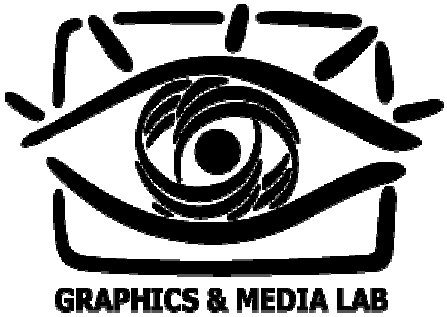

MPEG-4 Video Codecs Comparison

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Testing, charts, analysis: Dmitriy Kulikov, Alexander Parshin
Translating: Daria Kalinkina
Verification: Stanislav Soldatov

Codecs:

DivX 5.2.1

DivX 4.12

DivX 3.22

MS MPEG-4 3688 v3

XviD 1.0.3

3ivx D4 4.5.1

OpenDivX 0.3

March 2005
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videocodec-testing@compression.ru

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Overview

Codecs

	CODEC	MANUFACTURER	VERSION
1.	DivX 5.2.1	DivXNetworks, Inc.	5.2.1 build b1338
2.	DivX 4.12	DivXNetworks, Inc.	4.12 build 307
3.	DivX 3.22	Kristal Studio	3.22
4.	MS MPEG-4	Microsoft Corporation	3688 v3
5.	XviD 1.0.3	XviD development team	1.0.3 Dec 20 2004
6.	3ivx D4 4.5.1	3ivx Technologies Pty. Ltd.	D4 4.5.1
7.	OpenDivX 0.3	DivXNetworks, Inc.	4.0 alpha 50

Video sequences

	Sequence	Number of frames	Number of frames per second	Resolution and color space
1.	bankomatdi	376	30	704x352(RGB)
2.	battle	1599	24	704x288(RGB)
3.	bbc3di	374	25	704x576(RGB)
4.	foreman	300	30	352x288(RGB)
5.	susidi	374	25	704x576(RGB)

Goal and rules of testing

Goal of MPEG4 codecs comparison test

The main goal of this work was the comparative assessment of codecs quality in terms of their use by an ordinary user for home video compression.

Standard video sequences were used for the estimation. Codecs were used with their default settings except for bit rate and maximum distance between I-frames. DivX 5.2.1 was tested with enabled “GMC” and “Quarter Pixel” options.

Testing rules

- PSNR has been measured using luv_avi program.
- Frame size has been calculated as the ratio of the sequence size to the number of frames.
- Sequences have been compressed using VirtualDub 1.5.4 video processing tool.
- Codecs have been used with their default settings except for bit rate and maximum distance between I-frames. (Default settings are the settings specified in a codec after its installation.)
- Maximum distance between I-frames has been set to 300 for all the codecs. The similar “Keyframe every [x] seconds” option in MS MPEG-4 and DivX3.22 codecs has been set to the value that would approximately provide same 300 frame distance.
- Bit rate values have been set to 100, 225, 340, 460, 700, 938, 1140, 1340, 1840, and 2340 KBps.
- Some measures have been duplicated by a MSU Video Measure beta tool in order to verify the results and to test this application.

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

Video Sequences Used in the Testing

Bankomatdi

Sequence title	bankomatdi
Resolution	704x352
Number of frames	376
Color space	RGB
Frames per second	30
Source	MPEG-2 (DVD), Smart Deinterlace

Picture 1. Frame 168 from bankomatdi sequence

This sequence is a fragment of the “Terminator-2” movie, which represents the scene near the cash dispenser. The sequence is characterized by slow motion, very little change of background (in the second part of the sequence camera slowly goes to the right) and comparatively high resolution.

Battle

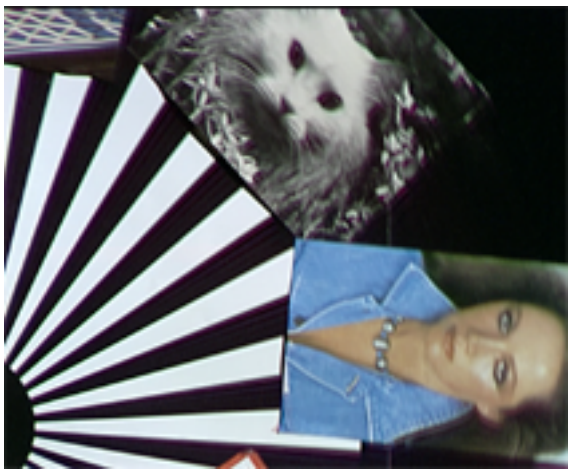
Sequence title	battle
Resolution	704x288
Number of frames	1599
Color space	RGB
Frames per second	24
Source	MPEG-2 (DVD), FlaskMPEG deinterlace

Picture 2. Frame 839 from battle sequence

This sequence is also a fragment of the “Terminator-2” movie, which represents the very beginning of the movie. In the terms of compression this sequence is the most difficult one among all other sequences that took part in the testing. It is caused by three main reasons: constant changing of brightness because of the 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.

Bbc3di

Sequence title	bbc3di
Resolution	704x576
Number of frames	374
Color space	RGB
Frames per second	25
Source	Original (standard sequence), Smart Deinterlace



Picture 3. Frame 185 from bbc3di sequence

Picture 4. Frame 258 from bbc3di sequence

This sequence is characterized by pronounced rotary motion. It contains a rotating striped drum with different pictures and photos on it. Quality of the compressed sequence can be estimated by the details on these images.

Foreman

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

Picture 5. Frame 77 from foreman sequence

Picture 6. Frame 258 from foreman sequence

This is another famous sequence. It represents a face with very rich mimicry. On the one hand motion here is not very intensive, but on the other it is disordered, not forward. Intricate character of motion creates problems for the motion compensation process. In addition camera is shaking which 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.

Susidi

Sequence title	susidi
Resolution	704x576
Number of frames	374
Color space	RGB
Frames per second	25
Source	MPEG-2 (40Mbit), Smart Deinterlace

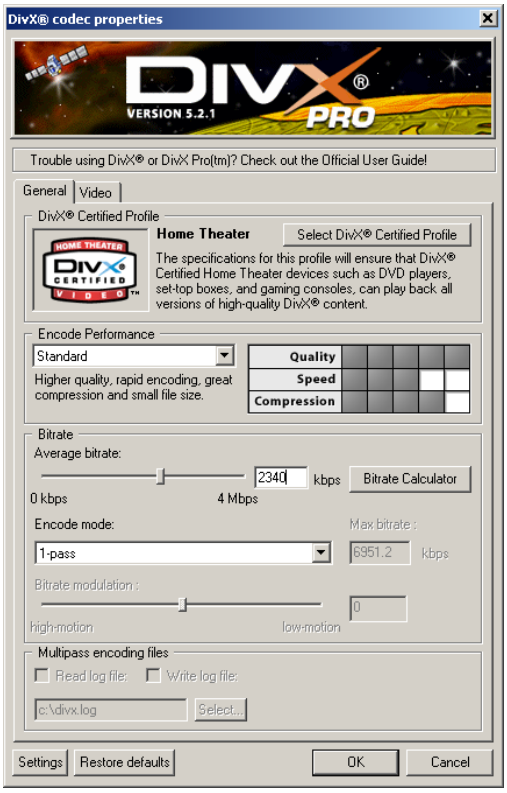
Picture 7. Frame 193 from susidi sequence

This sequence is characterized by high-level noise and slow motion. In its first part the scene is almost static (the girl only blinks), then there is some motion (she abruptly moves her head) and then the scene becomes almost static again. Noise is suppressed on every second frame due to the B-frames option in MPEG-2 codec.

Codecs

DivX 5.2.1

- This is a VfW (Video for Windows) codec.
- Compression has been performed using VirtualDub 1.5.4 video processing tool.
- Codec has been tested with its default settings.
- GMC and Quarter Pixel options have been enabled. In order to enable them follow these instructions:
  1. Press the “Select DivX© Certified Profile” button.
  2. Uncheck “DivX© Certified”.
  3. Press OK in the appeared “Warning” window.
  4. Press “Next”.
  5. Check “Use Quarter Pixel” and “Use GMC”.
  6. Press “Finish”.
- “Max bit rate” field value hasn`t been changed.



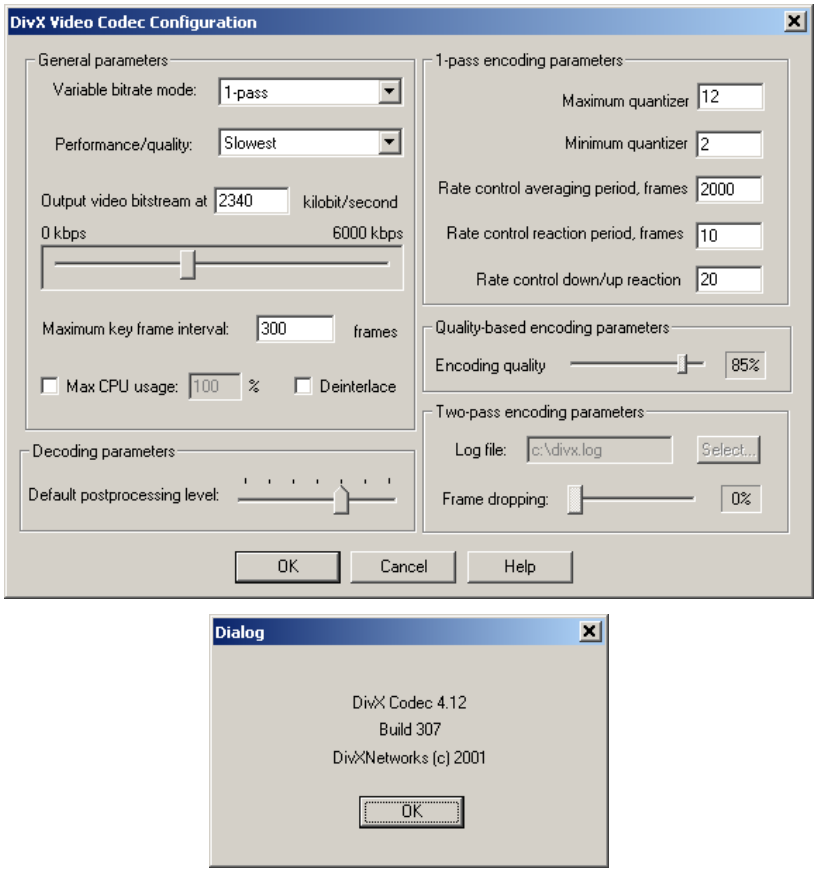
Picture 8. DivX 5.2.1

Remarks:

Codec was tested without problems.

DivX 4.12

- This is a VfW (Video for Windows) codec.
- Compression has been performed using VirtualDub 1.5.4 video processing tool.
- Codec has been tested with its default settings.



