MPEG-4 AVC/H.264 Video Codecs Comparison

Short version of report

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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)

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CS MSU Graphics&Media Lab

Video Group

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 2. 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 3. Tested Codecs».

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**

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 metrics 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 metrics' 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

Full Report Version

This document is a very brief version of the full report. This document contains some examples of charts and a small part of the performed analysis.

Full report contains the following information:

- 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

- More detailed testing results for DivX 6.2.5 codec (most presets of this codec)

Full version of this comparison may be requested on http://compression.graphicon.ru/video/codec_comparison/mpeg-4_avc_h264_2006_en.html.

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 metrics are noticeable different from the results for SSIM.

More detailed information about these metrics may be found here:

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

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[1] Only for Apple's codec investigation

Figures Explanation

This Brief version of the report contains only 2 types of graphs: Bitrate/Quality charts (the so-called Rate-Distortion Curves, RD curves) and Relative Bitrate/Relative Time charts.

RD curves. These charts show variation in codec quality by bitrate/file-size. For this metric, the higher the curve, the better the quality (from the metric's standpoint).
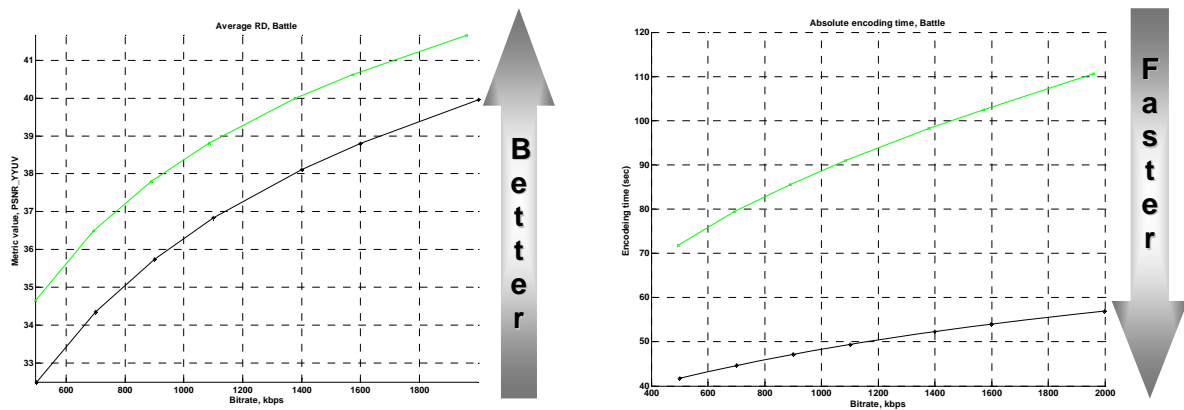
Relative Bitrate/Relative Time. These charts show the dependency of average bitrate with equal quality on relative encoding time. Y axis shows bitrate ratio between current and reference codecs in the spots equal quality. The lower is this value for each codec (i.e. the higher it is on graph), the better 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 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 4. 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!

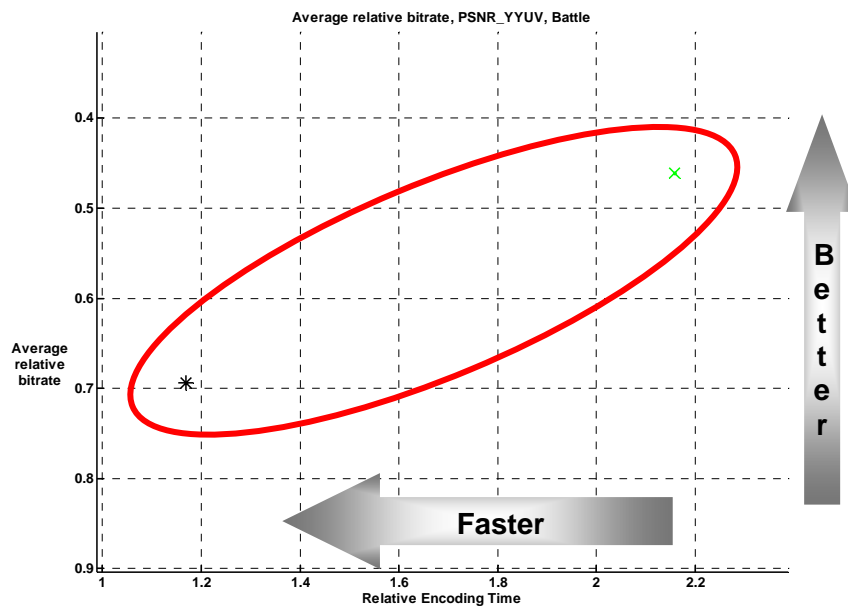**Encoding time (seconds). "Green codec is slower!**

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 (1 preset)
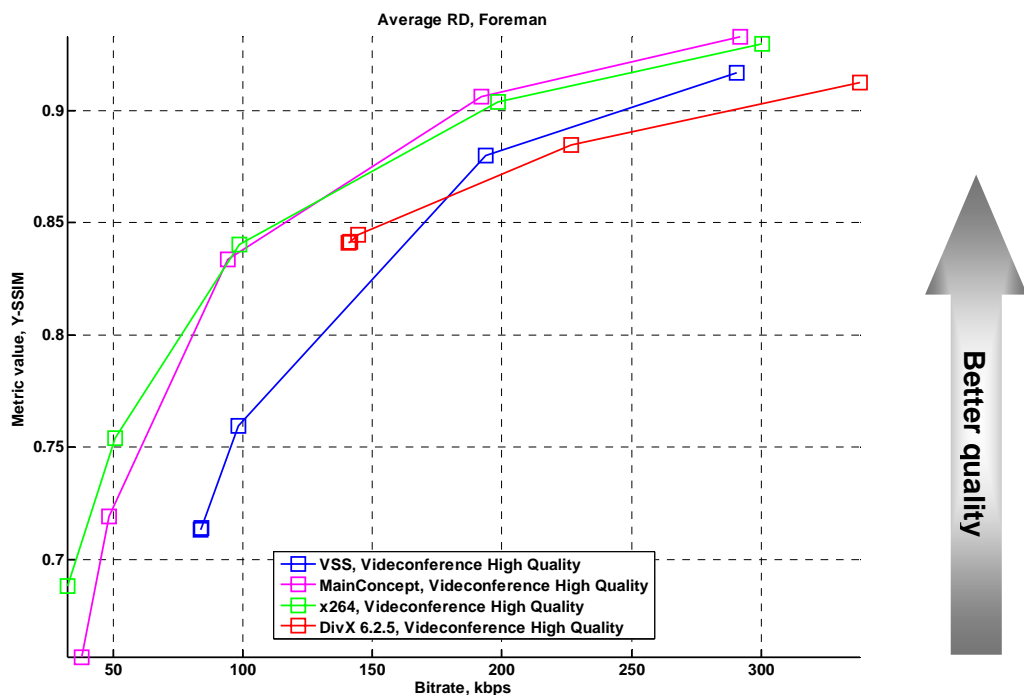- VSS (2 presets)
- x264 (2 presets)

Results

Figure 2.   Bitrate/Quality. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset
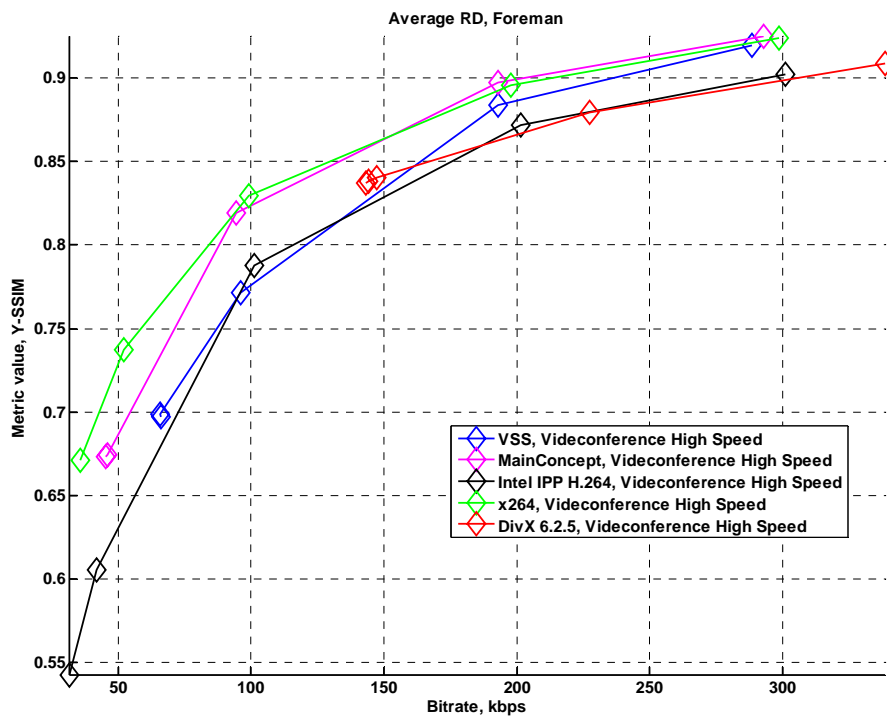
Figure 3.   Bitrate/Quality. Usage area "Videoconferences", "Foreman" sequence, "High Speed" preset

