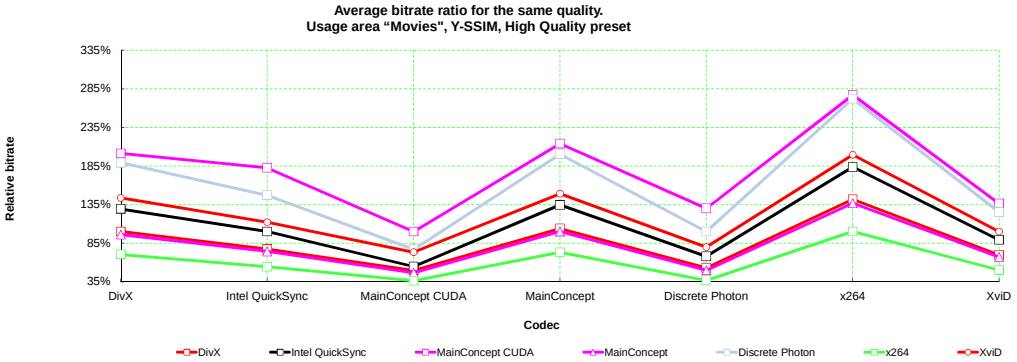

Figure 68. Average bitrate ratio for a fixed quality—usage area "Movies". High Speed preset, Y-SSIM metric.

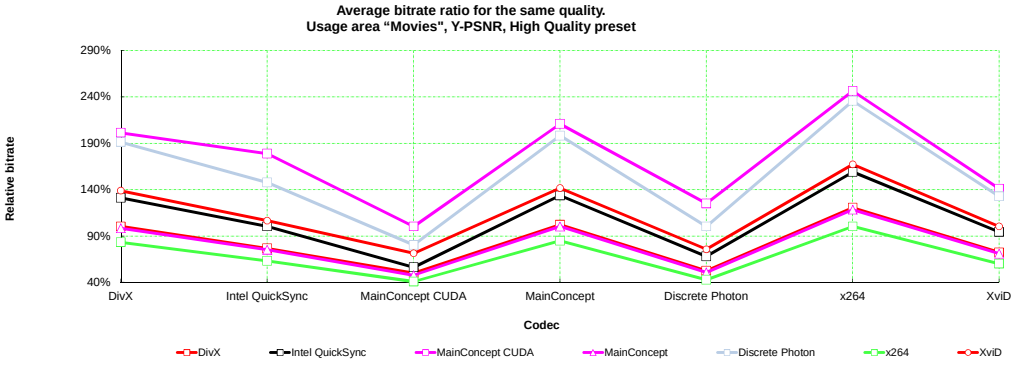

Figure 69. Average bitrate ratio for a fixed quality—usage area "Movies". High Quality preset, Y-PSNR metric.

4.3 HDTV

4.3.1 RD Curves

4.3.1.1 High Speed Preset

The High Speed preset results for each sequence are presented in Figure 70 through Figure 73. The leader is x264 followed by MainConcept (very close) at average but there are some video sequences (for example, Water Drops), where the situation changes strongly – the leader is MainConcept and x264 shows only fourth result. The next three encoders show second result close to each other: Elecard, DivX H.264 and Intel Ivy Bridge QuickSync.

PSNR metric usage changes the results: for some sequences encoders changes their places.

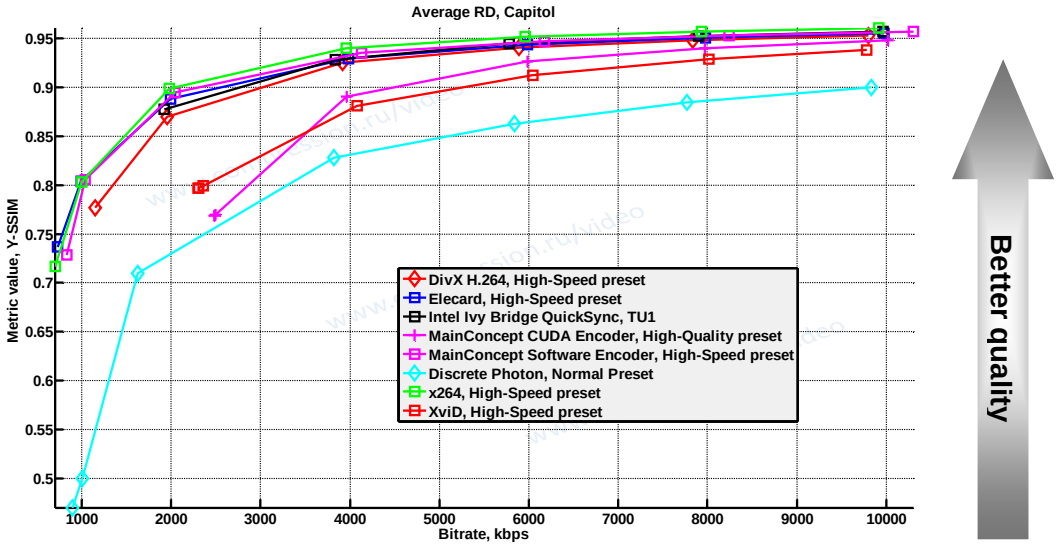

Figure 70. Bitrate/quality—usage area "HDTV," "Capitol" sequence, High Speed preset, Y-SSIM metric

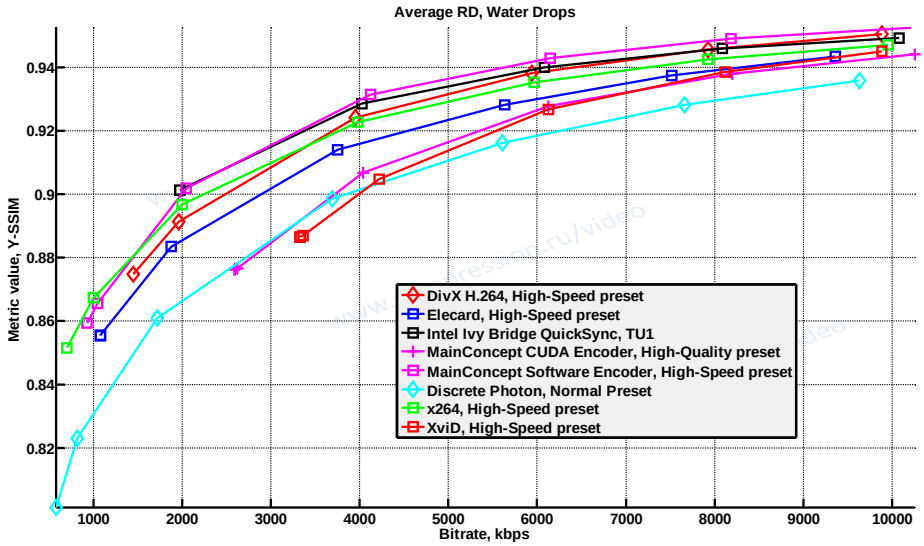

Figure 71. Bitrate/quality—usage area "HDTV," "Water Drops" sequence, High Speed preset, Y-SSIM metric.

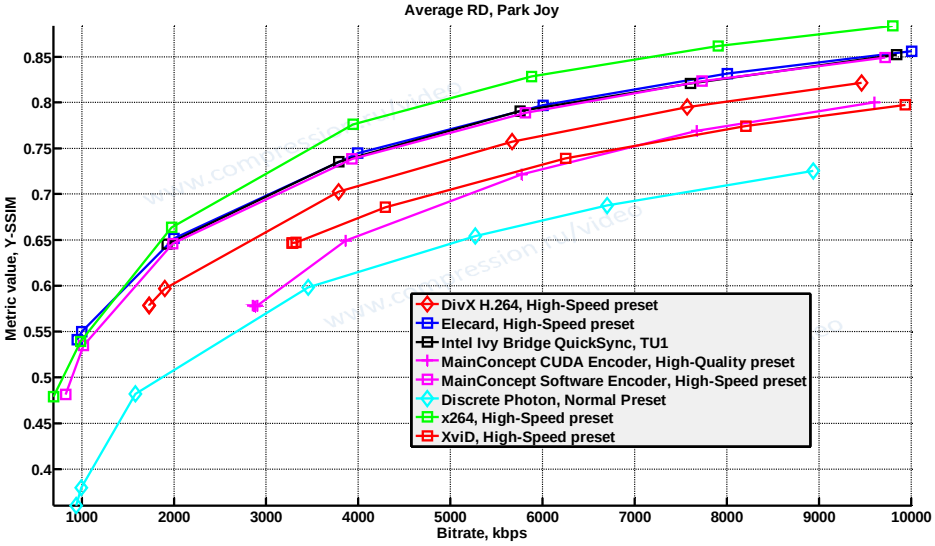

Figure 72. Bitrate/quality—usage area "HDTV," "Park Joy" sequence, High Speed preset, Y-SSIM metric

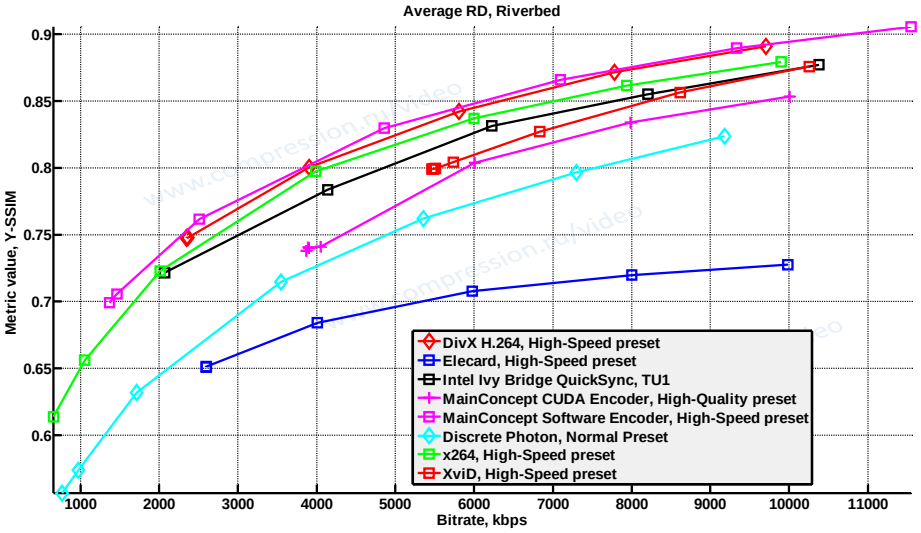

Figure 73. Bitrate/quality—usage area "HDTV," "Riverbed" sequence, High Speed preset, Y-SSIM metric

4.3.1.2 Normal Preset

The Normal preset results for each sequence are presented in Figure 74 through Figure 76.

The situation is close to High Speed preset – x264 is the leader by quality at average, and difference with MainConcept is greater, but Elecard and DivX show very close result.

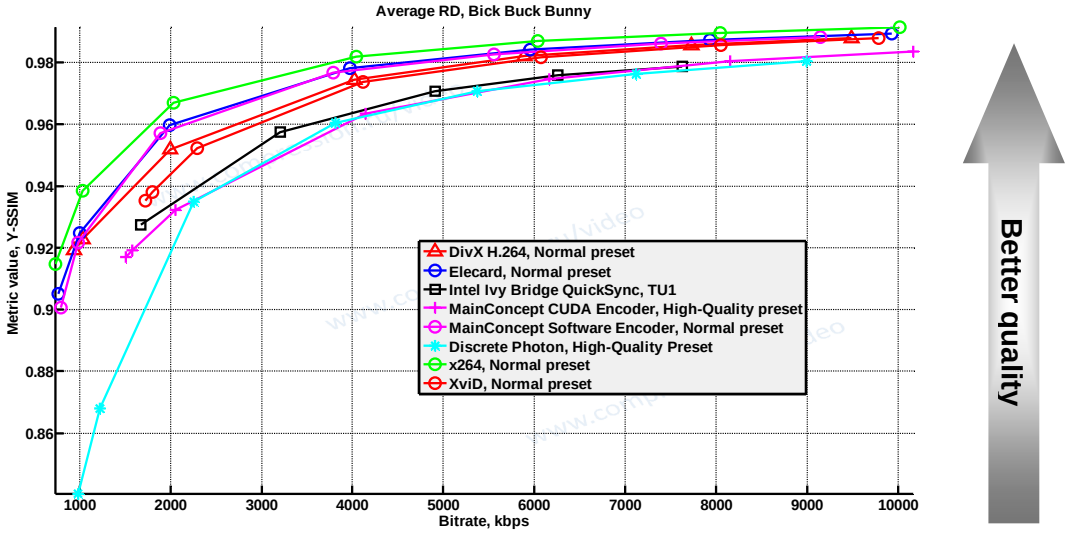

Figure 74. Bitrate/quality—usage area "HDTV," "Big Buck Bunny" sequence, Normal preset, Y-SSIM metric

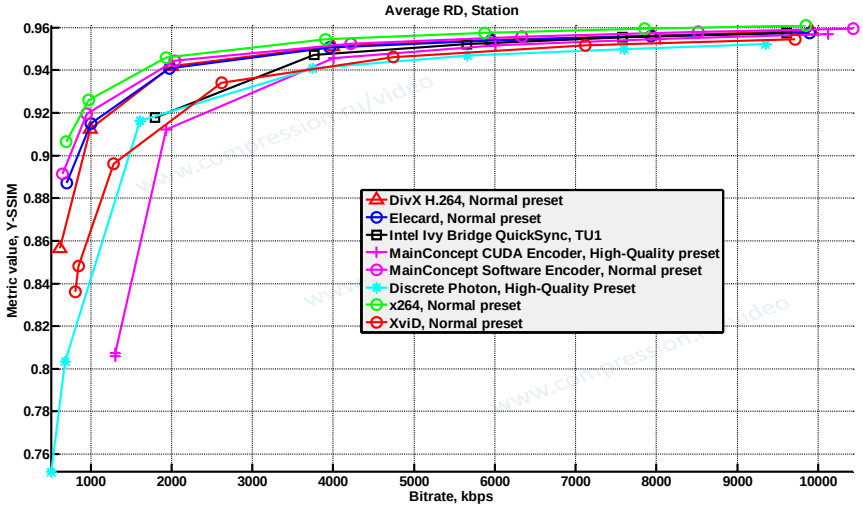

Figure 75. Bitrate/quality—usage area "HDTV," "Station" sequence, Normal preset, Y-SSIM metric

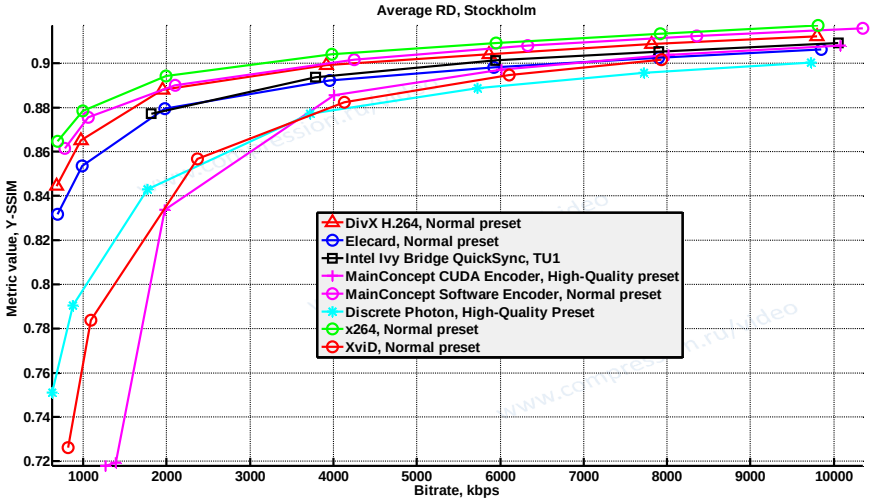

Figure 76. Bitrate/quality—usage area "HDTV," "Stockholm" sequence, Normal preset, Y-SSIM metric

4.3.1.3 High Quality Preset

The High Quality preset results for each sequence are presented in Figure 77 through Figure 80. The leader in this use case is x264, MainCocnpet is second and two encoders are the third: DivX H.264 and Elecard. The DiscretePhoton encoder demonstrates the poorest results close to MainConcept CUDA as for High Speed and Normal presets.

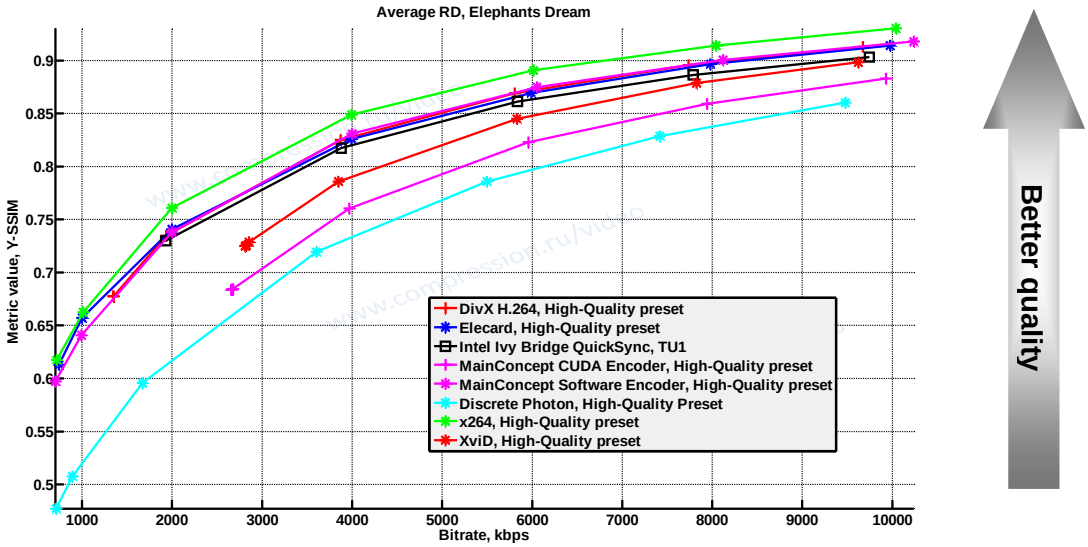

Figure 77. Bitrate/quality—usage area "HDTV," "Elephants Dream" sequence, High Quality preset, Y-SSIM metric

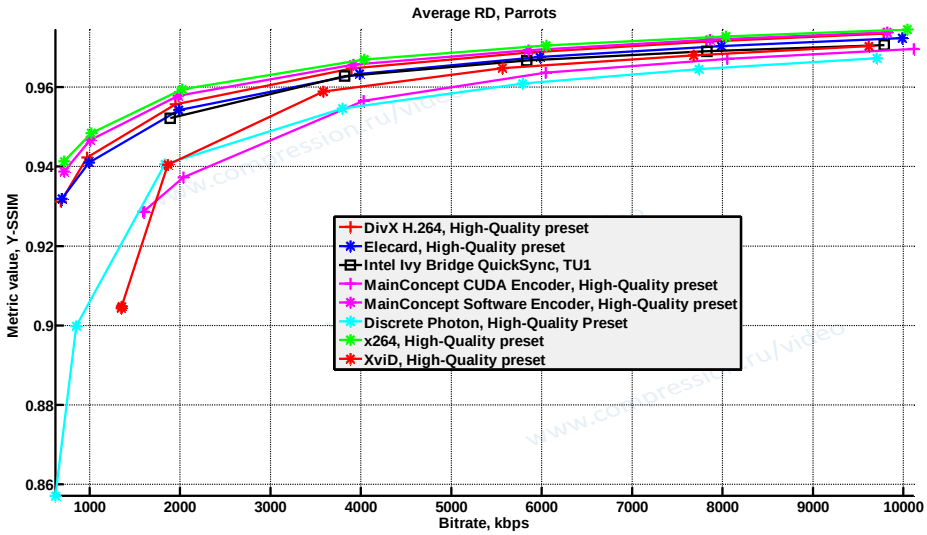

Figure 78. Bitrate/quality—usage area "HDTV," "Parrots" sequence, High Quality preset, Y-SSIM metric

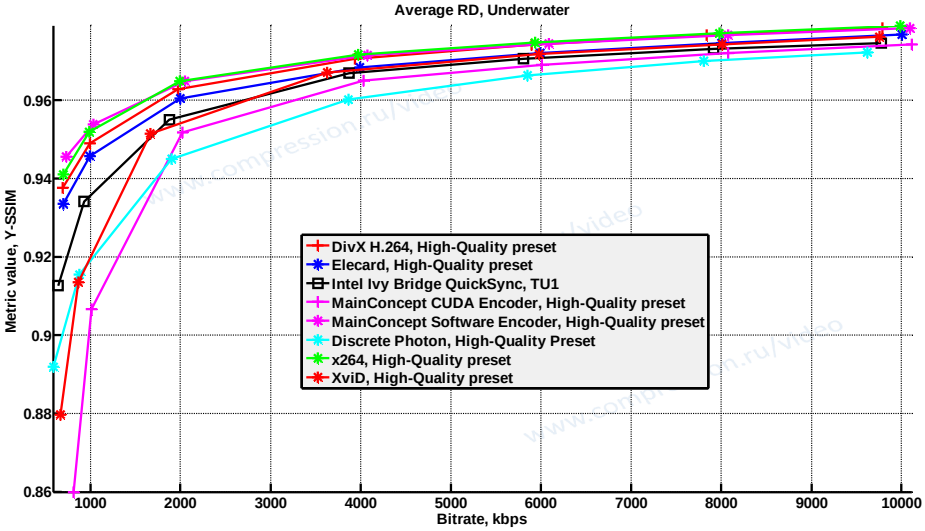

Figure 79. Bitrate/quality—usage area "HDTV," "Underwater" sequence, High Quality preset, Y-SSIM metric.

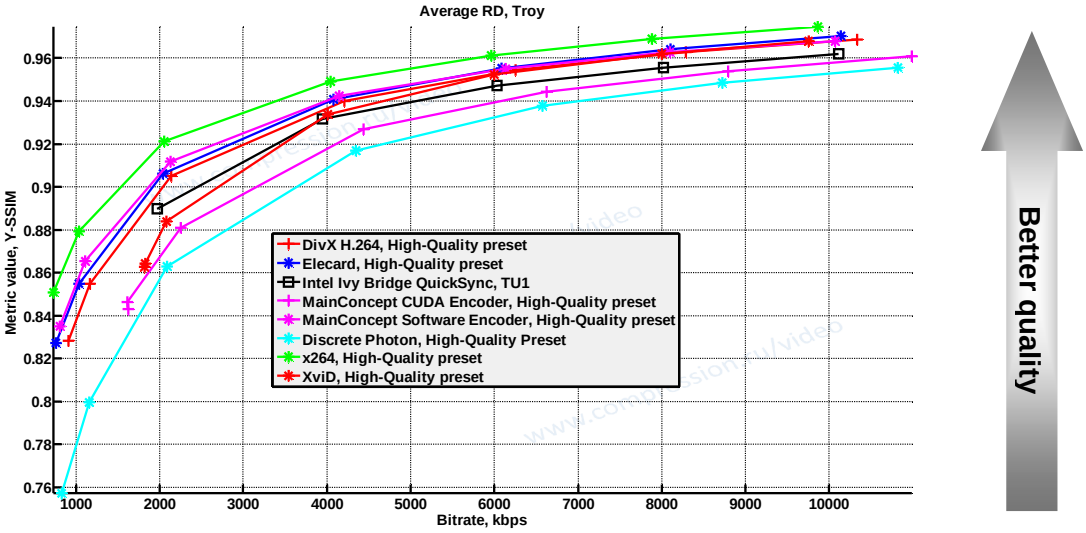

Figure 80. Bitrate/quality—usage area "HDTV," "Troy" sequence, High Quality preset, Y-SSIM metric

4.3.2 Encoding Speed

4.3.2.1 High Speed Preset

Absolute speed results are presented in Figure 81 through Figure 83. All the encoders, except hardware-based, have a similar growth rate for encoding time versus increasing bitrate. Intel Ivy Bridge QuickSync is the fastest.

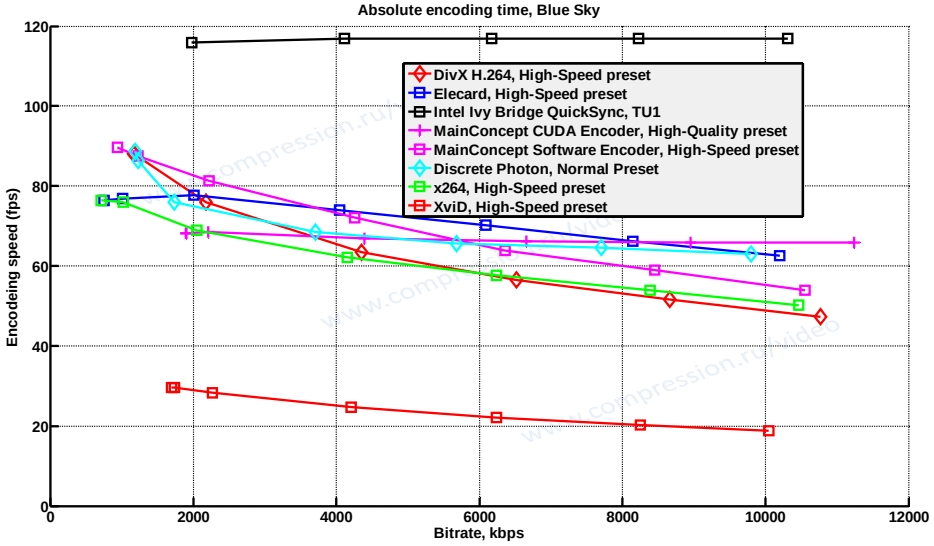

Figure 81. Encoding speed—usage area "HDTV," "Blue Sky" sequence, High Speed preset

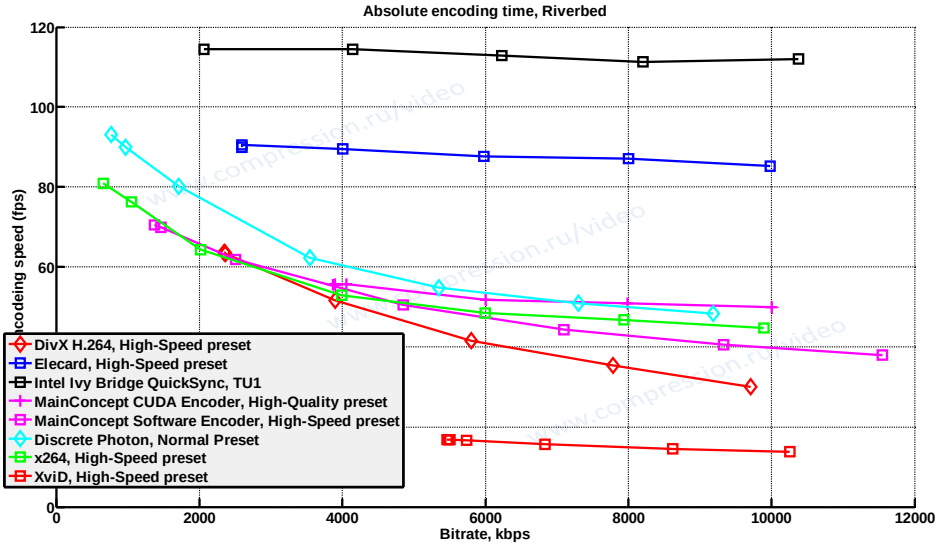

Figure 82. Encoding speed—usage area "HDTV," "Riverbed" sequence, High Speed preset

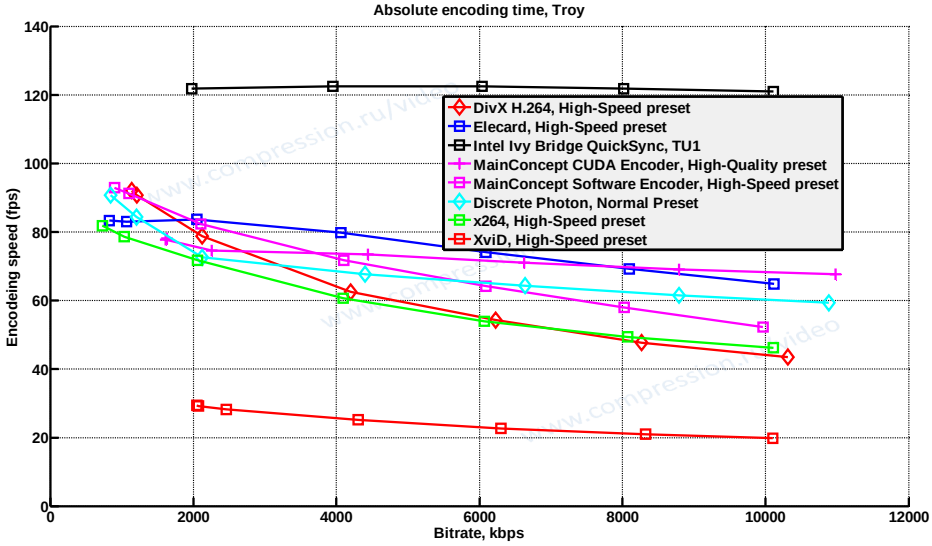

Figure 83. Encoding speed—usage area "HDTV," "Troy" sequence, High Speed preset

4.3.2.2 Normal Preset

Absolute speed results are presented in Figure 84 through Figure 87. All the encoders, except hardware-based, have a similar growth rate for encoding time versus increasing bitrate. Intel Ivy Bridge QuickSync is the fastest.