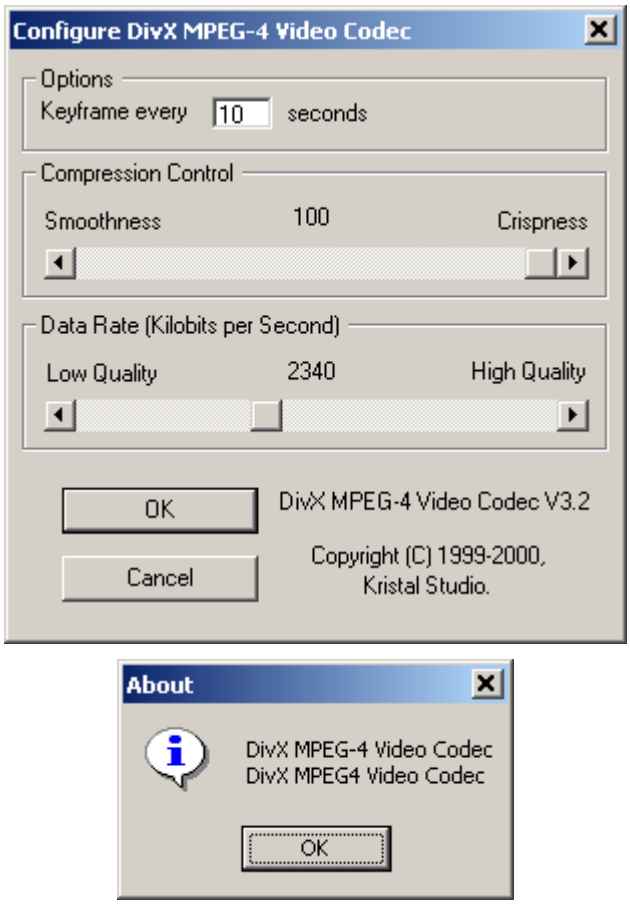
Picture 9. DivX 4.12

Remarks:

Codec was tested without problems.

DivX 3.22

- This is a VfW (Video for Windows) codec.
- Compression has been performed using VirtualDub 1.5.4 video processing tool.
- Codec has been tested with its default settings.
- “Keyframe every [x] seconds” field value has been set to 10 for bankomat and foreman and to 12 for battle, bbc3di and susidi.



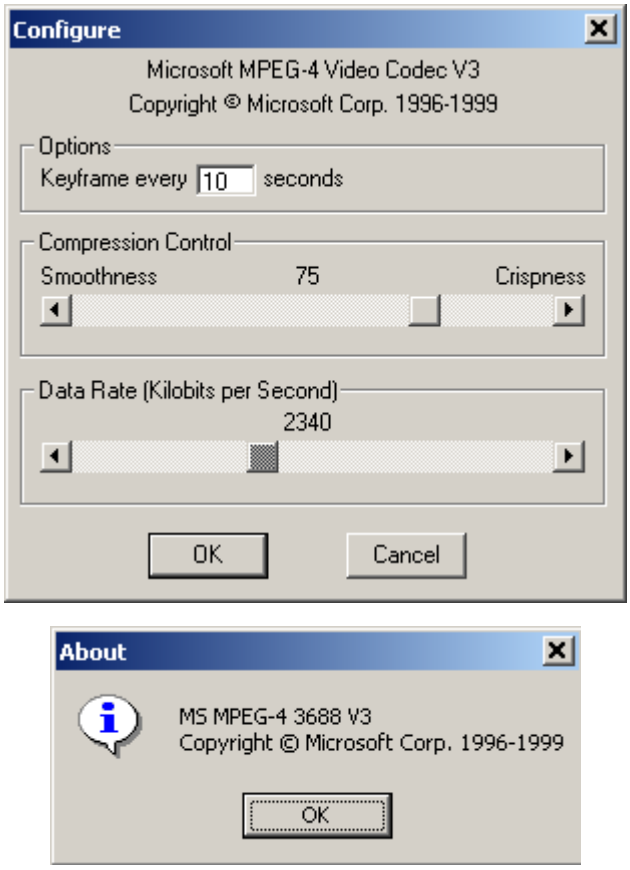
Picture 10. DivX 3.22

Remarks:

- Slider is rather inconvenient for specifying bit rate value.

MS MPEG-4

- This is a VfW (Video for Windows) codec.
- Compression has been performed using VirtualDub 1.5.4 video processing tool.
- Codec has been tested with its default settings.



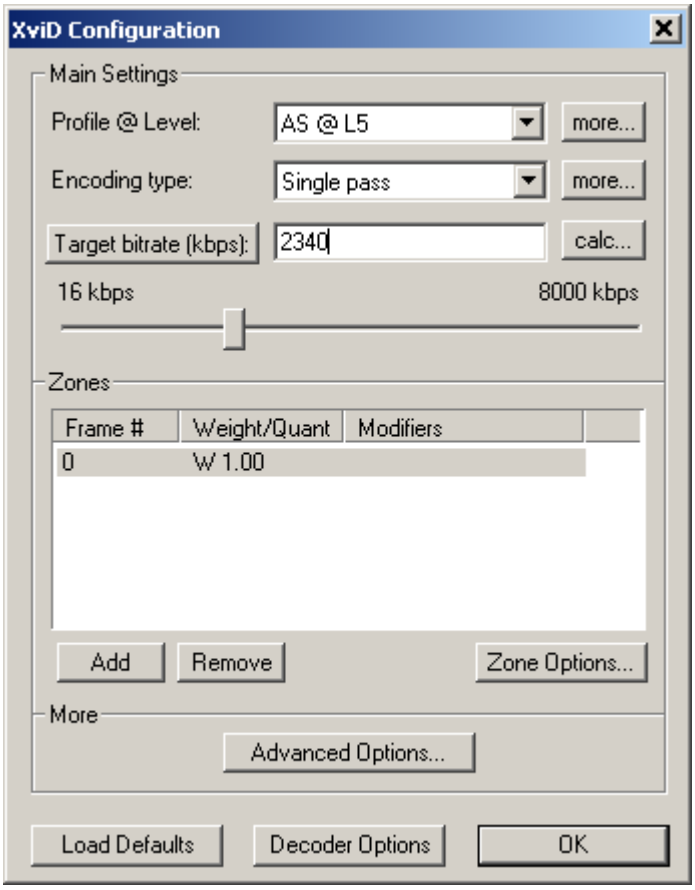
Picture 11. MS MPEG-4

Remarks:

Slider is rather inconvenient for specifying bit rate value.

XviD 1.0.3

- This is a VfW (Video for Windows) codec.
- Compression has been performed using VirtualDub 1.5.4 video processing tool.
- Codec has been tested with its default settings.



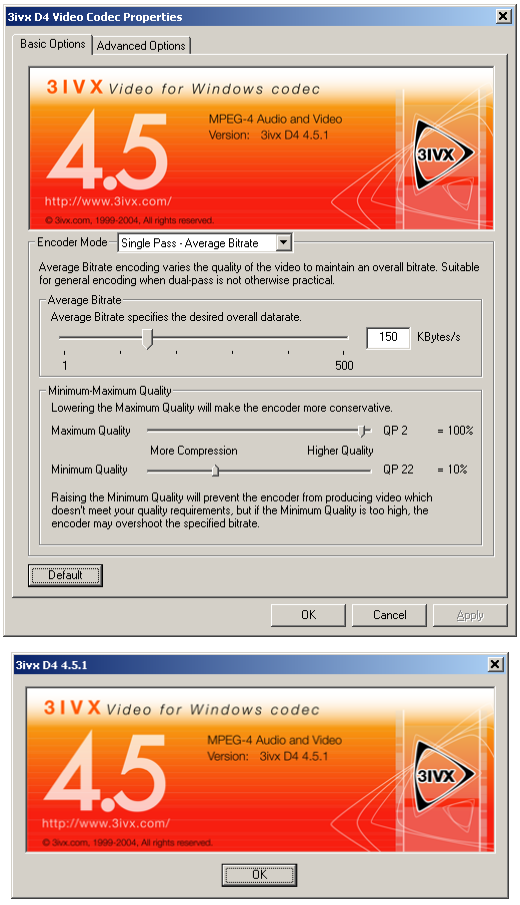
Picture 12. XviD 1.0.3

Remarks:

Codec was tested without problems.

3ivx D4 4.5.1

- This is a VfW (Video for Windows) codec.
- Compression has been performed using VirtualDub 1.5.4 video processing tool.
- Codec has been tested with its default settings.
- Bit rate should be specified in KBps for this codec. The codec has been tested with 12, 28, 42, 57, 87, 117, 142, 167, 230, and 292 KBps bitrate values.



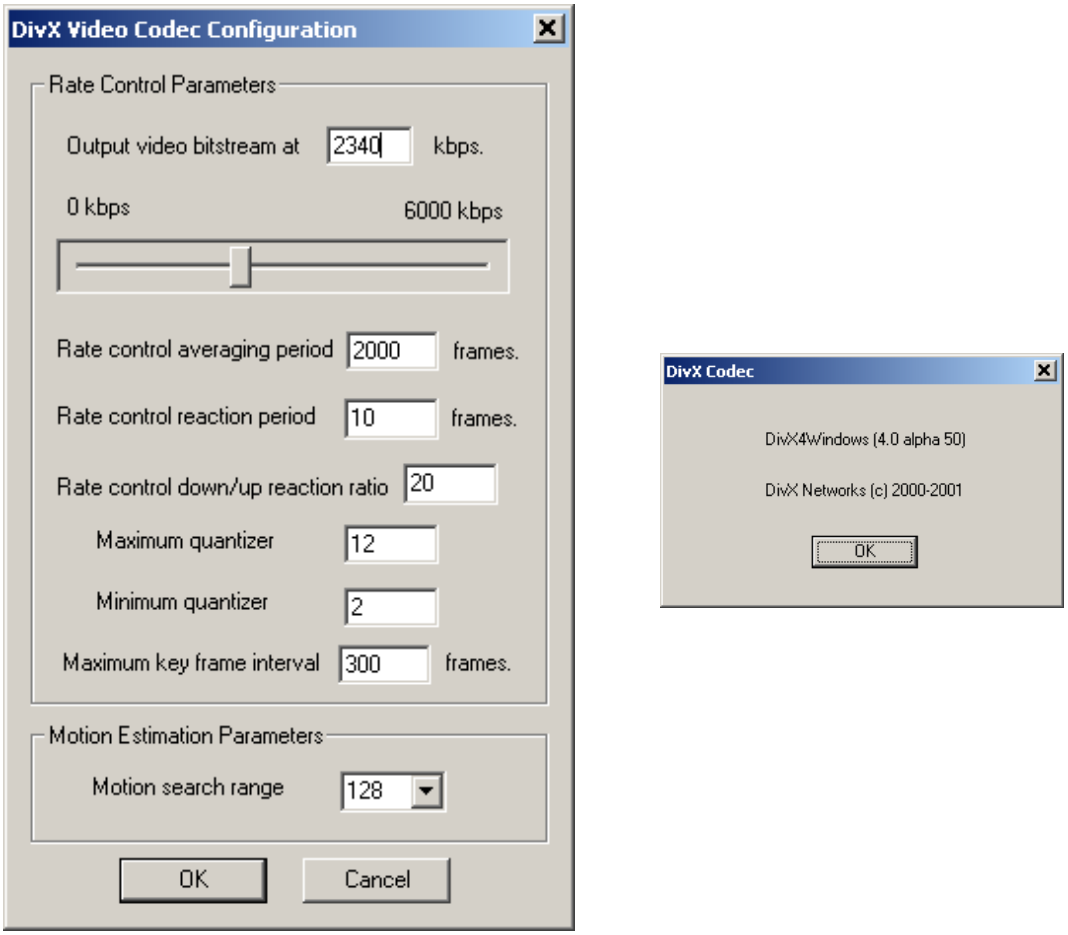
Picture 13. 3ivx D4 4.5.1

Remarks:

Codec was tested without problems.

OpenDivX 0.3

- This is a VfW (Video for Windows) codec.
- Compression has been performed using VirtualDub 1.5.4 video processing tool.
- Only battle sequence was used for testing this codec.



Picture 14. OpenDivX 0.3

Remarks:

Codec was tested without problems.