These charts show that MainConcept and x264 codecs provide similar quality for «High Quality» preset (with small advantage of x264) and show the best result among other codecs. These codecs also show similar quality for «High Speed» preset and become leaders. Codecs from VSS and Intel companies, providing similar quality, remain behind by video quality, which can be explained by significant speed reserve. Also one can see that DivX codec can not compress video sequences with very low bitrates, however it is a very important bitrate range for videoconferences.
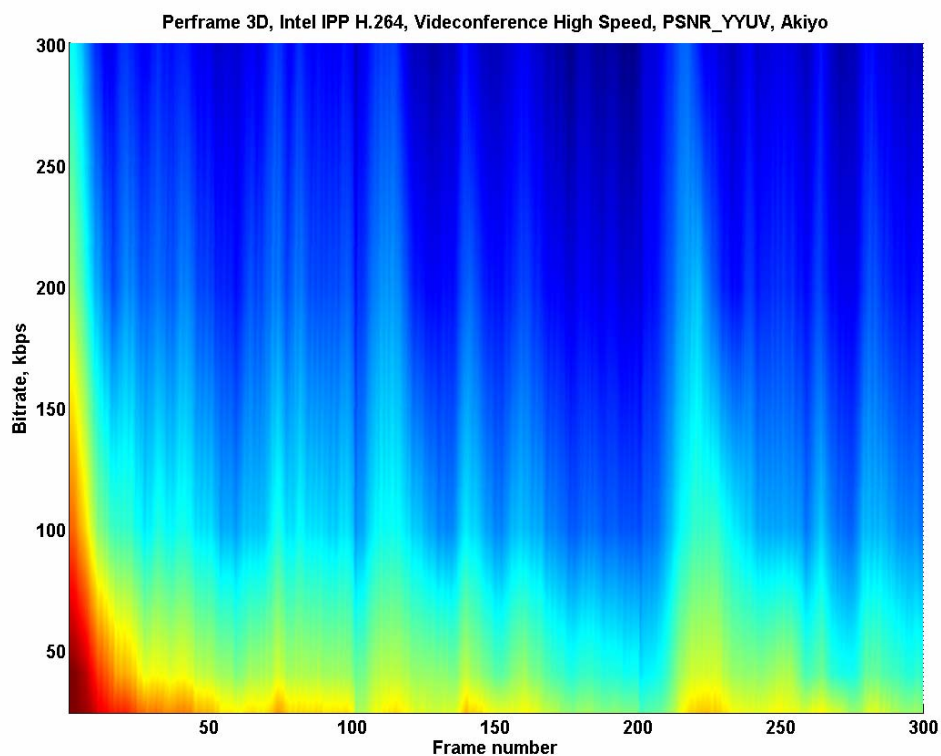
Figure 4.   **Perframe Y-PSNR. Usage area "Videoconferences", "Akiyo" sequence, Intel IPP H.264, "High Speed" preset**
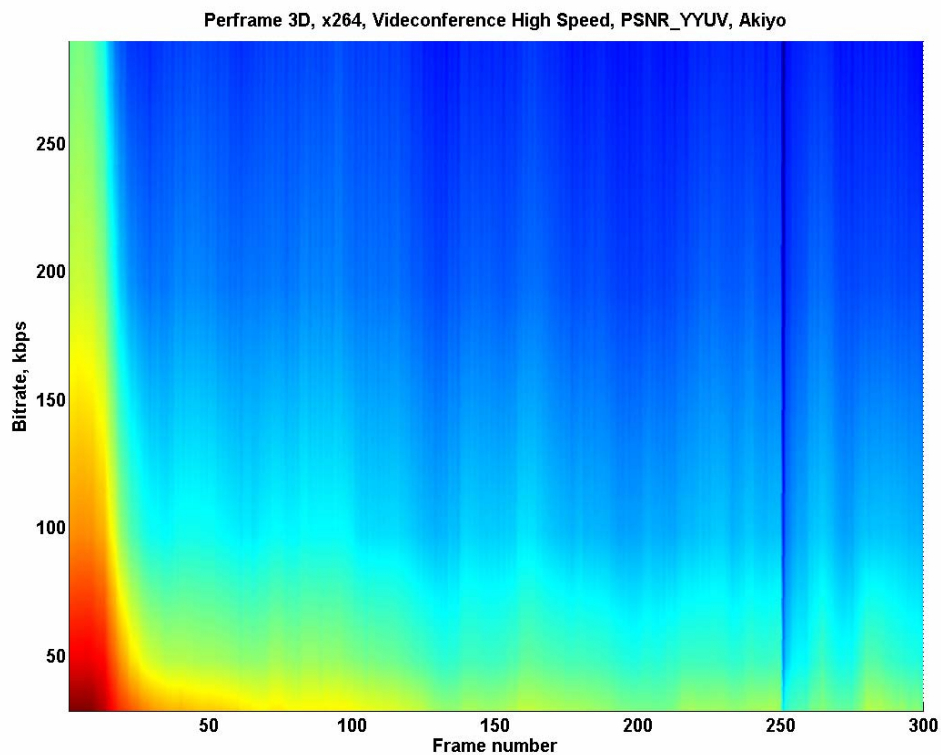

Figure 5.   **Perframe Y-PSNR. Usage area "Videoconferences", "Akiyo" sequence, x264, "High Speed" preset**

Figure 4 and Figure 5 shows per-frame quality for codecs Intel and x264. It is clearly visible different rate control strategies of that codecs.
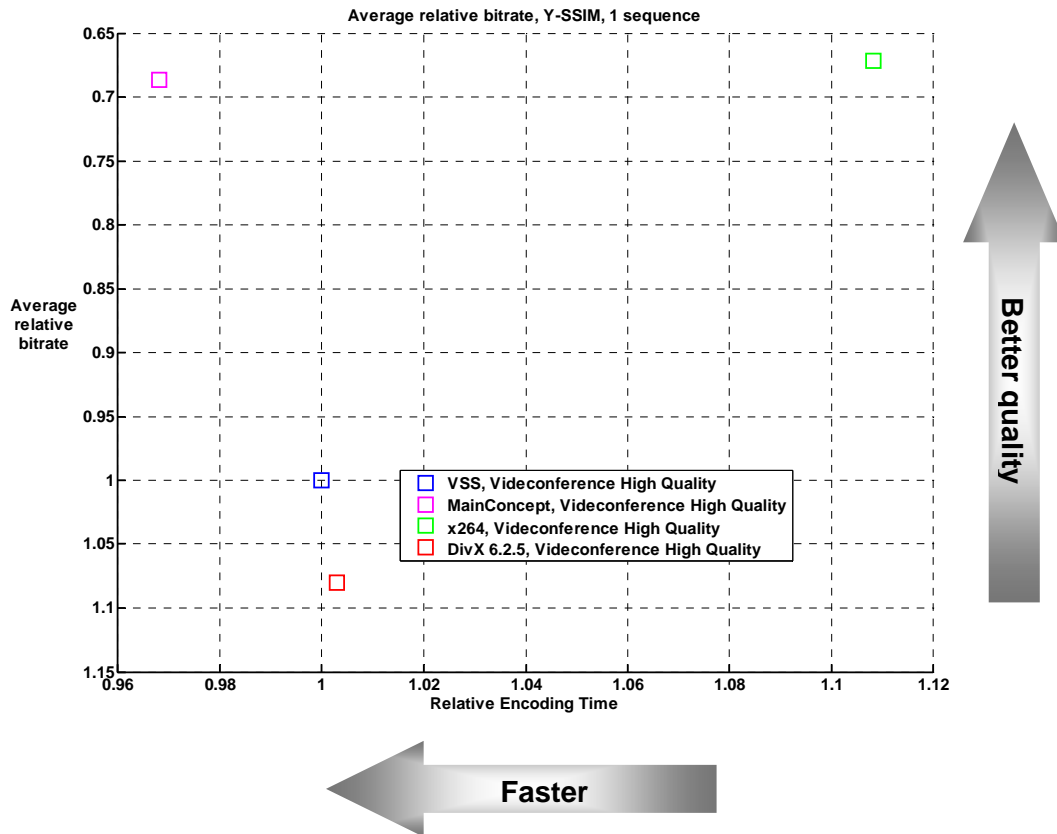

Figure 6.   **Relative bitrate/Relative time. Usage area "Videoconferences", "Foreman" sequence, "High Quality" preset**

This graph illustrates that codec from MainConcept showing very high compression speed provides very high quality whereas x264 codec shows slightly better quality at the expense of significant speed degradation. Codec from MainConcept provides better quality than codecs from VSS and DivX with higher compression speed.
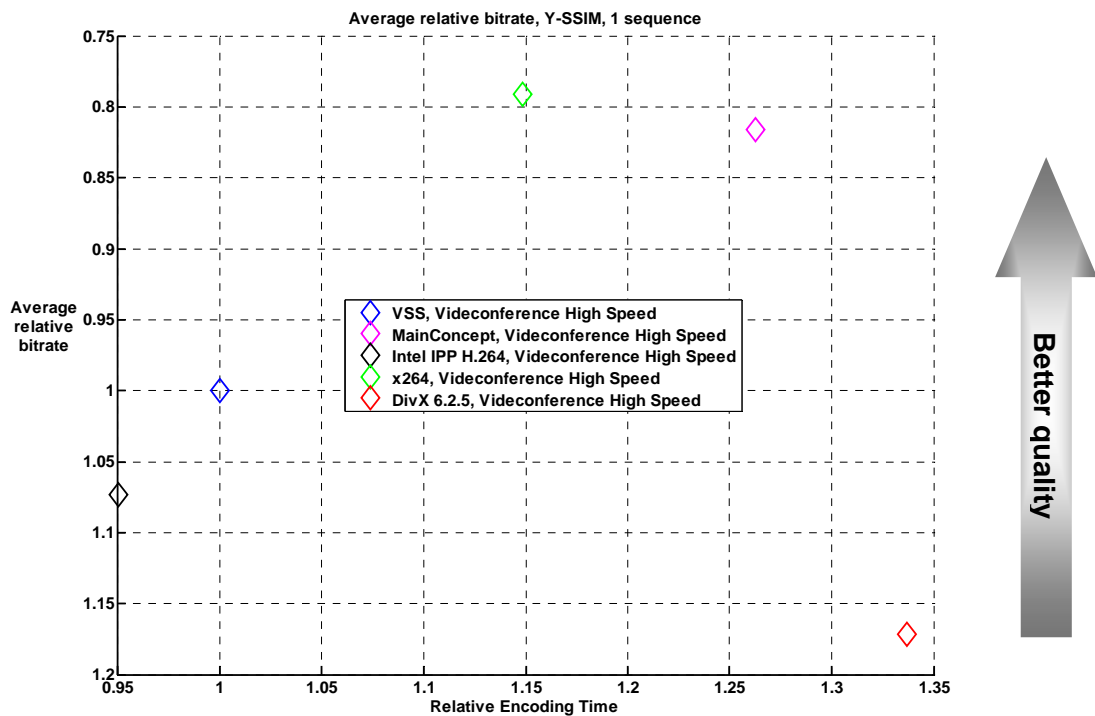
Figure 7.   **Relative bitrate/Relative time. Usage area "Videoconferences", Foreman sequence, "High Speed" preset.**

It is important to note high speed of codec from Intel on this graph. Also one can see that x264 codec provides higher quality than the codec from MainConcept while maintaining higher compression speed.

Conclusions for Figure 2, Figure 3, Figure 6, and Figure 7 are correct only for "Foreman" sequence; results for other sequences are different to some extent.

All results can be seen in full version of the report.

Table 4 and Table 5 contain average bitrate values for the same quality for all codecs. Averaging was performed using all sequences for the current type of application ("Foreman", "Akiyo" and "Carphone").

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

	DivX	VSS	MainConcept	Intel H.264	x264
Average ratio of file size relative to DivX	100%	78.67%	52.7%	n/a	62.58%

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

	DivX	VSS	MainConcept	Intel H.264	x264
Average ratio of file size relative to DivX	100%	75.59%	58.4%	90.86%	62.37%

Note that tables above are calculated using all test set. It can lead to some differences between averages results and previous figures.