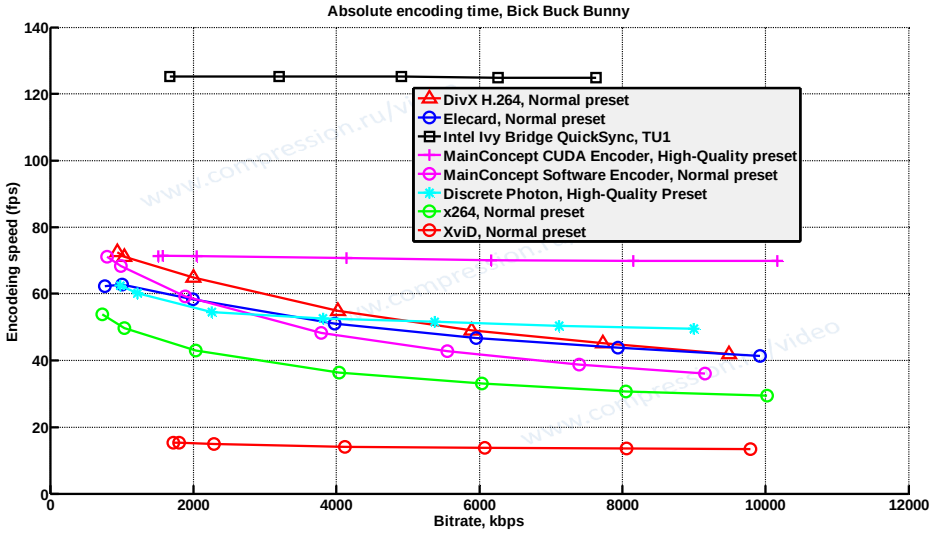

Figure 84. Encoding speed—usage area "HDTV," "Bick Buck Bunny" sequence, Normal preset

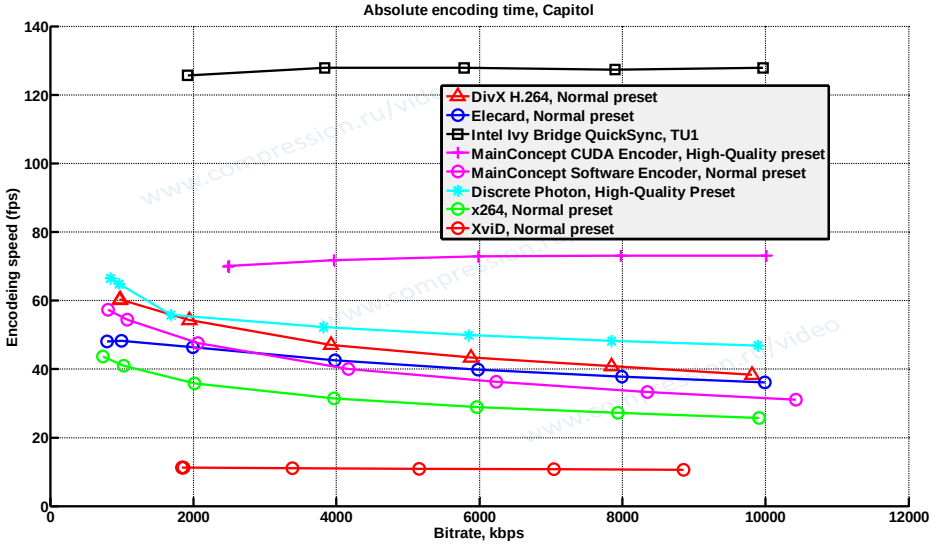

Figure 85. Encoding speed—usage area "HDTV," "Capitol" sequence, Normal preset

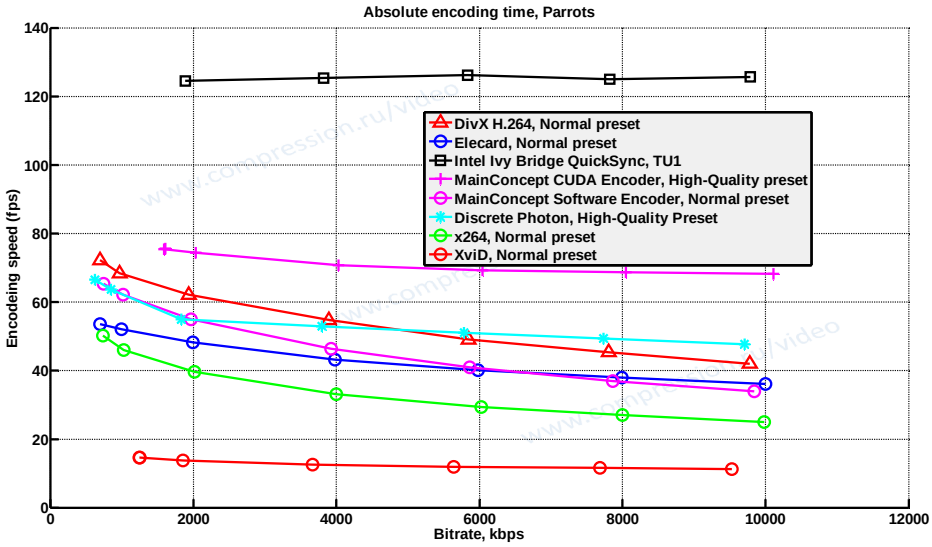

Figure 86. Encoding speed—usage area "HDTV," "Parrots" sequence, Normal preset

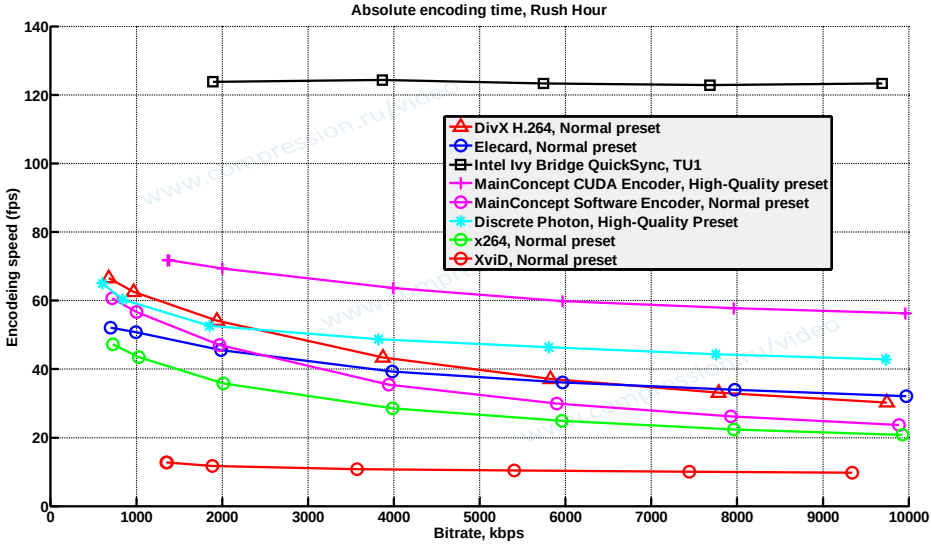

Figure 87. Encoding speed—usage area "HDTV," "Rush Hour" sequence, Normal preset

4.3.2.3 High Quality Preset

Absolute speed results are presented in Figure 88 through Figure 91. All the encoders, except hardware-based, have a similar growth rate for encoding time versus increasing bitrate. Intel Ivy Bridge QuickSync is the fastest.

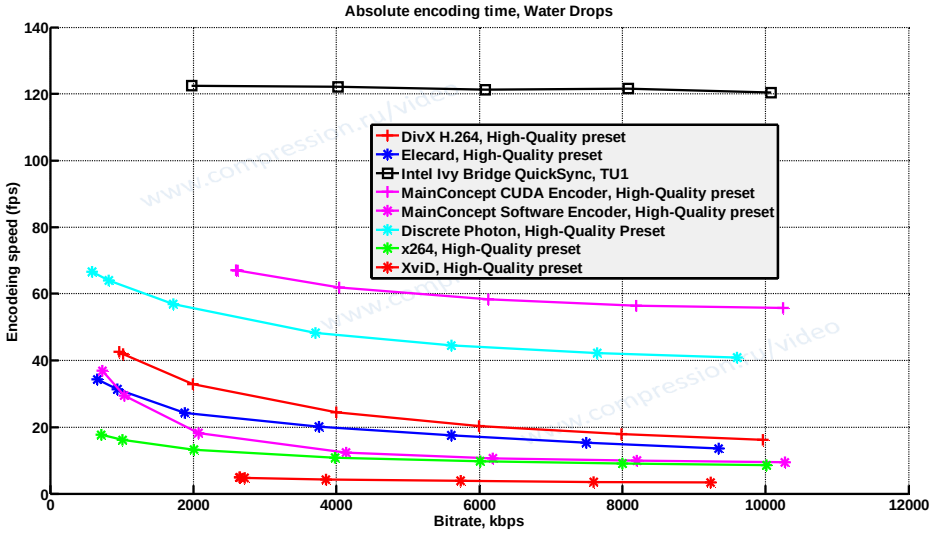

Figure 88. Encoding speed—usage area "HDTV," "Water Drops" sequence, High Quality preset

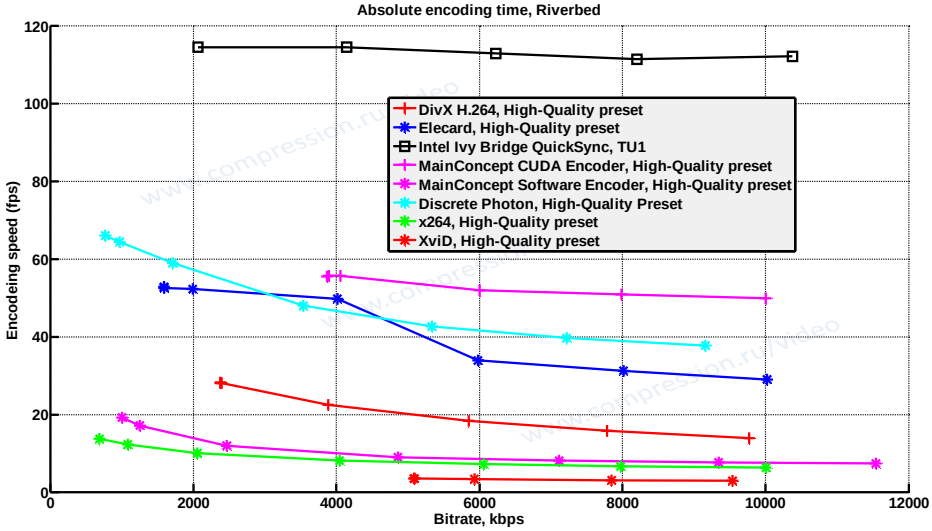

Figure 89. Encoding speed—usage area "HDTV," "Riverbed" sequence, High Quality preset

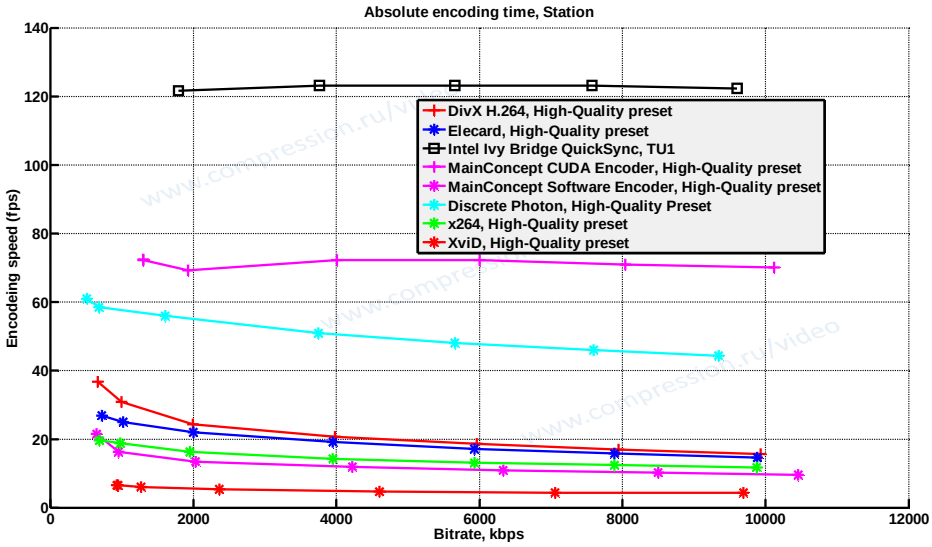

Figure 90. Encoding speed—usage area "HDTV," "Station" sequence, High Quality preset

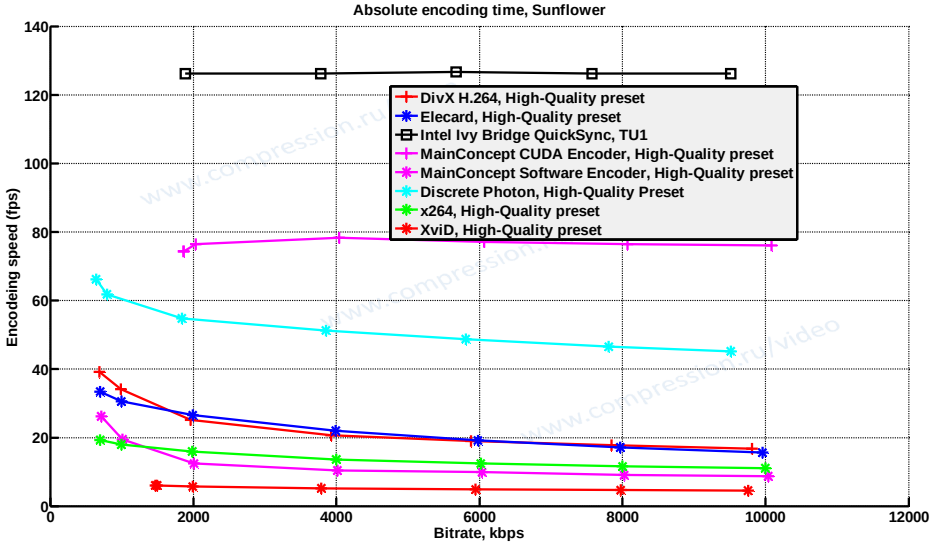

Figure 91. Encoding speed—usage area "HDTV," "Sunflower" sequence, High Quality preset

4.3.3 Speed/Quality Trade-Off

Detailed descriptions of the speed/quality trade-off graphs can be found in Appendix 3. Figures Explanation. Sometimes, codec results are not present in the particular graph owing to the codec's extremely poor performance. The codec's RD curve has no intersection with the reference's RD curve.

The speed/quality trade-off graphs simultaneously show relative quality and encoding speed for the encoders tested in this comparison. XviD is the reference codec, for which both quality and speed are normalized to unity for all of the graphs. The terms "better" and "worse" are used to compare codecs in the same manner as in previous portions of this comparison.

Please note that the method of averaging among all sequences assumes that all codecs produced results for each sequence. When this is not the case, only existing results are taken into account.

4.3.3.1 High Speed Preset

Figure 92 through Figure 96 show results for the High Speed preset. For the speed/quality trade-off using fast presets, the leaders are the x264, MainConcept and Intel QuickSync encoders. Some sequence (Water Drops for example) change results strongly.

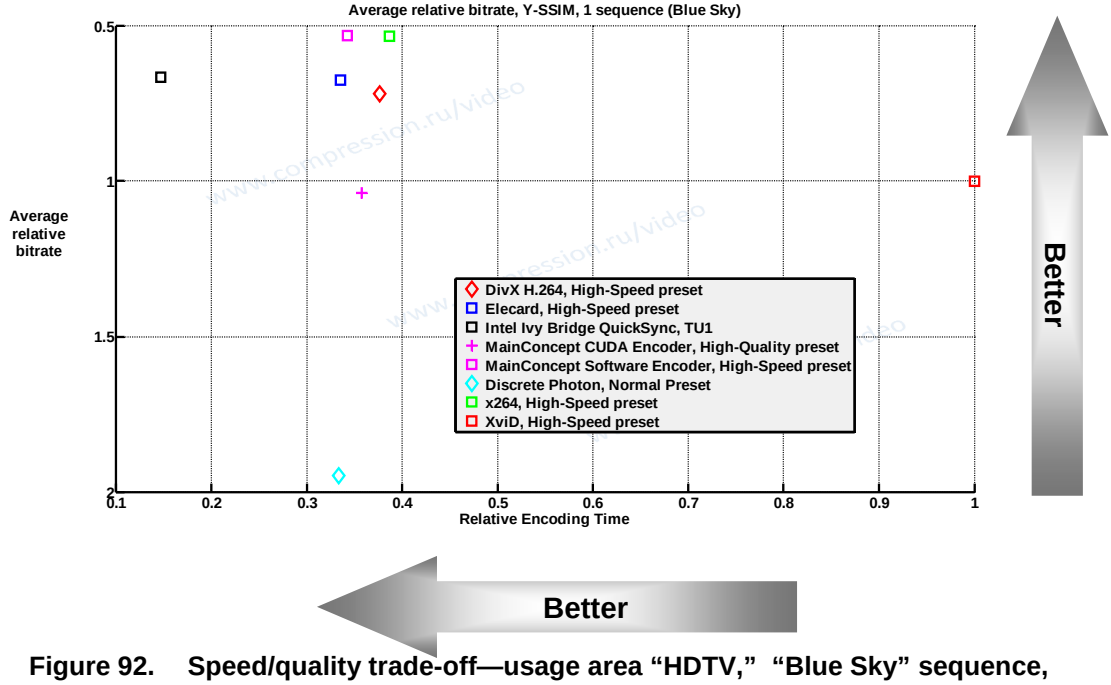

Figure 92. Speed/quality trade-off—usage area "HDTV," "Blue Sky" sequence, High Speed preset, Y-SSIM metric

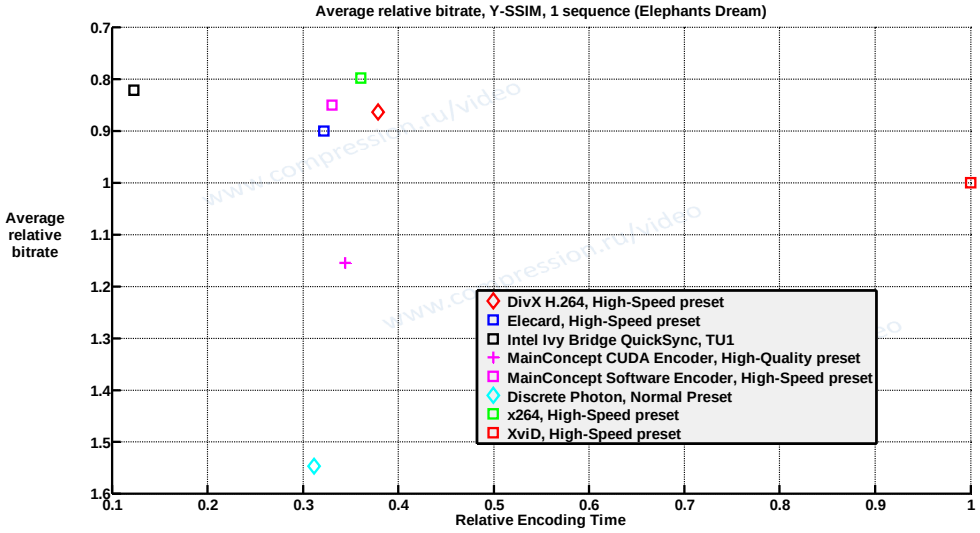

Figure 93. Speed/quality trade-off—usage area "HDTV," "Elephants Dream" sequence, High Speed preset, Y-SSIM metric.

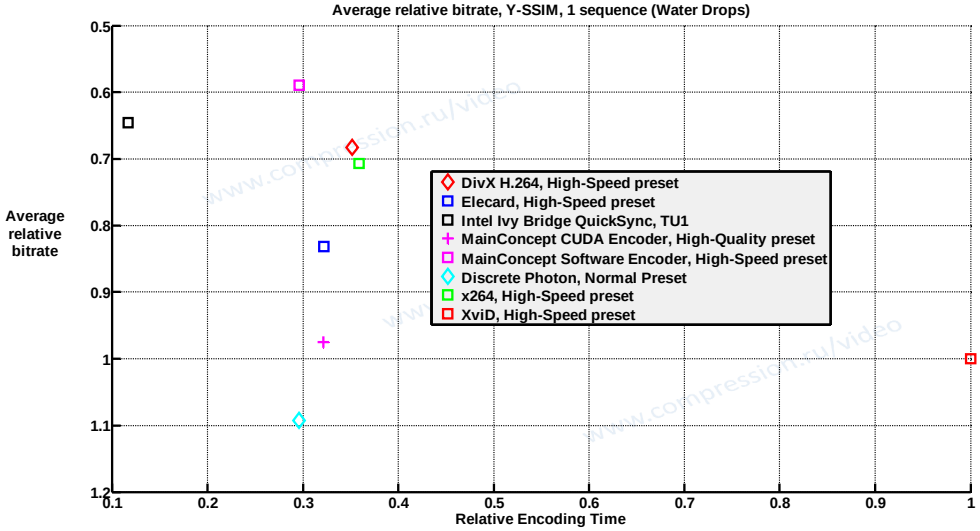

Figure 94. Speed/quality trade-off—usage area "HDTV," "Water Drops" sequence, High Speed preset, Y-SSIM metric.

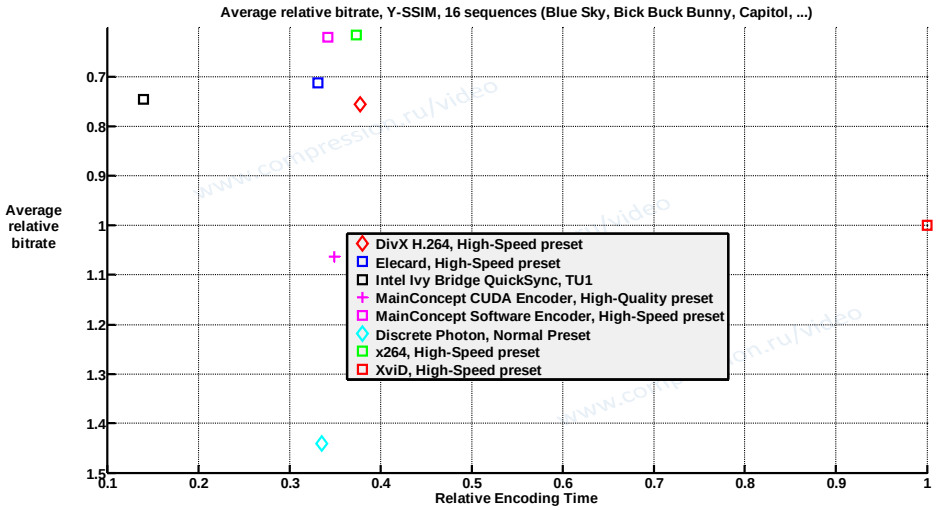

Figure 95. Speed/quality trade-off—usage area "HDTV," all sequences, High Speed preset, Y-SSIM metric

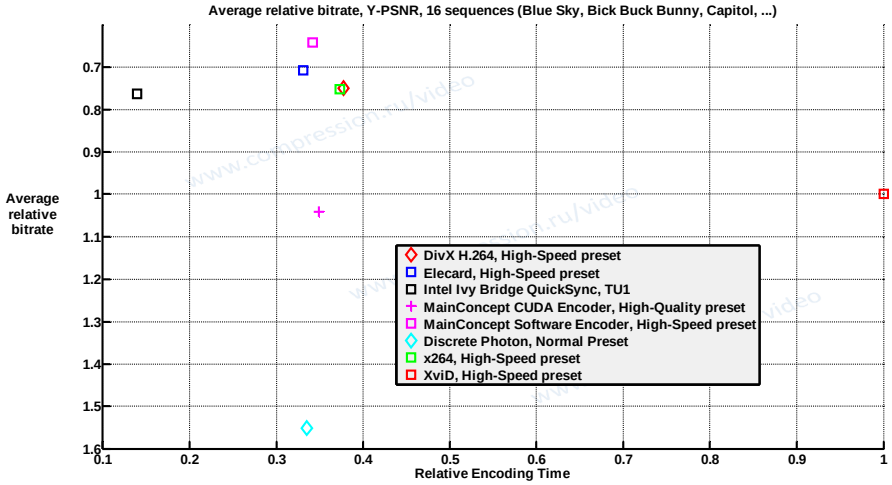

Figure 96. Speed/quality trade-off—usage area "HDTV," all sequences, High Speed preset, Y-PSNR metric

4.3.3.2 Normal Preset

Figure 97 through Figure 101 show results for the Normal preset. On average, the MainConcept, DivX H.264, Elecard, Intel QuickSync and x264 codecs demonstrate best speed-quality trade-off. PSNR metric usage excludes x264 form leaders list.

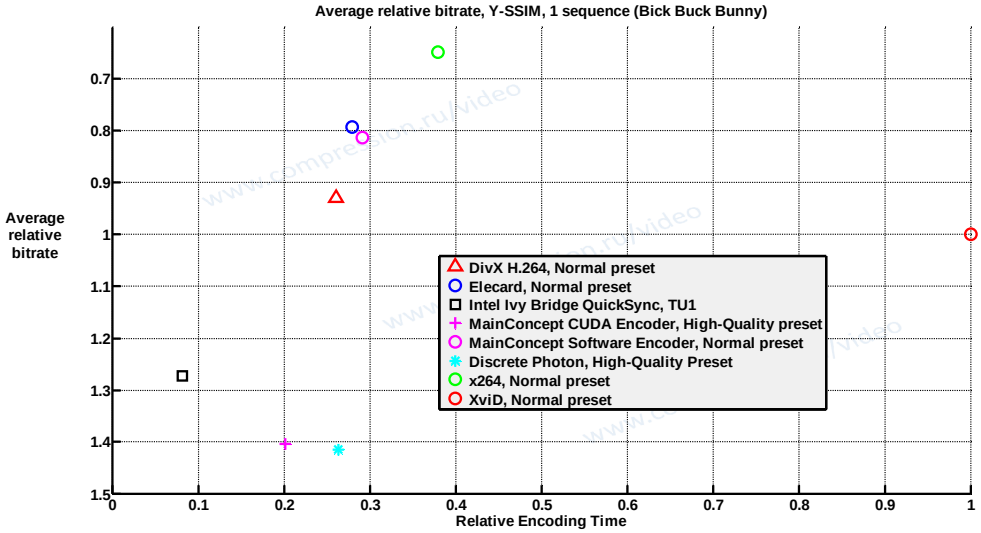

Figure 97. Speed/quality trade-off—usage area "HDTV," "Big Buck Bunny" sequence, Normal preset, Y-SSIM metric

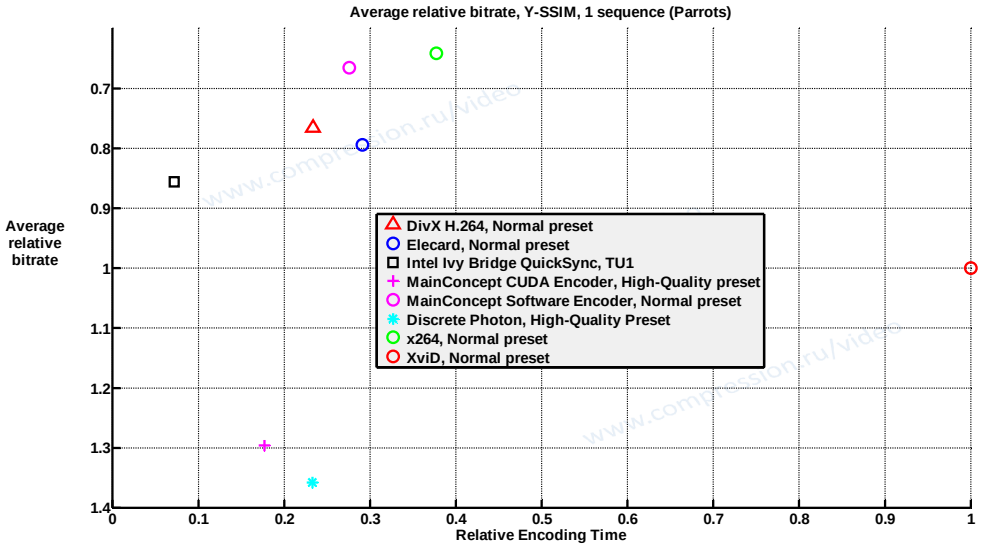

Figure 98. Speed/quality trade-off—usage area "HDTV," "Parrots" sequence, Normal preset, Y-SSIM metric.

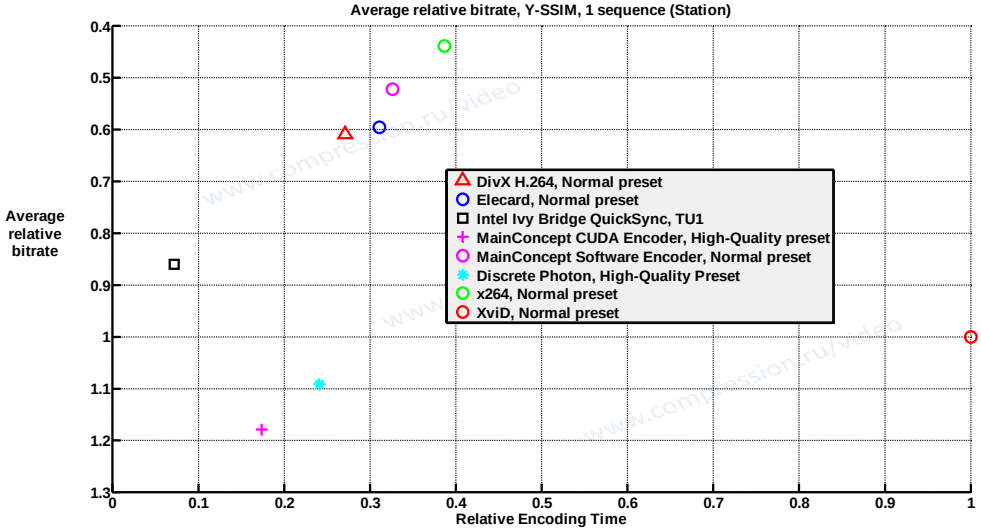

Figure 99. Speed/quality trade-off—usage area "HDTV," "Station" sequence, Normal preset, Y-SSIM metric.