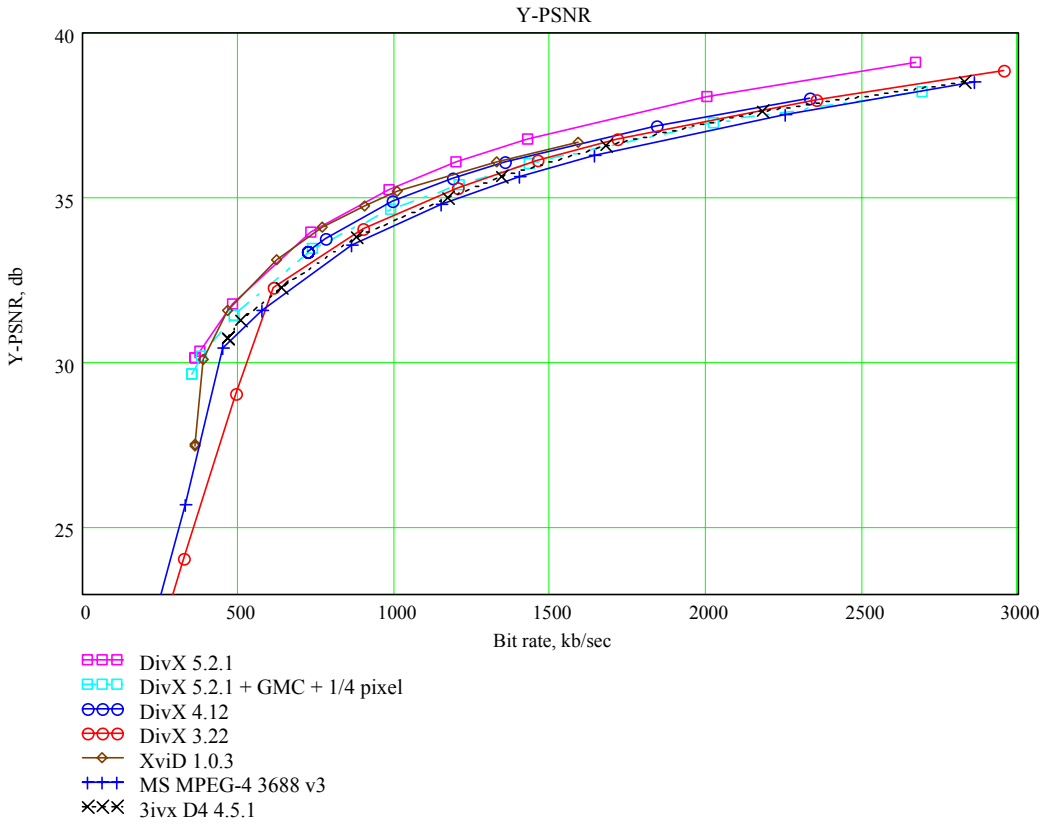
Y-PSNR/Bit rate, Delta-Y-PSNR/Bit rate, U-PSNR/Bit rate and V-PSNR/Bit rate diagrams

These diagrams show clearly the dynamics of dependency of the compressed sequence quality on its size. Coordinates of the basic point are represented by the average (for the whole sequence) PSNR-values and frame sizes. So each branch contains ten points that correspond to different bit rates.

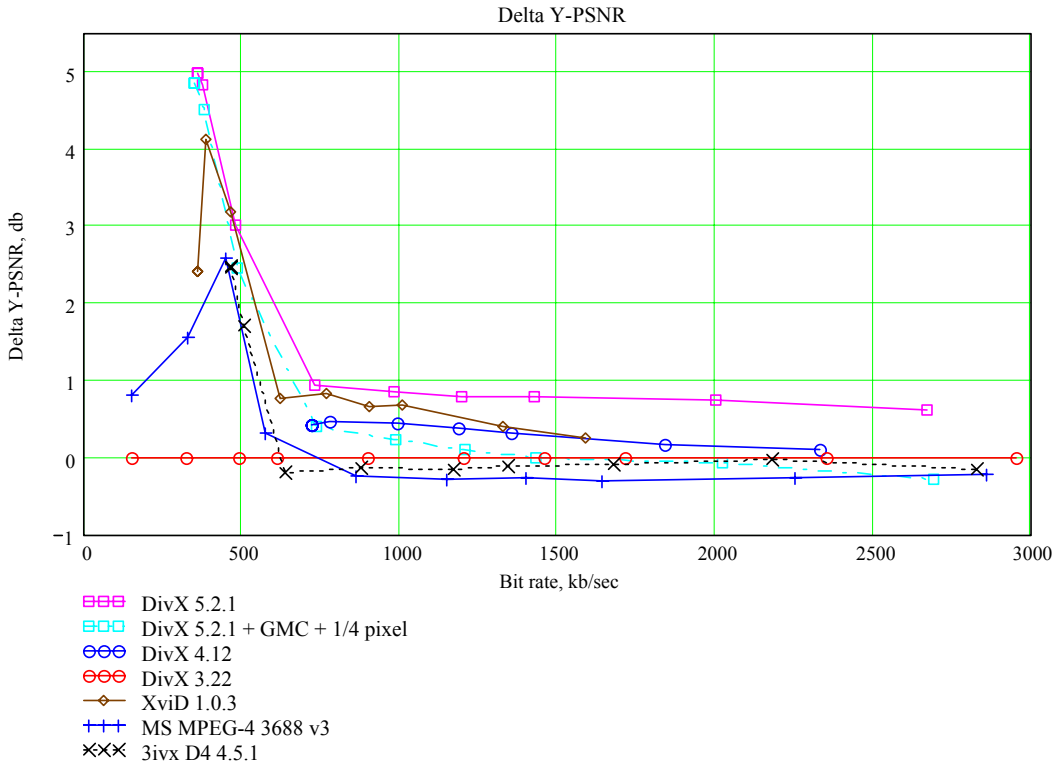
The higher level of PSNR measure (height of graphs) means better quality.

Delta Y-PSNR is the diagram of comparative PSNR value. It represents the difference from DivX 3.22 PSNR values for each tested MPEG4 codec measured using the same bit rate. DivX 3.22 PSNR values are linearly interpolated to obtain values that correspond to any bit rate used in other codecs` measures.

