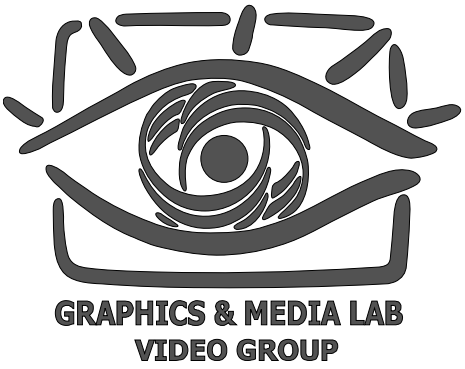

MPEG-4 AVC/H.264 Video Codecs Comparison

Full version of report

Project head: Dmitriy Vatolin
Measurements, analysis: Dmitriy Kulikov, Alexander Parshin
Translation: Artem Titarenko
Verification: Maxim Smirnov

Codecs:

DivX 6.2.5 (MPEG-4 ASP codec)

MainConcept H.264

Intel H.264

VSS H.264

x264

Apple H.264 (partial tested)

Sorenson H.264 (partial tested)

January 2007

CS MSU Graphics&Media Lab

Video Group

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Contents

Thanks

We would like to express our gratitude to the following companies for providing us with codecs and settings:

- **Intel Corp.**
- **MainConcept AG**
- **Vanguard Software Solutions, Inc.**
- **x264 Development Team**
- **Sorenson Media Corp.**

We would also like to thank these companies for their technical support and help during our tests.

We would like to express special thanks to Charles Wiltgen (digital media expert, was Apple's QuickTime Evangelist during 1995-1999) for invaluable help with performing comparison of a codec by Apple Company. Only with his help it became possible to overcome a lot of technical problems and at least partially include this codec into our comparison.

Overview

Sequences

Table 1. Summary Table of Sequences

	Sequence	Number of frames	Frame rate	Resolution and color space
1.	foreman	300	30	352x288(YV12)
2.	akiyo	300	25	352x288(YV12)
3.	carphone	382	25	176x144(YV12)
4.	battle	1599	24	704x288(YV12)
5.	rancho	1237	24	704x288(YV12)
6.	matrix	239	25	720x416(YV12)
7.	futurama	292	25	720x576(YV12)
8.	concert	390	25	1664x1088(YV12)

Brief description of sequences used in our comparison is given in Table 1.

More detailed description of all these sequences may be found in «Appendix 3. Test Set of Video Sequences».

Codecs

Table 2. Short codecs description

Codec		Developer	Version
1.	DivX	DivX, Inc	6.2.5
2.	VSS H.264 Codec Pro 3.0	Vanguard Software Solutions, Inc	3.0.7.5
3.	MainConcept H.264/AVC encoder	MainConcept AG	2.1.5217
4.	Intel H.264 Encoder	Intel Corp.	dev. version for 10.08.2006
5.	x264	x264 Development Team	version 544
6.	Apple	Apple Computers. Inc.	QuickTime 7.1.3 for Windows
7.	Sorenson	Sorenson Media, Inc.	Build 2.00.106.00

Brief description of codecs used in our comparison is given in Table 2.

DivX was used as a reference good MPEG-4 ASP codec for comparison purposes.

Detailed description of all codecs used in our comparison may be found in «Appendix 4. Tested Codecs».

Tested Presets

Table below show used in this comparison settings for all codecs.

Codec	Preset Name	Preset
VSS	VideoConference "High Quality"	-quality 3
	VideoConference "High Speed"	-quality 5
	Movie "High Quality"	-quality 3
	Movie "High Speed"	-quality 5
	HDTV "High Quality"	-quality 3
MainConcept	VideoConference "High Quality"	*This preset is taken as reference. All other MainConcept presets are described as differences to this preset.* Profile = 100 Level = 100 EntropyMode = 1 BFramesCount = 3 BFramesReference = 1 PyramidCoding = 1 AdaptiveB = 1 RCMode = 1 EnableIntra_8x8 = 1 EnableIntra_4x4 = 1 EnableInter_8x8 = 1 EnableInter_4x4 = 1 DeblockMode = 0 AlphaC0Offset = -1 BetaOffset = -1 EnableRDO = 1 InsaneRDO = 1 HadamardTransform = 1 FastIntraDecision = 1 FastInterDecision = 1 QuantOptimization = 2
	VideoConference "High Speed"	*Comparing to Videoconference "High Quality":* BFramesCount = 1 BFramesReference = 0 PyramidCoding = 0 EnableRDO = 0 InsaneRDO = 0
	Movie "High Quality"	*Comparing to Videoconference "High Quality":*

		SearchRange = 255
	Movie "High Speed"	*Comparing to Videoconference "High Quality":* SearchRange = 255 EnableRDO = 0 InsaneRDO = 0
	Movie "High Quality – 2pass"	*Comparing to Videoconference "High Quality":* *First pass:* Pass = 1 NumRefFrames = 2 SearchRange = 255 EnableInter_8x8 = 0 EnableInter_4x4 = 0 EnableRDO = 0 InsaneRDO = 0 HadamardTransform = 0 *Second pass:* Pass = 2 SearchRange = 255
	HDTV "High Quality"	*Comparing to Videoconference "High Quality":* *First pass:* Pass = 1 NumRefFrames = 2 SearchRange = 511 EnableInter_8x8 = 0 EnableInter_4x4 = 0 EnableRDO = 0 InsaneRDO = 0 HadamardTransform = 0 *Second pass:* Pass = 2 SearchRange = 511
Intel IPP	VideoConference "High Speed" Movie "High Speed" HDTV "High Quality"	*Intel IPP used same settings for all presets. Some of main parameters:* 1 100 0 /* IDR interval. */ 0 0 /* Number of B */ 1 1 1 /* num_ref_frames */ 77 51 /* profile_idc; level_idc */ 2 20 20 20 2222222 /* RC method (0 - quant_codes, 1 - CBR MBwise, 2 - CBR framewise, 3 - Debug); start

		qp values for I, P, B slices; bitrate (bits per second) */ 2 0 8 8 /* ME method (1-6), subblock split, search x,search_y */ 0 1 /* direct type (0 - temporal 1 - spatial); direct_inference_flag */ 0 3 3 /* disable_deblocking_idc: 1 - off, 0 - on, 2 – on (without crossing slice boundaries); deblocking_filter_alpha, deblocking_filter_beta */
x264	VideoConference “High Quality”	--no-psnr --bframes=3 --b-pyramid --8x8dct --vbv-bufsize=10000 --no-b-adapt --scenecut=10 --subme=6 --ref=3 --b-rdo --me umh --merange=8
	VideoConference “High Speed”	--no-psnr --bframes=3 --b-pyramid --8x8dct --vbv-bufsize=10000 --no-b-adapt --scenecut=10 --subme=4 --ref=2 --mixed-refs
	Movie “High Quality”	--no-psnr --bframes=3 --b-pyramid --8x8dct --vbv-bufsize=10000 --subme=7 --ref=5 --trellis=1 --mixed-refs --b-rdo --me umh --merange=12
	Movie “High Speed”	--no-psnr --bframes=3 --b-pyramid --8x8dct --vbv-bufsize=10000 --subme=4 --ref=3 --trellis=1
	Movie “High Quality – 2pass”	--no-psnr --bframes=3 --b-pyramid --8x8dct --pass=1 --direct=auto --subme=4 --ref=2 --no-psnr --bframes=3 --b-pyramid --8x8dct --pass=2 --direct=auto --subme=7 --ref=10 --trellis=2 --mixed-refs --b-rdo --me umh --merange=24 --analyse=all --bime
	HDTV “High Quality”	--no-psnr --bframes=3 --b-pyramid --8x8dct --pass=1 --direct=auto --subme=4 --ref=2 --no-psnr --bframes=3 --b-pyramid --8x8dct --pass=2 --direct=auto --subme=7 --ref=5 --trellis=2 --mixed-refs --b-rdo --me umh --merange=24
DivX	VideoConference “High Quality”	Preset 10
	VideoConference “High Speed”	Preset 5
	Movie “High Quality”	Preset 10
	Movie “High Speed”	Preset 8

Sorenson	Movie	# Misc. settings:
		Quality = 80
		KeyFrameRate = 1000

		# Packetization:
		PacketSizeEnabled = True
		PacketSize = 1466
		
		# Block Refresh:
		BlockRefreshEnabled = False
		BlockRefreshRate = 5
		
		# Scene Change Detection:
		SceneChangeDetectionEnabled = True
		SceneChangeSensitivity = 50
		
		# Minimum Quality:
		MinimumQualityEnabled = False
		MinimumQualityValue = 0
		
		# Frame Dropping:
		DropFrames = False
		
		# Compression Speed:
		CompressionSpeed = NormalSpeed
		
		# Bidirectionally-predicted Frames:
		NumBFrames = 0
		
		# Deblocking
		LoopFilterEnabled = True
		
		# One Pass VBR
		OnePassVBR = True

Apple	*External Encoding*	*External Encoding*

This report includes comparisons of two additional codecs from Apple and Sorenson Media, but these went through only partial testing. Eight codecs took part in our Over-Years Codecs Comparison.

Table 3. Number of codec in this year comparison

Comparison section	Codecs' qty
Comparison of year 2006	5
Additional Comparison of year 2006	2
Over-Years Codecs Comparison	8
Total	**15**

Table for Interesting Points in this Codec Comparison

Next table shows the bugs, errors and just interesting points of tested codecs.

Codec and Preset	Point Description	Reference

VSS, Videoconferences “High Quality”, sequence “Foreman”	On this sequence VSS codec shows extremely low quality comparing to other H.264 codecs in the usage area “Videoconferences”	Figure 2
VSS, Videoconferences “High Quality”, sequence “Akiyo”	Absolute encoding time for this sequence for target bitrate 100 kbps is lower than for target bitrate 50 kbps. It can be explained by the fact that VSS bitrate keeping for low bitrates is not very good	Figure 6
VSS, Videoconferences, “High Quality”	Almost constant encoding time for all bitrates	Figure 5, Figure 6, Figure 7
MainConcept and DivX, Videoconferences, “Akiyo”, 30kbps	Quality of MainConcept and DivX codecs are rather constant during all sequence	Figure 8
VSS and DivX, Videoconferences, “High Quality”	VSS codec is better than DivX both for quality and speed	Figure 17, Figure 18, Figure 19
VSS, Videoconferences “High Speed”, sequence “Akiyo”	Absolute encoding time for this sequence for target bitrate 100 kbps is lower than for target bitrate 50 kbps. It can be explained by the fact that VSS bitrate keeping for low bitrates is not very good	Figure 25
DivX, Videoconferences, “High Speed”	For all sequences most H.264 codecs are better than DivX by quality and speed	Figure 35, Figure 36, Figure 37
VSS, Videoconferences, sequence “Foreman”	Bitrate keeping problems for low bitrates	Figure 39
DivX, Videoconferences	Bitrate keeping problems on all sequences for all bitrates	Figure 39, Figure 40, Figure 41
All codecs, Movies, sequence “Rancho”, “High Quality”	Stable bitrate lowering for all codecs	Figure 49
x264, Movies, sequence “Matrix” , “High Quality”	Hard stable bitrate lowering	Figure 50
DivX, Movies, sequences “Matrix” and “Futurama”	Strong bitrate keeping problems	Figure 50, Figure 51, Figure 76, Figure 77
VSS, Movies, “High Quality” and “High Speed”	Very low dependency between encoding speed and bitrate	Figure 53 - Figure 56, Figure 79 - Figure 82
All codecs, Movies, sequence “Matrix”, “High Quality”	Quality fluctuations have periodic character	
DivX, Movies, “High	If to use PSNR as quality measure DivX is	Figure 67,

Quality”	comparable to VSS, but if to use SSIM – DivX is worse than VSS by quality and speed	Figure 68
All codecs, Movies, sequences “Rancho” and “Matrix”, “High Speed”	Stable bitrate lowering for all codecs except Intel IPP	Figure 75, Figure 76
x264, Movies, sequence “Matrix” , “High Speed”	Hard stable bitrate lowering	Figure 76
Intel IPP, Movies, “High Speed”	If to use PSNR as quality measure Intel IPP is comparable to VSS, but if to use SSIM – Intel IPP is worse than VSS by quality and speed	Figure 95, Figure 96
VSS, HDTV	Very low dependency between encoding speed and bitrate	Figure 126
All codecs, HDTV	Stable bitrate lowering for all codecs except Intel IPP	Figure 127

Differences from short version

There are number of additional topics in full version of report:

- SSIM RD curves individually for each sequence from all sequences
- All codecs presets
- Differences between PSNR and SSIM results
- Absolute encoding speed charts
- Relative Bitrate/Relative Speed graphs individually for each sequence from test set
- Relative bitrate for the same quality for all pairs of codecs
- Bitrate handling graphs
- Per-frame quality and dispersion graphs
- Additional results for Apple and Sorenson codecs

All sequences, used in this comparison are provided with this report. Write an e-mail to videocodec-testing@graphics.cs.msu.ru to get corresponding links.

Goal and Testing Rules

H.264 Codecs Testing Objectives

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

Testing Rules

- Entire test set was divided according to three primary types of application. These types differ by resolution, bitrates and encoding speed requirements:
  - Videoconferences (bitrates: 30-300 Kbps)
  - Movies (bitrates: 500-2000 Kbps)
  - High-Definition Television (HDTV; bitrates: 1-10 Mbps)
- There were special presets and speed limitations for every type of application:
  - Videoconferences (speed requirements for 200 Kbps CIF sequence):
    - At least 70 fps encoding for "Hiqh Speed" preset
    - At least 30 fps encoding for "High Quality" preset
  - Movies (speed requirements for 750 Kbps for 4CIF sequence):
    - At least 10 fps encoding for "High Speed" preset
    - At least 4 fps encoding for "High Quality" preset
    - At least 1 fps encoding for "2-pass High Quality" preset
  - HDTV (speed requirements for 3 Mbps for 1920x1080 sequence):
    - At least 0.4 fps encoding
- Every codec's developer provided settings for each type of application, except DivX.
- Each codec was tested for speed 3 times, than the median score (the middle value of the three measurements) was used as a resulting time.
- During the testing two types of video sequences were used:
  - Source sequences (*.yuv extension) in the YV12 format
  - Sequences (with *.avi extension) in YV12 format. These sequences were used for DivX 6.2.5 codec and differed from *.yuv sequences only by files' headers
- For all measures' measurements the PRO version of MSU Video Quality Measure Tool was used (http://www.compression.ru/video/quality_measure/video_measurement_tool.html).

- Two computers with the following configuration were used for testing:

OS Name	Microsoft Windows XP Professional
Version	5.1.2600 Service Pack 2 Build 2600
Processor	x86 Family 15 Model 4 Stepping 10 AuthenticAMD ~2009 Mhz
BIOS Version/Date	Phoenix Technologies, LTD 6.00 PG, 01.07.2005
Total Physical Memory	1 024.00 MB
Total Virtual Memory	2.00 GB
Video Adapter Type	NVidia GeForce 6600

Metrics Used in Comparison

During the evaluation the following measures were used:

- PSNR (Y, U, V components)
- SSIM (Y component)
- VQM (Y component)
- MSU Brightness Independent PSNR[1] (Y component)

Still only SSIM measure's results were included in this report as one of the most adequate to the human's perception measures. Interestingly, some results for other measures are noticeable different from the results for SSIM.

More detailed information about these measures may be found here:

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

Figures Explanation

Main charts in our comparison are classical RD curves (Quality/Bitrate graphs) and Relative Bitrate/Relative Time charts. Additionally we use Bitrate Handling charts (ration of real and target bitrates for all target bitrates) and per-frame quality charts.

RD curves. These charts show variation in codec quality by bitrate/file-size. For this measure, the higher the curve, the better the quality (from the measure's standpoint).

Relative Bitrate/Relative Time. These charts show the dependency of average bitrate with equal quality on relative encoding time. Y axis shows bitrate ratio between current and reference codecs in the spots equal quality. The lower is this value for each codec (i.e. the higher it is on graph), the better it is. For example, value 0.7 means that this codec can encode current sequence in 30% smaller file than the reference one.

X axis shows relative encoding time for this codec. The bigger is this value, the slower codec works. For example, value 2.5 means that this codec works 2.5 times slower than the etalon one on average.

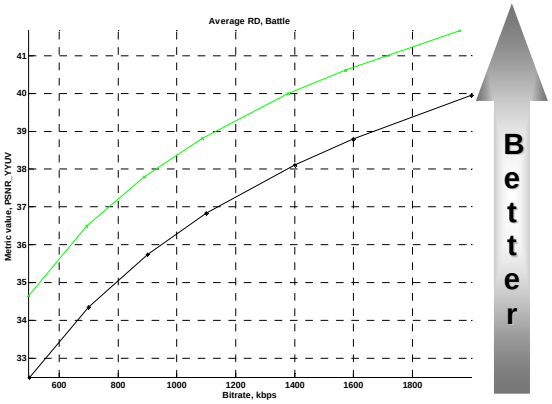
Graphs' usage example. Figure 1 shows the case when these graphs may be useful. On the top left graph one can see that the «Green» codec encodes with significantly better quality comparing to the «Black» one. However Absolute Encoding Time graph (top right) shows that «Green» codec is slightly slower. Exactly for such situations Relative Bitrate/Relative Time graphs may be useful: it is clearly seen on the

[1] Only for Apple's codec investigation

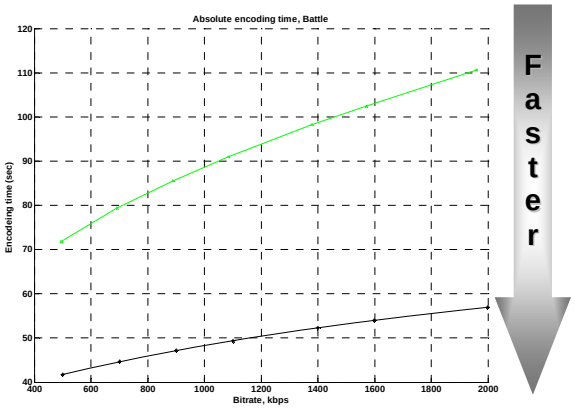
bottom graph that one of the codecs is slower and better by visual quality, and the second one is faster but has worse visual quality.

More information about construction of Relative Bitrate/Relative Time graphs may be found in «Appendix 5. Averaging Methods Description».

Note that in most graphs SSIM measure is used. Y axis label "SSIM_YYUV" means that we measure SSIM for YUV color space, but only Y component is displayed at charts.



RD curve. "Green" codec is better!



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

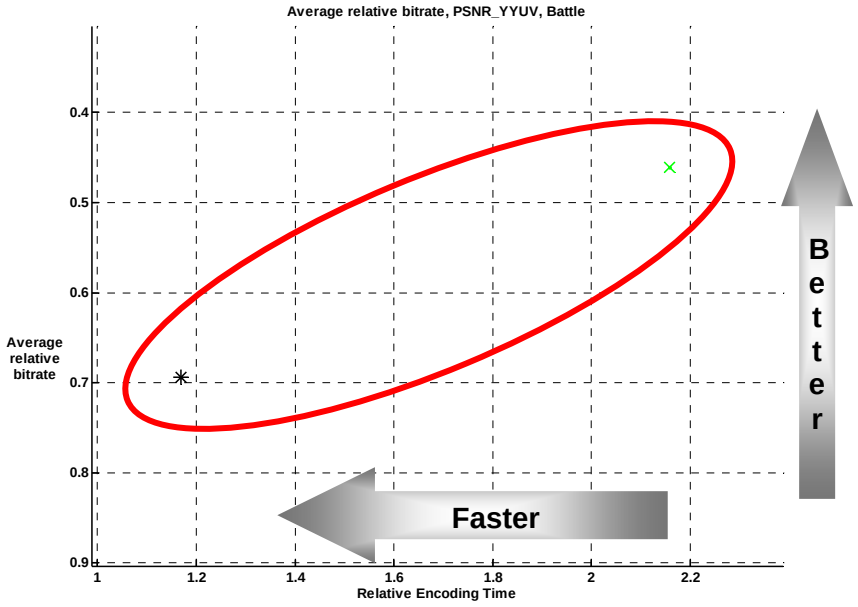


Figure 1. Integral situation with codecs. This plot shows the situation more clearly.

In that way similar Relative Bitrate/Relative Time graphs are frequently used in this report since they assist in better codecs' evaluation for the test set, especially when number of codecs is big.

Results of This Year

Videoconferences

In this section the codecs' behavior for videoconferences encoding is analyzed. Here sequences with relatively simple motion and small resolution were used. Chosen bitrates (30, 50, 100, 200, 300 Kbps) are intended for video transmission by restricted channels (low-speed ISDN and xDSL channels, mobile networks and etc.).

In this section the following codecs are considered:

- DivX 6.2.1 (2 presets)
- MainConcept (2 presets)
- Intel H.264 (only High Speed preset)
- VSS (2 presets)
- x264 (2 presets)

Three standard sequences were used in this type of application:

- Foreman (CIF)
- Akiyo (CIF)
- Carphone (QCIF)

"High Quality" Preset Results

First of all, let's see at RD curves (SSIM measure for luminance is used here).

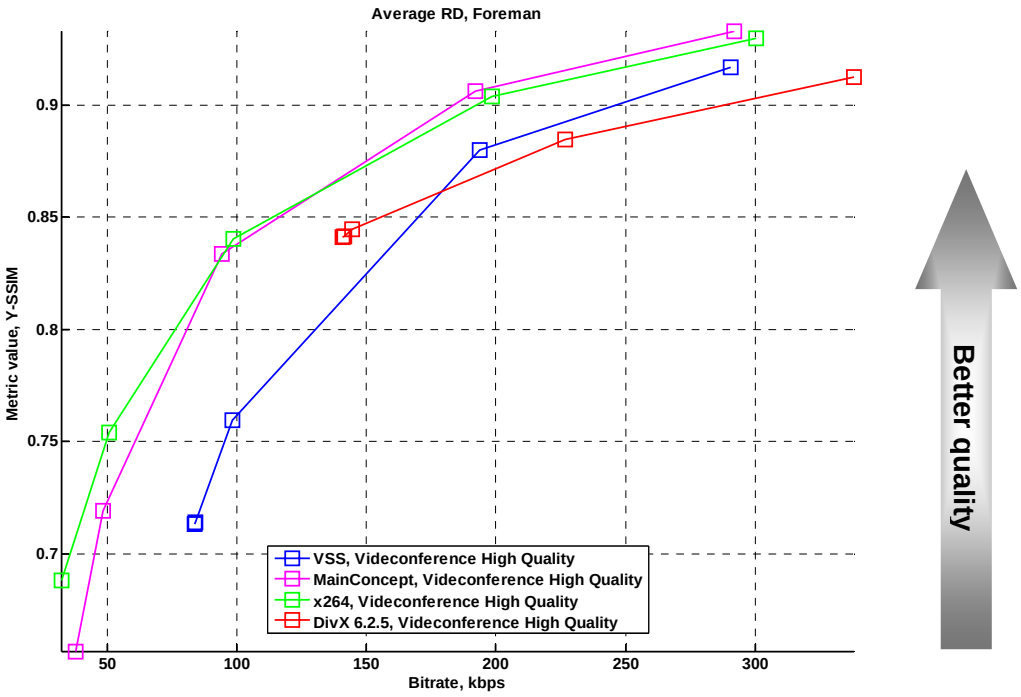


Figure 2. Bitrate/Quality. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset

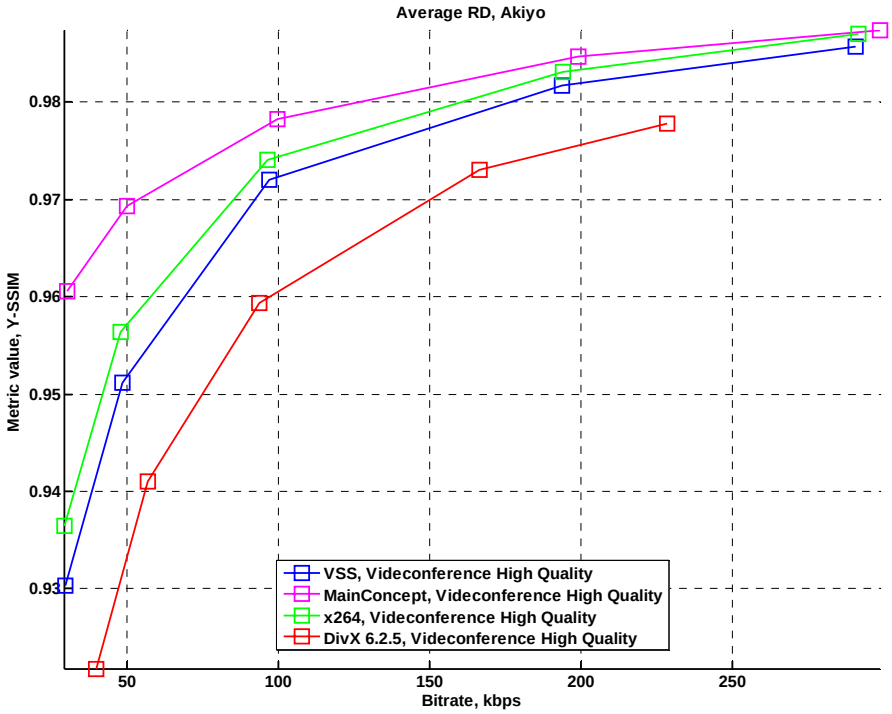


Figure 3. Bitrate/Quality. Usage area "Videoconferences", "Akiyo" sequence, "High Quality" preset

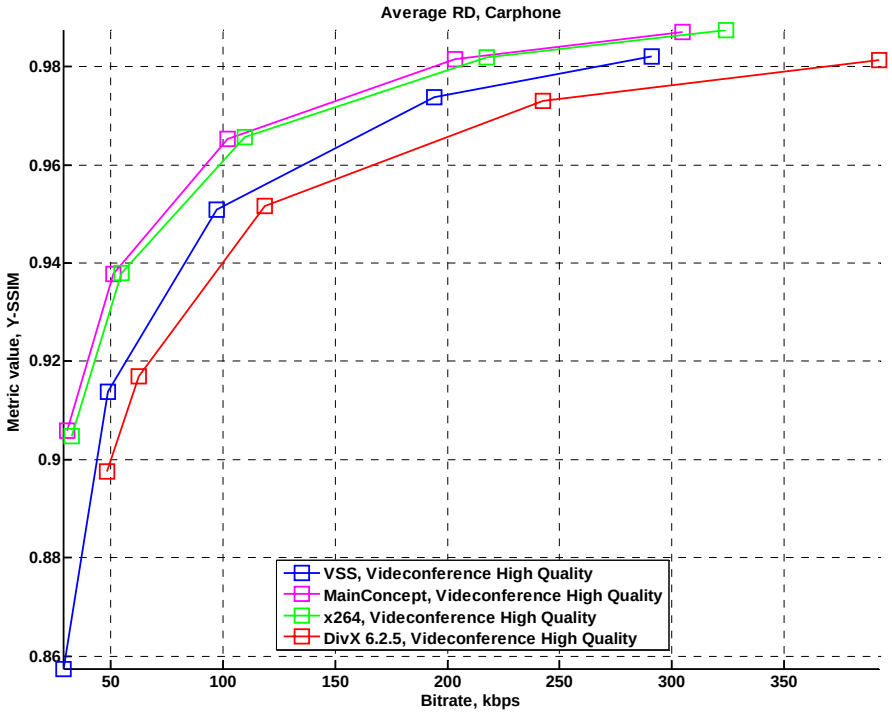


Figure 4. Bitrate/Quality. Usage area "Videoconferences", "Carphone" sequence, "High Quality" preset

We can see that situation is very similar for all sequences. There is a big difference between MainConcept and x264 at Akiyo and ambiguous situation with DivX and VSS codecs at Foreman.

The situation for PSNR measure on the whole is the same as for SSIM measure.

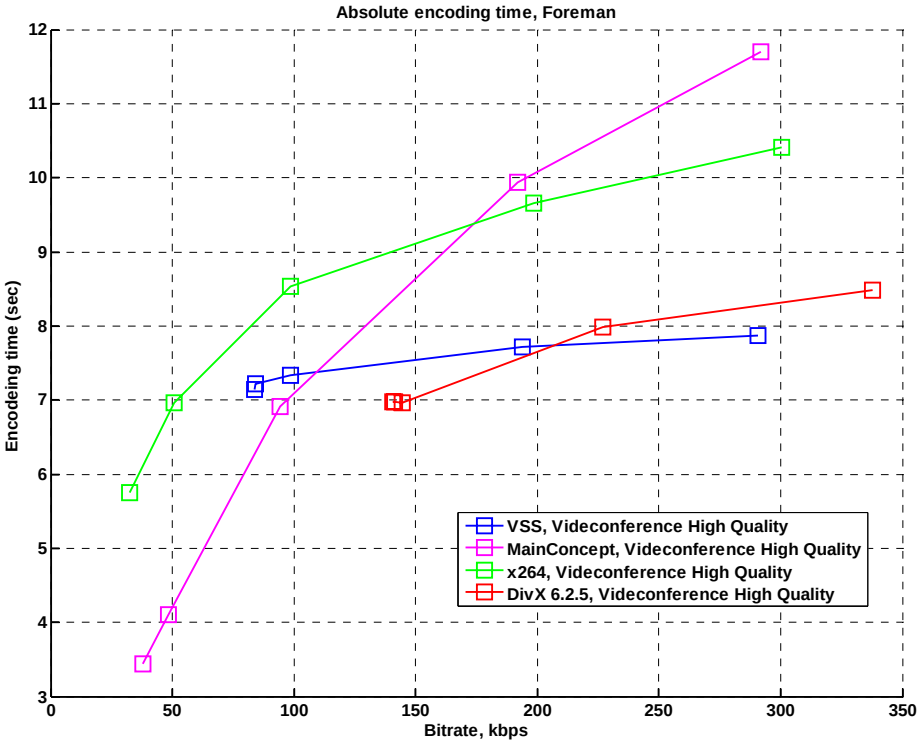


Figure 5. Absolute encoding time. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset

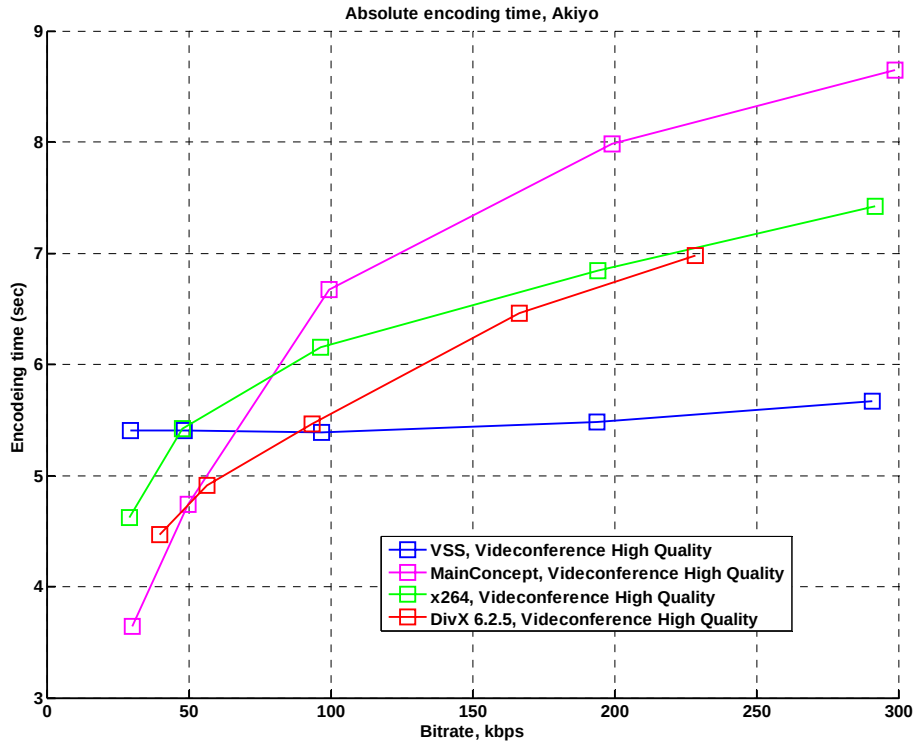


Figure 6. Absolute encoding time. Usage area "Videoconferences", "Akiyo" sequence, "High Quality" preset

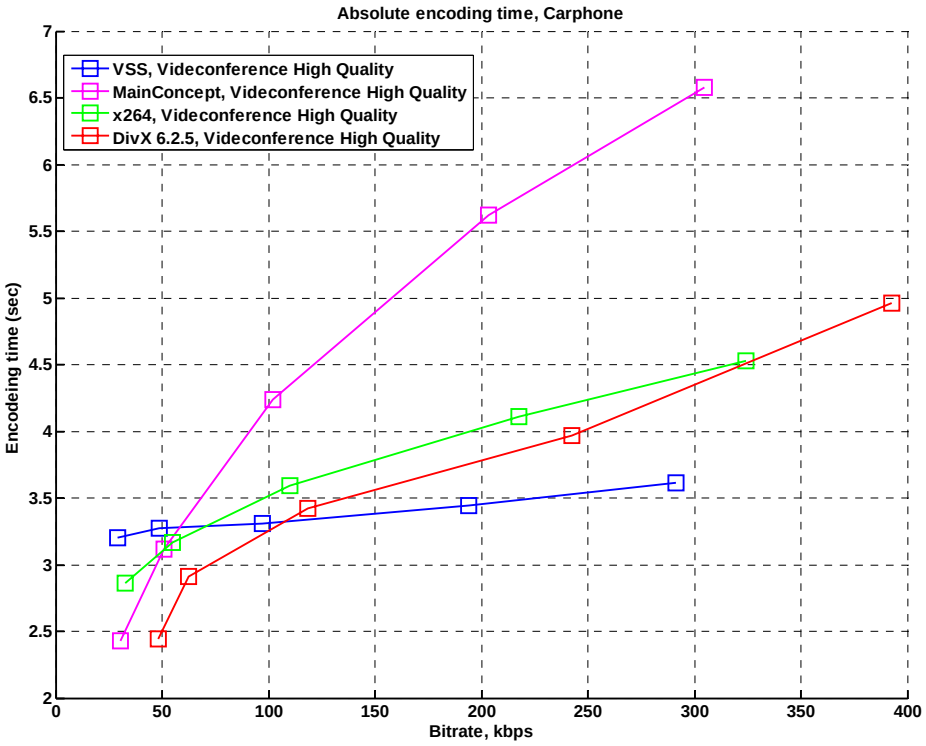


Figure 7. Absolute encoding time. Usage area "Videoconferences", "Carphone" sequence, "High Quality" preset

It is interesting to analyze encoding speed dependence on bitrate. Figure 5 – Figure 7 show this dependence for different sequences of test set. The strongest dependency has codec MainConcept, the weakest one – VSS.

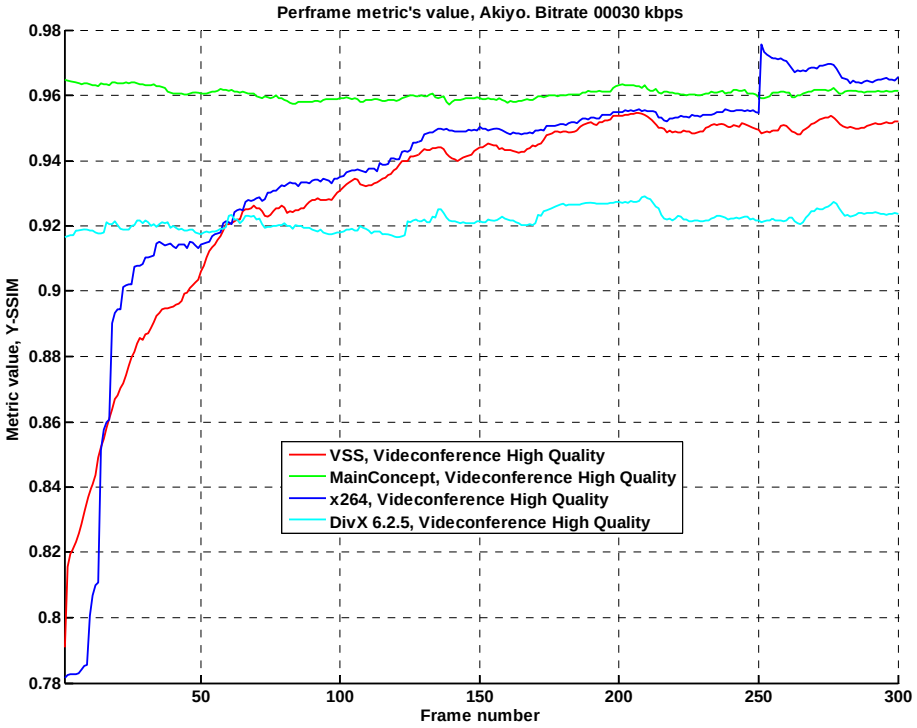


Figure 8. Per-frame quality. Usage area "Videoconferences", "Akiyo" sequence, "High Quality" preset, 30 kbps

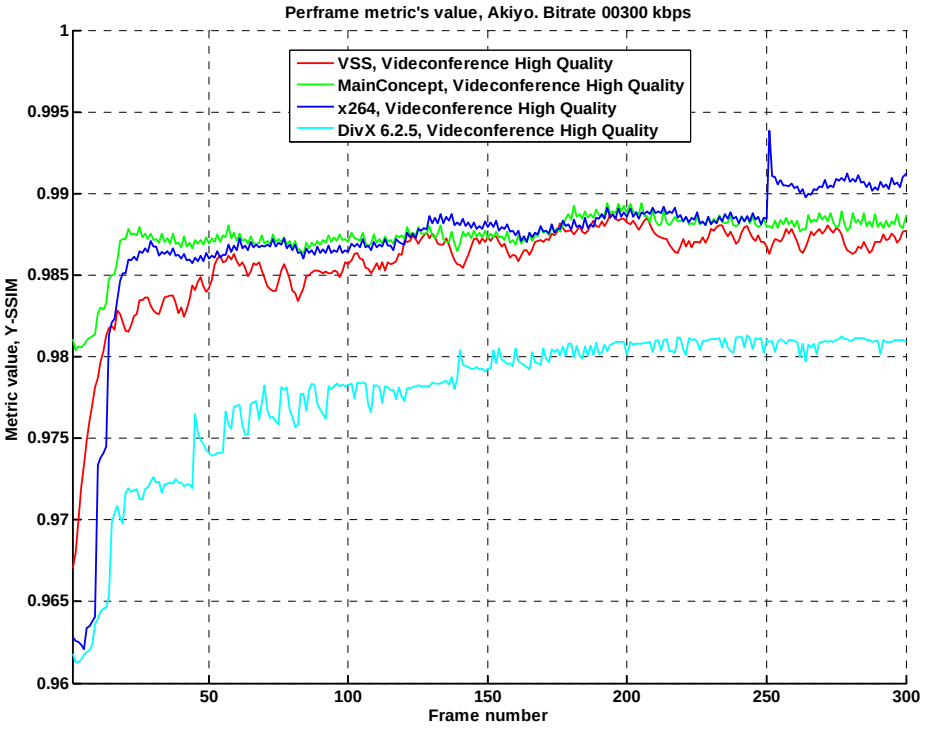


Figure 9. Per-frame quality. Usage area "Videoconferences", "Akiyo" sequence, "High Quality" preset, 300 kbps

Figure 8 shows per-frame quality of codecs at Akiyo sequence, 30 kbps. There is rather interesting situation at first frames. Quality of MainConcept and DivX codecs are rather constant during all sequence, but quality of x264 and VSS is understated at first frames. Probably, it is a problem (or feature) of initial RC parameters.

Another interesting thing is quality jump of x264 at 250 frame (I-frame was inserted there).

The same situation is presented at others bitrates (see Figure 9 for example).

Figure 10 – Figure 13 shows per-frame quality graphs for Foreman and Carphone sequences.

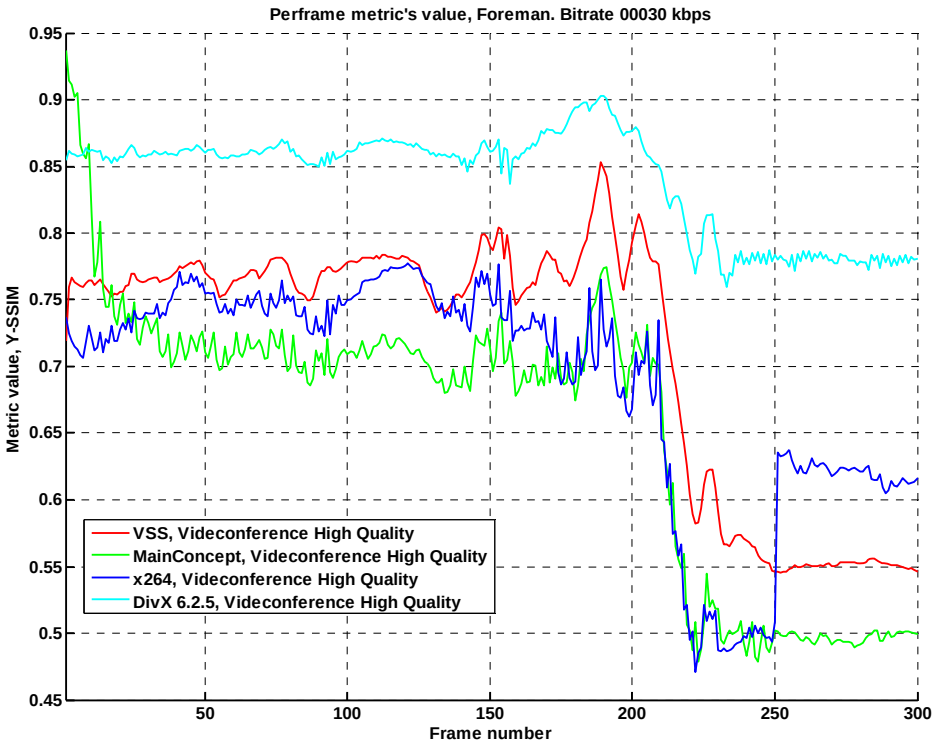


Figure 10. Per-frame quality. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset, 30 kbps

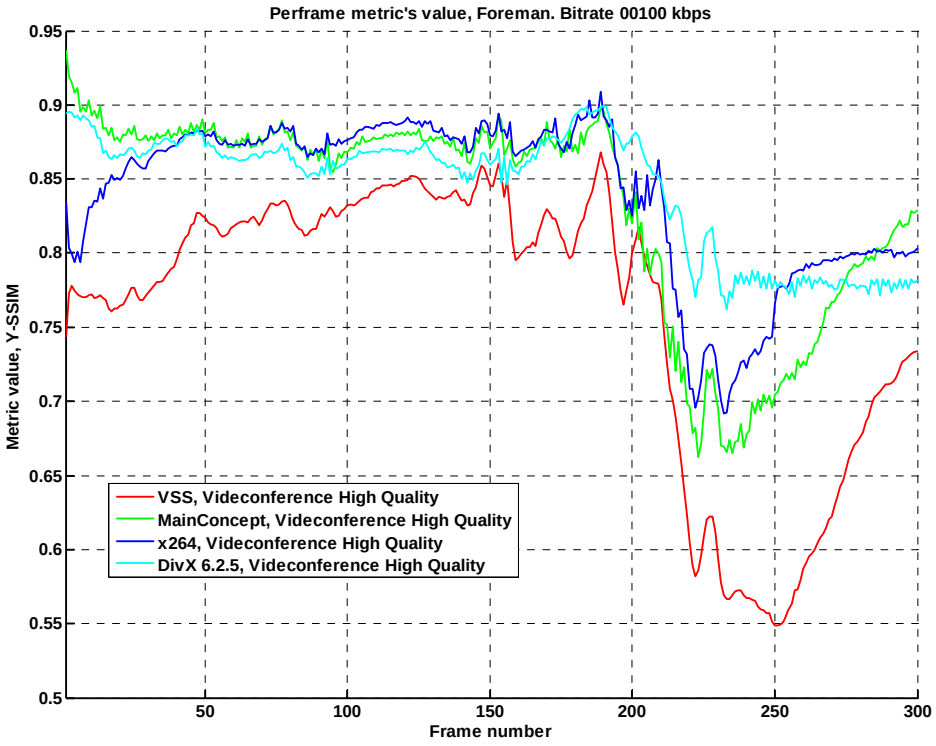


Figure 11. Per-frame quality. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset, 100 kbps

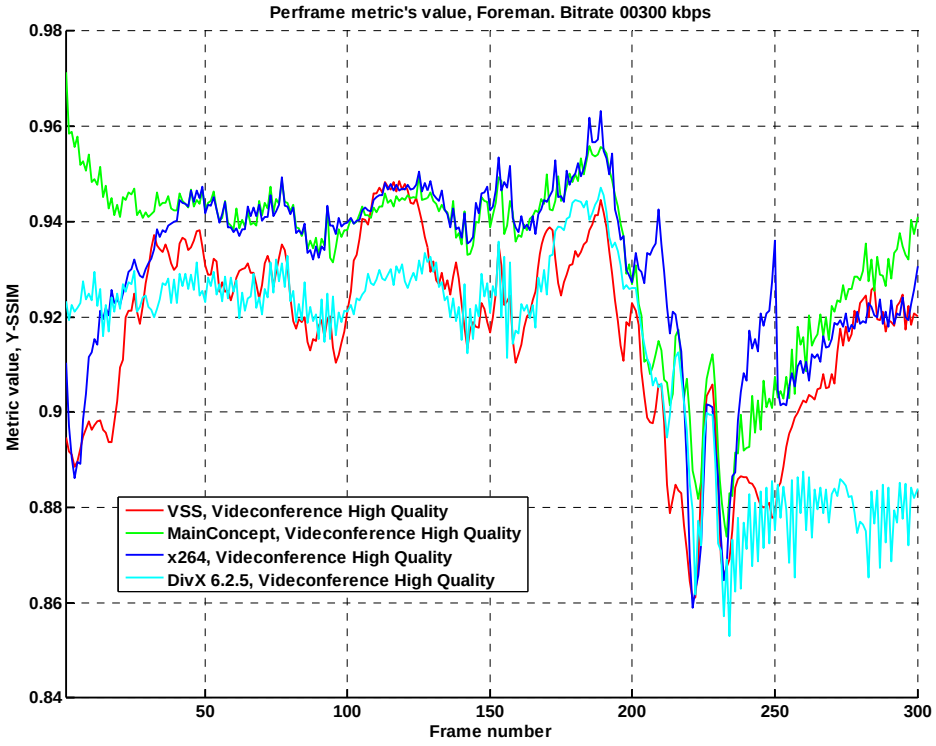


Figure 12. Per-frame quality. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset, 300 kbps

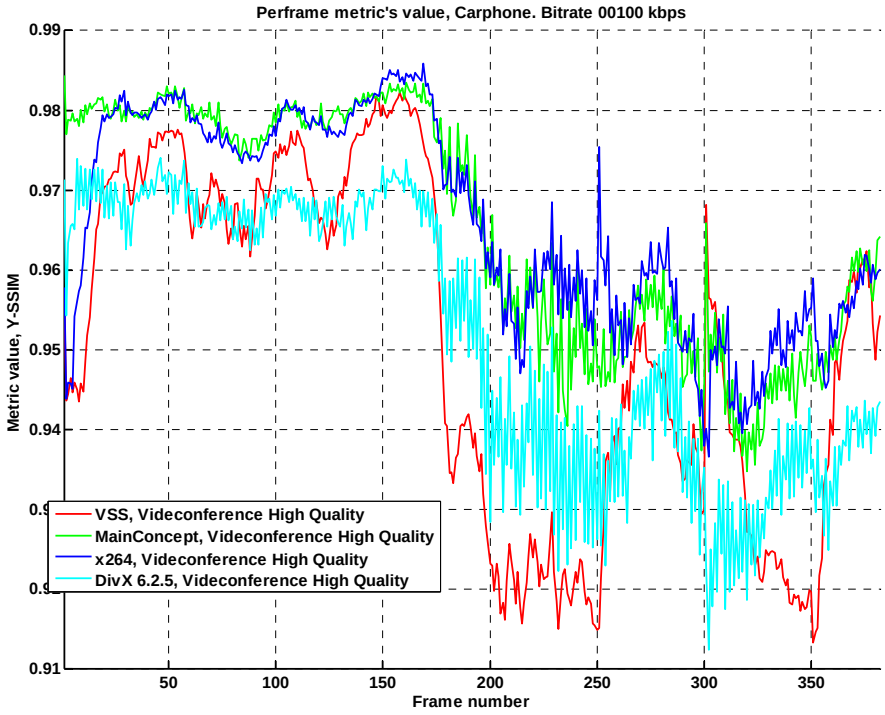


Figure 13. Per-frame quality. Usage area "Videoconferences", "Carphone" sequence, "High Quality" preset, 100 kbps

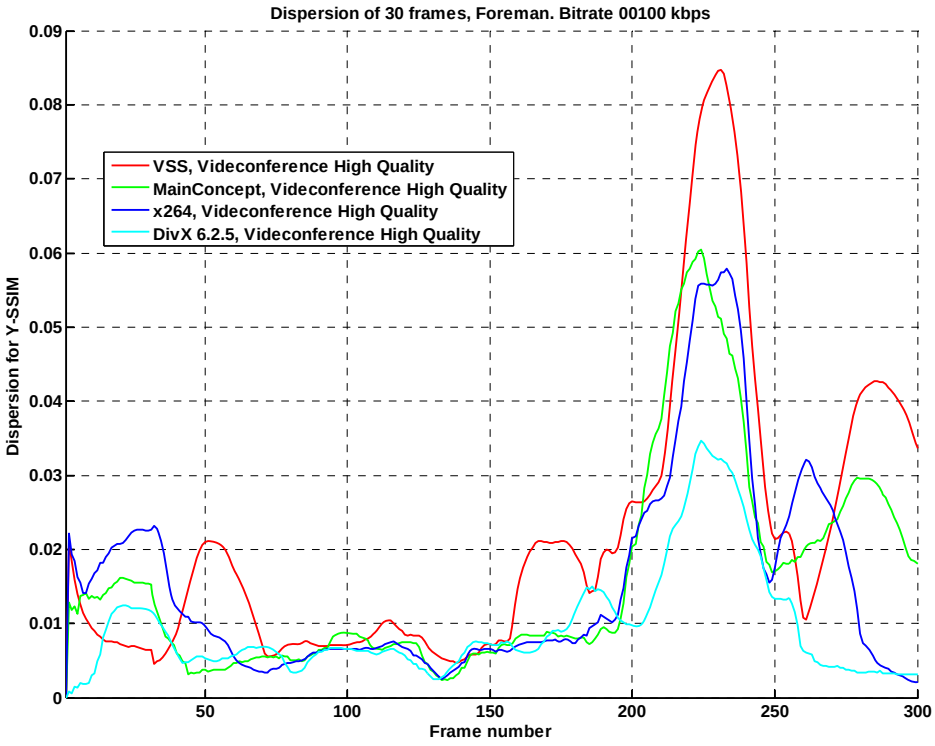


Figure 14. Quality dispersion (30 frames). Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset, 100 kbps

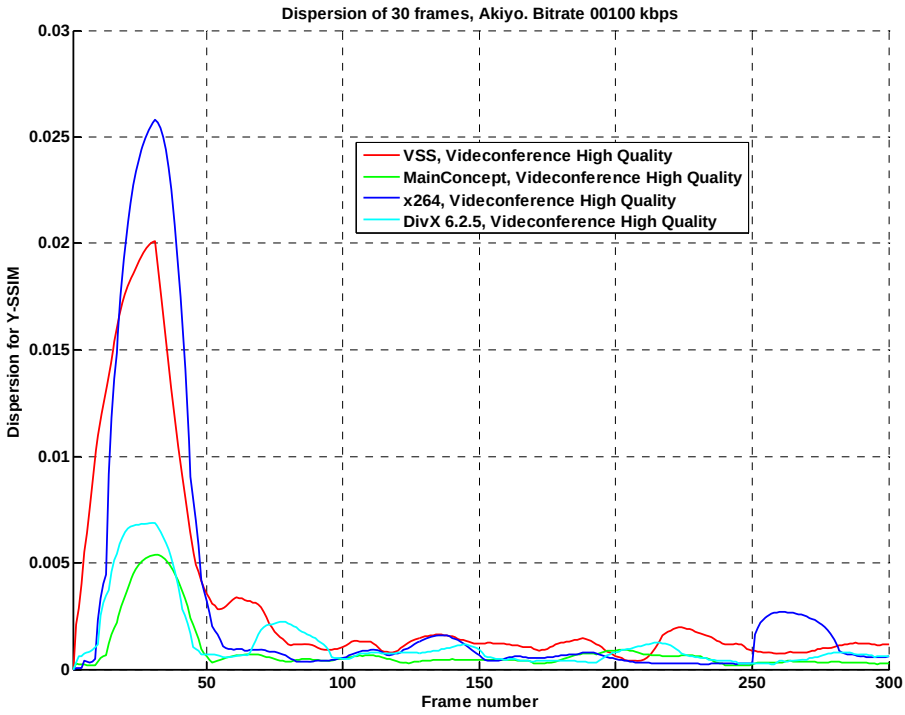


Figure 15. Quality dispersion (30 frames). Usage area "Videoconferences", "Akyio" sequence, "High Quality" preset, 100 kbps

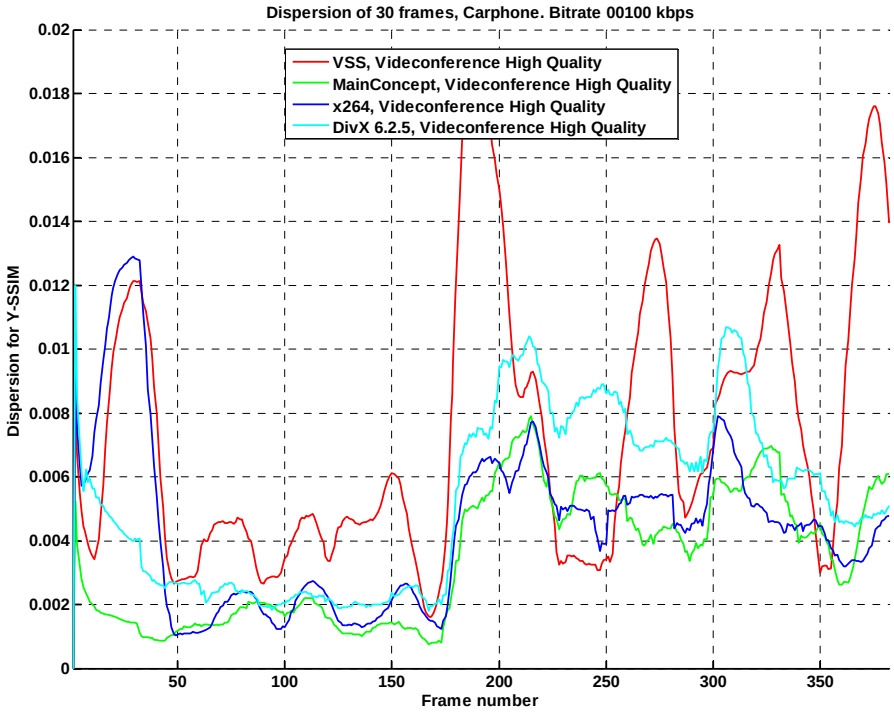


Figure 16. Quality dispersion (30 frames). Usage area "Videoconferences", "Carphone" sequence, "High Quality" preset, 100 kbps

Figure 14 – Figure 16 show frames dispersion for all sequences at 100 kbps. Areas in with big frame dispersion as a rule correspond to high motion in video.