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.

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)

Below there are SSIM/bitrate graphs and quality/speed ratio graphs for «rancho» sequence, presets "High Speed" and "High Quality".
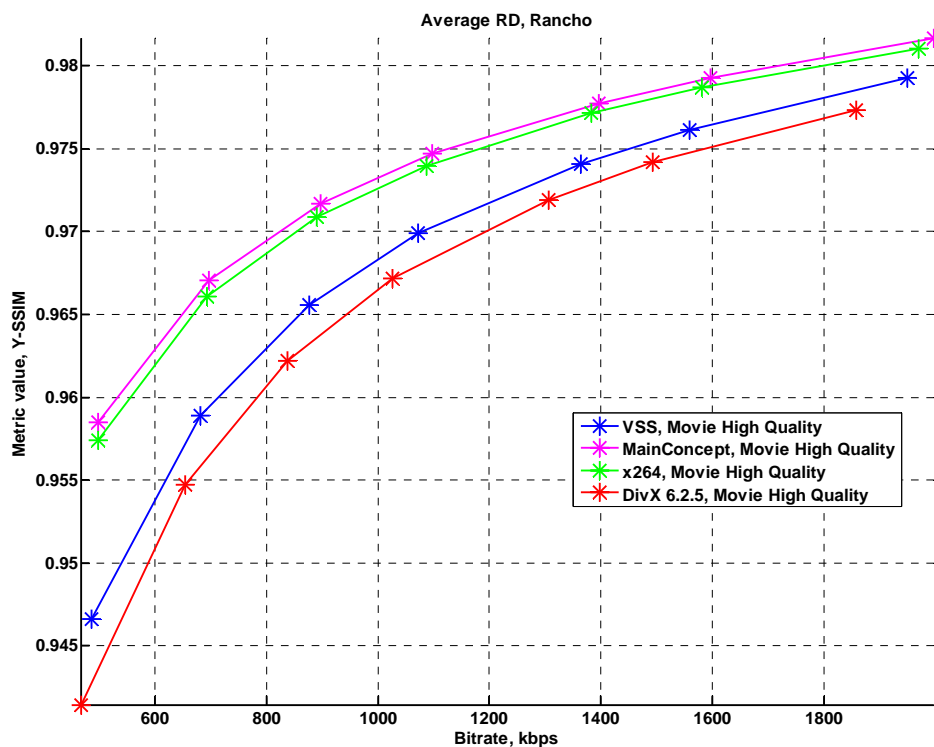
Results

Figure 8.   Bitrate/Quality. Usage area "Movies". "Rancho" sequence. "High Quality" preset

It is clearly seen on this chart that all H.264 standard's codecs show much better quality comparing to MPEG-4 ASP standard's codec (DivX) for "Rancho" sequence. But this situation is not typical for all test set for the current type of application. More detailed information can be found in the full version of the report.
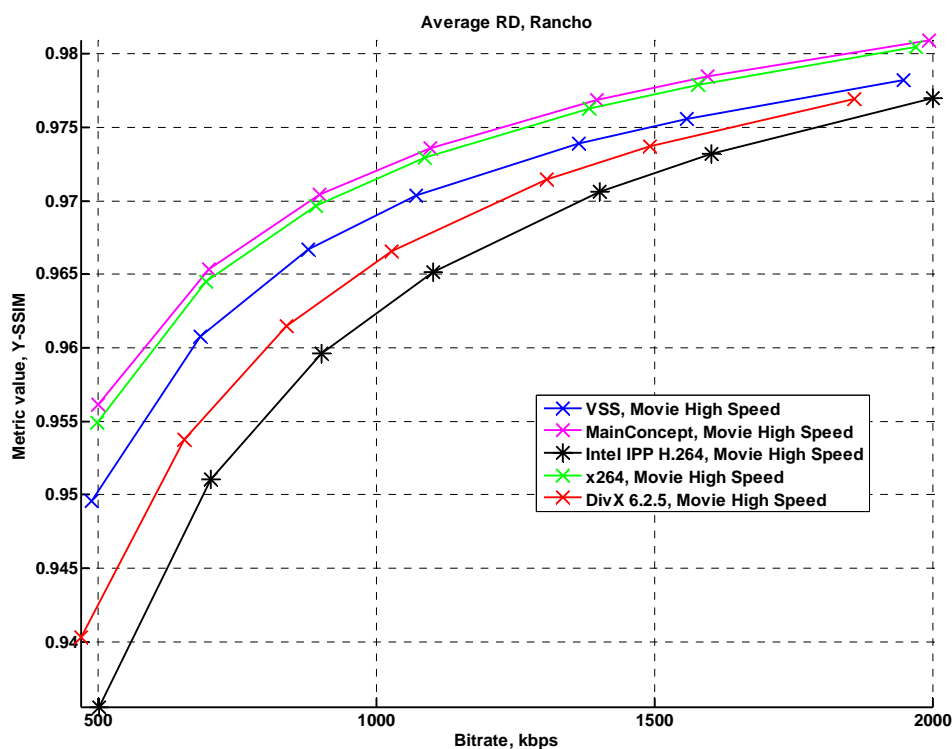
Figure 9.   Bitrate/Quality. Usage area "Movies". "Rancho" sequence. "High Speed" preset

The situation is slightly differ for "High Speed" preset on "Rancho" sequence – the lowest quality is shown not by the codec of the previous MPEG-4 ASP standard, but by the representative of new video coding standard from Intel company. This may be explained by encoding speed difference: Intel H.264 codec encoded this sequence 1.4 times quicker than DivX on average.
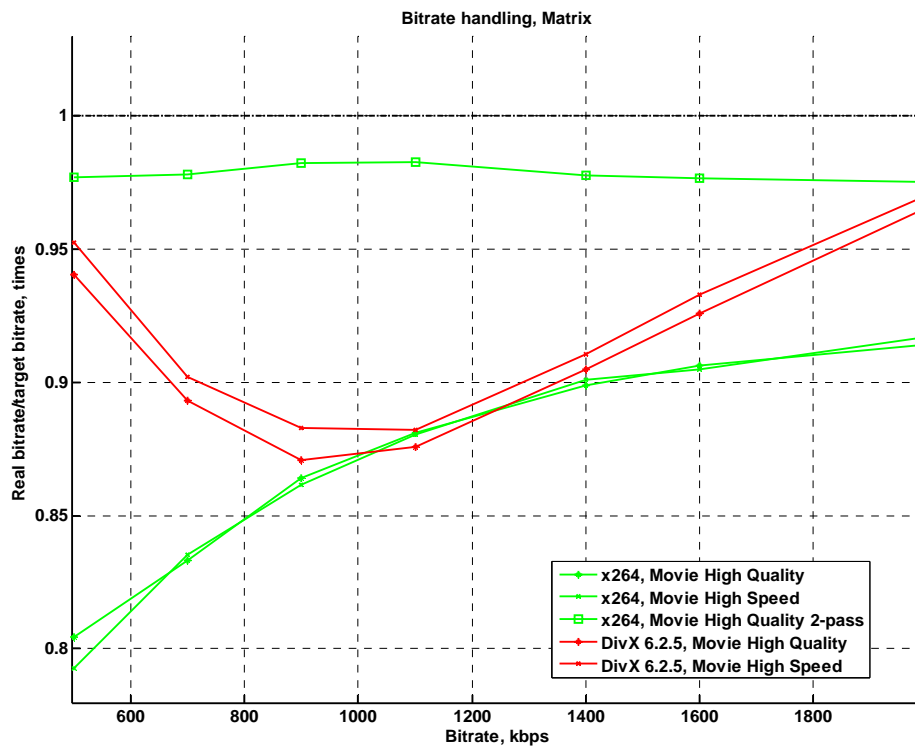
Figure 10. **Bitrate Handling. Usage area "Movies". "Matrix" sequence. DivX and x264.**

Figure 10 is an example of bitrate handling graphs. It shows, that 2-pass x264 keeps bitrate rather good for sequences "Matrix". Maximum bitrate difference is about 20% for 1-pass presets.
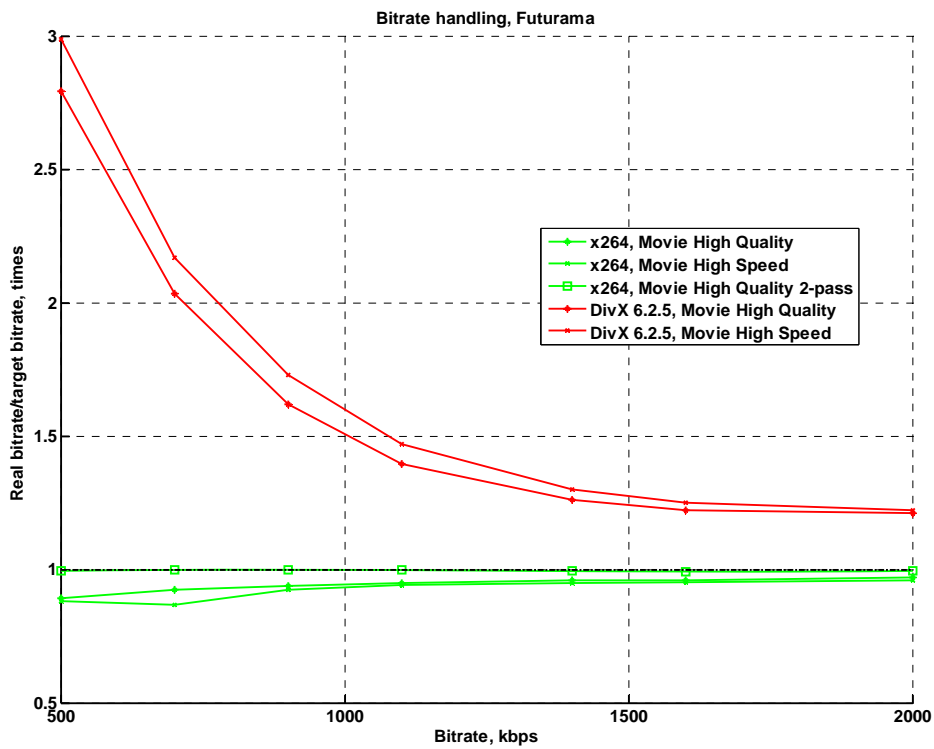
Figure 11.   **Bitrate Handling. Usage area "Movies". "Futurama" sequence. DivX and x264.**