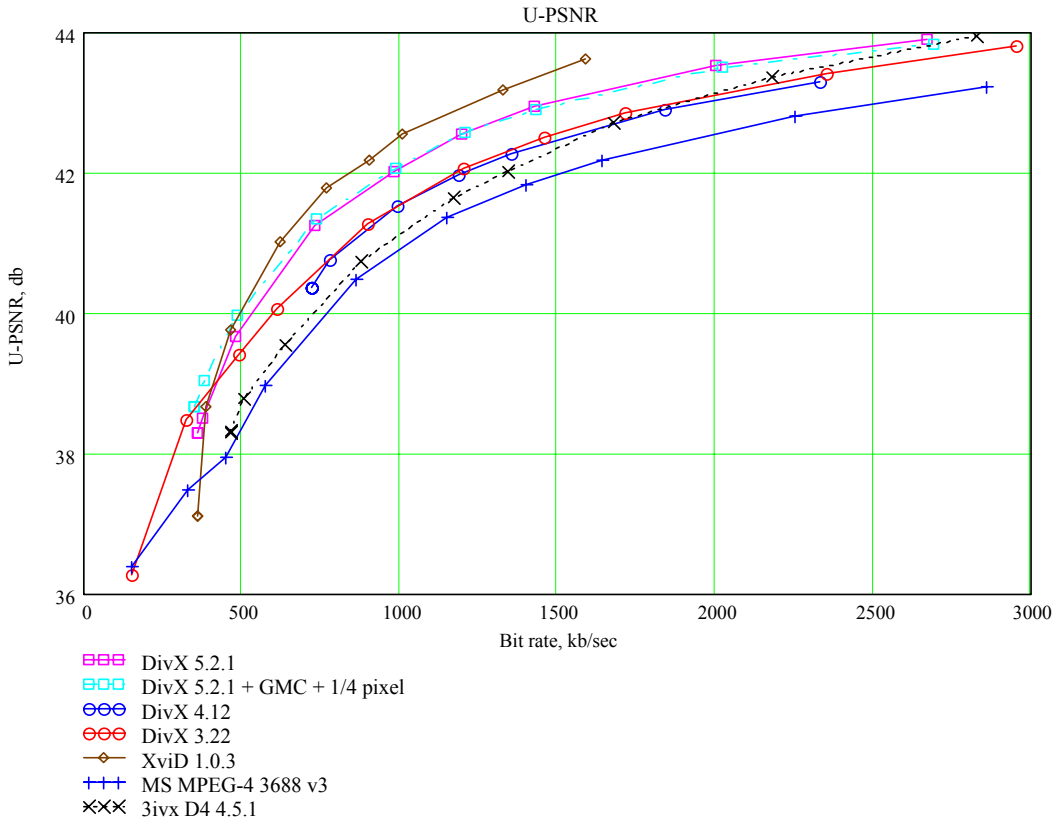
Bankomatdi sequence



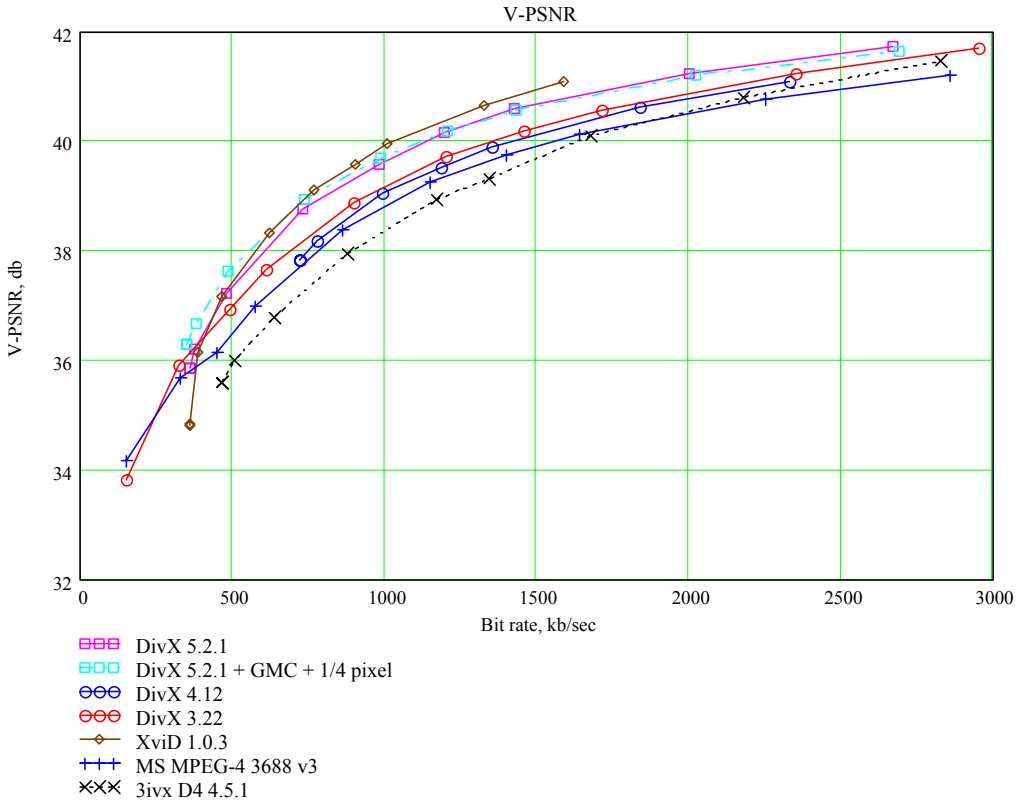
Picture 15. Y-PSNR. Sequence bankomatdi



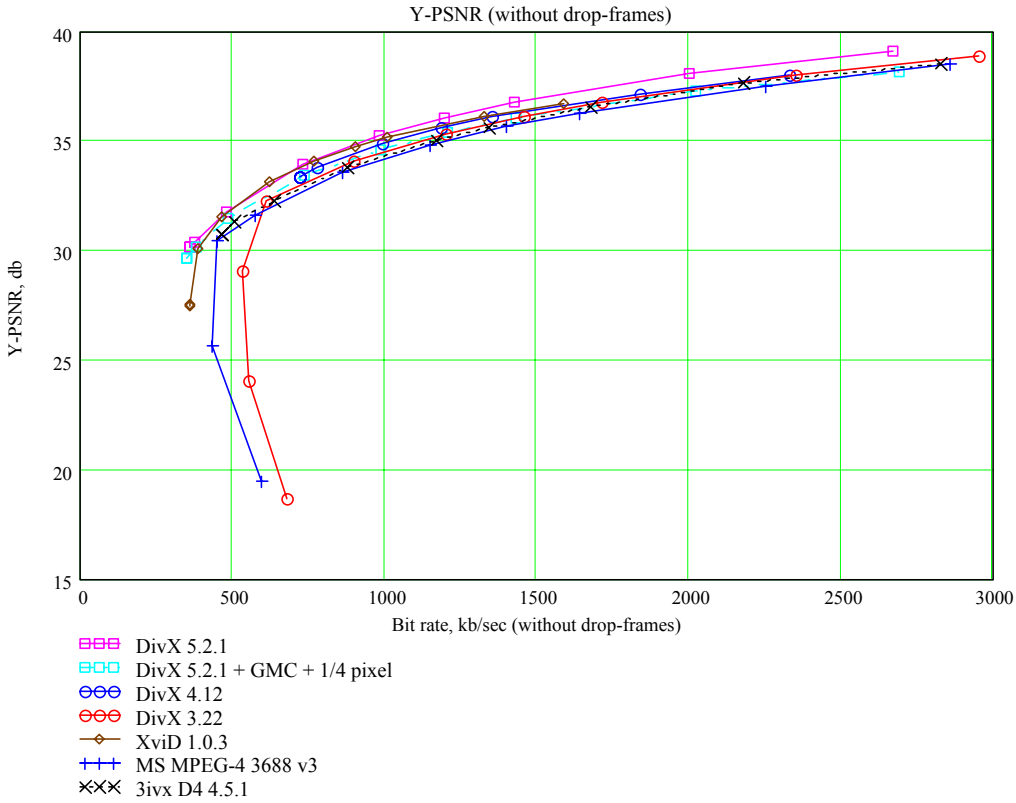
Picture 16. Delta Y-PSNR. Sequence bankomatdi



Picture 17. U-PSNR. Sequence bankomatdi



Picture 18. V-PSNR. Sequence bankomatdi

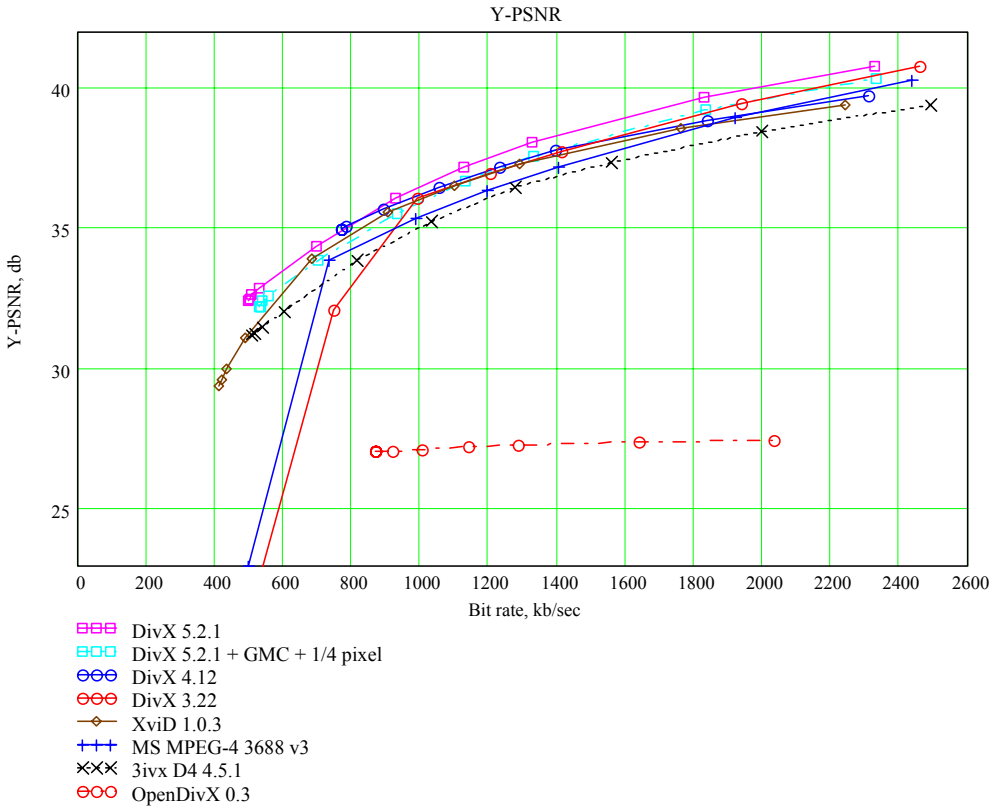


Picture 19. Y-PSNR without drop-frames. Sequence bankomatdi

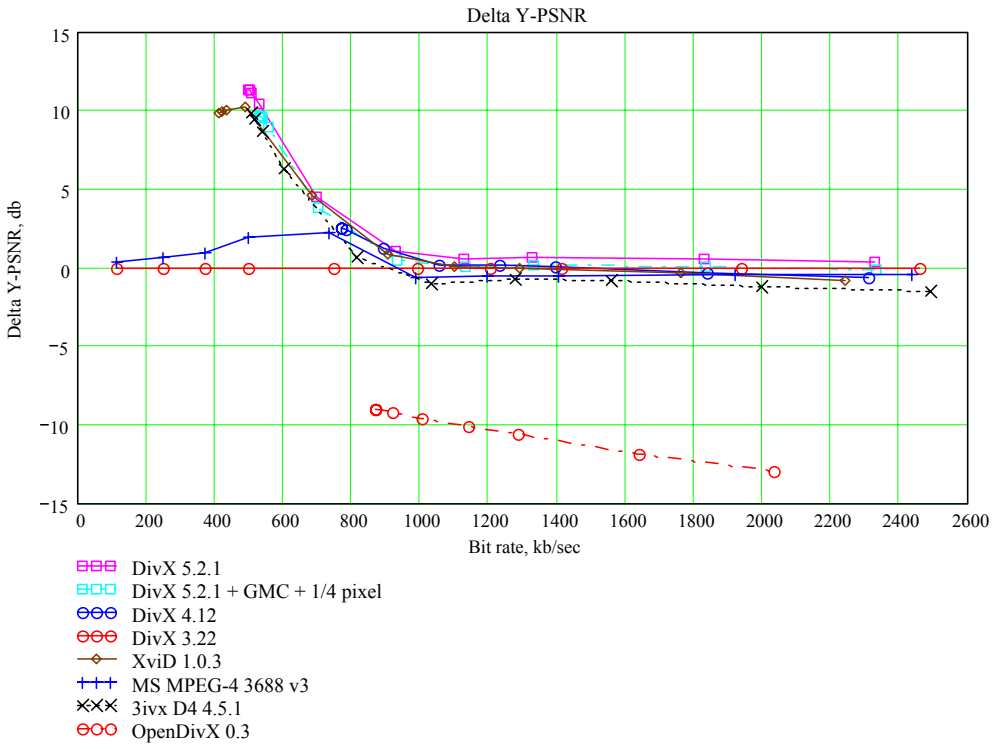
Conclusions:

- DivX 5.2.1 is the best on high bit rates.
- XviD provides almost the same quality on 500-1000 KBps.
- XviD provides the best quality in processing U and V components.
- DivX 3.22 and MS MPEG-4 keep low bit rate using drop frames.
- DivX4.12 doesn't compress this sequence with bit rate lower than 700 KBps.