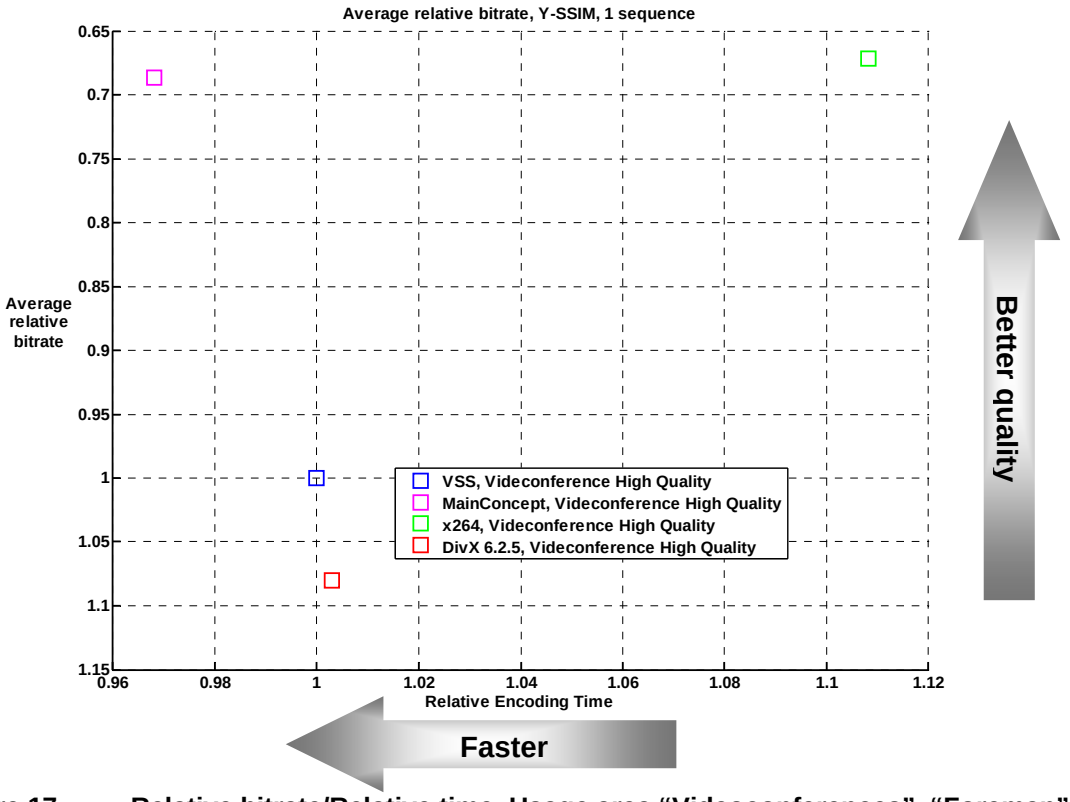


Figure 17. Relative bitrate/Relative time. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset

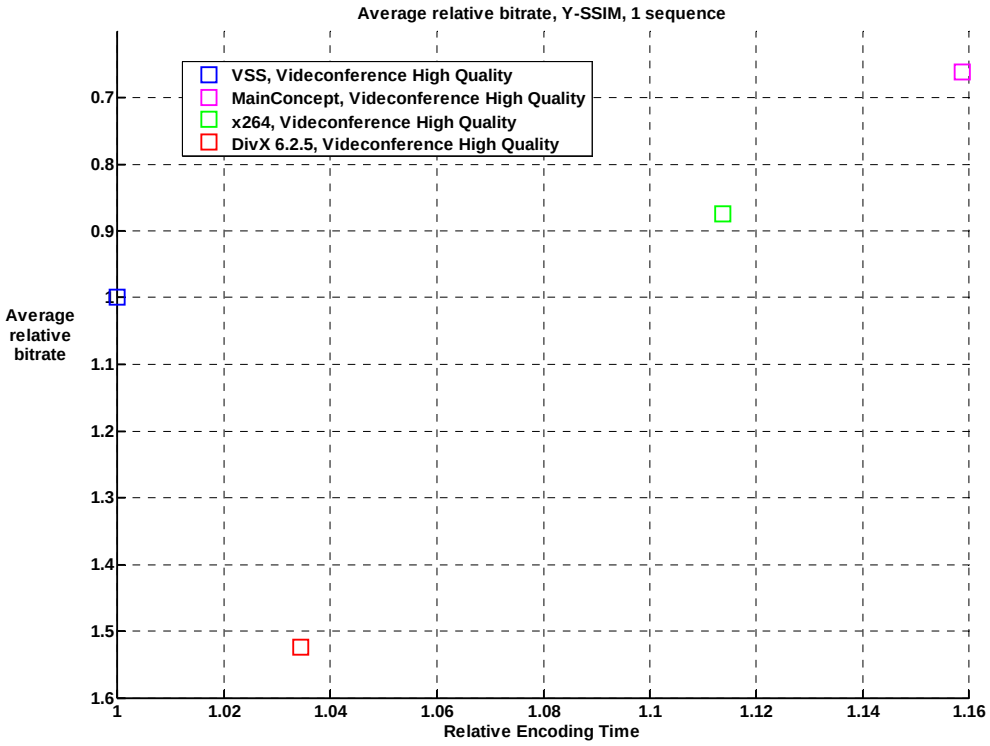


Figure 18. Relative bitrate/Relative time. Usage area "Videoconferences", "Akiyo" sequence, "High Quality" preset

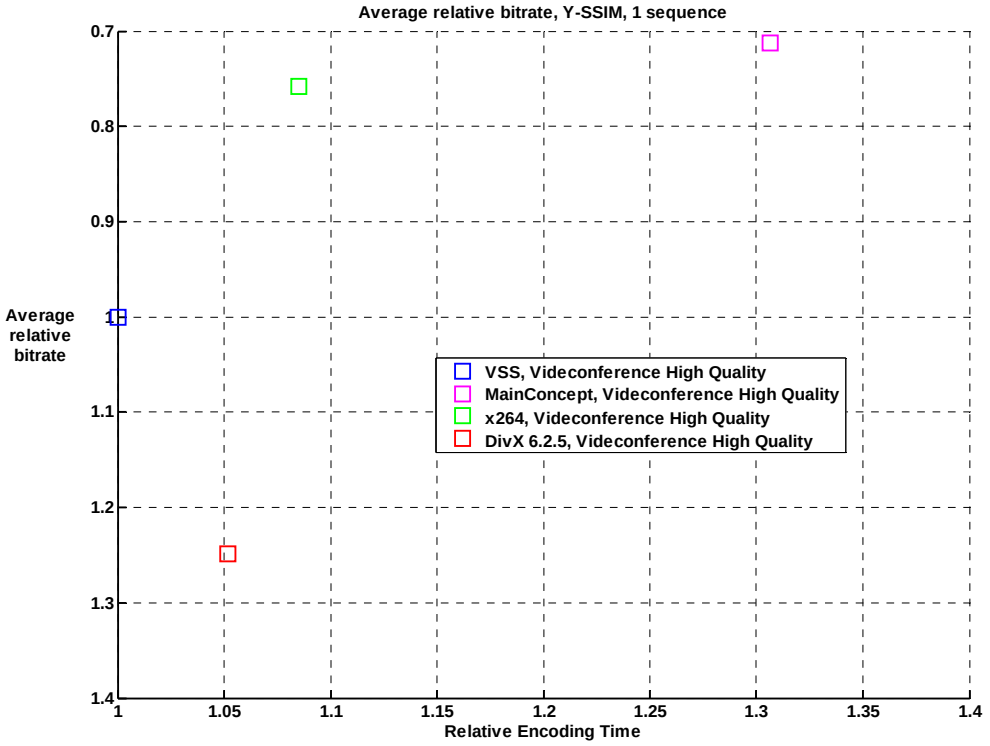


Figure 19. Relative bitrate/Relative time. Usage area "Videoconferences", "Carphone" sequence, "High Quality" preset

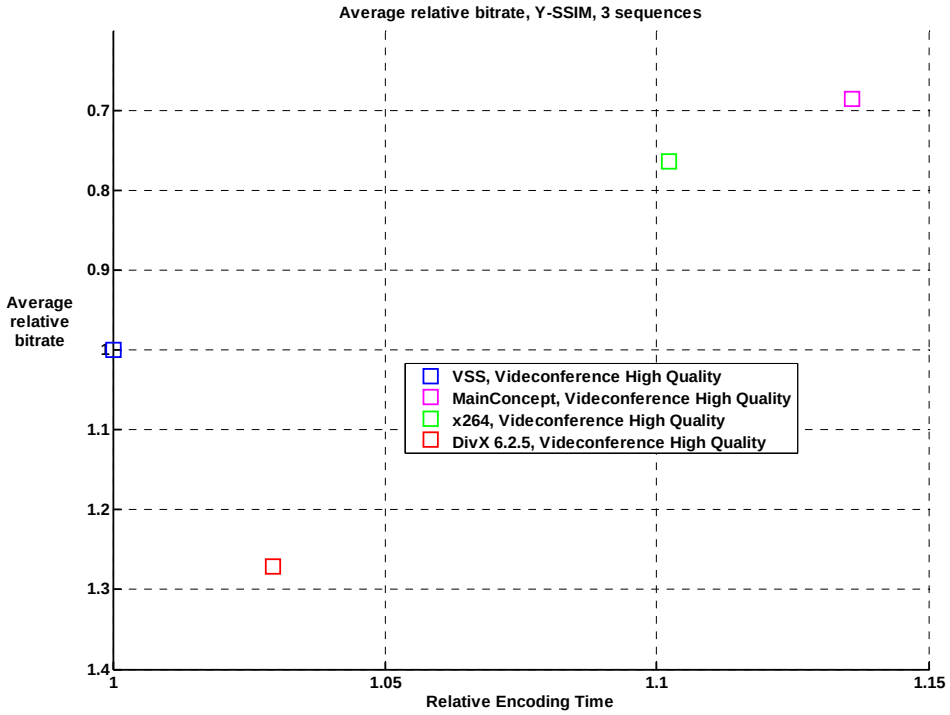


Figure 20. Relative bitrate/Relative time. Usage area "Videoconferences", All sequences ("Foreman", "Akiyo", "Carphone"), "High Quality" preset

MainConcept is the leader at sequence Foreman – it shows better quality and is faster than VSS and DivX and 15% faster than x264 for the same quality.

At "Akiyo" and "Carphone" sequences VSS codec is better than DivX both for quality and speed. All others codecs are not comparable with each other (shows better quality and lower).

Figure 20 shows averaged results of "High Quality" preset. VSS is better than DivX codec. All other codecs are not comparable.

PSNR results are very similar to SSIM.

"High Speed" Preset Results

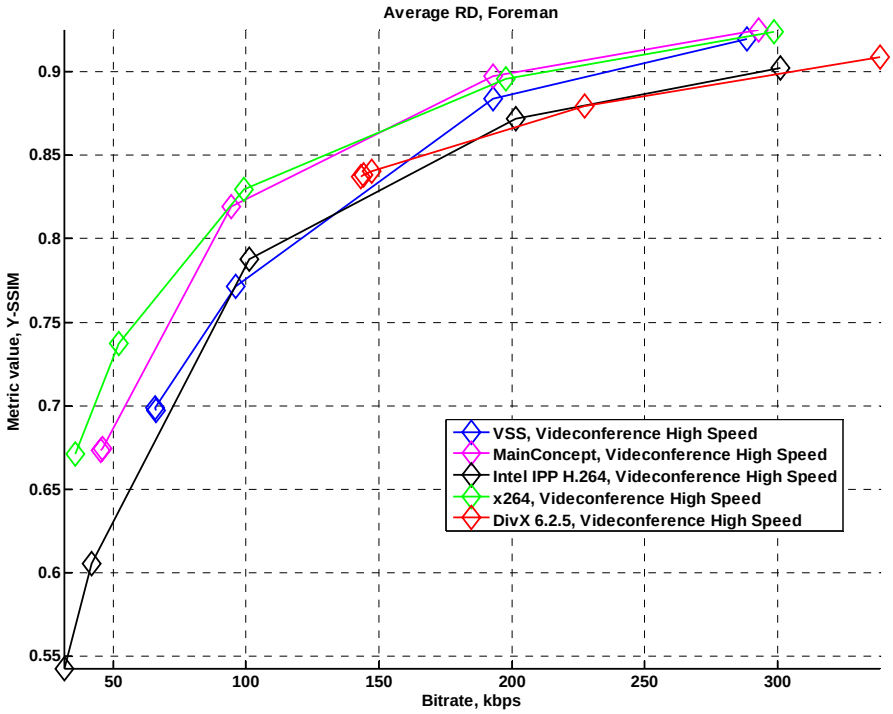


Figure 21. Bitrate/Quality. Usage area "Videoconferences", "Foreman" sequence, "High Speed" preset

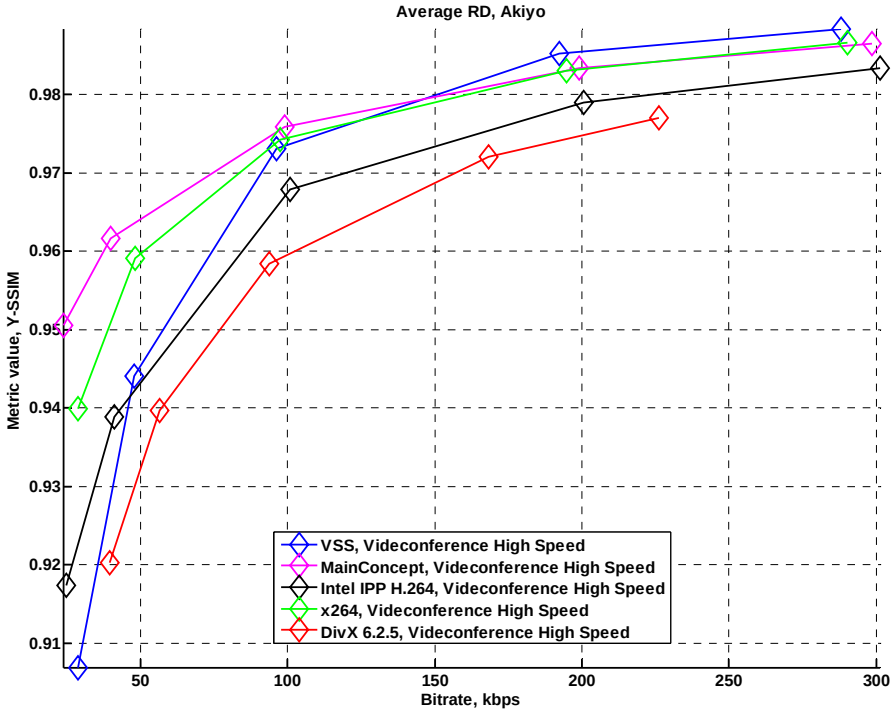


Figure 22. Bitrate/Quality. Usage area "Videoconferences", "Akiyo" sequence, "High Speed" preset

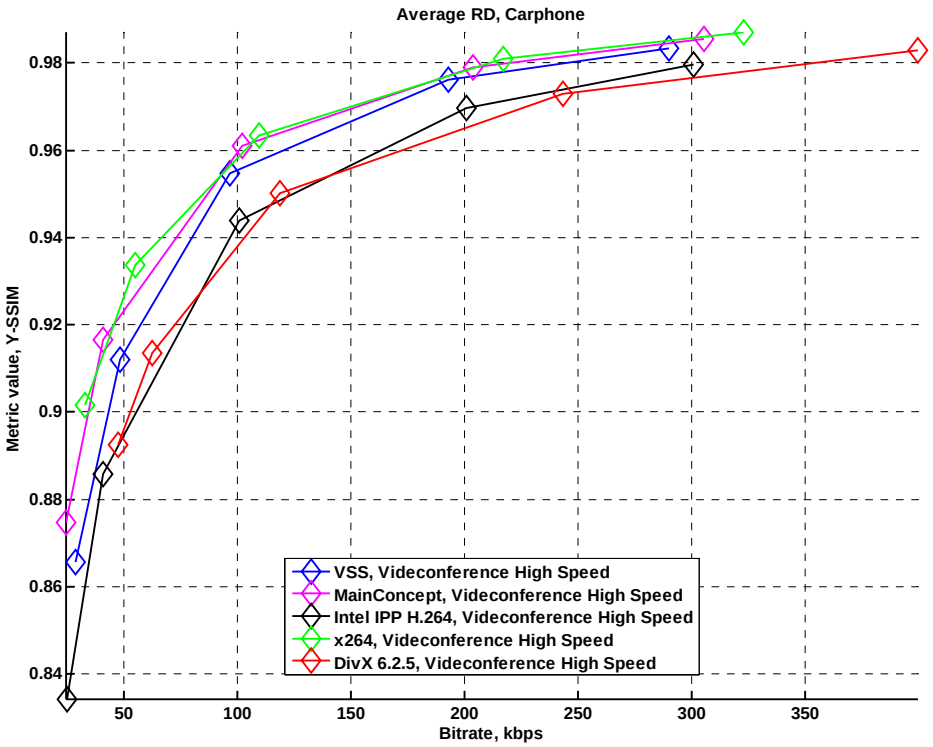


Figure 23. Bitrate/Quality. Usage area "Videoconferences", "Carphone" sequence, "High Speed" preset

With "High Speed" preset codecs show closer to each other results. So, conclusions for this preset are not so evident.

MainConcept and VSS are leaders for all sequences, but VSS codec is not so far as for "High Quality" preset, especially for high bitrates (at Akiyo sequence it is a little better than others). Intel IPP codec and DivX show lower quality, but the difference again is not large.

The worst sequence for DivX is "Akiyo", where it shows constant worst quality than all others codecs.

PSNR quality measure shows the same results, but differences are a little bigger.

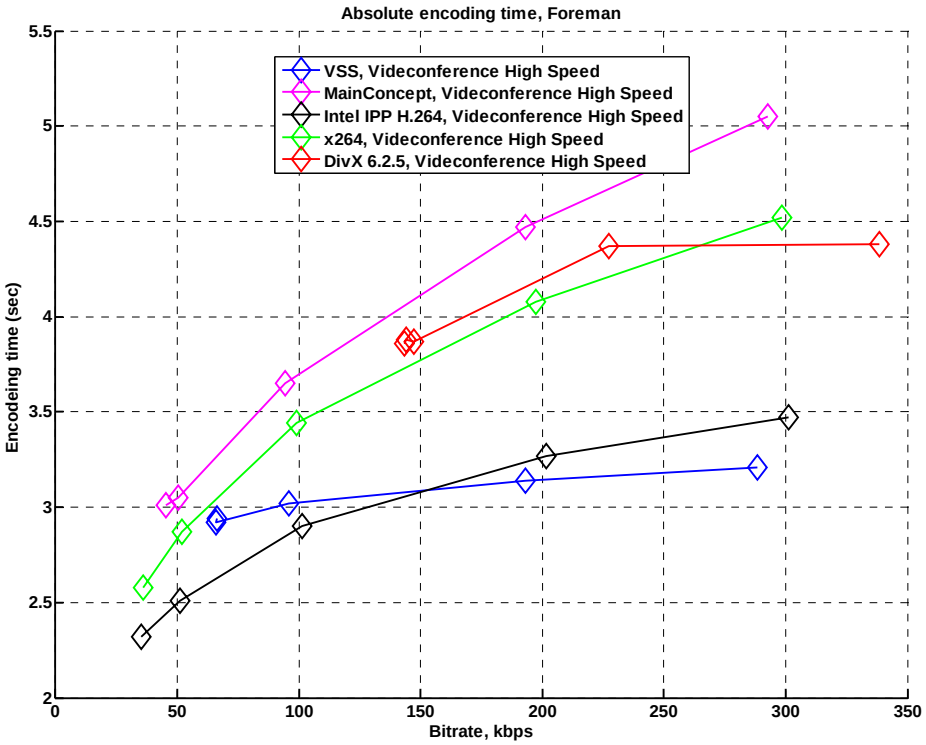


Figure 24. Absolute encoding time. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset

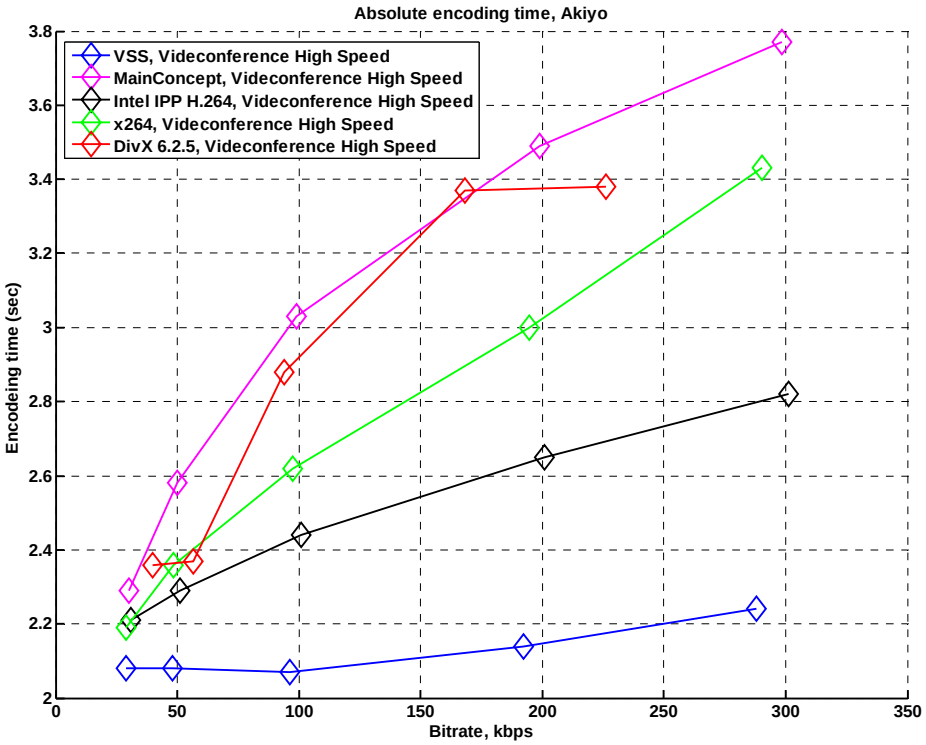


Figure 25. Absolute encoding time. Usage area "Videoconferences", "Akiyo" sequence, "High Quality" preset

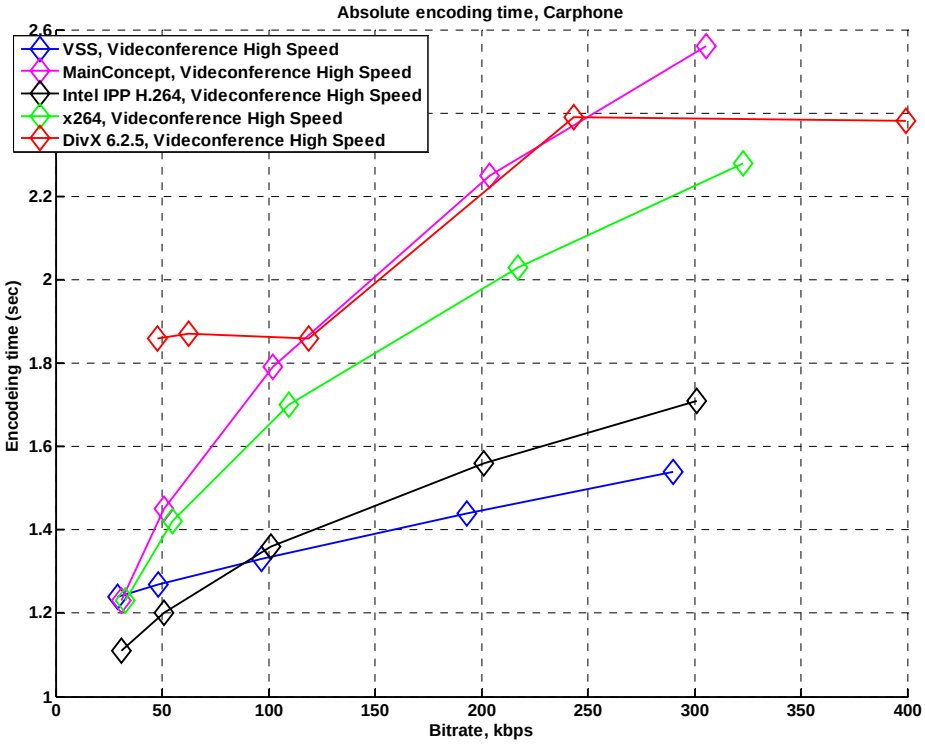


Figure 26. Absolute encoding time. Usage area "Videoconferences", "Carphone" sequence, "High Quality" preset

Situation with speed decreasing for high bitrates here is the same as for "High Quality" preset. Note that the curve for DivX codec is not continues, as for other codecs (Akiyo and Carphone sequences). One of the possible reasons of that is switching of different encoding modes of this codec. Another variant is speed measurements' errors (we used VirtualDub to run DivX, so, speed measurements of this codec are not very reliable).

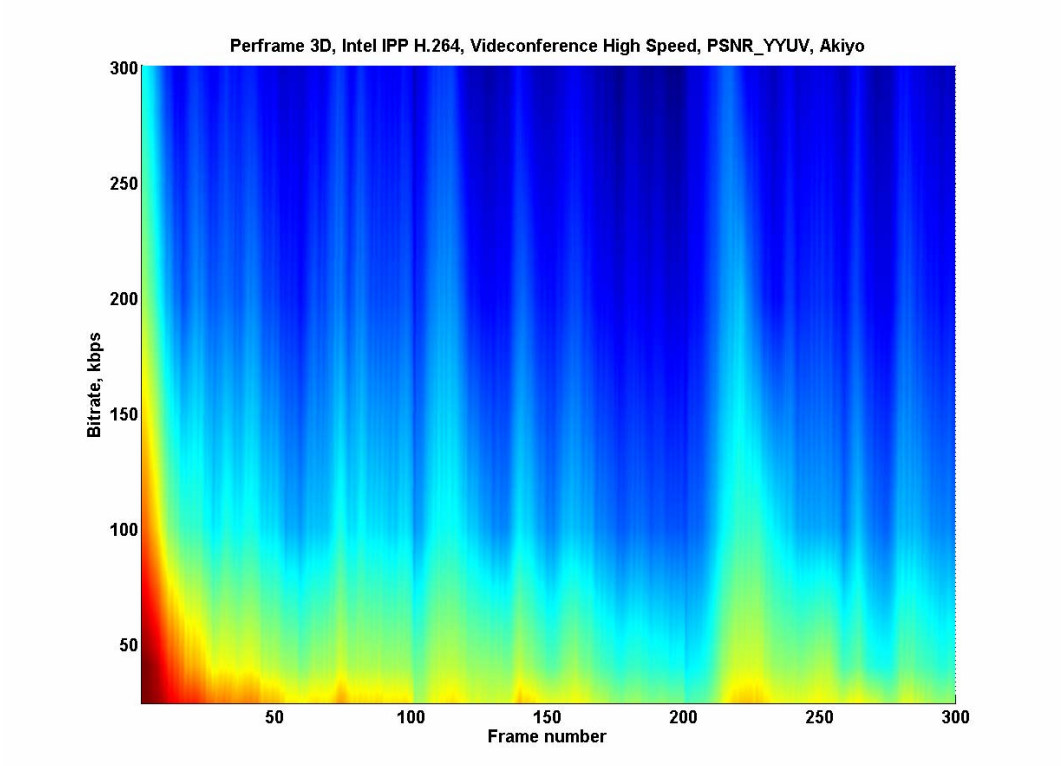


Figure 27. Per-frame Y-PSNR. Usage area "Videoconferences", "Akiyo" sequence, Intel IPP H.264, "High Speed" preset

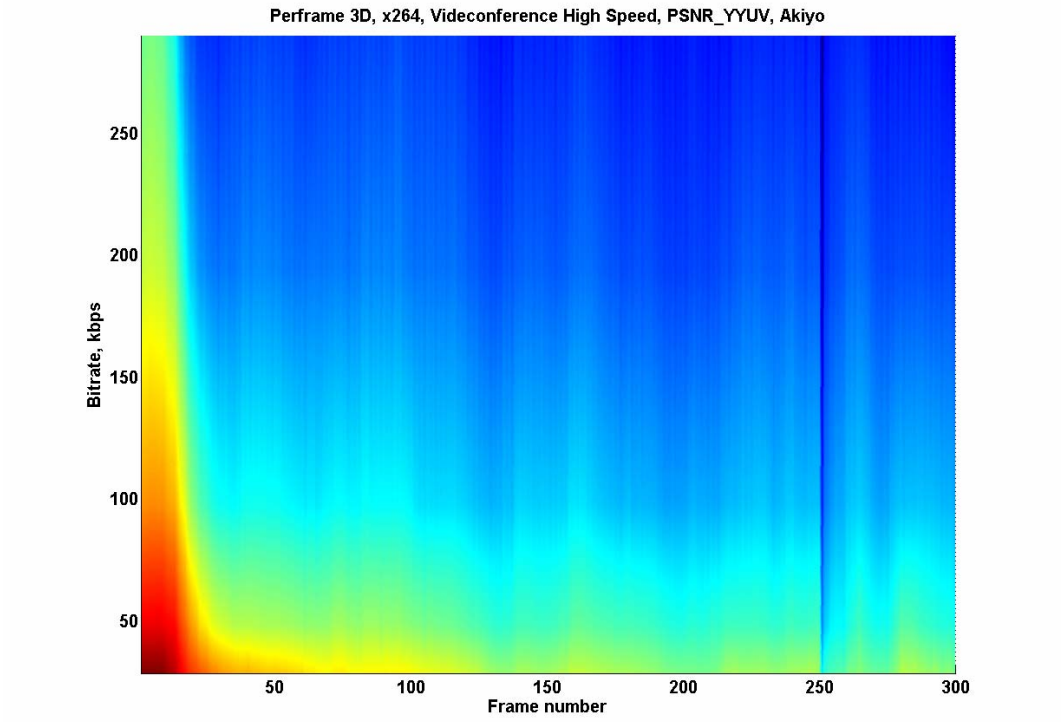


Figure 28. Per-frame Y-PSNR. Usage area "Videoconferences", "Akiyo" sequence, x264, "High Speed" preset

Figure 27 and Figure 28 show per-frame quality for codecs Intel and x264. It is clearly visible different rate control strategies of that codecs.

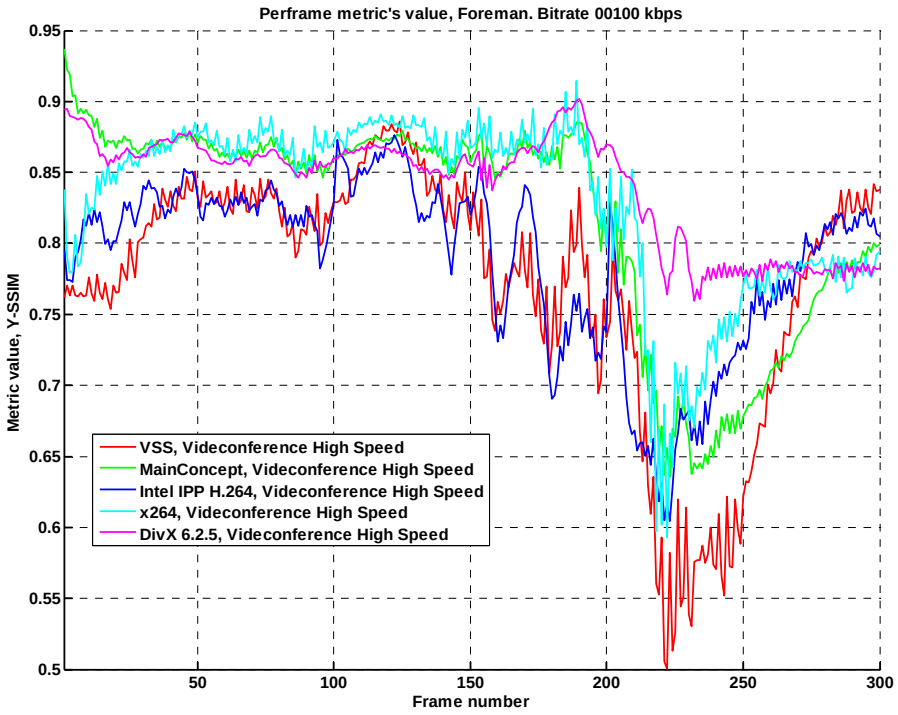


Figure 29. Per-frame quality. Usage area "Videoconferences", "Foreman" sequence, "High Speed" preset, 100 kbps

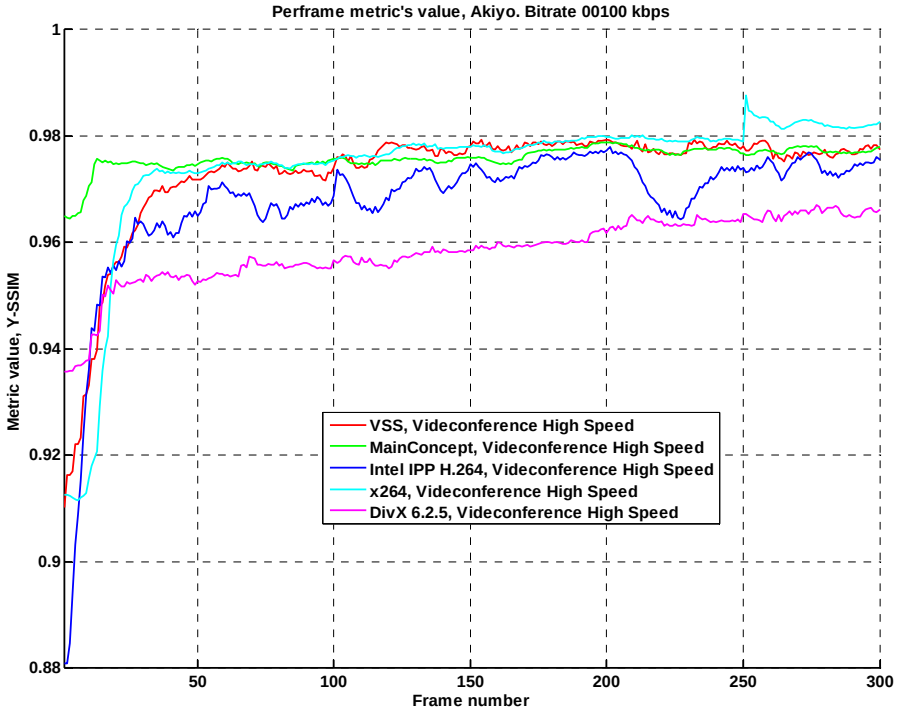


Figure 30. Per-frame quality. Usage area "Videoconferences", "Akiyo" sequence, "High Speed" preset, 100 kbps

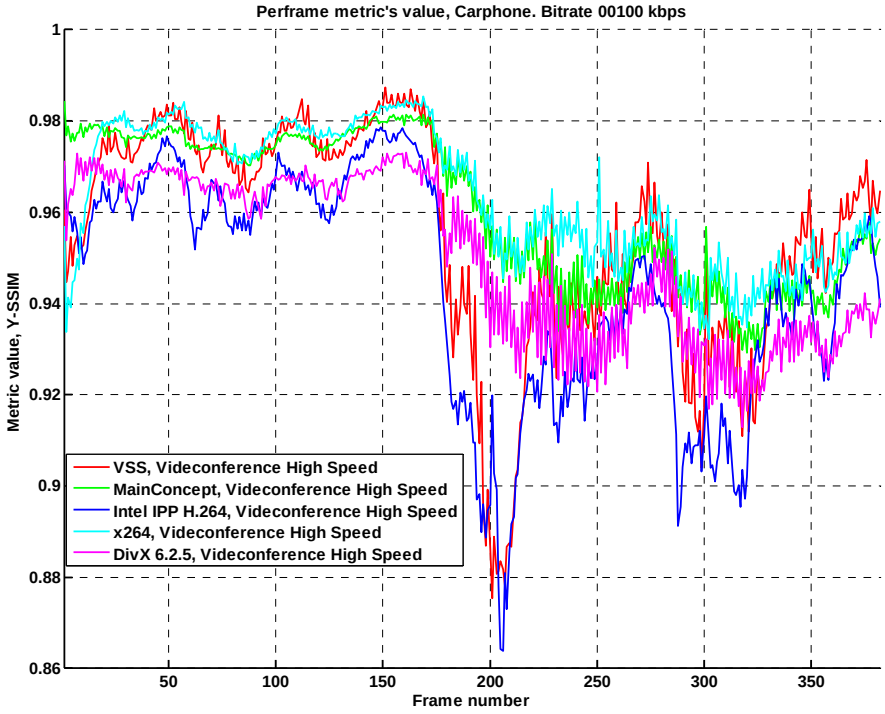


Figure 31. Per-frame quality. Usage area "Videoconferences", "Carphone" sequence, "High Speed" preset, 100 kbps

Figure 29 – Figure 31 show per-frame quality for all sequences at 100 kbps.

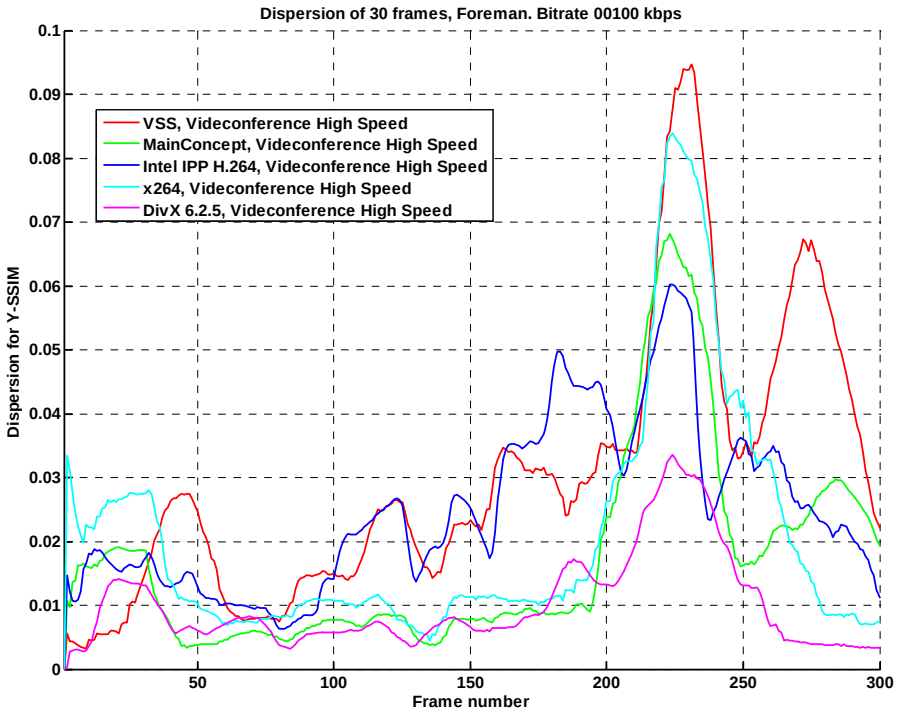


Figure 32. Quality dispersion (30 frames). Usage area "Videoconferences", "Foreman" sequence, "High Speed" preset, 100 kbps

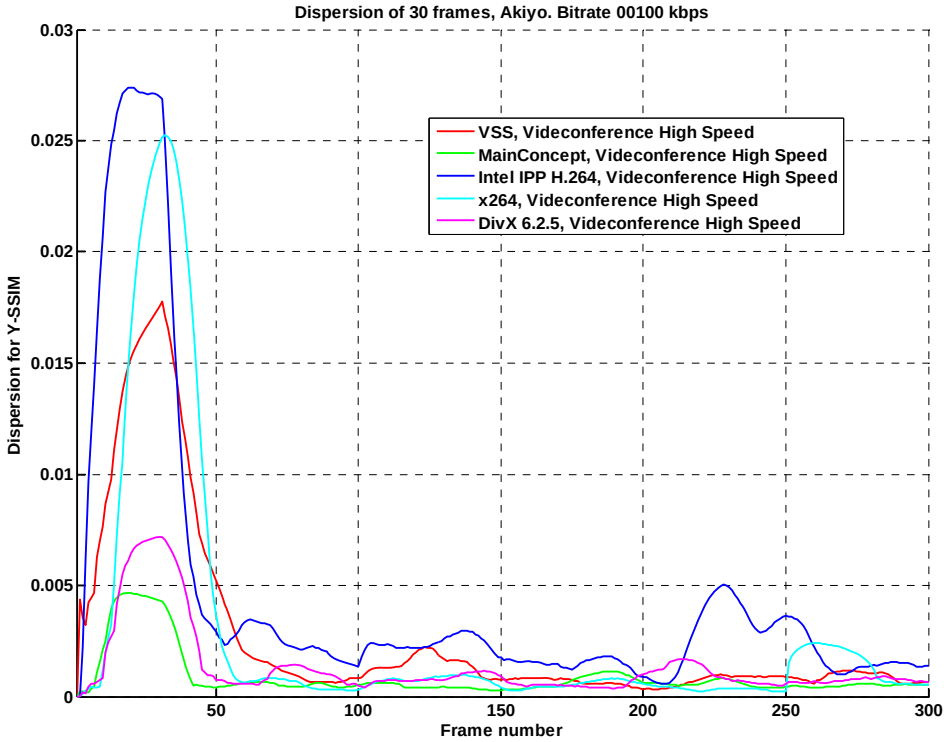


Figure 33. Quality dispersion (30 frames). Usage area "Videoconferences", "Akiyo" sequence, "High Speed" preset, 100 kbps

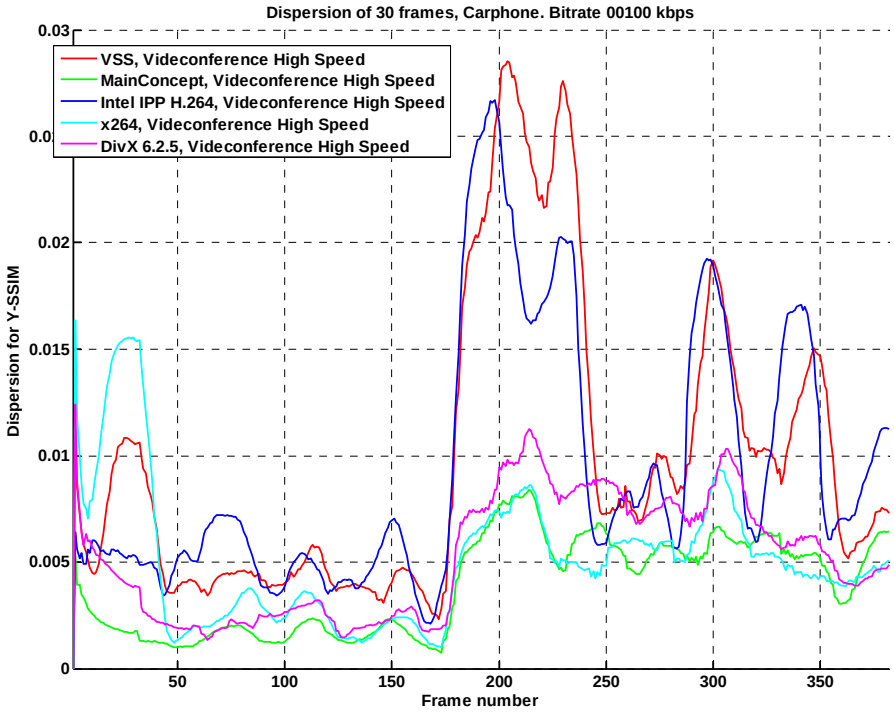


Figure 34. Quality dispersion (30 frames). Usage area "Videoconferences", "Carphone" sequence, "High Speed" preset, 100 kbps

Figure 32 – Figure 34 show frames dispersion (nearest 30 frames) for all sequences at 100 kbps.

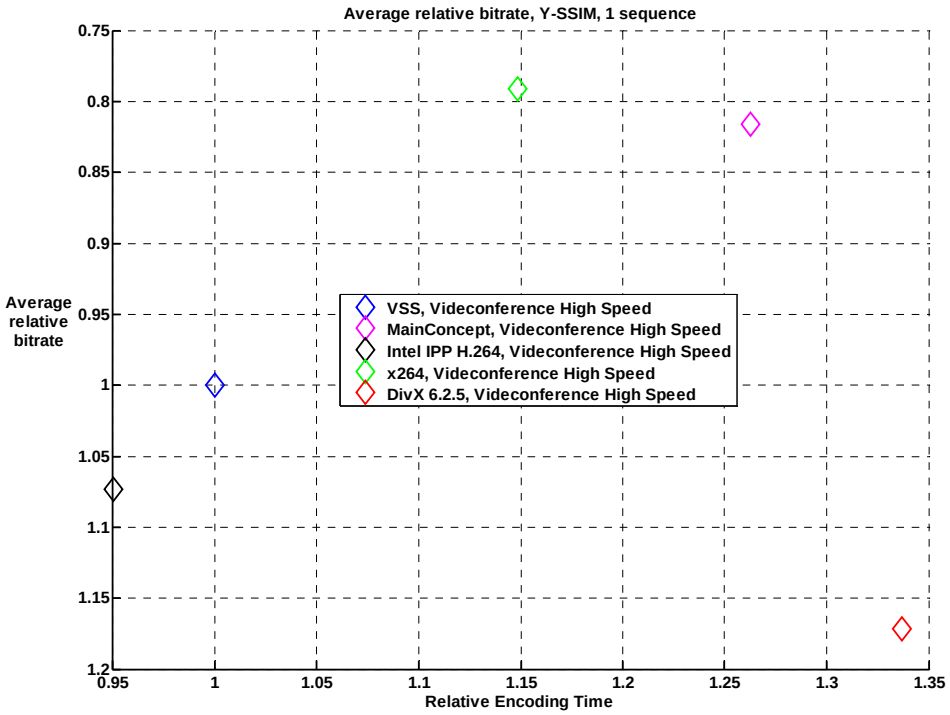


Figure 35. Relative bitrate/Relative time. Usage area "Videoconferences", "Foreman" sequence, "High Speed" preset

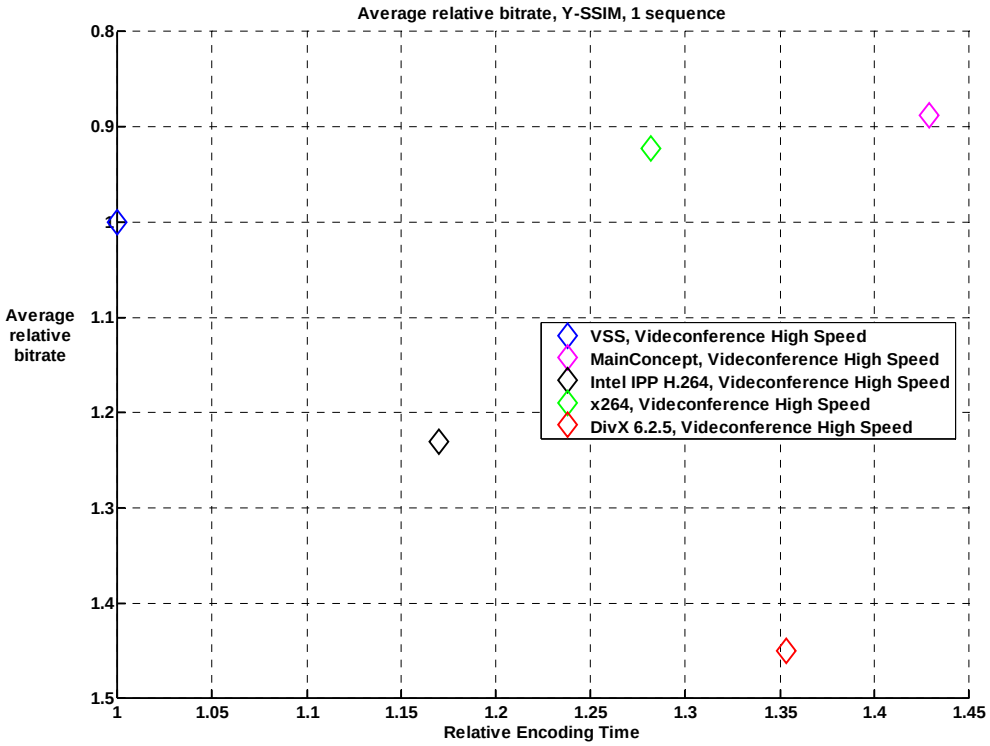


Figure 36. Relative bitrate/Relative time. Usage area "Videoconferences", "Akiyo" sequence, "High Speed" preset

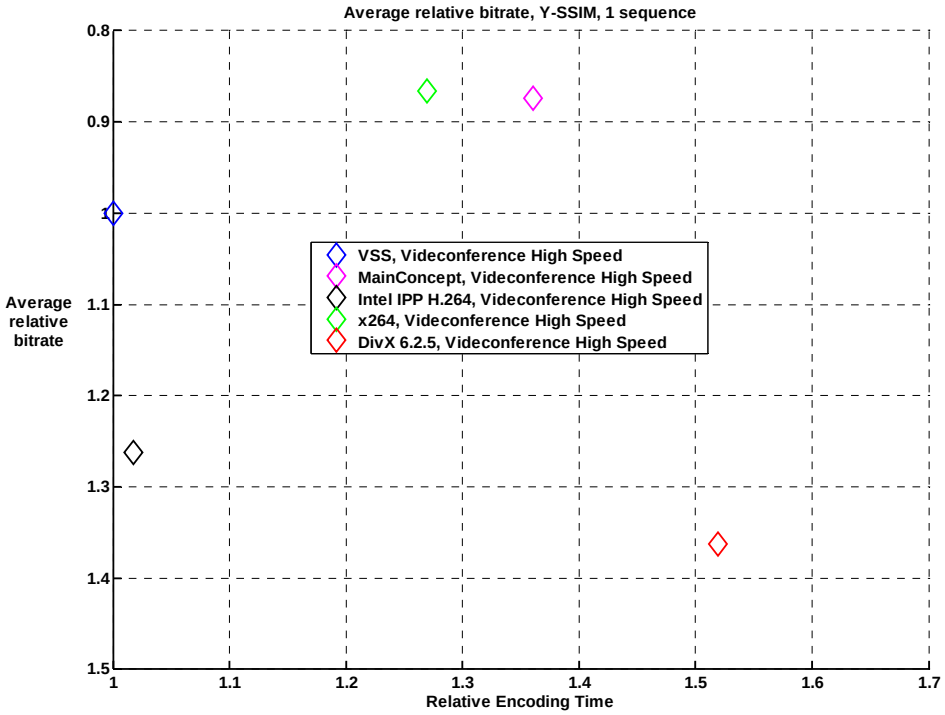


Figure 37. Relative bitrate/Relative time. Usage area "Videoconferences", "Carphone" sequence, "High Speed" preset

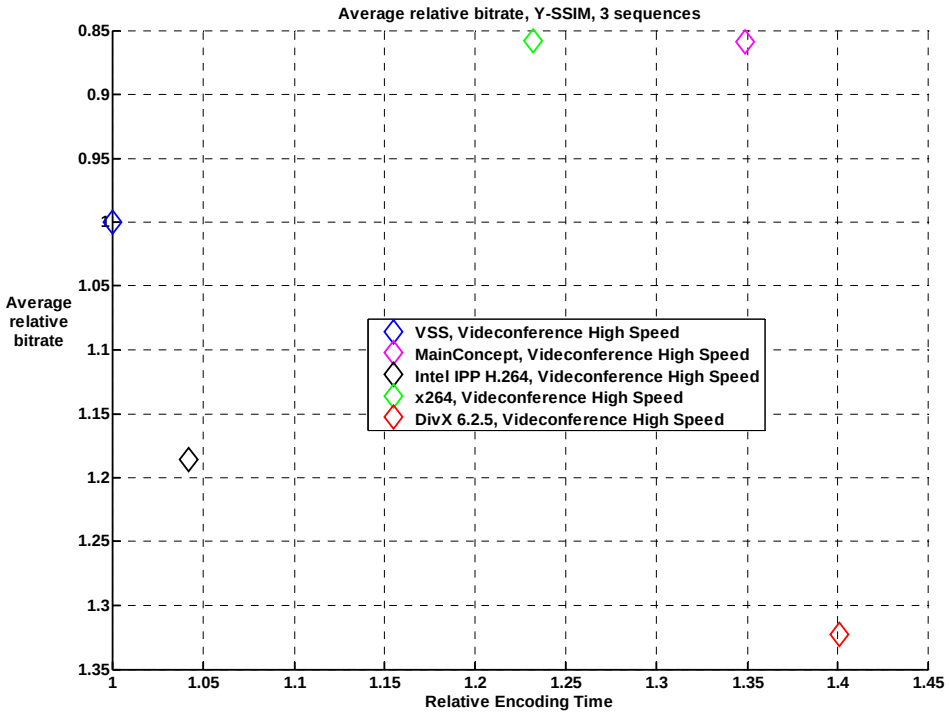


Figure 38. Relative bitrate/Relative time. Usage area "Videoconferences", All sequences ("Foreman", "Akiyo", "Carphone"), "High Speed" preset

First of all, let's note that for all sequences most H.264 codecs are better than DivX.

At "Foreman" sequence x264 is better than MainConcept both for speed and quality, but the difference is very small (12% of speed and 2.5% of bitrate for the same quality). All other codecs are not comparable.

At "Akiyo" sequence VSS is totally better than Intel IPP H.264 codec (23% of encoding time, 17% of bitrate). All other codecs are not comparable.

At "Carphone" sequence Intel IPP codec shows the same quality as VSS codec, but its quality is lower, MainConcept and x264 shows very close both quality and speed.

Figure 38 shows averaged results of "High Speed" preset. DivX is the worst codec in this preset (all codecs show better quality and are faster than it). VSS is better than Intel IPP. MainConcept and x264 show the same quality, but x264 codec is a little faster (11%).

Bitrate Handling

Note: We assume that 1 kbps = 1024 bps. If codec assumes that 1 kbps = 1000 bps, it's ideal bitrate handling curve at our curves will be at 1000/1024 = 0.9765625.

Now let's see bitrate keeping for all presets. We analyze results for "High Quality" and "High Speed" presets because of they are very similar.