Figure 11 is another example of bitrate handling graph. It shows problems with DivX bitrate keeping for sequence "Futurama" (maximum difference between real and target parameter is 3 times).
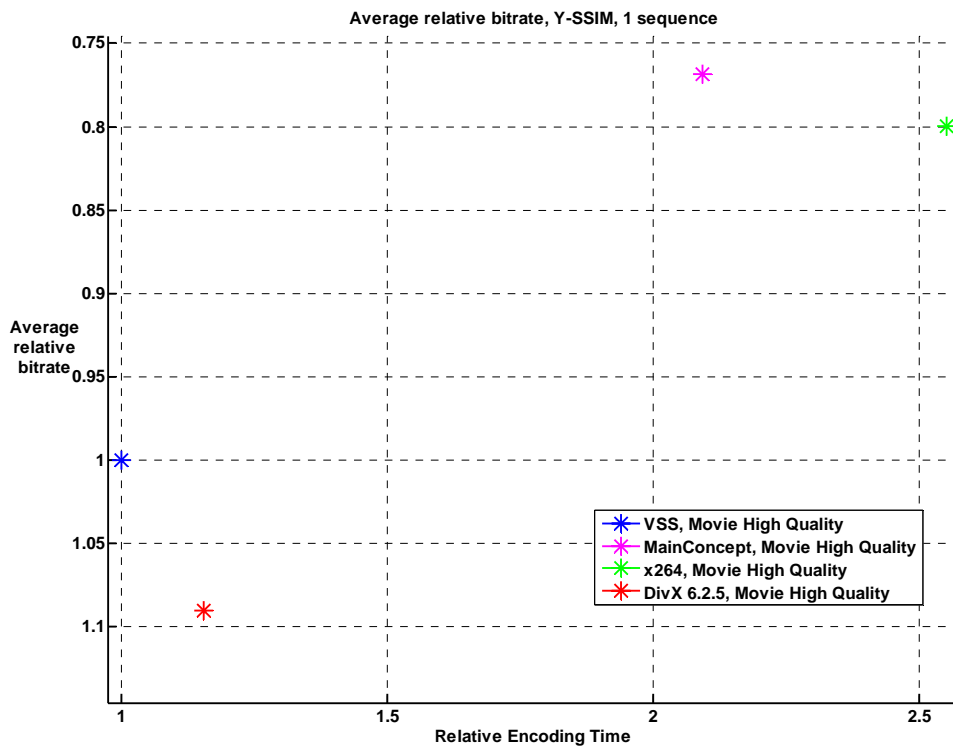
Average relative bitrate, Y-SSIM, 1 sequence

Figure 12.　　**Relative bitrate/Relative time. Usage area "Movies". "Rancho" sequence. "High Quality" preset**

The main conclusion from this graph is the VSS codec domination over DivX codec, since codec from VSS shows better quality (bitrate preservation) while maintaining faster encoding speed.
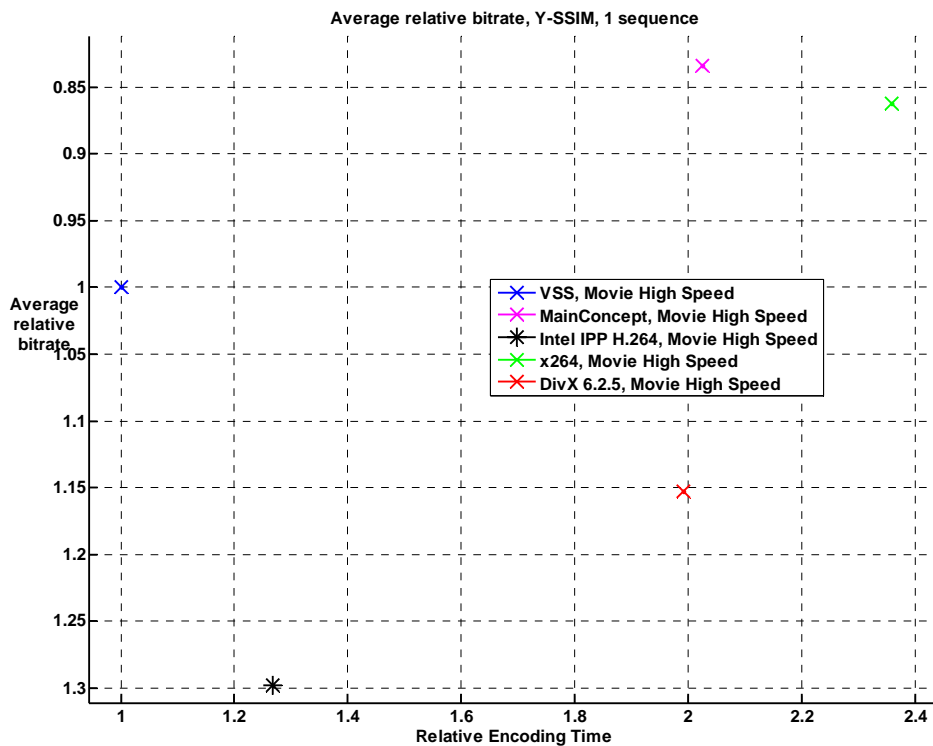
Figure 13.   **Relative bitrate/Relative time. Usage area "Movies". "Rancho" sequence. "Hiqh Speed" preset**

This graph indicates that codecs from DivX and Intel show worse visual quality and slower encoding speed than VSS codec on "Rancho" sequence (using SSIM metric).

Table 6, Table 7 and Table 8 contain averaged bitrate values for the same quality for all codecs. Averaging was performed using all sequences for the current type of application ("Battle", "Rancho", "Matrix" and "Futurama").

Table 6.   Average file size for the same quality.
Usage area "Movies". "High Speed" preset, Y-SSIM.
Bitrates 600-1800 Kbps.

	DivX	VSS	MainConcept	Intel H.264	x264
Average ratio of file size relative to DivX	100%	105%	78%	107%	76%

Table 7.   Average file size for the same quality.
Usage area "Movies". "High Quality – 1 pass" preset, Y-SSIM.
Bitrates 600-1800 Kbps.

	DivX	VSS	MainConcept	Intel H.264	x264
Average ratio of file size relative to DivX	100%	96%	77%	n/a	72%

Table 8.   Average file size for the same quality.
Usage area "Movies". "High Quality – 2 passes" preset, Y-SSIM.
Bitrates 600-1800 Kbps.

	DivX	VSS	MainConcept	Intel H.264	x264
Average ratio of file size relative to MainConcept	n/a	n/a	100%	n/a	90%

Note that tables above are calculated using all test set. It can lead to some differences between averages results and previous figures.

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.

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:
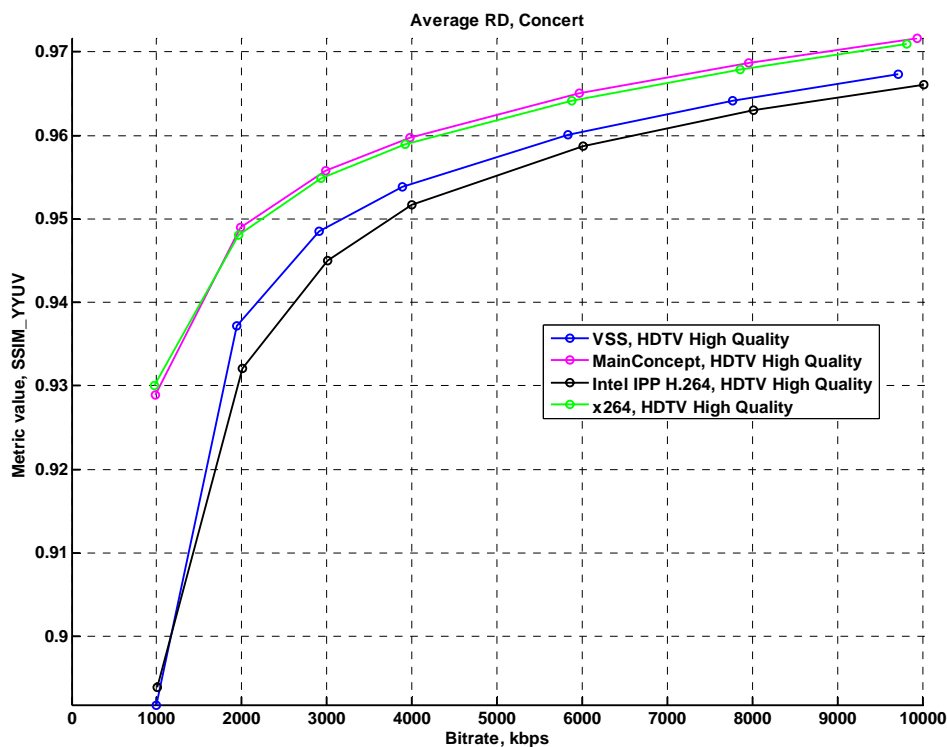
- MainConcept
- Intel H.264
- VSS
- x264

Results

Figure 14.   **Bitrate/Quality. Usage area "HDTV", "Concert" sequence, "High Quality" preset**

This graph shows significant advantage by quality for x264 codec and the codec from MainConcept. This is explained by the fact that the speed of codecs from Intel and VSS using this preset is several times faster than that of x264. There is an interesting fact though: while there is significant difference by speed between x264 and codec from MainConcept, there is no considerable difference in quality, and the faster codec shows better quality.