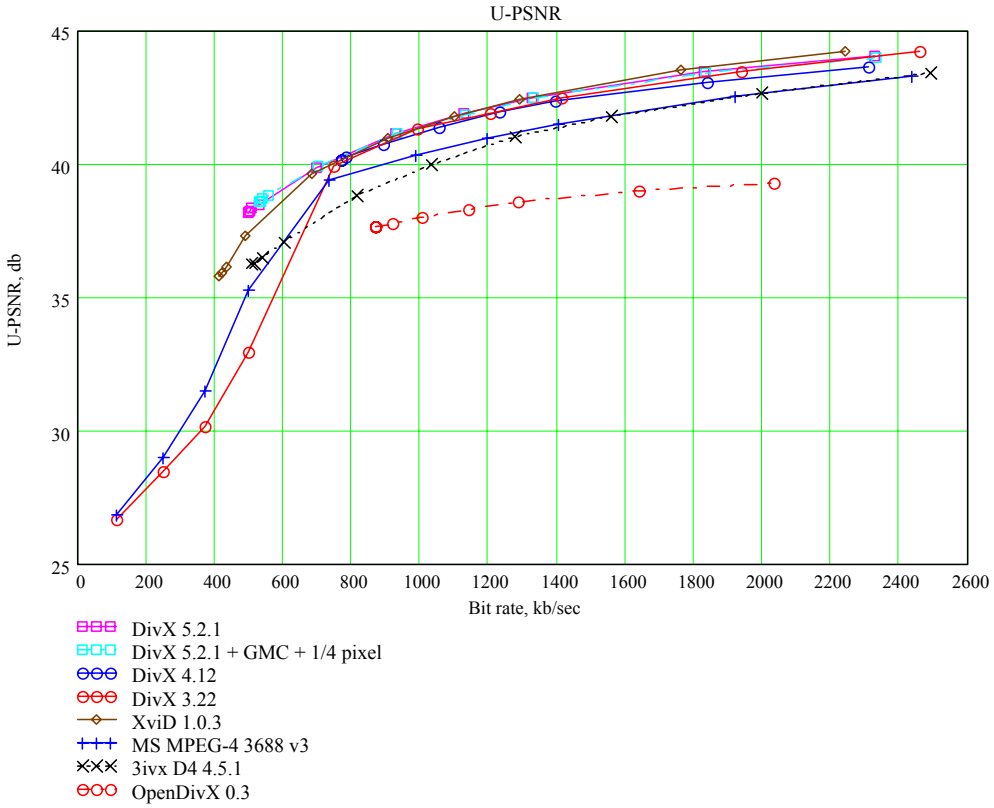
Battle sequence



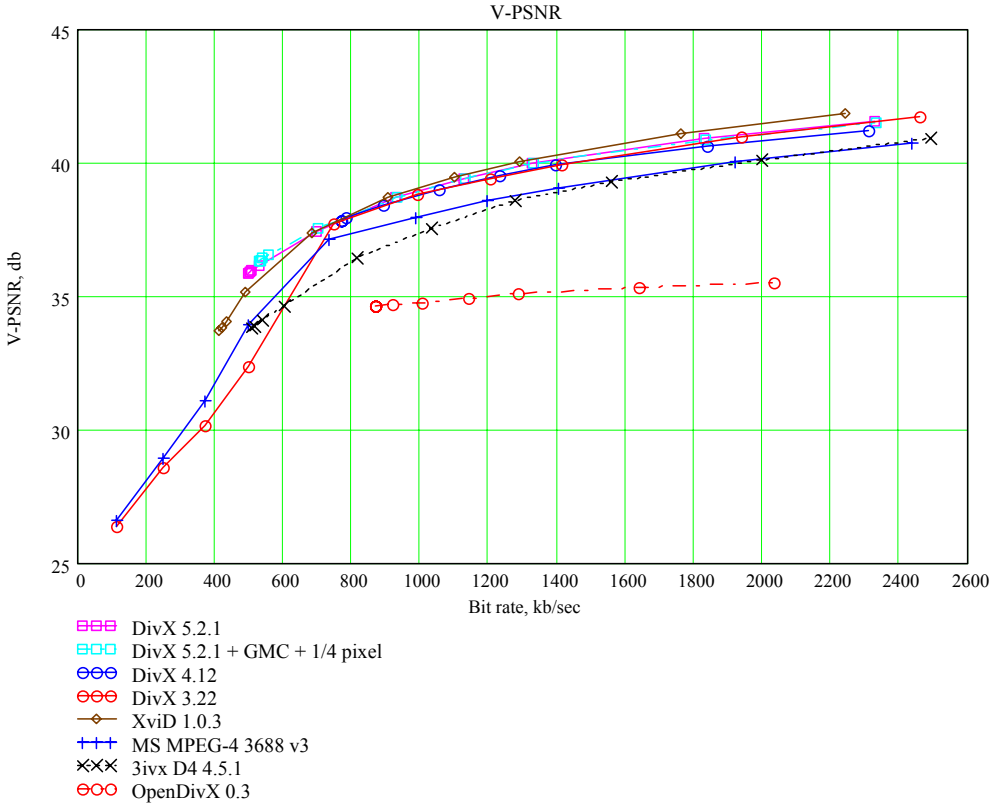
Picture 20. Y-PSNR. Sequence battle



Picture 21. Delta Y-PSNR. Sequence battle



Picture 22. U-PSNR. Sequence battle

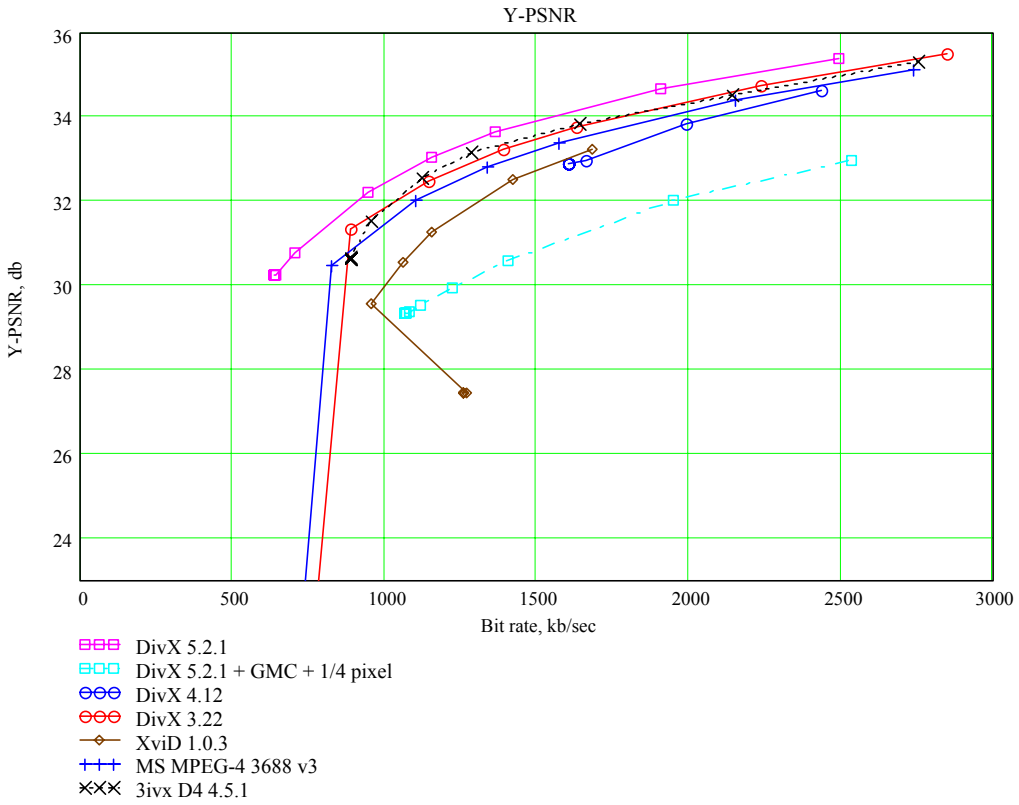


Picture 23. V-PSNR. Sequence battle

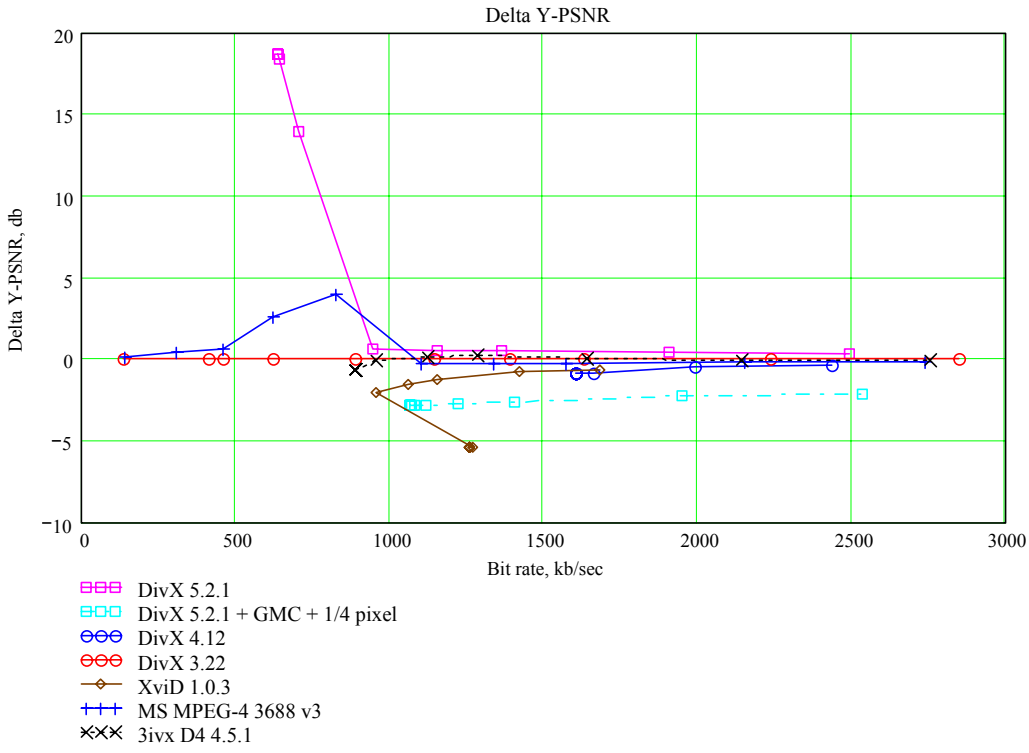
Conclusions:

- DivX 5.2.1 is the best for this sequence.
- 3ivX is the worst for this sequence.
- OpenDivX has been tested on this sequence only. The results were so poor that this codec has been excluded from further testing.