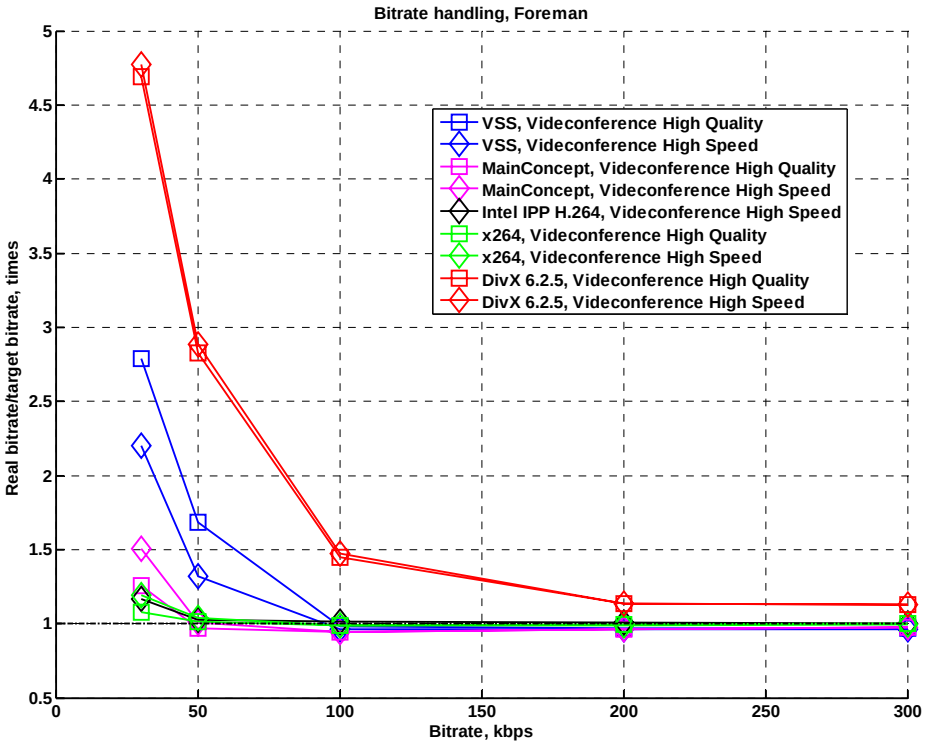


Figure 39. Bitrate handling. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset

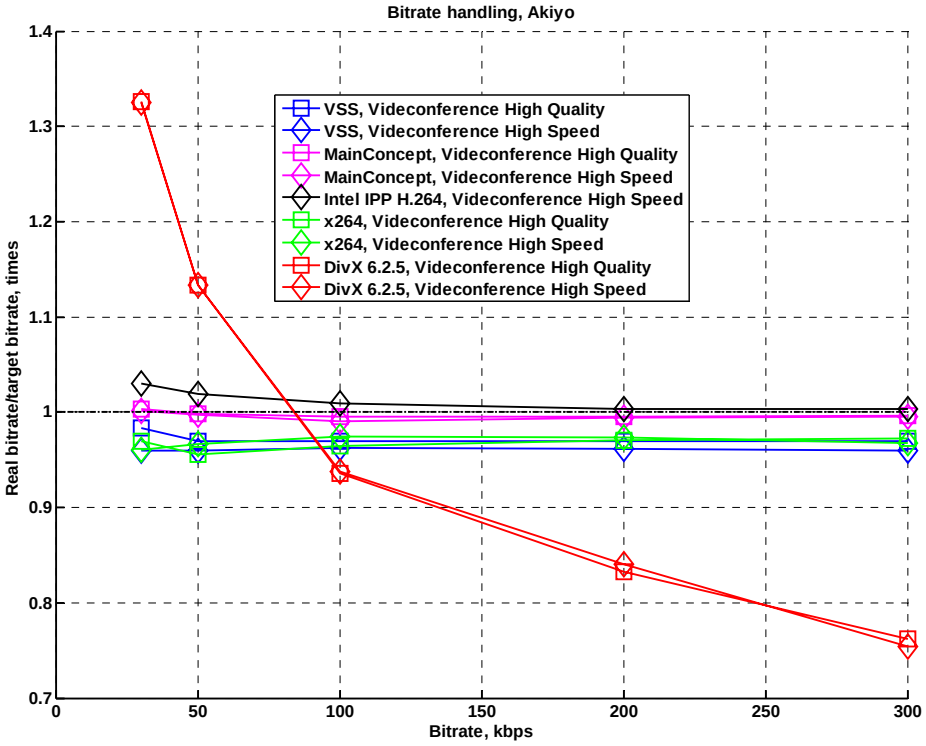


Figure 40. Bitrate handling. Usage area "Videoconferences", "Akiyo" sequence, "High Quality" preset

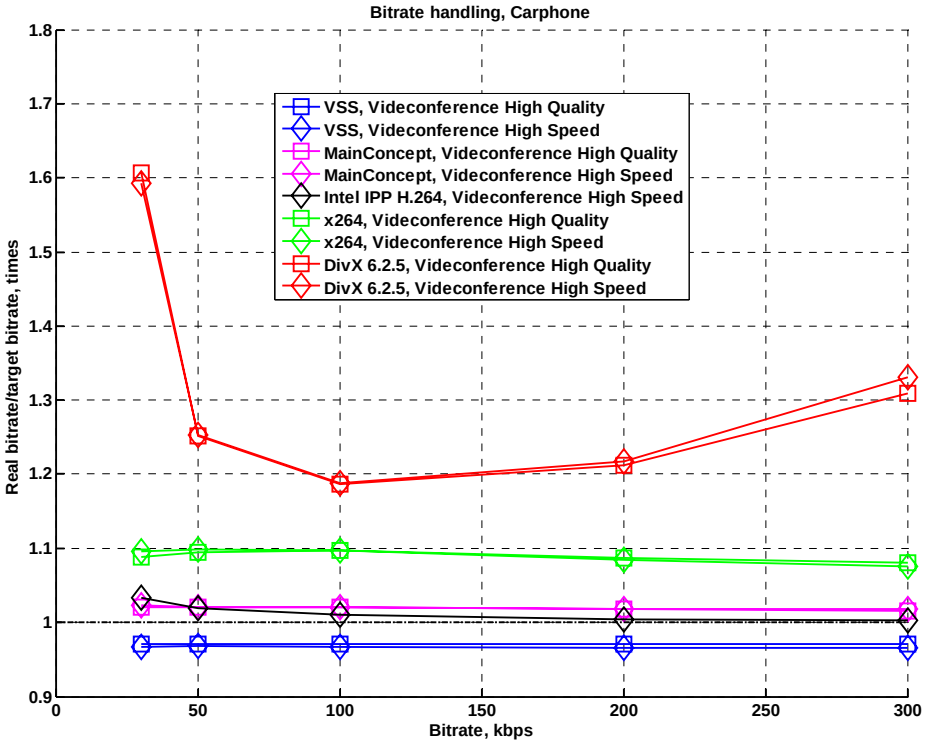


Figure 41. Bitrate handling. Usage area "Videoconferences", "Carphone" sequence, "High Quality" preset

First of all should be noted that bitrate keeping of DivX is very poor. It can exceeds target bitrate up to 4.7 times (Foreman, 30 kbps) and understate bitrate up to 24% (Akiyo, 300 kbps). Probably, it is the feature of the codec, because this situation is very similar for all others type of applications and presets.

For all others codecs situation is different for different sequences.

At "Foreman" sequence all codecs keep bitrate well starting from 100 kbps. VSS is the worst on in area 30-100 kbps (in fact, its minimum bitrate is app. 85 kbps).

All codecs at "Akiyo" sequence keep bitrate rather good.

"Carphone" is not very good sequence for x264 – it exceeds bitrate to 10%, but makes it rather stable. MainConcept and VSS keep bitrate rather good.

Averaged results

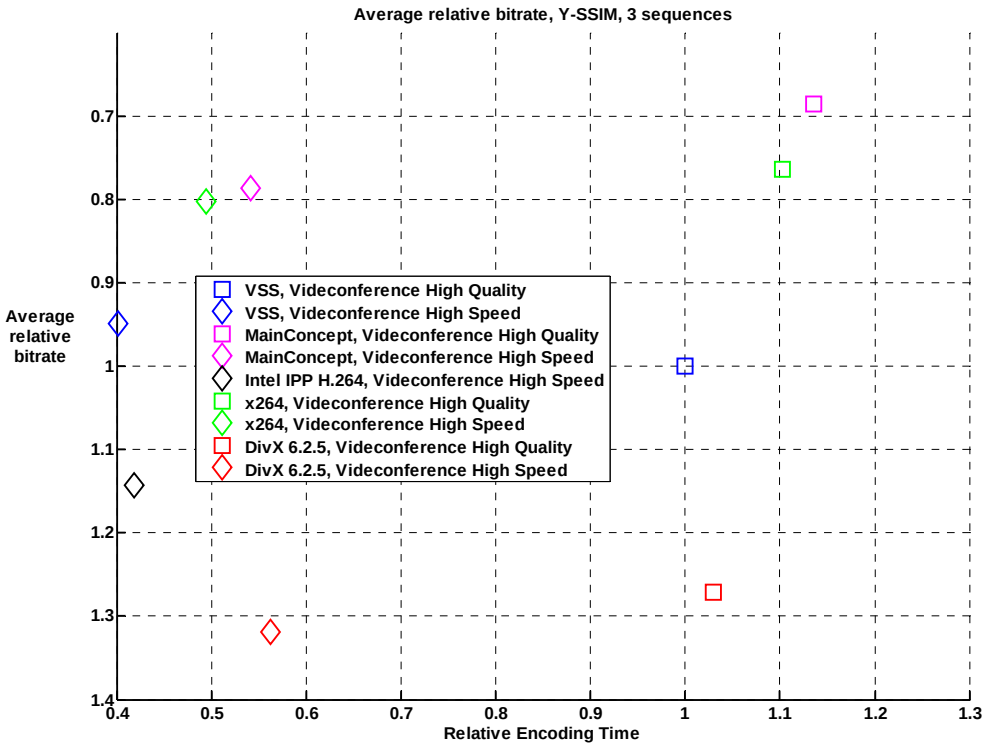


Figure 42. Relative bitrate/Relative time. Usage area "Videoconferences", All sequences ("Foreman", "Akiyo", "Carphone"), all presets

At Figure 42 both presets are shown. It is interesting to note that "High Quality" preset of VSS codec is worse than "High Speed" (and worth than fast presets of MainConcept and x264).

Table 4, Table 5 and Table 6 show average bitrates (or file size) ratio of all codecs for "High Quality" preset, "High Speed" preset and both presets correspondingly. The values in those tables are ration of bitrate for the same quality of codec in column and codec in row. For example value 68.6% in first row and second column in Table 4 means that MainConcept codec requires 31.4% (100 – 68.6) less size to encode sequence with the same quality comparing to VSS codec.

Table 4. Average bitrate ratio for the same quality. Usage area "Videoconferences". "High Quality" preset, Y-SSIM. Bitrates app. 100-300 Kbps.

	VSS	MainConcept	x264	DivX
VSS	100.0%	68.6%	76.4%	127.1%
MainConcept	145.7%	100.0%	110.7%	189.7%
x264	131.0%	90.3%	100.0%	159.8%
DivX	78.7%	52.7%	62.6%	100.0%

Table 5. Average bitrate ratio for the same quality. Usage area "Videoconferences". "High Speed" preset, Y-SSIM. Bitrates app. 100-300 Kbps.

	VSS	MainConcept	Intel IPP	x264	DivX
VSS	100.0%	85.9%	118.6%	85.8%	132.3%
MainConcept	116.4%	100.0%	149.3%	101.9%	171.2%
Intel IPP	84.3%	67.0%	100.0%	68.5%	111.0%
x264	116.5%	98.2%	146.0%	100.0%	160.3%
DivX	75.6%	58.4%	90.1%	62.4%	100.0%

Table 6. Average bitrate ratio for the same quality. Usage area "Videoconferences". All presets, Y-SSIM. Bitrates app. 100-300 Kbps.

	VSS HQ	MC HQ	x264 HQ	DivX HQ	VSS HS	MC HS	IPP HS	x264 HS	DivX HS
VSS HQ	100.0%	68.6%	76.4%	127.1%	94.9%	78.7%	114.3%	80.3%	131.8%
MC HQ	145.7%	100.0%	110.7%	189.7%	130.9%	115.6%	171.6%	117.1%	198.3%
x264 HQ	131.0%	90.3%	100.0%	159.8%	122.7%	103.4%	153.0%	105.2%	166.6%
DivX HQ	78.7%	52.7%	62.6%	100.0%	78.1%	61.1%	94.0%	65.1%	104.3%
VSS HS	105.4%	76.4%	81.5%	128.1%	100.0%	85.9%	118.6%	85.8%	132.3%
MC HS	127.1%	86.5%	96.7%	163.7%	116.4%	100.0%	149.3%	101.9%	171.2%
IPP HS	87.5%	58.3%	65.3%	106.3%	84.3%	67.0%	100.0%	68.5%	111.0%
x264 HS	124.6%	85.4%	95.1%	153.6%	116.5%	98.2%	146.0%	100.0%	160.3%
DivX HS	75.9%	50.4%	60.0%	95.9%	75.6%	58.4%	90.1%	62.4%	100.0%

Conclusions

On the basis of researches carried out all tested codecs may be ranked in the following way by criteria average bitrate saving for the same quality:

1. MainConcept
2. x264 (with small lag)
3. VSS
4. Intel H.264
5. DivX (MPEG-4 ASP)

It is important to note that for "Videoconferences" type of application MPEG-4 ASP codec showed itself as worst when compared with all tested implementations of new MPEG-4 AVC standard.

Bitrate keeping is good enough for all codec except DivX. The only weak places are low bitrates of VSS for "Foreman" and "Carphone" sequence for x264.

Movies

In this section behavior of codecs for encoding movies with standard resolution (SDTV) is analyzed. Here various sequences with different compression complexity were used including an example of cartoon film. Chosen bitrates (500, 700, 900, 1100, 1400, 1600, 2000 Kbps) are typical for video encoding for CD-ROM, cable television and digital satellite broadcasting.

The following codecs are considered in this section:

- DivX 6.2.1 (2 presets)
- MainConcept (3 presets)
- Intel H.264 (1 preset)
- VSS (2 presets)
- x264 (3 presets)

"High Quality" Preset Results

First of all, let's see at RD curves (SSIM measure for luminance is used here).

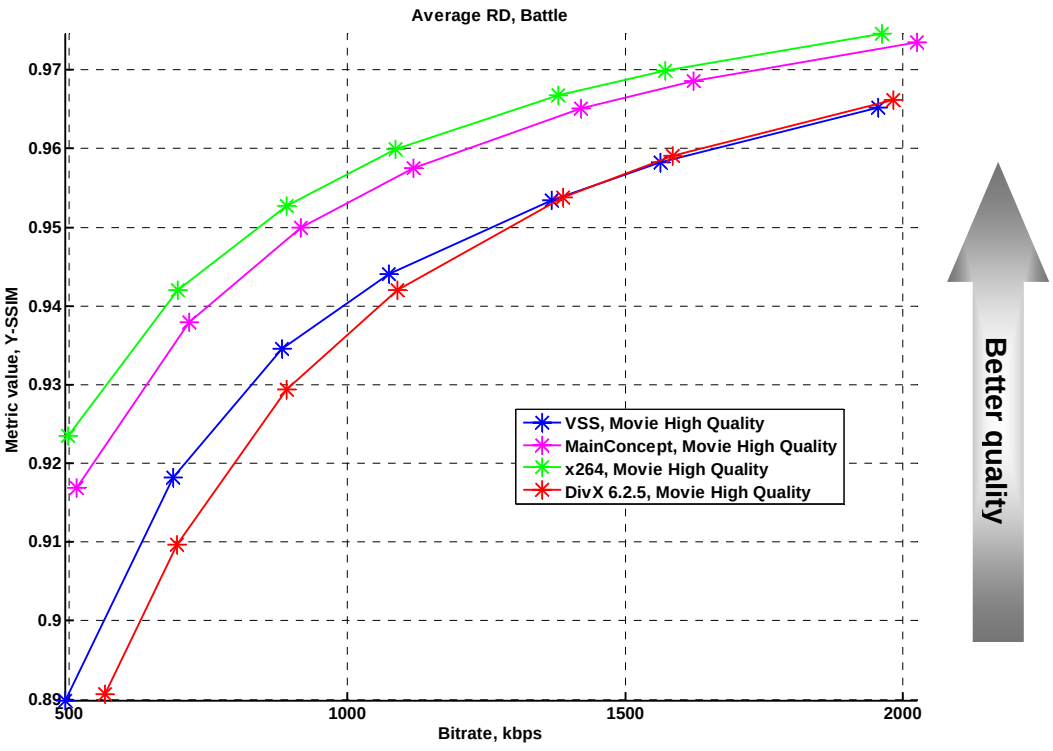


Figure 43. Bitrate/Quality. Usage area "Movies", "Battle" sequence, "High Quality" preset

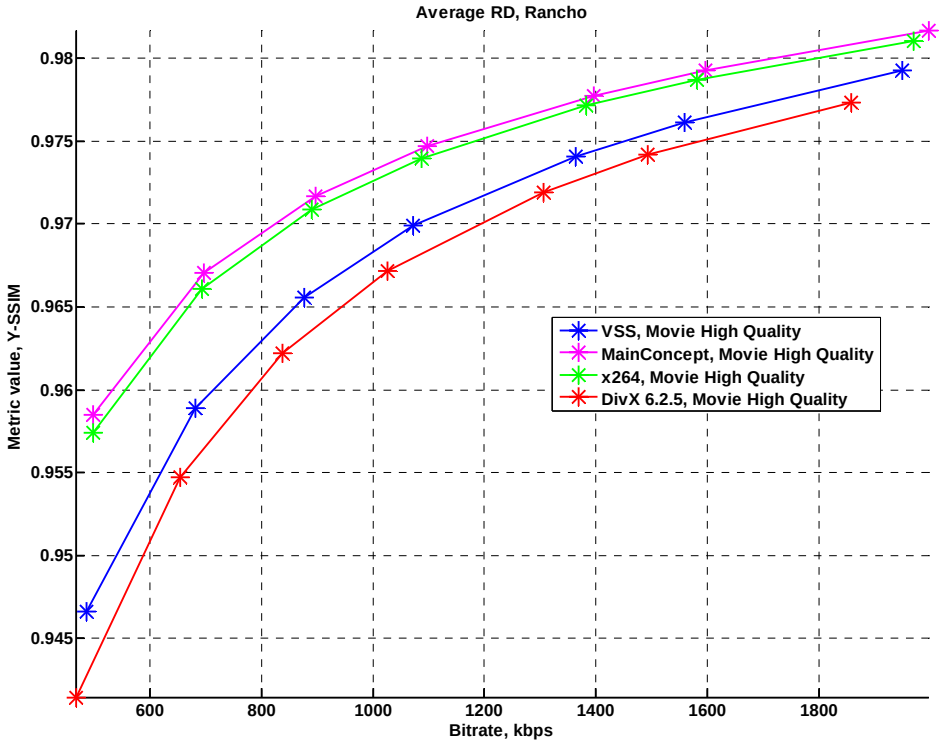


Figure 44. Bitrate/Quality. Usage area "Movies", "Rancho" sequence, "High Quality" preset

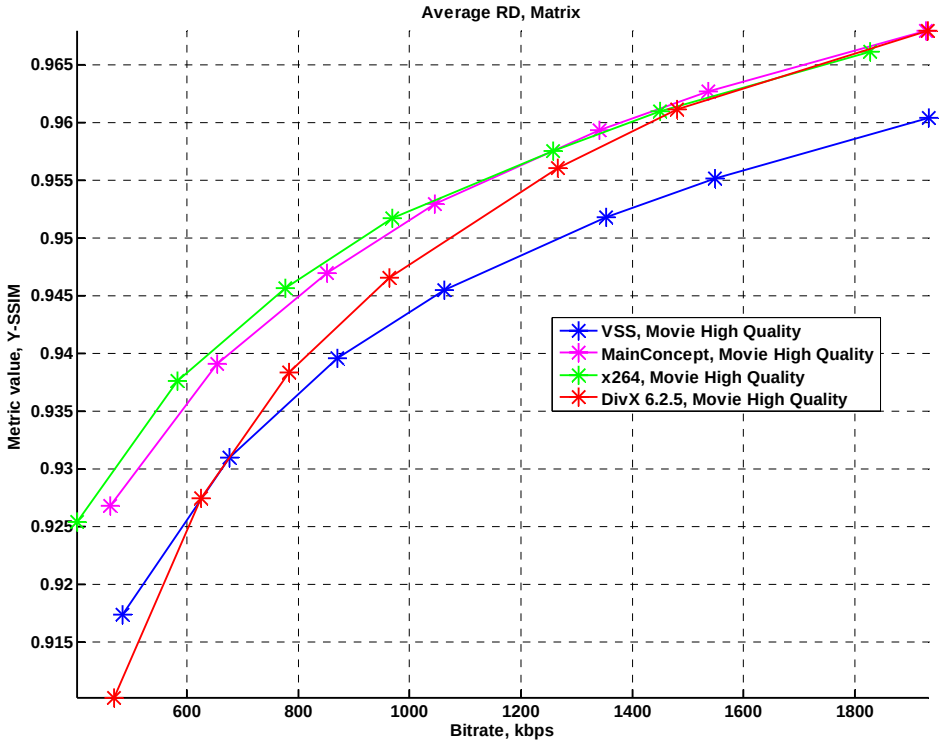


Figure 45. Bitrate/Quality. Usage area "Movies", "Matrix" sequence, "High Quality" preset

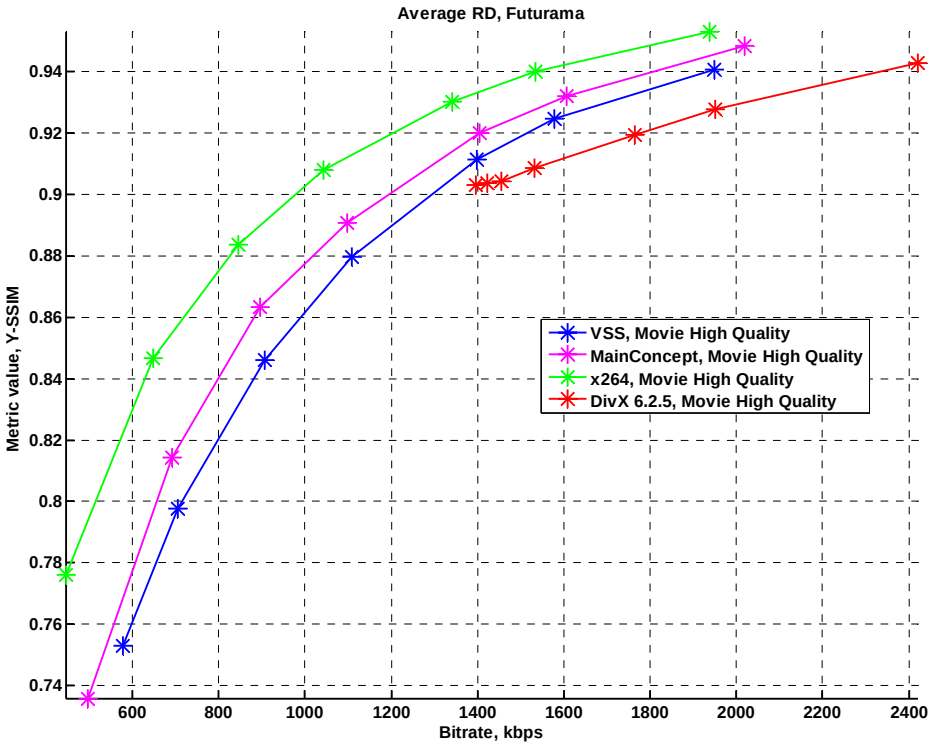


Figure 46. Bitrate/Quality. Usage area "Movies", "Futurama" sequence, "High Quality" preset

The whole situation is clear enough for these presets: x264 and MainConcept codecs show the best quality among other competitors, x264 is slightly better than MainConcept at average, VSS shows not very good quality – it is comparable to DivX codec, and for some sequences ("Rancho") DivX shows even better quality than VSS. There is one interesting fact – the sequence "Futurama" (animation movie) was a big difficulty for DivX to encode – it couldn't encode this sequence with low bitrates at all. And for this sequence x264 codecs shows the biggest difference to MainConcept codec than on all test set for "Movies".

These results are obtained without analyzing encoding speed and bitrate handling.

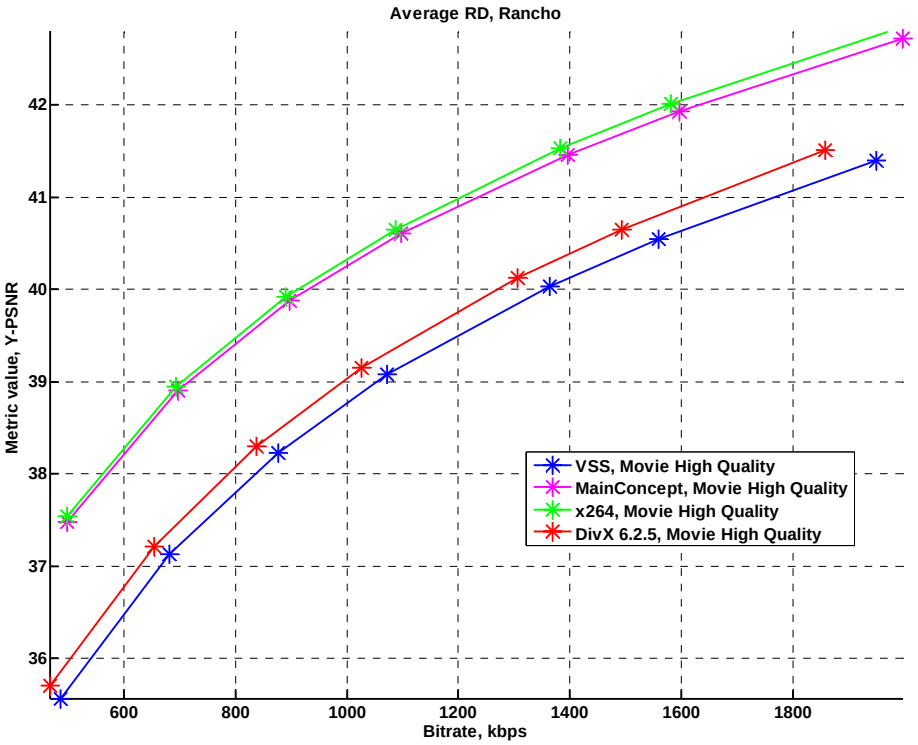


Figure 47. Bitrate/Quality. Usage area "Movies", "Rancho" sequence, "High Quality" preset Y-PSNR measure

It is interesting that incase of use PSNR measure as quality measure for codecs on this test set, than DivX shows better quality than VSS on all sequences. The main reason for it could be that DivX developers used PSNR measure for quality measurement during design and development stage for its codec. For other codecs situation didn't change strongly.

Now let's see bitrate keeping for these presets.

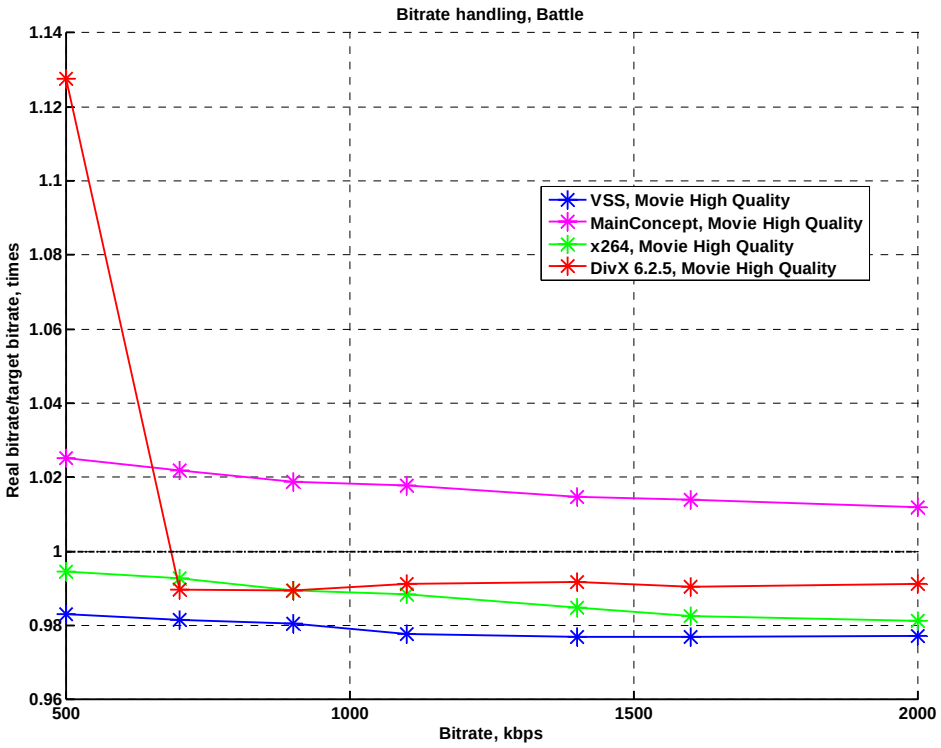


Figure 48. Bitrate handling. Usage area “Movies”, “Battle” sequence, “High Quality” preset

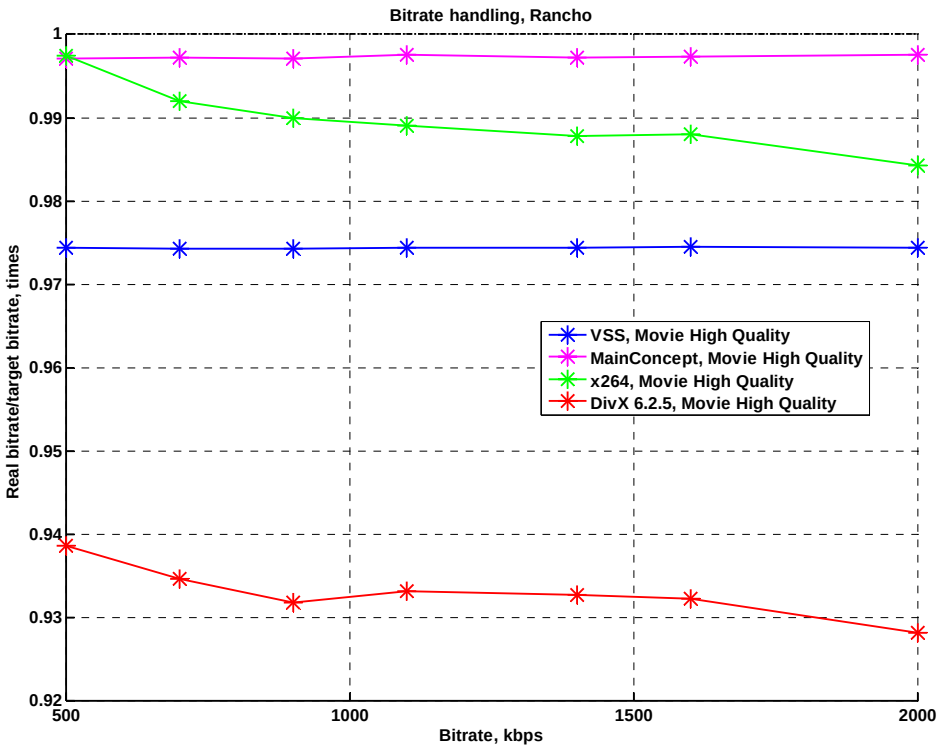


Figure 49. Bitrate handling. Usage area “Movies”. ”Rancho” sequence. “High Quality” preset

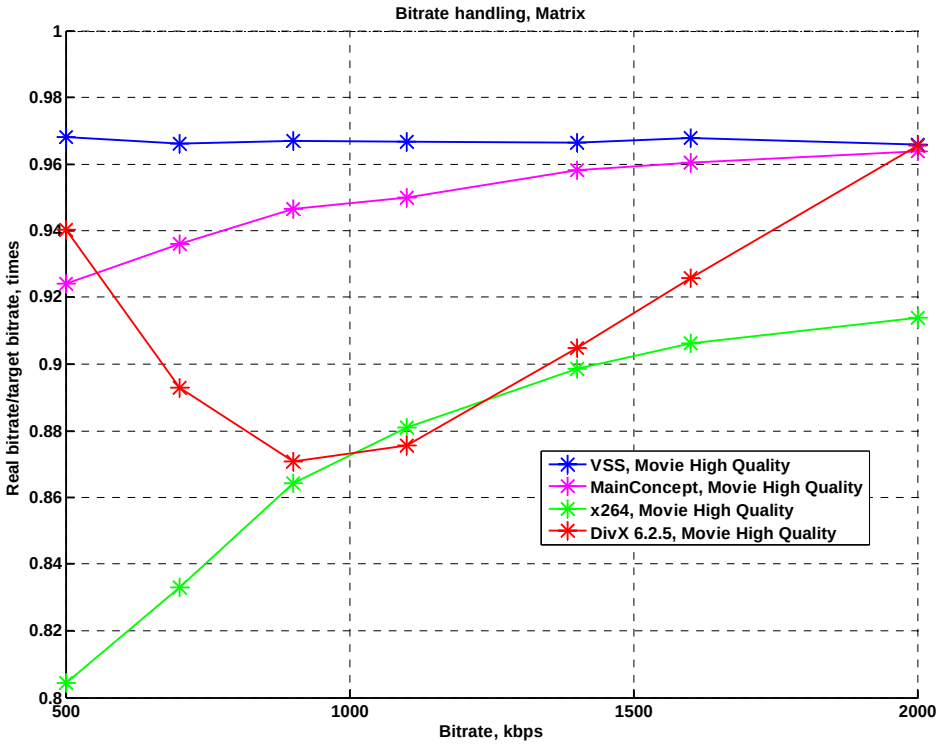


Figure 50. Bitrate handling. Usage area “Movies”. ”Matrix” sequence. “High Quality” preset

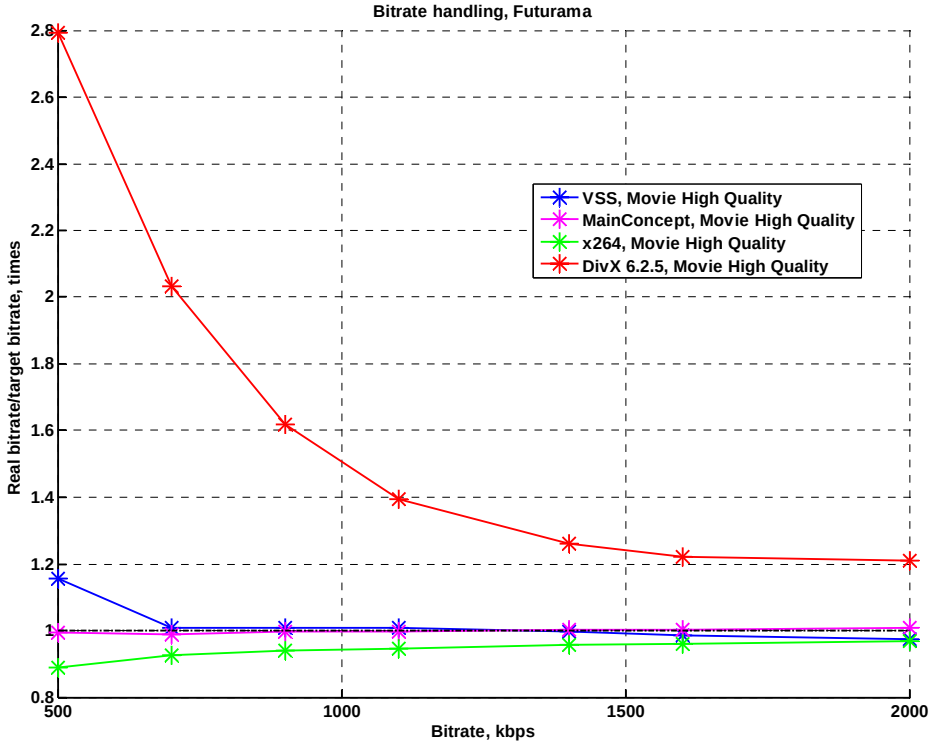


Figure 51. Bitrate handling. Usage area “Movies”. ”Futurama” sequence. “High Quality” preset

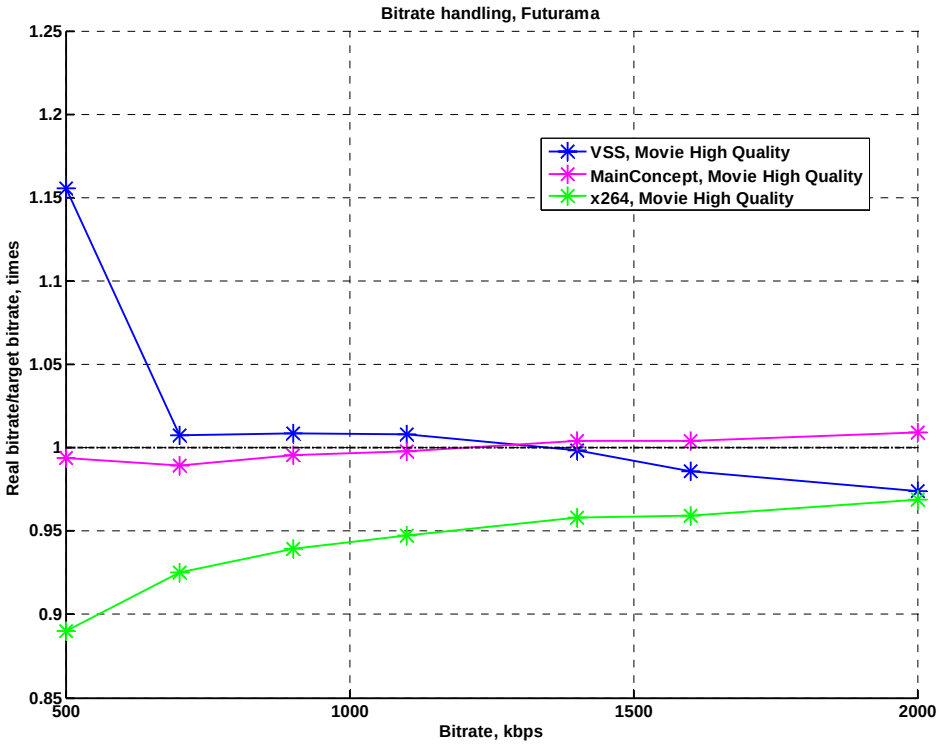


Figure 52. Bitrate handling. Usage area "Movies". "Futurama" sequence. "High Quality" preset without DivX codec

The main fact is that DivX's bitrate handling mechanism is not very good – this codec almost couldn't work with bitrates lower than 600-700 kbps and also has many problems with other bitrates.

Another important fact is sequence "Matrix" – all codecs has big or small problems with bitrate handling for this sequence – VSS and MainConcept codecs lowered bitrate (3% and 5% at average), x264 codec has strong problems with low bitrates (it lowered bitrate at 20%) and these problems are lowered with bitrate increasing (to 8-10% lowering). DivX bitrate handling curve is not monotonic and has a strange fall at 800-1200 kbps.

For sequence "Futurama" DivX codec shows stable bitrate exceeding (20-180%), x264 lowered bitrate for whole sequence, VSS codec has fluctuations – it exceeded low bitrates and lowered high bitrates and only MainConcept codec shows stable bitrate handling.

Note: We assume that 1 kbps = 1024 bps. If codec assumes that 1 kbps = 1000 bps, it's ideal bitrate handling curve at our curves will be at 1000/1024 = 0.9765625.

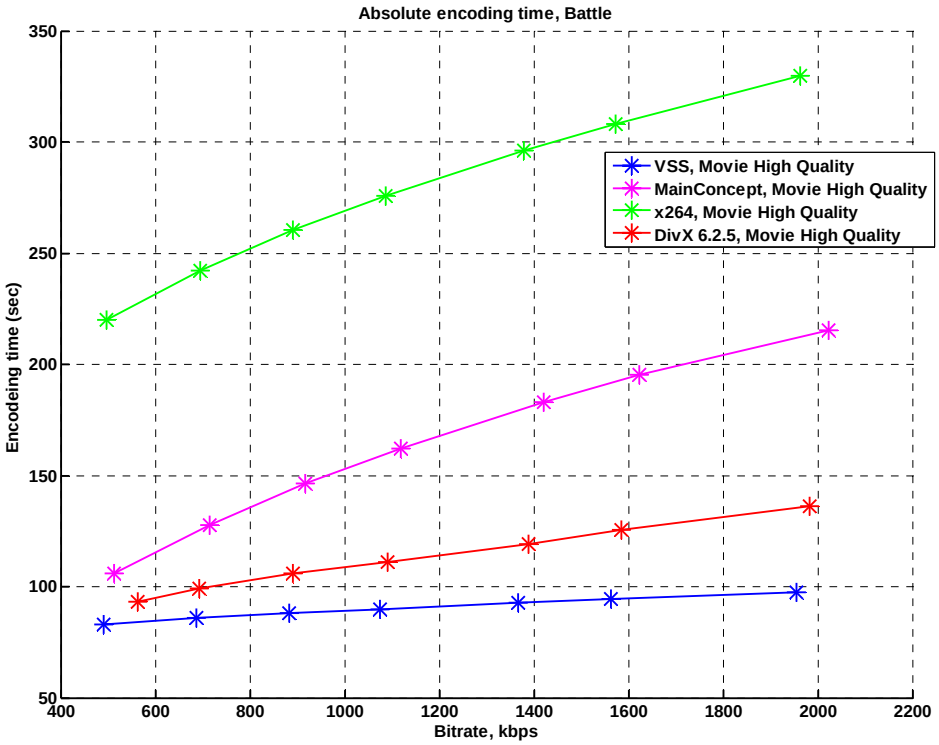


Figure 53. Absolute encoding time. Usage area "Movies", "Battle" sequence, "High Quality" preset

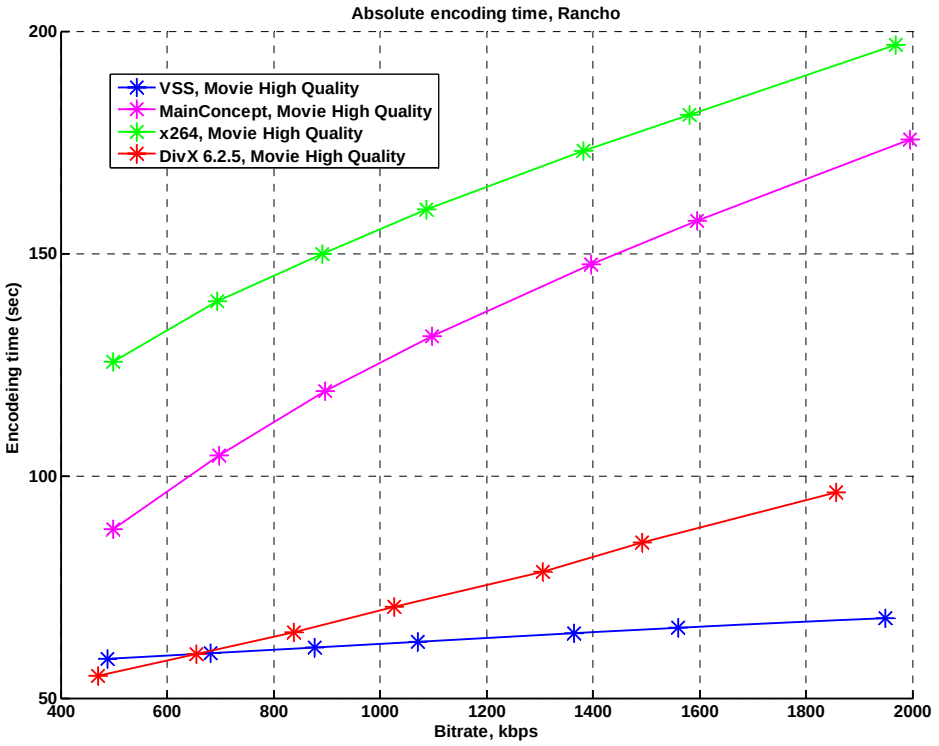


Figure 54. Absolute encoding time. Usage area "Movies", "Rancho" sequence, "High Quality" preset

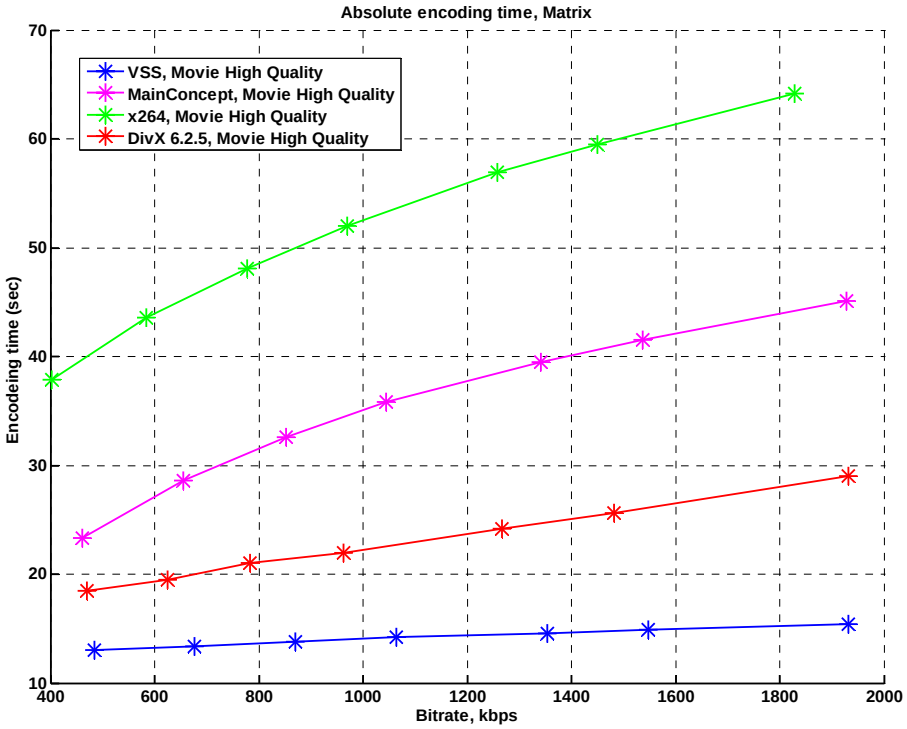


Figure 55. Absolute encoding time. Usage area "Movies", "Matrix" sequence, "High Quality" preset

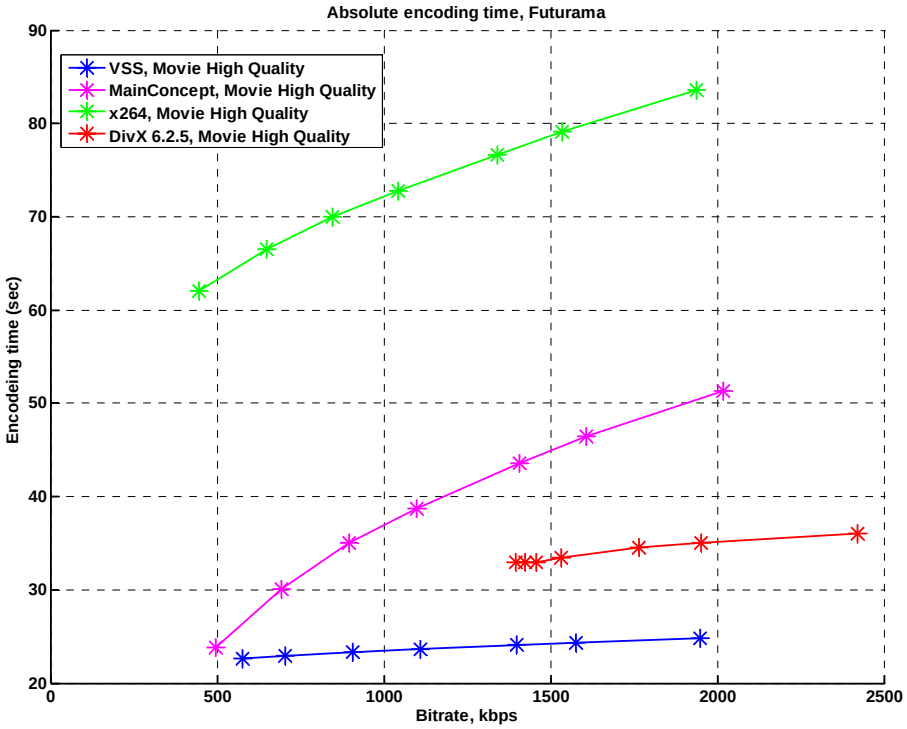


Figure 56. Absolute encoding time. Usage area "Movies", "Futurama" sequence, "High Quality" preset

It is interesting to analyze encoding speed dependence on bitrate. Figure 53 – Figure 56 shows this dependence for all sequences. The strongest dependency codec x264 has, the weakest – VSS. But the difference with dependency for all codecs is not very big. For other sequences the picture with encoding time has no principal differences.

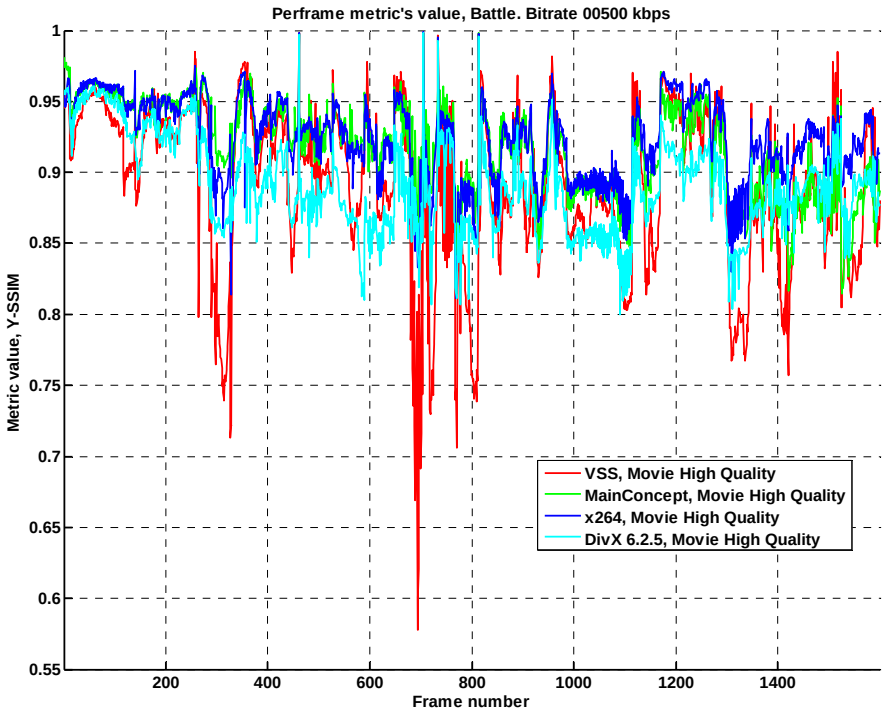


Figure 57. Per-frame quality. Usage area "Movies", "Battle" sequence, "High Quality" preset, 500 kbps

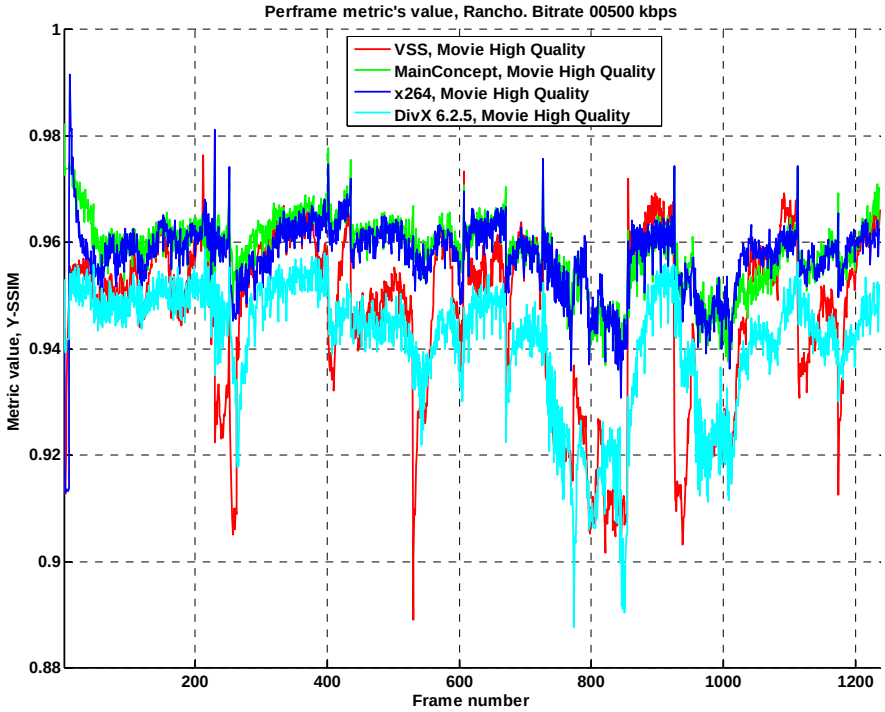


Figure 58. Per-frame quality. Usage area "Movies", "Rancho" sequence, "High Quality" preset, 500 kbps

Figure 59. Per-frame quality. Usage area "Movies", "Matrix" sequence, "High Quality" preset, 500 kbps

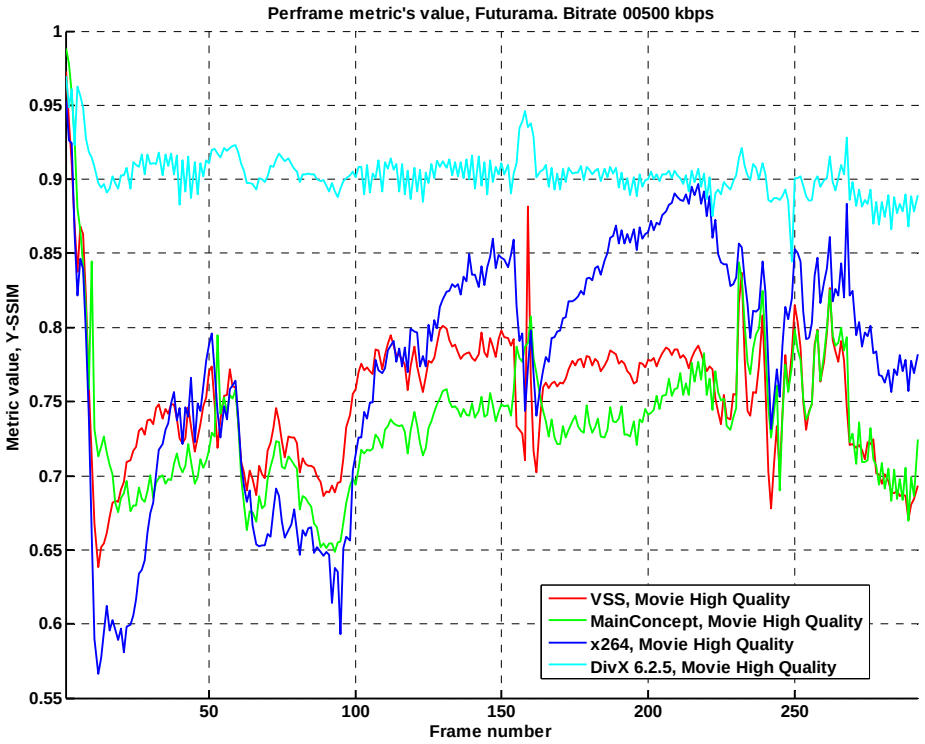


Figure 60. Per-frame quality. Usage area "Movies", "Futurama" sequence, "High Quality" preset, 500 kbps

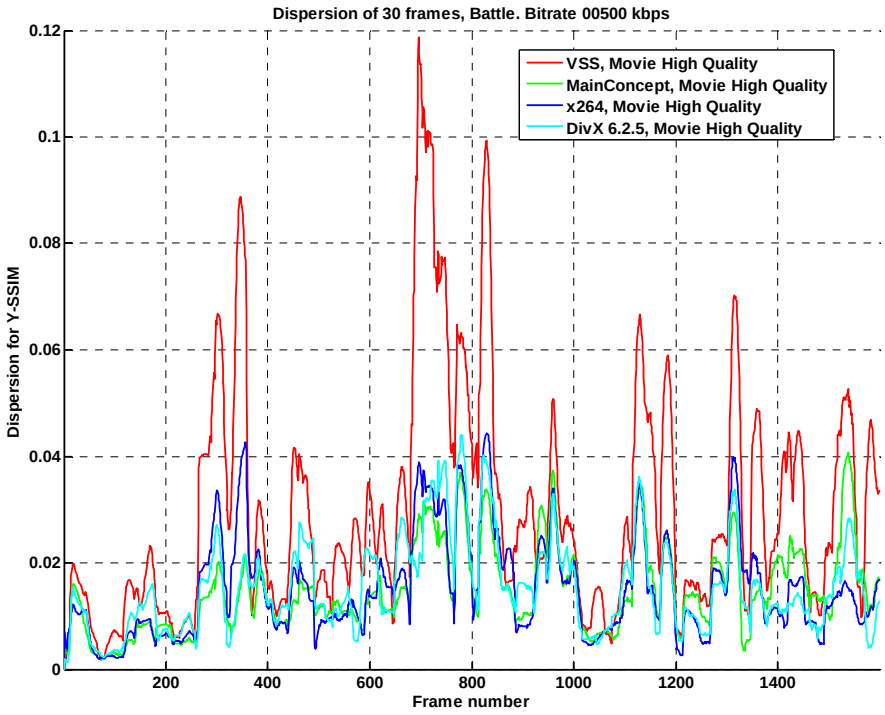


Figure 61. Quality dispersion (30 frames). Usage area "Movie", "Battle" sequence, "High Quality" preset, 500 kbps

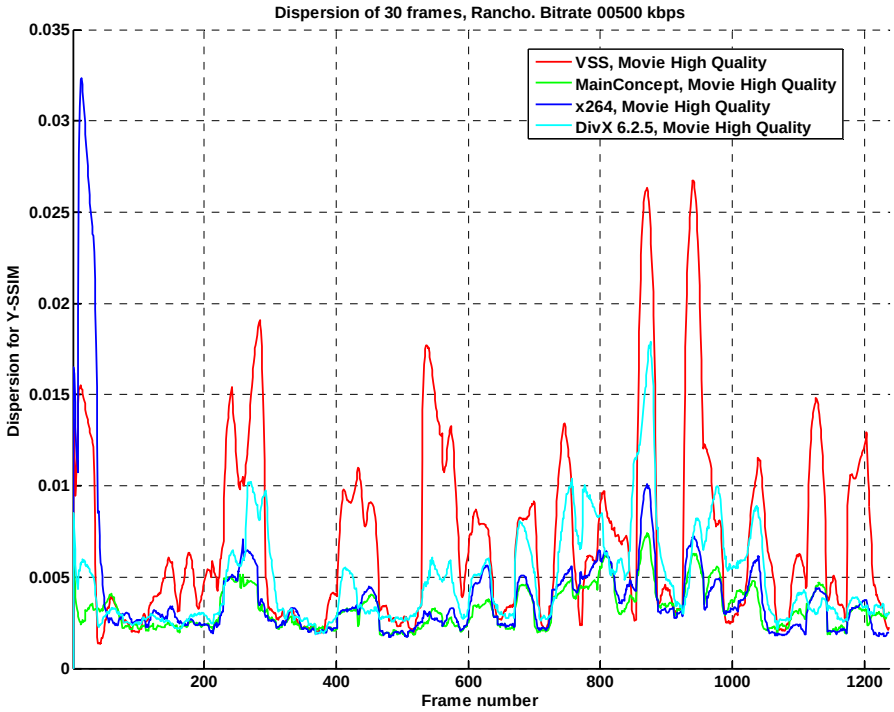


Figure 62. Quality dispersion (30 frames). Usage area "Movie", "Rancho" sequence, "High Quality" preset, 500 kbps

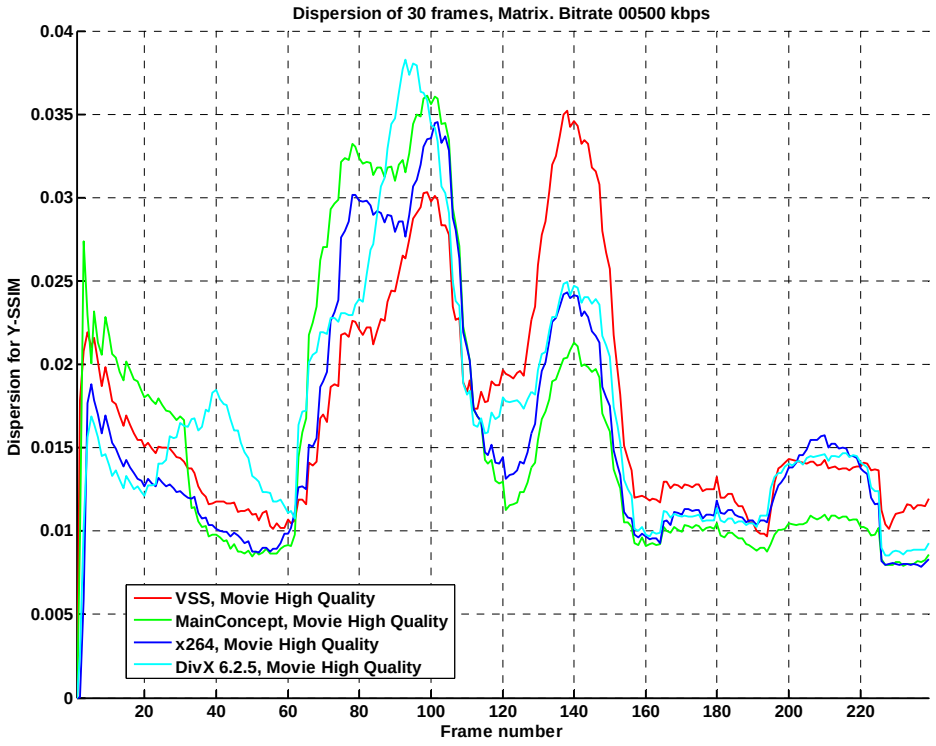


Figure 63. Quality dispersion (30 frames). Usage area "Movie", "Matrix" sequence, "High Quality" preset, 500 kbps

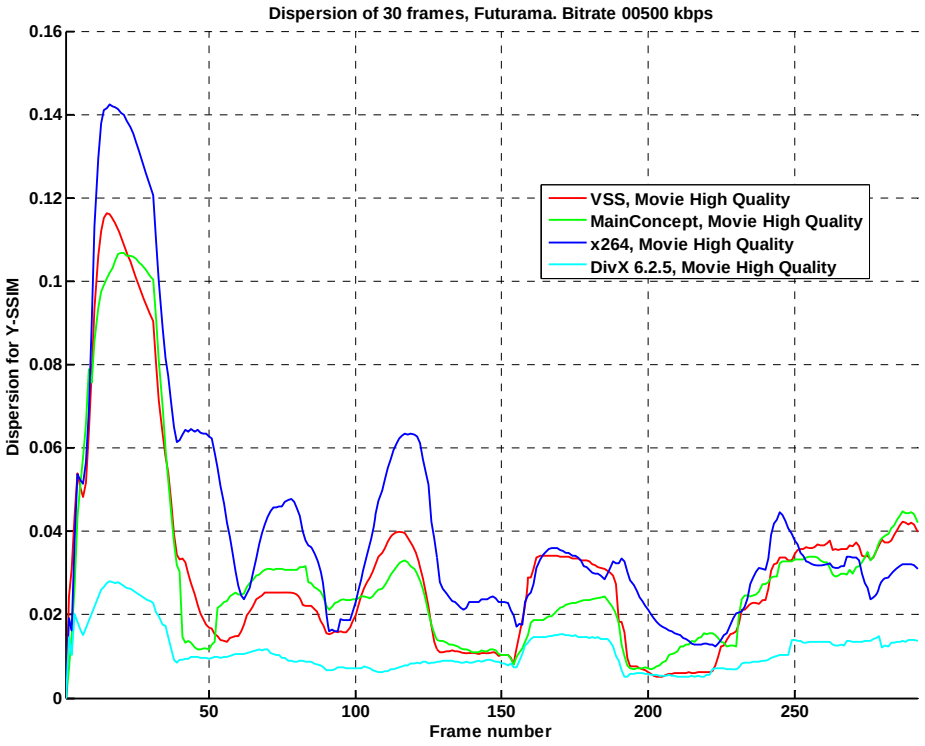


Figure 64. Quality dispersion (30 frames). Usage area "Movie", "Futurama" sequence, "High Quality" preset, 500 kbps

Figure 57 – Figure 60 show per-frame quality of all sequences at 500 kbps. As one can see the situation with sequence “Matrix” where all codecs show untypical behavior comparing to other sequences of the test set “Movie” can be explained by specific *per-frame* behavior of all codecs for this sequence – periodic and the same fluctuations for all codecs. One of possible reasons of this fact that this sequence was compressed before and it had strong quality difference between its frames due to rate control of previous codec.