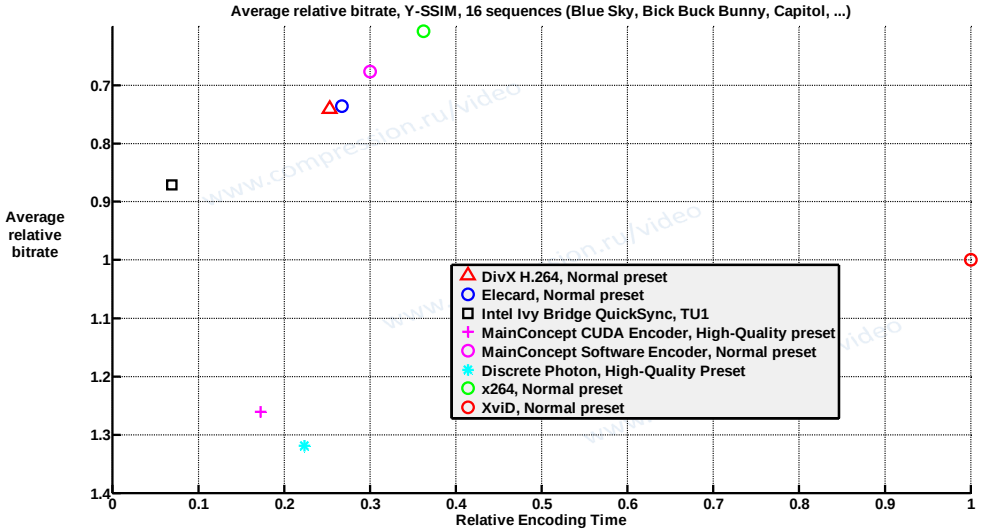

Figure 100. Speed/quality trade-off—usage area "HDTV," all sequences, Normal preset, Y-SSIM metric

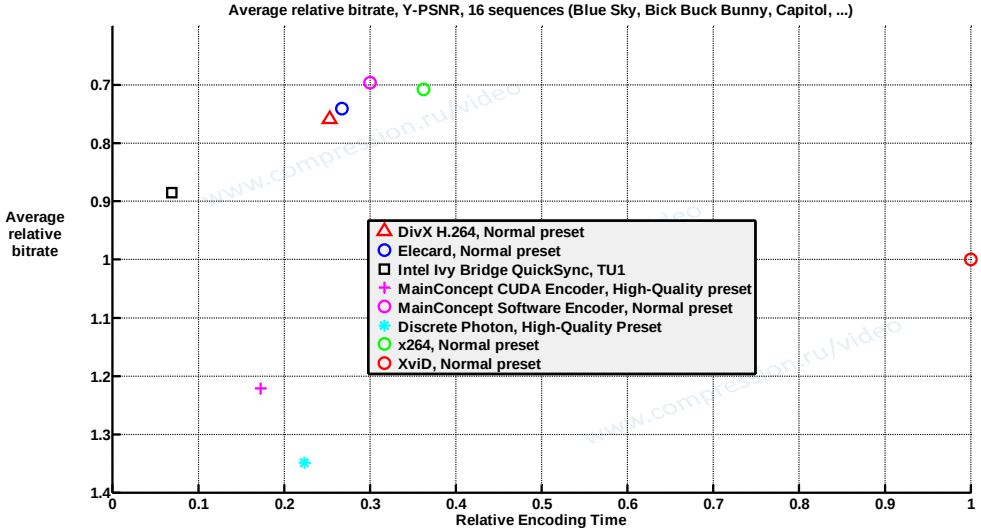

Figure 101. Speed/quality trade-off—usage area "HDTV," all sequences,

4.3.3.3 High Quality Preset

Figure 102 through Figure 106 show results for the High Quality preset. Intel QuickSync, DivX and x264 encoders are Pareto-optimal for this preset. The fastest codec is Intel Ivy Bridge QuickSync; x264 demonstrates the best quality. Y-PSNR usage does not change Pareto-optimal codecs list.

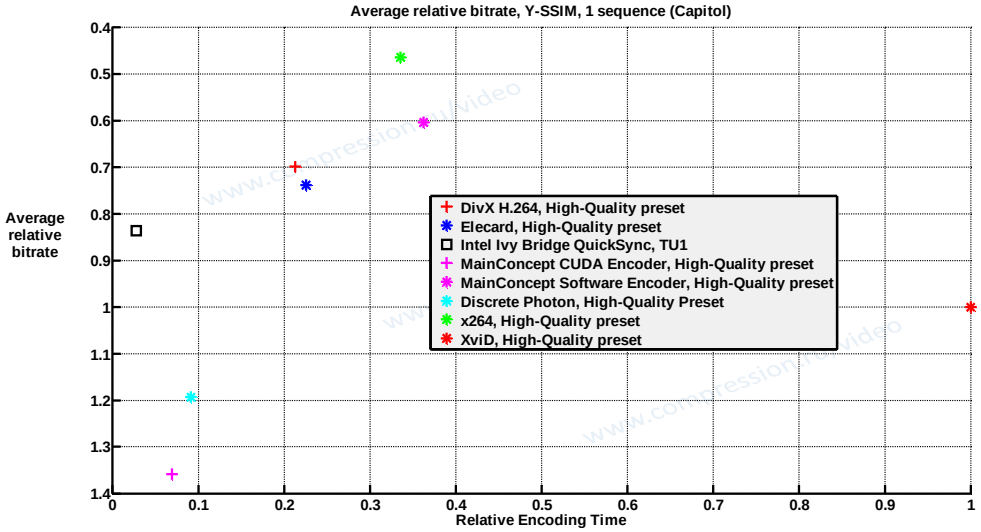

Figure 102. Speed/quality trade-off—usage area "HDTV," "Capitol" sequence, High Quality preset, Y-SSIM metric

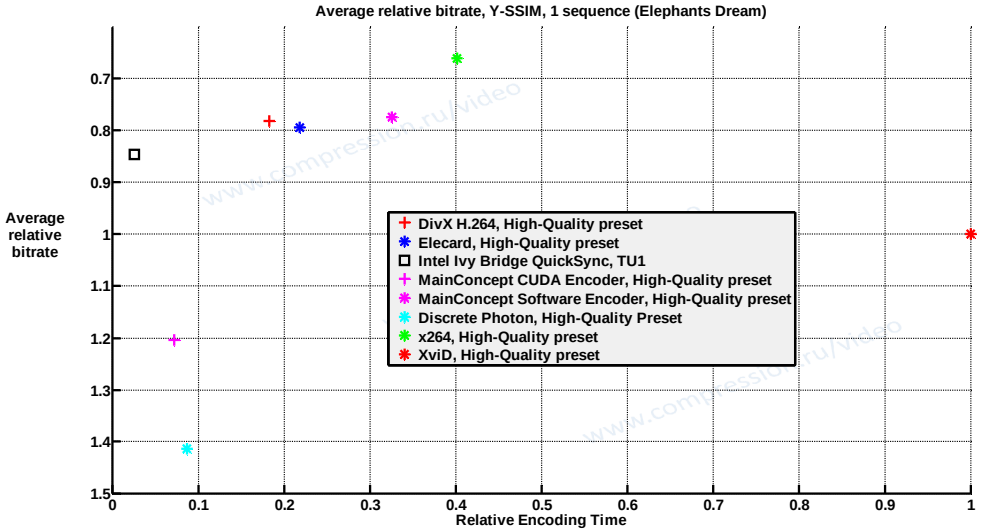

Figure 103. Speed/quality trade-off—usage area "HDTV," "Elephants Dream" sequence, High Quality preset, Y-SSIM metric.

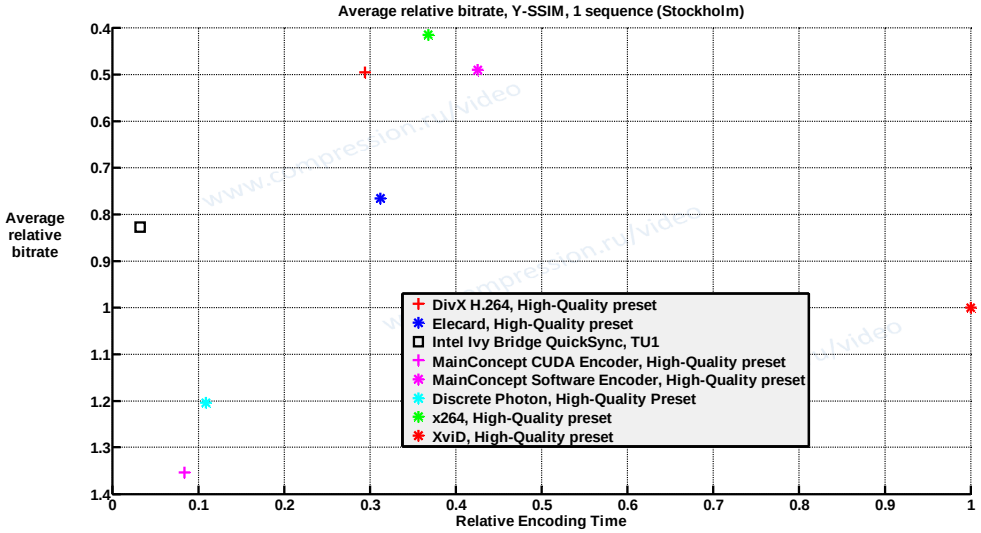

Figure 104. Speed/quality trade-off—usage area "HDTV," "Stockholm" sequence, High Quality preset, Y-SSIM metric.

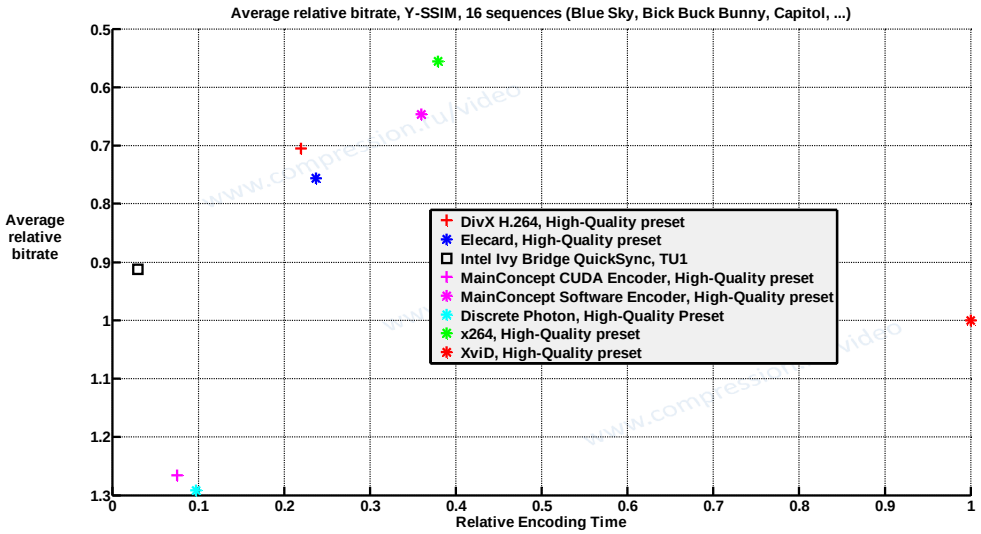

Figure 105. Speed/quality trade-off—usage area "HDTV," all sequences, High Quality preset, Y-SSIM metric

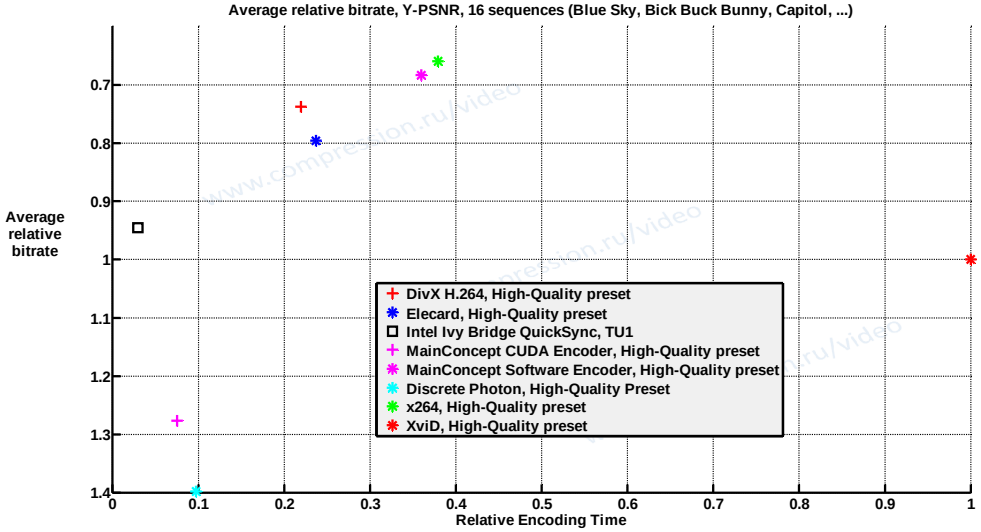

Figure 106. Speed/quality trade-off—usage area "HDTV," all sequences,

4.3.4 Bitrate Handling

4.3.4.1 High Speed Preset

Most codecs demonstrate problems maintaining steady low bitrate using fast presets. The XviD encoder provides the largest increase in bitrate – up to five times. Among the leaders (x264, MainConcept, Elecard, Intel QuickSync and DivX H.264) x264 has the best bitrate handling mechanism at average.

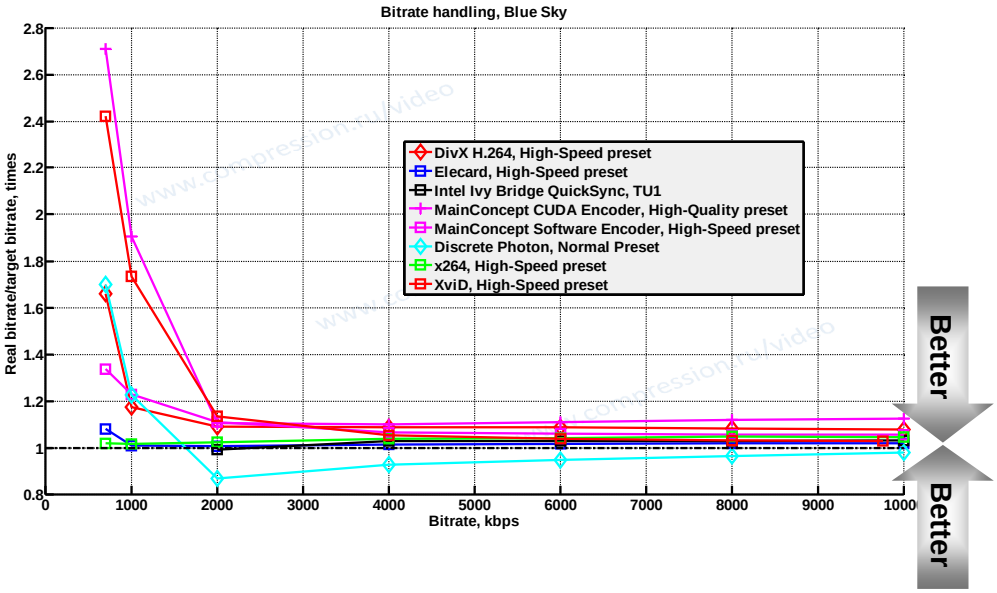

Figure 107. Bitrate handling—usage area "HDTV," "Blue Sky" sequence, High Speed preset

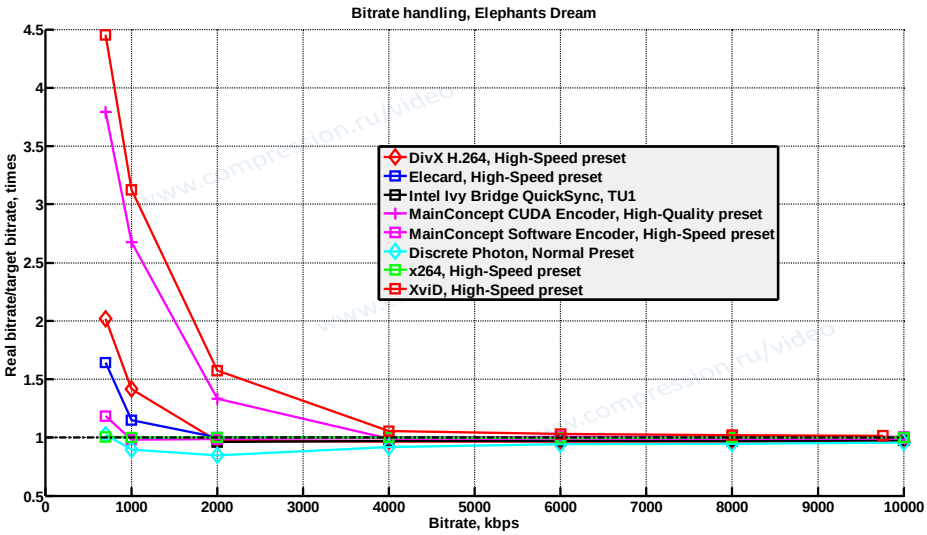

Figure 108. Bitrate handling—usage area "HDTV," "Elephants Dream" sequence, High Speed preset

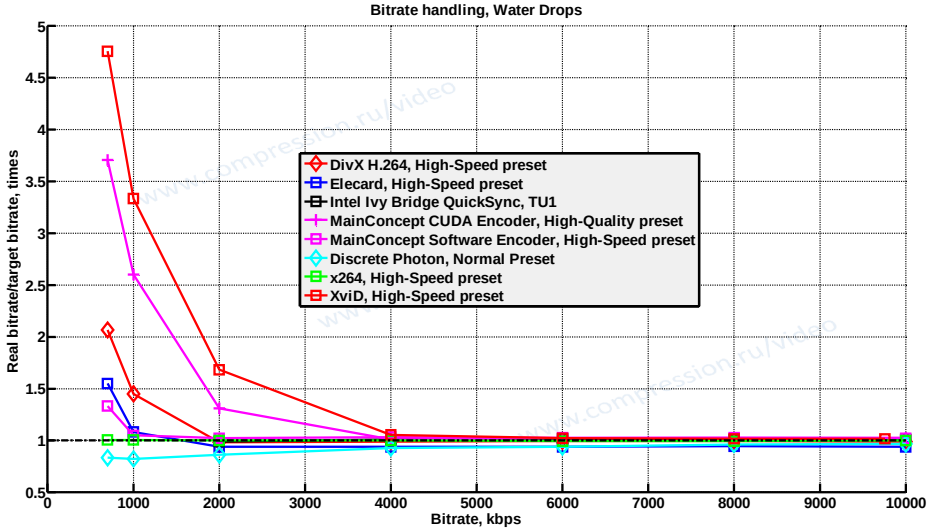

Figure 109. Bitrate handling—usage area "HDTV," "Water Drops" sequence, High Speed preset

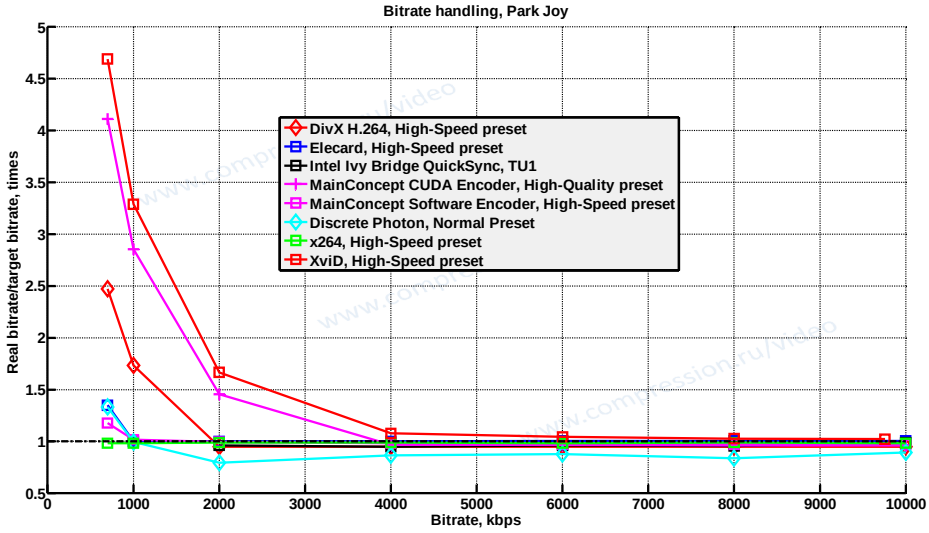

Figure 110. Bitrate handling—usage area "HDTV," "Park Joy" sequence, High Speed preset

4.3.4.2 Normal Preset

The codecs' behavior for the Normal preset is similar to that for the Fast preset. The XviD exhibits the worst bitrate handling. The leaders demonstrated good bitrate handling.

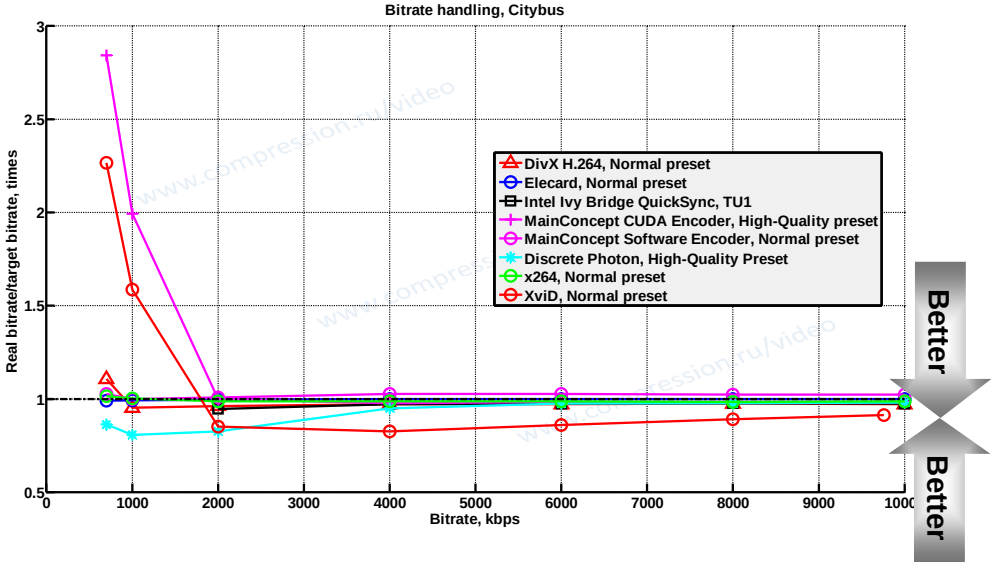

Figure 111. Bitrate handling—usage area "HDTV," "City Bus" sequence, Normal preset

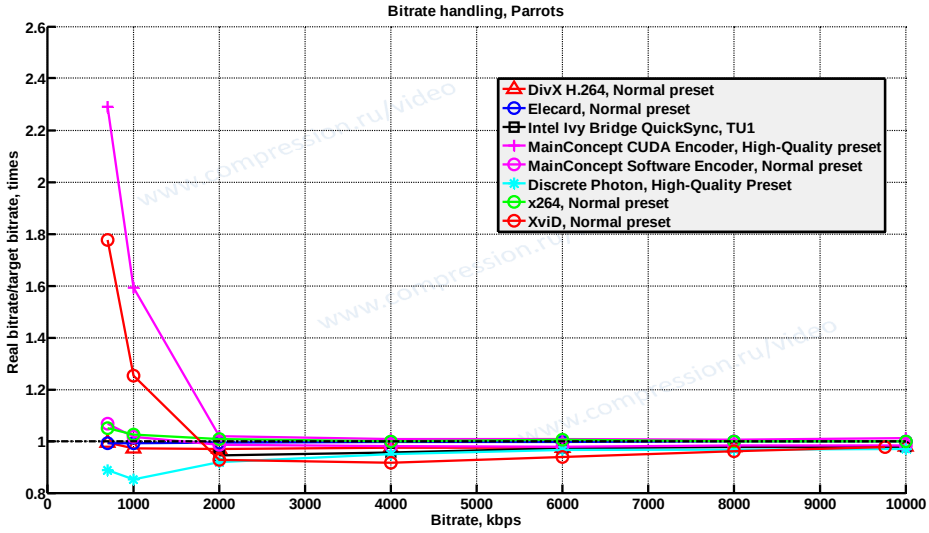

Figure 112. Bitrate handling—usage area "HDTV," "Parrots" sequence, Normal preset

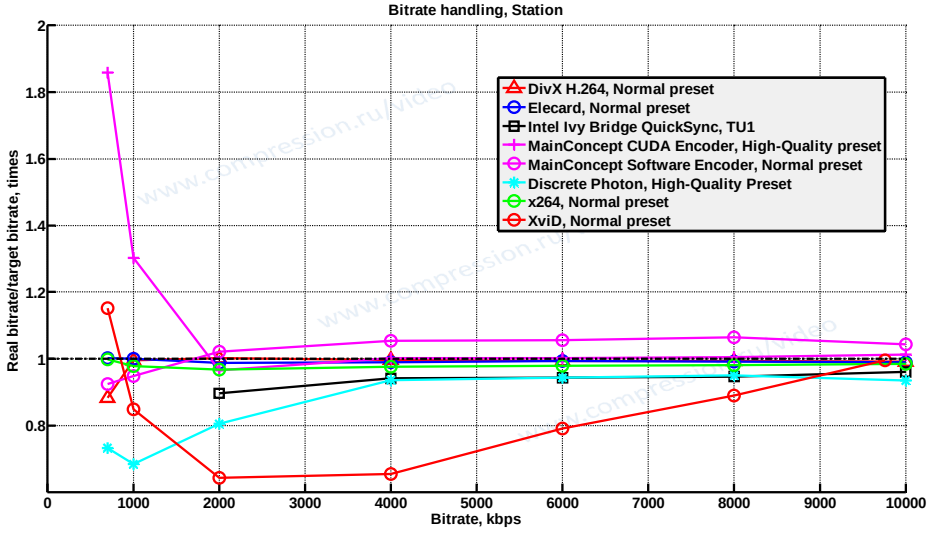

Figure 113. Bitrate handling—usage area "HDTV," "Station" sequence, Normal preset

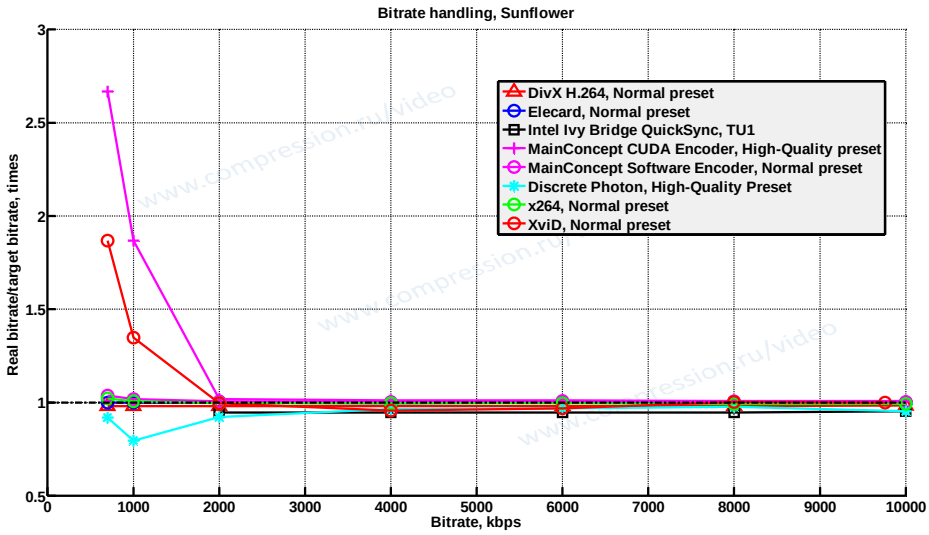

Figure 114. Bitrate handling—usage area "HDTV," "Sunflower" sequence, Normal preset

4.3.4.3 High Quality Preset

Most codecs, except XviD and MainConcept CUDA (at low bitrates), maintain bitrate rather well.