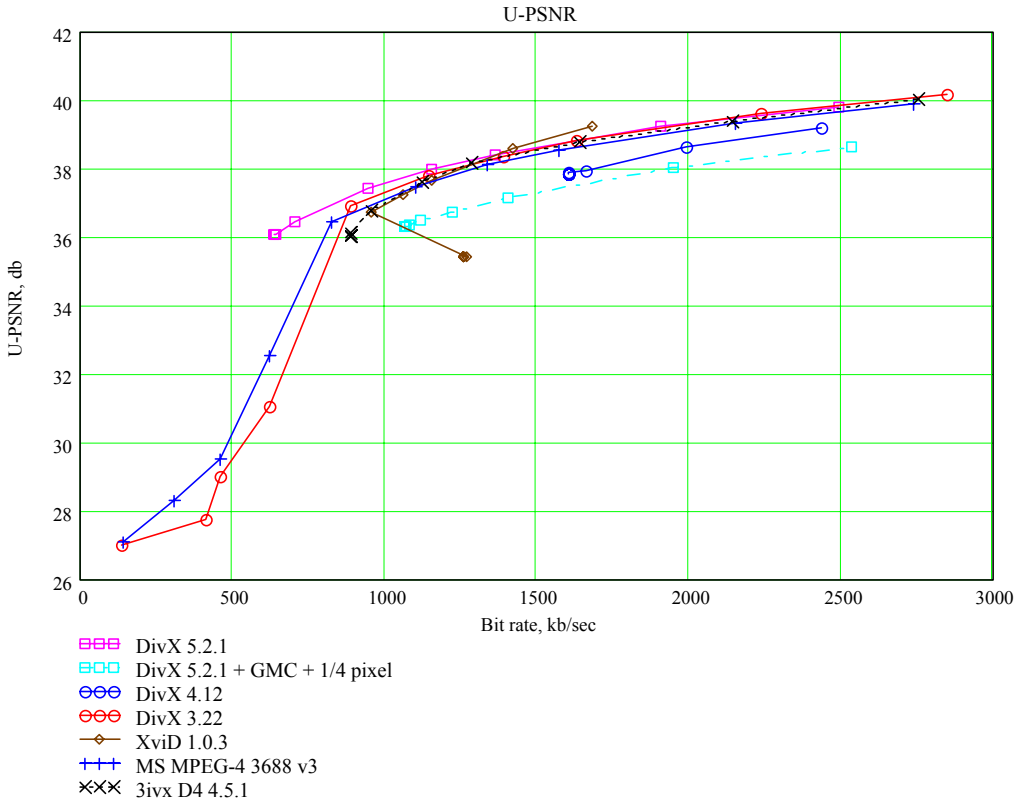
Bbc3di sequence



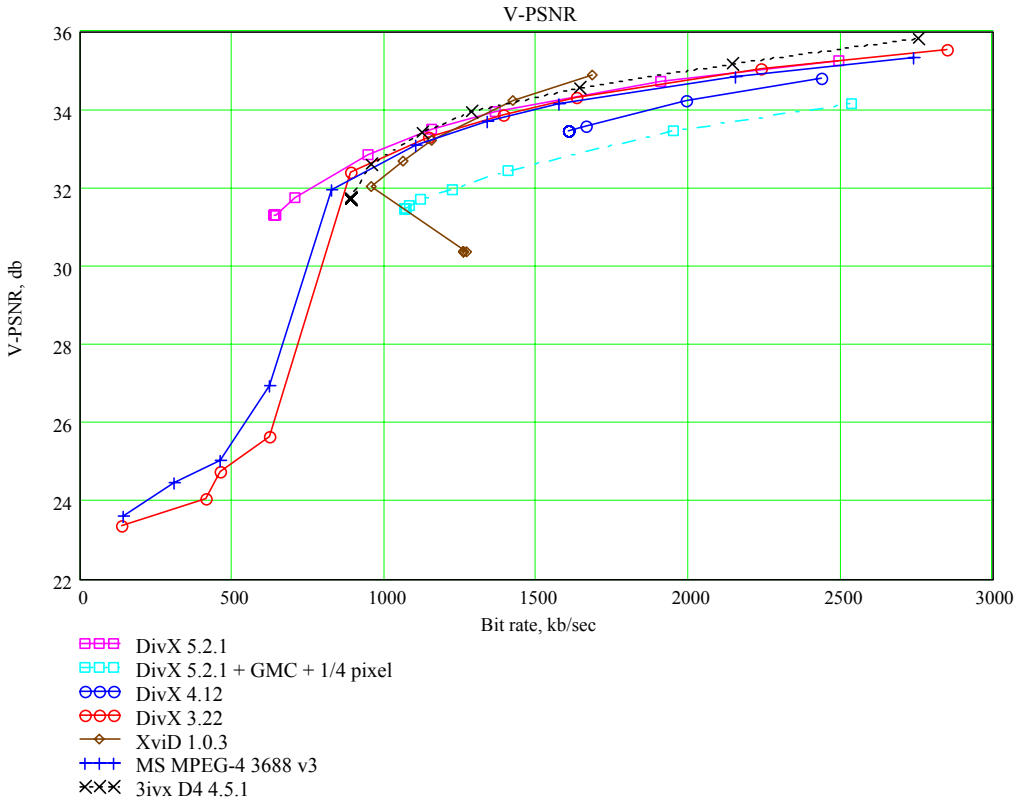
Picture 24. Y-PSNR. Sequence bbc3di



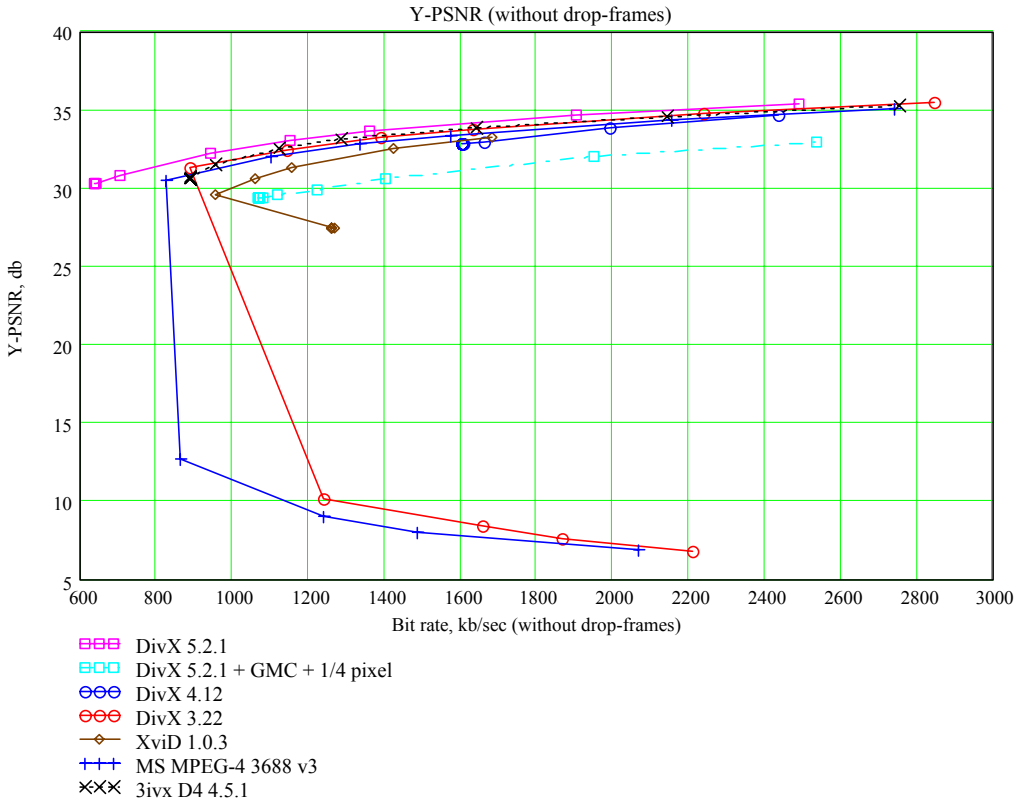
Picture 25. Delta Y-PSNR. Sequence bbc3di



Picture 26. U-PSNR. Sequence bbc3di



Picture 27. V-PSNR. Sequence bbc3di

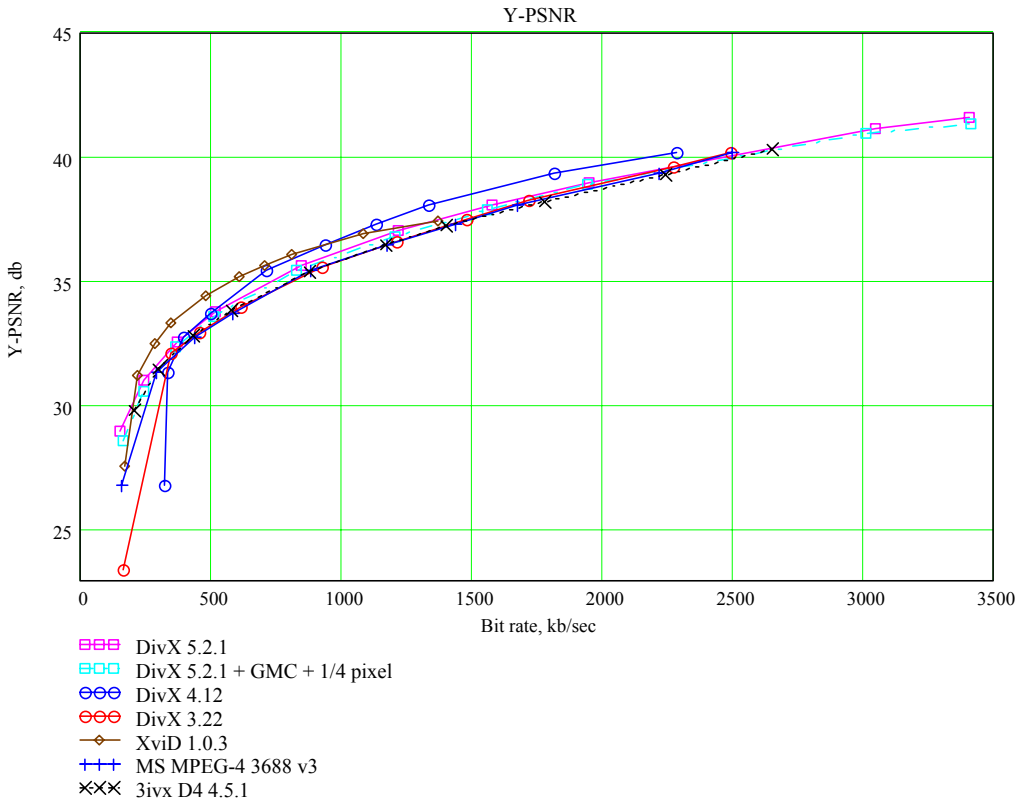


Picture 28. Y-PSNR without drop-frames. Sequence bbc3di

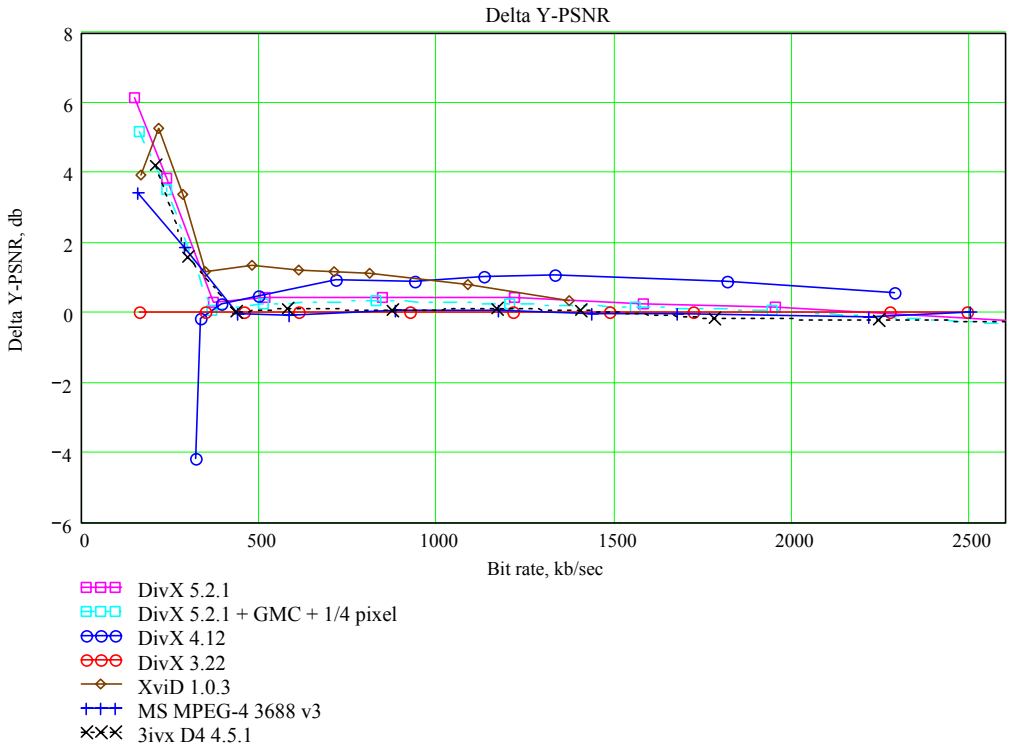
Conclusions:

- XviD behaved strangely on this sequence. When bit rate was set lower than 938 the compressed sequences became larger than it should have been and its quality became worse. Y-PSNR diagrams illustrate this fact.
- DivX 3.22 and MS MPEG-4 keep low bit rate using drop frames. The first one left 23 frames of 374 on 100 KBps and the other - 25. As a result the compressed sequence is almost impossible to watch.
- DivX 5.2.1 proves to be the best once more. Its results are much better especially on 460 and 700 KBps.
- Enabling of GMC and Quarter Pixel options made DivX 5.2.1 one of the worst. It is caused by the motion character in this sequence (rotation).
- DivX4.12 doesn't compress this sequence with bitrate lower than 1500 KBps.