Figure 61 – Figure 64 show per-frame quality dispersion of all sequences.

Now let's consider average integral quality with the encoding speed.

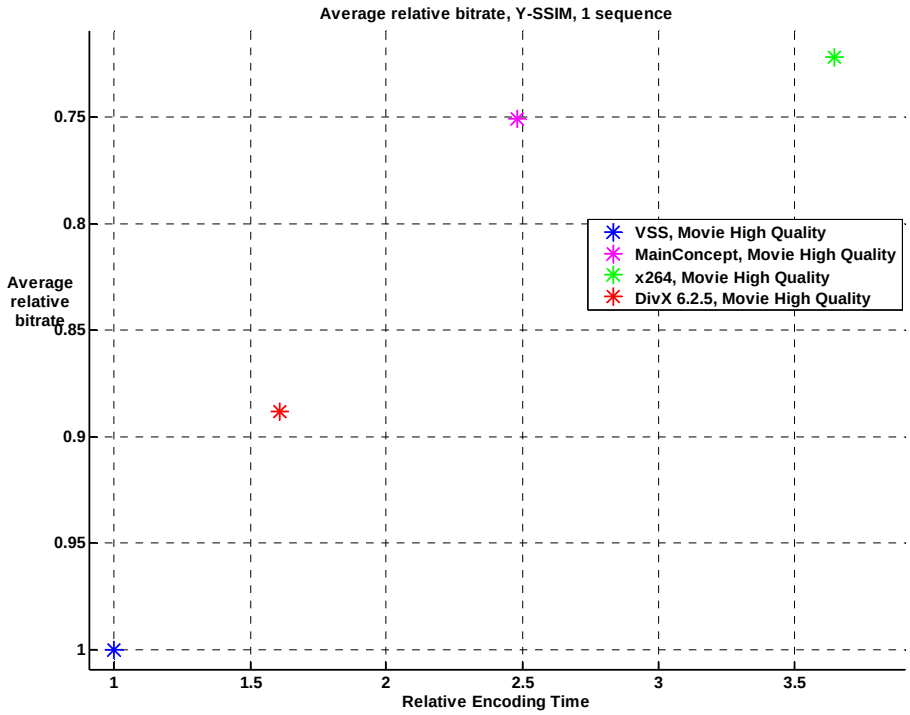


Figure 65. Relative bitrate/Relative time. Usage area "Movies", "Matrix" sequence, "High Quality" preset.

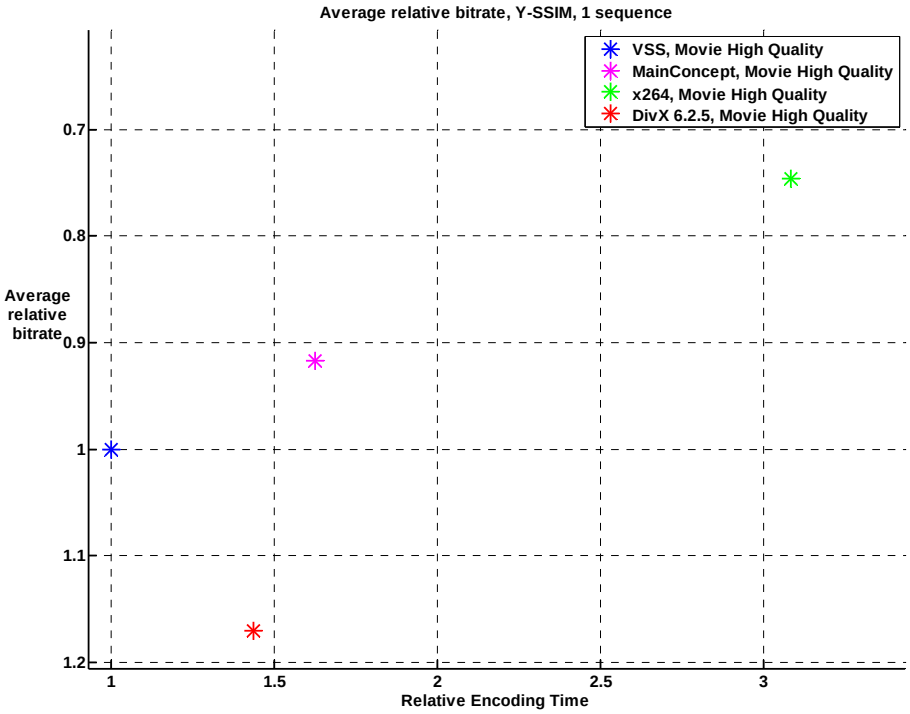


Figure 66. Relative bitrate/Relative time. Usage area "Movies", "Futurama" sequence, "High Quality" preset.

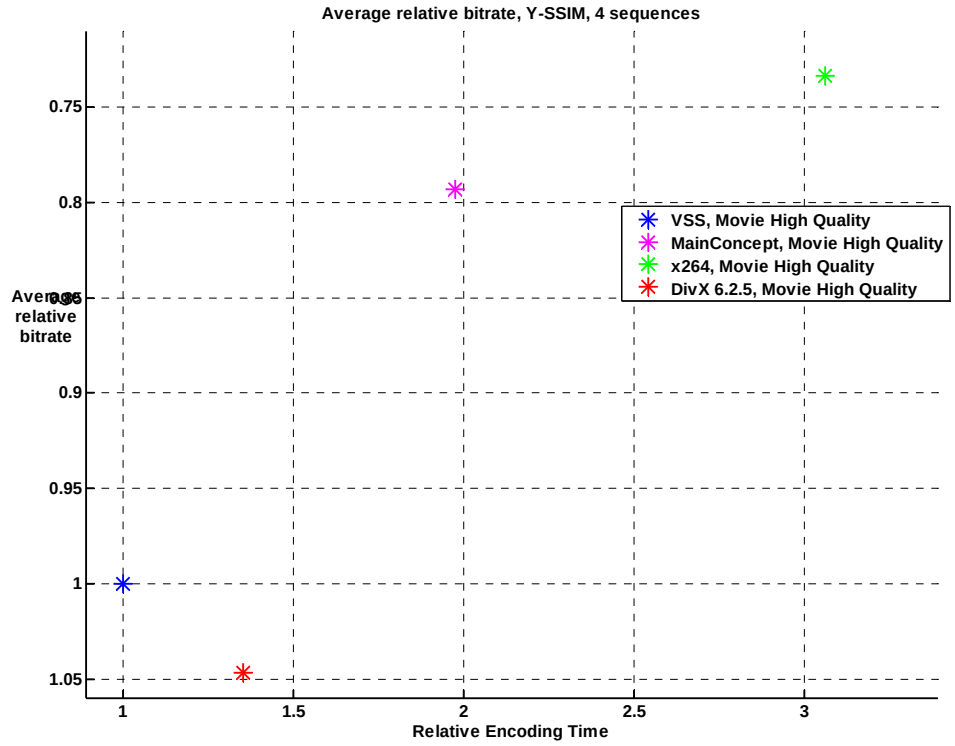


Figure 67. Relative bitrate/Relative time. Usage area "Movies", 4 sequences, "High Quality" preset.

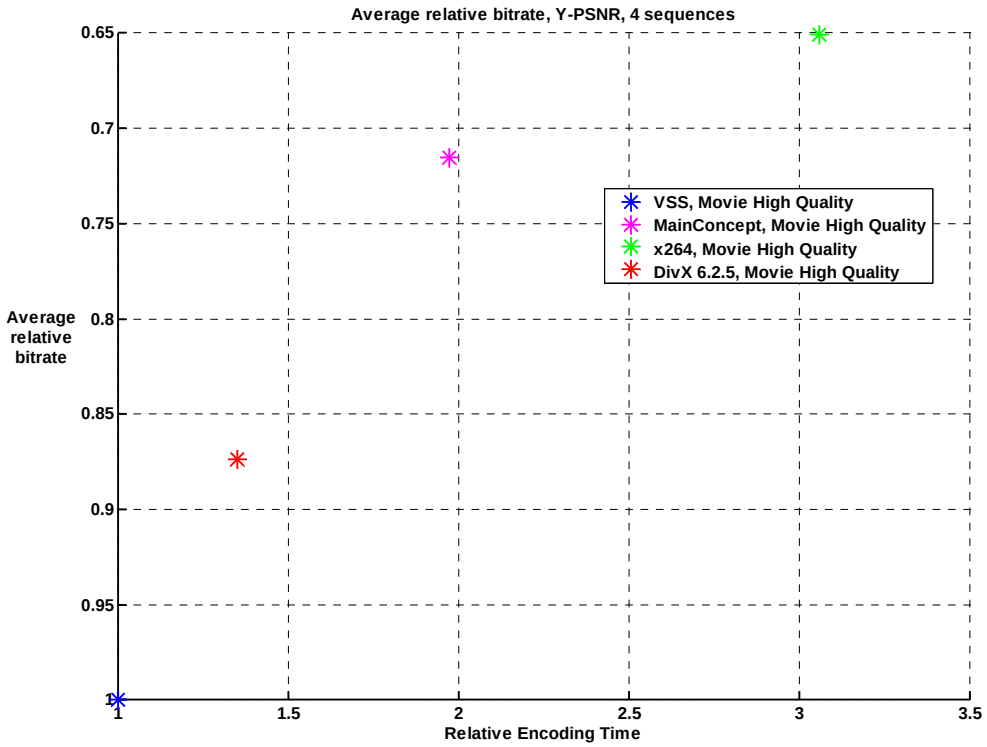


Figure 68. Relative bitrate/Relative time. Usage area "Movies", 4 sequences, "High Quality" preset. Y-PSNR measure

On all sequences except “Matrix” DivX has worse quality than H.264 codecs – its encoding time is bigger than VSS encoding time and DivX has lower quality.

But if to use PSNR measure as main quality measure than DivX is comparable to H.264 codecs by speed/quality tradeoff.

But if to use more adequate SSIM measure the situation is clear enough:

- All H.264 codecs lay on “sub-optimal” curve – with encoding speed increases the quality of encoding also rises, except “Rancho” sequence, where MainConcept codec is a little better than x264 (both by quality and speed).
- DivX is worse than H.264 codecs by speed/quality tradeoff

“High Speed” Preset Results

First of all, let’s see at RD curves (SSIM measure for luminance is used here).

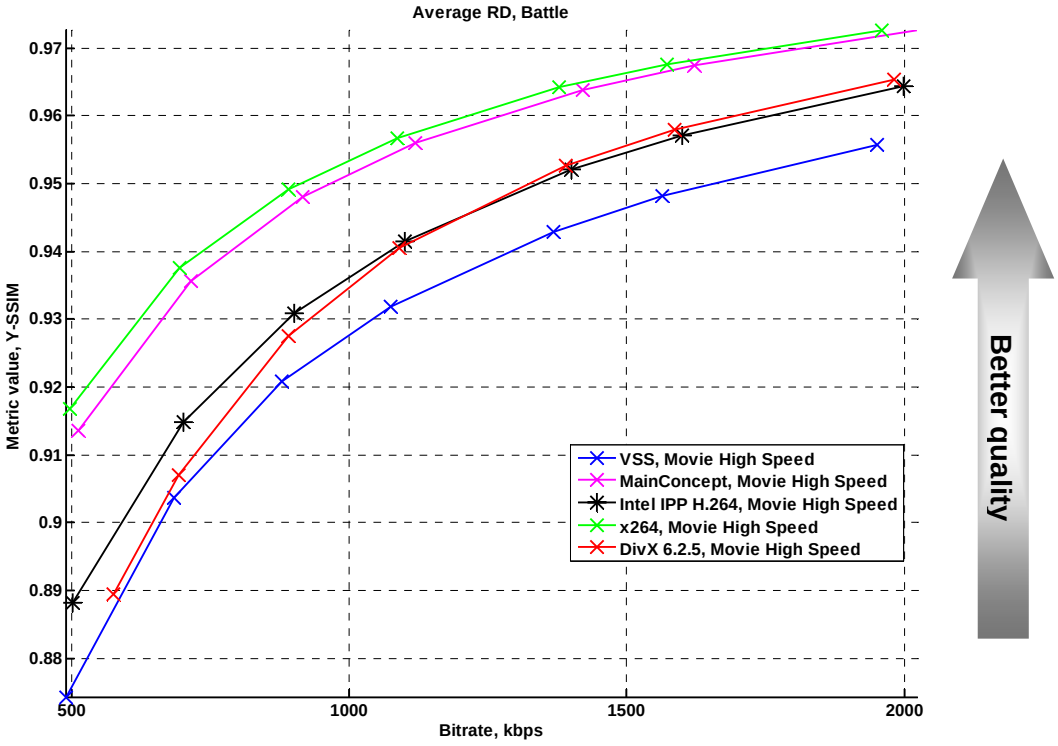


Figure 69. Bitrate/Quality. Usage area “Movies”, “Battle” sequence, “High Speed” preset

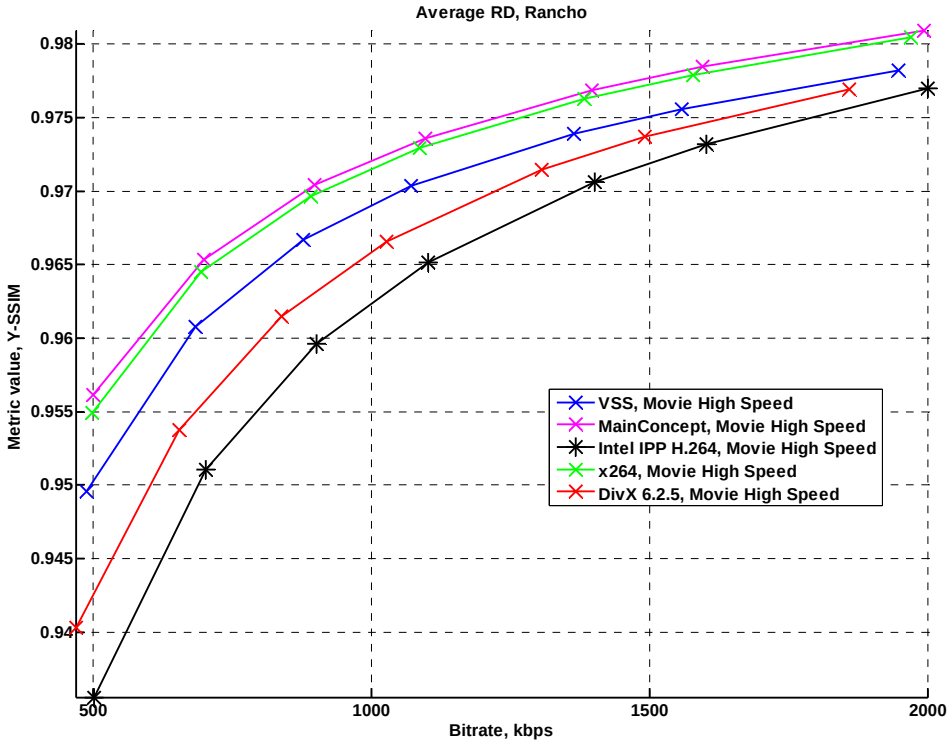


Figure 70. Bitrate/Quality. Usage area “Movies”, “Rancho” sequence, “High Speed” preset

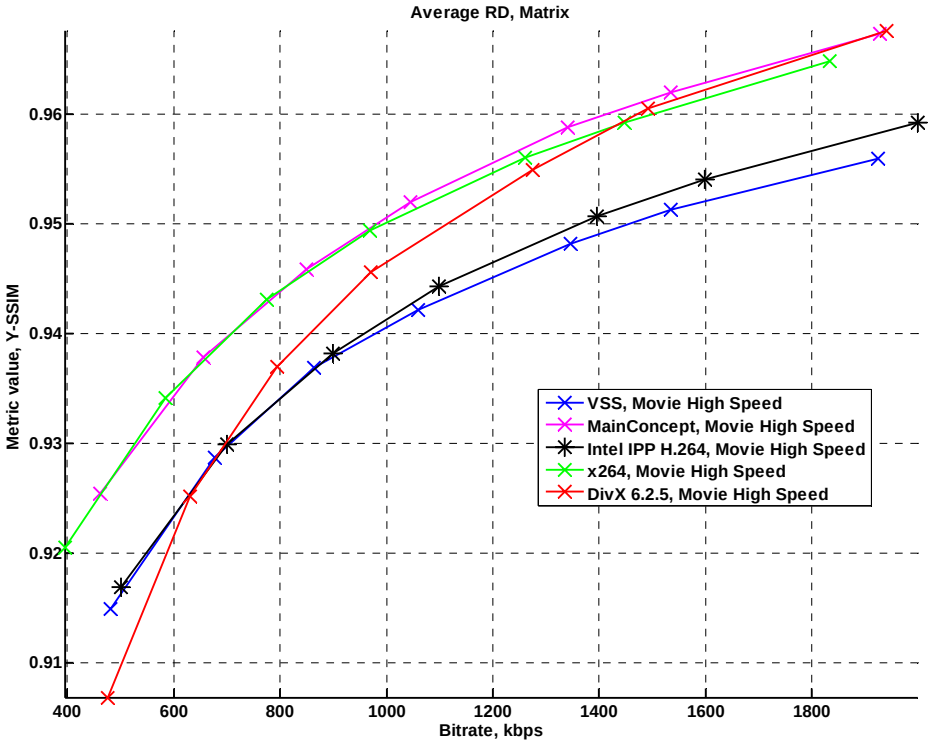


Figure 71. Bitrate/Quality. Usage area “Movies”, “Matrix” sequence, “High Speed” preset

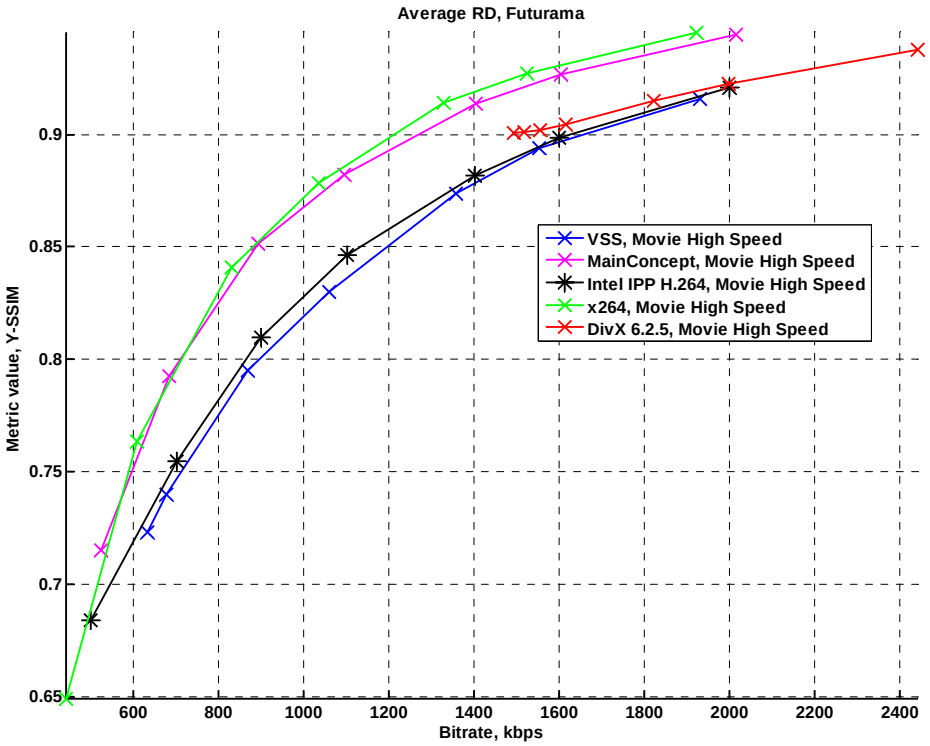


Figure 72. Bitrate/Quality. Usage area "Movies", "Futurama" sequence, "High Speed" preset

The whole situation is clear enough for these presets:

- x264 and MainConcept codecs show the best quality among other competitors
- DivX is good enough comparing to H.264 codecs at such high encoding speed, it is better than Intel IPP and VSS codecs. The solution of this fact is that DivX is very fast codec with good quality and VSS and Intel IPP codecs has no flexible parameters set that could help them to find optimal speed/quality tradeoff
- VSS and Intel IPP codecs have comparable results. Intel IPP is slightly better than VSS, except sequence "Rancho"
- There is one interesting fact – the sequence "Futurama" (animation movie) was a big difficulty for DivX to encode – it couldn't encode this sequence with low bitrates at all.

These results are obtained without analyzing encoding speed and bitrate handling.

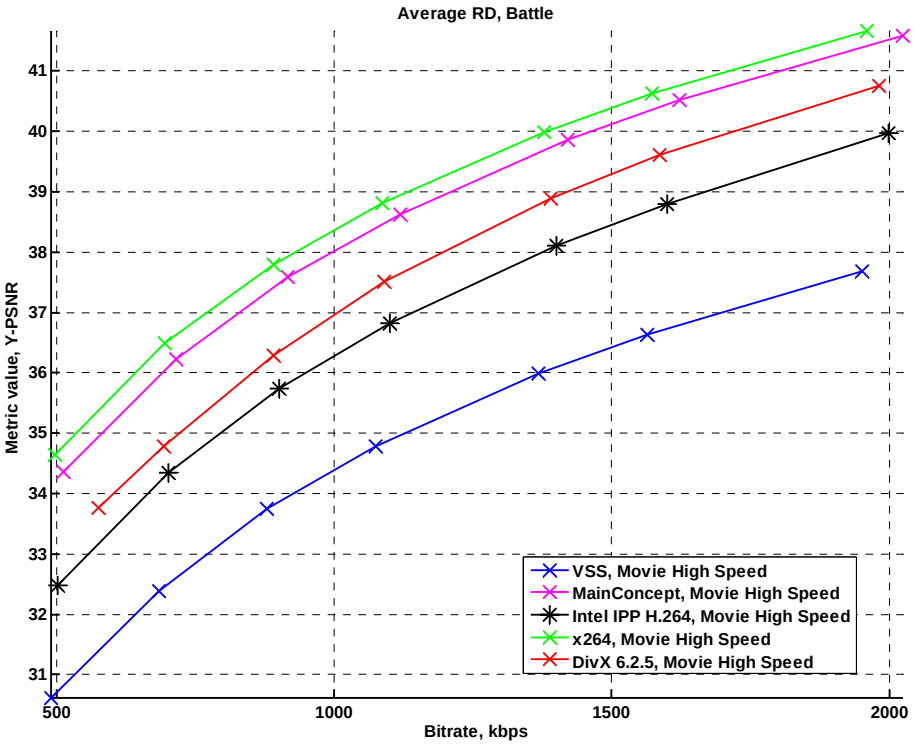


Figure 73. Bitrate/Quality. Usage area "Movies", "Battle" sequence, "High Speed" preset Y-PSNR measure

Interesting that in case of use PSNR measure as quality measure for codecs on this test set, than DivX shows slightly better quality than if to use SSIM on all sequences. The main reason for it could be that DivX developers used PSNR measure for quality measurement during design and development stage for its codec. For other codecs situation didn't change strongly.

Now let's see bitrate keeping for these presets.

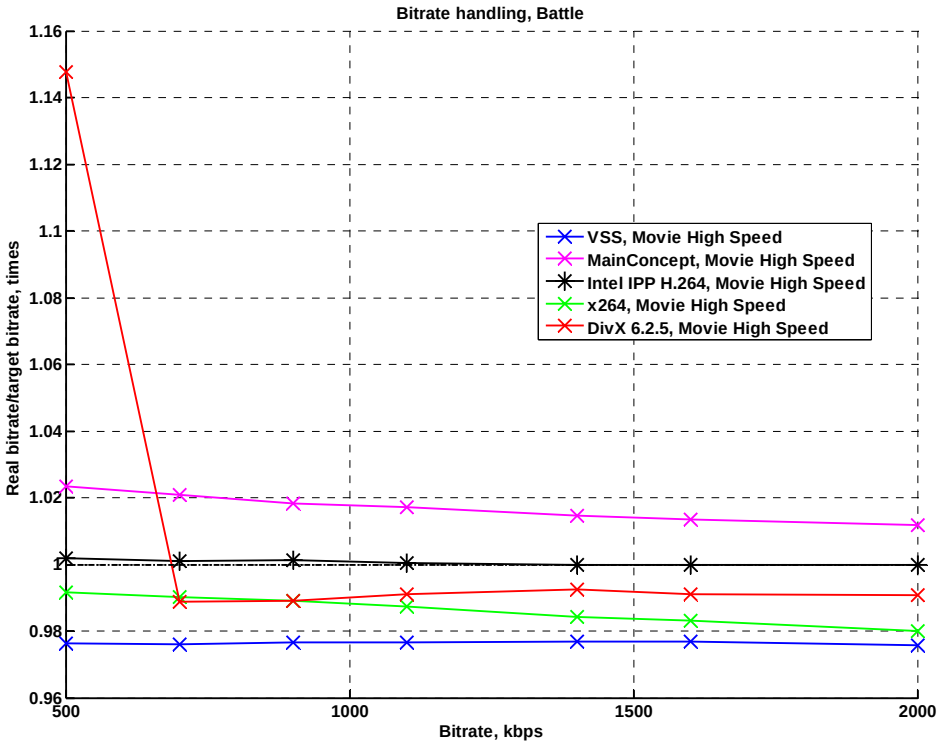


Figure 74. Bitrate handling. Usage area “Movies”, “Battle” sequence, “High Speed” preset

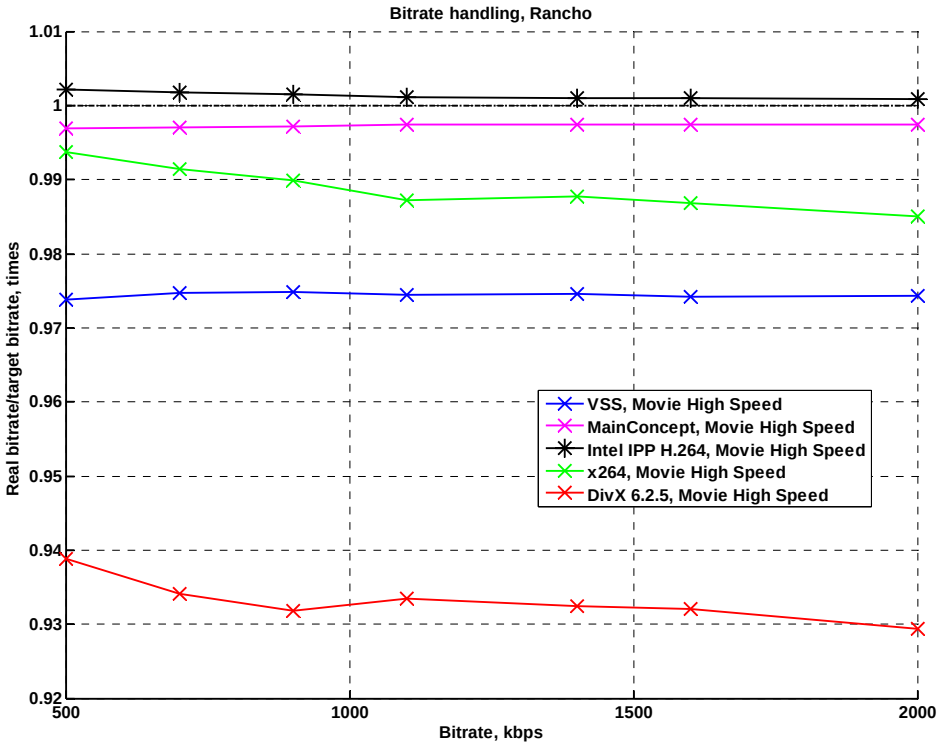


Figure 75. Bitrate handling. Usage area “Movies”. ”Rancho” sequence. “High Speed” preset

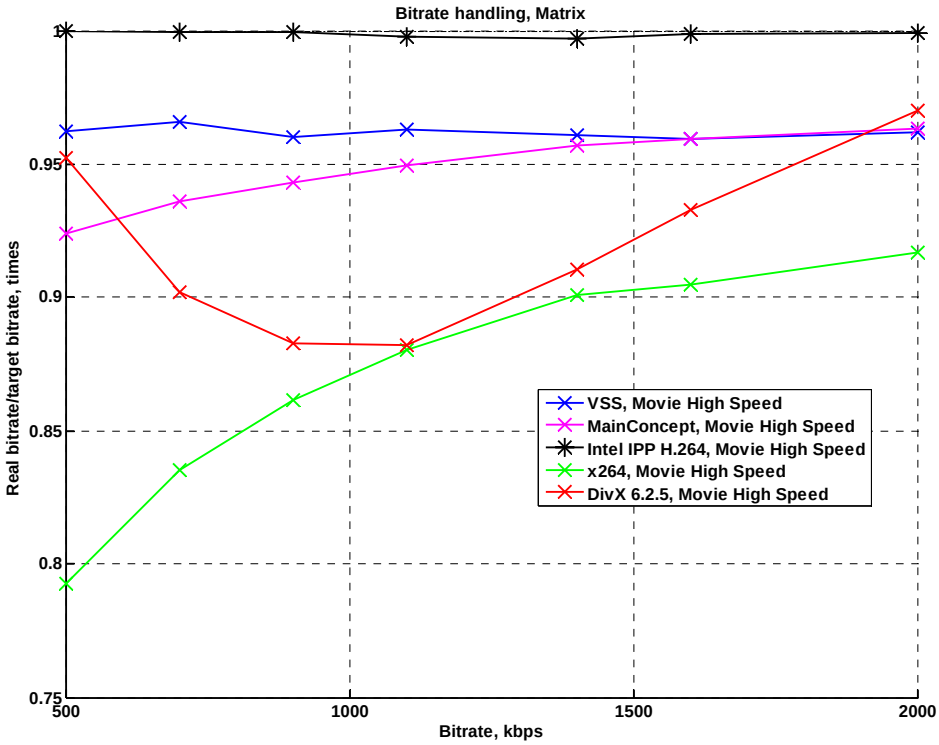


Figure 76. Bitrate handling. Usage area “Movies”. ”Matrix” sequence. “High Speed” preset

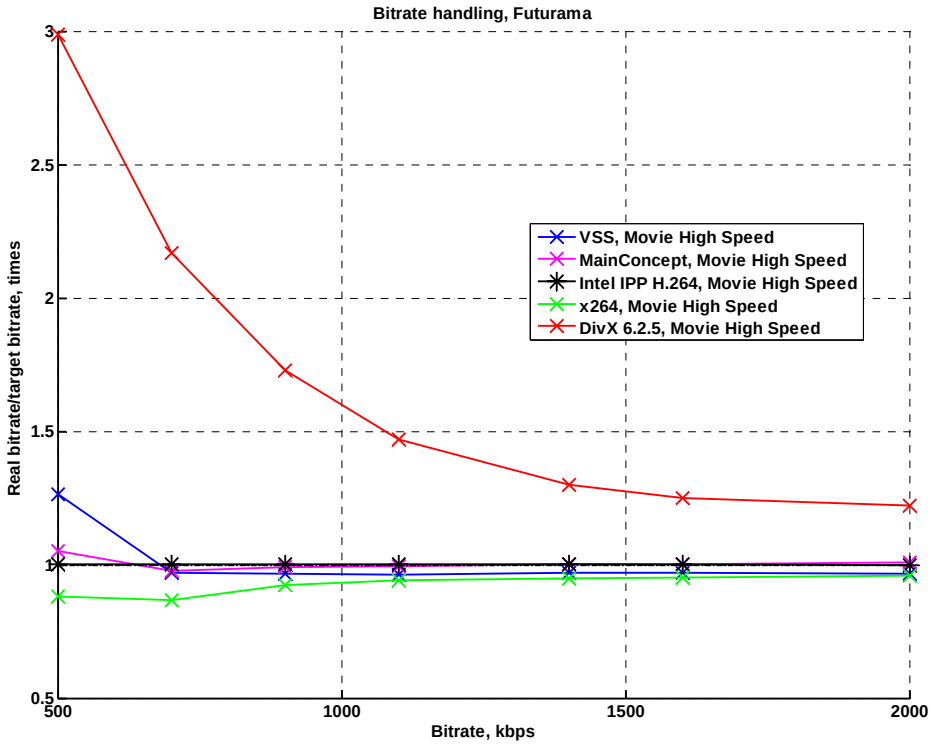


Figure 77. Bitrate handling. Usage area “Movies”. ”Futurama” sequence. “High Speed” preset

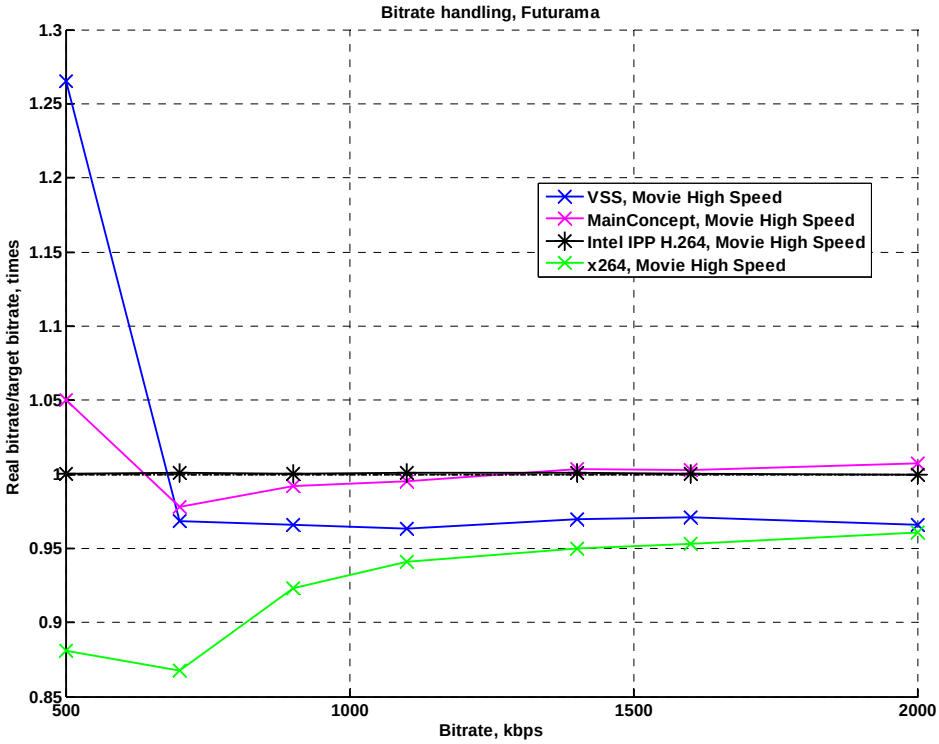


Figure 78. Bitrate handling. Usage area "Movies". "Futurama" sequence. "High Speed" preset without DivX codec

The results of bitrate handling analysis are:

- IPP has a perfect bitrate handling mechanism – its differences between real and target bitrates are less than 0.2% at average.
- DivX's bitrate handling mechanism is not very good – this codec couldn't work with bitrates lower than 600-700 kbps at some sequences, sometimes has a stable bitrate lowering and also has many problems with other bitrates.
- Another fact is sequence "Matrix" – all codecs lower bitrates for this sequence. Intel IPP has little bitrate handling imperfection, VSS and MainConcept codecs lowered bitrate (3.5% and 5% at average), x264 codec has strong problems with low bitrates (it lowered bitrate at 20%) and these problems are lowered with bitrate increasing (to 8-10% lowering). DivX bitrate handling curve is not monotonic and has a strange fall at 800-1200 kbps.
- For sequence "Futurama" DivX codec shows stable bitrate exceeding (20-200%), x264 lowered bitrate for whole sequence.

***Note** We assume that 1 kbps = 1024 bps. If codec assumes that 1 kbps = 1000 bps, its ideal bitrate handling curve at our curves will be at 1000/1024 = 0.9765625.*

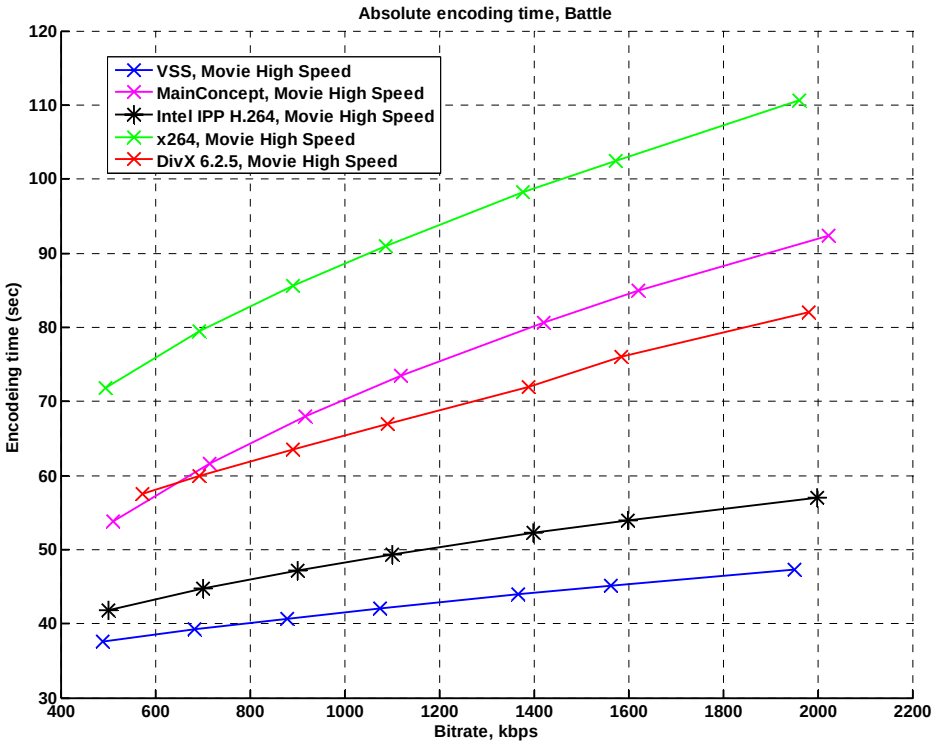


Figure 79. Absolute encoding time. Usage area “Movies”, “Battle” sequence, “High Speed” preset

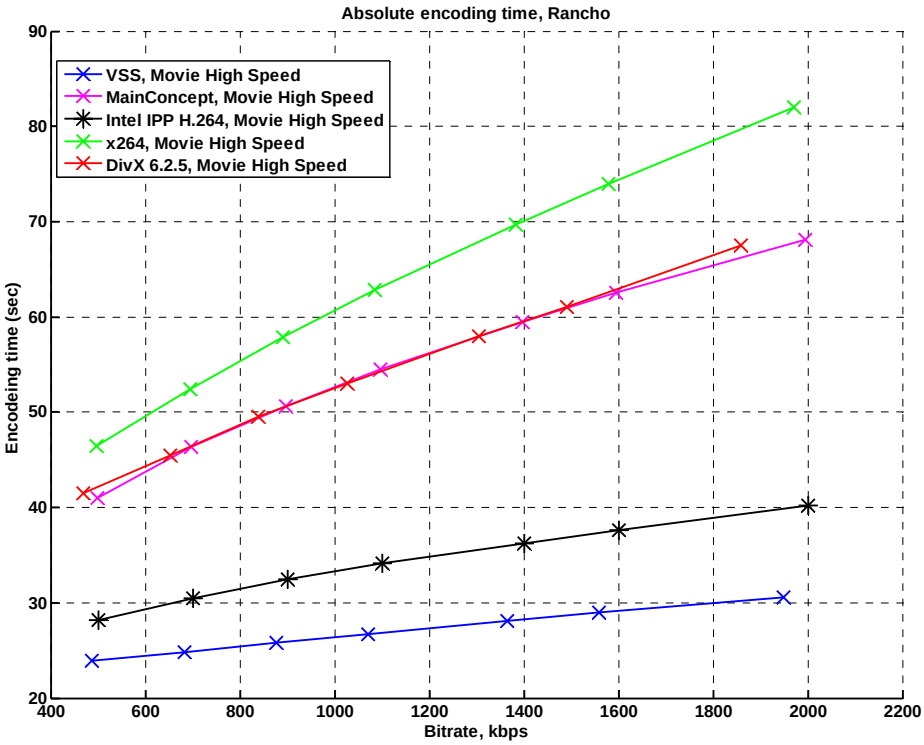


Figure 80. Absolute encoding time. Usage area “Movies”, “Rancho” sequence, “High Speed” preset

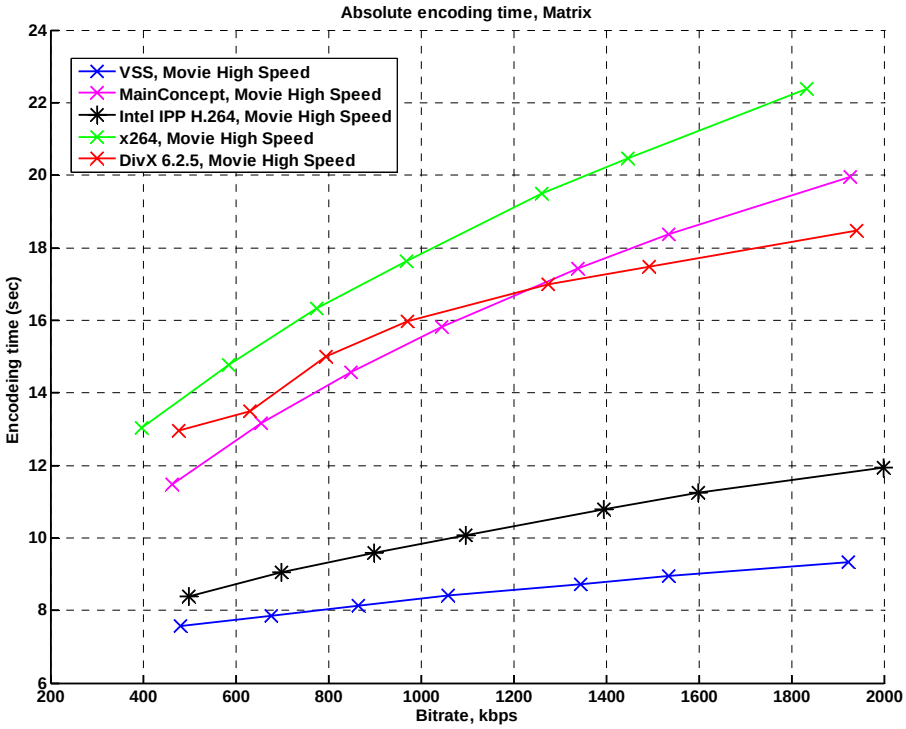


Figure 81. Absolute encoding time. Usage area “Movies”, “Matrix” sequence, “High Speed” preset

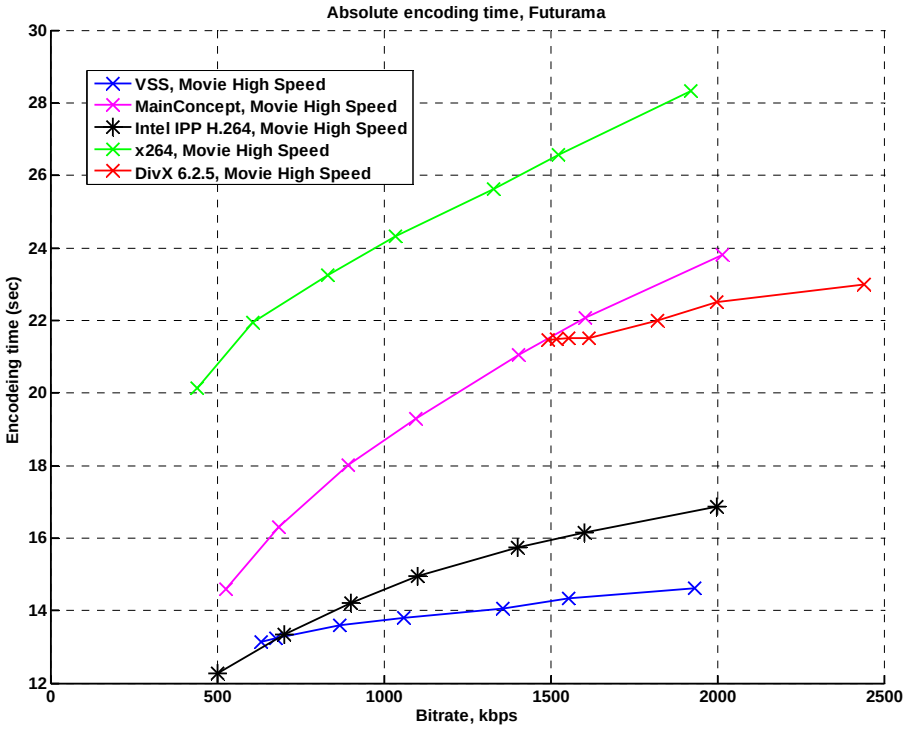


Figure 82. Absolute encoding time. Usage area “Movies”, “Futurama” sequence, “High Speed” preset

It is interesting to analyze encoding speed dependence on bitrate. Figure 79 – Figure 82 show this dependence for different sequences. The strongest dependency codecs x264 and MainConcept have, the weakest one – VSS. But the difference with dependency for all codecs is not very big.