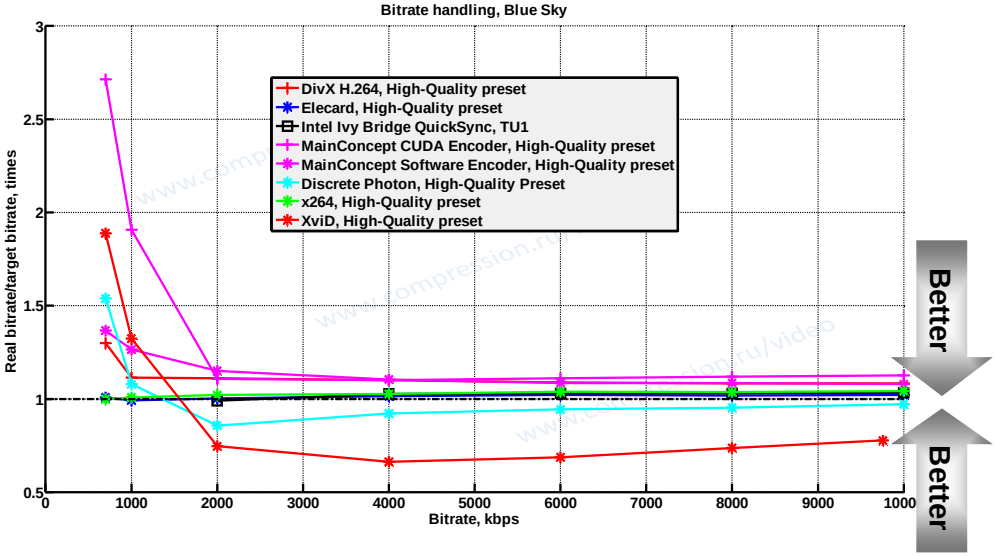

Figure 115. Bitrate handling—usage area "HDTV," "Blue Sky" sequence, High Quality preset

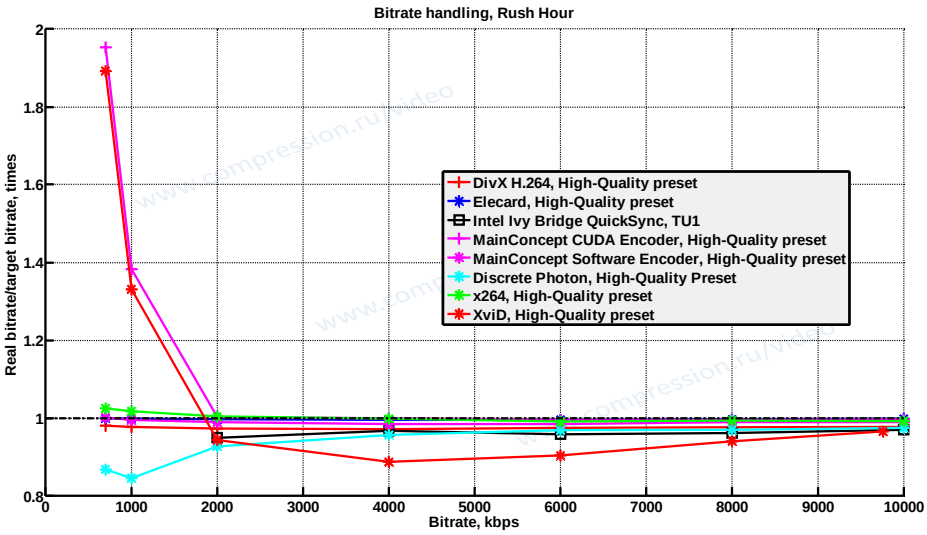

Figure 116. Bitrate handling—usage area "HDTV," "Rush Hour" sequence, High Quality preset

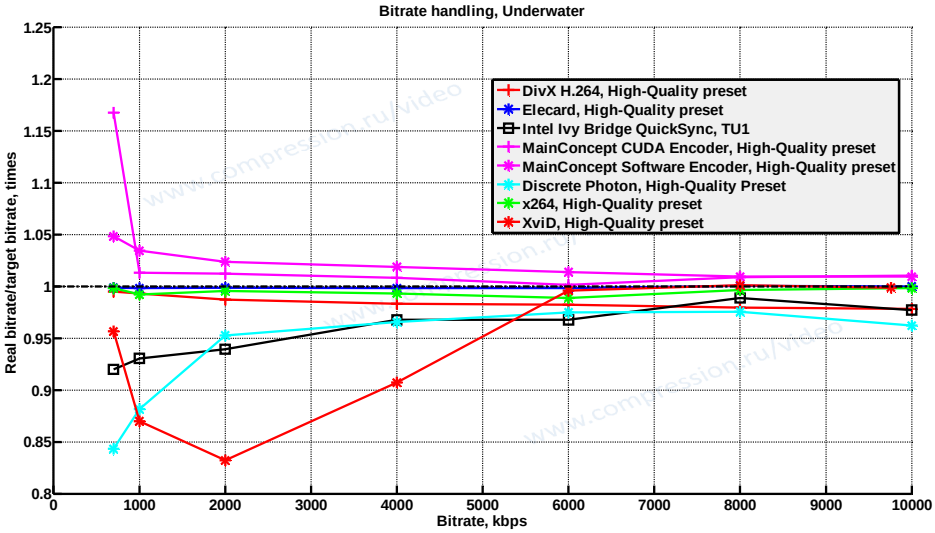

Figure 117. Bitrate handling—usage area "HDTV," "Underwater" sequence, High Quality preset

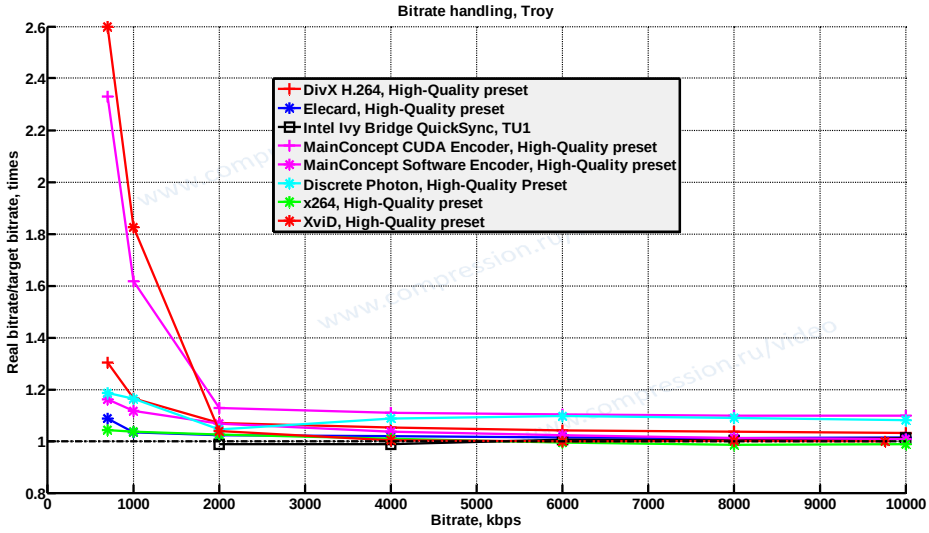

Figure 118. Bitrate handling—usage area "HDTV," "Troy" sequence, High Quality preset

4.3.5 Relative Quality Analysis

Table 11 through Table 16 show relative bitrates for a fixed-quality output for all codecs and presets. Note that these tables do not include information about encoder speed.

Note that each number in the tables below corresponds to some range of bitrates. Unfortunately, these ranges can differ significantly because of differences in the quality produced by the encoders under comparison. This situation can lead to some inadequate results when comparing three or more codecs.

Table 11. Average bitrate ratio for a fixed quality—usage area "HDTV". High Speed preset, Y-SSIM metric.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	93%	95%	142%	82%	203%	80%	133%
Elecard	107%	100%	87%	149%	79%	212%	77%	141%
Intel QuickSync	105%	115%	100%	139%	88%	215%	85%	134%
MainConcept CUDA	70%	67%	72%	100%	58%	130%	58%	94%
MainConcept	123%	127%	114%	171%	100%	271%	98%	161%
Discrete Photon	49%	47%	47%	77%	37%	100%	37%	69%
x264	125%	129%	117%	173%	102%	271%	100%	163%
XviD	75%	71%	75%	106%	62%	144%	62%	100%

Table 12. Average bitrate ratio for a fixed quality—usage area "HDTV". High Speed preset, Y-PSNR metric.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	95%	99%	140%	86%	218%	101%	133%
Elecard	105%	100%	100%	146%	90%	223%	106%	141%
Intel QuickSync	101%	100%	100%	134%	88%	225%	106%	131%
MainConcept CUDA	71%	68%	75%	100%	62%	140%	73%	96%
MainConcept	116%	111%	114%	162%	100%	282%	119%	156%
Discrete Photon	46%	45%	44%	71%	36%	100%	42%	64%
x264	99%	94%	94%	137%	84%	240%	100%	133%
XviD	75%	71%	76%	104%	64%	155%	75%	100%

Table 13. Average bitrate ratio for a fixed quality—usage area "HDTV". Normal preset, Y-SSIM metric.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	99%	115%	171%	90%	186%	80%	135%
Elecard	101%	100%	103%	172%	82%	175%	74%	136%
Intel QuickSync	87%	97%	100%	139%	79%	159%	70%	115%
MainConcept CUDA	59%	58%	72%	100%	54%	103%	48%	79%
MainConcept	111%	121%	127%	187%	100%	210%	89%	148%
Discrete Photon	54%	57%	63%	97%	48%	100%	43%	76%
x264	125%	135%	143%	207%	113%	230%	100%	165%
XviD	74%	74%	87%	126%	68%	132%	61%	100%

Table 14. Average bitrate ratio for a fixed quality—usage area "HDTV". Normal preset, Y-PSNR metric.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	98%	114%	161%	91%	185%	94%	132%
Elecard	102%	100%	115%	165%	93%	170%	95%	135%
Intel QuickSync	88%	87%	100%	134%	80%	160%	83%	113%
MainConcept CUDA	62%	61%	75%	100%	57%	107%	58%	82%
MainConcept	109%	108%	125%	175%	100%	205%	102%	144%
Discrete Photon	54%	59%	63%	93%	49%	100%	49%	74%
x264	107%	105%	121%	172%	98%	203%	100%	141%
XviD	76%	74%	88%	122%	70%	135%	71%	100%

Table 15. Average bitrate ratio for a fixed quality—usage area "HDTV". High Quality preset, Y-SSIM metric.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	108%	126%	183%	91%	198%	78%	142%
Elecard	93%	100%	103%	172%	77%	181%	66%	132%
Intel QuickSync	80%	97%	100%	139%	73%	159%	62%	110%
MainConcept CUDA	55%	58%	72%	100%	50%	103%	43%	79%
MainConcept	110%	130%	138%	201%	100%	227%	85%	155%
Discrete Photon	50%	55%	63%	97%	44%	100%	38%	77%
x264	128%	152%	161%	232%	117%	263%	100%	180%
XviD	70%	76%	91%	127%	65%	129%	56%	100%

Table 16. Average bitrate ratio for a fixed quality—usage area "HDTV". High Quality preset, Y-PSNR metric.

	DivX	Elecard	Intel QuickSync	MainConcept CUDA	MainConcept	Discrete Photon	x264	XviD
DivX	100%	108%	125%	174%	93%	198%	91%	135%
Elecard	93%	100%	113%	163%	85%	174%	81%	126%
Intel QuickSync	80%	88%	100%	134%	74%	160%	72%	106%
MainConcept CUDA	57%	61%	75%	100%	53%	107%	51%	78%
MainConcept	108%	118%	136%	189%	100%	223%	98%	146%
Discrete Photon	50%	58%	63%	93%	45%	100%	43%	72%
x264	110%	123%	139%	196%	102%	234%	100%	151%
XviD	74%	80%	95%	128%	68%	140%	66%	100%

Figure 119 through Figure 124 depict the data in the tables above. Each line in these figures corresponds to one codec. Values along the vertical axis are average relative bitrates as compared with the codecs along the horizontal axis. A lower bitrate indicates better relative results.

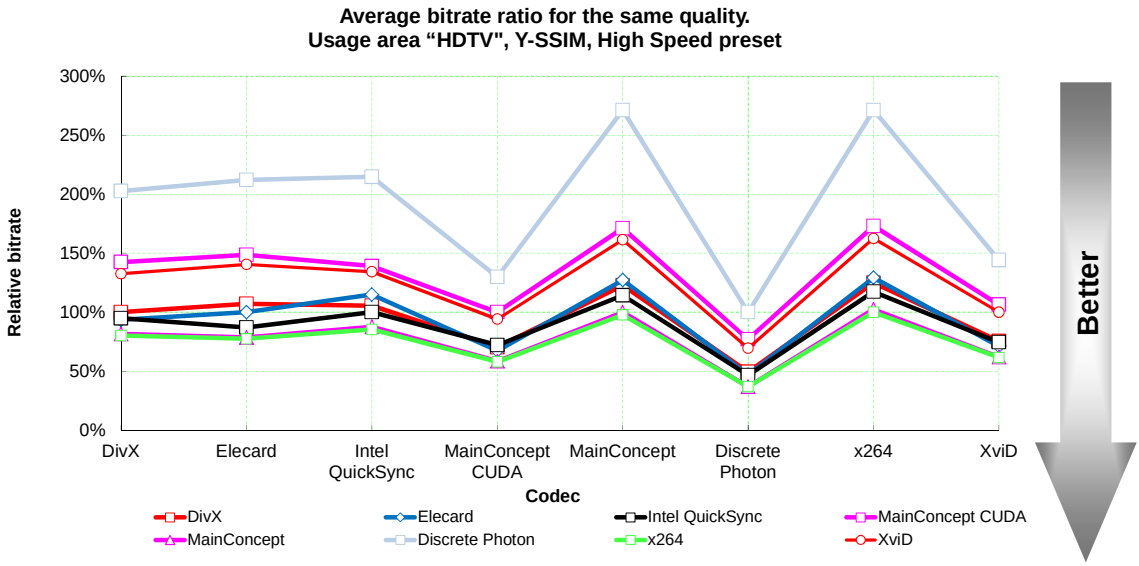

Figure 119. Average bitrate ratio for a fixed quality—usage area "HDTV". High Speed preset, Y-SSIM metric.

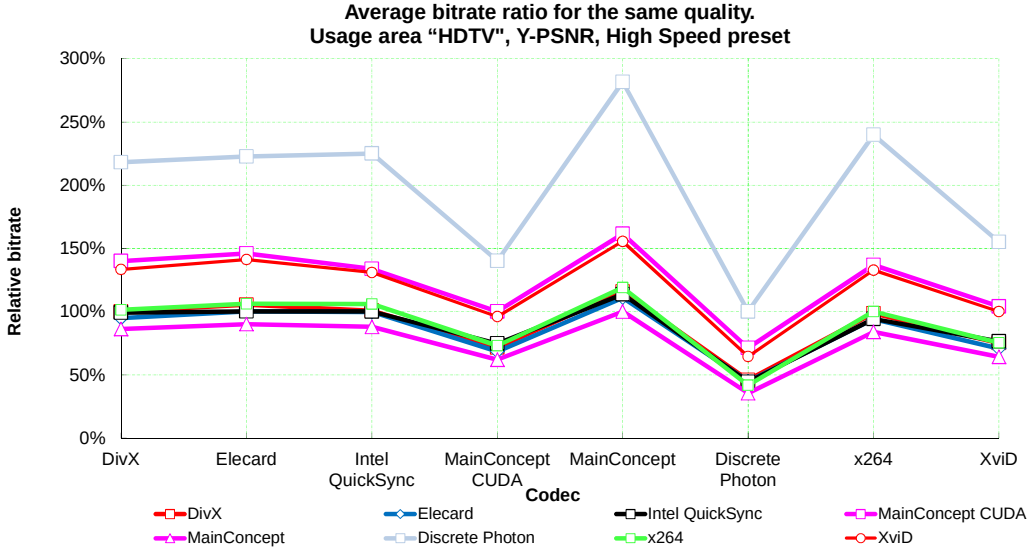

Figure 120. Average bitrate ratio for a fixed quality—usage area "HDTV". High Speed preset, Y-PSNR metric.

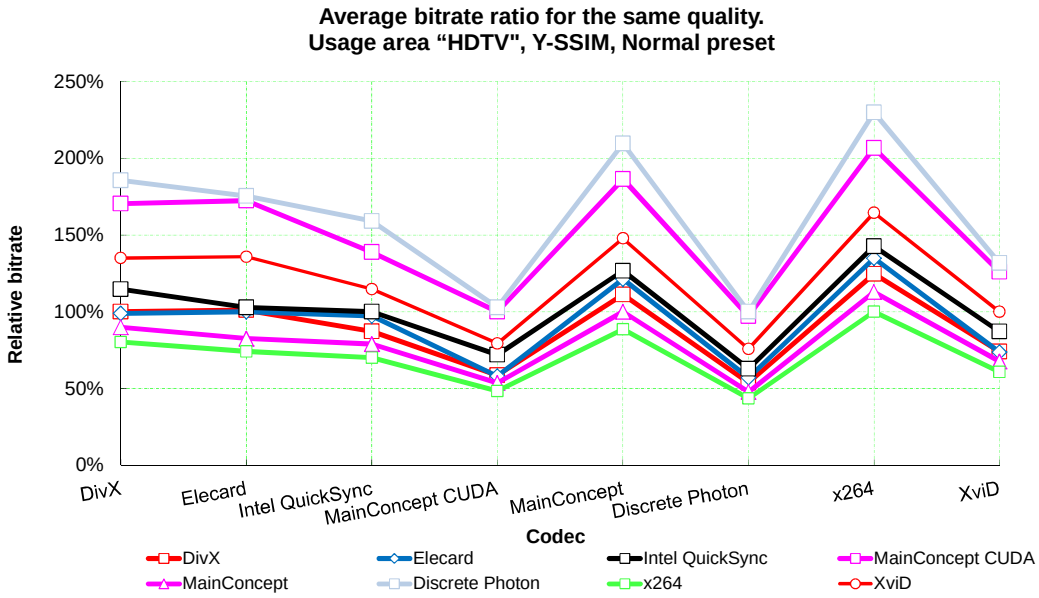

Figure 121. Average bitrate ratio for a fixed quality—usage area "HDTV". Normal preset, Y-SSIM metric.

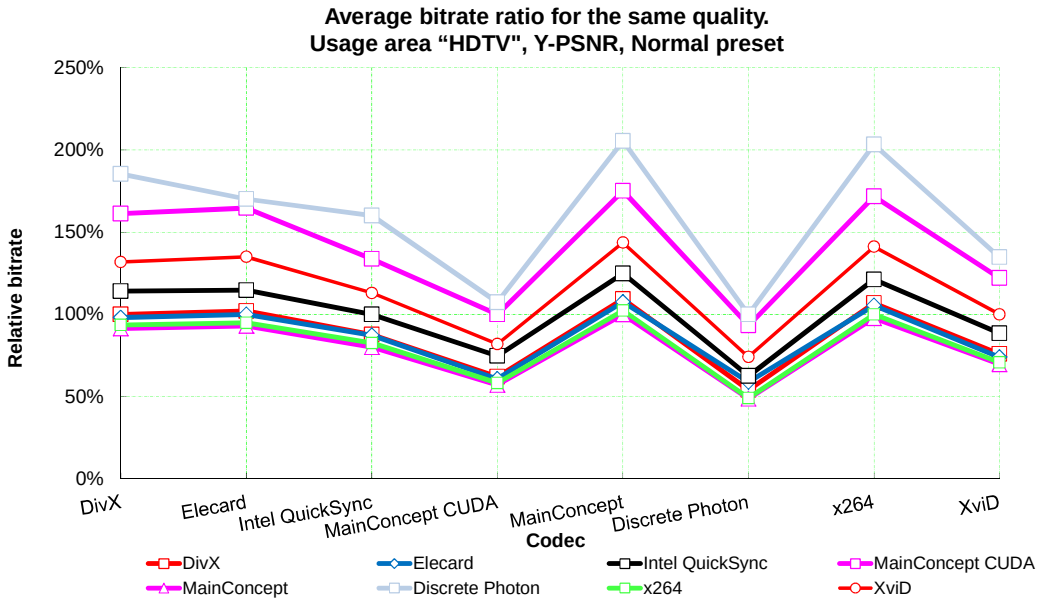

Figure 122. Average bitrate ratio for a fixed quality—usage area "HDTV". Normal preset, Y-PSNR metric.

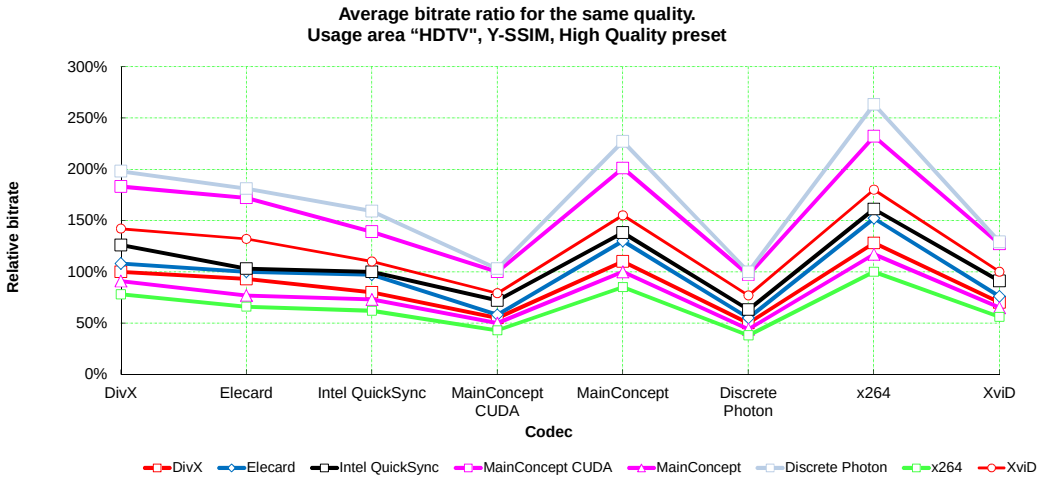

Figure 123. Average bitrate ratio for a fixed quality—usage area "HDTV". High Quality preset, Y-SSIM metric.

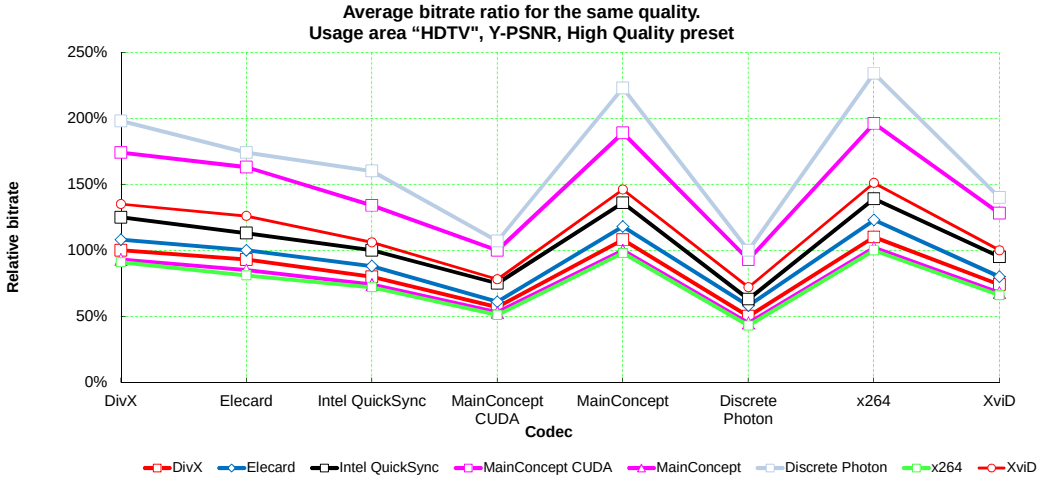

Figure 124. Average bitrate ratio for a fixed quality—usage area "HDTV". High Quality preset, Y-PSNR metric.

4.4 Conclusions

4.4.1 Video Conference

The x264 encoder demonstrates better quality on average. The top three codecs for this preset are the following:

1. x264
2. MainConcept
3. DivX H.264

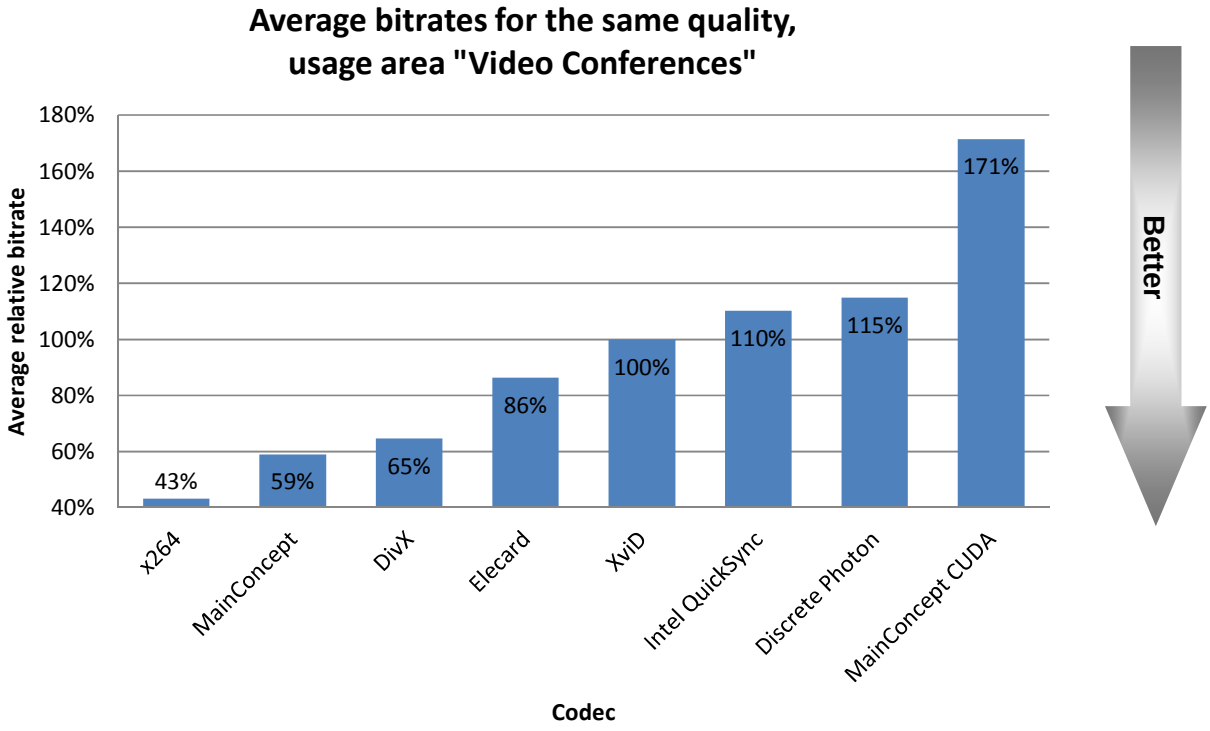

Figure 125. Average bitrate ratio for a fixed quality—usage area "Video Conference," Y-SSIM.

4.4.2 Movies

The leading encoder in this usage area is x264, followed by MainConcept, DivX H.264 and Elecard. Elecard was only in High Speed preset.

4.4.2.1 High Speed Preset

The x264 encoder demonstrates better quality on average, and Elecard shows slightly lower quality. The top three codecs for this preset are the following:

1. x264
2. Elecard
3. MainConcept

4.4.2.2 Normal Preset

The results for the Normal preset differ from those for the High Speed presets in second and third places. The x264 encoder demonstrates better quality on average, and MainConcept and Divx H.264 show slightly lower quality. The top three codecs for this preset are the following:

1. x264

2. MainConcept
3. DivX H.264

4.4.2.3 High Quality Preset

The results for this preset are similar to those of the Normal preset. The leader is the x264, followed by two codecs. The top three codecs for this preset are the following:

1. x264
2. MainConcept
3. DivX H.264

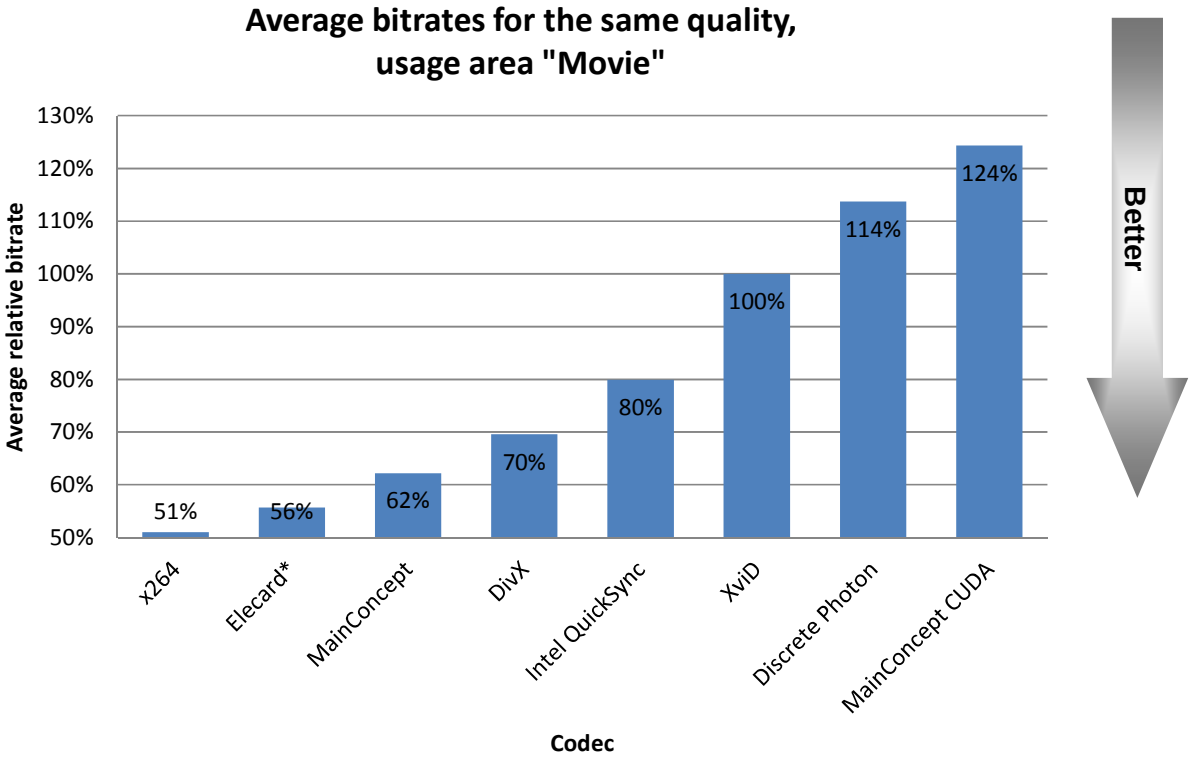

Figure 126. Average bitrate ratio for a fixed quality—usage area "Movies," all presets, Y-SSIM.

**Elecard was only in High Speed preset, so instead average for three presets we have u value for High Speed preset.*

4.4.3 HDTV

The leaders in the HDTV area are x264, DivX H.264, Elecard and MainConcept. The MainConcept CUDA encoder trails all other H.264 encoders.

4.4.3.1 High Speed Preset

The x264 and MainConcept encoders demonstrate better quality on average The top five codecs for this preset are the following:

1. x264 and MainConcept
2. Elecard
3. DivX H.264 and Intel QuickSync

4.4.3.2 Normal Preset

The results for the Normal preset differ slightly from those of the High Speed presets. x264 and MainConcept show best result. The top four codecs for this preset are the following:

1. x264 and MainConcept
2. Elecard
3. DivX H.264

4.4.3.3 High Quality Preset

The results for the High Quality preset differ to Normal preset results: x264 held first place, MainConcept is in second place, DivX H.264 took third place. The top three codecs for this preset are the following:

1. x264
2. MainConcept
3. DivX H.264

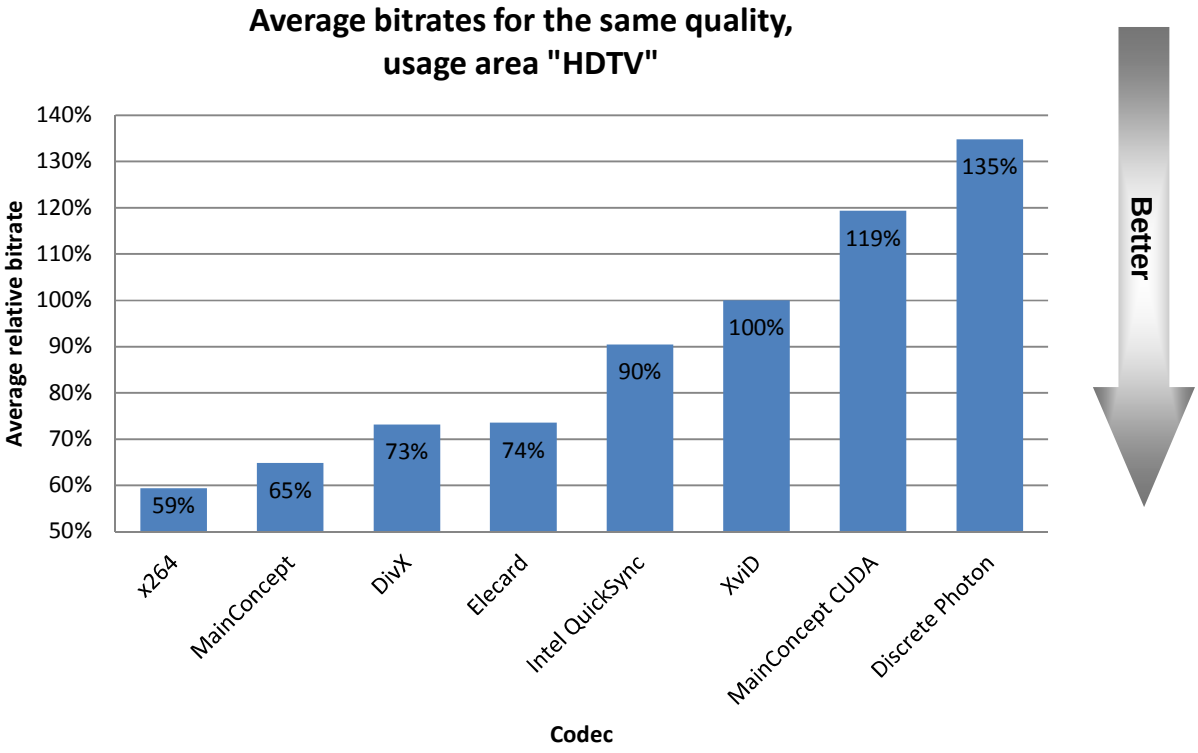

Figure 127. Average bitrate ratio for a fixed quality—usage area "HDTV," all presets, Y-SSIM.