Figure 15.   Bitrate/Quality. Usage area "HDTV", "Concert" sequence, "High Quality" preset

Figure 15 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.
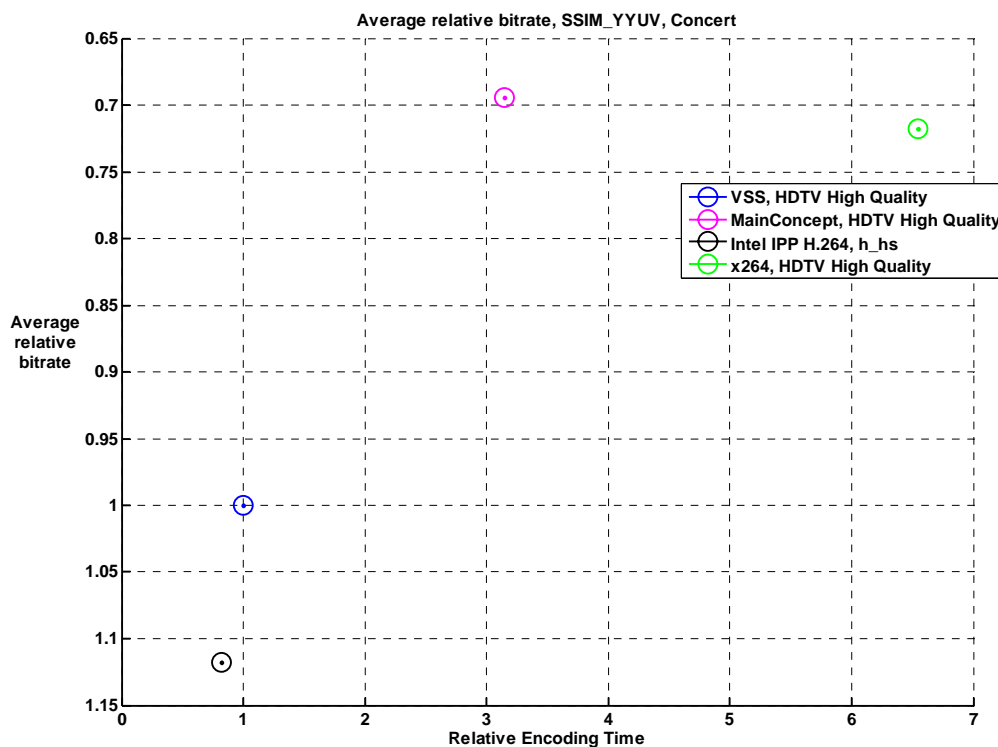
Figure 16.   Relative bitrate/Relative time. Usage area "HDTV", "Concert" sequence, "High Quality" preset

There is an evident conclusion from this graph that codec from MainConcept works faster and with slightly better quality on average. But this is not the case when using PSNR metric instead of SSIM metric for quality evaluation.

Table 9 contains averaged bitrate values for the same quality for all codecs. Averaging was performed using "Concert" sequence.

**Table 9.   Average file size for the same quality.
Usage area "HDTV", Y-SSIM. Bitrates 2-10 Mbps.**

	VSS	MainConcept	Intel H.264	x264
Average ratio of file size relative to VSS encoder	100%	69.43%	111.8%	71.76%

Note that tables above are calculated using all test set. It can lead to some differences between averages results and previous figures.

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 company 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 10 demonstrates obtained average bit rate **saving** results. Values on this figure are relative bitrate with equal quality (the lower is the better).

Table 11 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 10.   Testing results of 2006 year.
Average file size for the same quality

	MainConcept	x264	VSS	DivX	Intel H.264
Videoconferences «High Quality»	56%	63%	79%	100%	
Videoconferences «High Speed»	62%	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%**

Bitrate saving

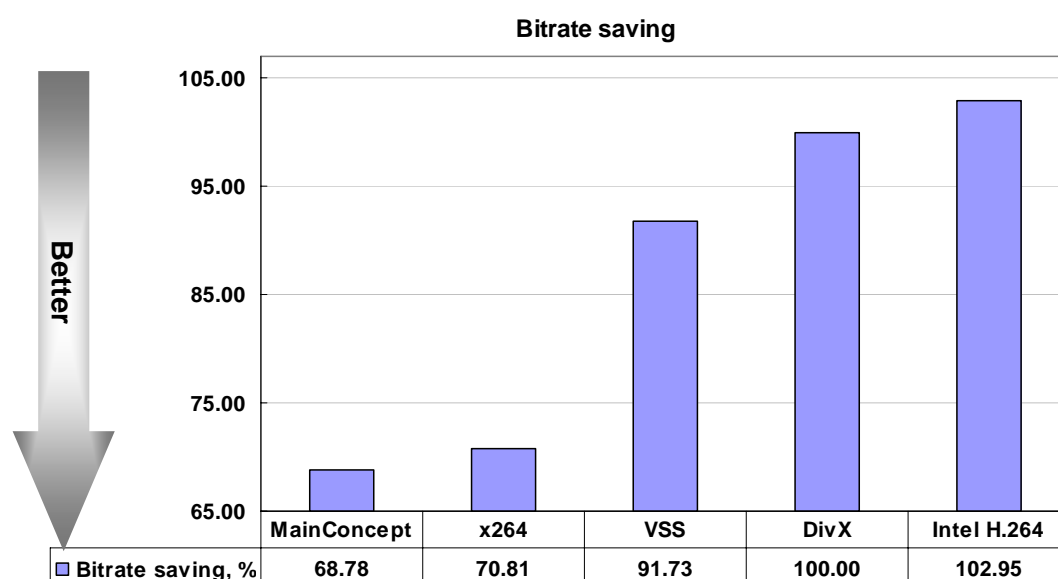|	MainConcept	x264	VSS	DivX	Intel H.264
Bitrate saving, %	68.78	70.81	91.73	100.00	102.95

Figure 17. **Average sequence size for the same quality for whole test set**

Table 11. **Testing results of 2006 year. Average encoding time**

	VSS	Intel H.264	MainConcept	DivX	x264
Videoconferences «High Quality»	91%	n/a	84%	93%	100%
Videoconferences «High Speed»	71%	74%	91%	100%	88%
Videoconferences	**81%**	**74%**	**88%**	**97%**	**94%**
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	**46%**	**47%**	**66%**	**80%**	**98%**

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 12 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 12.   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	grey	magenta	grey	grey	magenta	blue	magenta	grey	grey	magenta	blue	magenta
2005	blue	magenta	grey	blue	magenta	blue	grey	blue	blue	grey	blue	grey
2006	grey	blue	blue	blue	blue	grey	grey	grey	grey	blue	grey	grey

[grey] This codec did not take part in comparison of specified year

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

[blue] 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 4. Averaging Methods Description».
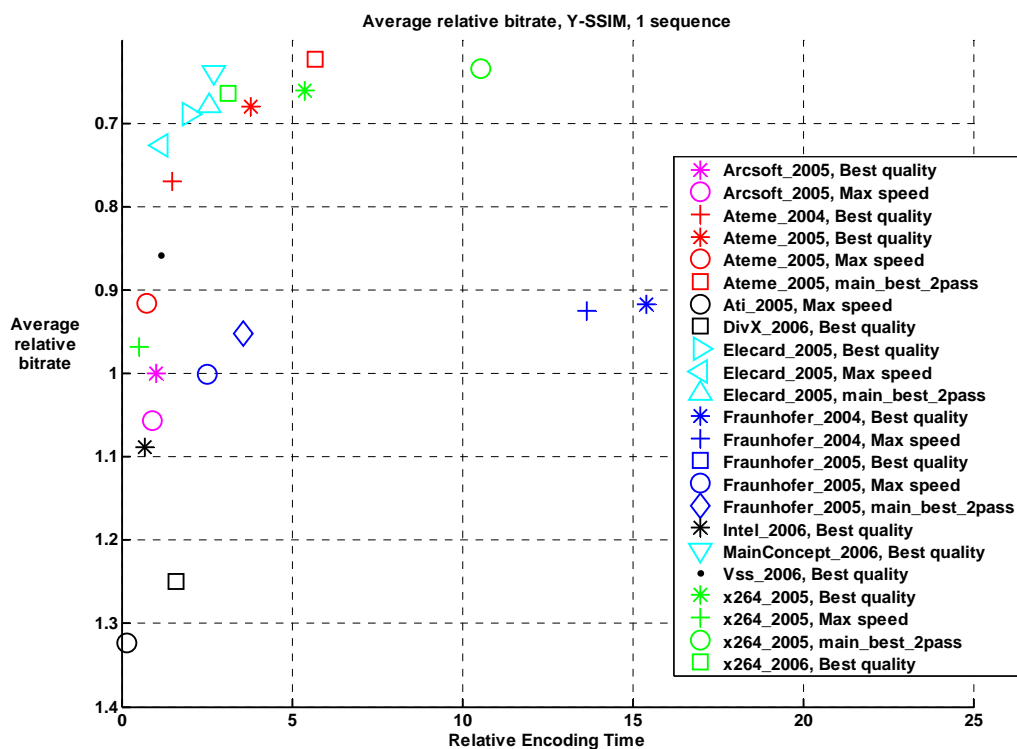
Figure 18.   **Relative Bitrate/Relative Time. "Foreman" sequence, year 2004, 2005 and 2006 codecs**

Figure 18 shows codecs' position for "Foreman" sequence. Codec from ArcSoft company from comparison of year 2005 was used as a reference.
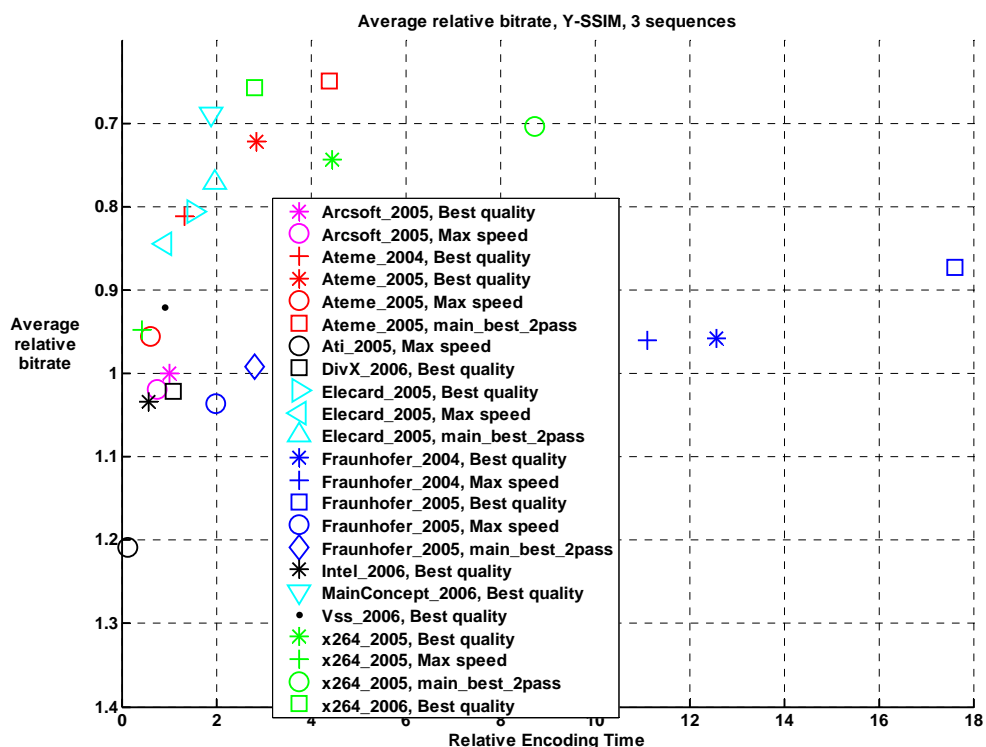
Figure 19.   **Relative Bitrate/Relative Time. "Foreman", "Battle" and "Matrix" sequences – average values, year 2004, 2005 and 2006 codecs**