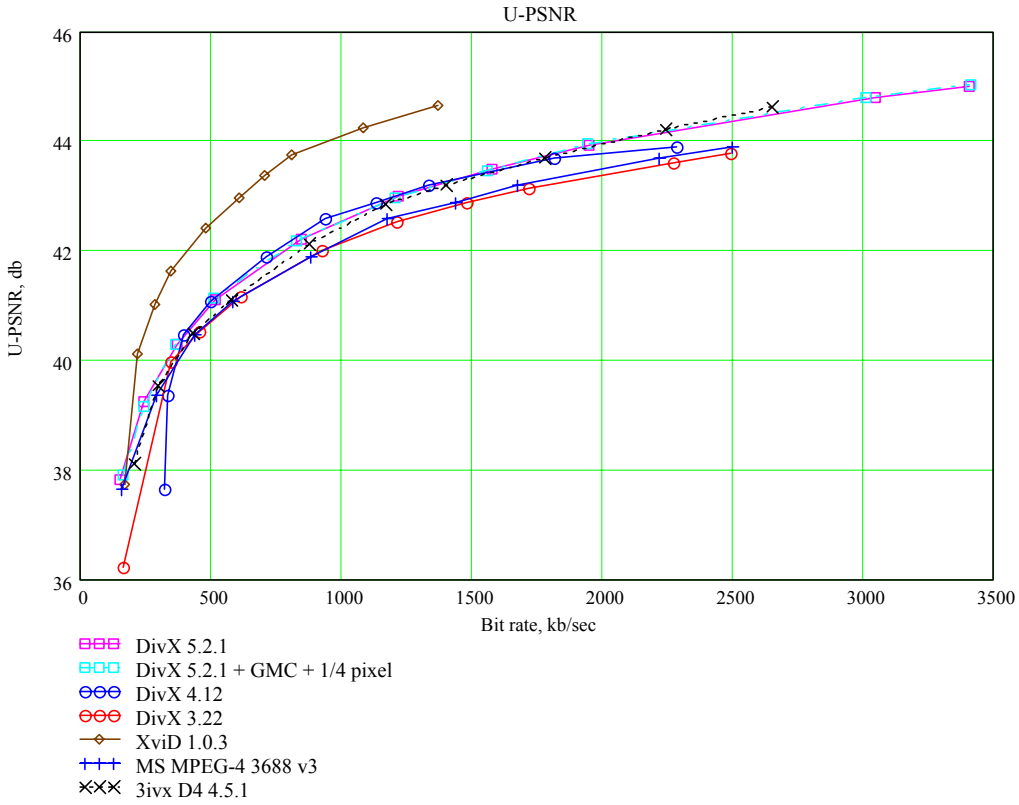
Foreman sequence



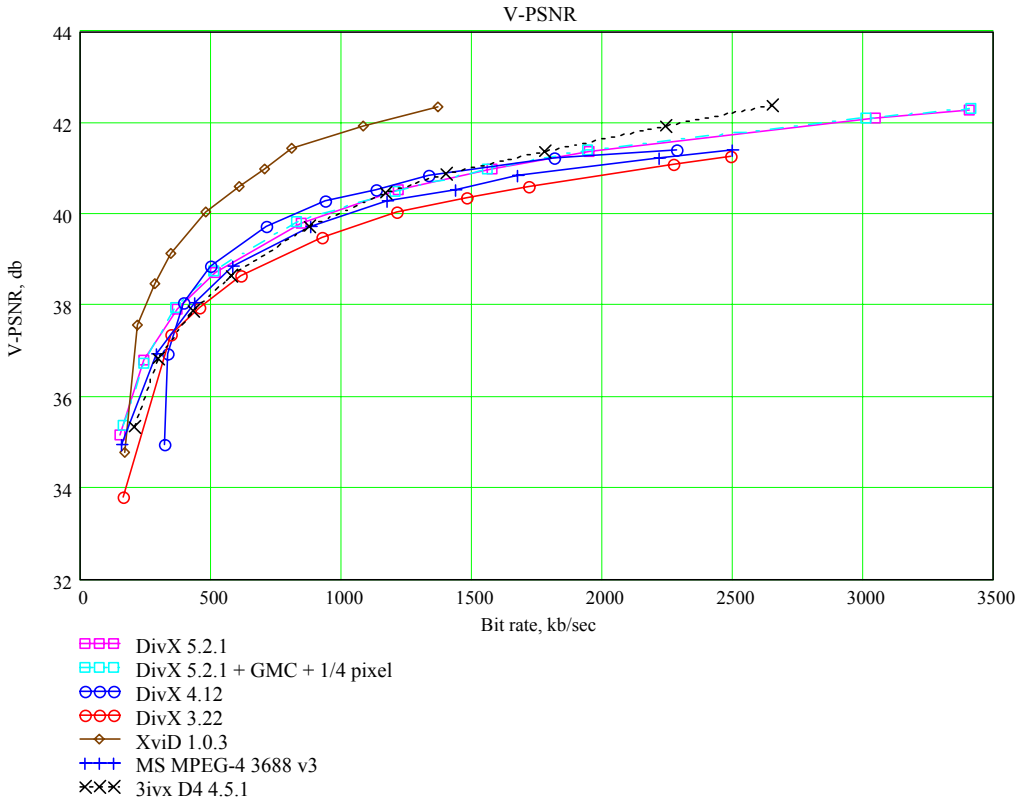
Picture 29. Y-PSNR. Sequence foreman



Picture 30. Delta Y-PSNR. Sequence foreman



Picture 31. U-PSNR. Sequence foreman

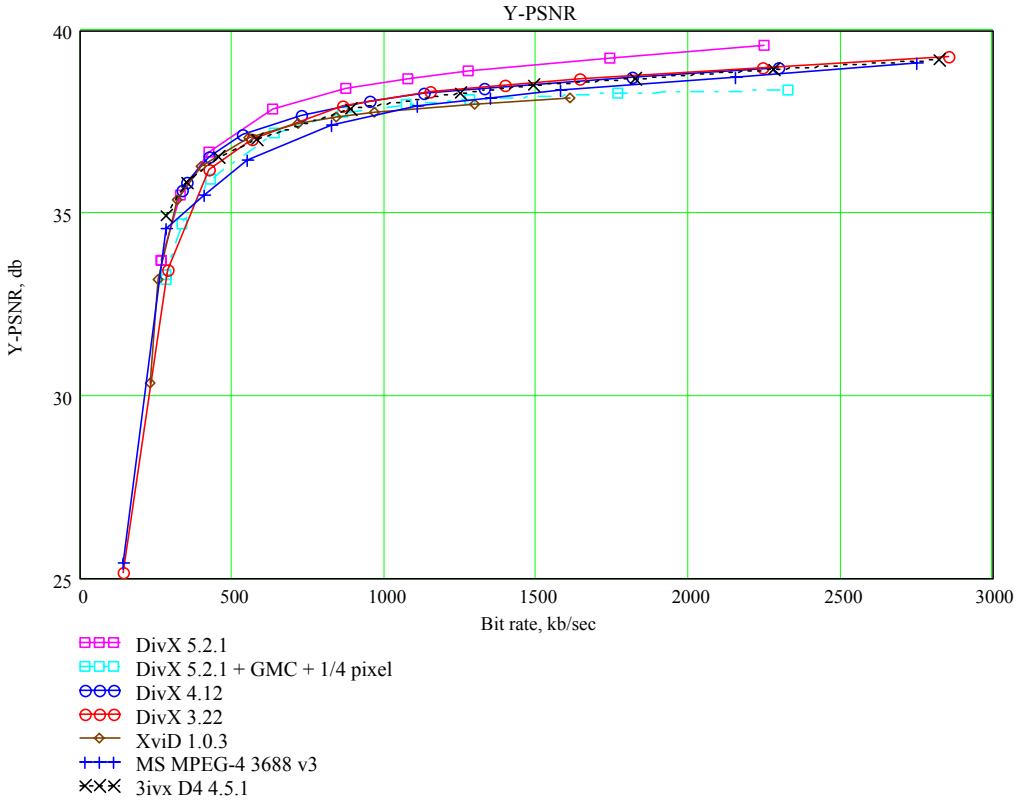


Picture 32. V-PSNR. Sequence foreman

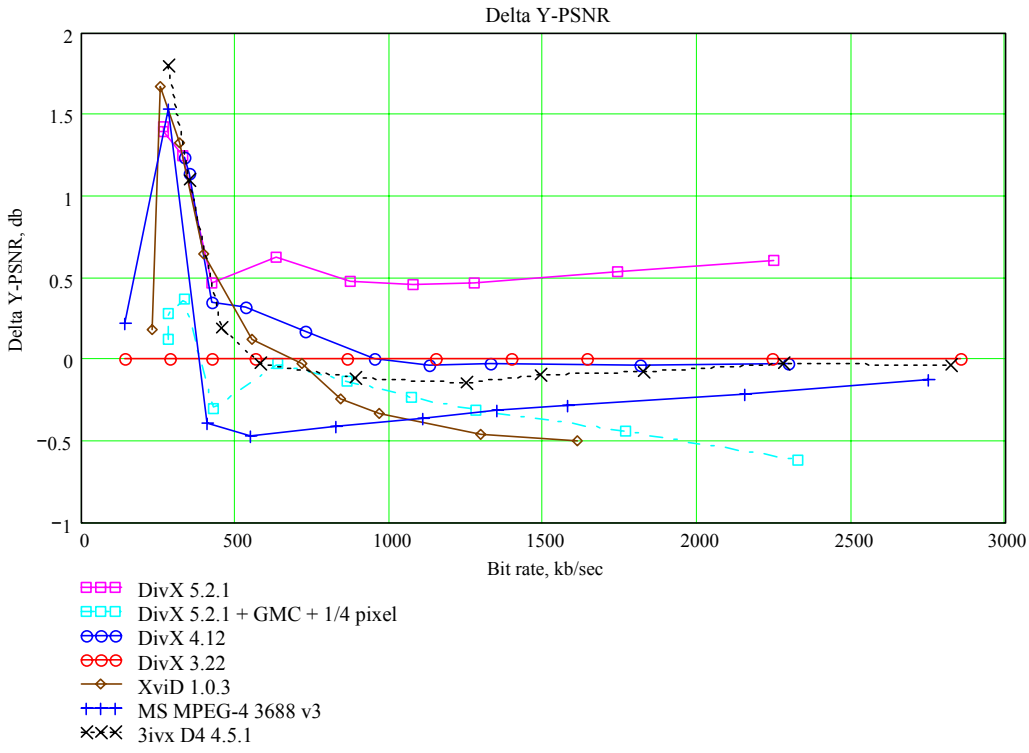
Conclusions:

- The leaders on this sequence are XviD and DivX4.12. The first one is better on low bit rates and the other on high ones.
- XviD is the best in processing U and V components on low bit rates.
- When trying to compress the sequence by DivX 4.12 with bit rate lower than 340 KBps the quality of the compressed sequence became much worse though its size almost hasn't changed.