4.4.4 Overall Conclusions

Overall, the leader in this comparison is x264, followed MainConcept, and DivX H.264 and Elecard share third place. The MainConcept CUDA encoder demonstrates the worst results among all codecs tested.

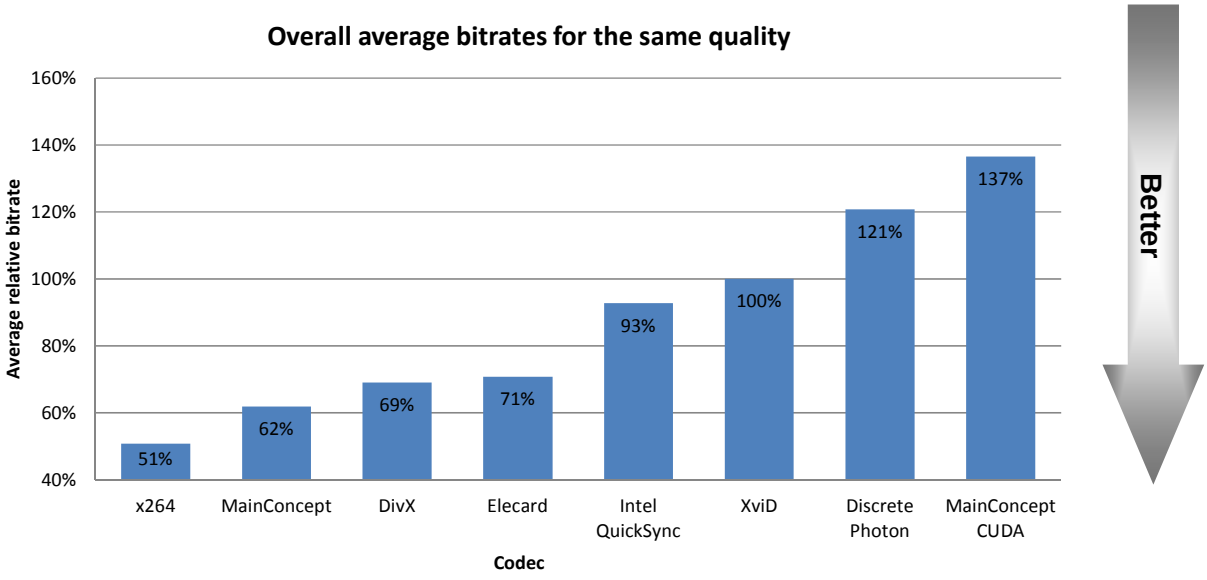

Figure 128. Average bitrate ratio for a fixed quality for all categories and all presets (Y-SSIM).

The overall ranking of the codecs tested in this comparison is as follows:

1. x264
2. MainConcept
3. DivX H.264
4. Elecard
5. Intel Ivy Bridge QuickSync
6. XviD
7. DiscretePhoton
8. MainConcept CUDA

The leader in this comparison is x264—its quality difference (according to the SSIM metric) could be explained by the special encoding option ("tune-SSIM").

The difference between the Elecard and DivX H.264 encoders is almost nothing, so these encoders tied for third and fourth in this comparison.

This rank is based only on the encoders' quality results (see Figure 128). Encoding speed is not considered here.

4.4.5 Codec Conclusions

- **Discrete Photon—**one of the fastest software encoder for this comparison, but because of its speed the encoding quality was not very good
- **DivX H.264—**one of comparison leaders, quite balanced encoder with not very big number of parameters, this fact could be comfortable for users. This encoder is designed as a free sample application for DivX Plus HD compliant video encoding, and is a feature-constrained, for-purpose application.
- **Elecard—**one of comparison leaders, codec with good encoding quality and very flexible settings. Many adjustable encoding settings

are provided. Also it provides very good encoding speed for software encoders.

- **Intel Ivy Bridge QuickSync —** the fastest encoder in this comparison. Preset TU1 that was used is slowest preset for Intel QuickSync with maximal quality. So this codec could be used for very fast encoding using Ivy Bridge Hardware.
- **MainConcept —** one of comparison leaders, showing very close to x264 result for HDTV use-case; has many encoding settings that can be adjusted**.**
- **MainConcept CUDA —** fast GPU-based encoder with not very good encoding quality comparing to leaders.
- **x264—**one of the best codecs by encoding quality; has very user-friendly predefined presets, as well as many adjustable encoding settings.
- **XviD—**an MPEG-4 ASP codec; its quality could be very close to or even higher than that of some commercial H.264 standard implementations, especially for encoding “Movie” sequences, but not for “HDTV” sequences.

MSU Graphics & Media Lab will make **Appendixes** to this report in 3-4 weeks. It will contain Very High Speed Encoders comparison and one new GPU encoder.

Current test shows that hardware-based encoders are much faster than software so we will make additional **Very High Speed Encoders comparison** to analyze hardware and software encoders at close speed.

This type of encoding is interesting to many users who want to transcode video fast with good quality.

1 Appendix 1. Test Set of Video Sequences

1.1 Videoconference Sequences

1.1.1 "Deadline"

Sequence title	Deadline
Resolution	352x288
Number of frames	1374
Color space	YV12
Frames per second	30
Source	Uncompressed, progressive

Figure 129. Deadline sequence, frame 1

Figure 130. Deadline sequence, frame 190

This is standard sequence. This sequence includes static background and foreground with very low motion – only announcer's face with not very rich mimic, except when he takes off his glasses. As a result, this sequence can e used to test the behavior of the codec for typical conference.

1.1.2 "Developers 4CIF"

Sequence title	Developers 4CIF
Resolution	640x480
Number of frames	3600
Color space	YV12
Frames per second	30
Source	HuffYUV, 57Mbps, progressive

Figure 131. Developers 4CIF sequence, frame 743

Video with some movement and facial expressions in foreground and some very bright movement at background (man in red shirt at background).

1.1.3 "Developers 720p"

Sequence title	Developers 720p
Resolution	1280x720
Number of frames	1500
Color space	YV12
Frames per second	30
Source	HuffYUV, 160Mbps, progressive

Figure 132. Developers 720p sequence, frame 750

Same as in 4CIF version, typical videoconference sequence with talking head.

1.1.4 "Presentation"

Sequence title	Presentation
Resolution	720x480
Number of frames	548
Color space	YV12
Frames per second	30
Source	Sony PD-170, 32Mbps

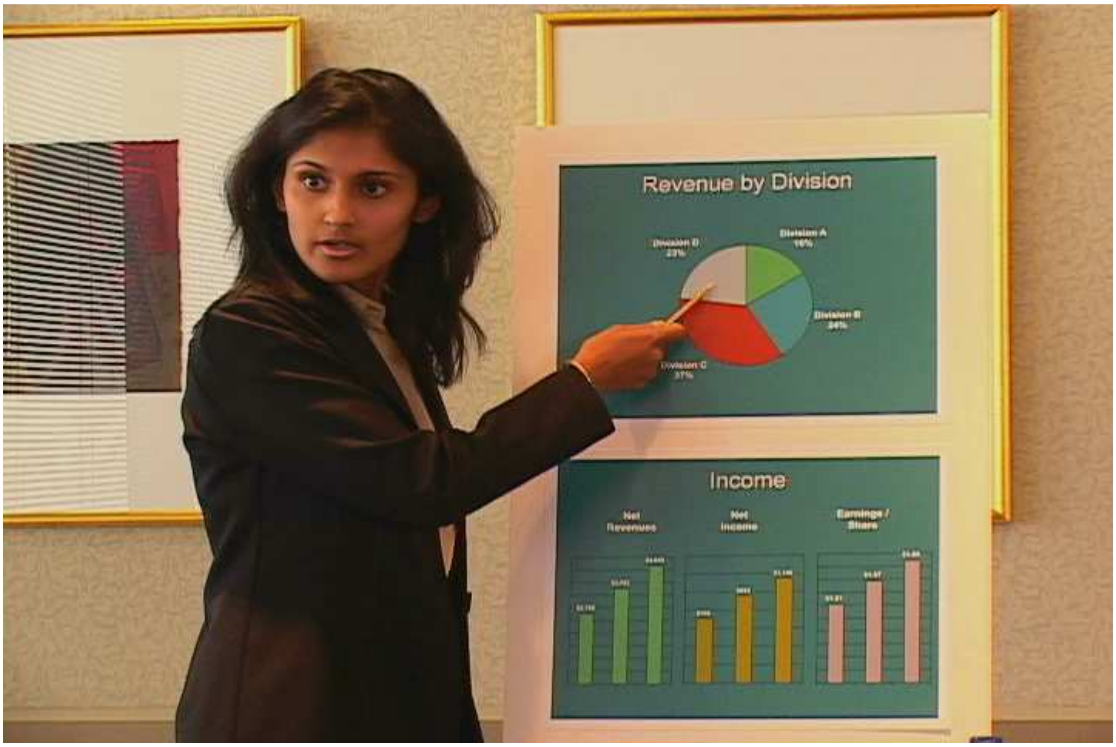

Figure 133. Presentation sequence, frame 400

Typical presentation webcast video. Static camera with a very little amount of motion.

1.1.5 “Business”

Sequence title	Business
Resolution	1920x1080
Number of frames	493
Color space	YV12
Frames per second	30
Source	CANON 5D MK2, 104Mbps

Figure 134. Business sequence, frame 400

1080p video captured from the company group meeting. Static camera with a very little amount of motion.

1.2 Movie Sequences

1.2.1 "City"

Sequence title	City
Resolution	704x576
Number of frames	600
Color space	YV12
Frames per second	60
Source	Uncompressed, progressive

Figure 135. City sequence, frame 400

This sequence is a panorama of New York city. A lot of small details such as building windows. Pretty similar colors all over the frames of the sequence. Camera shakes a little through the sequence.

1.2.2 "Indiana Jones"

Sequence title	Indiana Jones
Resolution	704x288
Number of frames	5000
Color space	YV12
Frames per second	30
Source	MPEG-2 (DVD), FlaskMPEG deinterlace

Figure 136. Indiana Jones sequence, frame 1

This sequence is a fragment from the *Indiana Jones* movie. Compression of this sequence is difficult for two main reasons: the presence of low-contrast scenes and the high level of motion in different scenes. Also, several scenes have very different types of motion, ranging from almost static scenes with talking people to scenes with strong motion (for example, the scene where stones fall).

1.2.3 "State Enemy"

Sequence title	State Enemy
Resolution	720x304
Number of frames	6500
Color space	YV12
Frames per second	24
Source	MPEG-2 (DVD), FlaskMPEG deinterlace

Figure 137. State Enemy sequence, frame 1115

This sequence is a fragment from the *Enemy of the State* movie. This sequence includes outdoor scenes with strong motion at the beginning when the bicyclist runs, as well as scenes with low motion and indoor scenes with normal motion. This sequence has scenes with different lighting conditions.

1.2.4 "Crew"

Sequence title	Crew
Resolution	704x576
Number of frames	600
Color space	YV12
Frames per second	60
Source	Uncompressed, progressive

Figure 138. Crew sequence, frame 301

This is a standard sequence of NASA crew. A lot of movement on the frames. Crew wears very bright suits and they are very distinct from grey background. A lot of camera flashes.

1.2.5 "Harbour"

Sequence title	Harbour
Resolution	704x576
Number of frames	600
Color space	YV12
Frames per second	60
Source	Uncompressed, progressive

Figure 139. Harbour sequence, frame 150

Standard sequence with harbor scene. A lot of vertical lines (boats masts) and other small details. Boats move a little, so there is pretty much movement of vertical lines. Also some water waving and sparkling included.

1.2.6 "Ice Skating"

Sequence title	Ice Skating
Resolution	704x576
Number of frames	600
Color space	YV12
Frames per second	60
Source	Uncompressed, progressive

Figure 140. Ice Skating sequence, frame 425

Standard sequence with public ice skating. People moves around on a pretty monotonous background. In the second half of the scene camera zooms out.

1.2.7 "Soccer"

Sequence title	Soccer
Resolution	704x576
Number of frames	600
Color space	YV12
Frames per second	60
Source	Uncompressed, progressive

Figure 141. Soccer sequence, frame 550

This sequence is a fragment from soccer team training in a sunny day. A lot of fast moving figures. Camera zooms out at the end of the sequence.

1.2.8 "Race Horses"

Sequence title	Race Horses
Resolution	832x480
Number of frames	300
Color space	YV12
Frames per second	30
Source	Uncompressed, progressive

Figure 142. Race Horses sequence, frame 196

This sequence contains horses walk in different directions. Camera moves around a bit too. Also sequence includes camera focus\defocus of the horses\grass. Some small details such as focused grass, horse hairs. A lot of horses overlapping.

1.2.9 "Party Scene"

Sequence title	Party Scene
Resolution	832x480
Number of frames	500
Color space	YV12
Frames per second	30
Source	Uncompressed, progressive

Figure 143. Party Scene sequence, frame 193

This sequence contains a party scene with camera zooming in. There are some transparent bubbles moving around through the sequence. There are some background movement such as kids on the left and dancing chicken. Some small details and contrast colors.

1.2.10 “Ice Age”

Sequence title	Ice Age
Resolution	720x480
Number of frames	2014
Color space	YV12
Frames per second	24
Source	MPEG-2 (DVD9), 5.7Mbps

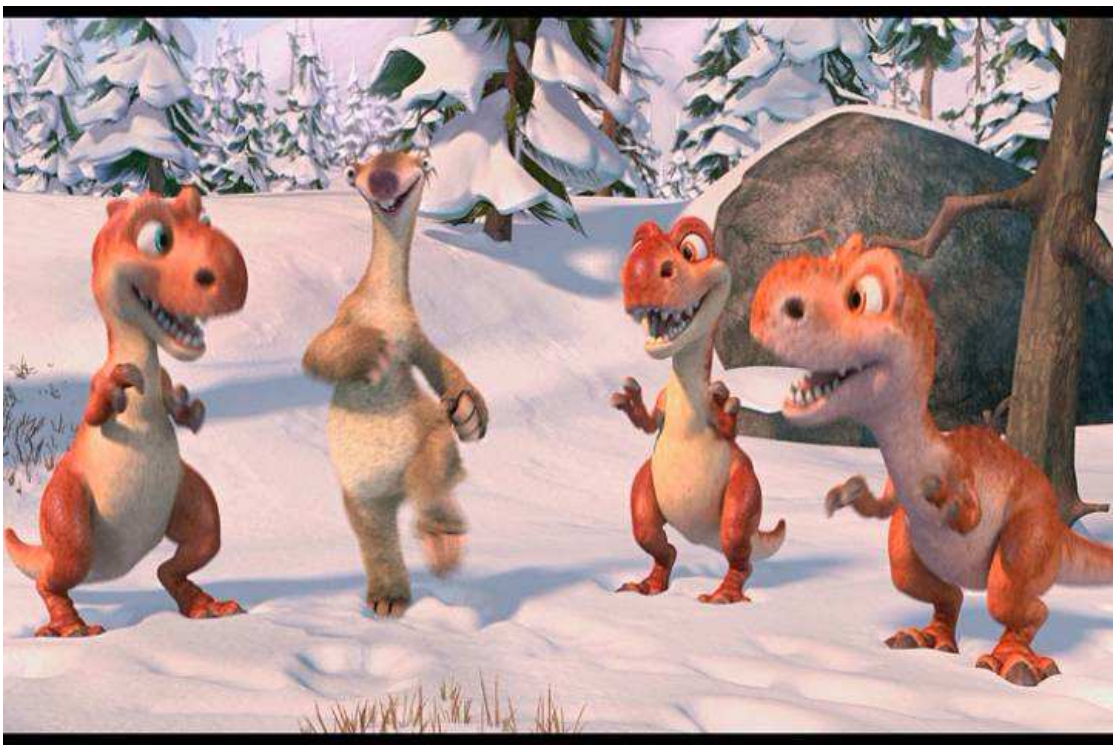

Figure 144. Ice Age sequence, frame 500

This sequence is a fragment from the *Ice Age 3* animated movie. This movie has low-contrast portions and high-contrast portions, and it has many types of motion: camera panning, slow motion and very fast motion. Also, it has a scene with colors that differ completely from those of other scenes. Small black letterboxes appear at the top and bottom of the video.

1.3 HDTV Sequences

1.3.1 "Park Joy"

Sequence title	Park Joy
Resolution	1280x720
Number of frames	500
Color space	YV12
Frames per second	50
Source	Uncompressed, progressive

Figure 145. Park Joy sequence, frame 210

This standard sequence with strictly horizontal camera movement contains small figures of running people. Sometimes a large objects (trees) near the camera moves to the left, overlapping all the scene. At the end of the sequence camera slows the motion. Very bright colors on the top and some dark tones on the bottom.

1.3.2 "Riverbed"

Sequence title	Riverbed
Resolution	1920x1080
Number of frames	250
Color space	YV12
Frames per second	25
Source	Uncompressed, progressive

Figure 146. Riverbed sequence, frame 125

Riverbed seen through the water. Very hard to code. Static camera, no global moving, but there is no static parts in this sequence.

1.3.3 "Troy"

Sequence title	Troy
Resolution	1920x1072
Number of frames	300
Color space	YV12
Frames per second	24
Source	MPEG-2

Figure 147. Troy sequence, frame 1

This sequence is a fragment of the "Troy" movie and contains three parts with sharp scene changes. The video includes medium scene motion and slow camera motion. In terms of compression, this sequence is difficult to compress because of the many small details.

1.3.4 "Stockholm"

Sequence title	Stockholm
Resolution	1280x720
Number of frames	604
Color space	YV12
Frames per second	50
Source	Uncompressed, progressive

Figure 148. Stockholm sequence, frame 574

Panning view over the Old Town of Stockholm. Detailed houses, water and moving cars. Panning view over the Old Town of Stockholm. Detailed houses, water and moving cars. This sequence is interesting for compression because of high level of noise and sharp details in the scenes and moving camera and objects such as cars a and water

1.3.5 "Rush Hour"

Sequence title	Rush Hour
Resolution	1920x1080
Number of frames	250
Color space	YV12
Frames per second	25
Source	Uncompressed, progressive

Figure 149. Rush Hour sequence, frame 250

Rush-hour in Munich city. Many cars moving slowly, high depth of focus. Fixed camera.

1.3.6 "Blue Sky"

Sequence title	Blue Sky
Resolution	1920x1080
Number of frames	217
Color space	YV12
Frames per second	25
Source	Uncompressed, progressive

Figure 150. Blue Sky sequence, frame 100

Top of two trees against blue sky. High contrast, small color differences in the sky, many details. Camera rotation.

1.3.7 "Station"

Sequence title	Station
Resolution	1920x1080
Number of frames	313
Color space	YV12
Frames per second	25
Source	Uncompressed, progressive

Figure 151. Station sequence, frame 155

View from a bridge to Munich station. Evening shot. Long zoom out. Many details, regular structures (tracks)

1.3.8 "Sunflower"

Sequence title	Sunflower
Resolution	1920x1080
Number of frames	500
Color space	YV12
Frames per second	25
Source	Uncompressed, progressive

Figure 152. Sunflower sequence, frame 370

Sunflower, very detailed shot. One bee at the sunflower, small color differences and very bright yellow. Fixed camera, small global motion.

1.3.9 "Tractor"

Sequence title	Tractor
Resolution	1920x1080
Number of frames	690
Color space	YV12
Frames per second	25
Source	Uncompressed, progressive

Figure 153. Tracktor sequence, frame 470

A tractor in a field. Whole sequence contains parts that are very zoomed in and a total view. Camera is following the tractor, chaotic object movement, structure of a harvested field.

1.3.10 "Big Buck Bunny"

Sequence title	Big Buck Bunny
Resolution	1920x1080
Number of frames	600
Color space	YV12
Frames per second	24
Source	Uncompressed, progressive

Figure 154. Big Buck Bunny sequence, frame 110

Scene from a cartoon movie Big Buck Bunny. Contains a lot of movement, very bright colors, different type of motion. The web-site for this movie is http://www.bigbuckbunny.org/

1.3.11 "Elephants Dream"

Sequence title	Elephants Dream
Resolution	1920x1080
Number of frames	600
Color space	YV12
Frames per second	24
Source	Uncompressed, progressive

Figure 155. Elephants Dream sequence, frame 460

Part of a cartoon movie Elephants Dream. Contains a lot of contrast thin lines and motion all over the scenes. Combination of dark colors with very bright small details makes this sequence pretty hard for encoding. The web-site for this movie is http://www.elephantsdream.org/

1.3.12 “Water drops”

Sequence title	Water drops
Resolution	1920x1080
Number of frames	535
Color space	YV12
Frames per second	30
Source	142Mbps, progressive

Figure 156. Drops sequence, frame 100

Video from a farm in a rainy day. Camera captured a rain drops with a high quality. Camera also performs some motion and zoom-in and zoom-out.

1.3.13 “Capitol”

Sequence title	Capitol
Resolution	1920x1080
Number of frames	600
Color space	YV12
Frames per second	30
Source	Panasonic DVCPRO HD, HDX-900, 410Mbps

Figure 157. Capitol sequence, frame 450

Flying around Austin Texas and surroundings neighborhood. Video captured from a helicopter and contains panoramic view over some building. Sequence contains some rotation motion and camera shaking.

1.3.14 “Parrots”

Sequence title	Parrots
Resolution	1920x1080
Number of frames	600
Color space	YV12
Frames per second	30
Source	100Mbps, progressive (deinterlaced)

Figure 158. Parrots sequence, frame 300

Sequence contains two high-contrast parrots. Camera is static, parrots move slowly in this sequence.

1.3.15 “Citybus”

Sequence title	Citybus
Resolution	1920x1080
Number of frames	600
Color space	YV12
Frames per second	30
Source	Sony HVR-V1, 150Mbps

Figure 159. Citybus sequence, frame 100

City Bus and vehicles drive by. Crane Shot. Sequence contains fast moving vehicles in the right and some pedestrians in the left. Camera slowly moves upwards with a little shaking.

1.3.16 “Underwater”

Sequence title	Underwater
Resolution	1920x1080
Number of frames	600
Color space	YV12
Frames per second	30
Source	Canon 500D, 26 Mbps

Figure 160. Underwater sequence, frame 400

This is a low-contrast high-brightness sequence from the underwater. Contains a lot of focused and defocused details. Almost no camera motion, but almost everything in the sequence moves slowly. Also some water-specific brightness flicking.

2 Appendix 2. Tested Codecs and Presets

2.1 Codecs

2.1.1 DivX AVC/H.264 Video Encoder

- Console encoding program version 1.1.1.9
- Presets were chosen by ourselves to meet the comparison requirements

***Remarks**: Owing to our choice of presets, the results for the DivX H.264 encoder could be slightly diminished compared with the case where the developers provide the presets.*

```
DivX AVC/H.264 Video Encoder (version 1.1.1.9) Copyright (c) 2010 DivX, Inc.
Usage: [options] -i <input file> -o <output file>

Available options are:

General:

                    -help   This help information
                      -h
              -noprogress   Do not display progress information
                 -version   Display version information
                   -v <0¦1>   Verbose level

Input/Output:

          -i <input file>   AVI file or AVISynth script (avi¦avs)
                              Pixel format in one of these formats:
                              YV12 IYUV YUY2 YVYU UYVY BGR24 BGR32
                            or raw yuv (use - for stdin) (requires -y)
         -o <output file>   Raw AVC bit stream
                            (Annex B raw byte stream format, type II)
      -y <width>x<height>   Input resolution (e.g. 1920x1080)
       -fps <int>[/<num>]   Override input frame rate (e.g. 30 or 30/1.001)
                    -tff   Interlaced input, top field first
                    -bff   Interlaced input, bottom field first
    -sar <width>:<height>   Sample Aspect Ratio [1:1]
             -start <int>   First frame to encode
            -frames <int>   Maximum number of frames to encode

Rate control:

                -br <int>   Target bitrate in kbps
                -qf <int>   Target Quality Factor
                              Lower number results in higher quality [0..51]

  Multipass:

            -npass <1¦2>   Specify multipass mode
         -sf <stat file>   Specify multipass statistics file name [divx264_stat
.dat]

Encoder:

             -aqo <0¦1¦2>   Algorithm quality optimized for:
                             0 = Fast encoding
                             1 = Balanced performance/quality (default)
                             2 = Highest quality
                -I <1..4>   Gop length (seconds) [4]
            -fmode <1¦2>   Interlace coding mode
                             1 = MBAFF
                             2 = Field
             -ref <1..4>   Maximum number of reference frames [4]
                -pyramid   Enables pyramid encoding (implies -bref)
                  -bref    Enables B as reference
              -bf <0..3>   Maximum consecutive B-frames [2]
          -threads <int>   Maximum number of threads [auto]


The following frame rates for DivX Plus are permitted:

  60 Hz
  60000/1001 Hz
  50 Hz
  30 Hz
  30000/1001 Hz (i)
  25 Hz (i)
  24 Hz
  24000/1001 Hz

This pre-release version will expire on Wed Aug 29 01:00:00 2012
Please check http://labs.divx.com for new versions.
```

Figure 161. DivX AVC/H.264 video encoder

2.1.2 Elecard AVC Video Encoder 8-bit edition,

- Console encoding program version 2.1.032820.120220
- Codec and presets were provided by Elecard Ltd Company specifically for this test

```
Elecard AVC Video Encoder 8-bit edition, ver. 2.1.032820.120220
usage: avcenc.exe config.cfg [parameters list]
```

Figure 162. Elecard AVC Video Encoder 8-bit edition

2.1.3 MainConcept AVC/H.264 Video Encoder Console Application

- Console software and CUDA encoder applications and presets for them were provided by MainConcept AG Company specifically for this test

2.1.4 x264

- Console encoding application with core:120 r2146 bcd41dbwas from the public repository
- Presets were provided by developers specifically for this test

Remarks: The presets provided by the developers for this comparison were specifically chosen for the SSIM metric.

```
x264 core:120 r2146 bcd41db
Syntax: x264 [options] -o outfile infile

Infile can be raw (in which case resolution is required),
  or YUV4MPEG (*.y4m),
  or Avisynth if compiled with support (yes).
  or libav* formats if compiled with lavf support (yes) or ffms support (yes).
Outfile type is selected by filename:
 .264 -> Raw bytestream
 .mkv -> Matroska
 .flv -> Flash Video
 .mp4 -> MP4 if compiled with GPAC support (yes)
Output bit depth: 8 (configured at compile time)

Options:

  -h, --help                  List basic options
      --longhelp              List more options
      --fullhelp              List all options

Example usage:

      Constant quality mode:
            x264 --crf 24 -o <output> <input>

      Two-pass with a bitrate of 1000kbps:
            x264 --pass 1 --bitrate 1000 -o <output> <input>
            x264 --pass 2 --bitrate 1000 -o <output> <input>

      Lossless:
            x264 --qp 0 -o <output> <input>

      Maximum PSNR at the cost of speed and visual quality:
            x264 --preset placebo --tune psnr -o <output> <input>

      Constant bitrate at 1000kbps with a 2 second-buffer:
            x264 --vbv-bufsize 2000 --bitrate 1000 -o <output> <input>

Presets:

      --profile <string>      Force the limits of an H.264 profile
                                  Overrides all settings.
```

Figure 163. x264 encoder

2.1.5 XviD raw mpeg4 bitstream encoder

- Console encoding program
- Codec and presets used was taken from previous comparison

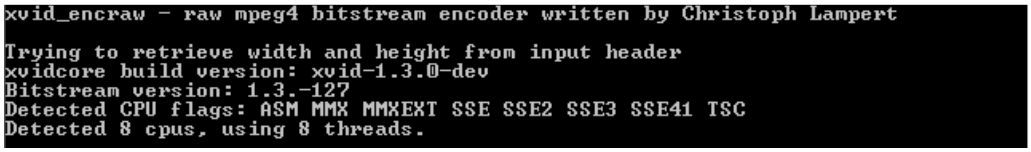

Figure 164. XviD encoder

2.1.6 Discrete Photon

- Console encoding application version (1.1.0.4) and presets was provided by developers specifically for this test

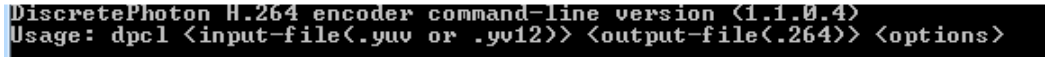

Figure 165. Discrete Photon encoder

2.1.7 Intel Ivy Bridge QuickSync

- Transcoder and presets was provided by Intel specifically for this test
- Intel Ivy Bridge Platform used in hardware/software comparison was provided by Intel

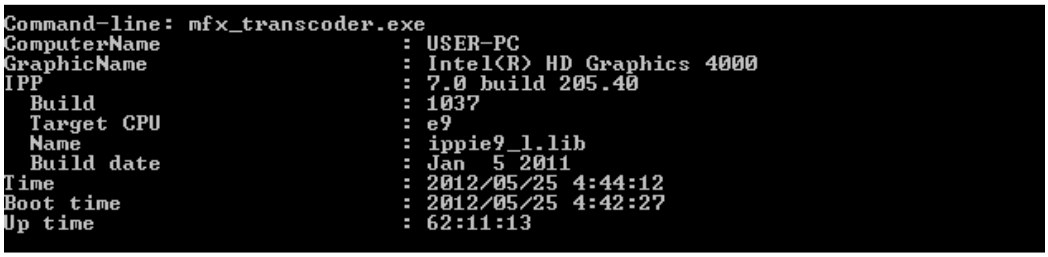

Figure 166. ntel Ivy Bridge QuickSync

2.2 Presets

The table below lists the settings used in this comparison for all of the codecs.