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.
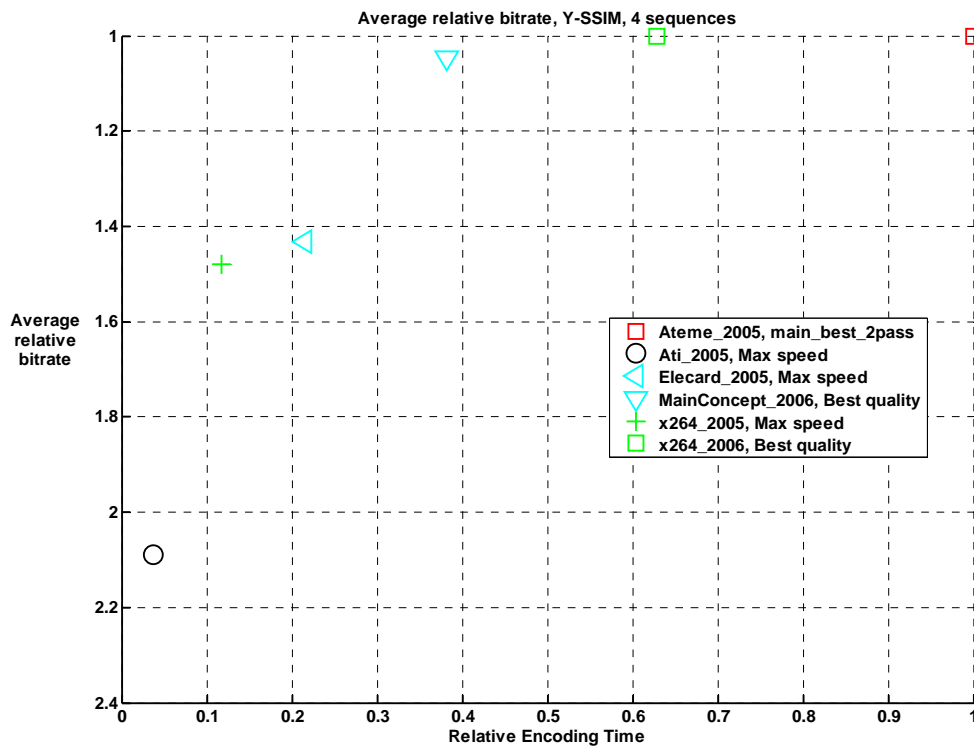
Figure 20.   Extract for Relative bitrate/Relative time graph. "Foreman", "Battle", "Matrix" and "Concert" sequences, 2004, 2005 and 2006 years codecs

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.
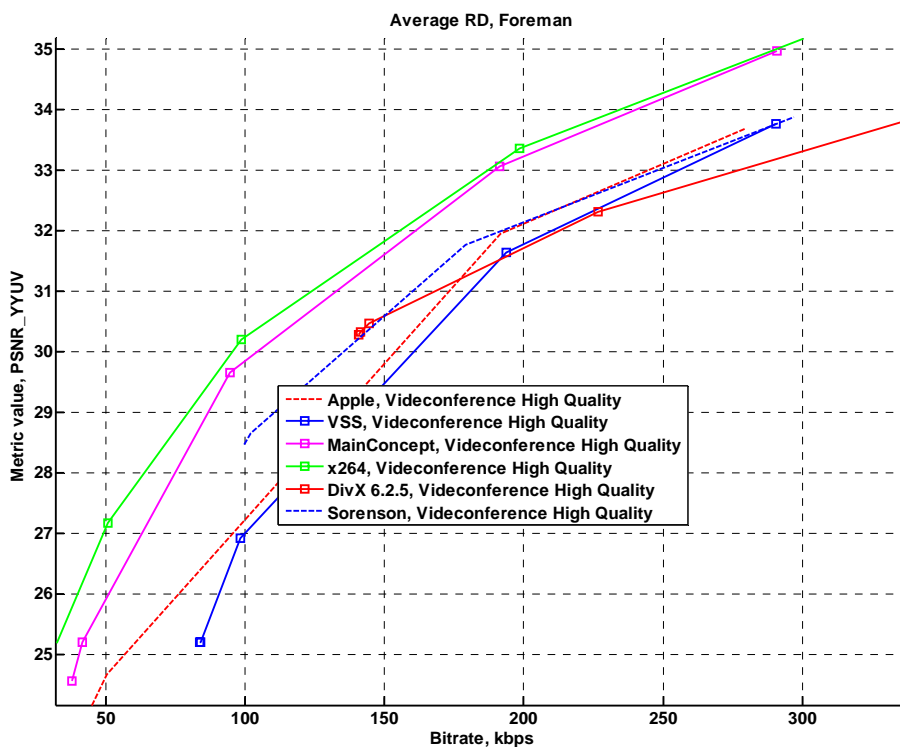

Figure 21.   Sequence "Foreman". "High Quality" preset. Y-PSNR
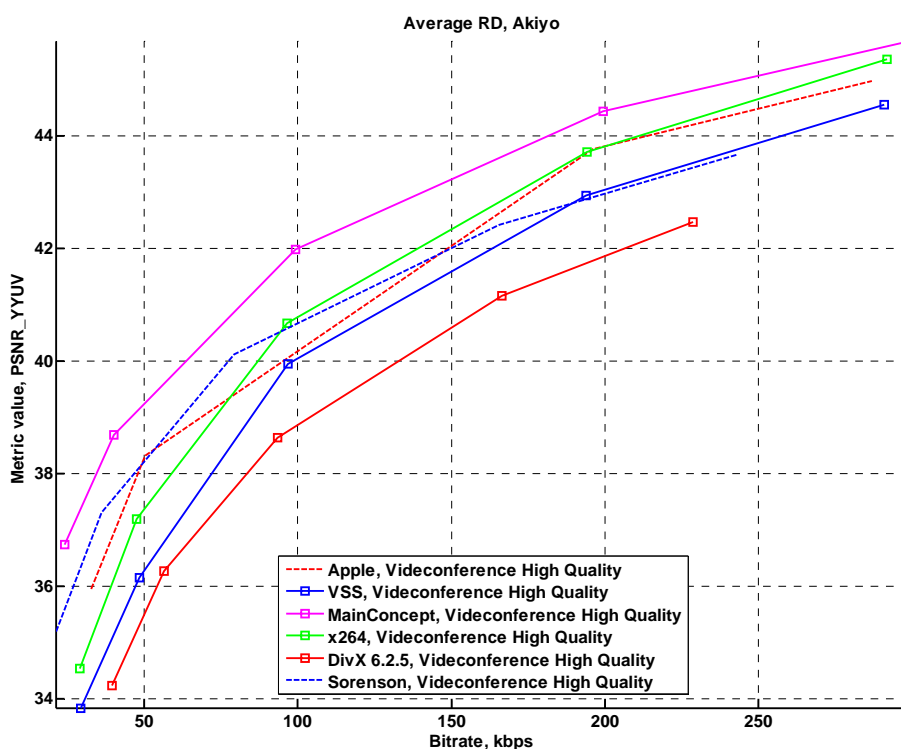
Figure 22.   Sequence "Akiyo". "High Quality" preset. Y-PSNR

Codecs' behavior on other sequences somewhat differs from the one given above.

Below is the typical situation for sequence from «Movies» type of application.
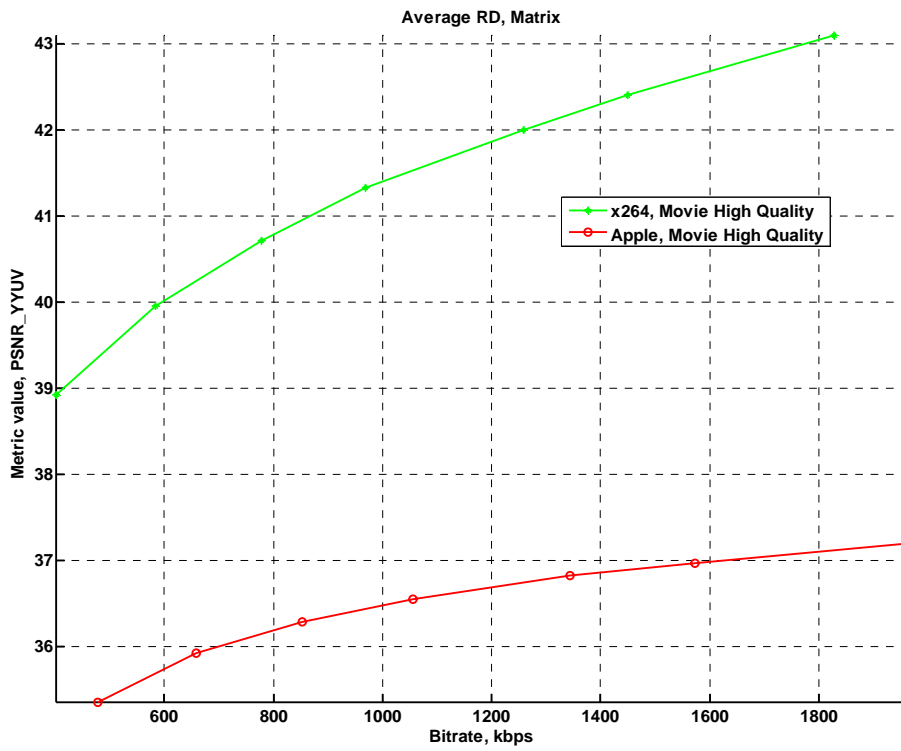
Figure 23.   Sequence "Matrix". "High Quality" preset. Y-PSNR

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
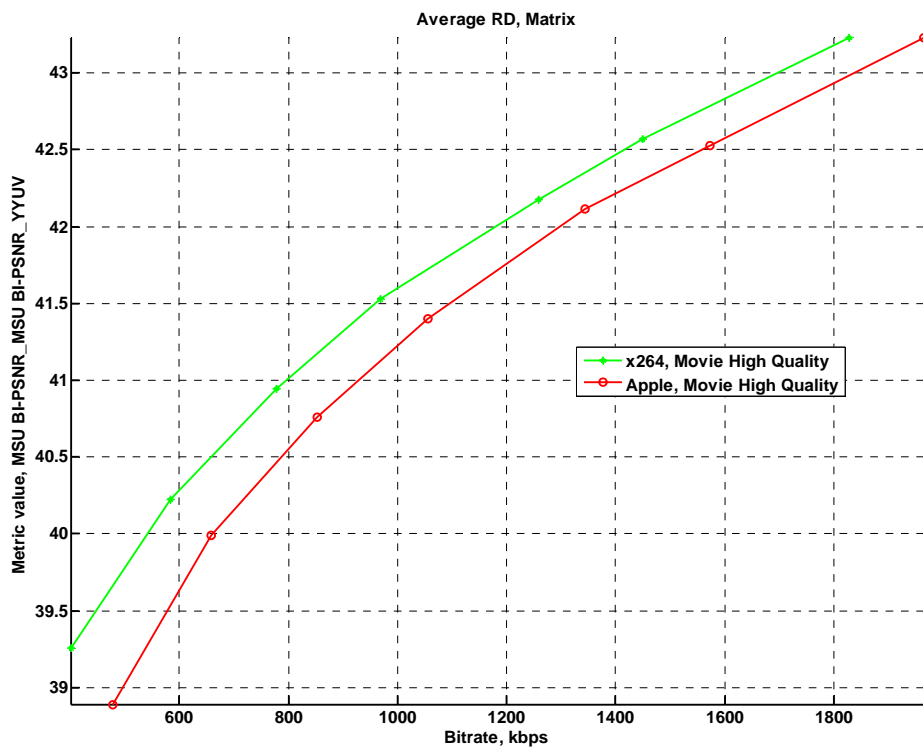
Figure 24.   **Sequence "Matrix". "High Quality" preset.
Both codecs were measured using Y-BI-PSNR**

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 metric that is independent to brightness shifts (MSU BI-PSNR), quality of codec from Apple becomes comparable with others – see Figure 23 and Figure 24.