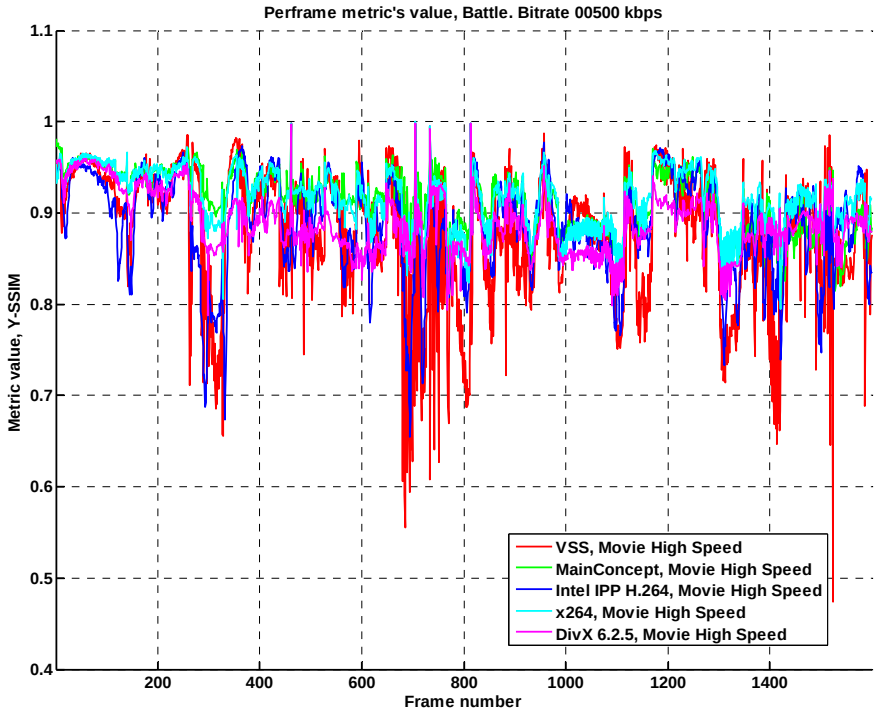


Figure 83. Per-frame quality. Usage area "Movies", "Battle" sequence, "High Speed" preset, 500 kbps

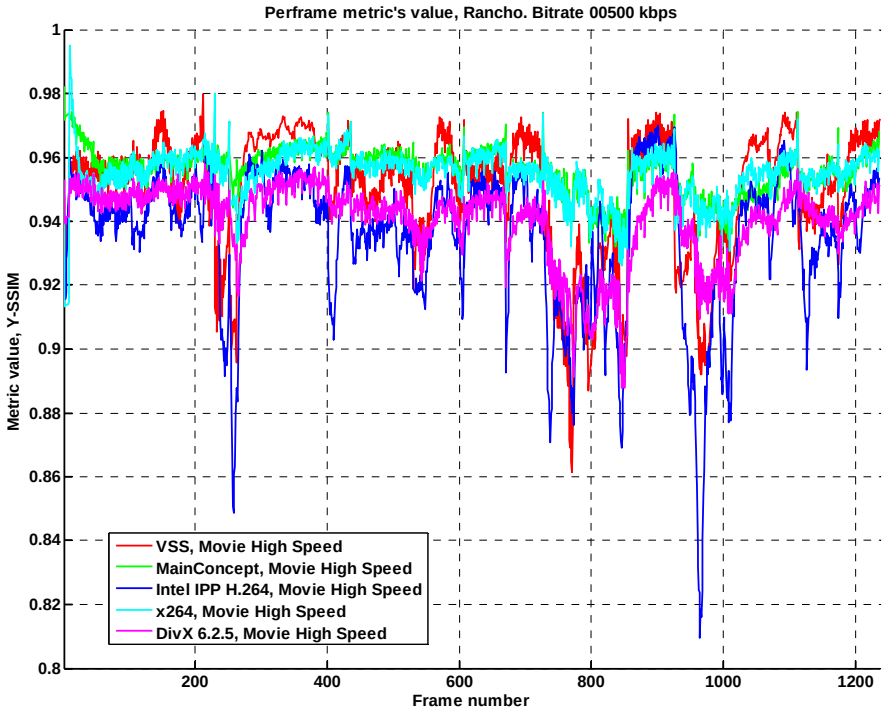


Figure 84. Per-frame quality. Usage area "Movies", "Rancho" sequence, "High Speed" preset, 500 kbps

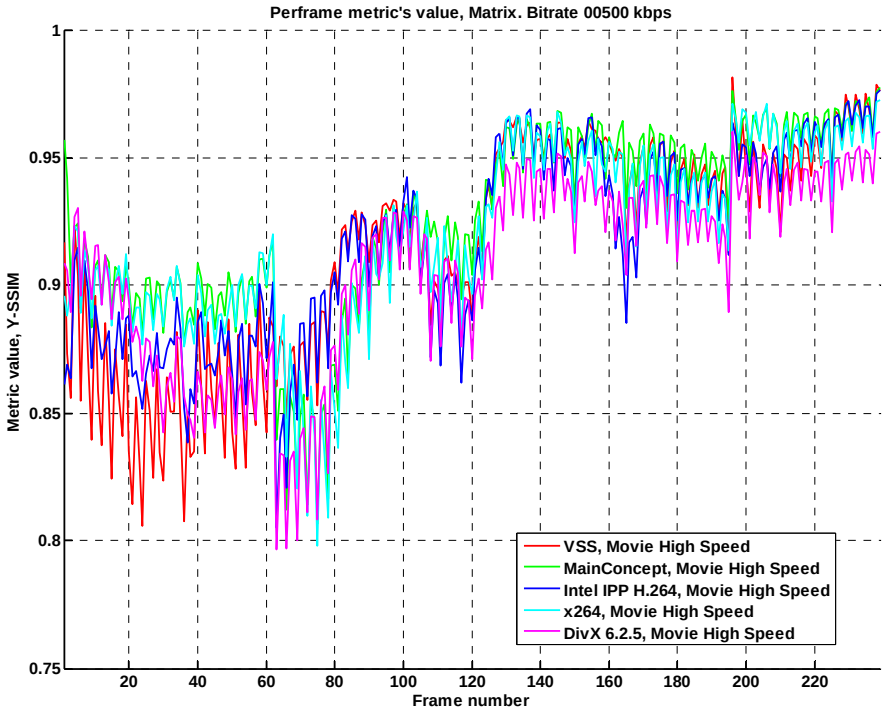


Figure 85. Per-frame quality. Usage area "Movies", "Matrix" sequence, "High Speed" preset, 500 kbps

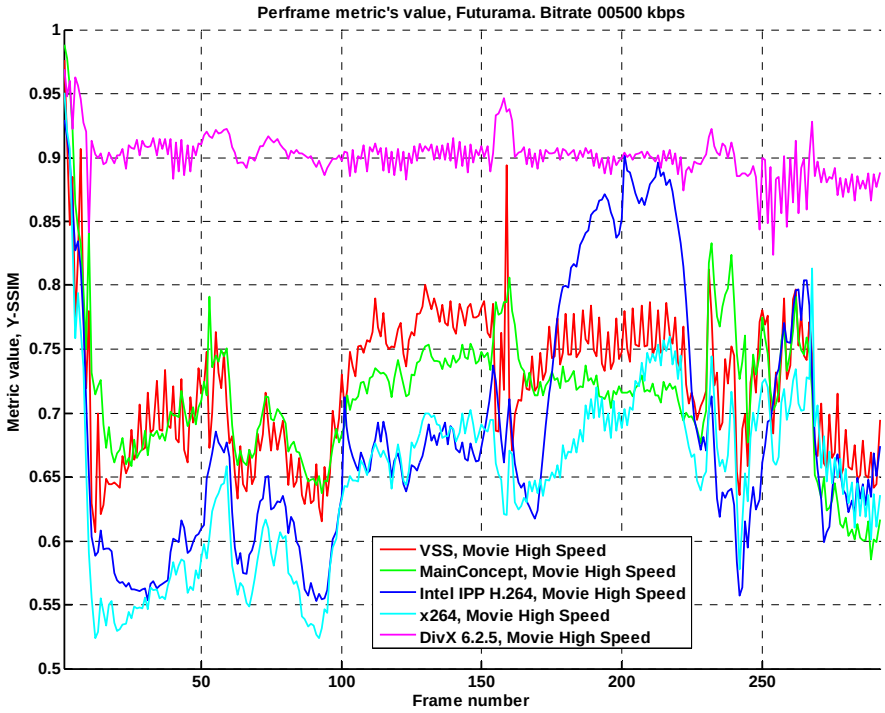


Figure 86. Per-frame quality. Usage area "Movies", "Futurama" sequence, "High Speed" preset, 500 kbps

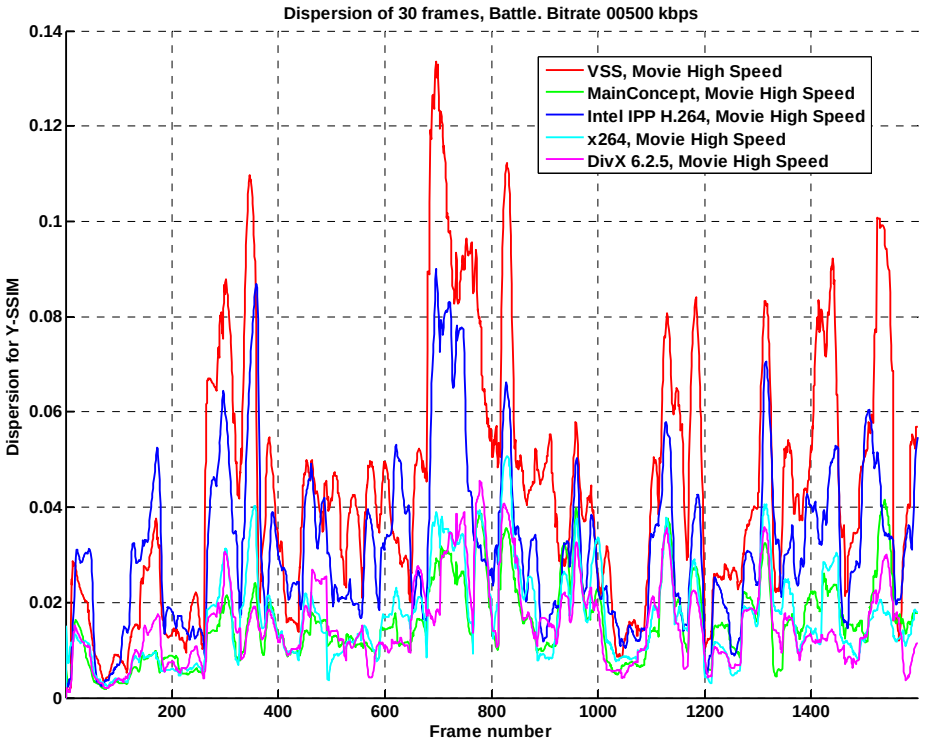


Figure 87. Quality dispersion (30 frames). Usage area "Movie", "Battle" sequence, "High Speed" preset, 500 kbps

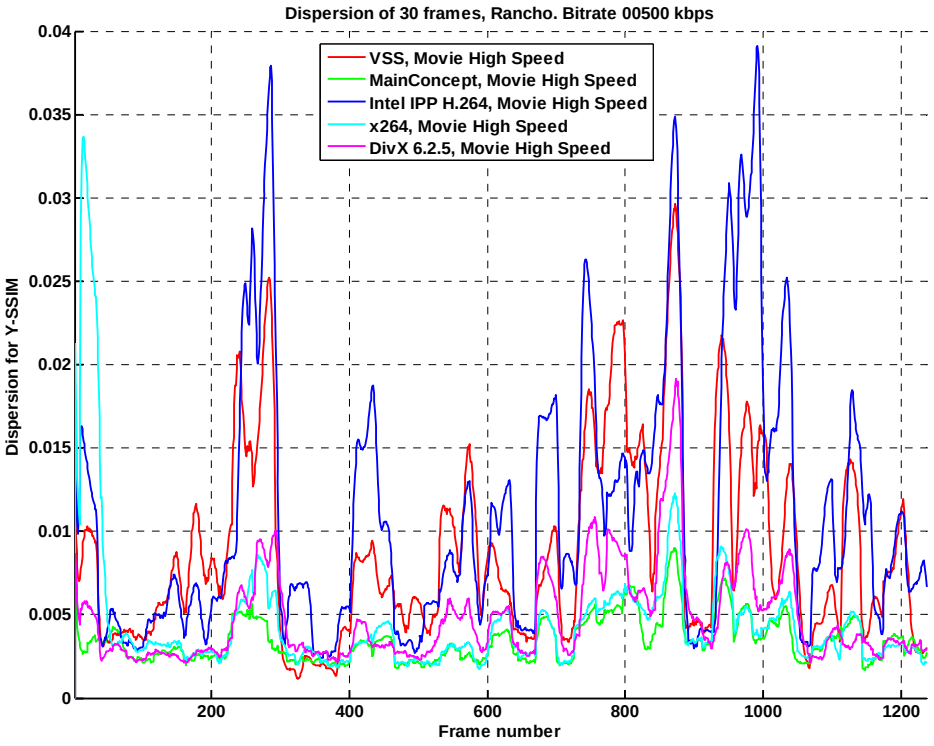


Figure 88. Quality dispersion (30 frames). Usage area "Movie", "Rancho" sequence, "High Speed" preset, 500 kbps

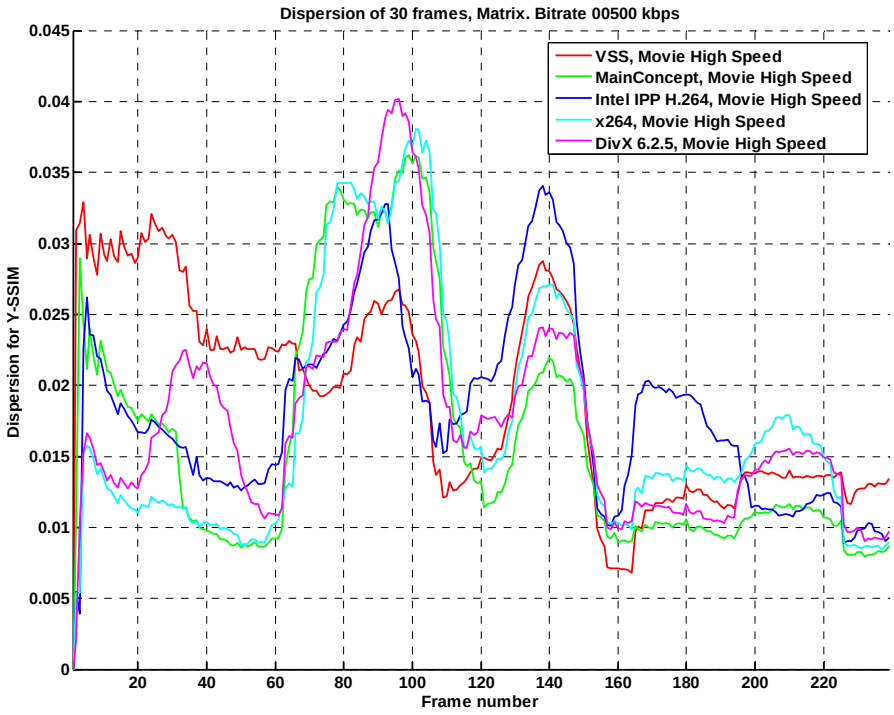


Figure 89. Quality dispersion (30 frames). Usage area "Movie", "Matrix" sequence, "High Speed" preset, 500 kbps

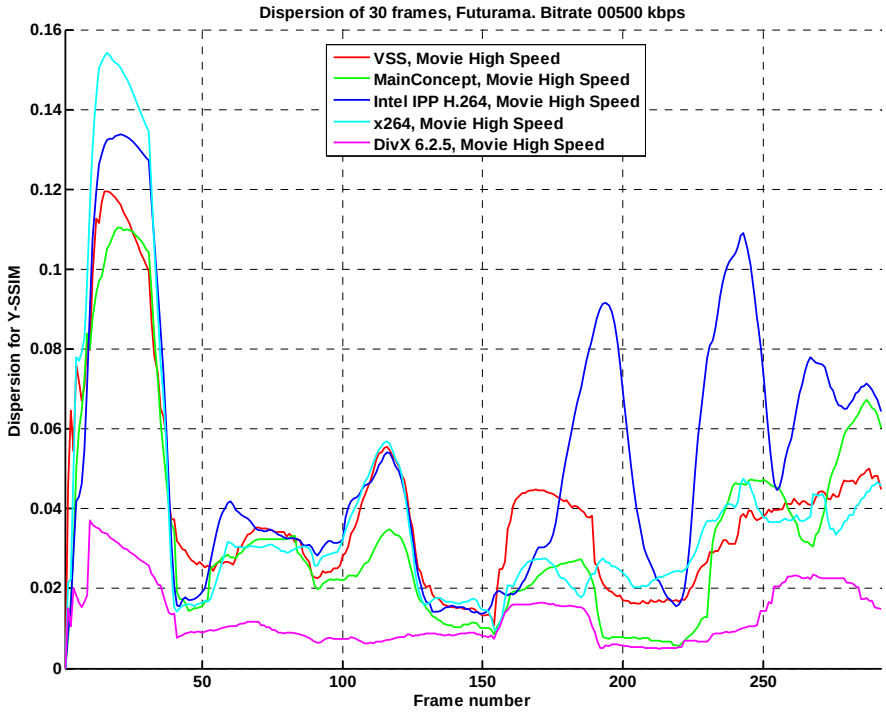


Figure 90. Quality dispersion (30 frames). Usage area "Movie", "Futurama" sequence, "High Speed" preset, 500 kbps

Figure 83 – Figure 86 show per-frame quality of all sequences at 500 kbps.

Figure 87 – Figure 90 show per-frame quality dispersion of all sequences.

Now let's consider average integral quality with the encoding speed.

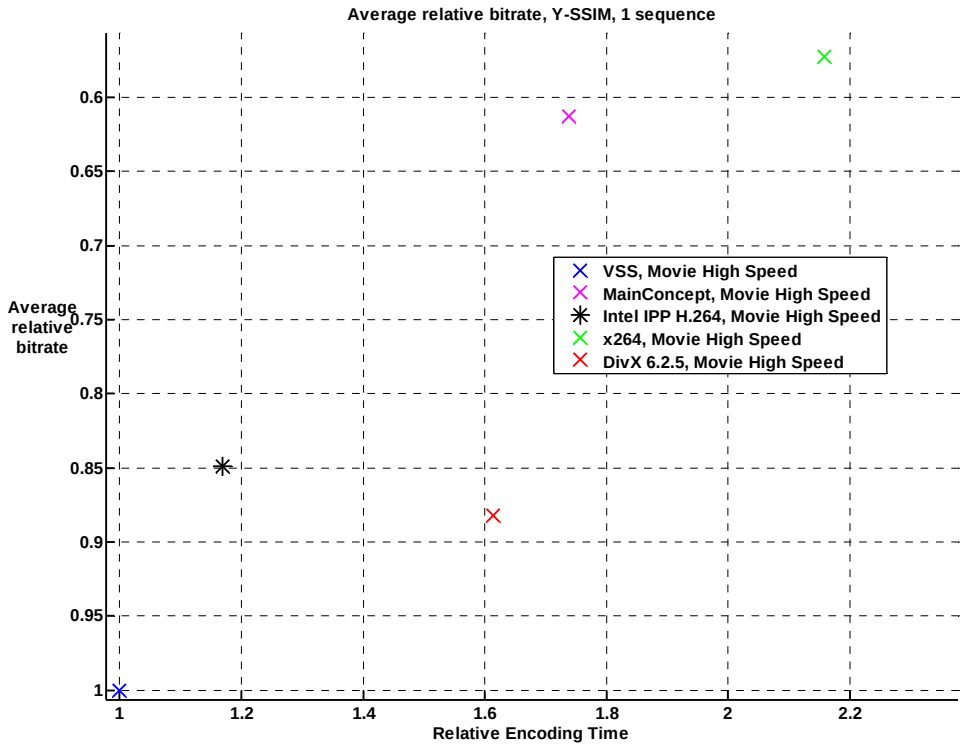


Figure 91. Relative bitrate/Relative time. Usage area "Movies", "Battle" sequence, "High Speed" preset.

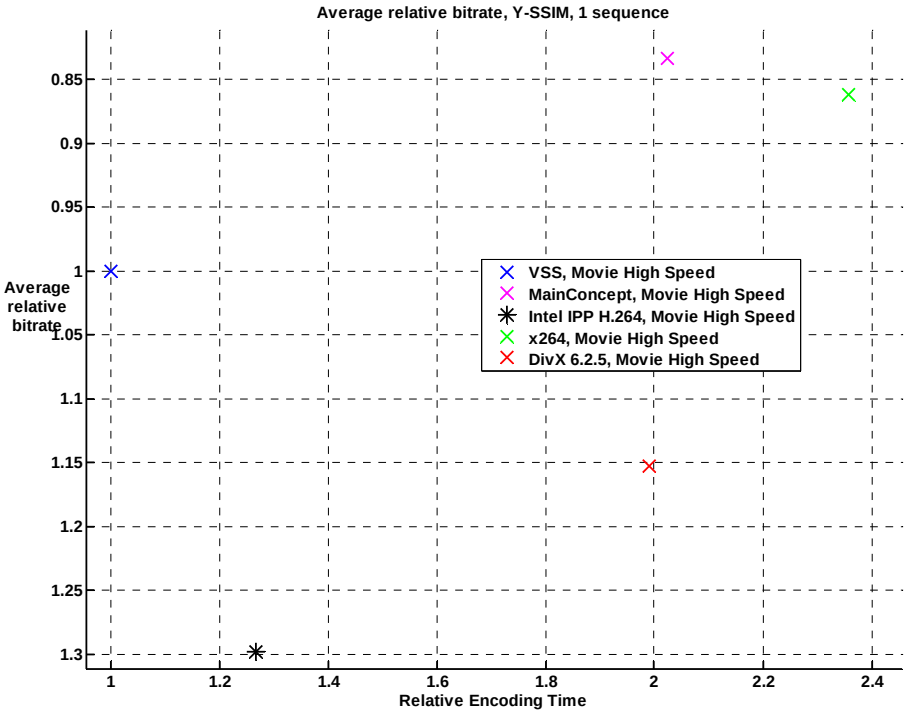


Figure 92. Relative bitrate/Relative time. Usage area "Movies", "Rancho" sequence, "High Speed" preset.

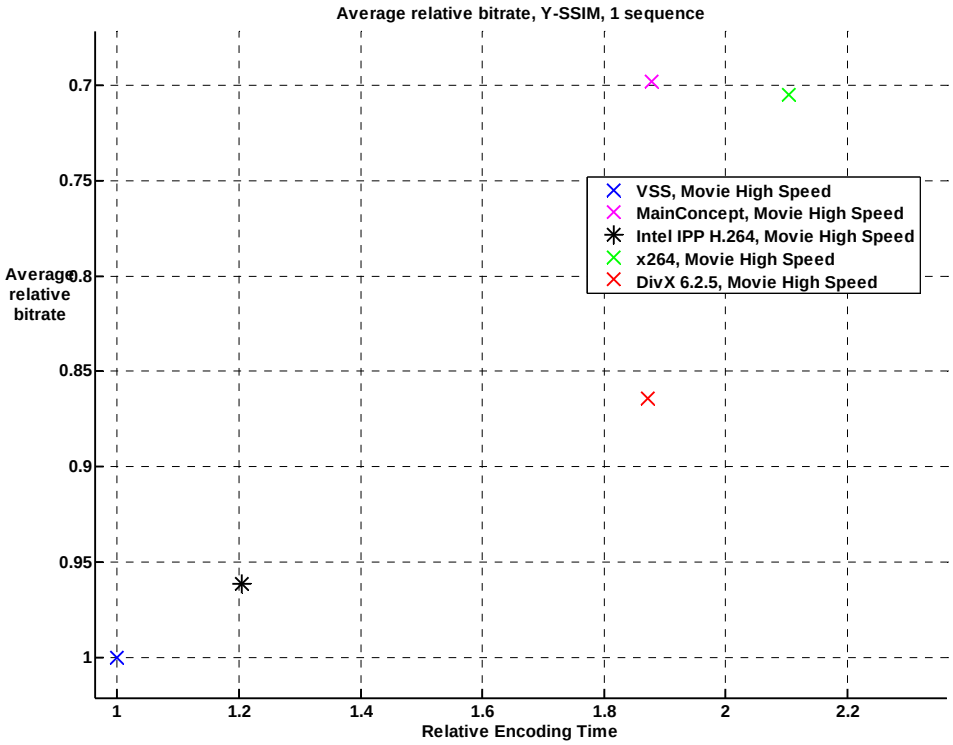


Figure 93. Relative bitrate/Relative time. Usage area "Movies", "Matrix" sequence, "High Speed" preset.

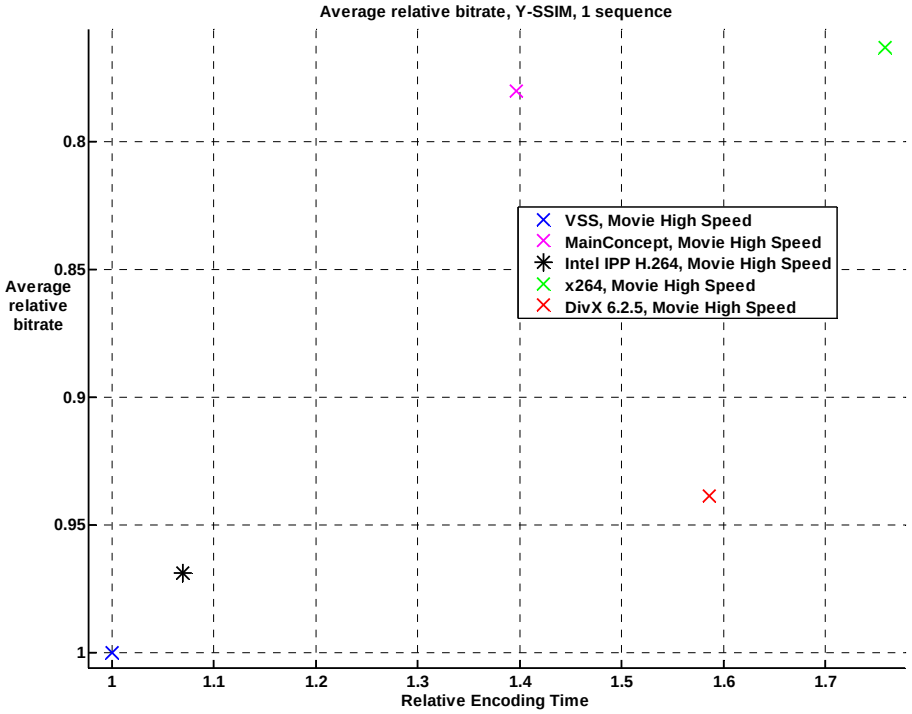


Figure 94. Relative bitrate/Relative time. Usage area "Movies", "Futurama" sequence, "High Speed" preset.

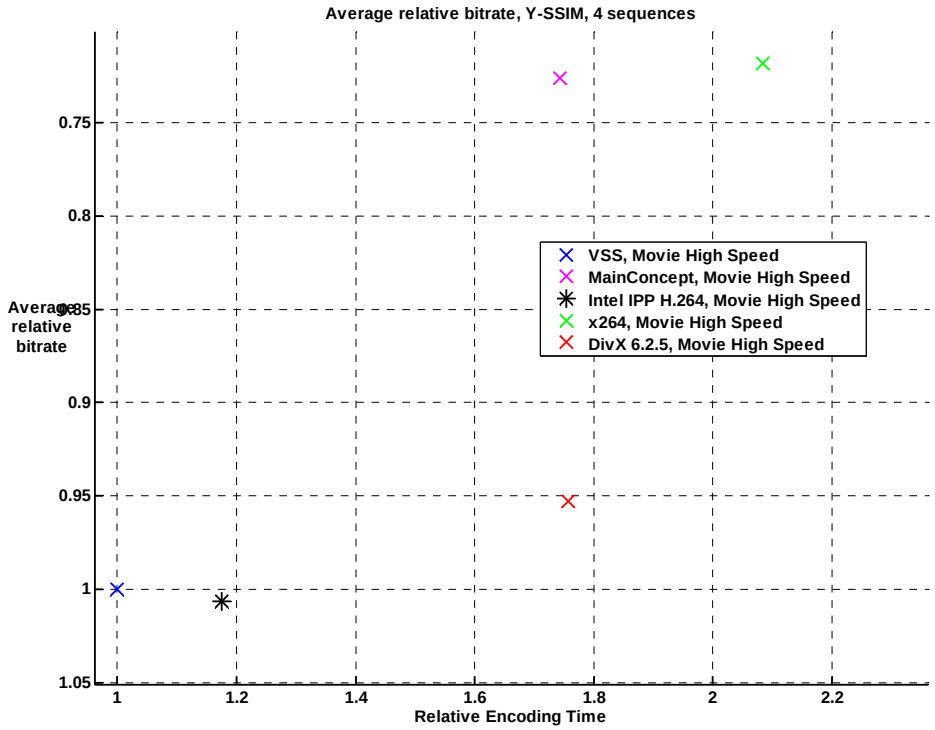


Figure 95. Relative bitrate/Relative time. Usage area "Movies", 4 sequences, "High Quality" preset.

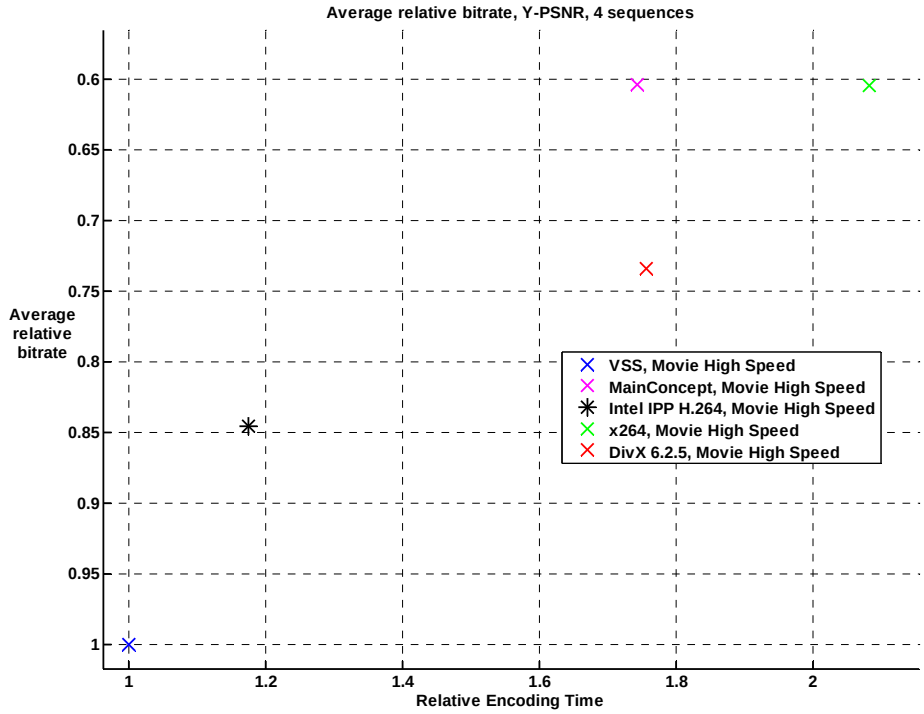


Figure 96. Relative bitrate/Relative time. Usage area "Movies", 4 sequences, "High Speed" preset. Y-PSNR measure

On all sequences except "Matrix" DivX has worse quality than H.264 codecs – its encoding time is bigger than VSS or Intel IPP encoding time and DivX has lower quality.

But if to use PSNR measure as main quality measure than DivX is more comparable to H.264 codecs by speed/quality tradeoff and Intel IPP became comparable to VSS.

But if to use more adequate SSIM measure the situation is clear enough:

- All H.264 codecs except Intel IPP lay on "sub-optimal" curve – with encoding speed increases the quality of encoding also rises. On "Rancho" sequence Intel IPP has bigger encoding time than VSS with worse quality and because of very big difference for this sequence Intel IPP has not good results at average
- MainConcept is better than x264 at average – it has little lag in quality (~1%), but faster on 20-25%.
- DivX is worse than H.264 codecs by speed/quality tradeoff – it is comparable to VSS an Intel IPP, but is totally worse than x264 and MainConcept

"High Quality 2-pass" Preset Results

Only leaders of this comparison MainConcept and x264 codecs have provided us 2-pass presets. And because of it this part of comparison is slightly lesser than others.

First of all, let's see at RD curves (SSIM measure for luminance is used here).

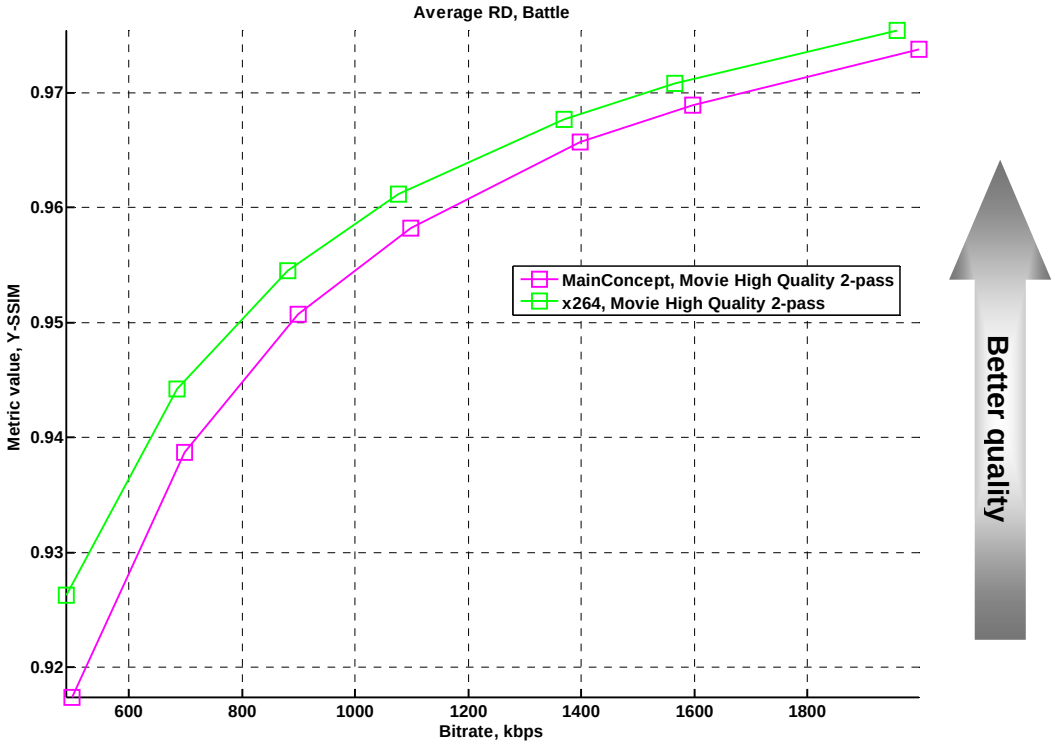


Figure 97. Bitrate/Quality. Usage area "Movies", "Battle" sequence, "High Quality 2-pass" preset

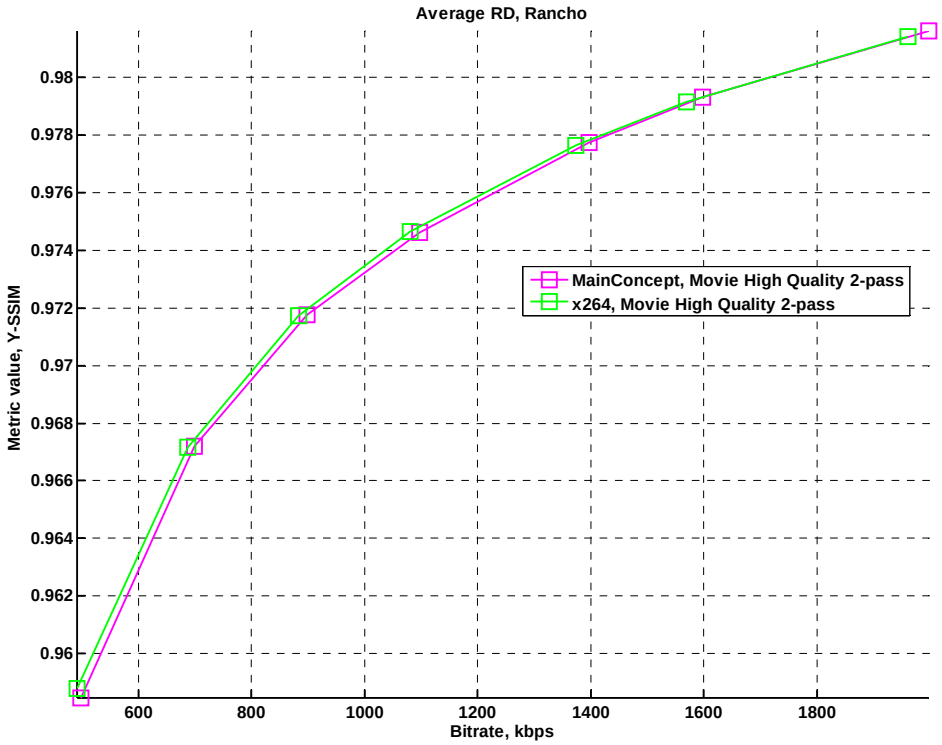


Figure 98. Bitrate/Quality. Usage area "Movies", "Rancho" sequence, "High Quality 2-pass" preset

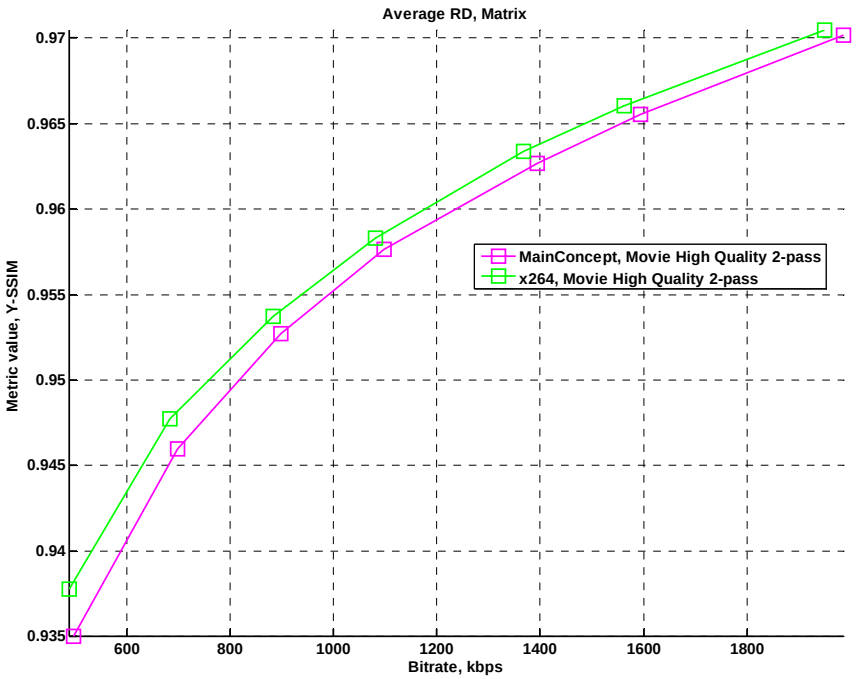


Figure 99. Bitrate/Quality. Usage area "Movies", "Matrix" sequence, "High Quality 2-pass" preset

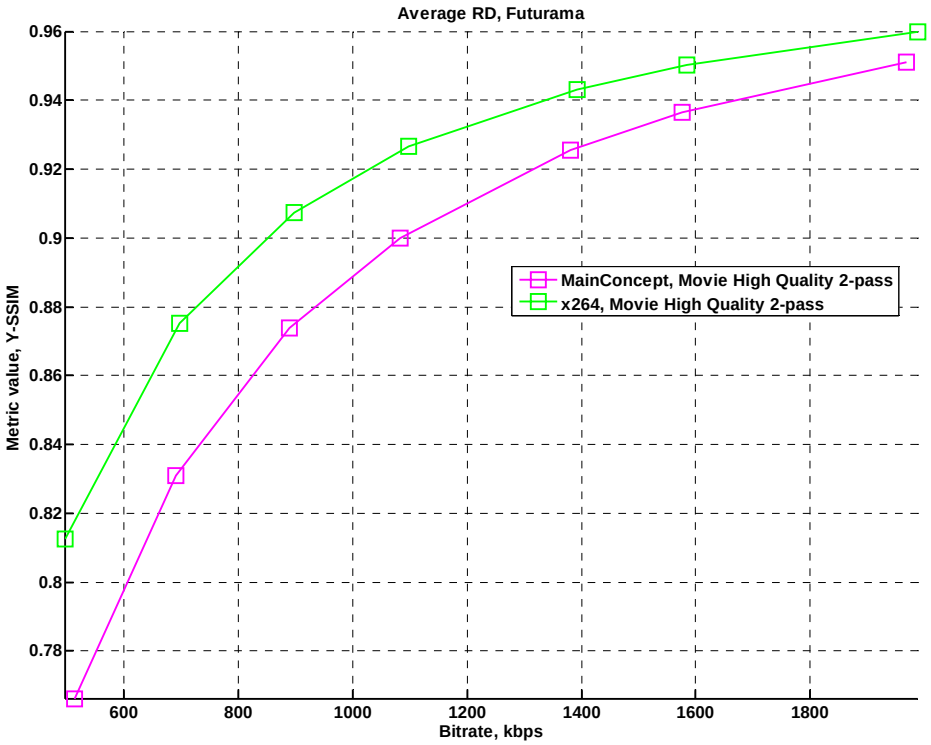


Figure 100. Bitrate/Quality. Usage area "Movies", "Futurama" sequence, "High Quality 2-pass" preset

The whole situation is clear enough for these presets – x264 shows slightly better quality than MainConcept codec.

These results are obtained without analyzing encoding speed and bitrate handling.

Now let's see bitrate keeping for these presets.

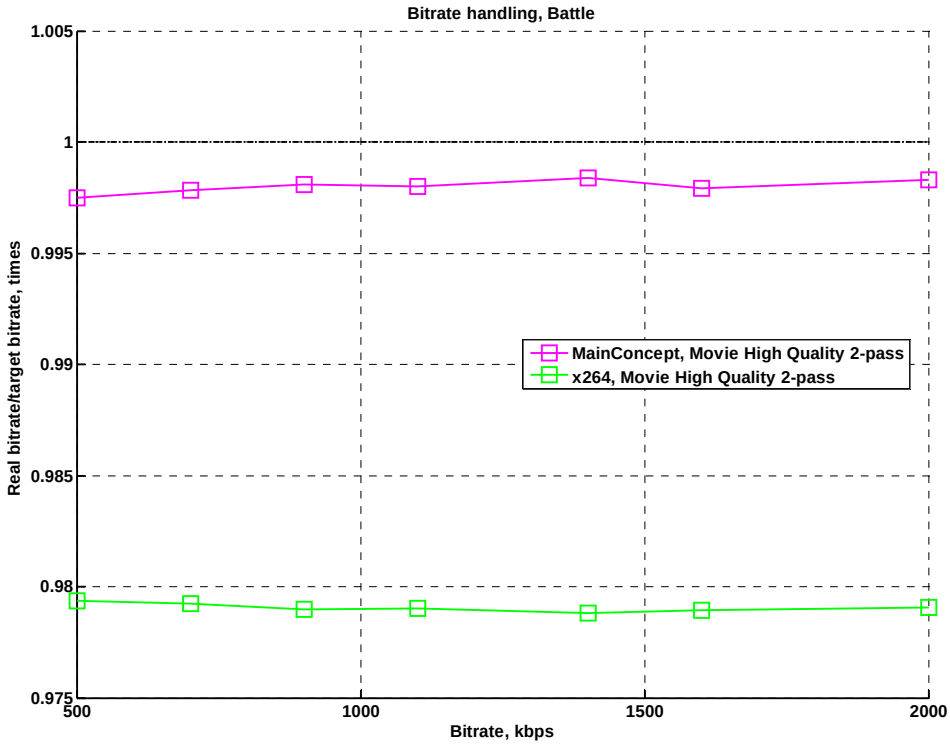


Figure 101. Bitrate handling. Usage area “Movies”, “Battle” sequence, “High Quality 2-pass” preset

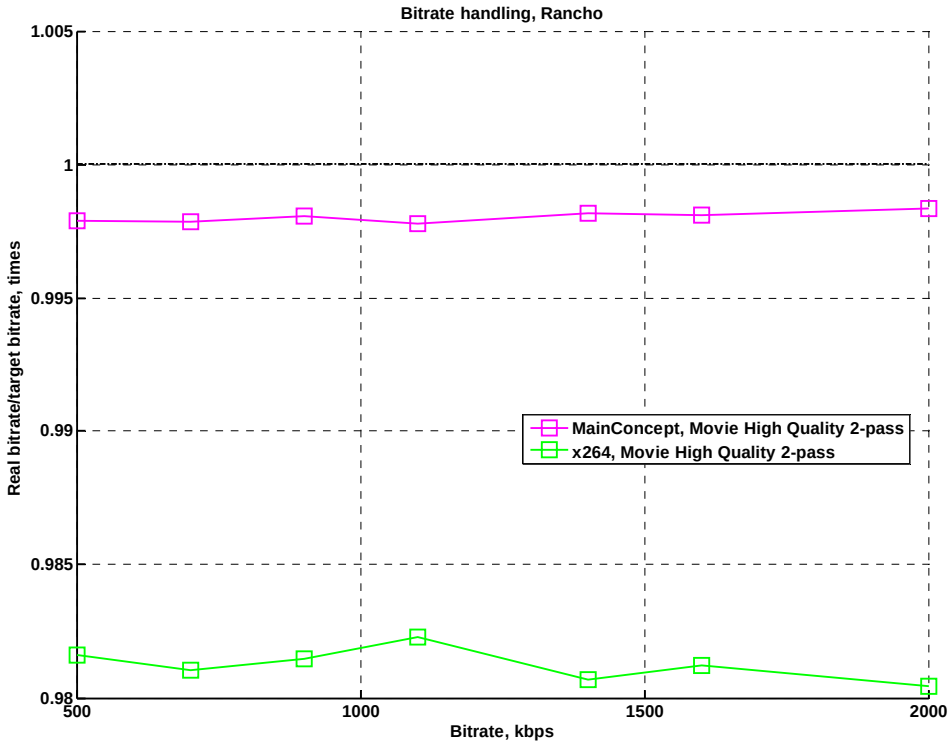


Figure 102. Bitrate handling. Usage area “Movies”. ”Rancho” sequence. “High Quality 2-pass” preset

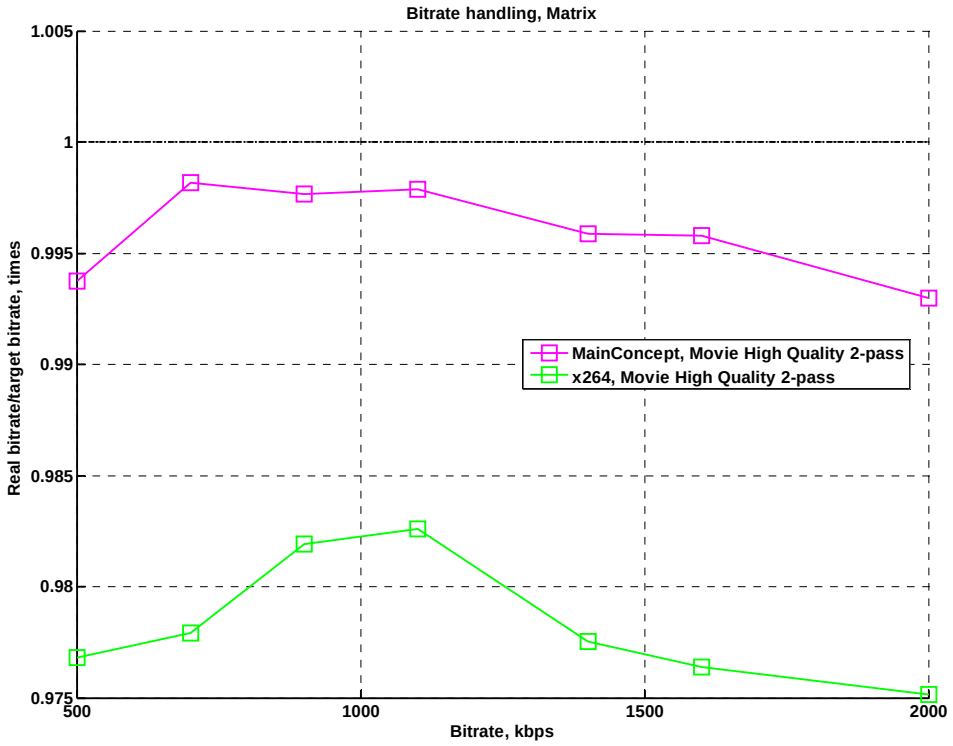


Figure 103. Bitrate handling. Usage area “Movies”. ”Matrix” sequence. “High Quality 2-pass” preset

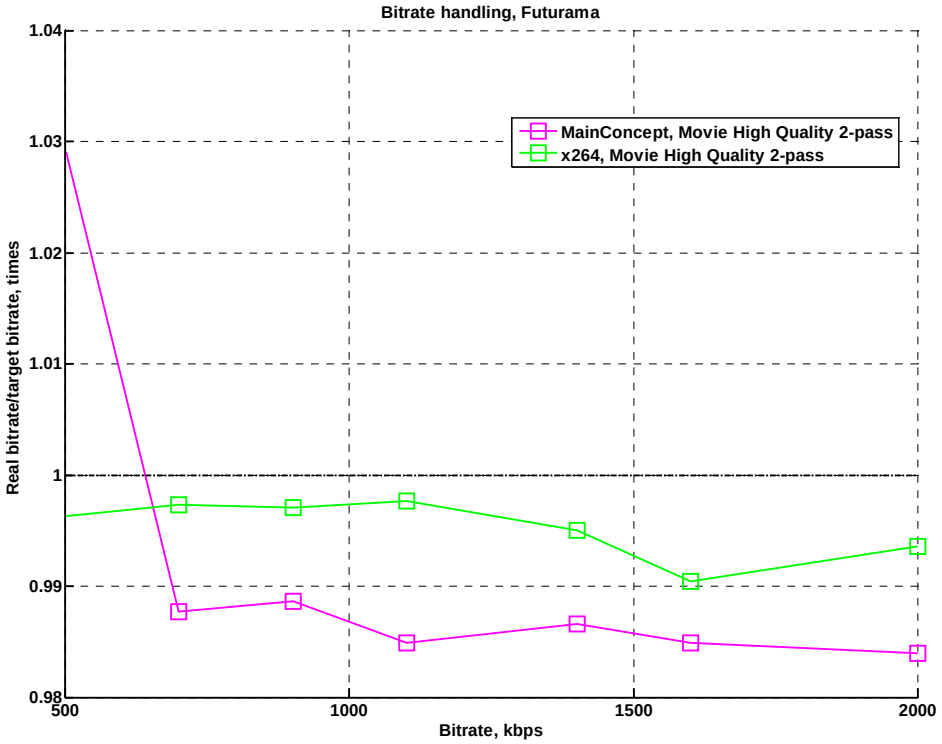


Figure 104. Bitrate handling. Usage area “Movies”. ”Futurama” sequence. “High Quality 2-pass” preset

The results of bitrate handling analysis are:

- MainConcept codec shows better bitrate handling strategy than x264 on all sequences except “Futurama”
- At average MainConcept bitrate differs to ideal less than 1%
- At average x264 bitrate differs to ideal almost 2%

***Note** We assume that 1 kbps = 1024 bps. If codec assumes that 1 kbps = 1000 bps, its ideal bitrate handling curve at our curves will be at 1000/1024 = 0.9765625.*

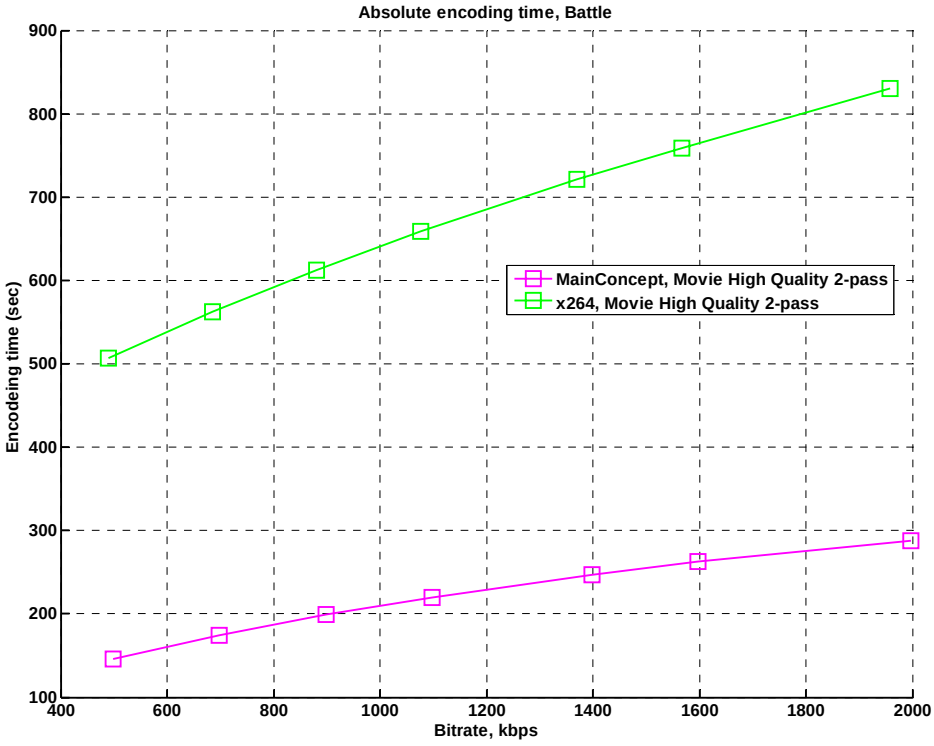


Figure 105. Absolute encoding time. Usage area “Movies”, “Battle” sequence, “High Quality 2-pass” preset

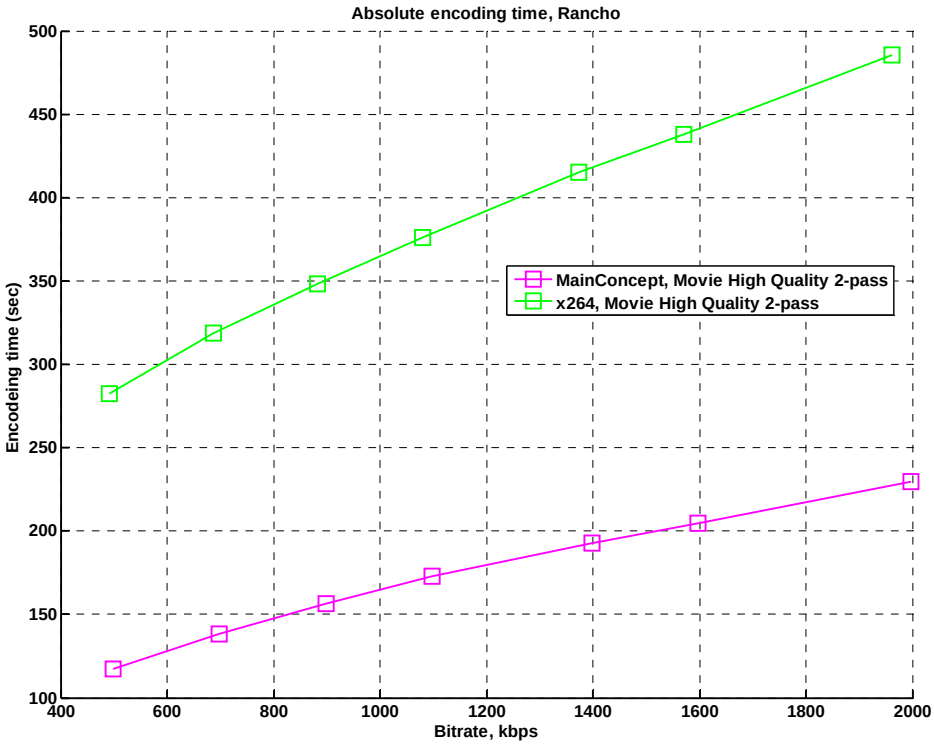


Figure 106. Absolute encoding time. Usage area "Movies", "Rancho" sequence, "High Quality 2-pass" preset

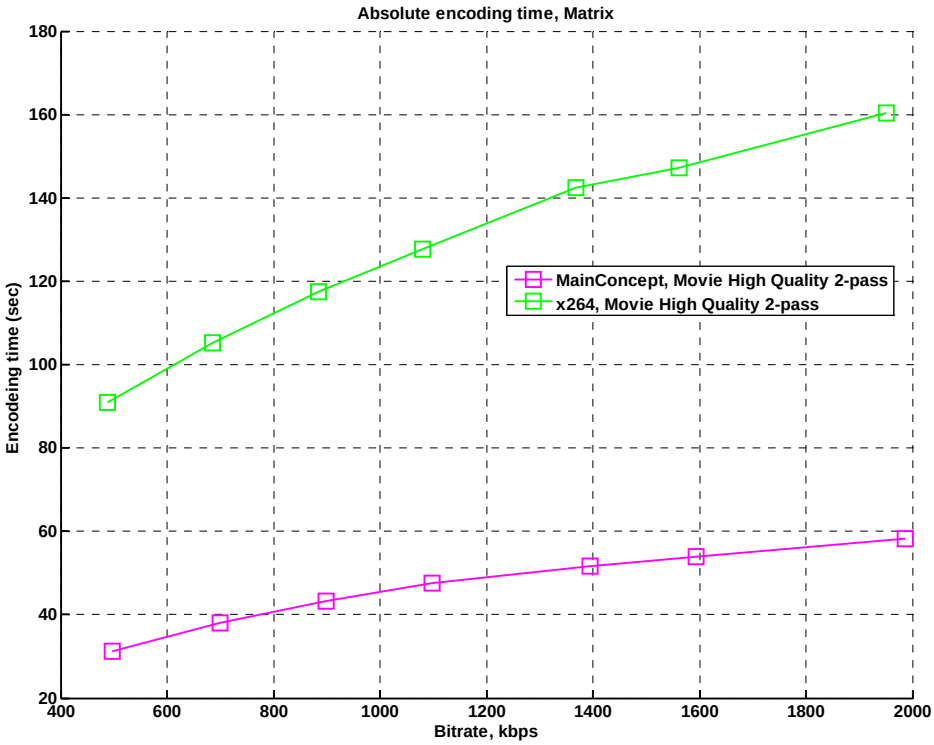


Figure 107. Absolute encoding time. Usage area "Movies", "Matrix" sequence, "High Quality 2-pass" preset

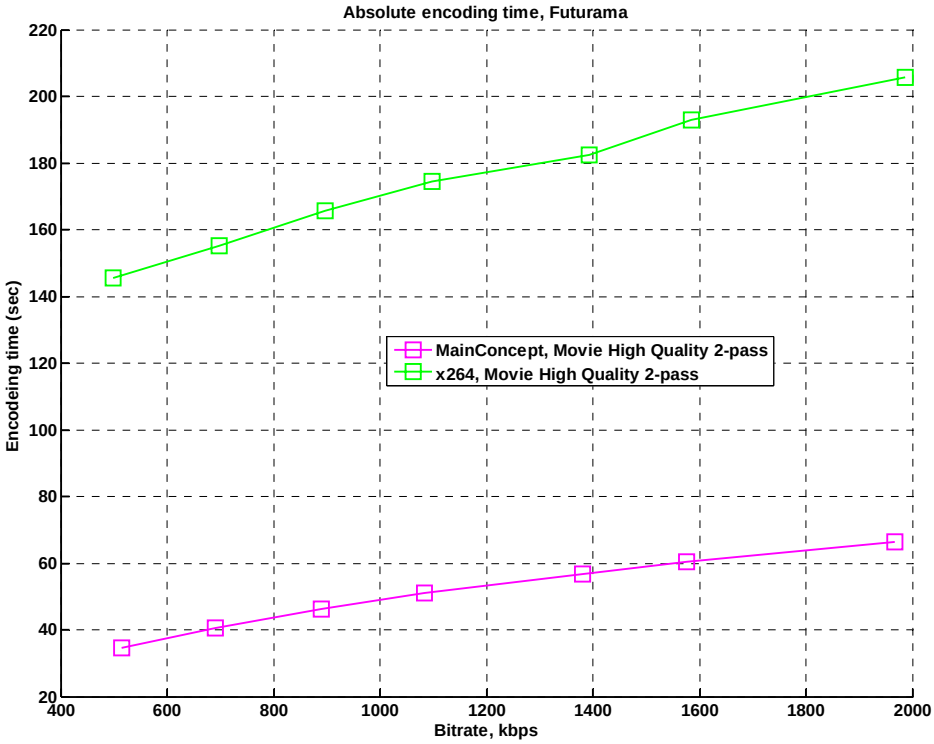


Figure 108. Absolute encoding time. Usage area "Movies", "Futurama" sequence, "High Quality 2-pass" preset

It is interesting to analyze encoding speed dependence on bitrate. Figure 105 – Figure 108 show this dependence for all sequence. The dependence for x264 is slightly bigger than for MainConcept.