<table>
<tr><th>Codec</th><th>Preset Name</th><th>Preset</th></tr>
<tr><td rowspan="7">DivX H.264</td><td>Movie
“High Speed”</td><td>-aqo 0 -ref 1 -bf 0</td></tr>
<tr><td>Movie “Normal”</td><td>Default presets</td></tr>
<tr><td>Movie
“High Quality”</td><td>1-st pass: -npass 1
2-nd pass: -npass 2</td></tr>
<tr><td>HDTV
“High Speed”</td><td>-aqo 0 -ref 1 -bf 0</td></tr>
<tr><td>HDTV “Normal”</td><td>-aqo 0</td></tr>
<tr><td>HDTV
“High Quality”</td><td>-bf 3 -pyramid -bref</td></tr>
<tr><td>Elecard</td><td>Movie
“Normal”</td><td>
<table>
<tr><th>Parameter name</th><th>Value</th><th>Comment</th></tr>
<tr><td>BMax</td><td>1</td><td>max number of b-frames</td></tr>
<tr><td>BMode</td><td>0</td><td>2 - hierarchical structure</td></tr>
<tr><td>ModeDecision</td><td>1</td><td>1 - SATD</td></tr>
<tr><td>WPredMode</td><td>1</td><td>1 - explicit mode (for both P- and B-frames)</td></tr>
</table>
</td></tr>
</table>

		NumRefFrames: 2 (actual size of DPB) AQMode: 4 (0 - do not use) Lookahead: 3 (lookahead length in seconds) OffsetCb: 1 ([-10,+10] i prefer 0 or -1) OffsetCr: 1 ([-10,+10] i prefer 0 or -1.) DeblockAlpha: -1 ([-6,+6] really depends on source) DeblockBeta: -1 ([-6,+6] really depends on source.) DeblockMode: 0 (0 - filter whole picture) IntraNewInI: 1 (enables MB intra in I-slices) Intra8x8InI: 1 Intra4x4InI: 1 (same for P-slices) IntraNewInP: 1 Intra8x8InP: 1 Intra4x4InP: 1 (same for B-slices) IntraNewInB: 1 Intra8x8InB: 1 Intra4x4InB: 0 BlockMode: 1 (1 - MC down to 8x8) MaxVectorLen: 511 (for both horz and vert components)
	HDTV "Normal"	**Parameter name / Value / Comment** Intra4x4InP: 0 Intra8x8InB: 0 WPredBiMode: 2 (disables MB intra in corresponding slices) Other settings are the same as for Movie Normal
	HDTV "High Speed"	**Parameter name / Value / Comment** BMax: 1 (max number of b-frames) Lookahead: 2 Trellis: 0 (0 - plain vanilla) IntraNewInB: 0 (disables 4x4 in I-slices) ModeDecision: 0 (0 - SAD) WPredBiMode: 0 (0 - not used) NumRefFrames: 1 (actual size of DPB) Other settings are the same as for HDTV Normal
	HDTV "High Quality"	**Parameter name / Value / Comment** Intra4x4InP: 1 IntraNewInB: 1 Intra8x8InB: 1 (enables MB intra in corresponding slices) Transofrm: 1 ModeDecision: 2 Trellis: 2 NumRefFrames: 3 Other settings are the same as for HDTV Normal
	VideoConference	**Parameter name / Value / Comment** Lookahead: 3 Other settings are the same as for Movie Normal
MainConcept	Movie "Normal"	**Parameter name / Value** FastIntraDecision: 0 FastInterDecision: 0 FastMRME: 0 FastSBME: 1 NumRefFrames: 7 BFramesReference: 1 PyramidCoding: 1 SubBlockMode: 1 WeightedPred: 1 NumRefFrames: 4 EnableIntra_4x4: 1 RDOMode: 3 QuantOptimization: 1
	Movie "High Speed"	**Parameter name / Value** FastIntraDecision: 1

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“High Quality”</td><td>
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<tr><td>FastSBME</td><td>0</td></tr>
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“Normal”</td><td>
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<tr><th>Parameter name</th><th>Value</th></tr>
<tr><td>FastIntraDecision</td><td>1</td></tr>
<tr><td>FastInterDecision</td><td>1</td></tr>
<tr><td>FastMRME</td><td>1</td></tr>
</table>
Other settings are the same as for Movie Normal
</td></tr>
<tr><td></td><td>HDTV
“High Speed”</td><td>
<table>
<tr><th>Parameter name</th><th>Value</th></tr>
<tr><td>BFramesReference</td><td>0</td></tr>
<tr><td>PyramidCoding</td><td>0</td></tr>
<tr><td>SubBlockMode</td><td>0</td></tr>
<tr><td>WeightedPred</td><td>0</td></tr>
<tr><td>NumRefFrames</td><td>3</td></tr>
<tr><td>EnableIntra_4x4</td><td>0</td></tr>
<tr><td>RDOMode</td><td>1</td></tr>
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Other settings are the same as for HDTV Normal
</td></tr>
<tr><td></td><td>HDTV
“High Quality”</td><td>
<table>
<tr><th>Parameter name</th><th>Value</th></tr>
<tr><td>NumRefFrames</td><td>5</td></tr>
<tr><td>FastInterDecision
FastMRME
FastSBME</td><td>1
1
1</td></tr>
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Other settings are the same as for HDTV Normal
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<tr><td></td><td>VideoConference</td><td>
<table>
<tr><th>Parameter name</th><th>Value</th></tr>
<tr><td>FastSBME</td><td>0</td></tr>
<tr><td>QuantOptimization</td><td>0</td></tr>
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Other settings are the same as for Movie Normal
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<tr><td>x264</td><td>Movie
“Normal”</td><td>1-st pass:
--tune ssim --pass 1 --keyint 500 --preset medium --direct auto --me umh --merange 12 --subme 8
2-nd pass:
--tune ssim --pass 2 --keyint 500 --preset medium --direct auto --me umh --merange 12 --subme 8</td></tr>
<tr><td></td><td>Movie
“High Speed”</td><td>1-st pass:
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2-nd pass:
--tune ssim --pass 2 --keyint 500 --preset fast</td></tr>
<tr><td></td><td>Movie
“High Quality”</td><td>1-st pass:
--tune ssim --pass 1 --keyint 500 --preset slow --subme 9 --trellis 2 --ref 6
2-nd pass:
--tune ssim --pass 2 --keyint 500 --preset slow --subme 9 --trellis 2 --ref 6</td></tr>
<tr><td></td><td>HDTV
“Normal”</td><td>1-st pass:
--tune ssim --pass 1 --keyint 500 --preset fast --subme 1</td></tr>
</table>

		2-nd pass: --tune ssim --pass 2 --keyint 500 --preset fast
	HDTV “High Speed”	1-st pass: --tune ssim --pass 1 --keyint 500 --preset veryfast --subme 1 2-nd pass: --tune ssim --pass 2 --keyint 500 --preset veryfast
	HDTV “High Quality”	1-st pass: --tune ssim --pass 1 --keyint 500 --preset slow 2-nd pass: --tune ssim --pass 2 --keyint 500 --preset slow
	VideoConference	--tune ssim --keyint 500 --preset veryslow --bframes 5 --ref 12
XviD	Movie “High Speed”	-type 0 -quality 5 -vhqmode 1 -max_bframes 0 -reaction 8 -averaging 50 -smoother 50
	Movie “Normal”	1-st pass: -type 0 -pass1 -quality 6 -vhqmode 1 -ostrength 20 -oimprove 10 -odegrade 10 2-nd pass: -type 0 -pass2 -quality 6 -vhqmode 1 -ostrength 20 -oimprove 10 -odegrade 10
	Movie “High Quality”	1-st pass: -type 0 -pass1 -quality 6 -vhqmode 4 -bvhq -qpel -ostrength 20 -oimprove 10 -odegrade 10 2-nd pass: -type 0 -pass2 -quality 6 -vhqmode 4 -bvhq -qpel -ostrength 20 -oimprove 10 -odegrade 10
	HDTV “High Speed”	-type 0 -quality 5 -vhqmode 1 -max_bframes 0 -reaction 8 -averaging 50 -smoother 50
	HDTV “Normal”	1-st pass: -type 0 -pass1 -quality 6 -vhqmode 1 -ostrength 20 -oimprove 10 -odegrade 10 2-nd pass: -type 0 -pass2 -quality 6 -vhqmode 1 -ostrength 20 -oimprove 10 -odegrade 10
	HDTV “High Quality”	1-st pass: -type 0 -pass1 -quality 6 -vhqmode 4 -bvhq -qpel -ostrength 20 -oimprove 10 -odegrade 10 2-nd pass: -type 0 -pass2 -quality 6 -vhqmode 4 -bvhq -qpel -ostrength 20 -oimprove 10 -odegrade 10
	VideoConference	-type 0 -max_bframes 2 -quality 6 -vhqmode

<table>
<tr><td></td><td></td><td>4 -bvhq -qpel -gmc</td></tr>
<tr><td rowspan="2">Discrete Photon</td><td>Normal preset</td><td>-dbv:0 -speed:1</td></tr>
<tr><td>Quality preset</td><td>-dbv:0 -speed:0</td></tr>
<tr><td rowspan="2">Intel Ivy Bridge QuickSync</td><td>Use-case 1</td><td>-h264 -hw -d3d -async 10 -s 0 -l 1 -u 1 -i:yv12</td></tr>
<tr><td>Use-case 7</td><td>-h264 -hw -d3d -async 10 -s 0 -l 1 -u 7 -i:yv12</td></tr>
<tr><td rowspan="2">MainConcept CUDA Transcoder</td><td>Fast</td><td><table><tr><th>Parameter name</th><th>Value</th></tr><tr><td>NumRefFrames</td><td>1</td></tr><tr><td>EnableInter_16x16</td><td>0</td></tr></table></td></tr>
<tr><td>Quality</td><td><table><tr><th>Parameter name</th><th>Value</th></tr><tr><td>NumRefFrames</td><td>2</td></tr><tr><td>EnableInter_16x16</td><td>1</td></tr></table></td></tr>
</table>

3 Appendix 3. Figures Explanation

The main charts in this comparison are classical RD curves (quality/bitrate graphs) and relative bitrate/relative time charts. Additionally, bitrate handling charts (ratio of real and target bitrates) and per-frame quality charts were also used.

3.1.1.1 RD curves

These charts show variation in codec quality by bitrate or file size. For this metric, a higher curve presumably indicates better quality.

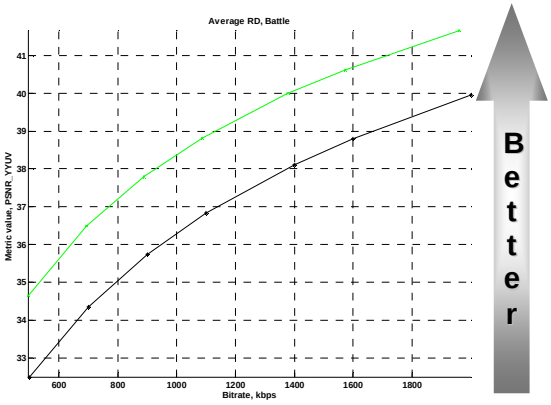
3.1.1.2 Relative Bitrate/Relative Time Charts

Relative bitrate/relative time charts show the dependence on relative encoding time of the average bitrate for a fixed quality output. The Y-axis shows the ratio of the bitrate of the codec under test to that of the reference codec for a fixed quality. A lower value (that is, the higher the value is on the graph) indicates a better-performing codec. For example, a value of 0.7 means that codec under test can encode the sequence under test in a file that is 30% smaller than that encoded by the reference codec.

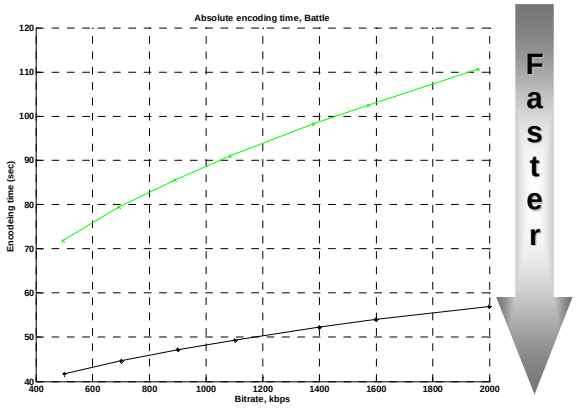
The X-axis shows the relative encoding time for the codec under test. Larger values indicate a slower codec. For example, a value of 2.5 means that the codec under test works 2.5 times slower, on average, than the reference codec.

3.1.1.3 Graph Example

Figure 167 shows a case where these graphs can be useful. In the top left graph, it is apparent that the “Green” codec encodes with significantly better quality than the “Black” codec. On the other hand, the top right graph shows that the “Green” codec is slightly slower. Relative bitrate/relative time graphs can be useful in precisely these situations: it is clearly visible in the bottom graph that one of the codecs is slower, but yields higher visual quality, and that the other codec is faster, but yields lower visual quality.



RD curve. “Green” codec is better!



Encoding time (seconds). “Green codec is slower!

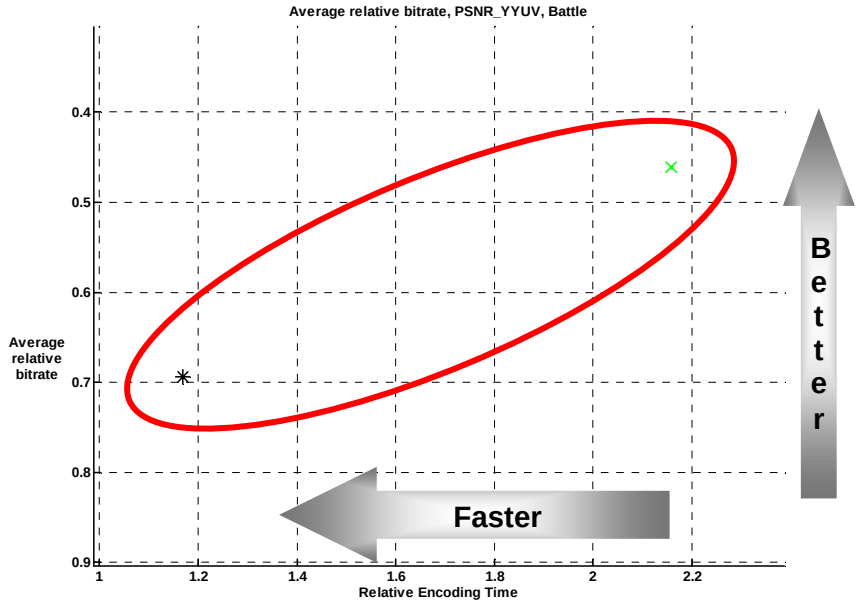


Figure 167. Integral situation with codecs. This plot shows the situation more clearly.

As a result of these advantages, relative bitrate/relative time graphs are used frequently in this report since they assist in the evaluation of the codecs in the test set, especially when number of codecs is large.

A more detailed description of the preparation of these graphs is given below.

3.2 Bitrates Ratio with the Same Quality

The first step in computing the average bitrate ratio for a fixed quality is inversion of the axes of the bitrate/quality graph (see Figure 169). All further computations are performed using the inverted graph.

The second step involves averaging the interval over which the quality axis is chosen. Averaging is performed only over those segments for which there are results for both codecs. This limitation is due to the difficulty of developing extrapolation methods for classic RD curves; nevertheless, for interpolation of RD curves, even linear methods are acceptable.

The final step is calculation of the area under the curves in the chosen interpolation segment and determination of their ratio (see Figure 170). This result is an average bitrate ratio for a fixed quality for the two codecs. If more

than two codecs are considered, then one of them is defined as a reference codec and the quality of others is compared to that of the reference.

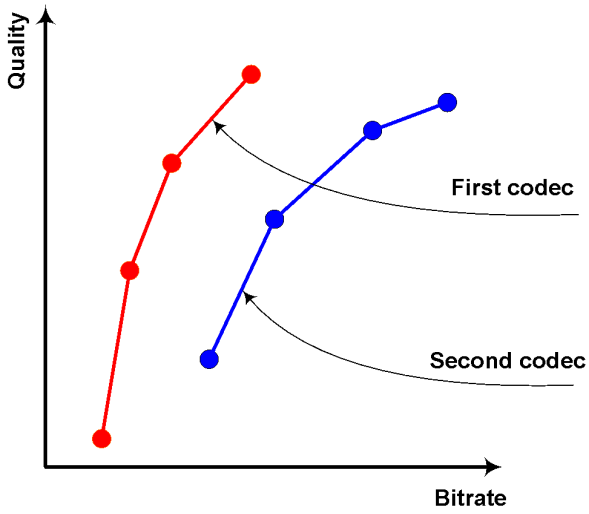


Figure 168. Source Data

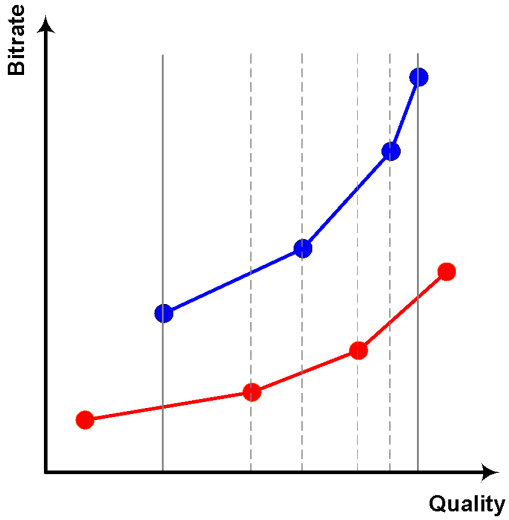


Figure 169. Axes' Inversion and Averaging Interval Choosing

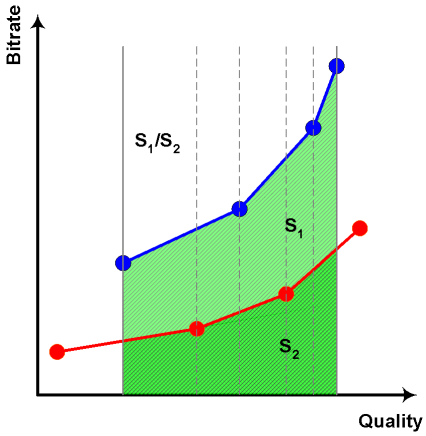


Figure 170. Areas' under Curves Ratio

4 Appendix 4. Objective Quality Metrics Description

4.1 SSIM (Structural SIMilarity)

4.1.1 Brief Description

The original paper on the SSIM metric was published by Wang, et al.[1] The paper can be found at the following URL:
http://ieeexplore.ieee.org/iel5/83/28667/01284395.pdf

The SSIM author homepage is found at the following URL: http://www.cns.nyu.edu/~lcv/ssim/

The scheme of SSIM calculation can be presented as follows. The main idea that underlies the structural similarity (SSIM) index is comparison of the distortion of three image components:

- Luminance
- Contrast
- Structure

The final formula, after combining these comparisons, is the following:

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

where

$$\mu_x = \sum_{i=1}^{N} \omega_i x_i$$

$$\sigma_x = \left(\sum_{i=1}^{N} \omega_i (x_i - \mu_x) \right)^{\frac{1}{2}}$$

$$\sigma_{xy} = \sum_{i=1}^{N} \omega_i (x_i - \mu_x)(y_i - \mu_y)$$

The constants C_1 and C_2 are defined according to the following expressions:

$$C_1=(K_1L)^2$$
$$C_2=(K_2L)^2$$

where L is the dynamic range of the pixel values (255 for 8-bit grayscale images), and $K_1, K_2 << 1$.

The values $K_1 = 0.01$ and $K_2 = 0.03$ were used for the comparison presented in this report, and the matrix filled with a value “1” in each position to form a filter for the result map.

For the implementation used in this comparison, one SSIM value corresponds to two sequences. The value is in the range [-1, 1], with higher values being more desirable (a value of 1 corresponds to identical frames). One of the advantages of the SSIM metric is that it better represents human visual

[1] Zhou Wang, Alan Conrad Bovik, Hamid Rahim Sheikh and Eero P. Simoncelli, “Image Quality Assessment: From Error Visibility to Structural Similarity,” *IEEE Transactions on Image Processing*, Vol. 13, No. 4, April 2004.

perception than does PSNR. SSIM is more complex, however, and takes more time to calculate.

4.1.2 Examples

The following is an example of an SSIM result for an original and processed (compressed with lossy compression) image. The resulting value of 0.9 demonstrates that the two images are very similar.

Original Processed SSIM

Figure 171. SSIM example for compressed image

The following are more examples how various types of distortion influence the SSIM value.

Original image

Image with added noise

Blurred image

Sharpen image

Figure 172. Original and processed images (for SSIM example)

The SSIM values for the Y-plane for these images are given below.

SSIM for image with itself, value = 1

SSIM for image with noisy image, value = 0.552119

SSIM for image with blurred image, value = 0.9225

SSIM for image with sharpen image, value = 0.958917

Figure 173. SSIM values for original and processed images

4.2 PSNR (Peak Signal-to-Noise Ratio)

4.2.1 Brief Description

This metric, which is often used in actual practice, is called the peak signal-to-noise ratio, or PSNR.

$$d(X,Y) = 10 \cdot \log_{10} \frac{255^2 \cdot m \cdot n}{\sum_{i=1,j=1}^{m,n} (x_{ij} - y_{ij})^2},$$

Where *d(X,Y)* – PSNR value between *X* and *Y* frames

x_{ij} – the pixel value for *(i,j)* position for the *X* frame

y_{ij} – the pixel value for *(i,j)* position for the *Y* frame

m,n – frame size *mxn*

Generally, this metric has the same form as the mean square error (MSE), but it is more convenient to use because of the logarithmic scale. It still has the same disadvantages as the MSE metric, however.

In MSU Video Quality Measurement Tool the PSNR can be calculated for all YUV and RGB components and for the L component of LUV color space. The PSNR value is quick and easy to calculate, but it is sometimes inappropriate as relates to human visual perception.

A maximum deviation of 255 is used for the PSNR for the RGB and YUV color components because, in YUV files, there is 1 byte for each color component. The maximum possible difference, therefore, is 255. For the LUV color space, the maximum deviation is 100.

The values of the PSNR in the LUV color space are in the range [0, 100]; the value 100 means that the frames are identical.

4.2.2 Examples

PSNR visualization uses different colors for better visual representation:

- Black – value is very small (99 – 100)
- Blue – value is small (35 – 99)
- Green – value is moderate (20 – 35)
- Yellow –value is high (17 – 20)
- Red –value is very high (0 – 17)

The following is an example of the PSNR metric:

Original Processed PSNR

Figure 174. PSNR example for two frames

The following are further examples demonstrating how various distortions can influence the PSNR value.

Original image

Image with added noise

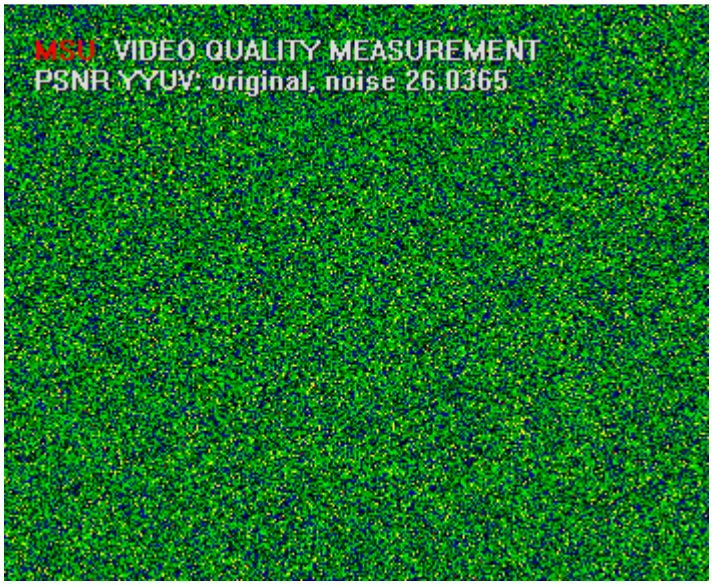
Blurred image

Sharpen image

Figure 175. Original and processed images (for PSNR example)

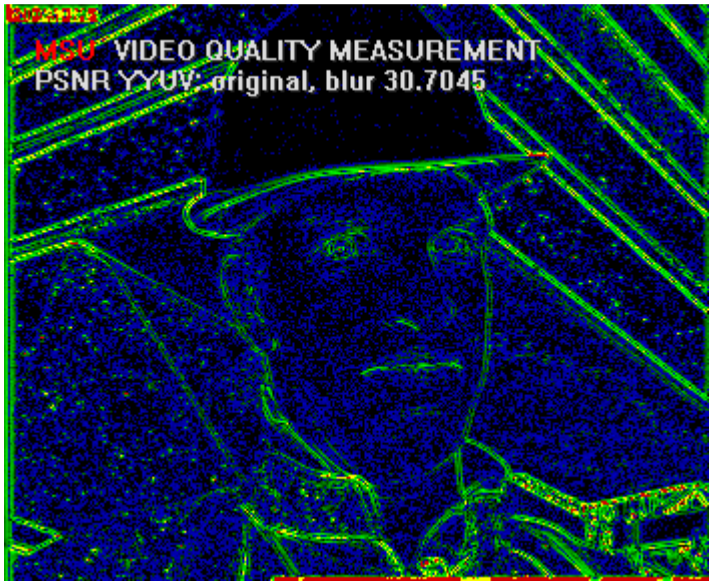
Next are the PSNR values for the Y–plane for these images

PSNR for image with itself, value = 0

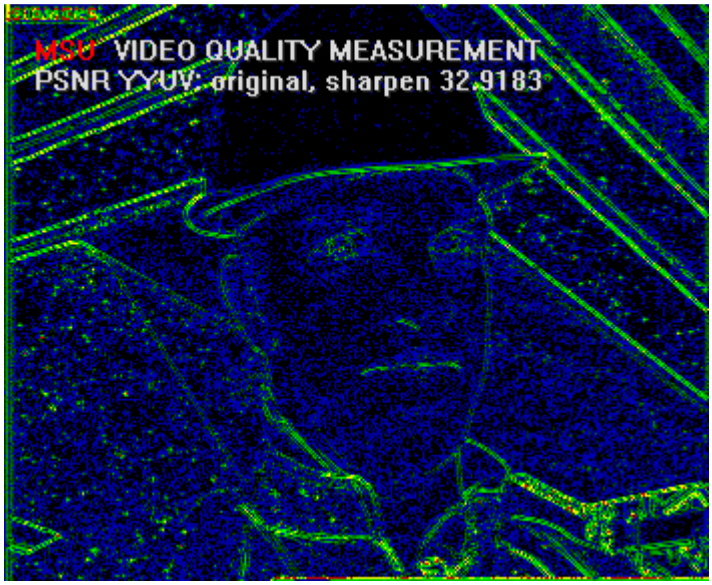


PSNR for image with noisy image,

value = 26.0365



PSNR for image with blurred image,
value = 30.7045



PSNR for image with sharpen image,
value = 32.9183

Figure 176. PSNR values for original and processed images

5 Appendix 5. Hardware (GPU) based encoders comparison

Comparing software and hardware (GPU) based encoders directly is not very correct sometimes due to the fact that GPU-based encoders could use much more computational power than software encoders and because of it have much more encoding speed. But GPU-usage makes encoders do not use some features that could improve encoding quality. So it is interesting to compare only hardware based encoders.

In this part MSU compares three GPU-based encoders:

- Intel Ivy Bridge QuickSync (GPU encoder)
- MainConcept H.264 (CUDA based encoder)
- MainConcept H.264 (OpenCL based encoder), ATI 6970 graphic card was used

MainConcept OpenCL does not take part in basic comparison due some technical and logistical problems on the MSU side.

MSU used only HD sequences in his part of comparison because it is main usage for GPU encoders.

5.1 RD Curves

The leader is Intel QuickSync at average, but at some sequences MainConcept OpenCL shows better results. MainConcept CUDA is typically at third place.