- Thus with inclusion of codecs from Apple and Sorenson leading positions of x264 codec and codec from MainConcept remains unshakable.

Appendix 2. Test Set of Video Sequences

VideoConference

Foreman

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

Figure 25.   **Frame 77**

Figure 26.   **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 27.   **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 28.   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

Battle

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

Figure 29.   **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 30.   **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 31.   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 32.   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

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 33.   **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 3. 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:

  o Preset 10 for "Videoconferences" type of application, "High Quality"

  o Preset 5 for "Videoconferences" type of application, "High Speed"

  o Preset 10 for "Movies" type of application, "High Quality"

  o Preset 8 for "Movies" type of application, "High Speed"
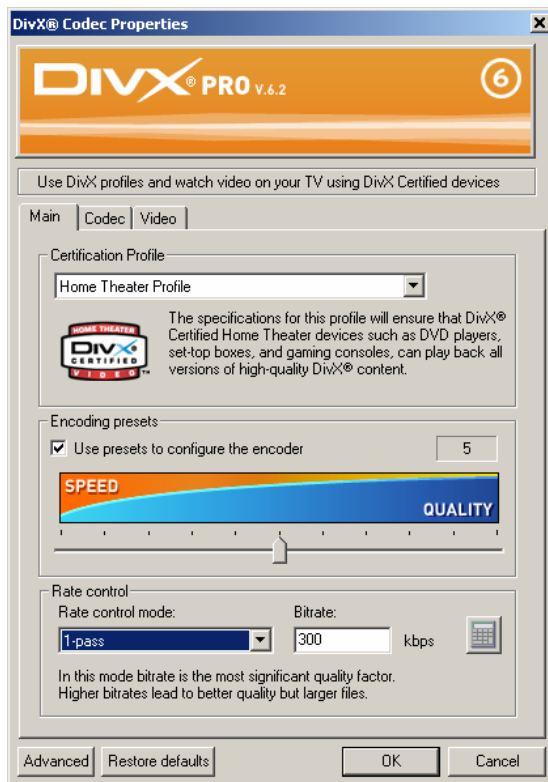
Figure 34.   DivX 6.0

Remarks:
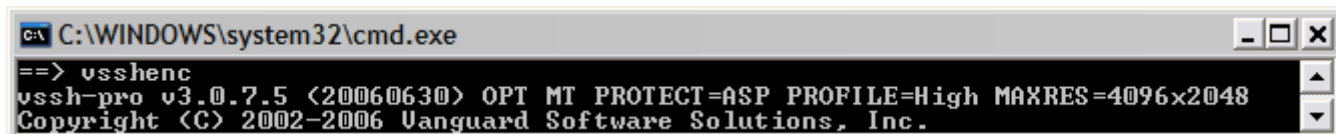
- Codec was not able to encode the "Concert" sequence due to the internal error

- 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:
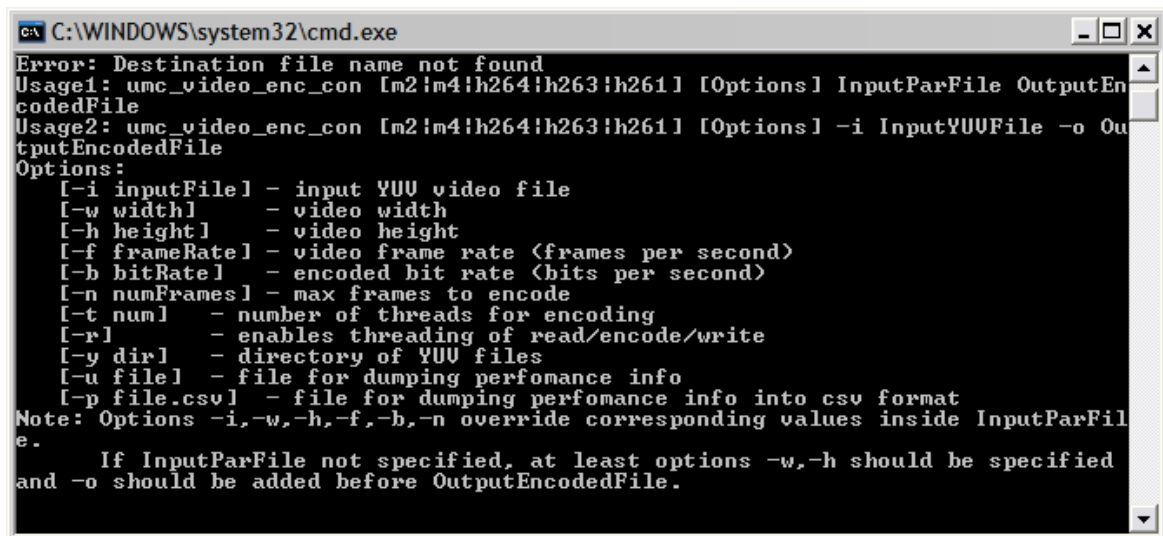
Codec worked without remarks
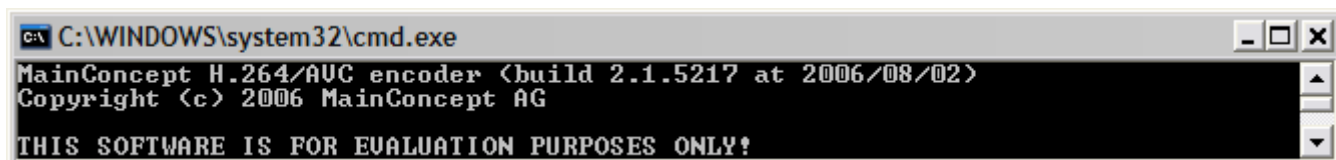
Figure 35.   **VSS H.264 Codec Pro 3.0**

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 36.   **Mainconcept H.264/AVC encoder**

Intel H.264 encoder

- Console encoding program

- Reference decoder JM 9.8 was used for decoding

- Codec and presets were provided by Intel Corp especially for this test

Remarks:

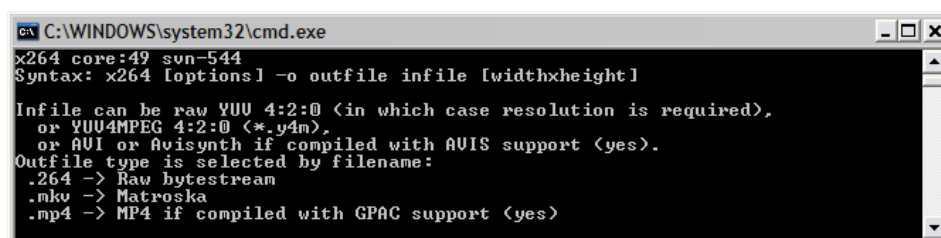Codec worked without remarks

Figure 37.   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 38.   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 39.   **Apple H.264**
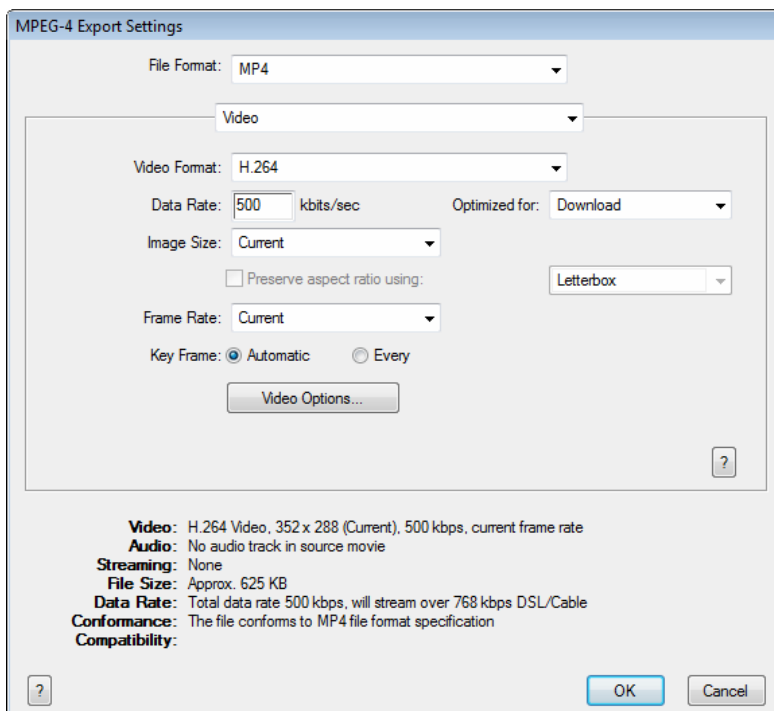
Sorenson H.264