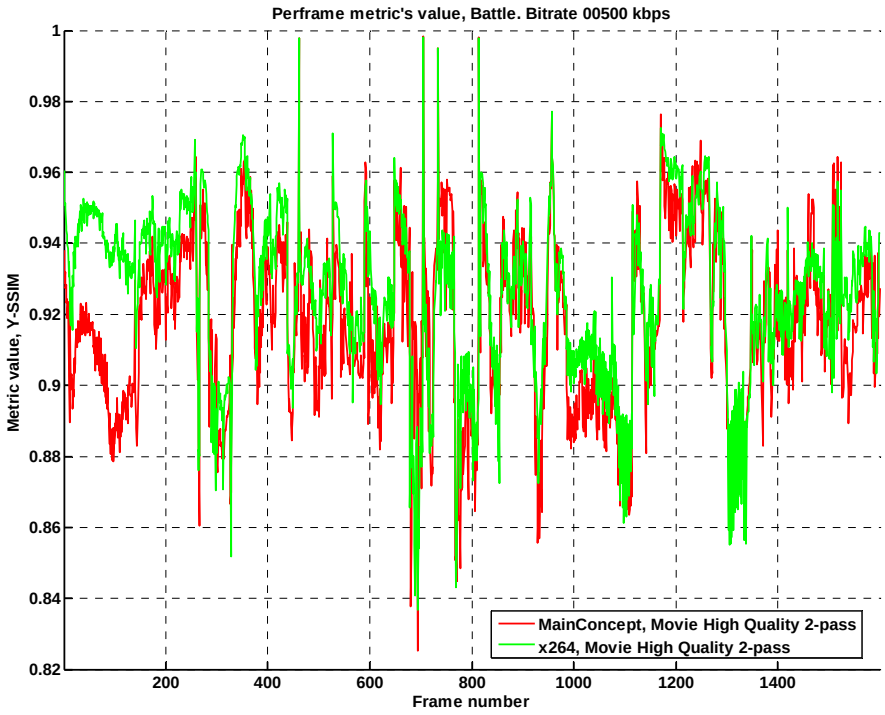


Figure 109. Per-frame quality. Usage area "Movies", "Battle" sequence, "High Quality 2-pass" preset, 500 kbps

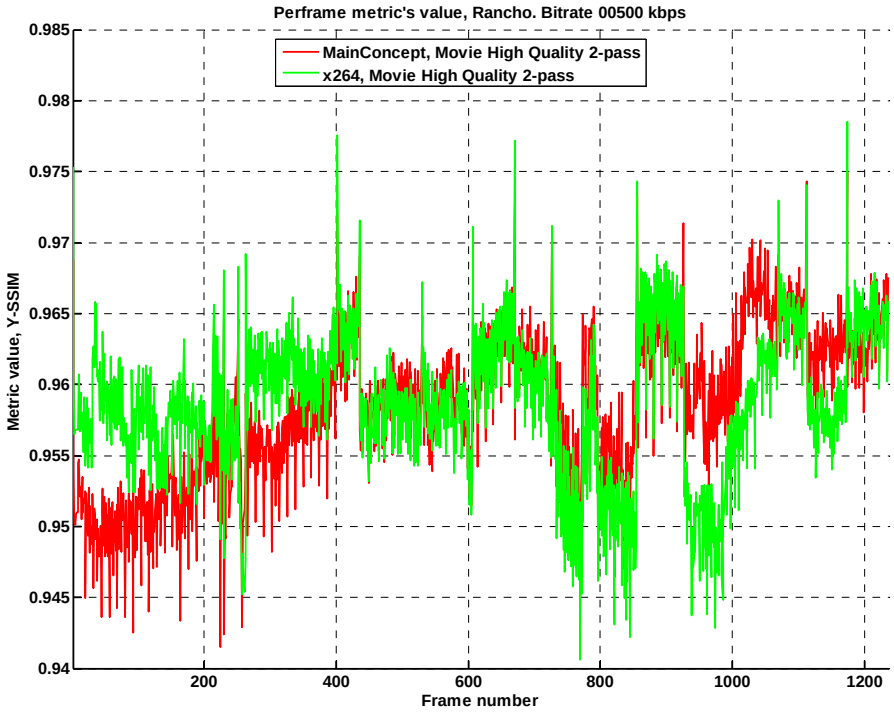


Figure 110. Per-frame quality. Usage area "Movies", "Rancho" sequence, "High Quality 2-pass" preset, 500 kbps

Figure 111. Per-frame quality. Usage area "Movies", "Matrix" sequence, "High Quality 2-pass" preset, 500 kbps

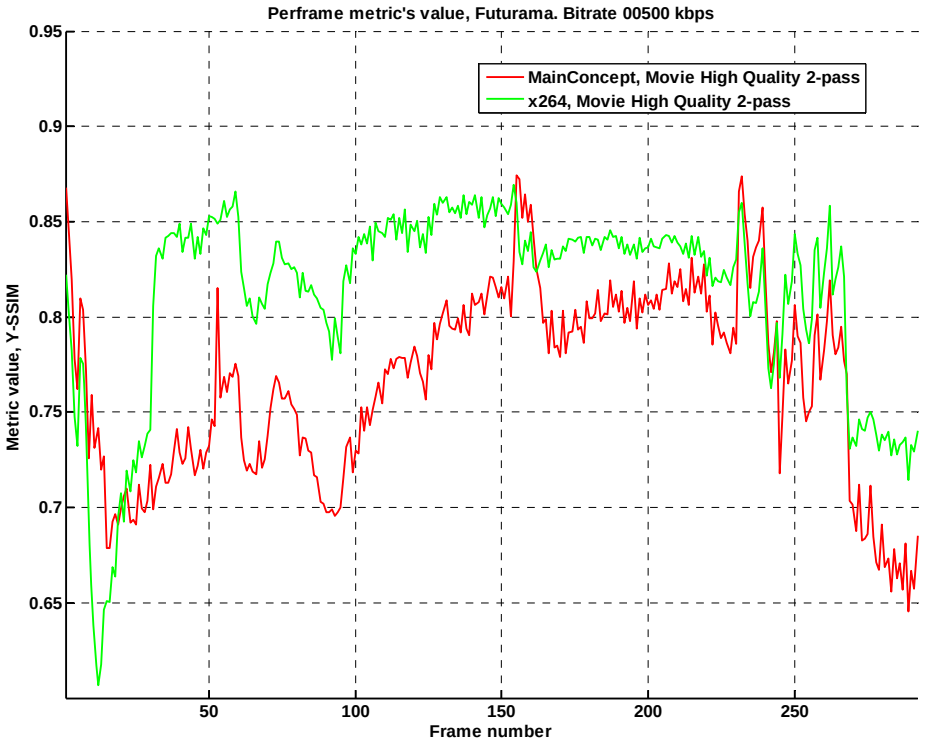


Figure 112. Per-frame quality. Usage area "Movies", "Futurama" sequence, "High Quality 2-pass" preset, 500 kbps

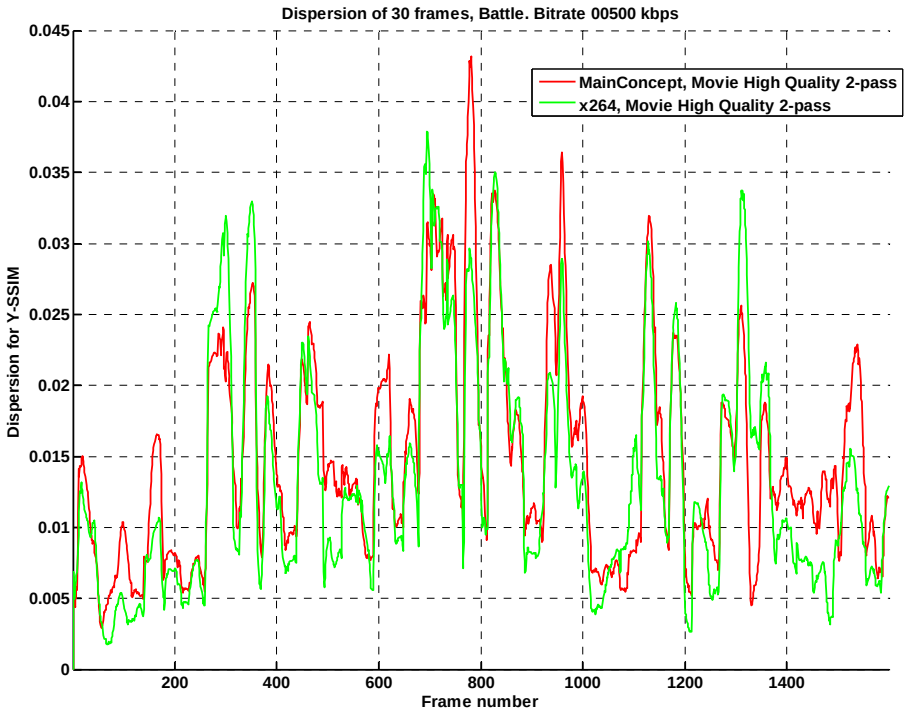


Figure 113. Quality dispersion (30 frames). Usage area "Movie", "Battle" sequence, "High Quality 2-pass" preset, 500 kbps

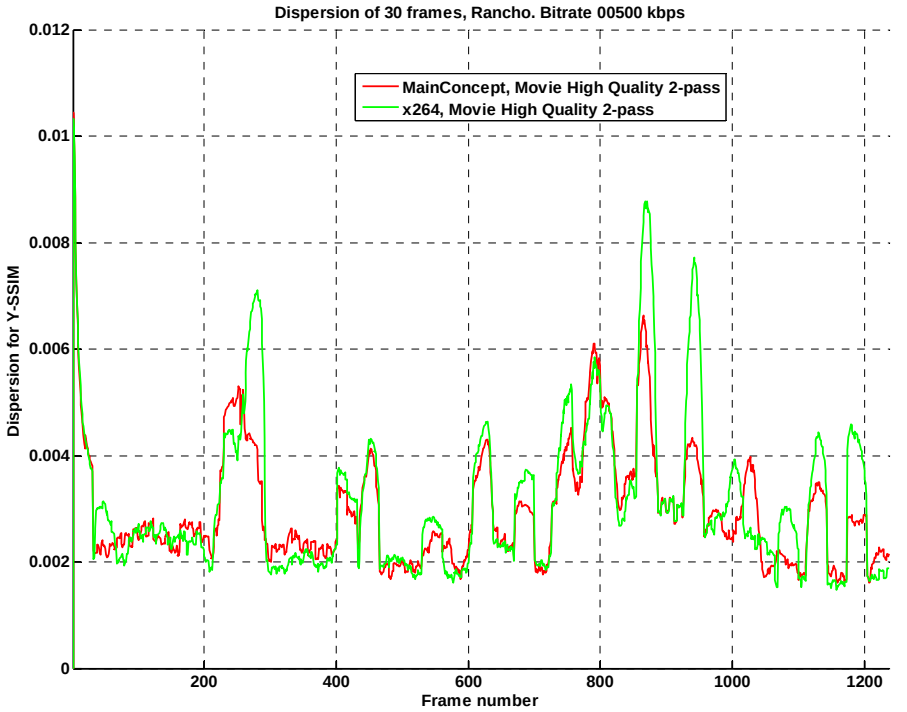


Figure 114. Quality dispersion (30 frames). Usage area "Movie", "Rancho" sequence, "High Quality 2-pass" preset, 500 kbps

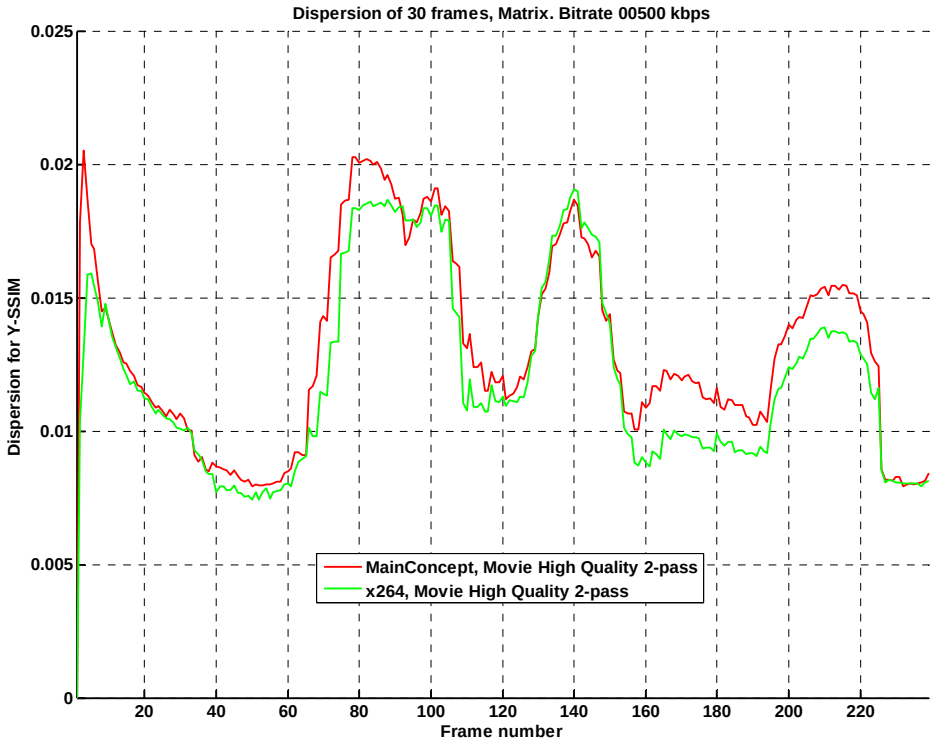


Figure 115. Quality dispersion (30 frames). Usage area “Movie”, “Matrix” sequence, “High Quality 2-pass” preset, 500 kbps

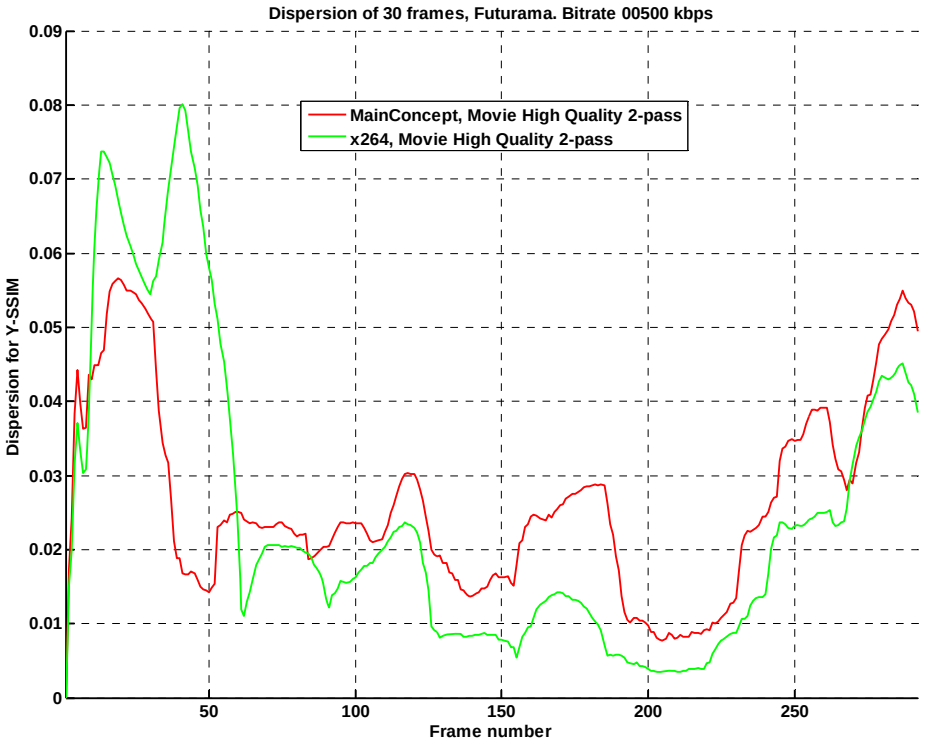


Figure 116. Quality dispersion (30 frames). Usage area "Movie", "Futurama" sequence, "High Quality 2-pass" preset, 500 kbps

Figure 109 – Figure 112 show per-frame quality of all sequences at 500 kbps.

Figure 113 – Figure 116 show per-frame quality dispersion of all sequences.

Now let's consider average integral quality with the encoding speed.

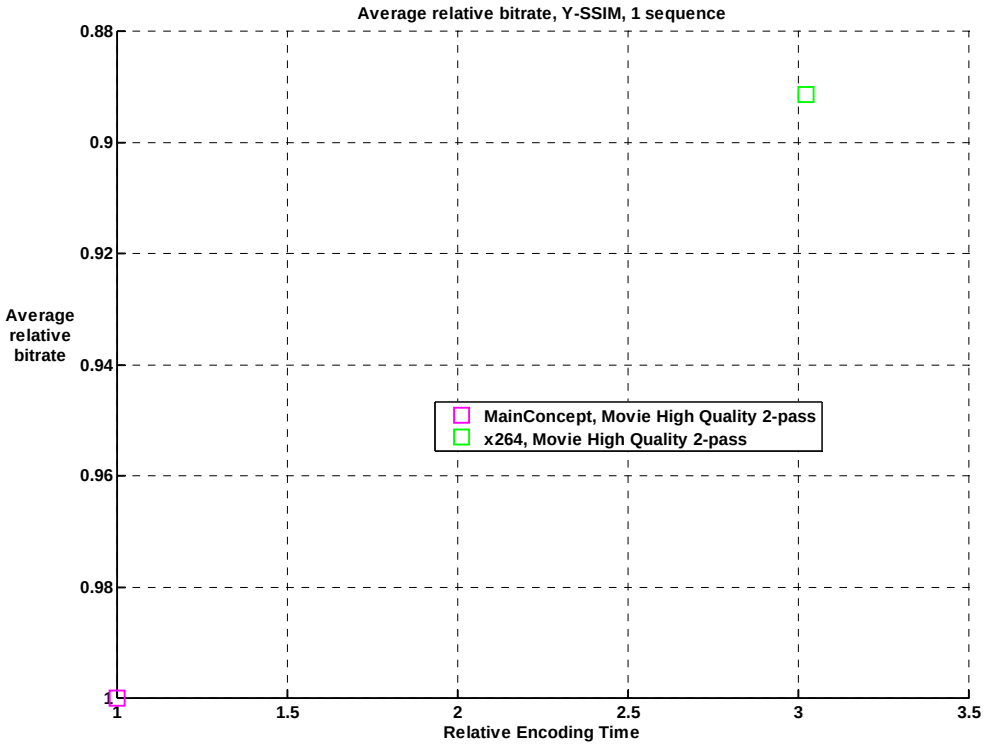


Figure 117. Relative bitrate/Relative time. Usage area "Movies", "Battle" sequence, "High Quality 2-pass" preset.

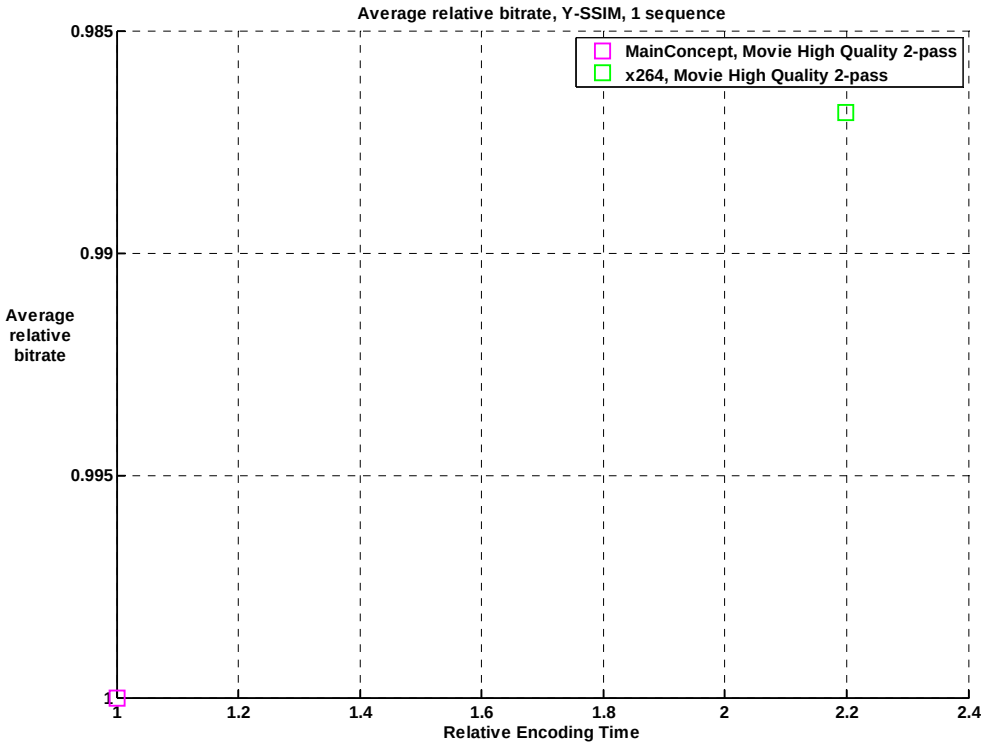


Figure 118. Relative bitrate/Relative time. Usage area "Movies", "Rancho" sequence, "High Quality 2-pass" preset.

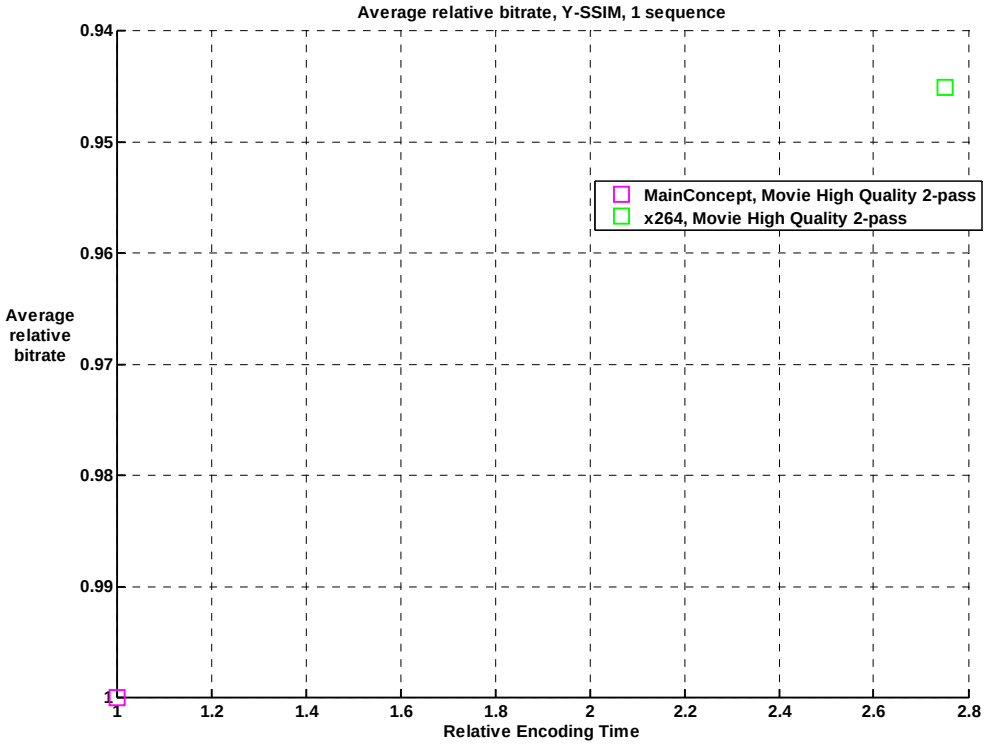


Figure 119. Relative bitrate/Relative time. Usage area "Movies", "Matrix" sequence, "High Quality 2-pass" preset.

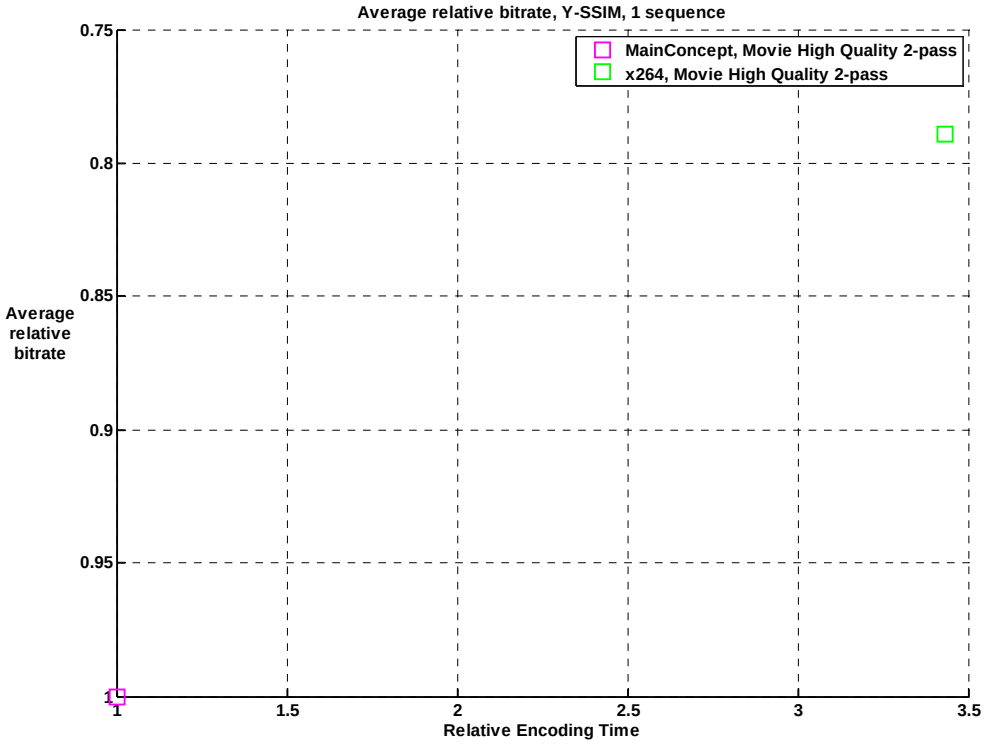


Figure 120. Relative bitrate/Relative time. Usage area "Movies", "Futurama" sequence, "High Quality 2-pass" preset.

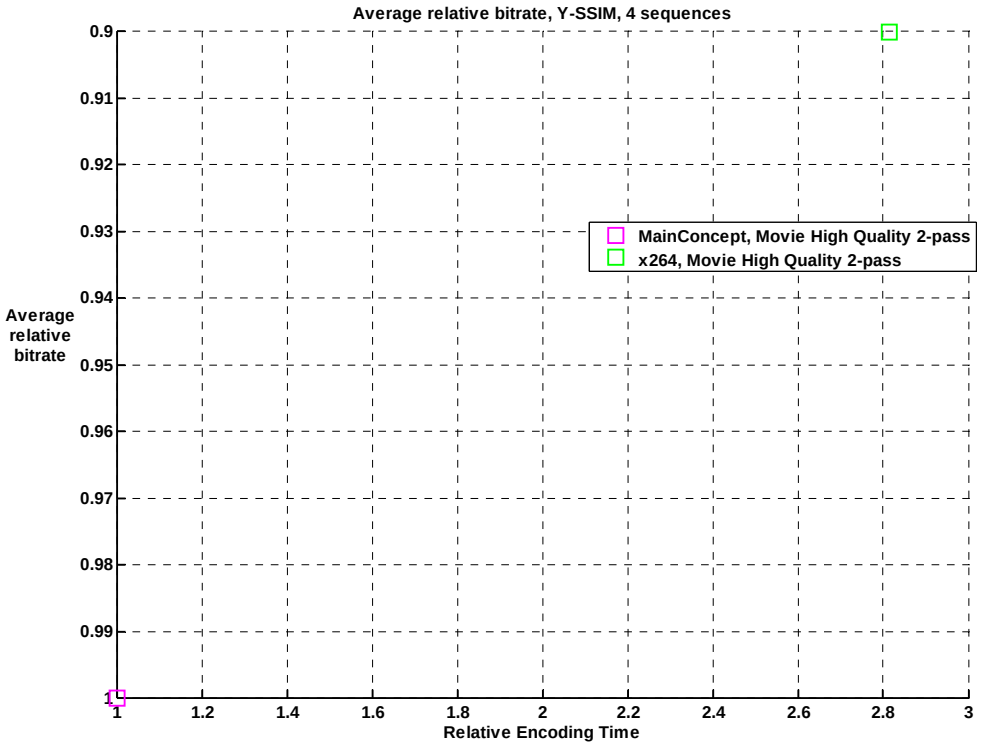


Figure 121. Relative bitrate/Relative time. Usage area "Movies", 4 sequences, "High Quality 2-pass preset.

On all sequences x264 has better quality with bigger encoding speed (it saves 10% of bitrate for the same quality, but works 2.8 times longer).

Let's consider all presets for usage area "Movies".

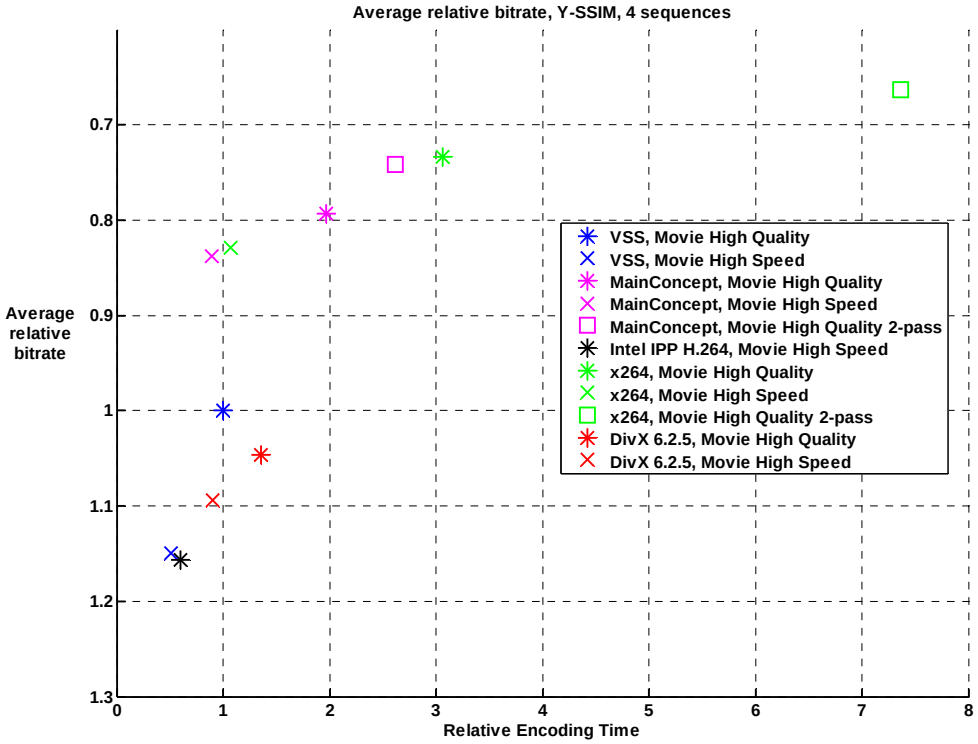


Figure 122. Relative bitrate/Relative time. Usage area "Movies", 4 sequences, all presets

- DivX "High Quality" preset is worse than VSS "High Quality"
- Intel IPP "High Speed" preset is worse than VSS "High Speed"
- VSS "High Quality" is worse than MainConcept "High Speed"
- DivX "High Speed" is worse than MainConcept "High Speed"

Now let's consider only optimal presets.

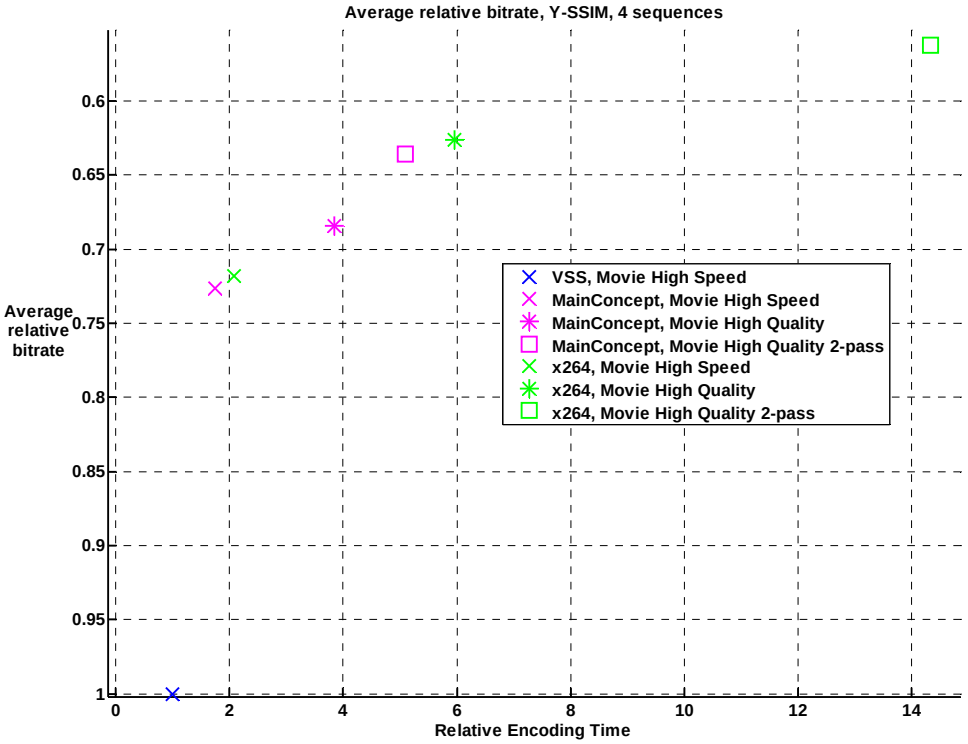


Figure 123. Relative bitrate/Relative time. Usage area "Movies", 4 sequences, optimal presets

Absolute leader by quality is x264 "High-Quality 2-passes" but with 3-7 times bigger encoding time than other codecs. VSS "High Speed" preset has best speed values but it has a lowest quality (30-40% additional bitrate at average). And other codecs are quite comparable.

Global Results for usage area "Movies"

Table 7, Table 8, Table 9 and Table 10 show average bitrates (or file size) ratio of all codecs for "High Quality" preset, "High Speed" preset, "High Quality 2-passes" and all three presets correspondingly. The values in those tables are ration of bitrate for the same quality of codec in column and codec in row. For example value 79.3% in first row and second column in Table 7 means that MainConcept codec requires 20.7% (100 – 79.3) less size to encode sequence with the same quality comparing to VSS codec.

Table 7. Average bitrate ratio for the same quality. Usage area "Movies". "High Quality" preset, Y-SSIM. Bitrates 600-1800 Kbps.

	VSS	MainConcept	x264	DivX
VSS	100.0%	79.3%	73.3%	104.7%
MainConcept	126.1%	100.0%	93.2%	129.2%
x264	136.4%	107.3%	100.0%	138.1%
DivX	95.5%	77.4%	72.4%	100.0%

Table 8. Average bitrate ratio for the same quality. Usage area "Movies". "High Speed" preset, Y-SSIM. Bitrates 600-1800 Kbps.

	VSS	MainConcept	Intel IPP	x264	DivX
VSS	100.0%	72.6%	100.6%	71.8%	95.3%
MainConcept	137.7%	100.0%	137.9%	99.4%	128.5%
Intel IPP	99.4%	72.5%	100.0%	72.1%	93.2%
x264	139.3%	100.6%	138.7%	100.0%	131.2%
DivX	104.9%	77.8%	107.4%	76.2%	100.0%

Table 9. Average bitrate ratio for the same quality. Usage area "Movies". "High Quality 2-pass" preset, Y-SSIM. Bitrates 600-1800 Kbps.

	MainConcept	x264
MainConcept	100.0%	90.0%
x264	111.1%	100.0%

Table 10. Average bitrate ratio for the same quality. Usage area "Movies". All presets, Y-SSIM. Bitrates 600-1800 Kbps.

	VSS HQ	VSS HS	MC HQ	MC HS	MC 2-pass	IPP HS	X264 HS	x264 HQ	x264 2-pass	DivX HQ	DivX HS
VSS HQ	100.0%	115.0%	79.3%	83.8%	74.1%	115.6%	73.3%	82.9%	66.3%	104.7%	109.4%
VSS HS	87.0%	100.0%	68.4%	72.6%	63.6%	100.6%	62.6%	71.8%	56.3%	90.8%	95.3%
MC HQ	126.1%	146.1%	100.0%	105.6%	94.1%	146.1%	93.2%	105.0%	84.7%	129.2%	135.0%
MC HS	119.4%	137.7%	94.7%	100.0%	89.1%	137.9%	88.2%	99.4%	80.2%	123.0%	128.5%
MC 2-pass	134.9%	157.2%	106.3%	112.2%	100.0%	156.6%	99.4%	111.8%	90.0%	136.7%	142.7%
IPP HS	86.5%	99.4%	68.5%	72.5%	63.8%	100.0%	63.0%	72.1%	56.9%	88.9%	93.1%
x264 HQ	136.4%	159.6%	107.3%	113.4%	100.6%	158.8%	100.0%	112.7%	90.2%	138.1%	144.4%
x264 HS	120.7%	139.3%	95.3%	100.6%	89.5%	138.7%	88.7%	100.0%	80.5%	125.5%	131.2%
x264 2-pass	150.9%	177.7%	118.1%	124.7%	111.1%	175.9%	110.9%	124.3%	100.0%	151.8%	158.8%
DivX HQ	95.5%	110.2%	77.4%	81.3%	73.2%	112.5%	72.4%	79.7%	65.9%	100.0%	104.7%
DivX HS	91.4%	104.9%	74.1%	77.8%	70.1%	107.4%	69.2%	76.2%	63.0%	95.5%	100.0%

Conclusions

On the basis of performed research all tested codecs may be arranged in the following way by criteria average bitrate saving for the same quality:

1. x264
2. MainConcept
3. DivX (MPEG-4 ASP)
4. Intel H.264
5. VSS

It is important to note that in "Movies" type of application MPEG-4 ASP standard's codec is better than several codecs of the new standard, and the best quality was showed by non-commercial x264 codec.

Bitrate keeping is good enough for all codec except DivX. And the best bitrate handling for "High Quality" and "High Quality 2-passes" is for MainConcept codec and for "High Speed" Intel IPP is absolute leader by bitrate handling.

High Definition Television (HDTV)

In this section behavior of codecs for encoding movies with high definition resolution (HDTV) is analyzed. Here typical for this type of application sequence with high resolution was used. Chosen bitrates (1, 2, 3, 4, 6, 8, 10 Mbps) allow encoding sequences with such resolution with acceptable quality for viewing on HDTV equipment with large screens.

The following codecs are considered in this section:

- MainConcept
- Intel H.264
- VSS
- x264

The only sequences, which was used in this section is “Concert”.

Note: The only requirement for HDTV-preset was speed requirement, so different codecs used 1-pass or 2-pass presets. x264 and MainConcept used 2-pass presets, and Intel IPP with VSS used 1-pass preset. So pay attention to this fact when analyzing speed/quality results for these codecs.

Results

First of all, let’s see RD curves of codecs.

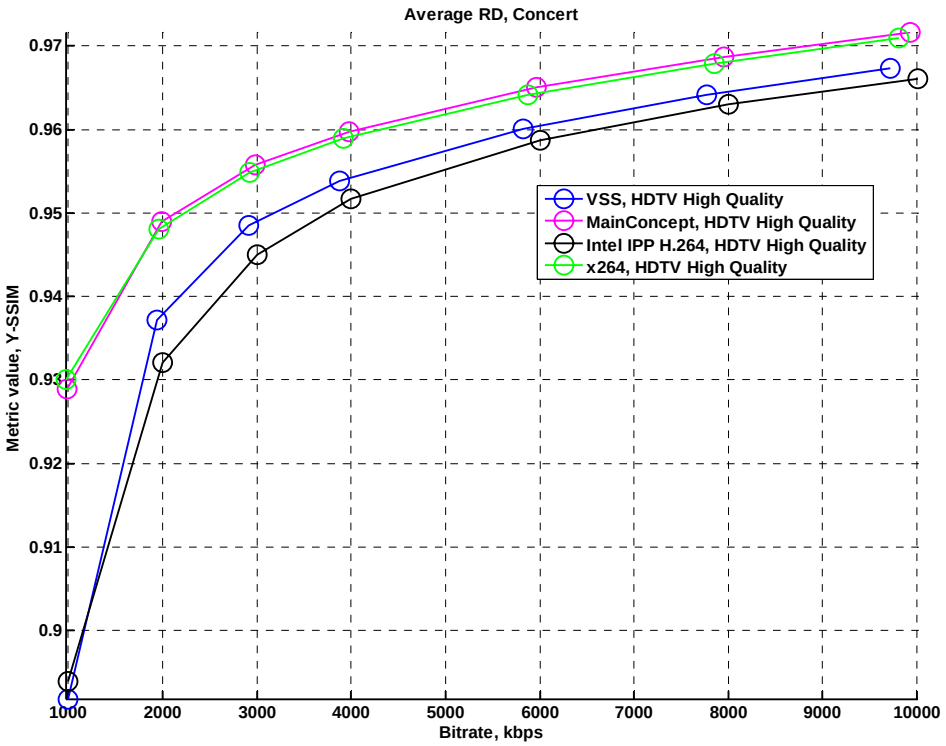


Figure 124. Bitrate/Quality. Usage area “HDTV”, “Concert” sequence, Y-PSNR.

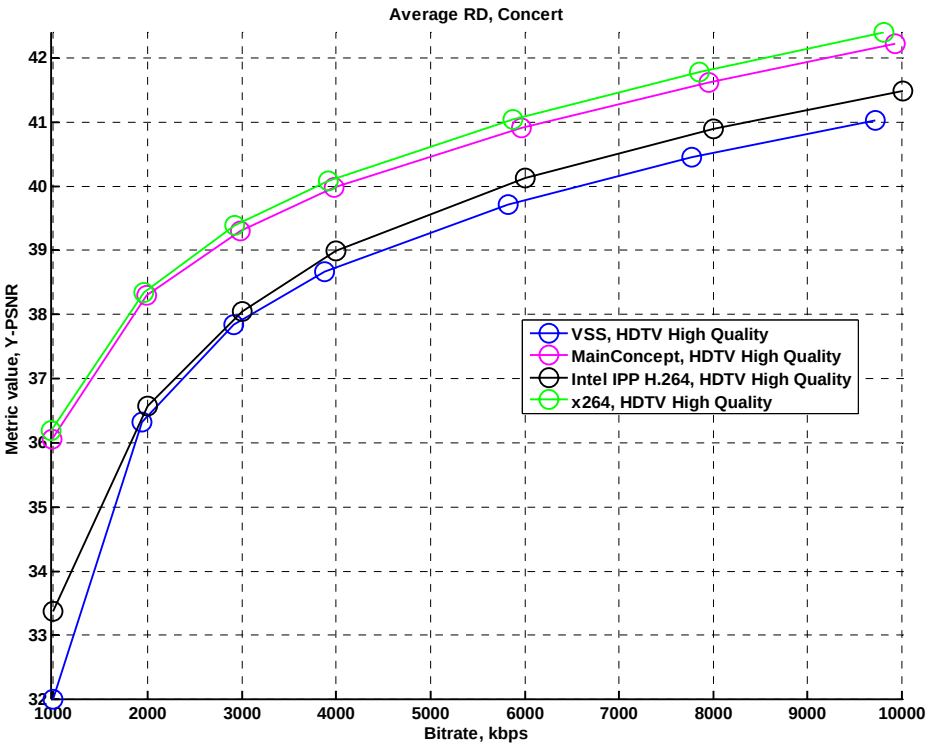


Figure 125. Bitrate/Quality. Usage area "HDTV", "Concert" sequence, Y-SSIM

Figure 124 shows RD curves for SSIM measure, Figure 125 – for PSNR measure. Both measures show that MainConcept and x264 outperform VSS and Intel IPP codec.

But situation in those two groups is rather ambiguous. SSIM measure shows that MainConcept is better than x264, PSNR – that x264 is better. Note, that the difference between codecs is very small and its not very important, which one is better.

According to SSIM results, VSS codec outperforms Intel IPP codec, according to PSNR – Intel IPP is better.

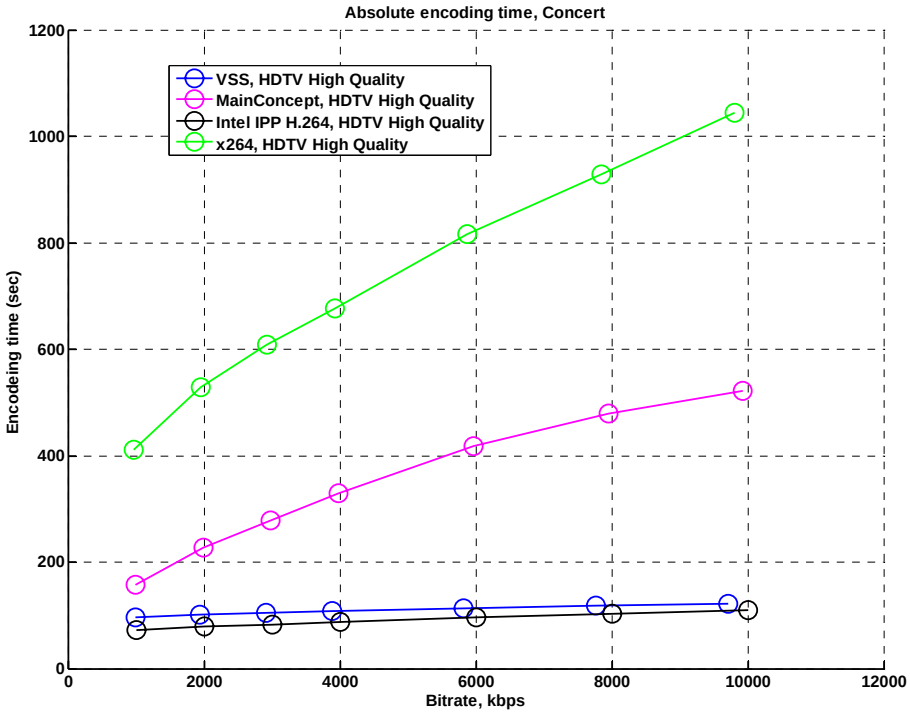


Figure 126. Absolute encoding time. Usage area "HDTV", "Concert" sequence.

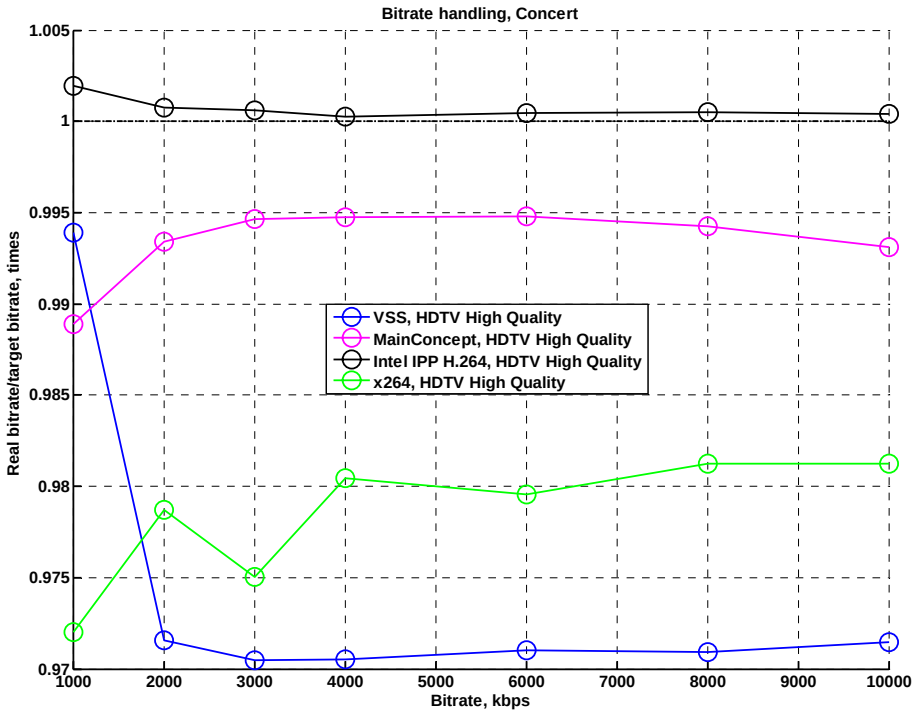


Figure 127. Bitrate handling. Usage area "HDTV", "Concert" sequence.

All codecs keep bitrate rather good. In case if VSS and x264 suppose that 1 kbps = 1000 bps, the real situation is even better.

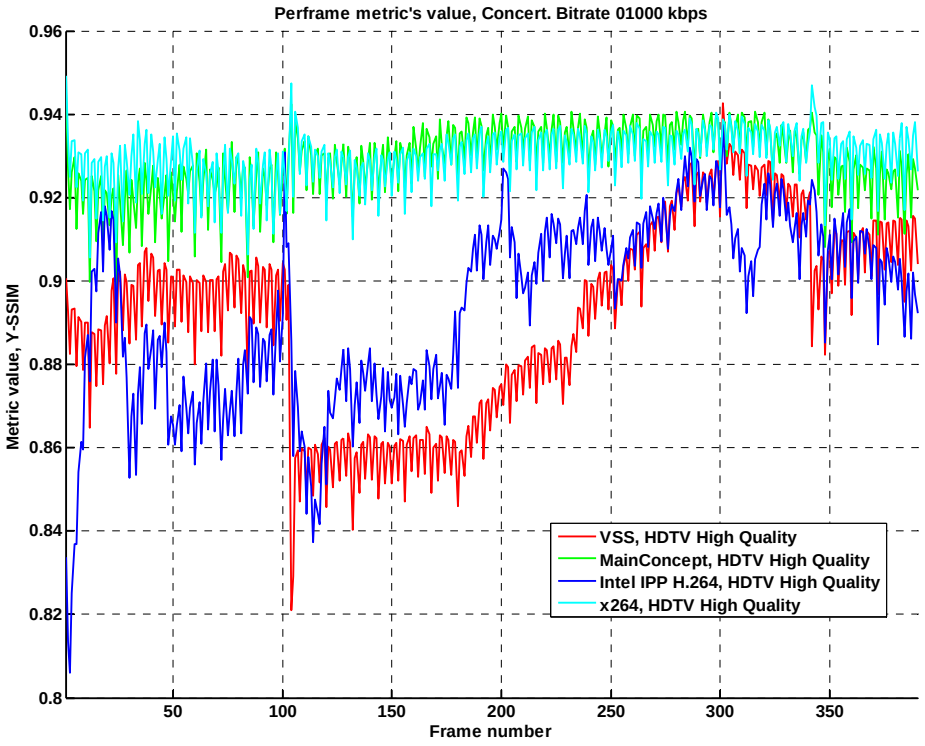


Figure 128. Per-frame quality. Usage area "HDTV", "Concert" sequence, 1 mbps

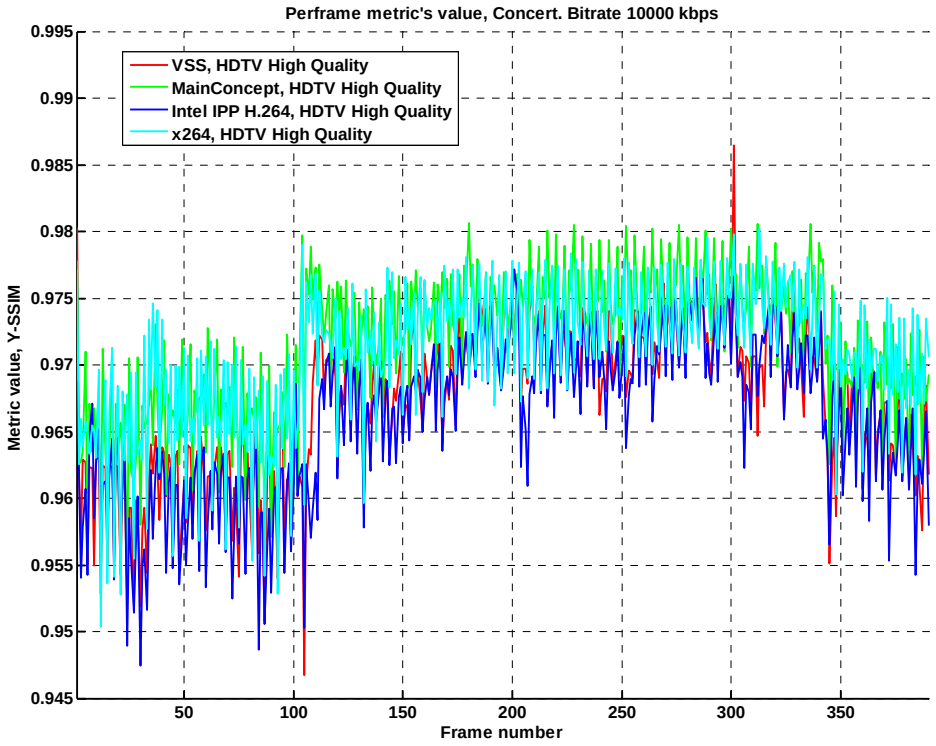


Figure 129. Per-frame quality. Usage area "HDTV", "Concert" sequence, 10 mbps

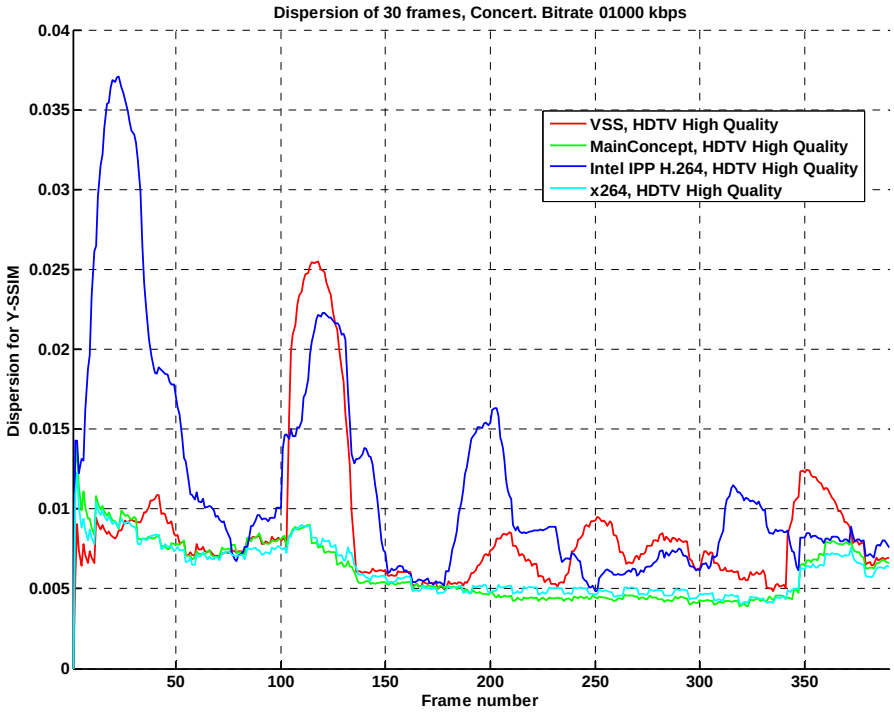


Figure 130. Quality dispersion (30 frames). Usage area "HDTV", "Concert" sequence, 1 mbps

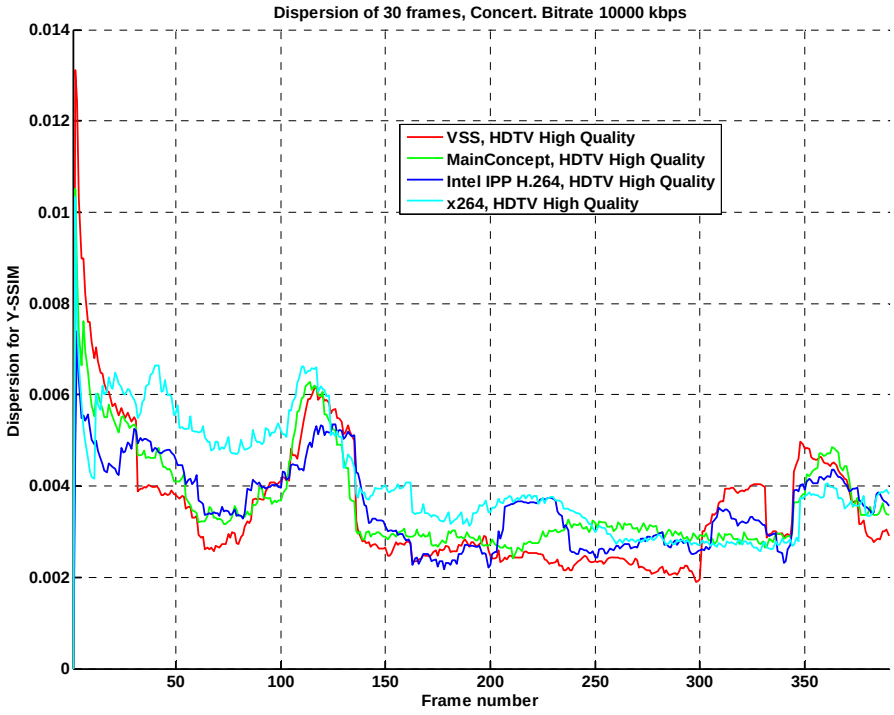


Figure 131. Quality dispersion (30 frames). Usage area "HDTV", "Concert" sequence, 10 kbps

Figure 128 – Figure 131 show per-frame quality and quality dispersion for Concert sequence at 1 and 10 Mbps.