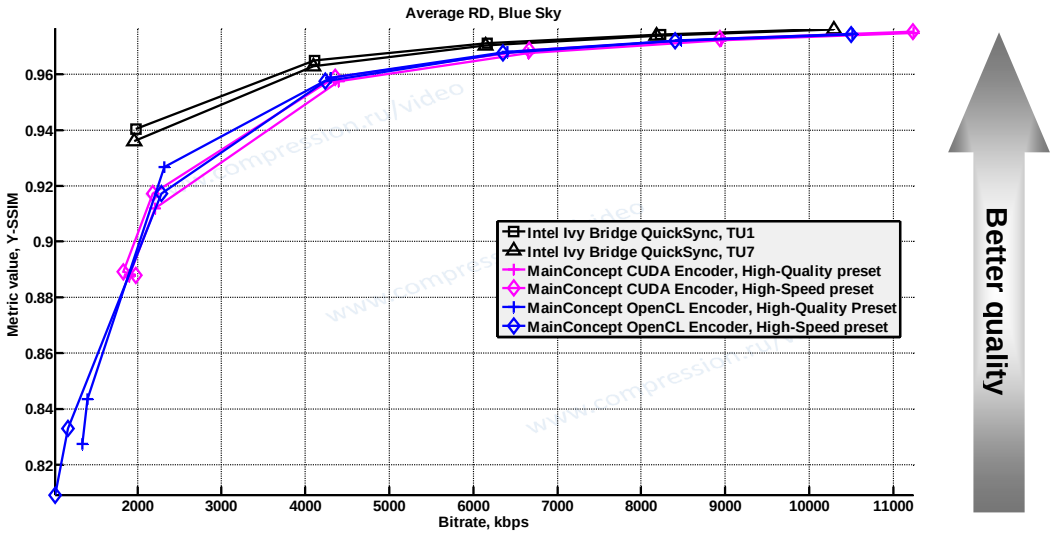


Figure 177. Bitrate/quality, GPU encoders, "Blue Sky" sequence, Y-SSIM metric

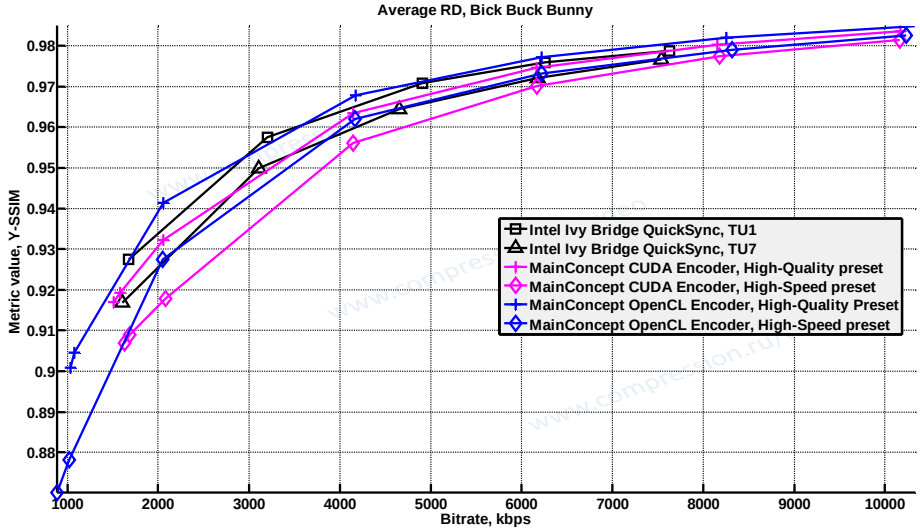


Figure 178. Bitrate/quality, GPU encoders, "Bick Buck Bunny" sequence, Y-SSIM metric

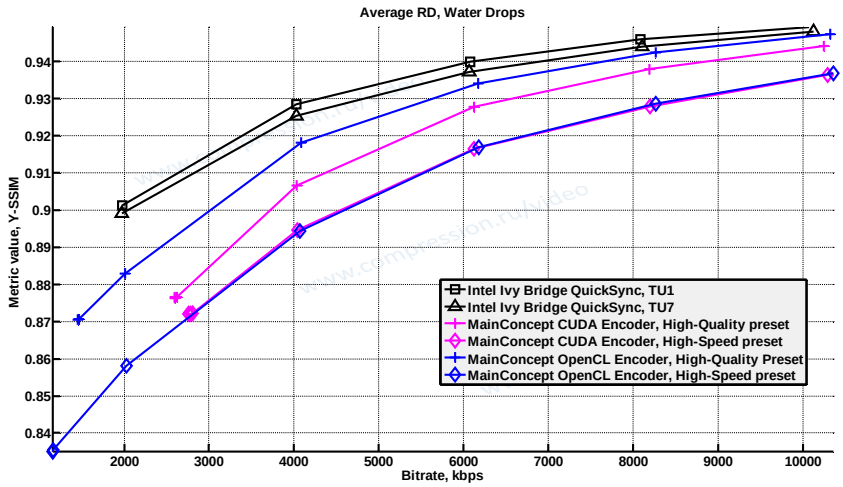


Figure 179. Bitrate/quality, GPU encoders, "Water Drops" sequence, Y-SSIM metric

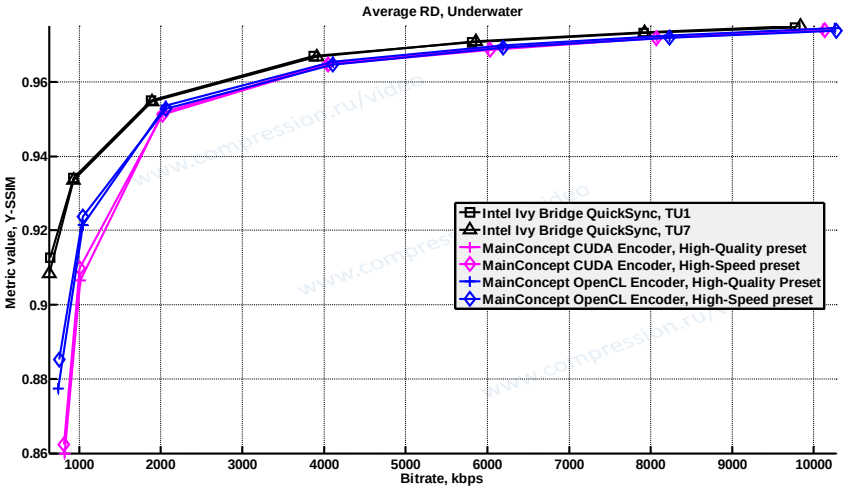


Figure 180. Bitrate/quality, GPU encoders, "Underwater" sequence, Y-SSIM metric

5.2 Bitrate Handling

Bitrate handling for all encoders is good except low bitrates: both MainConcept encoders typically increase low bitrates and Intel QuickSync does not encode low bitrates.

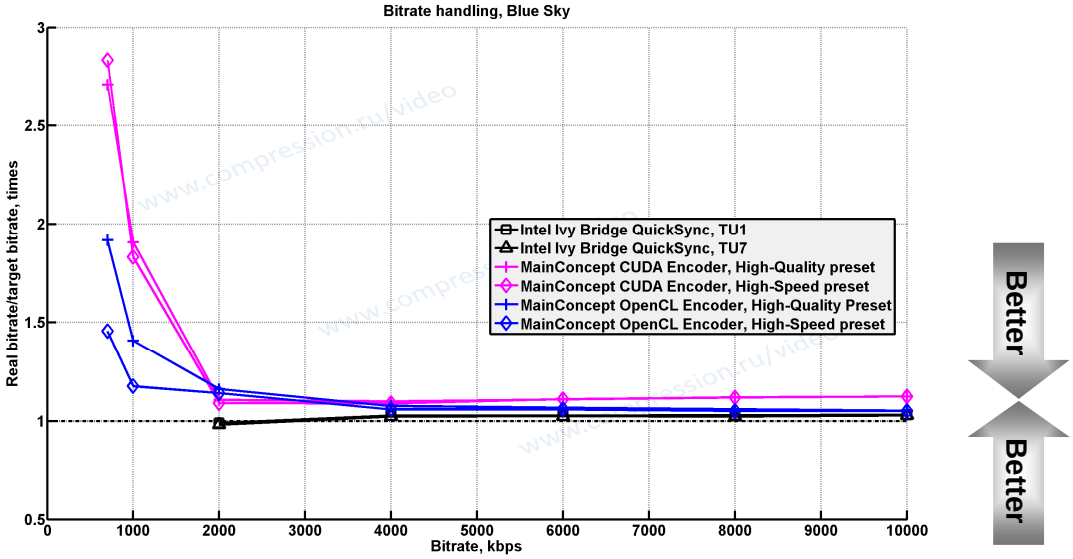


Figure 181. Bitrate handling, GPU encoders," "Blue Sky" sequence

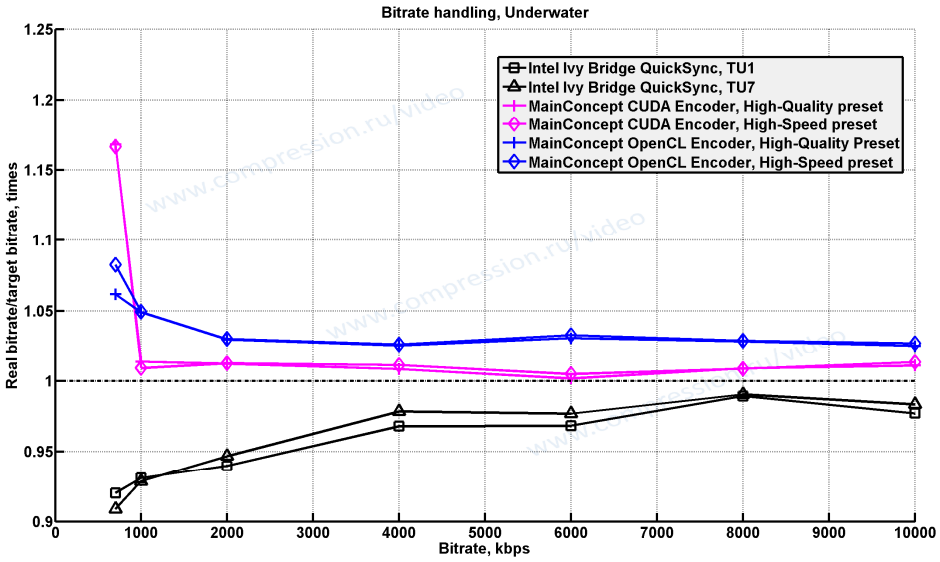


Figure 182. Bitrate handling, GPU encoders," "Underwater" sequence

5.3 Speed/Quality Trade-Off

Intel QuickSync is faster and shows higher quality comparing to MainConcept encoders, but there are sequences (Riverbed for example) where Intel QuickSync is not optimal. Comparing MainConcept CUDA and OpenCL encoders one could say that OpenCL encoder is better at average than CUDA based.

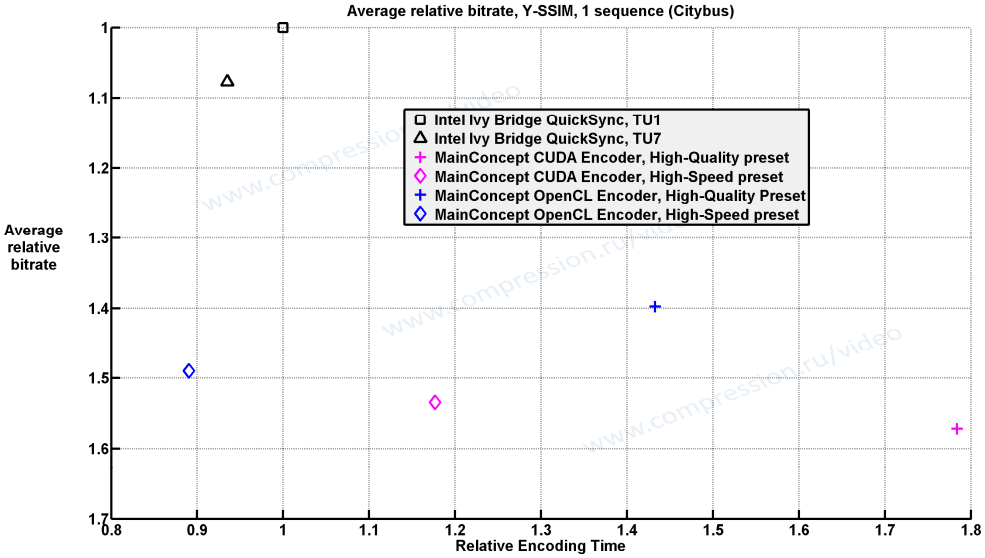


Figure 183. Speed/quality trade-off, GPU encoders, "Citybus" sequence, Y-SSIM metric

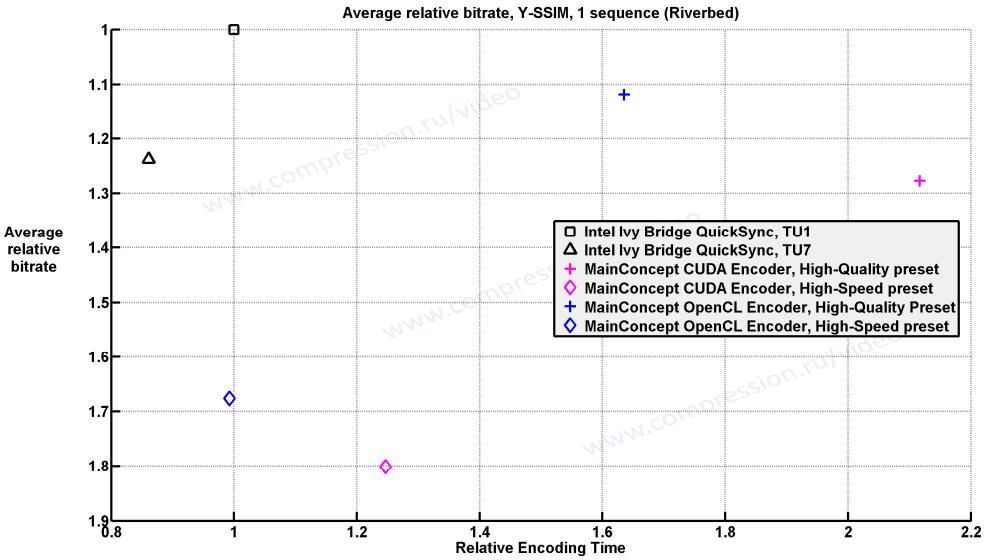


Figure 184. Speed/quality trade-off, GPU encoders, "Riverbed" sequence, Y-SSIM metric

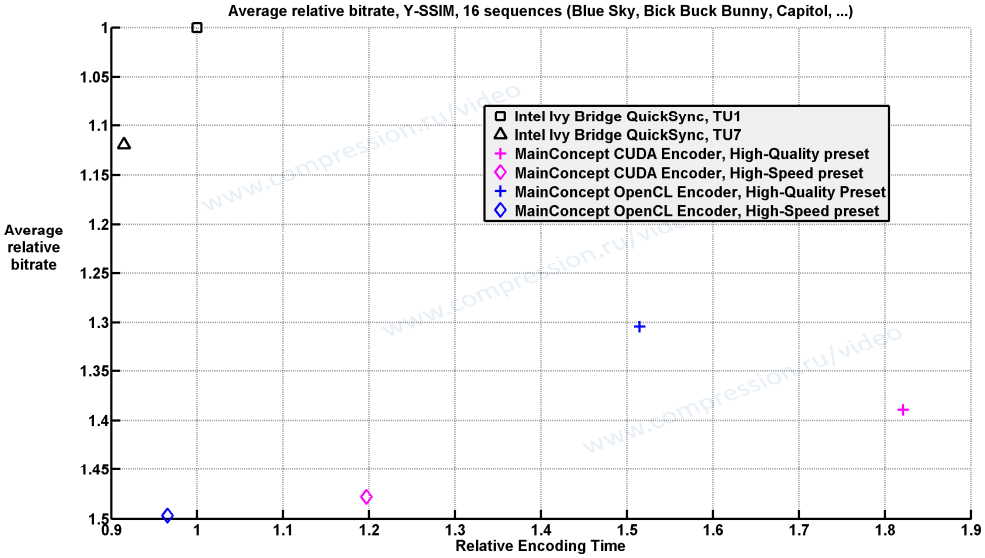


Figure 185. Speed/quality trade-off, GPU encoders, all sequences, Y-SSIM metric

5.4 Conclusion

The overall ranking of the codecs tested in this part of comparison is as follows:

1. Intel Ivy Bridge QuickSync
2. MainConcept OpenCL
3. MainConcept CUDA

6 Appendix 6. Fast encoders comparison

Most GPU-encoders participated in comparison were much faster than software one. In this Appendix MSU decided to compare very fast encoders (software and GPU based) with encoding speed close to faster GPU encoders from main part of comparison.

In this part MSU compares three GPU-based encoders:

- Intel Ivy Bridge QuickSync (GPU encoder) with TU1 preset
- MainConcept H.264 (CUDA based encoder)
- MainConcept H.264 (OpenCL based encoder), ATI 6970 graphic card was used
- x264 with superfast 1-pass preset

MSU used only HD sequences in his part of comparison because it is main usage for GPU encoders.

6.1 RD Curves

There were two leaders – Intel QuickSync and x264 at average, MainConcept OpenCL shows third results. MainConcept CUDA is typically at fourth place.

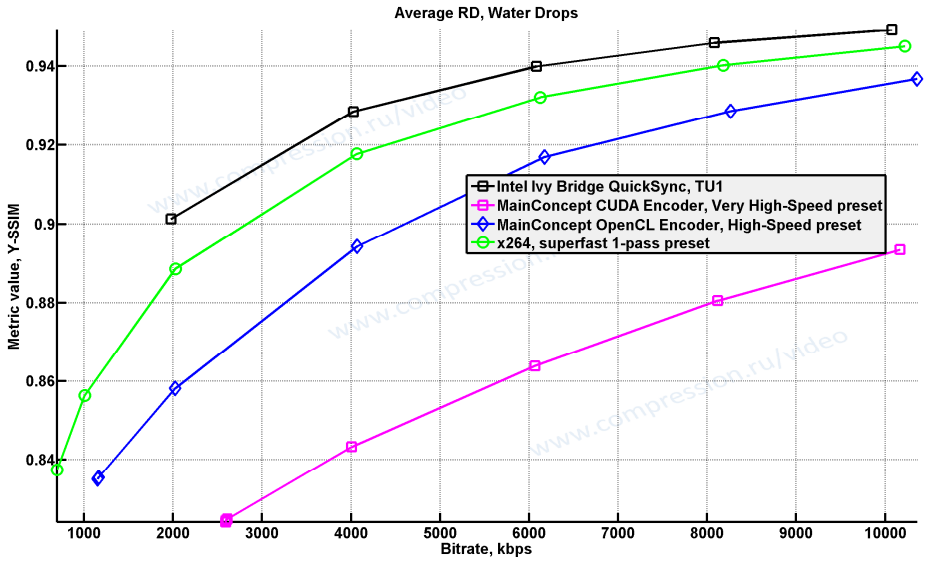


Figure 186. Bitrate/quality, Fast encoders, "Water Drops" sequence, Y-SSIM metric

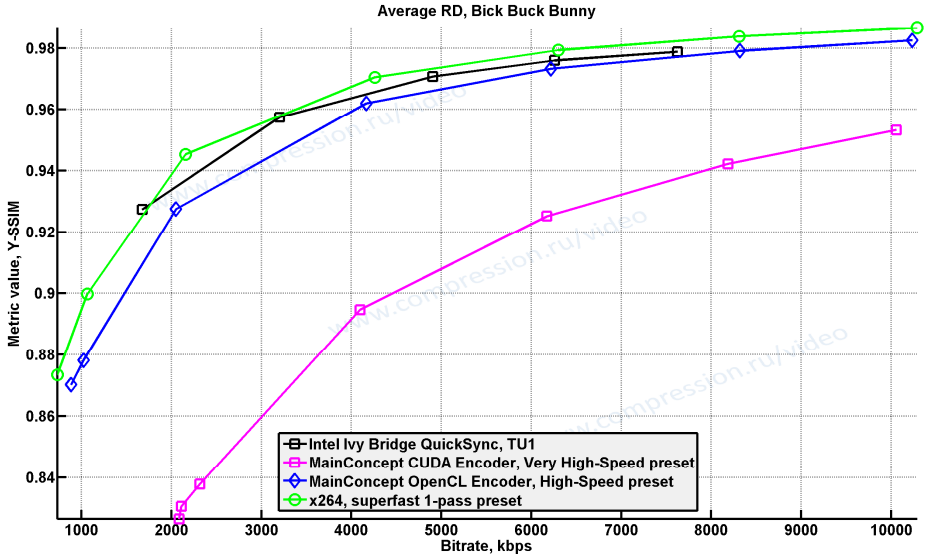


Figure 187. Bitrate/quality, Fast encoders, "Bick Buck Bunny" sequence, Y-SSIM metric

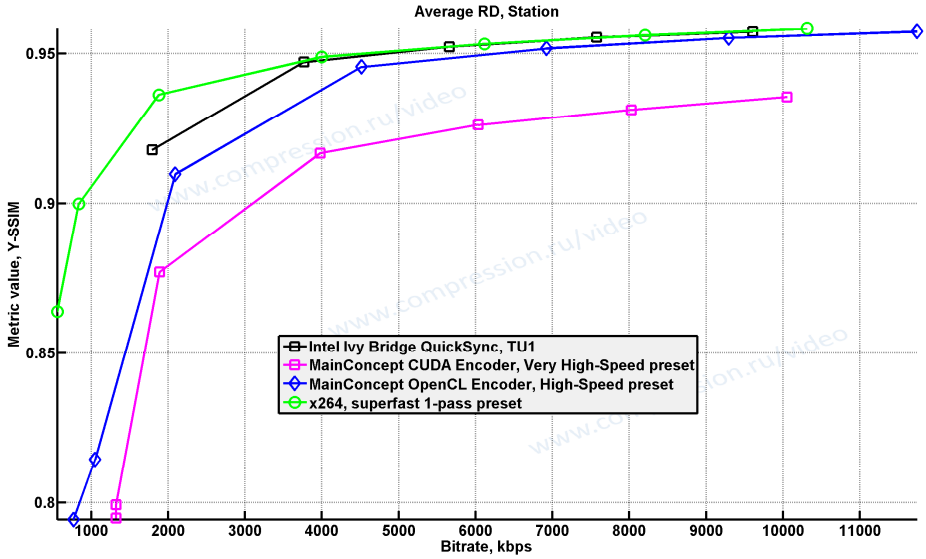


Figure 188. Bitrate/quality, Fast encoders, "Station" sequence, Y-SSIM metric

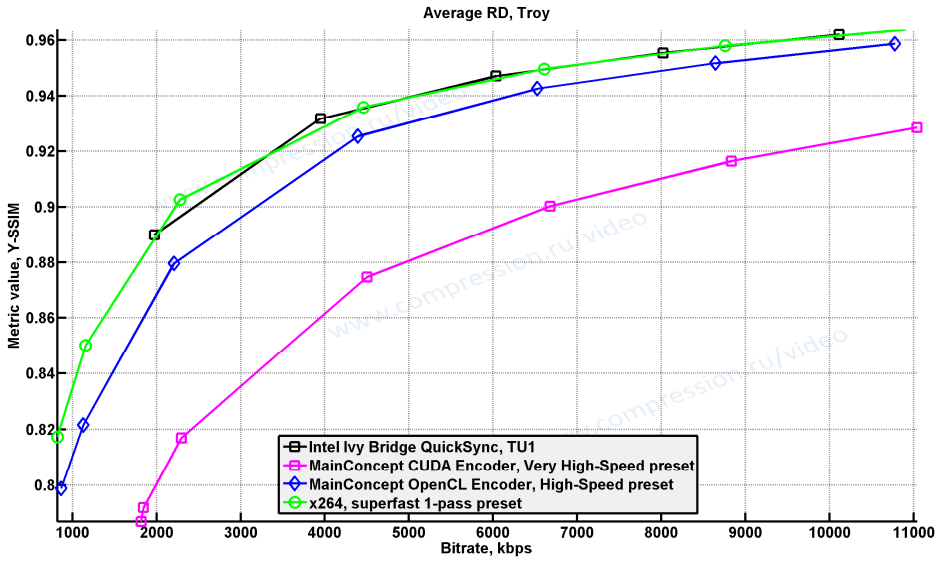


Figure 189. Bitrate/quality, GPU encoders, "Troy" sequence, Y-SSIM metric

6.2 Bitrate Handling

Bitrate handling for all GPU encoders is good except low bitrates: both MainConcept encoders typically increase low bitrates and Intel QuickSync does not encode low bitrates. X264 handles low bitrates slightly better.

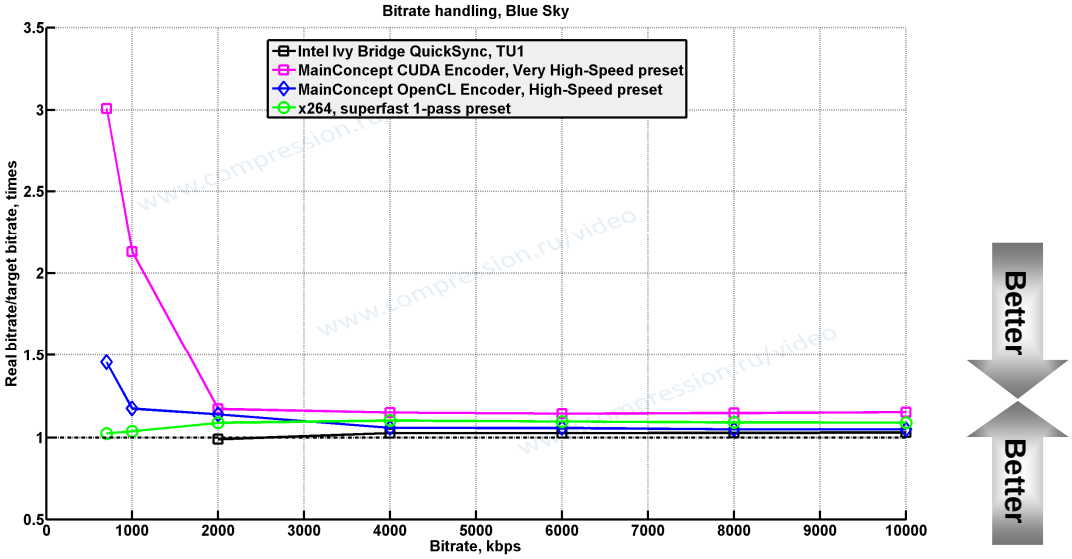


Figure 190. Bitrate handling, Fast encoders," "Blue Sky" sequence

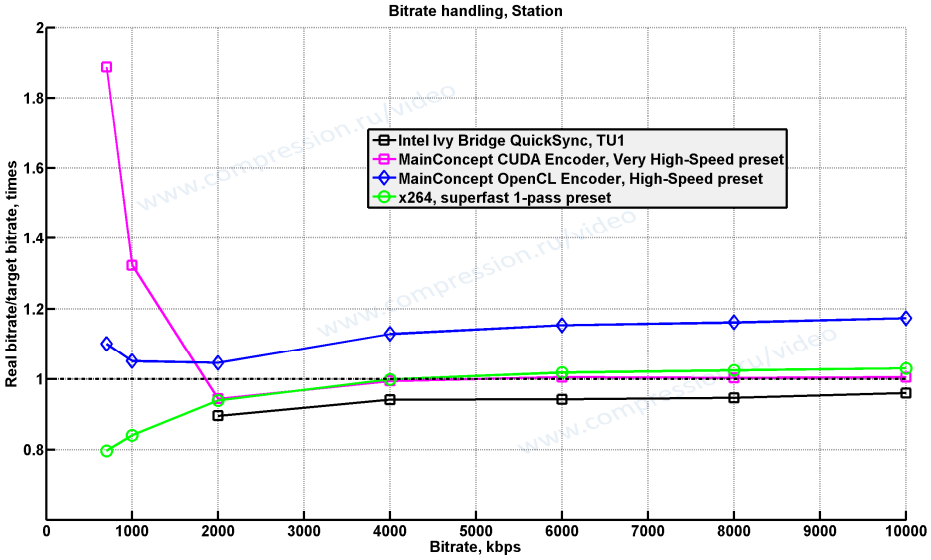


Figure 191. Bitrate handling, Fast encoders," "Station" sequence

6.3 Encoding Speed

All encoders encode full-HD sequences at 100-200fps. X264 and MainConcept CUDA have strong dependency between bitrate and encoding speed, MainConcept OpenCL has lower dependency and Intel QuickSync has almost no dependency between encoding speed and target bitrate.

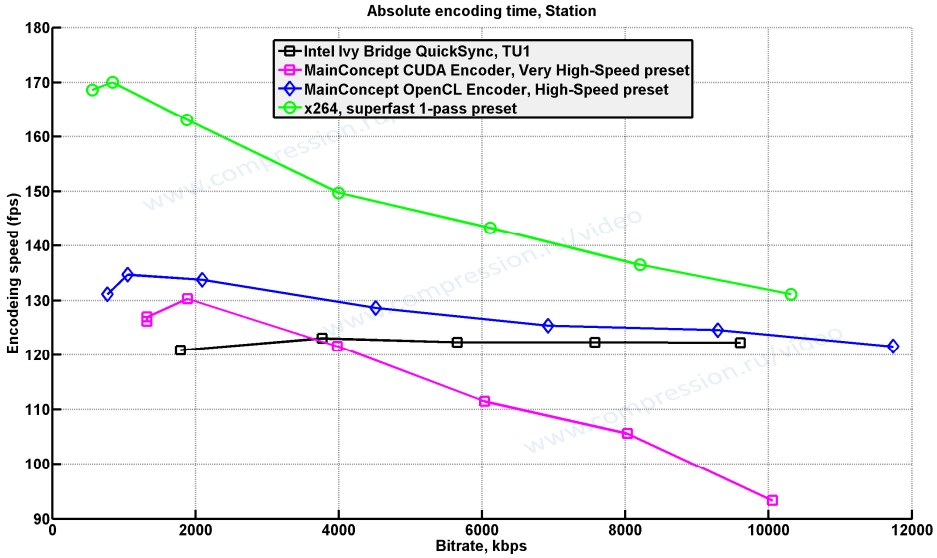


Figure 192. Encoding speed handling, Fast encoders," "Station" sequence

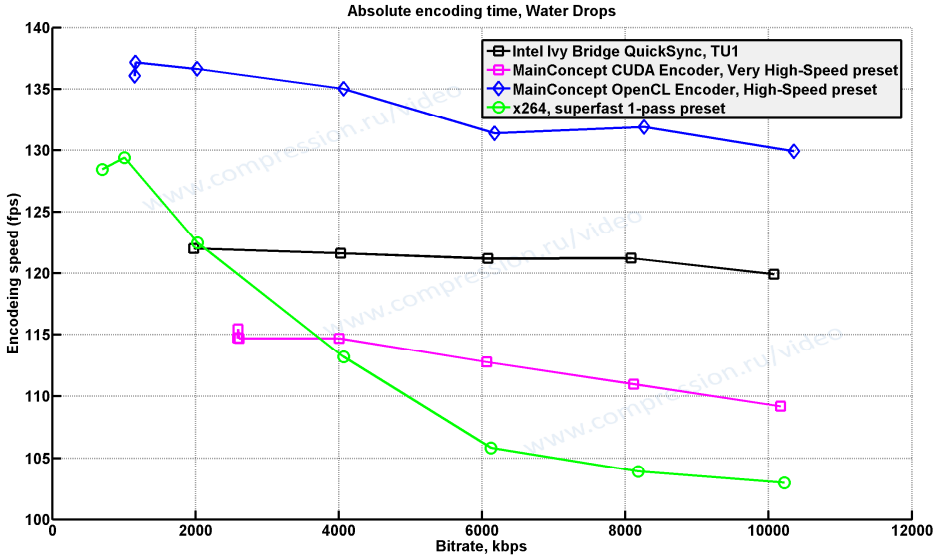


Figure 193. Encoding speed handling, Fast encoders," "Water Drops" sequence

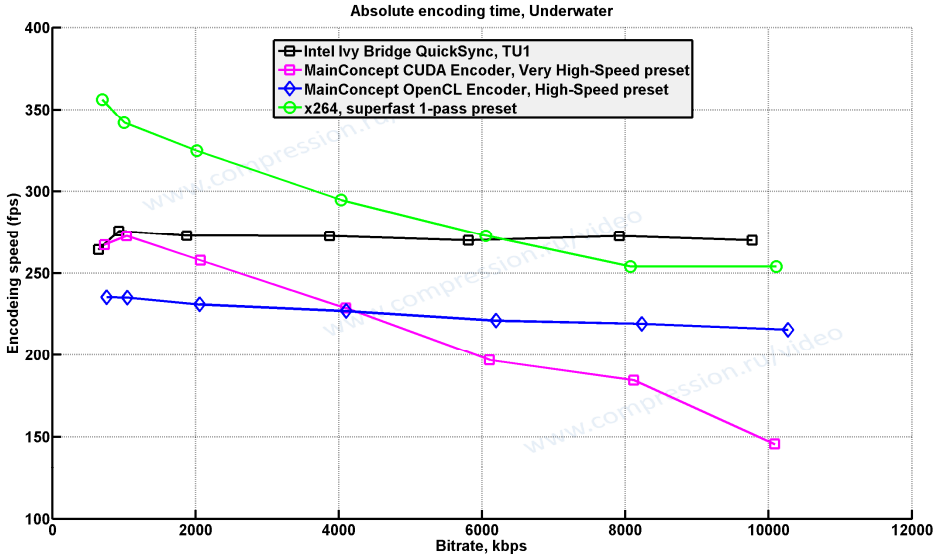


Figure 194. Encoding speed handling, Fast encoders," "Underwater" sequence

6.4 Speed/Quality Trade-Off

Intel QuickSync and x264 are close to each other in terms of optimal speed/quality trade-off – typically Intel QuickSync TU1 preset is slower than x264 superfast preset but with higher encoding quality. Both MainConcept encoders (CUDA and OpenCL) are slower and with lower quality at average than Intel QuickSync and x264. .