- 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 4. 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 41). 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 42). 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.
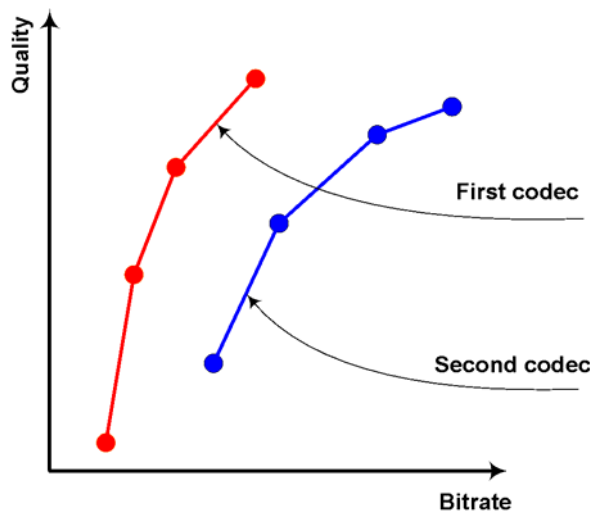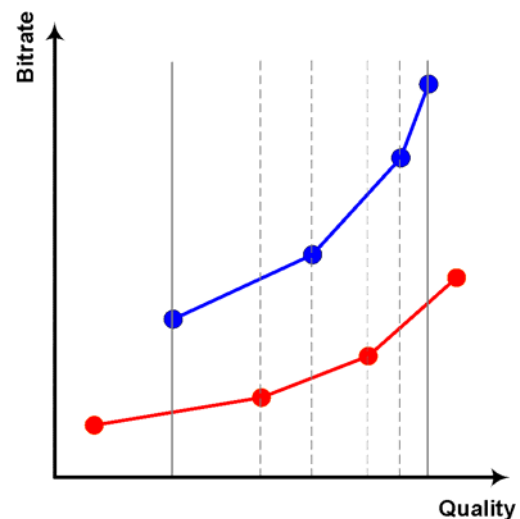

Figure 40. Source Data

Figure 41. Axes' Inversion and Averaging Interval Choosing
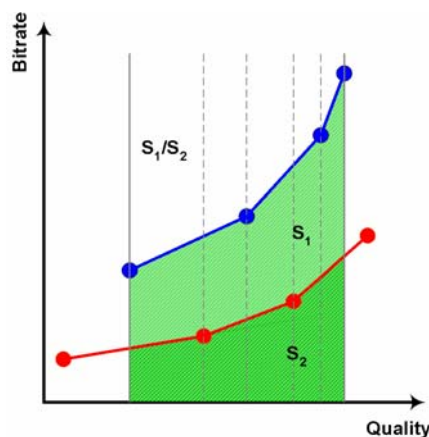
Figure 42. Areas' under Curves Ratio

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.

Moscow State University

Computer Science Department
Graphics&Multimedia Laboratory

About Us

Graphics&Media lab was founded at 1996. Our researchers have a great experience in different areas of Computer Graphics, Computer Vision, Digital Signal Processing (audio, image and video processing). Some of research results were patented, other results were presented in different articles.

One of the biggest parts of Graphics&Media lab is Video Group – the group of experts in video and image processing area. It has a great variety of interests in this area. Our main researches are devoted to

- Video filtering (pre- and postfiltering) of the video
  - Methods and algorithms for video quality enhancement
    - Brightness&Contrast enhancement
    - Color restoration
    - Sharpness imrovement
  - Algorithms for different artifact removal/reducing for quality enhancement and compression ratio improvement
    - Noise removal
    - Brightness flicking removal
    - Video stabilizer
    - Scratches, spots, dropout removal
  - Special processing algorithms
    - Object removal
    - Logo removal
    - Subtitle removal
    - Panorama reconstruction from video
    - Video to Photo
  - Algorithms for format conversion
    - Frame Rate Conversion
    - Deinterlacing
    - Super Resolution
    - Super Precision (повышение битности цвета)

- Researches in Video, audio and image codec
  - Great experience in different codec testing, comparisons and analysis
    - MPEG-4, H.264 video codec testing
    - Audio codec testing

- MPEG-2 decoders testing for work with corrupted streams
- JPEG-2000 and WMP testing
  - o Special projects
    - Own lossless codec
    - Own screen-capture codec
    - Researches on quality of x264 codec
    - Work on own lossy codec

- And much more

Our customers are different companies that work on video/image processing. The main clients are Samsung, Intel, Real.

If you work on video processing we can help you!

Full Version of Report

Dear video codec professionals!

You can support this comparison by buying the full version of our report. This contribution will help us:

- To help us to continue this comparison without any participation fees (this is important for x264 and xViD AVC next year)
- To avoid comparison sponsorship by codecs' developers
- To keep comparison detailed and useful.
  Thank you for your contribution in advance! The full report will be available immediately following this link.

If you have a discount code **please use this form** (if you are a member of scientific/academic organization, please contact us).

This comparison was performed with ViCoS – Video Codec Scoring System

About the Video Codec Scoring System

ViCoS is a fully automatic quality evaluation system for video codecs and video processing algorithms.

It is an advanced system with client-server architecture and relational data base support. It allows robust codec launches with user-friendly interface and functions for video codec or video filter analysis with easy-to-use visualizations of results. With ViCoS you can:

1. **Perform QA with much lesser resources**
   ViCoS usage allows to do Quality Assurance tasks in a highly automatic way. Now video codec features or entire codec quality can be tested very easily without big number of QA specialists.

2. **Perform codec testing without subjective codec testing**
   ViCoS implements many different quality analyzers that can replace expensive subjective quality evaluation for almost every task.

3. **Fast comparison to competitors**
   ViCoS provides functionality for video codecs comparison. Now codec developers can compare their video codec quality to competitors very fast and easily.

4. **Choose optimal default and predefined parameters**
   ViCoS can help to choose optimal (speed/quality trade-off) encoding parameters using preset analysis subsystem.

5. **Compare different versions of a product easily**
   ViCoS helps to perform quick speed and quality comparison of different versions of a codec or video processing software.
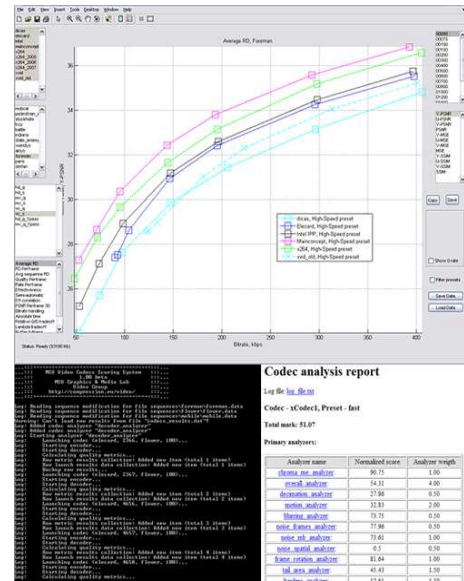
And much more.

Main key features of the system:

1) *Client-server architecture*.

2) *Easy modifications* to add a new codec, preset or video sequence.

3) *Robust launches* – if a codec fails the system continues to work, marking the error for this codec

4) *DB usage* – all results can be saved in a data base (almost any relational data base management systems: MySQL, MSSQL, Oracle, etc.)

5) *Result visualization* – all obtained results can be visualized very quickly with user friendly-interface.

6) *Huge Amount of Data Processing* – during ViCoS work huge amount of data is produced, it is processed and categorized very easily and user friendly.

7) *Specific Analysis Types* – ViCoS uses specific types of analysis: well-known and specially developed (Edge capture, Borders quality, Tail area, Blurring, Synthetic motion, and more than 10 other types).

More information could be found at http://yuvsoft.com/technologies/vicos/

E-mail: vicos@yuvsoft.com

YUVsoft Corp. was born out of the research of the Moscow State University video group. The technologies and solutions offered by YUVsoft are based upon more than 10 years of experience in video codec analysis, video processing, image processing and multimedia compression.

MSU Video Quality Measurement Tool
MSU Graphics & Media Lab. Video Group.

Main Features

1. 12 Objective Metric + 5 Plugins

PSNR several versions,   MSU Blurring Metric,
MSAD,   MSU Brightness Flicking Metric,
Delta,   MSU Brightness Independent PSNR,
MSE,   MSU Drop Frame Metric,
SSIM Fast,   MSU Noise Estimation Metric,
SSIM Precise,   MSU Scene Change Detector,
VQM,   MSU Blocking Metric.

2. More Than 30 Supported Formats, Extended Color Depth Support

*.AVI,   *.AVS: Extended Color
*. YUV: *.MOV,   Depth:
   YUV,   *.VOB,   P010, P014,
   YV12,   *.WMV,   P016, P210,
   IYUV,   *.MP4,   P214, P216,
   UYVY,   *.MPG,   P410, P414,
   Y,   *.MKV,   P416,
   YUY2,   *.FLV,   P410_RGB,
*.BMP,   etc.,   P414_RGB,
                                    P416_RGB.

3. Multi-core Processors Support
MMX, SSE and OpenMP Optimizations

4. Comparative Analysis
Comparison of 3 files at a time

5. ROI Support
Metric calculation for ROI (Region of Interest)
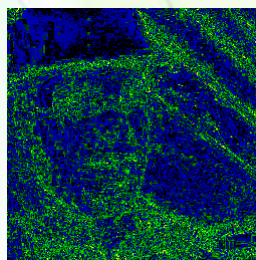
6. GUI & Batch Processing
GUI and command line tools

7. Plugins Interface
You can easily develop your own metric
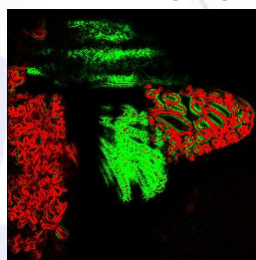
Visualization Examples

Allows easily detect where codec/filter fails
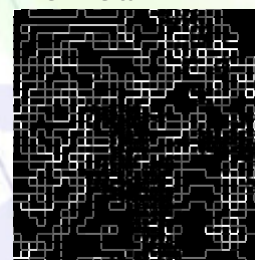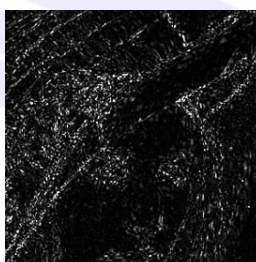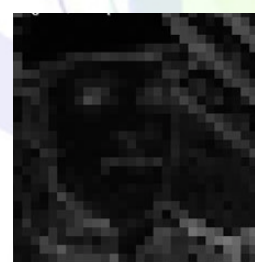

Y-YUV PSNR   Y-YUV Delta

MSU Blurring Metric   MSU Blocking Metric

Y-YUV MSE   VQM

8. Universal Format of Results
Results are saved in *.csv files

9. HDTV Support

10. Open-Source Plugins Available

11. Metric Visualization
Fast problem analysis, see examples above.

---

http://www.compression.ru/video/quality_measure/index_en.html
Tool was downloaded more than 100 000 times!
Free and Professional versions are available

Big thanks to our contributors:

Apple Inc.   intel   skype   nVIDIA.   NASA

DOLBY   CISCO   Sun microsystems   NBC UNIVERSAL   DivX