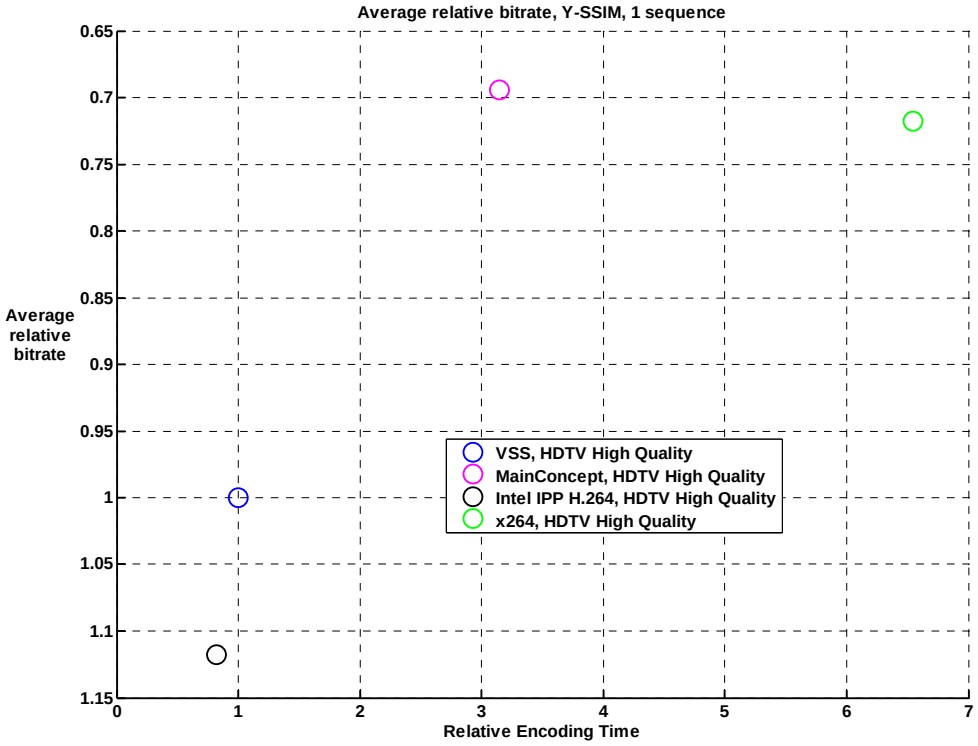


Figure 132. Relative bitrate/Relative time. Usage area "HDTV", "Concert" sequence, Y-SSIM.

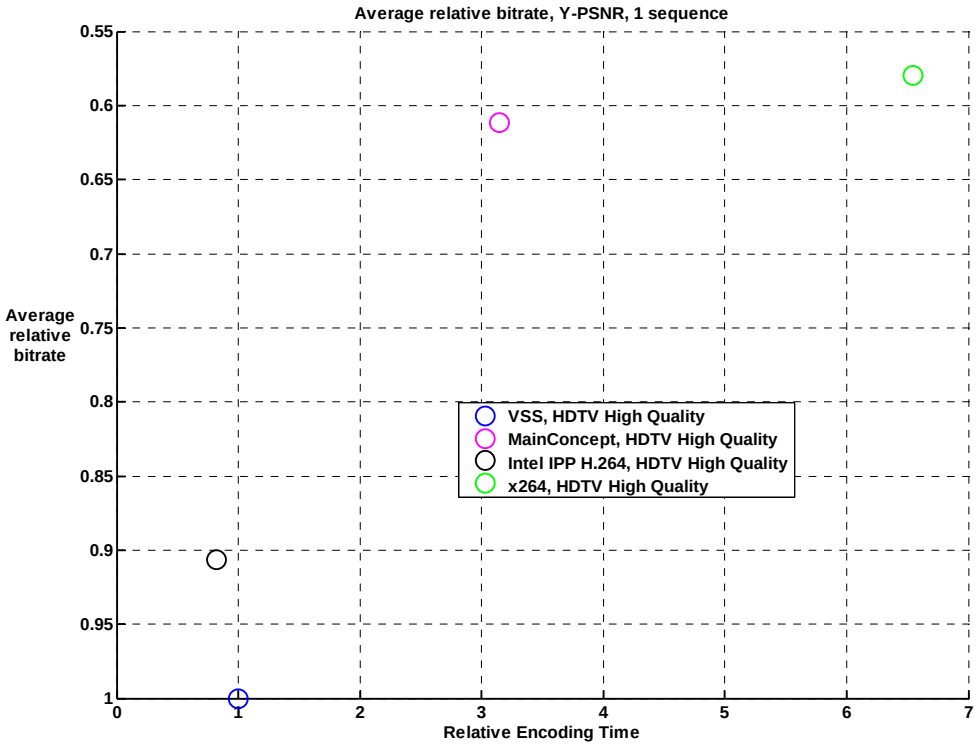


Figure 133. Relative bitrate/Relative time. Usage area "HDTV", "Concert" sequence, Y-PSNR.

Figure 132 and Figure 133 show Quality/Speed tradeoff according SSIM and PSNR measures accordingly.

VSS and Intel codecs are much faster than MainConcept and x264 codecs (main reason of this fact is that MainConcept and x264 use 2-pass encoding), so, those pairs are not comparable for this chart type.

MainConcept is approximately twice faster than x264 with very similar quality according to objective quality measures. This fact allows us to say that MainConcept codec is better than x264 codec for this type of application.

Speed of Intel IPP and VSS codecs are very close (Intel IPP codec is 18% faster). Different objective measures shows different results of codec's visual quality; that is why we can't with certainty say something about relatively quality of those codecs.

Figure 134. Bitrate/Quality. Usage area "HDTV", "Concert" sequence, "High Quality" preset, 3 mbps

Figure 134 shows per-frame quality of codecs VSS and MainConcept. Few slumps of quality in the beginning and peaks in the end of the sequence show, that quality of VSS codec varies bigger, than visual quality of MainConcept.

Table 11 and Table 12 show average bitrates (or file size) ratio of all codecs for SSIM and PSNR. The values in those tables are ration of bitrate for the same quality of codec in column and codec in row.

Table 11. Average bitrate ratio for the same quality. Usage area "HDTV". Y-SSIM. Bitrates app. 1-10 Mbps.

	VSS	MainConcept	Intel IPP	x264
VSS	100.0%	69.4%	111.8%	71.8%
MainConcept	144.0%	100.0%	165.8%	103.5%
Intel IPP	89.4%	60.3%	100.0%	62.2%
x264	139.4%	96.6%	160.8%	100.0%

Table 12. Average bitrate ratio for the same quality. Usage area "HDTV". Y-PSNR. Bitrates app. 1-10 Mbps.

	VSS	MainConcept	Intel IPP	x264
VSS	100.0%	61.1%	90.7%	58.0%
MainConcept	163.5%	100.0%	145.7%	93.9%
Intel IPP	110.3%	68.6%	100.0%	64.9%
x264	172.4%	106.5%	154.1%	100.0%

Conclusions

On the basis of carried out testing for «HDTV» type of application all codecs may be arranged in the following way:

1. MainConcept
2. x264
3. VSS
4. Intel H.264

Basing on our testing we conclude that, among all tested codecs, the best codecs for encoding HDTV content are codec from MainConcept and x264 codec by criterion of quality/speed ratio.

Common Results of 2006 Year Codecs

In this section we combined all obtained results into one table. Data from resulting tables for each type of application were used for its creation.

At first, data were averaged by presets for each type of application, and then they were averaged across types of application. As an averaging method we chose geometric mean of values. Leaders in each type of application and on average for all applications' type are marked with the red color.

Table 13 demonstrates obtained average bit rate **saving** results. Values on this figure are relative bitrate with equal quality (the lower is the better).

Table 14 shows average encoding for all tested codecs. Numbers in that table means relative encoding time, averaged among all sequences in preset. Same as relative quality, data were averaged by presets for each type of application, and then they were averaged across types of application. In every preset the longest preset is equal 100% all other encoding times are relative to this one.

Table 13. Testing results of 2006 year.
Average file size for the same quality.

	MainConcept	x264	VSS	DivX	Intel H.264
Videoconferences «High Quality»	53%	63%	79%	100%	
Videoconferences «High Speed»	58%	62%	76%	100%	91%
Videoconferences	**55%**	**62%**	**77%**	**100%**	**91%**
Movies «High speed»	78%	76%	105%	100%	107%
Movies «One pass»	77%	72%	96%	100%	n/a
Movies «Two passes»	100%	90%	n/a	n/a	n/a
Movies	**84%**	**79%**	**100%**	**100%**	**107%**
HDTV	69%	72%	100%		112%
HDTV	**69%**	**72%**	**100%**		**112%**
Total	***69%***	***71%***	***92%***	***100%***	***103%***

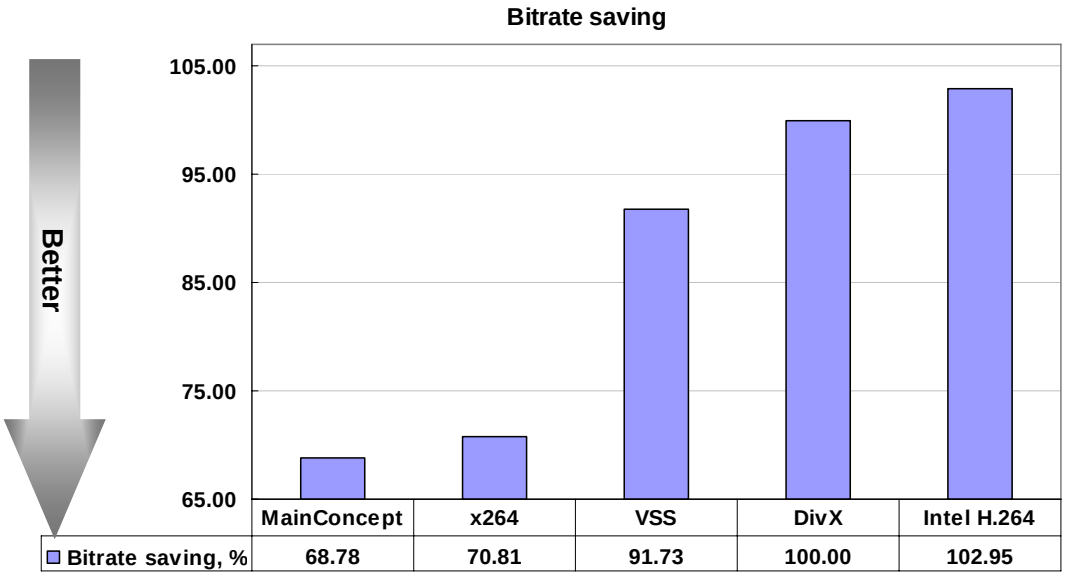


Figure 135. Average sequence size for the same quality for whole test set

Table 14. Testing results of 2006 year. Average encoding time.

	VSS	Intel H.264	MainConcept	DivX	x264
Videoconferences «High Quality»	88%	n/a	100%	91%	97%
Videoconferences «High Speed»	71%	74%	96%	100%	88%
Videoconferences	**80%**	**74%**	**98%**	**95%**	**92%**
Movies «High speed»	48%	56%	84%	84%	100%
Movies «One pass»	33%	n/a	64%	44%	100%
Movies «Two passes»	n/a	n/a	36%	n/a	100%
Movies	**40%**	**56%**	**61%**	**64%**	**100%**
HDTV	15%	13%	48%	n/a	100%
HDTV	**15%**	**13%**	**48%**	**n/a**	**100%**
Total	***45%***	***47%***	***69%***	***80%***	***97%***

Conclusions

- On the basis of the results for three types of application all tested codecs may be arranged in the following way:

  1. MainConcept
  2. x264
  3. VSS
  4. DivX (MPEG-4 ASP)
  5. Intel H.264

  It is necessary to observe that for each type of application different codecs show different effectiveness.

- On 2 from 3 field of usage the test set the leader by speed is Intel H.264 codec. Perhaps because of this codec from Intel showed low results by quality. But in average VSS and Intel H.264 codec are very close by encoding speed – VSS is slightly better.
- Leaders by quality are codec from MainConcept's codec and x264. MainConcept is leader in fields "Videoconferencing" and "HDTV", but difference with x264 is not significant.
- For "Videoconferences" type of application codecs of new H.264 standard are more applicable than DivX (MPEG-4 ASP standard).
- For "Movies" type of application DivX codec as a representative of MPEG-4 ASP standard showed quite competitive results comparing to codecs of the new standard.
- For "HDTV" type of application use of DivX codec is not possible due to technical reasons, while new standard's codecs show a wide range of encoding time and quality of encoded sequences.

Over-Years Codecs Comparison

During 3 years of conducting our comparison we have accumulated an interesting material regarding with codecs' performance. This time we have decided to combine all this material and to analyze performance of codecs of different years.

Since the first comparison we have changed hardware used for codecs' testing. To make it possible to compare codecs by speed we measured codecs' work speed on our present-day hardware. Only speed results were changed, quality results remained the same.

Table 15 contains cumulative information about codecs that took part in our H.264 comparisons for the last 3 years. By different mainly technical reasons some of the tested codecs were not included in this part of the comparison.

Table 15. Overall table of codecs, that were tested during H.264 comparisons

Codecs / Year	ATI	VSS	Intel	x264	DivX	Ateme	Moonlight	ArcSoft	Elecard	Main Concept	Fraunhoffer IIS	Mpegable AVC
2004												
2005												
2006												

This codec did not take part in comparison of specified year

This codec took part in comparison in specified year, but due to technical reasons was not included in Over-Years Codecs Comparison

The version of codec for specified year is included in Over-Years Codecs Comparison

Below are some graphs from this part of codecs' comparison. Mainly Relative Bitrate/Relative Time graphs are used in this part. More detailed information about these graphs one can read in «Appendix 5. Averaging Methods Description».

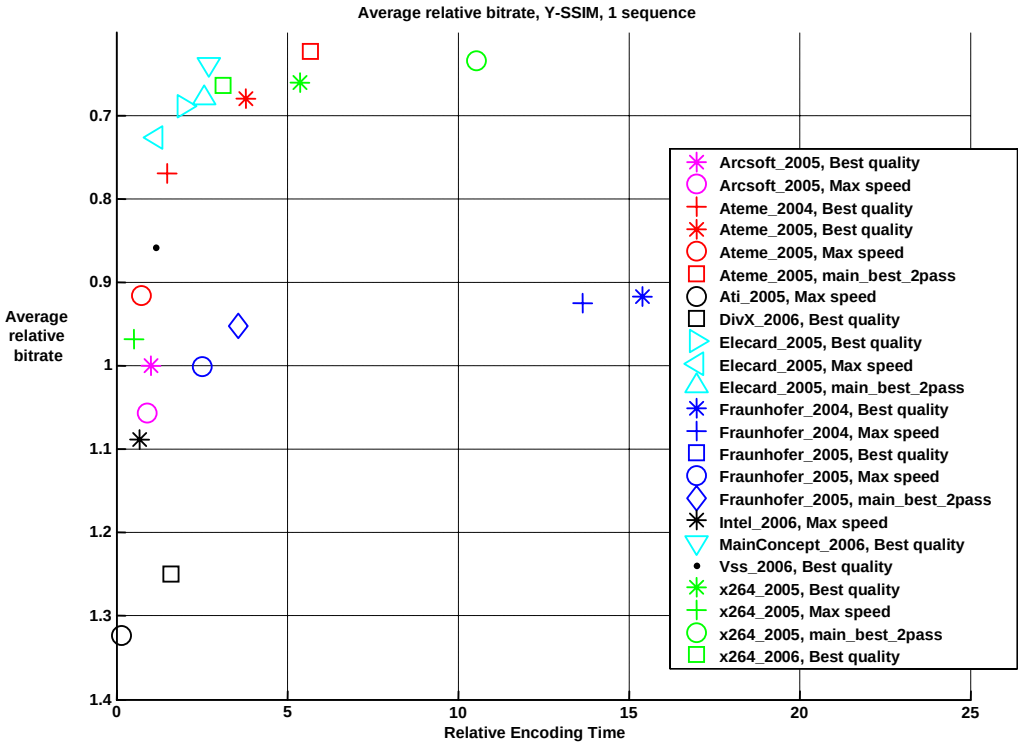


Figure 136. Relative Bitrate/Relative Time. "Foreman" sequence, year 2004, 2005 and 2006 codecs

Figure 136 shows codecs' position for "Foreman" sequence. Codec from ArcSoft company from comparison of year 2005 was used as a reference.

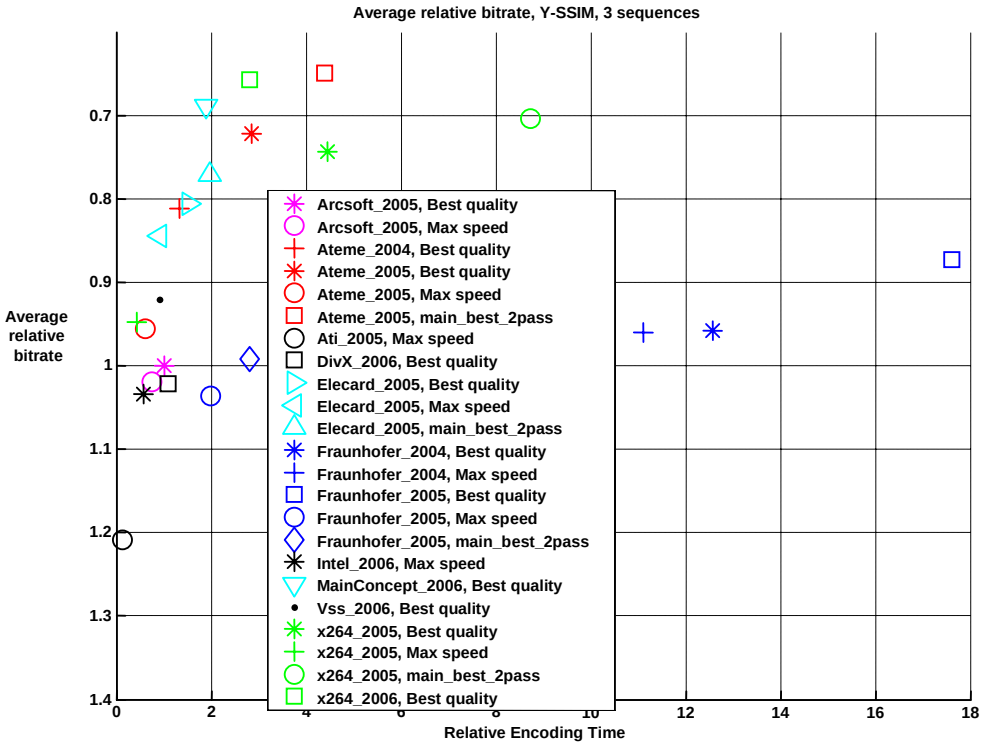


Figure 137. Relative Bitrate/Relative Time. “Foreman”, “Battle” and “Matrix” sequences – average values, year 2004, 2005 and 2006 codecs

This graph is an average by three out of four re-measured sequences. Unfortunately it is impossible to accumulate on one graph the data for all codecs and for all sequences due to DivX codec’s errors during encoding “Concert” sequence.

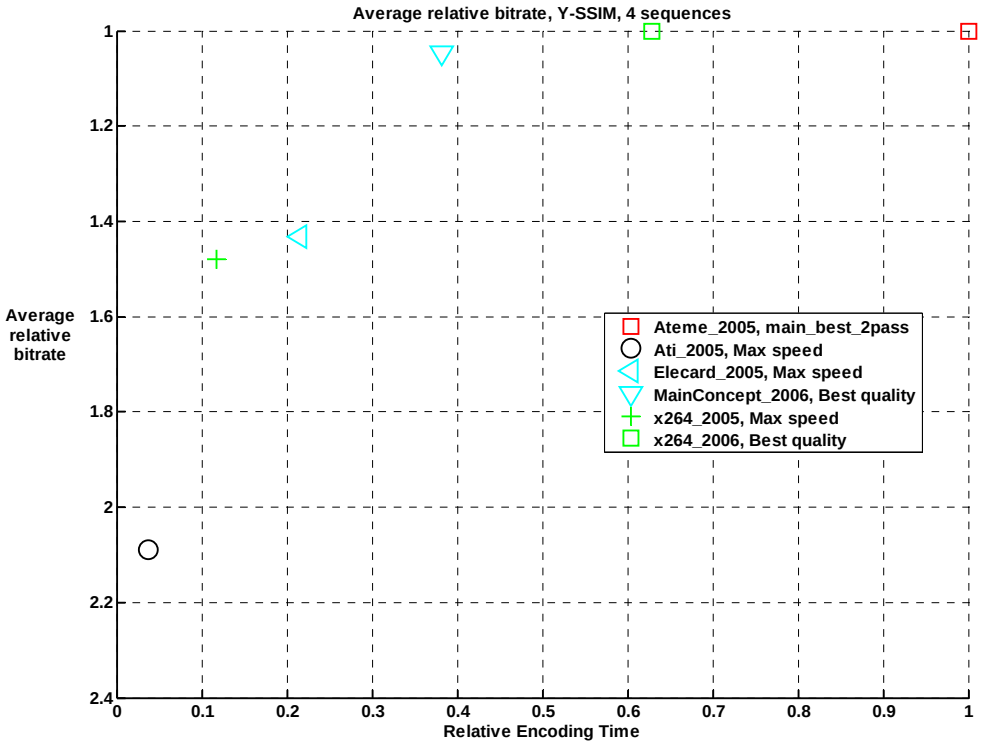


Figure 138. Extract for Relative bitrate/Relative time graph. "Foreman", "Battle", "Matrix" and "Concert" sequences, 2004, 2005 and 2006 years codecs

This graph shows an extract, i.e. optimal codec and presets in term of speed/quality ratio; other codecs showed lower speed or resulted in worse quality than the chosen codecs on four sequences on average.

Common Conclusions for Over-Years Codecs Comparison

In spite of the field's development in general, codecs' quality is not been improved quickly, i.e. previous years' codecs compete with new implementations as equals. It means both approaching to limits of the new standard and that due to the standard's complexity it is very difficult to find the best codec of any kind.

Appendix 1. Measurements for Apple and Sorenson Videocodecs

Codecs from Apple Computers and Sorenson Media companies did not take part in our main comparison due to the technical reasons, but their results may be analyzed in this appendix.

Both codecs took part in «High Quality» category because of time measuring impossibility for codec from Apple: coding process was performed by exterior specialist (Charles Wiltgen) and some internal problems with Sorenson's codec measurements.

Videoconferences

Let's consider codecs behavior on videoconferences usage area. Graphs below show RD-curves for Y-PSNR and Y-SSIM measures.

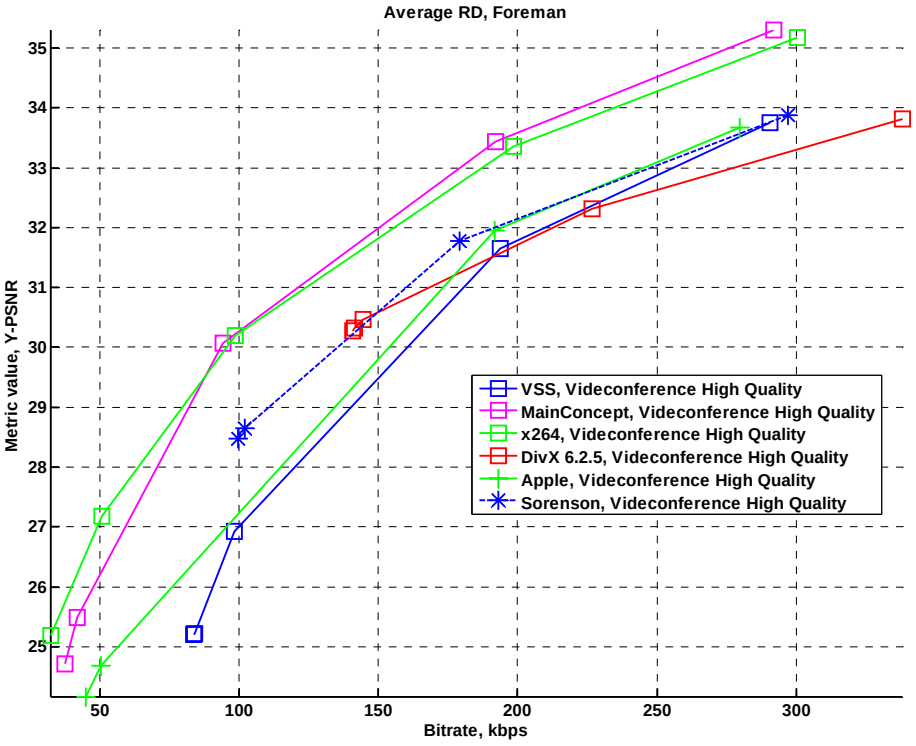


Figure 139. Sequence "Foreman". "High Quality" preset. Y-PSNR

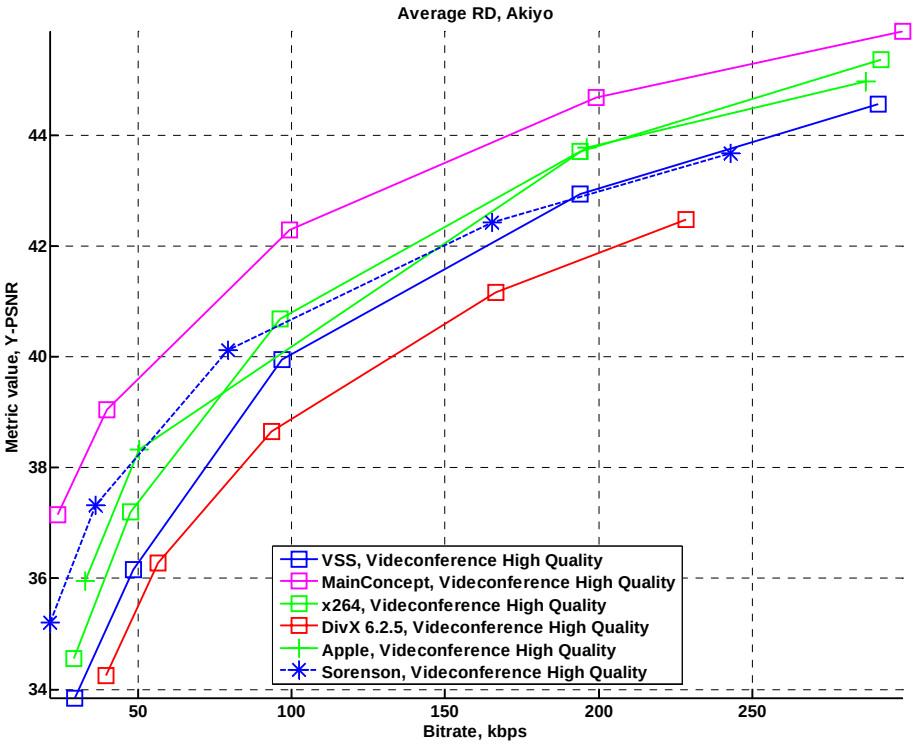


Figure 140. Sequence "Akiyo". "High Quality" preset. Y-PSNR

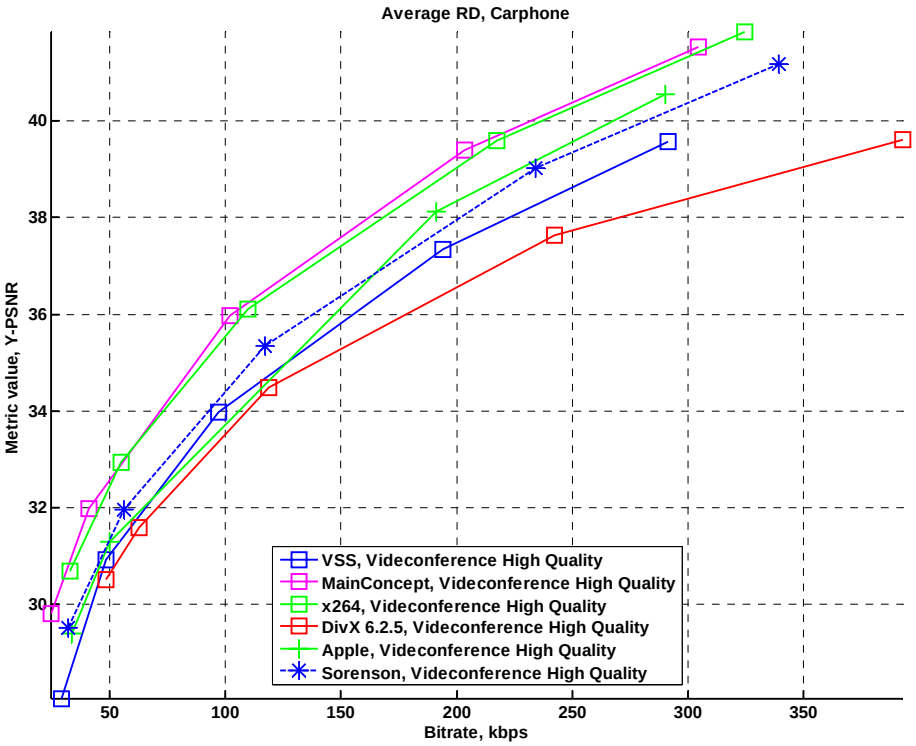


Figure 141. Sequence "Carphone". "High Quality" preset. Y-PSNR

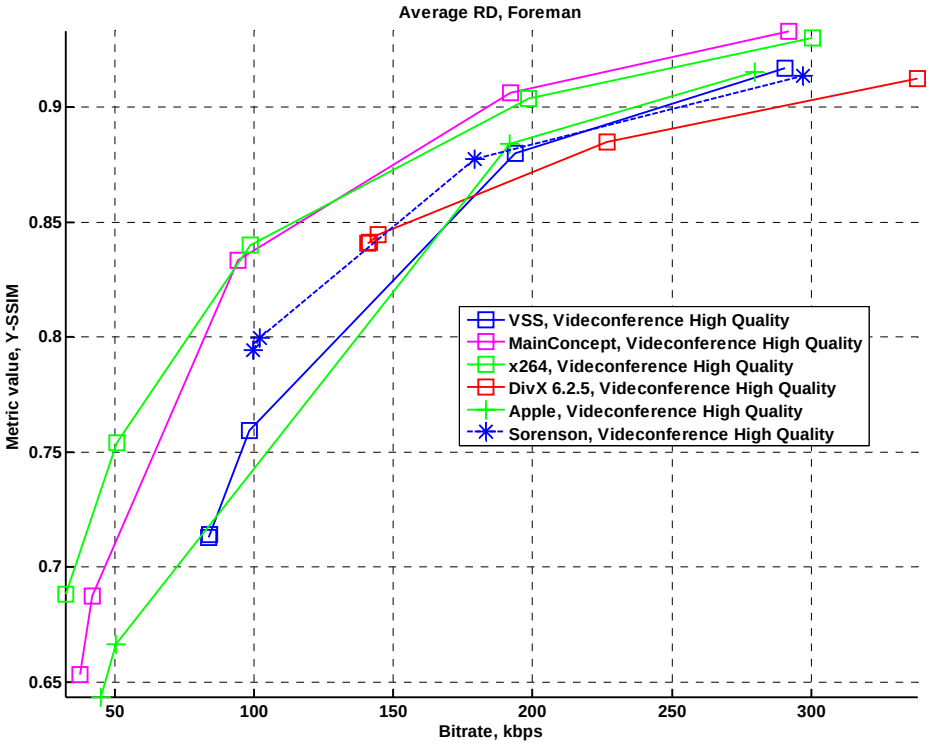


Figure 142. Sequence "Foreman". "High Quality" preset. Y-SSIM

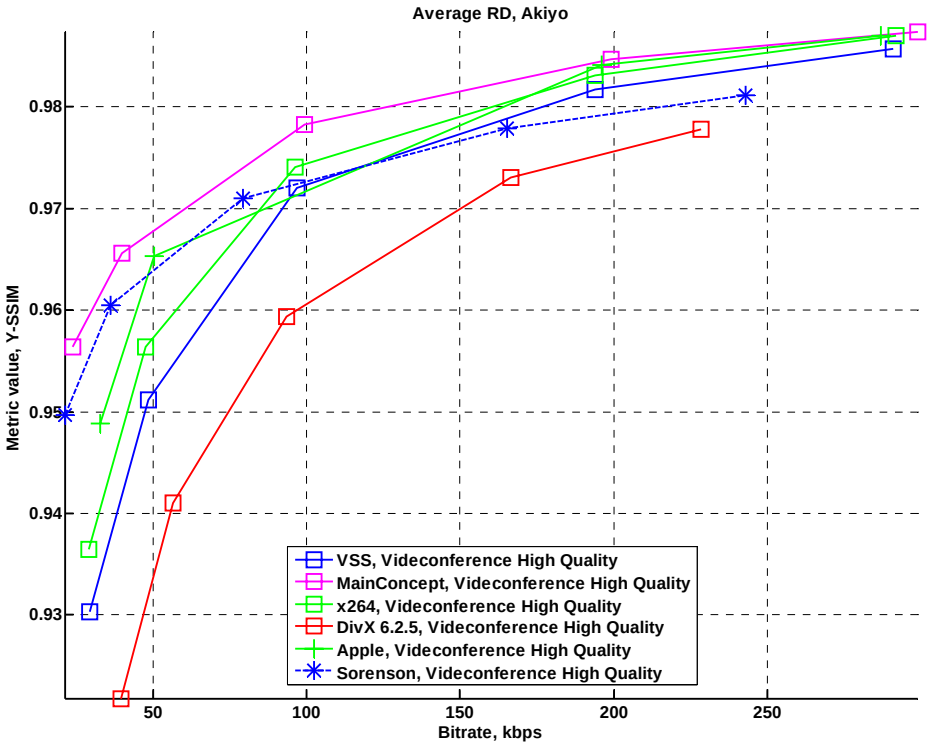


Figure 143. Sequence "Akiyo". "High Quality" preset. Y-SSIM

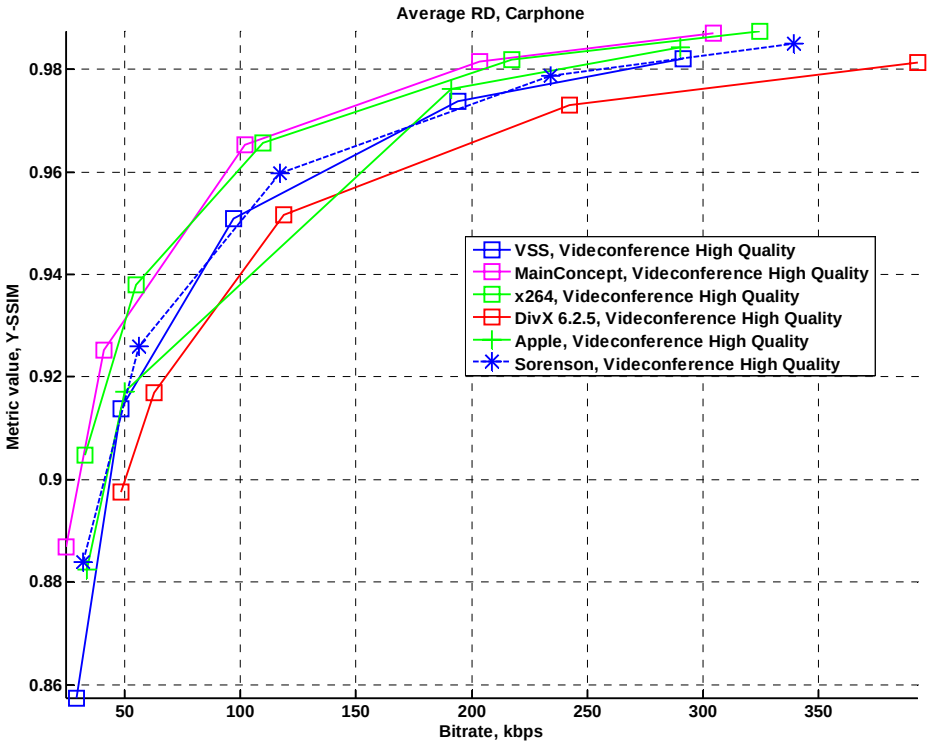


Figure 144. Sequence “Carphone”. “High Quality” preset. Y-SSIM

As one can see codecs from Apple and Sorenson has a medium quality comparing to other codecs – at average they are slightly better than VSS codec.

Now let’s consider bitrate handling for the codecs.

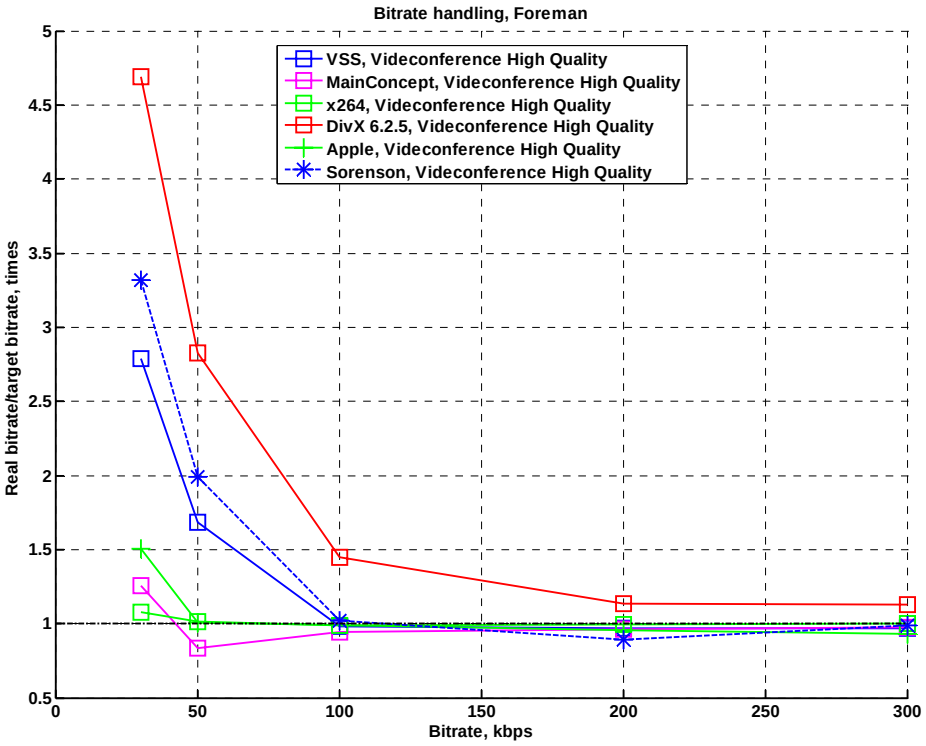


Figure 145. Sequence “Foreman”. “High Quality” preset. Bitrate handling

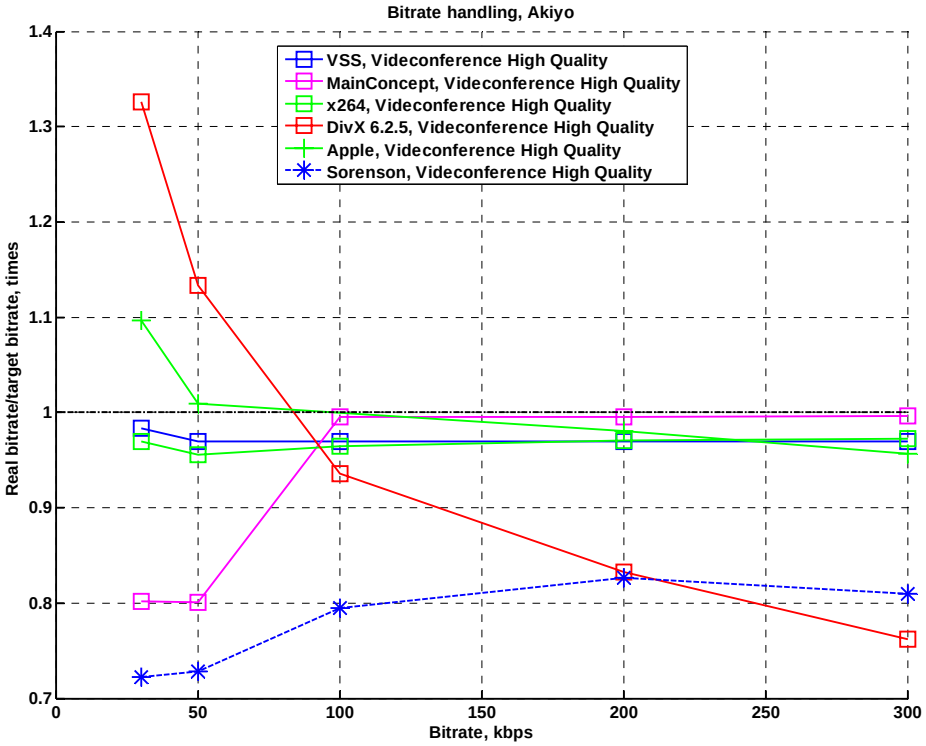


Figure 146. Sequence “Akiyo”. “High Quality” preset. Bitrate handling

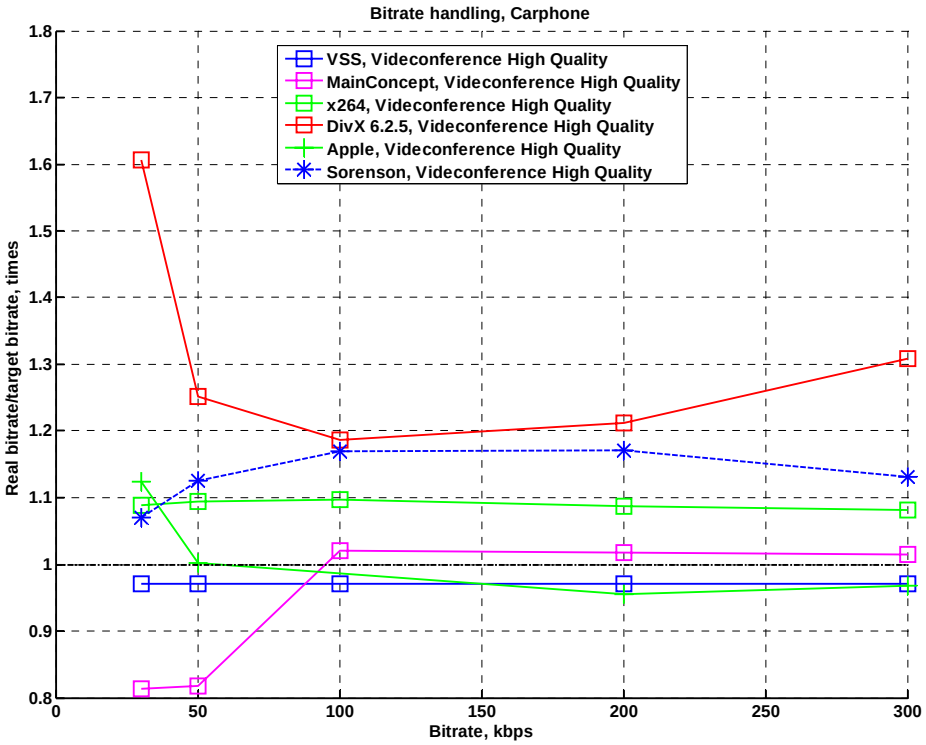


Figure 147. Sequence “Carphone”. “High Quality” preset. Bitrate handling

As one can see Apple codec has a very good bitrate handling while Sorenson has some problems, like strong increasing low bitrates for sequence “Foreman”, stable bitrate lowering or sequence “Akiyo” and stable bitrate increasing for sequence “Carphone”.

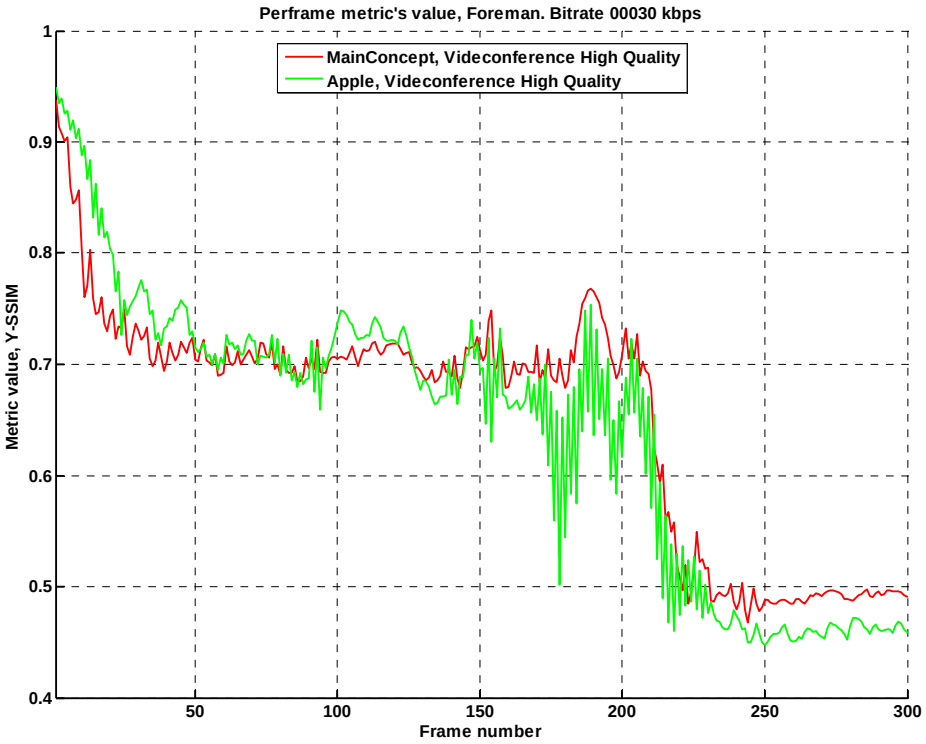


Figure 148. Sequence “Foreman”. “High Quality” preset. Per-frame quality measurement. 30 kbps

Apple codec has much stronger quality fluctuations at low bitrates on sequence “Foreman” comparing to MainConcept codec.

Movies

Now lets analyze the situation for usage are “Movies”.