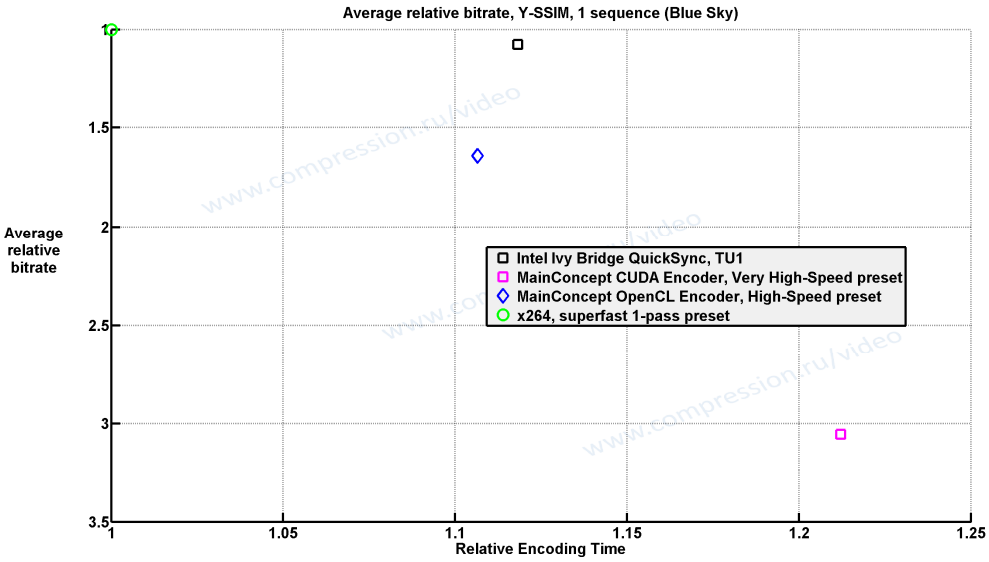


Figure 195. Speed/quality trade-off, Fast encoders, "Blue Sky" sequence, Y-SSIM metric

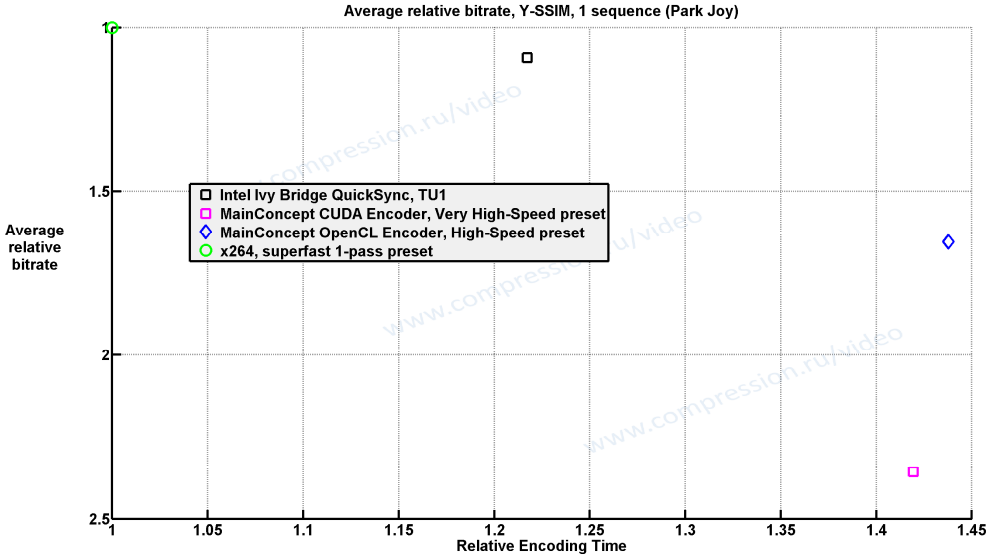


Figure 196. Speed/quality trade-off, Fast encoders, "Park Joy" sequence, Y-SSIM metric

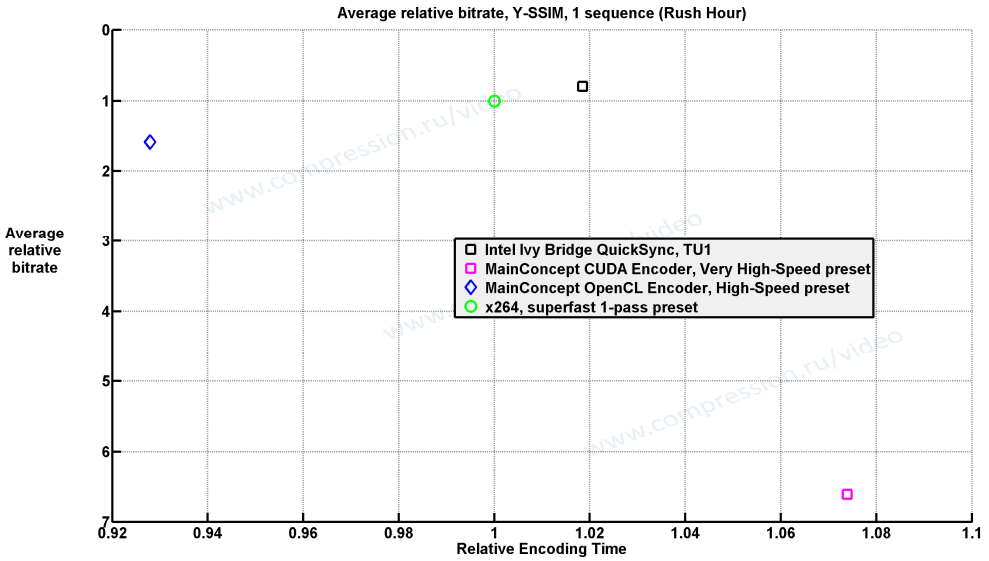


Figure 197. Speed/quality trade-off, Fast encoders, "Rush Hour" sequence, Y-SSIM metric

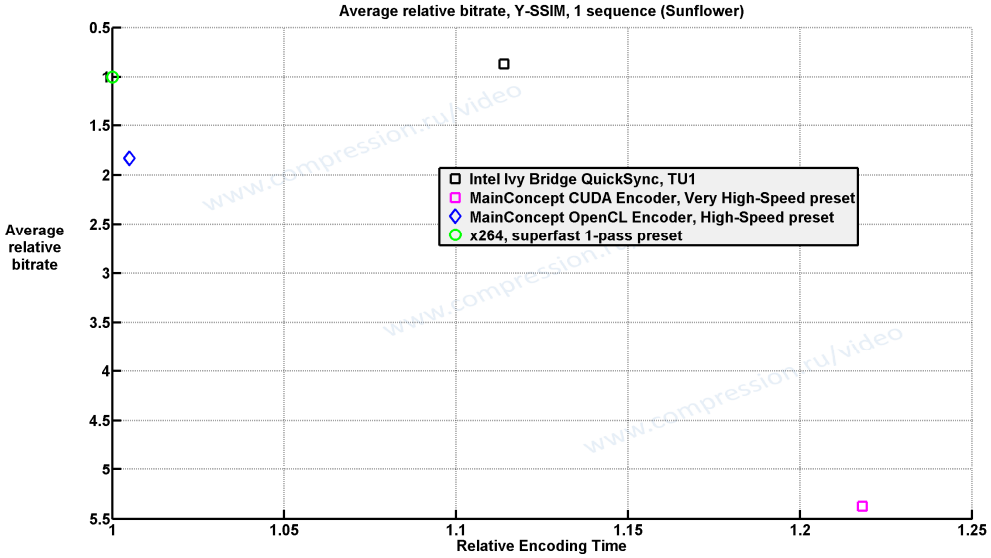


Figure 198. Speed/quality trade-off, Fast encoders, "Sunflower" sequence, Y-SSIM metric

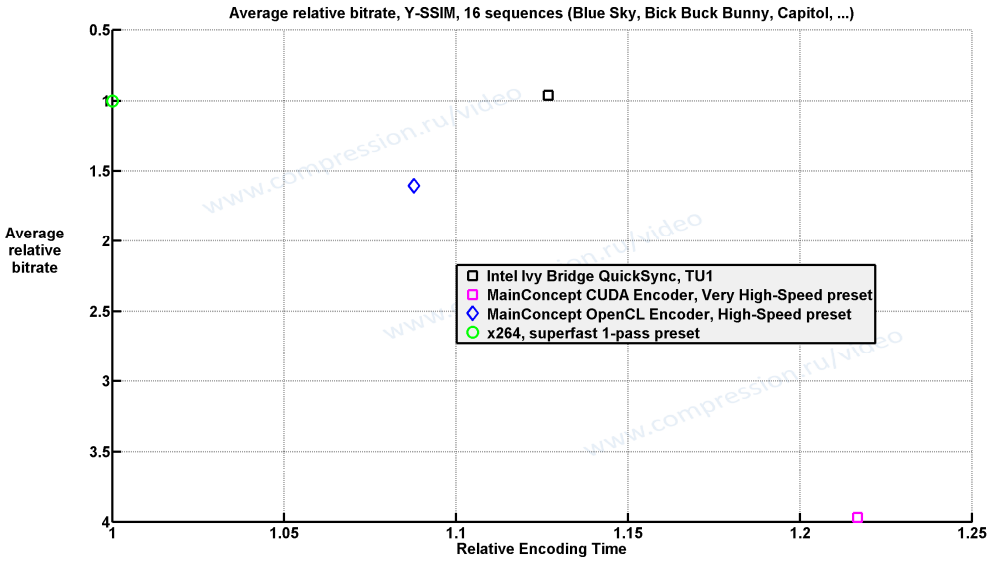


Figure 199. Speed/quality trade-off, Fast encoders, all sequences, Y-SSIM metric

6.5 Conclusion

Comparing all results from Fast encoders comparison part one could say that x264 and Intel QuickSync are best in terms of speed/quality trade-off. MainConcept OpenCL is third and MainConcept CUDA is fourth.

So best of hardware encoders Intel QuickSync and best of software encoders x264 are comparable by speed/quality at very high speed encoding.

6.6 Encoders on Laptop Comparison

Fast encoders on good desktop hardware (Core i7 3770(IVB), 4 Cores CPU @3.4 GHz with integrated GPU Intel HD Graphics 4000) comparison shown that x264 and Intel QuickSync are best in terms of speed/quality trade-off. And it was interesting to compare the same leading encoders at weaker hardware – laptop with next charactertcics (Core i7 3610QM (IVB), 4 Cores CPU @2.30GHz with integrated GPU Intel HD Graphics 4000)

The quality of encoders remains the same only encoding speed was changed.

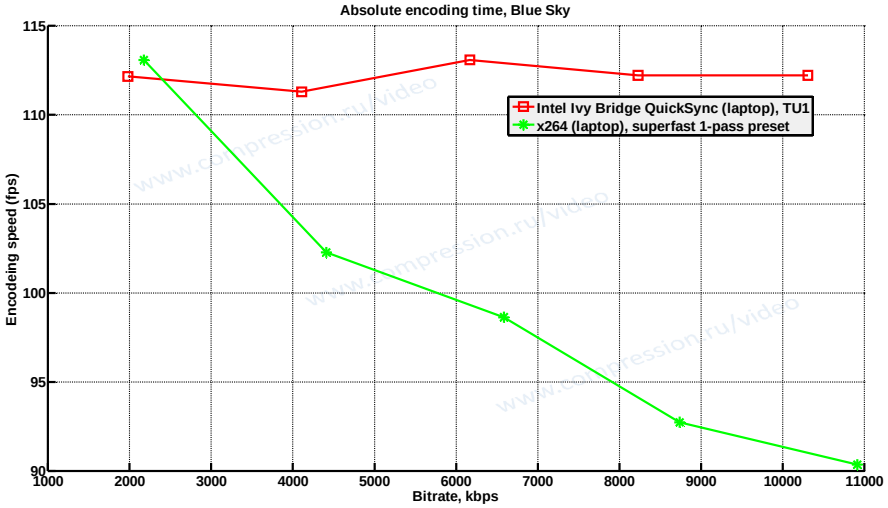


Figure 200. Encoding speed handling, Fast encoders at Laptop, "Blue Sky" sequence

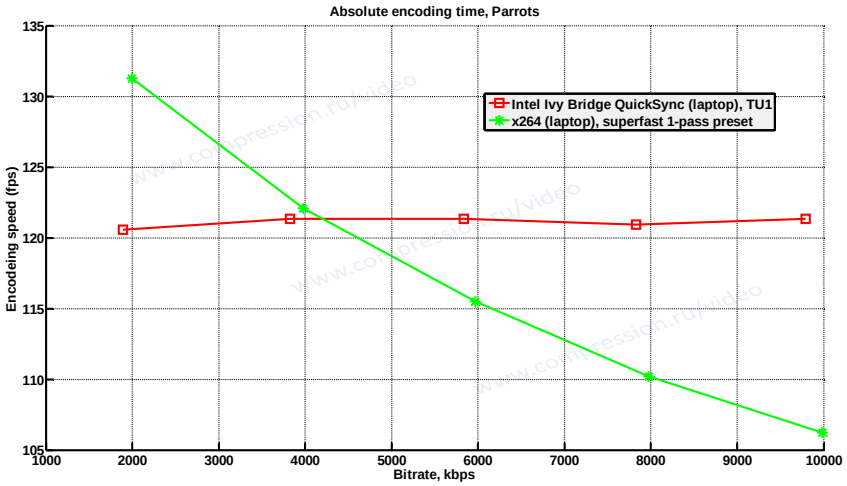


Figure 201. Encoding speed handling, Fast encoders at Laptop, "Parrots" sequence

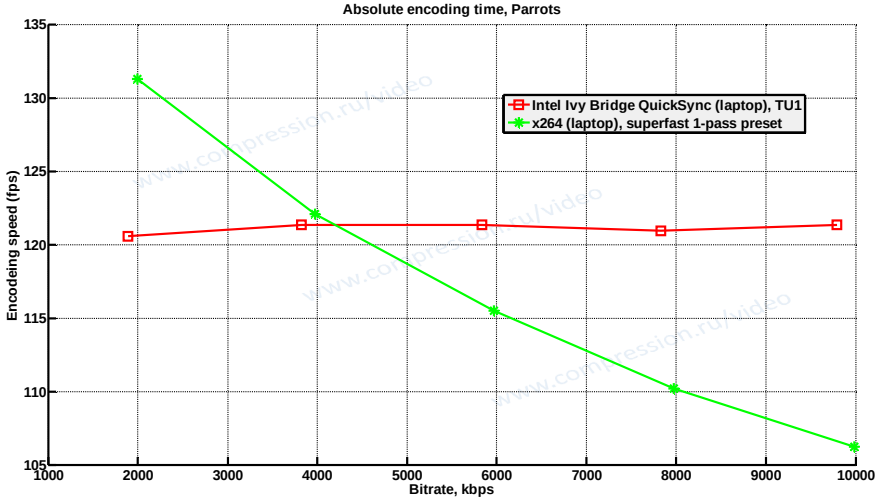


Figure 202. Encoding speed handling, Fast encoders at Laptop, "Troy" sequence

As one can see at laptop hardware encoding speed for QuickSync is higher than for x264 because of the fact that CPU (that x264 used) is much weaker and integrated GPU (that QuickSync used) is almost the same.

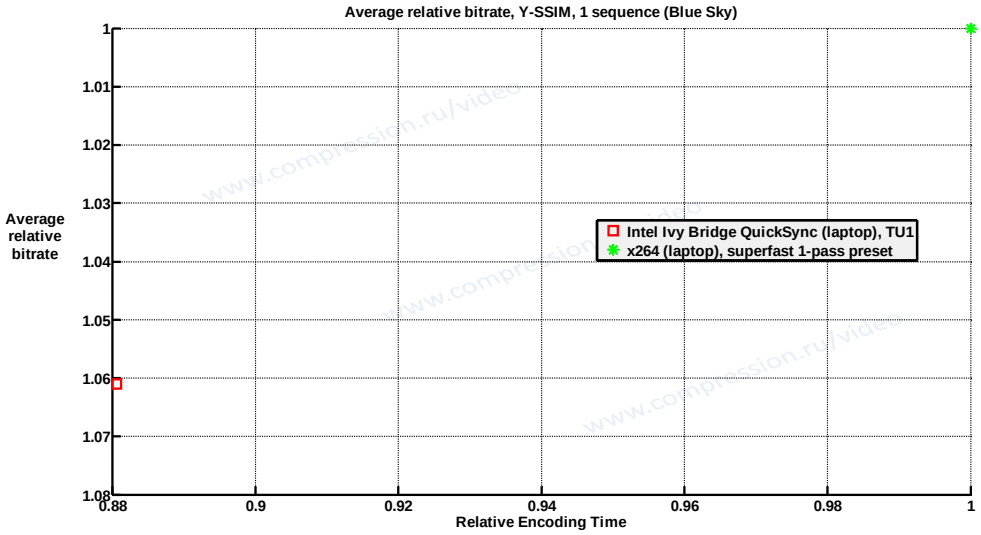


Figure 203. Speed/quality trade-off, Fast encoders at Laptop, "Blue Sky" sequence, Y-SSIM metric

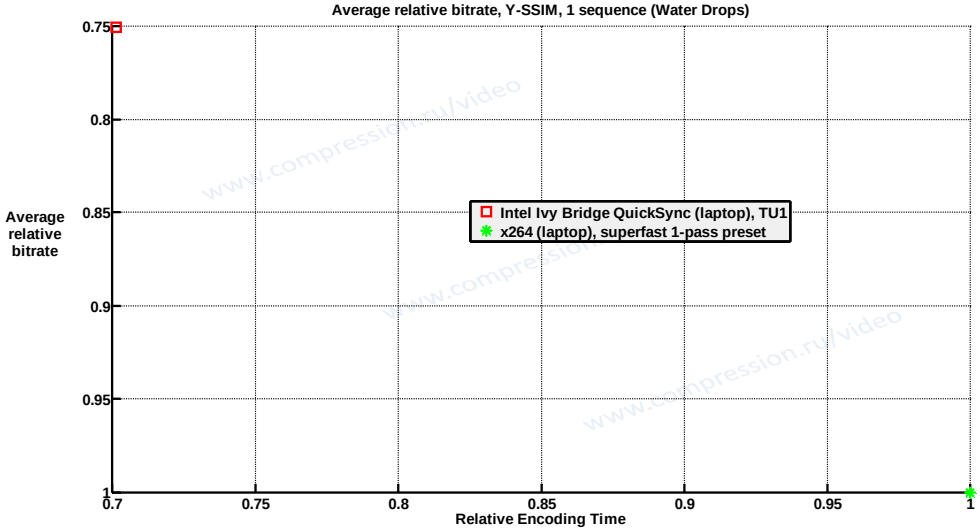


Figure 204. Speed/quality trade-off, Fast encoders at Laptop, "Water Drops" sequence, Y-SSIM metric

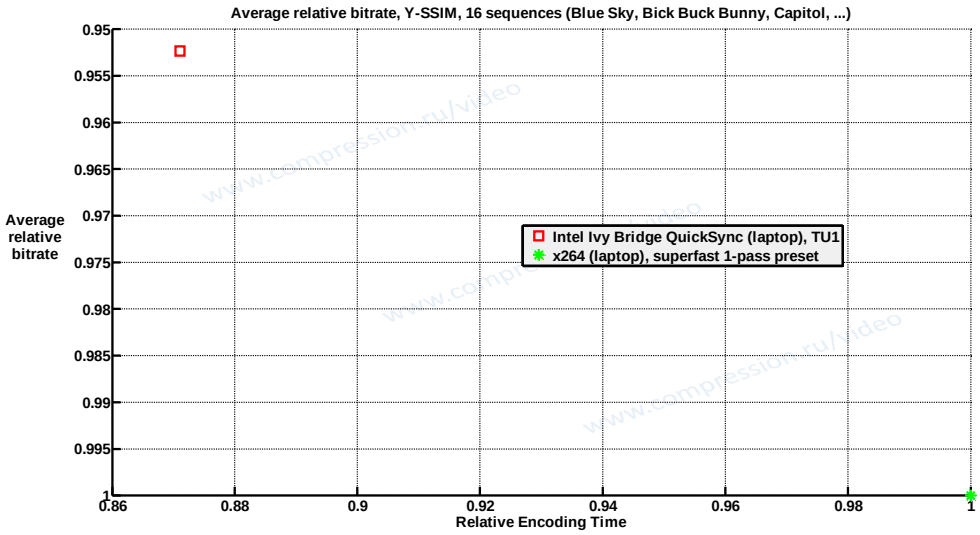


Figure 205. Speed/quality trade-off, Fast encoders at Laptop, all sequences, Y-SSIM metric

This test shows that using Laptop hardware with weaker CPU with basic integrated GPU hardware encoder QuickSync is better in terms speed/quality trade-off than best pure software encoder x264 at very high-speed encoding.

7 Appendix 7. x264 Comparison Over Time

The quality of an H.264 codec, over several years, can be compared for a given video sequence. The x264 encoder was chosen for this task because it is present in almost every MSU VIDEO MPEG-4 AVC/H.264 codec comparison, and it produces good results compared with other encoders. For all years except 2005, x264 shows the best results. For years 2006–2011, we have shown results using Y-SSIM as the quality metric; for 2005, we did not use this as the main metric. In light of these results, x264 could be a good reference encoder for analyzing the overall progress of H.264 encoders over time.

Figure 206 shows the RD curve for the "Battle" sequence using x264 encoders from different years. The best encoder is this year's x264; the worst is the 2005 version. Using SSIM, the codecs can be ranked as follows:

1. x264 (2012)
2. x264 (2011)
3. x264 (2010)
4. x264 (2009)
5. x264 (2007)
6. x264 (2006)
7. x264 (2005)

These results are shown in Figure 207. This figure indicates that the overall progress is very good, and that the x264 encoder has increased in speed and quality over recent years. But the old x264 does not use multithreading, so encoding speed varies considerably.

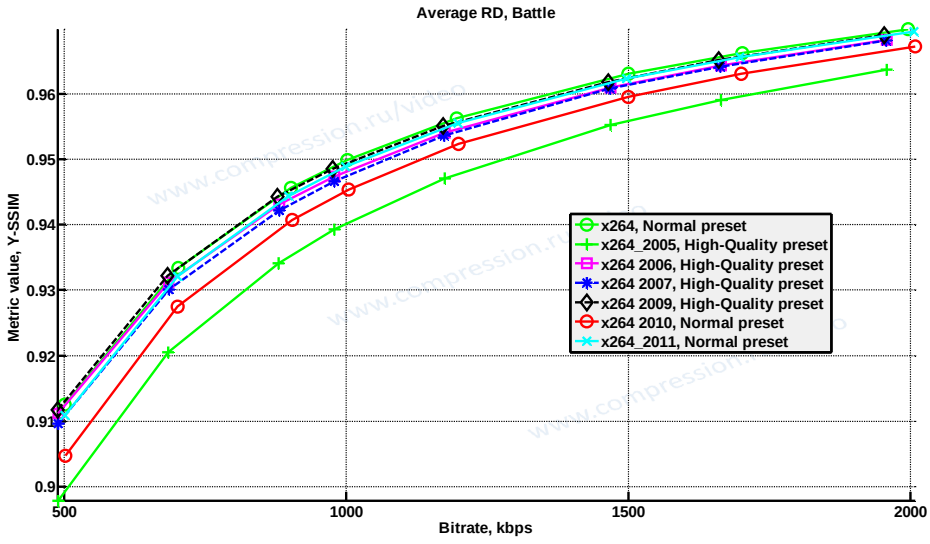


Figure 206. Bitrate/quality, x264 encoders, "Battle" sequence, Y-SSIM metric

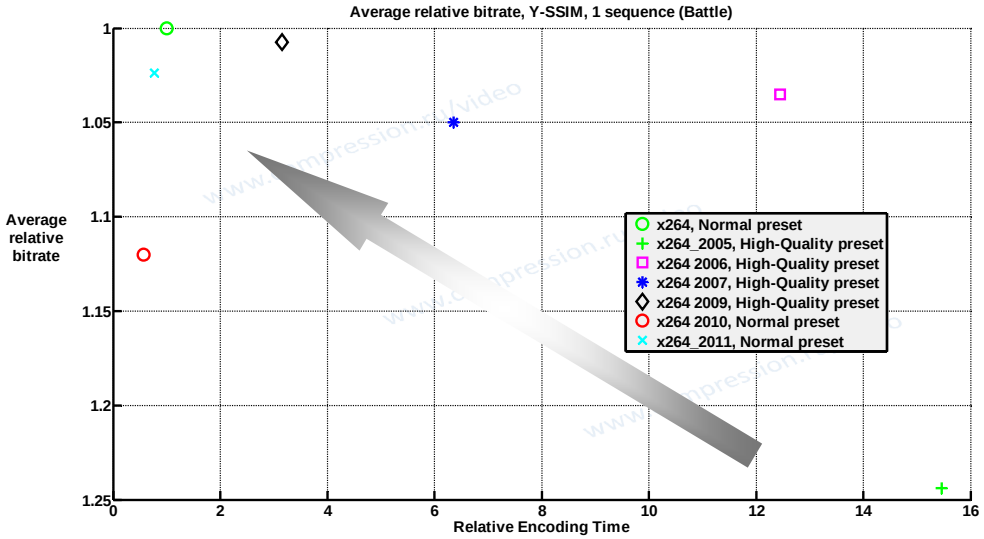
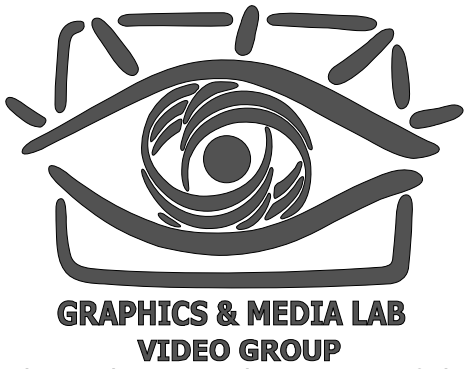


Figure 207. Speed/quality trade-off, x264 encoders, "Battle" sequence, Y-SSIM metric

8 List of Figures

9 About the Graphics & Media Lab Video Group



The Graphics & Media Lab Video Group is part of the Computer Science Department of Moscow State University. The Graphics Group began at the end of 1980's, and the Graphics & Media Lab was officially founded in 1998. The main research avenues of the lab include areas of computer graphics, computer vision and media processing (audio, image and video). A number of patents have been acquired based on the lab's research, and other results have been presented in various publications.

The main research avenues of the Graphics & Media Lab Video Group are video processing (pre- and post-, as well as video analysis filters) and video compression (codec testing and tuning, quality metric research and codec development).

The main achievements of the Video Group in the area of video processing include:

- High-quality industrial filters for format conversion, including high-quality deinterlacing, high-quality frame rate conversion, new, fast practical super resolution and other processing tools.
- Methods for modern television sets, such as a large family of up-sampling methods, smart brightness and contrast control, smart sharpening and more..
- Artifact removal methods, including a family of denoising methods, flicking removal, video stabilization with frame edge restoration, and scratch, spot and drop-out removal.
- Application-specific methods such as subtitle removal, construction of panorama images from video, video to high-quality photo conversion, video watermarking, video segmentation and practical fast video deblur.

The main achievements of the Video Group in the area of video compression include:

- Well-known public comparisons of JPEG, JPEG-2000 and MPEG-2 decoders, as well as MPEG-4 and annual H.264 codec testing; codec testing for weak and strong points, along with bug reports and codec tuning recommendations.
- Video quality metric research; the MSU Video Quality Measurement Tool and MSU Perceptual Video Quality Tool are publicly available.
- Internal research and contracts for modern video compression and publication of MSU Lossless Video Codec and MSU Screen Capture Video Codec; these codecs have one of the highest available compression ratios.

The Video Group has also worked for many years with companies like Intel, Samsung and RealNetworks.

In addition, the Video Group is continually seeking collaboration with other companies in the areas of video processing and video compression.

E-mail: video@graphics.cs.msu.ru