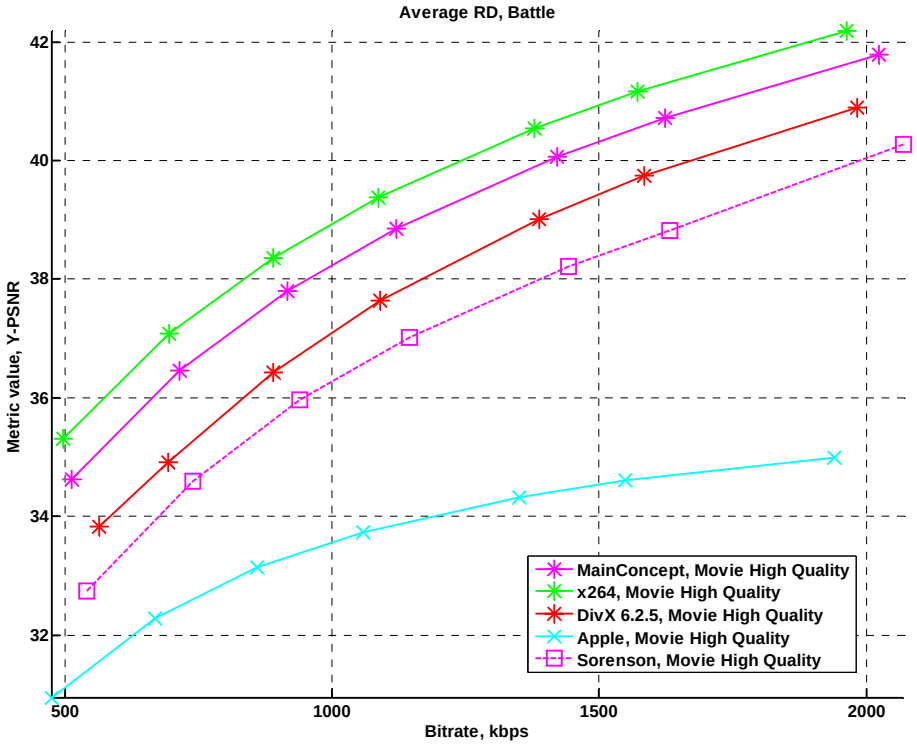


Figure 149. Bitrate/Quality. Sequence “Battle”. “High Quality” preset. Y-PSNR

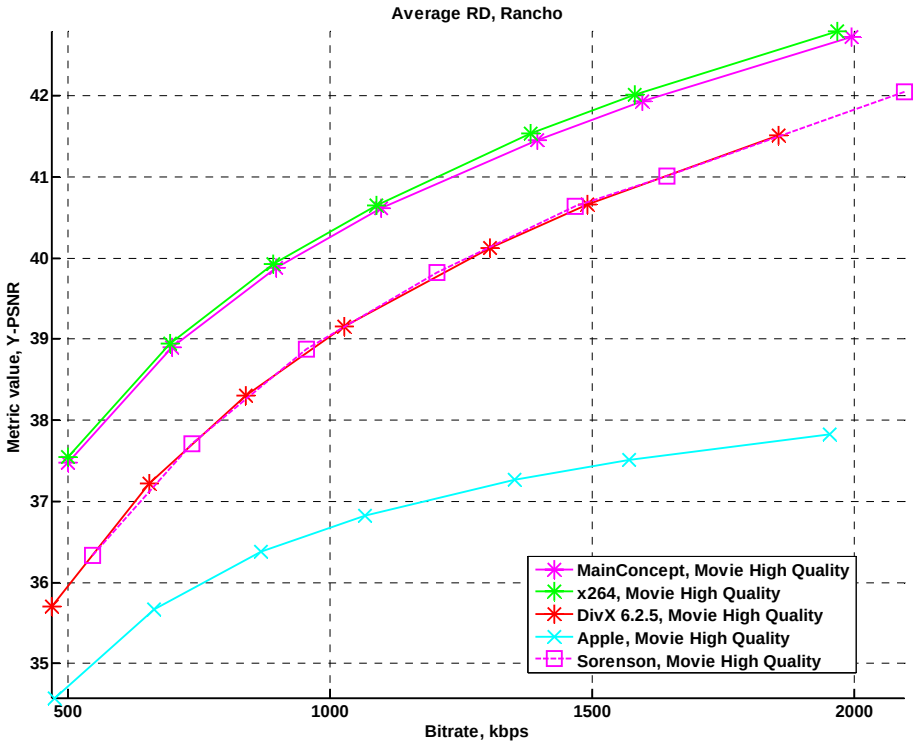


Figure 150. Bitrate/Quality. Sequence "Rancho". "High Quality" preset. Y-PSNR

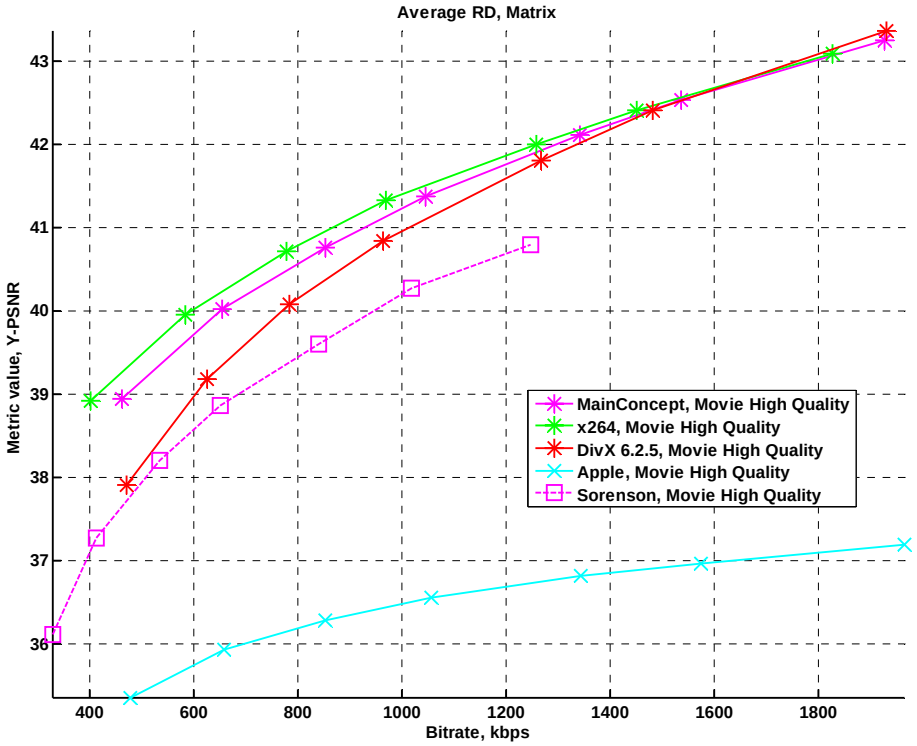


Figure 151. Bitrate/Quality. Sequence "Matrix". "High Quality" preset. Y-PSNR

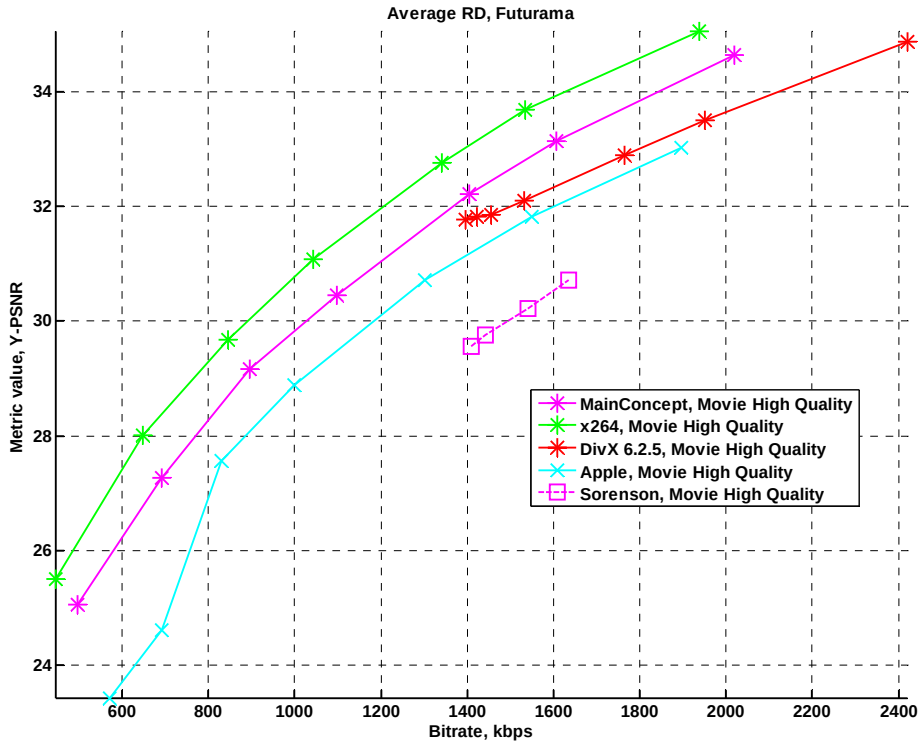


Figure 152. Bitrate/Quality. Sequence "Futurama". "High Quality" preset. Y-PSNR

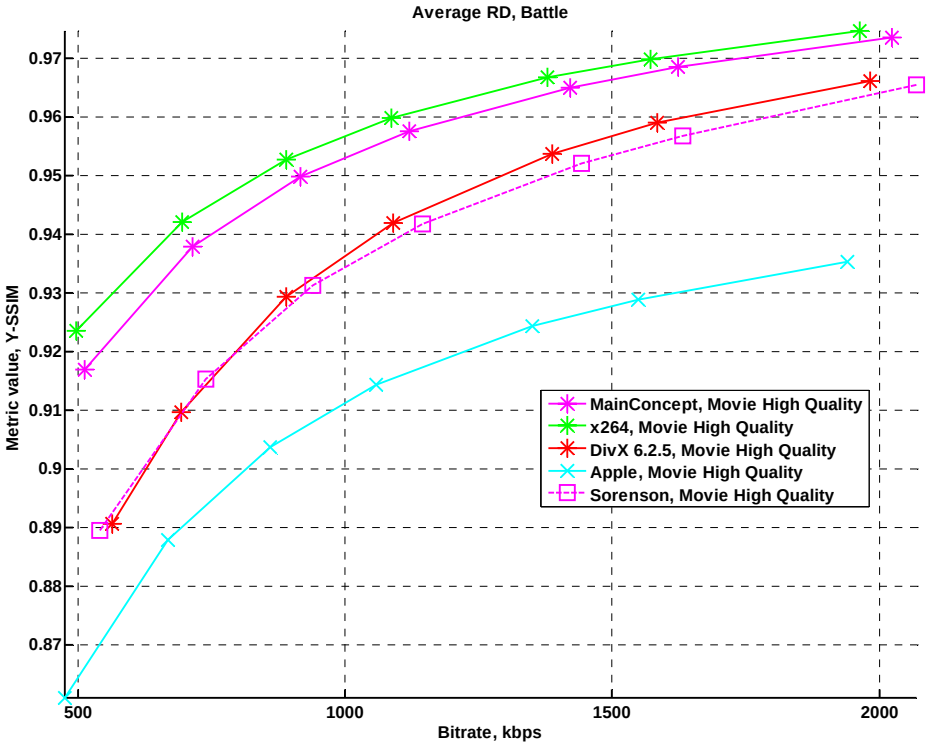


Figure 153. Bitrate/Quality. Sequence "Battle". "High Quality" preset. Y-SSIM

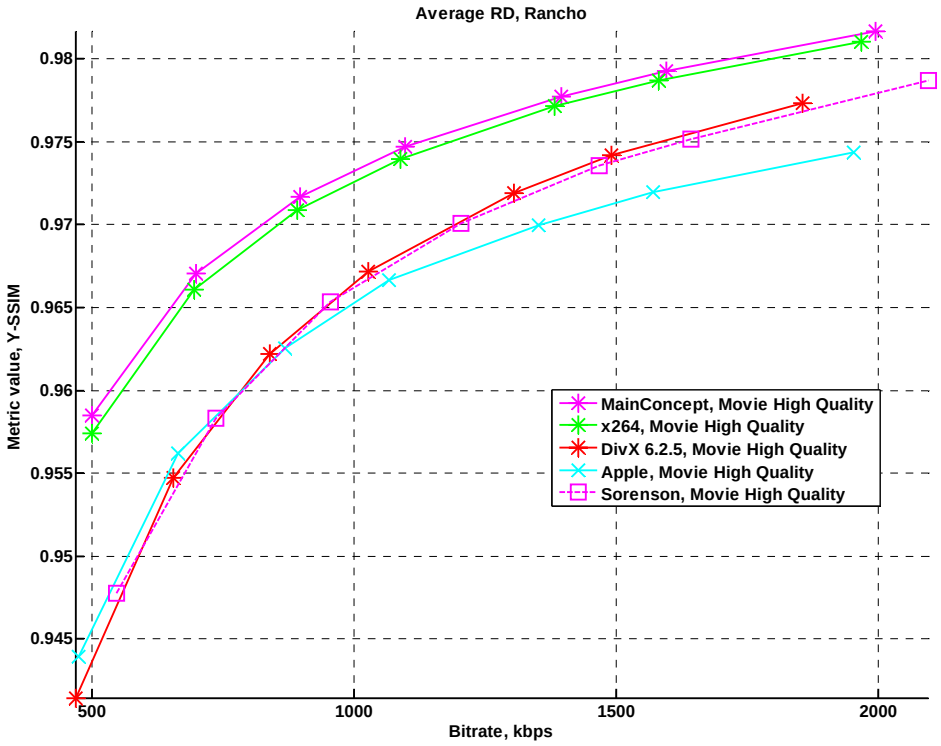


Figure 154. Bitrate/Quality. Sequence "Rancho". "High Quality" preset. Y-SSIM

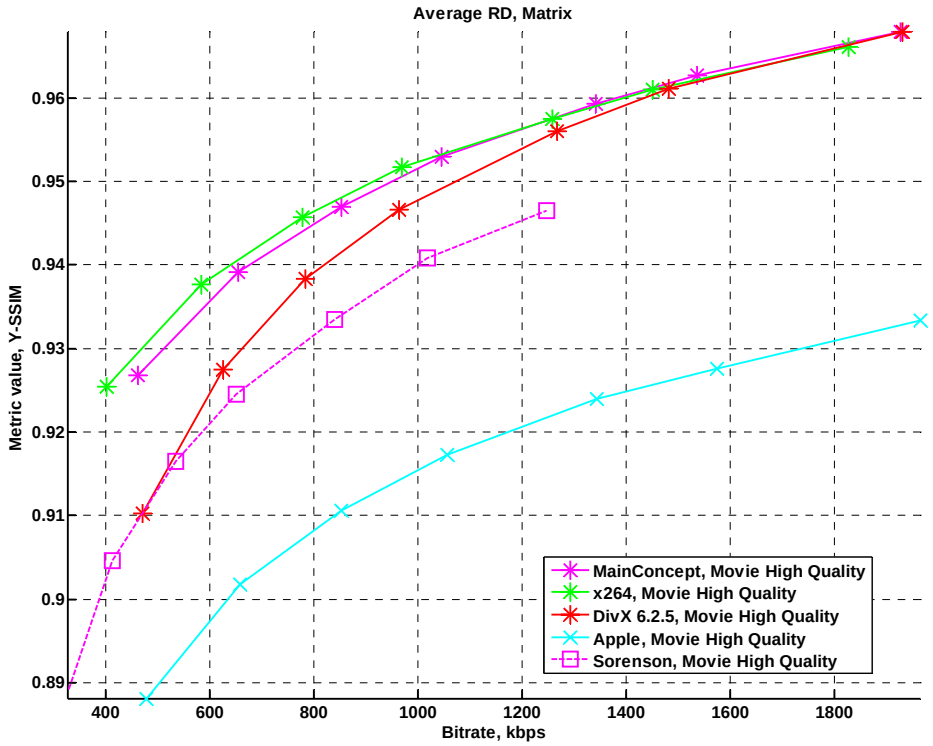


Figure 155. Bitrate/Quality. Sequence "Matrix". "High Quality" preset. Y-SSIM

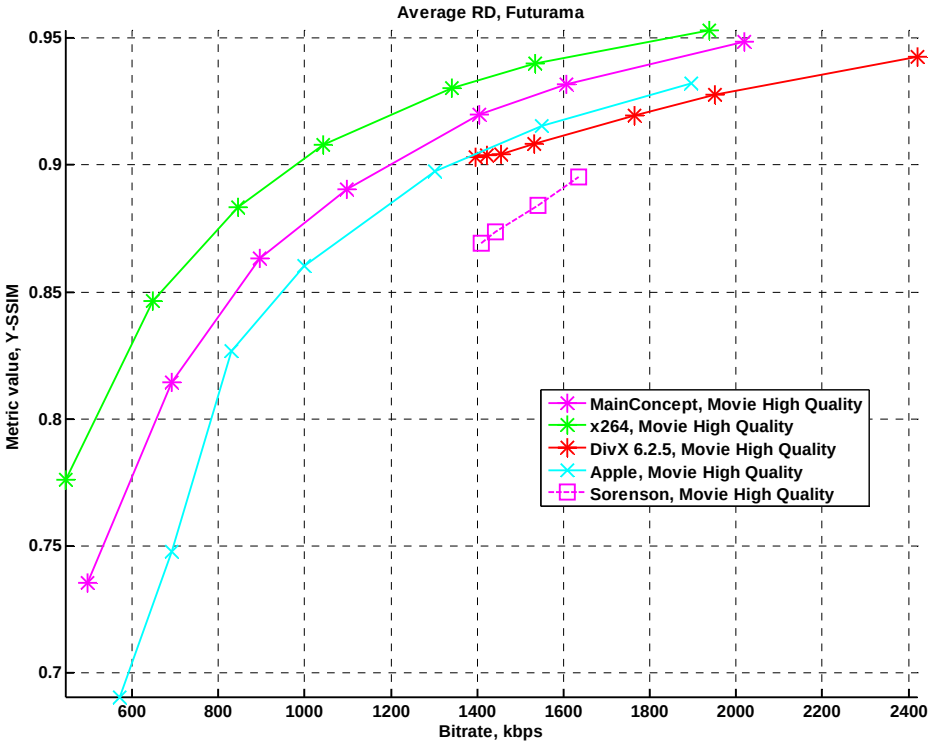


Figure 156. Bitrate/Quality. Sequence “Futurama”. “High Quality” preset. Y-SSIM

The quality of Apple and Sorenson codecs for the usage area “Movies” are rather low. If to use SSIM metric quality for Apple codec is slightly better comparing to other codecs, but is almost always is the worst. For Sorenson codec sequence “Futurama” was very difficult to compress – this codec shows the worst quality comparing to other codecs on this sequence.

Now let’s analyze the situation with Apple codec

Below is the typical situation for sequence from «Movies» type of application.

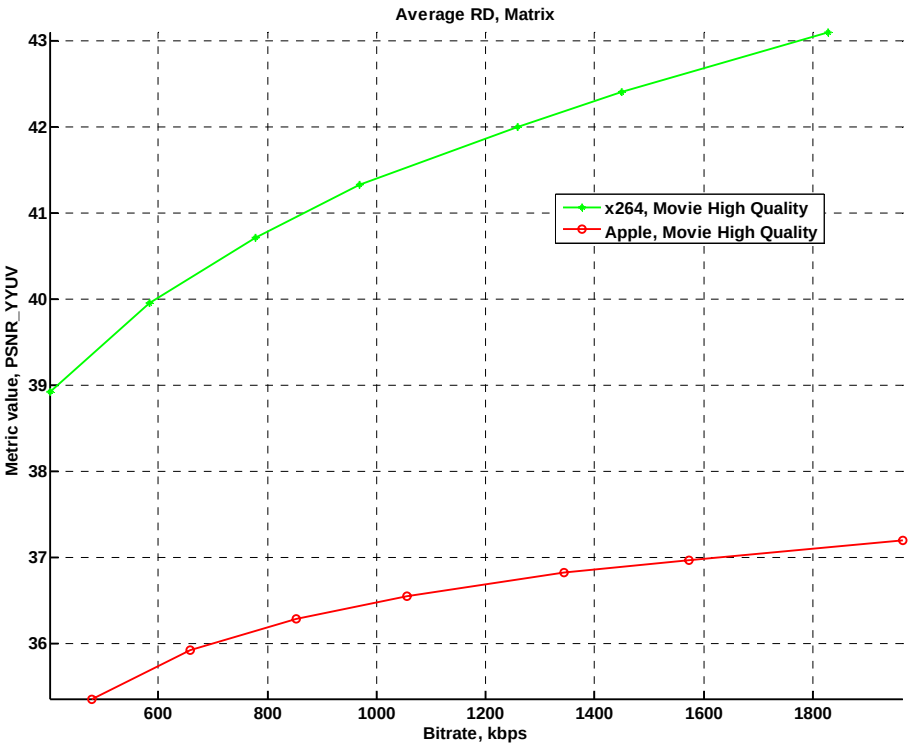


Figure 157. Bitrate/Quality. Sequence “Matrix”. “High Quality” preset. Y-PSNR

But the results significantly differ when MSU Brightness Independent PSNR measure is used which means that codec from Apple shifts brightness.

http://www.compression.ru/video/quality_measure/metric_plugins/bi-psnr_en.htm

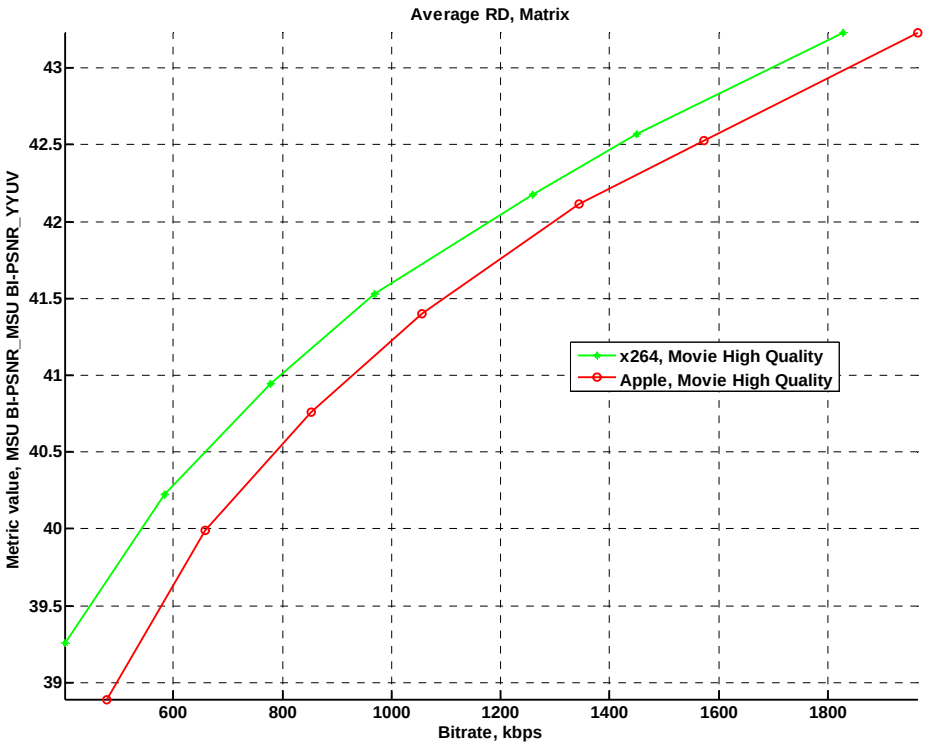


Figure 158. Bitrate/Quality. Sequence "Matrix". "High Quality" preset. Both codecs were measured using Y-BI-PSNR

Now let's consider bitrate handling.

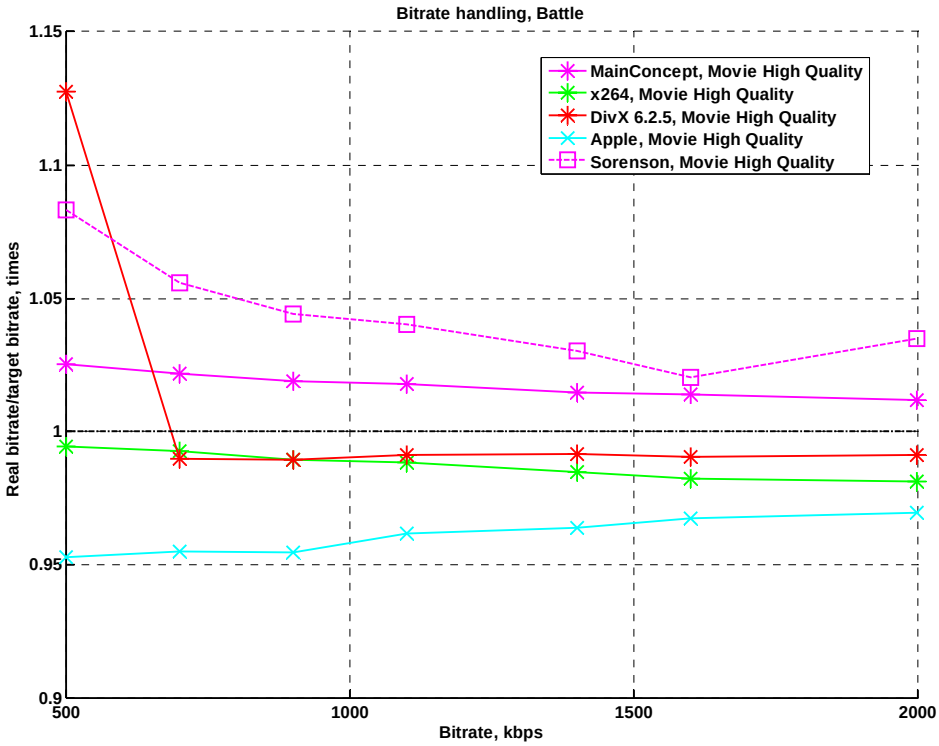


Figure 159. Bitrate handling. Sequence "Battle". "High Quality" preset

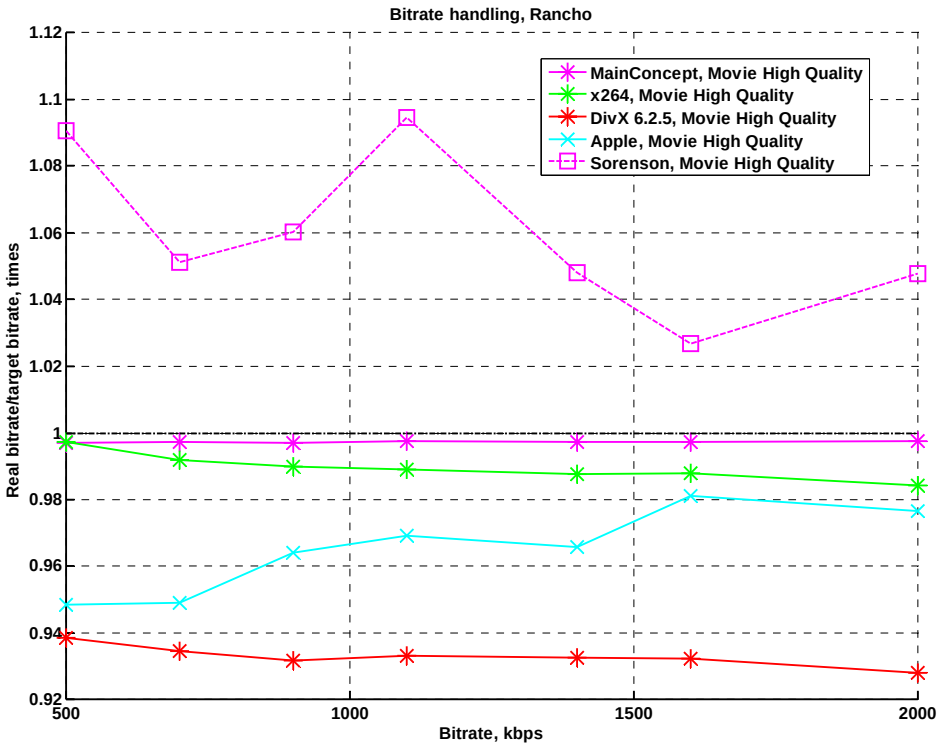


Figure 160. Bitrate handling. Sequence “Rancho”. “High Quality” preset

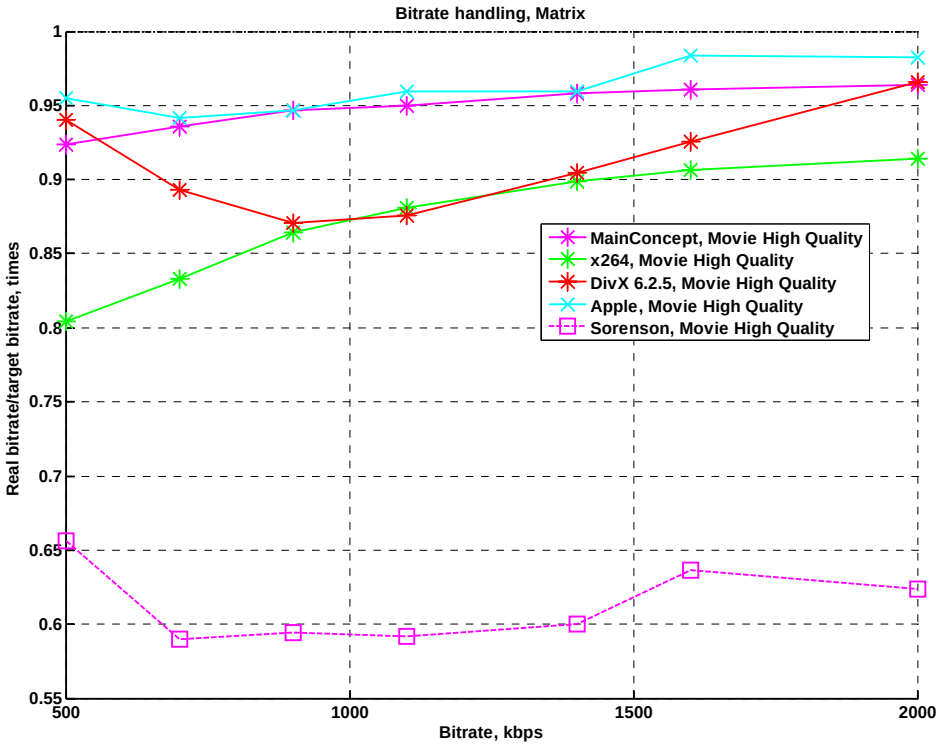


Figure 161. Bitrate handling. Sequence “Matrix”. “High Quality” preset

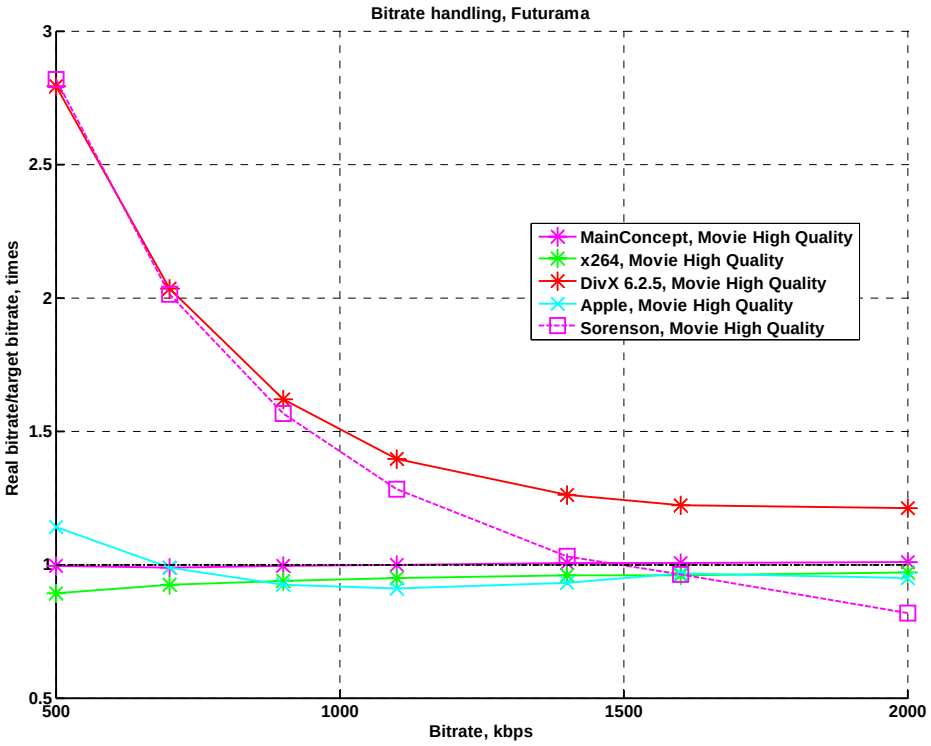


Figure 162. Bitrate handling. Sequence "Futurama". "High Quality" preset

Conclusions

- Codecs from Apple and Sorenson show average quality compared with other codecs and are not leaders in their spheres.
- Codec from Apple shows low quality on some types of sequences («Movies») when it is evaluated using measures like Y-PSNR; this is explained by brightness shift introduced by this codec. Yet using objective measure that is independent to brightness shifts (MSU BI-PSNR), quality of codec from Apple becomes comparable with others – see Figure 157 and Figure 158.
- Thus with inclusion of codecs from Apple and Sorenson leading positions of x264 codec and codec from MainConcept remains unshakable.
- Bitrate handling for Sorenson codec is quite bad and for Apple is medium.

Appendix 2. DivX Additional Results

During DivX preset selecting for main comparison we have made many additional measurements. Probably, this information can be useful for codec's developers.

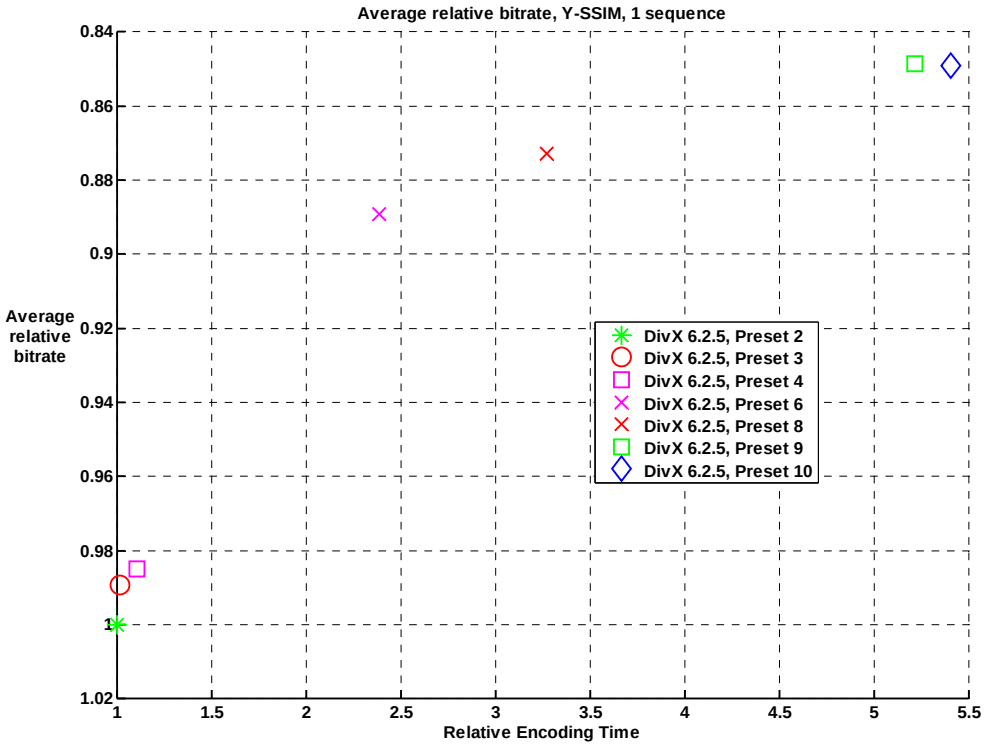


Figure 163. Relative bitrate/Relative time. Usage area "Movies", "Battle" sequence, Y-SSIM.

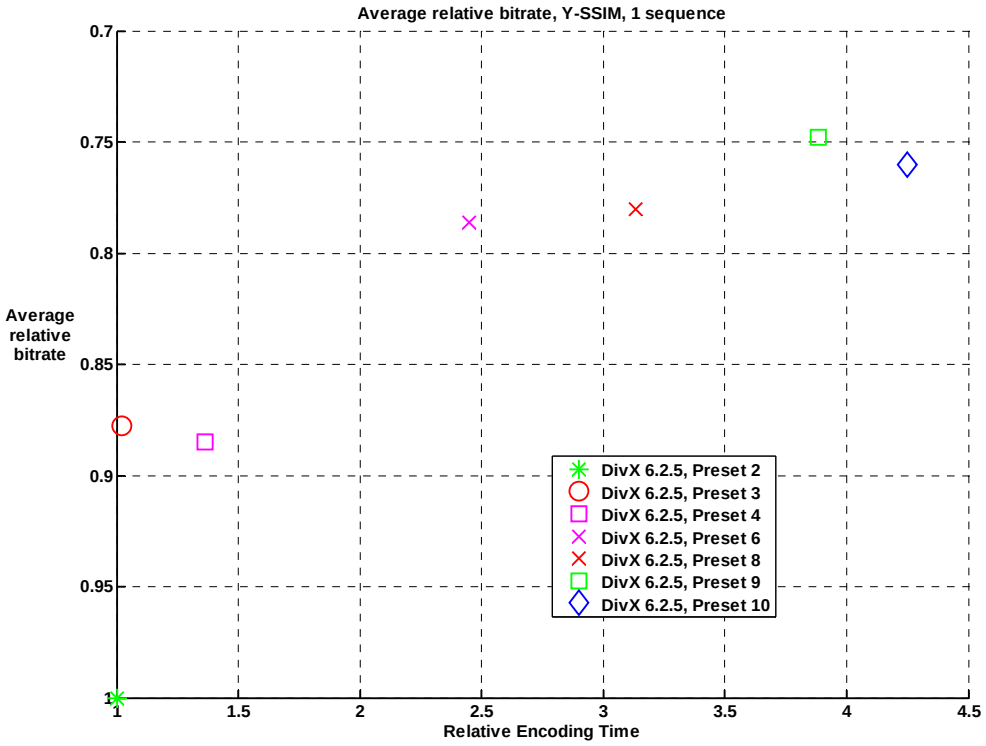


Figure 164. Relative bitrate/Relative time. Usage area “Movies”, “Rancho” sequence, Y-SSIM.

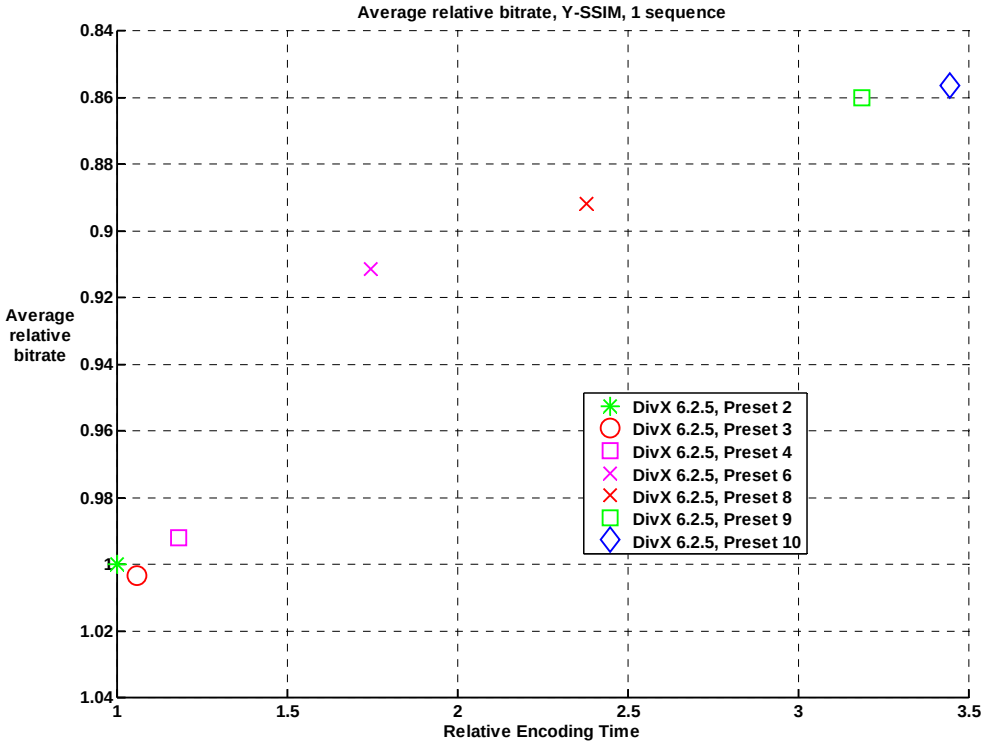


Figure 165. Relative bitrate/Relative time. Usage area “Movies”, “Matrix” sequence, Y-SSIM.

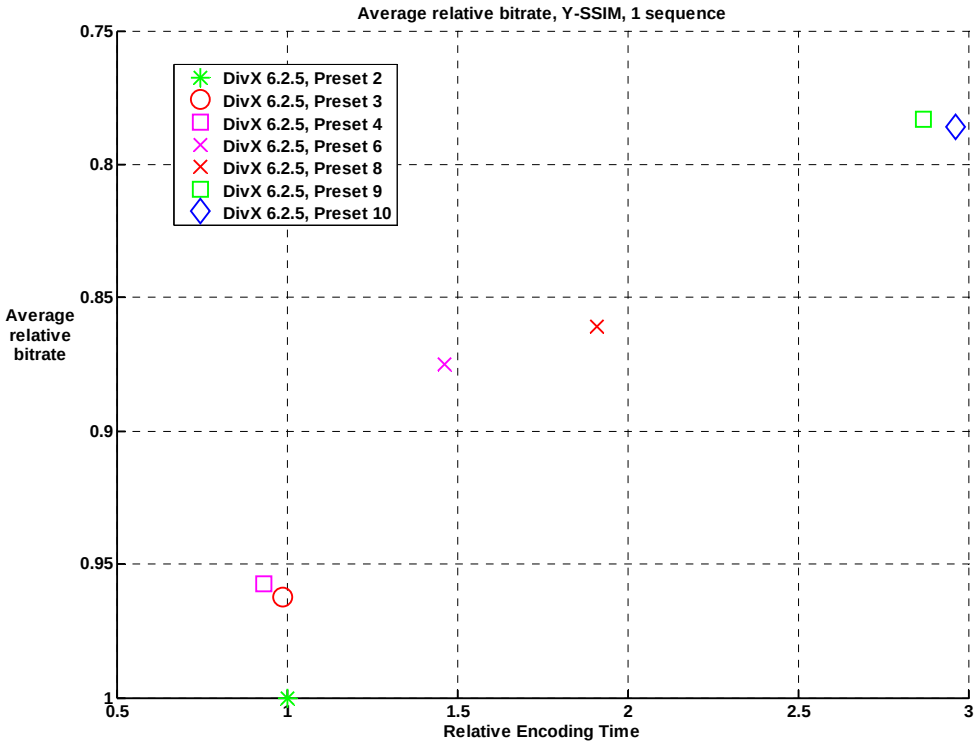


Figure 166. Relative bitrate/Relative time. Usage area "Movies", "Futurama" sequence, Y-SSIM.

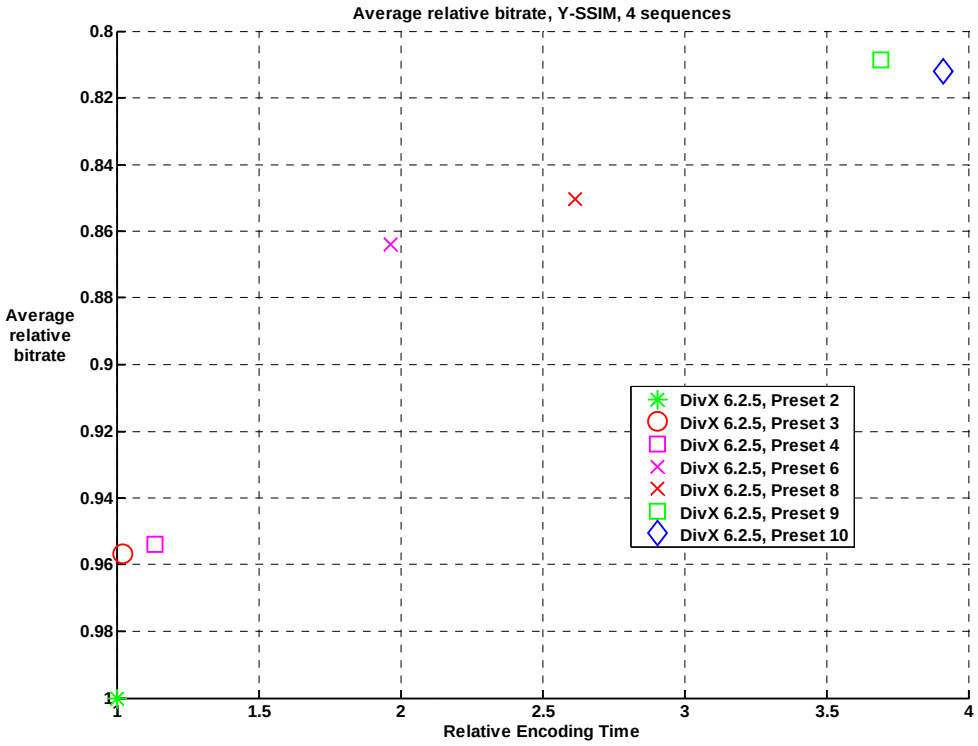


Figure 167. Relative bitrate/Relative time. Usage area "Movies", all sequences, Y-SSIM.

Figure 163 – Figure 166 shows Quality/Speed tradeoff of number of DivX presets for sequences from “Movies” type of application, Figure 167 – average results for all sequences.

In whole situation with new “presets” of DivX is rather good – more slow presets show better quality forming rather continues Speed-Quality curve.

One can separate all presets into 3 groups:

- Presets 2, 3, 4. Encoding speed app. 30-40 fps for SD sequences. Lowest quality comparing to other presets.
- Presets 6, 8. Encoding speed app. 25-15 fps for SD sequences. These presets save approximately 10% of bitrate comparing to first group presets.
- Presets 9, 10. Encoding speed app. 15-10 fps for SD sequences. They save approximately 15% of bitrate for the same quality.

Appendix 3. Test Set of Video Sequences

Videoconference Sequences

Foreman

Sequence title	foreman
Resolution	352x288
Number of frames	300
Color space	YV12
Frames per second	30
Source	Uncompressed (standard sequence), progressive

Figure 168. Frame 77

Figure 169. Frame 258

This is one of the most famous sequences. It represents a face with very rich mimic. Motion is not very intensive here, but on the other hand it is disordered, not forward. Intricate character of motion creates problems for the motion compensation process. In addition camera is shaking that makes the image unsteady. In the end of the sequence camera suddenly turns to the building site and there follows an almost motionless scene. So this sequence also shows codec's behavior on a static scene after intensive motion.

Akiyo

Sequence title	akiyo
Resolution	352x288
Number of frames	300
Color space	YV12
Frames per second	25
Source	Standard sequence, progressive

Figure 170. Frame 1

Akiyo is typical videoconferencing sequence: static background and talking speaker at foreground, slow speaker movement, no scene change.

Carphone

Sequence title	carphone
Resolution	176x144
Number of frames	382
Color space	YV12
Frames per second	25
Source	Standard sequence, progressive

Figure 171. Frame 319

Carphone is typical videoconferencing sequence: slowly changing foreground including typical camera shaking, speaking men at foreground. Movements of the men are rather intensive because of fast gesticulation.

Movie Sequences

Battle

Sequence title	battle
Resolution	704x288
Number of frames	1599
Color space	YV12
Frames per second	24
Source	MPEG-2 (DVD), FlaskMPEG deinterlace

Figure 172. Frame 839

This sequence is a fragment of the “Terminator-2” movie, which represents its very beginning. In terms of compression this sequence is the most difficult one among all other sequences that took part in the testing. That is because of three main reasons: constant brightness changes (explosions and laser flashes, see the picture above), very quick motion and frequent changes of the scene that make codecs often compress frames as I-frames.

Rancho

Sequence title	rancho
Resolution	704x288
Number of frames	1237
Color space	YV12
Frames per second	24
Source	MPEG-2 (DVD), FlaskMPEG deinterlace

Figure 173. Frame 570

This sequence is a fragment of the “Terminator-2” movie. Movements inside the scenes are rather smooth, but there are number of abrupt scene changes.

Futurama

Sequence title	futurama
Resolution	720x576
Number of frames	292
Color space	YV12
Frames per second	25
Source	MPEG-2 (DVD), progressive

Figure 174. Frame 262

This sequence is a fragment of “Futurama” cartoon film (first pictures). This is a classical representative of cartoon films: sketchy movement, great number of monochrome regions with abrupt borders between them. Previously this sequence was compressed in MPEG-2 with rather low bitrate.

Matrix

Sequence title	matrix
Resolution	720x416
Number of frames	239
Color space	YV12
Frames per second	25
Source	MPEG-2 (DVD), Smart Deinterlace

Figure 175. Frame 226

This sequence is a fragment of ”Matrix” movie. Relatively simple movement, quite dim colors and small resolution allows codec to treat this sequence in rather simple way.

HDTV Sequences

Concert

Sequence title	concert
Resolution	1664x1088
Number of frames	390
Color space	YV12
Frames per second	25
Source	MPEG-2 (HDTV broadcast), Smart Deinterlace

Figure 176. Frame 128

This sequence is a part of HDTV broadcast of symphonic orchestra concert. Sequence's spatial resolution is very high. At the same time motion is rather simple and sometimes it completely disappears. There are two scene changes in this sequence.

Appendix 4. Tested Codecs

DivX 6.2.5

- This is a VfW (Video for Windows) codec
- Compression was performed using VirtualDub 1.6.10 video processing program.
- Evaluation version of codec works for 15 days
- There were no presets from developers. All tests were performed using “Home Theater Profile”
- At first all “Encoding presets” from 0 to 10 were measured. Then the closest to the given speed borders presets were chosen as presets for measurements:
  - Preset 10 for “Videoconferences” type of application, “High Quality”
  - Preset 5 for “Videoconferences” type of application, “High Speed”
  - Preset 10 for “Movies” type of application, “High Quality”
  - Preset 8 for “Movies” type of application, “High Speed”

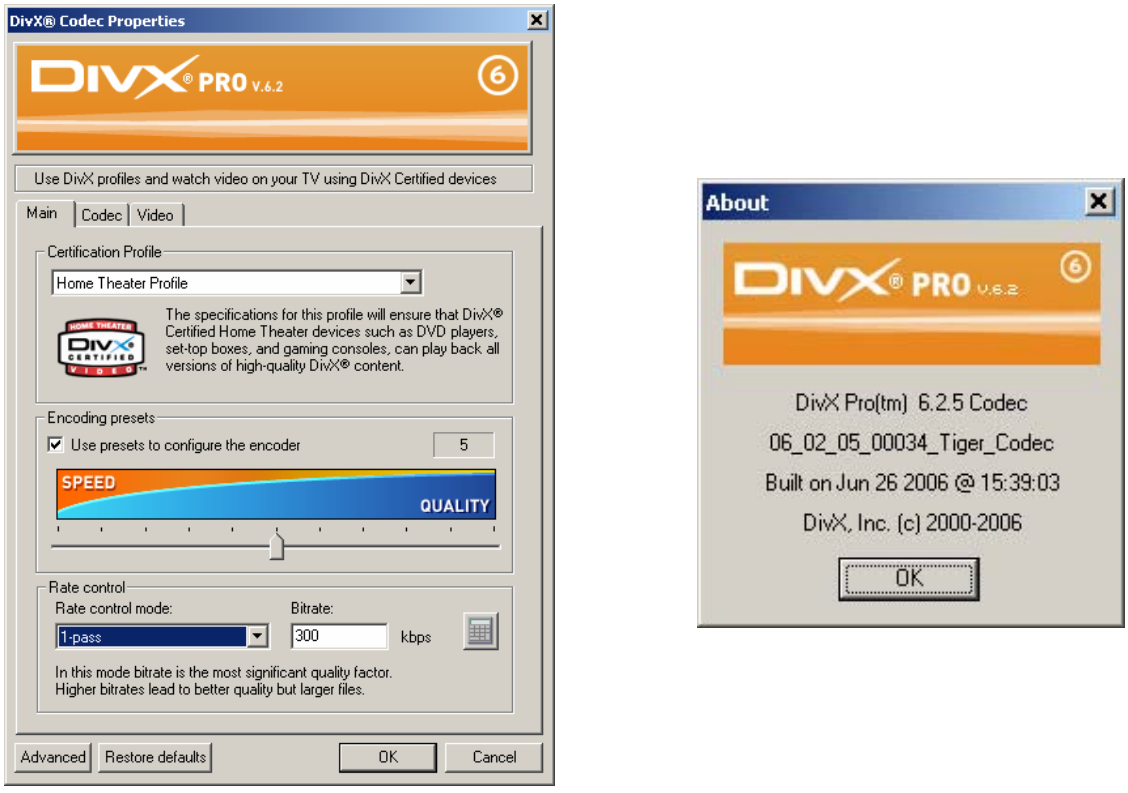


Figure 177. DivX 6.0

Remarks:

- Codec was not able to encode the “Concert” sequence due to the internal error
- More detailed presets’ analysis of DivX 6.2.5 codec is in full version of the report

VSS H.264 Codec Pro 3.0

- Console encoding program
- Reference decoder JM 9.8 was used for decoding
- Codec and presets were provided by Vanguard Software Solutions, Inc Company especially for this test

Remarks:

Codec worked without remarks

Figure 178. VSS H.264 Codec Pro 3.0

MainConcept H.264/AVC encoder

- Console encoding program
- Reference decoder JM 9.8 was used for decoding
- Codec and presets were provided by MainConcept AG Company especially for this test

Remarks:

Codec worked without remarks

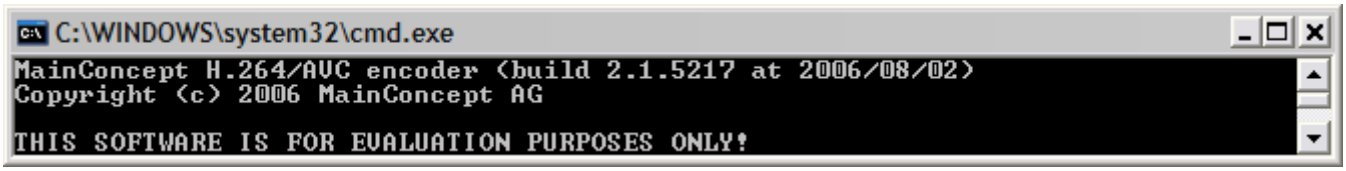


Figure 179. MainConcept H.264/AVC encoder

Intel H.264 encoder

- Console encoding program based on Intel(r) IPP v. 5.1
- Reference decoder JM 9.8 was used for decoding
- Codec and presets were provided by Intel Corp especially for this test

Remarks:

Codec worked without remarks

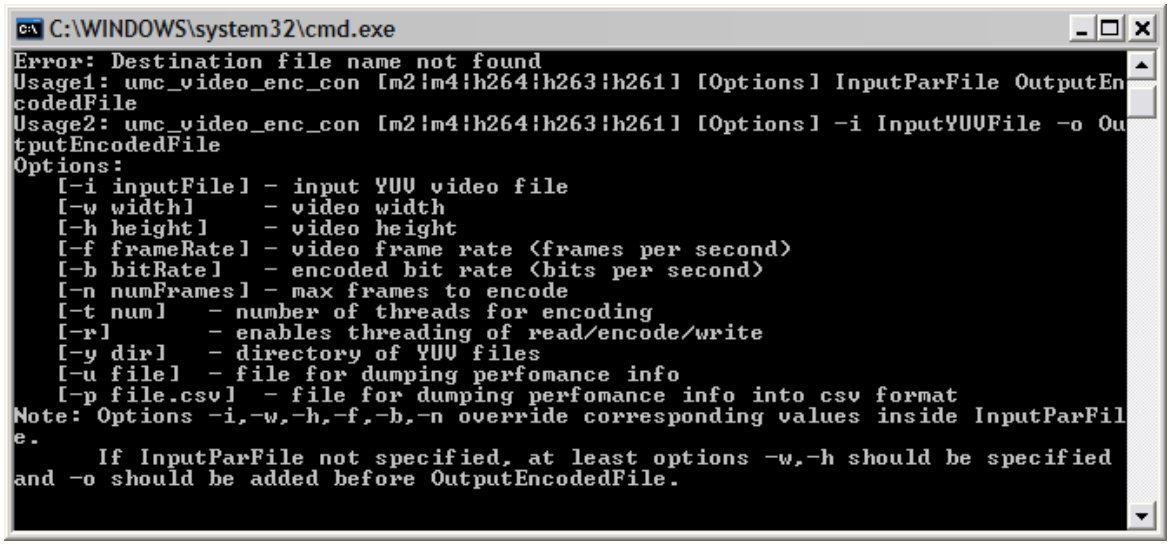


Figure 180. Intel H.264 encoder

x264 encoder

- Console encoding program
- Reference decoder JM 9.8 was used for decoding
- Codec and presets were provided by developers especially for this test

Remarks:

Codec worked without remarks

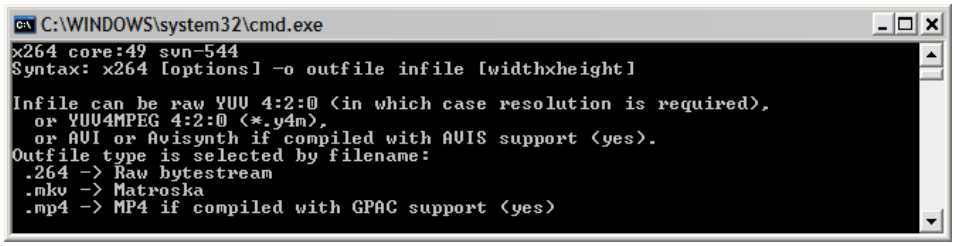


Figure 181. x264 encoder

Apple H.264

- QuickTime 7.1.3 for Windows (.Net encoding program) were used for encoding
- Reference decoder JM 9.8 was used for decoding
- Presets and encodes were provided by Charles Wiltgen especially for this test

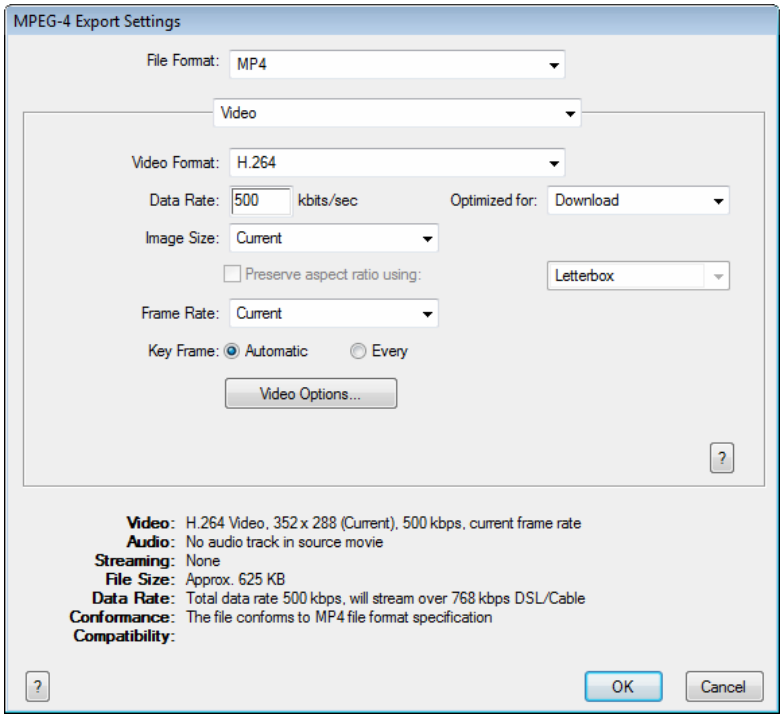


Figure 182. Apple H.264

Sorenson H.264

- Console encoding program
- Reference decoder JM was used for decoding
- Codec and presets were provided by developers especially for this test
- Build 2.00.106.00 were used for encoding

Remarks:

Codec worked without remarks

Appendix 5. Averaging Methods Description

Bitrates Ratio with the Same Quality

First step for computing average bitrate ratio at the same quality is the Bitrate/Quality graph's axes' "inversion" (see Figure 184). All further actions will be taken upon the "inversed" graph.

On the second step averaging interval on the quality axis is chosen. We perform averaging only in those segments where there are results for both codecs. This is concerned with the fact that it is very difficult to find extrapolation methods for classic RD curves while even linear methods are good for their interpolation.

At last we compute area under obtained curves in chosen interpolation segment and find their ratio (see Figure 185). This ratio is an average bitrate ratio with equal quality for two codecs. In case of presence more than two codecs one of them is defined as a reference and the quality of others is compared to the reference's one.

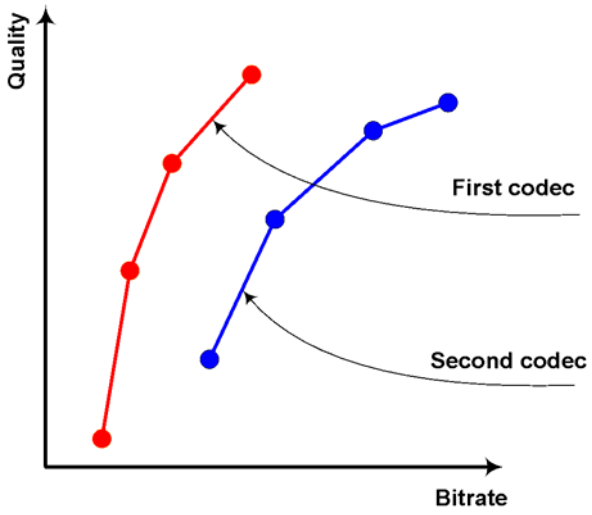


Figure 183. Source Data

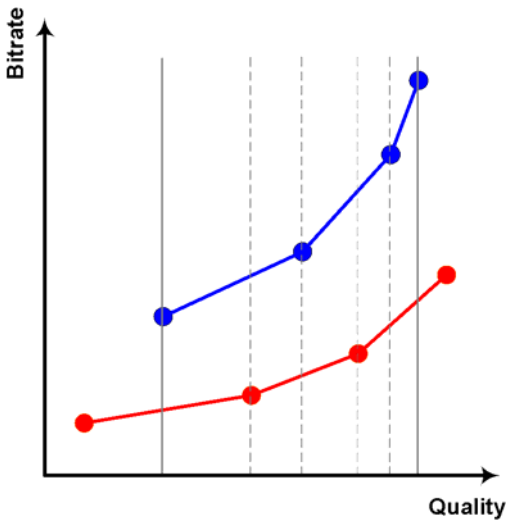


Figure 184. Axes' Inversion and Averaging Interval Choosing

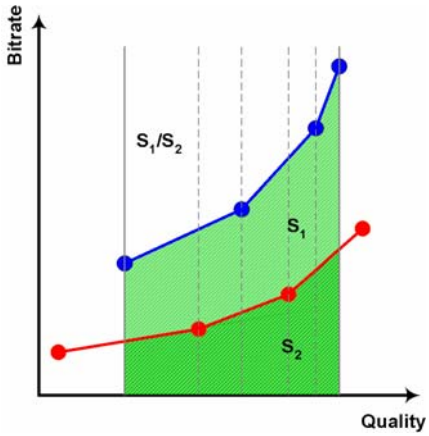


Figure 185. Areas' under Curves Ratio

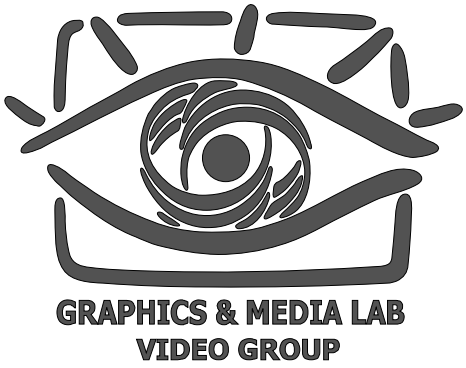
Relative Codecs Work Time Computation

For relative work time computation for two codecs on one sequence we computed encoding time for each of these codecs on this sequence (we summed encoding times for all bitrates) and divided them one by another. For three and more codecs one codec was chosen as an etalon and the ratio of its encoding time to the others' encoding time was taken up.

In case of several sequences an arithmetic mean of average relative encoding times for codecs on each sequence was used.

List of Figures

About us (Graphics & Media Lab Video Group)



Graphics&Media Lab Video Group is a part of Graphics&Media Lab of Computer Science Department in Moscow State University. The history of Graphics Group began at the end of 1980's. Graphics&Media Lab was officially founded in 1998. Main research directions of the lab lie in different areas of Computer Graphics, Computer Vision and Media Processing (audio, image and video processing). Some of research results were patented, other results were presented in a number of publications.

Main research directions of Graphics&Media Lab Video Group are video processing (pre-, post- and video analysis filters) and video compression (codecs' testing and tuning, quality metrics research, development of codecs).

Our main achievements in video processing:

- High quality industrial filters for format conversion including high quality deinterlacing, high quality frame rate conversion, new fast practical super resolution, etc.
- Methods for modern TV-sets: big family of up-sampling methods, smart brightness and contrast control, smart sharpening, etc.
- Artifacts' removal methods: family of denoising methods, flicking removal, video stabilization with frame edges restoration, scratches, spots, drop-outs removal, etc.
- Specific methods like: subtitles removal, construction of panorama image from video, video to high quality photo, video watermarking, video segmentation, practical fast video deblur, etc.

Our main achievements in video compression:

- Well-known public comparisons of JPEG, JPEG-2000, MPEG-2 decoders, MPEG-4 and annual H.264 codec's testing; also we provide tests for "weak and strong points of codec X" for companies with bugreports and codec tuning recommendations.
- Our own video quality metrics research, public part is MSU Video Quality Measurement Tool and MSU Perceptual Video Quality Tool.
- We have internal research and contracts on modern video compression and publish our MSU Lossless Video Codec and MSU Screen Capture Video Codec – codecs with ones of the highest compression ratios.

We are really glad to work many years with companies like Intel, Samsung, RealNetworks and others.

A mutual collaboration in areas of video processing and video compression is always interesting for us.

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