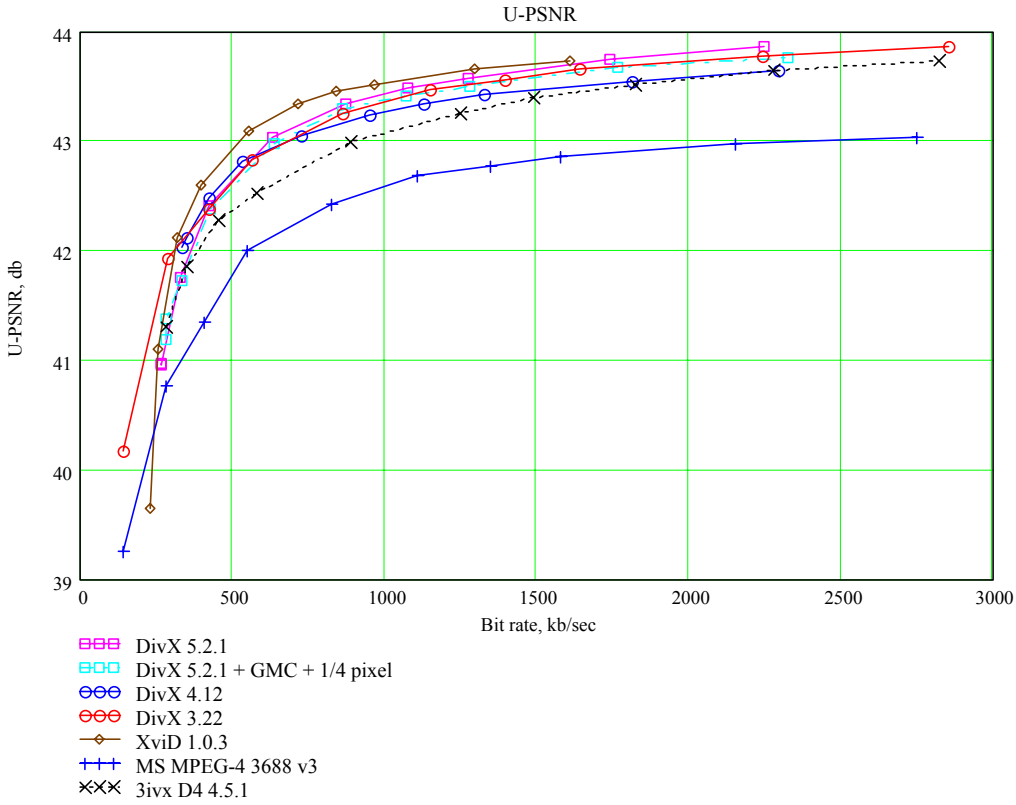
Susidi sequence



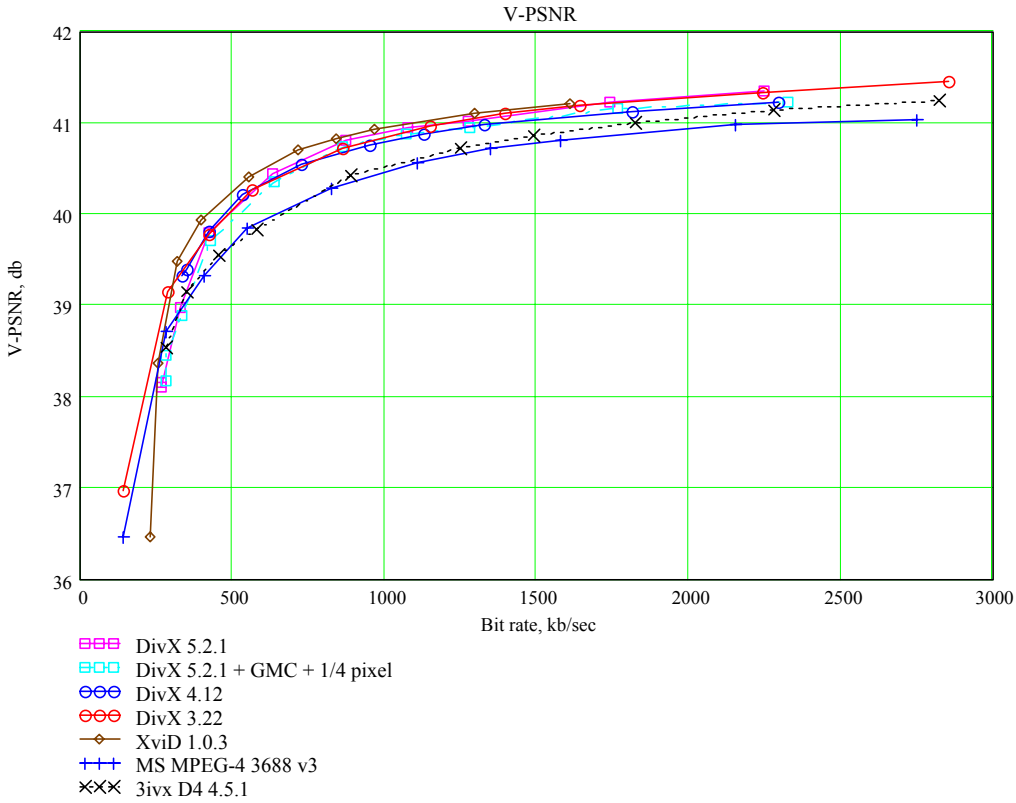
Picture 33. Y-PSNR. Sequence susidi



Picture 34. Delta Y-PSNR. Sequence susidi



Picture 35. U-PSNR. Sequence susidi



Picture 36. V-PSNR. Sequence susidi

Conclusions:

- DivX 5.2.1 happened to be the best again.
- And again enabling of GMC and Quarter Pixel options made it the worst.

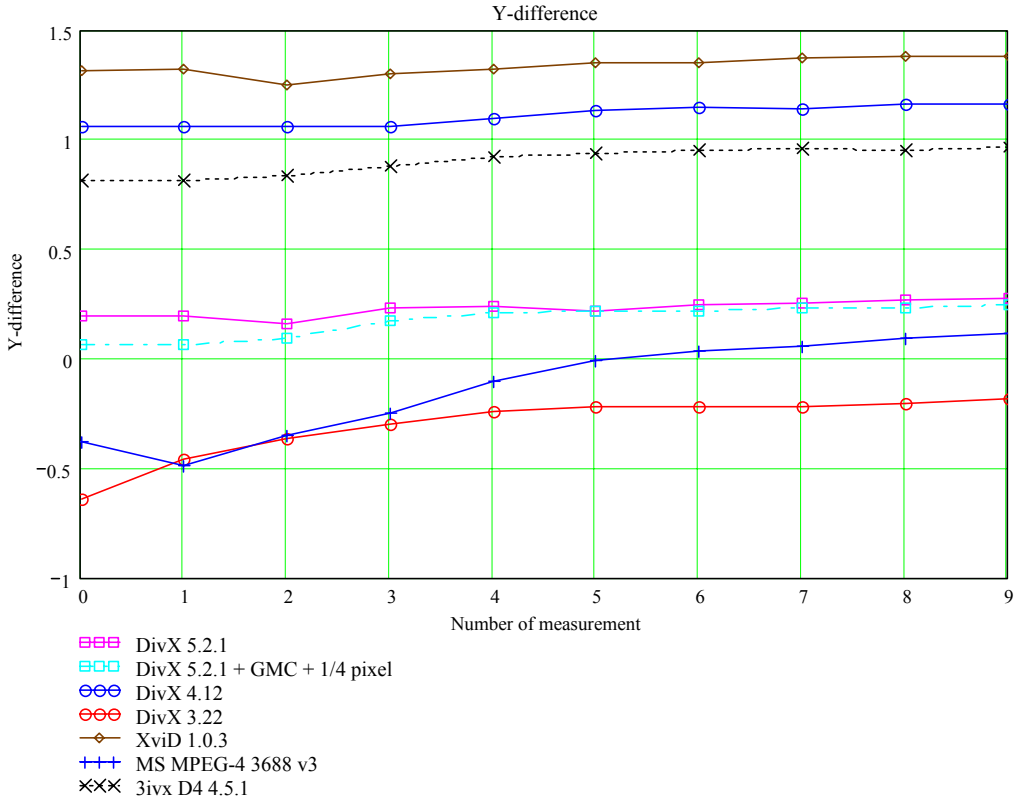
Average brightness change diagrams

These diagrams show average change of brightness performed by the codecs. Coordinates of the basic points are represented by the average (for the whole sequence) brightness values and the number of measurement (actually, the bitrate). So each branch contains ten points that correspond to different bit rates.

Number of measurement	0	1	2	3	4	5	6	7	8	9
Bit rate (KBps)	100	225	340	460	700	938	1140	1340	1840	2340

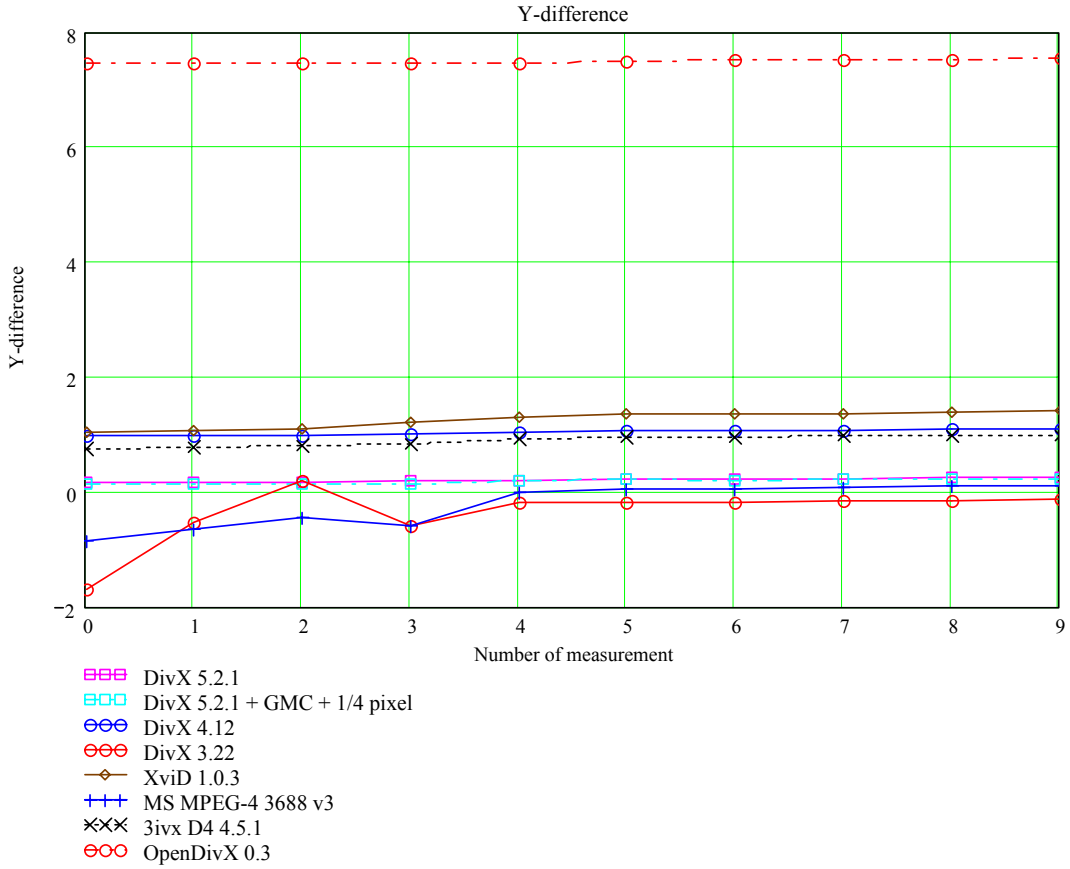
Strong and stable brightness increase indicates most often that there has been some truncation inaccuracy, so the codec's developers can easily correct it and raise PSNR.

Bankomatdi sequence



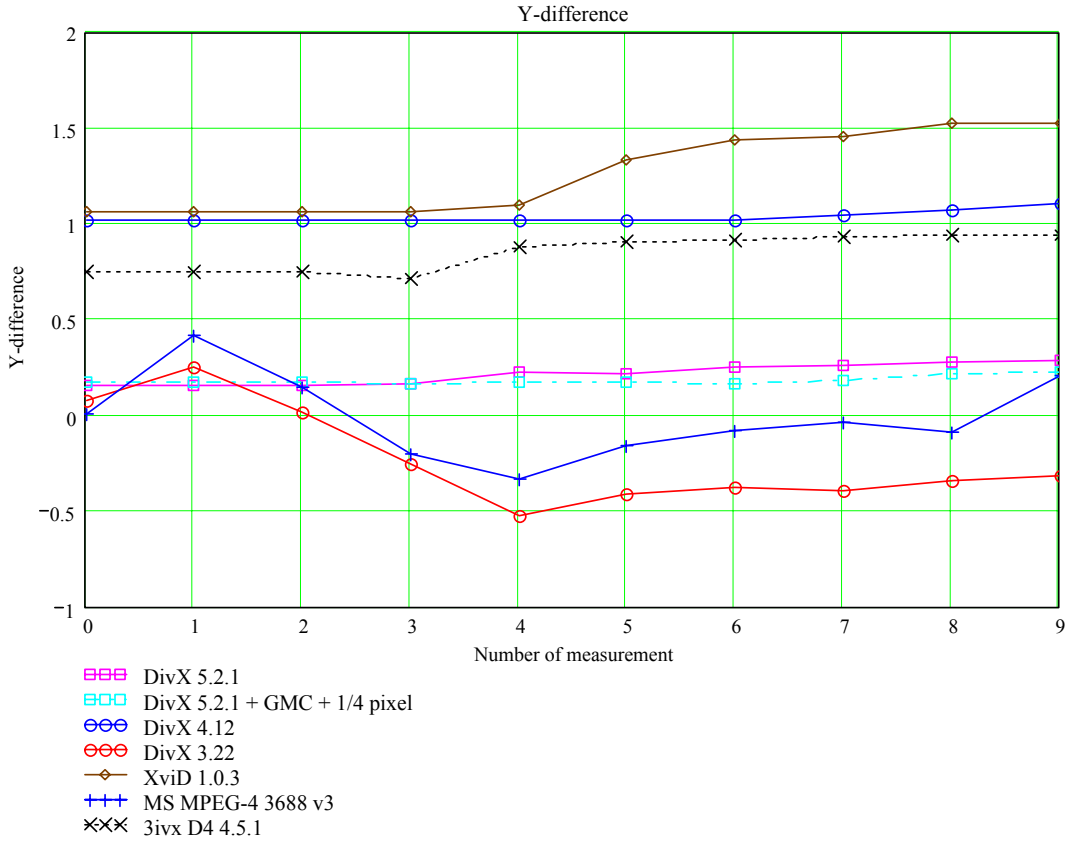
Picture 37. Y-difference. Sequence bankomatdi

Battle sequence



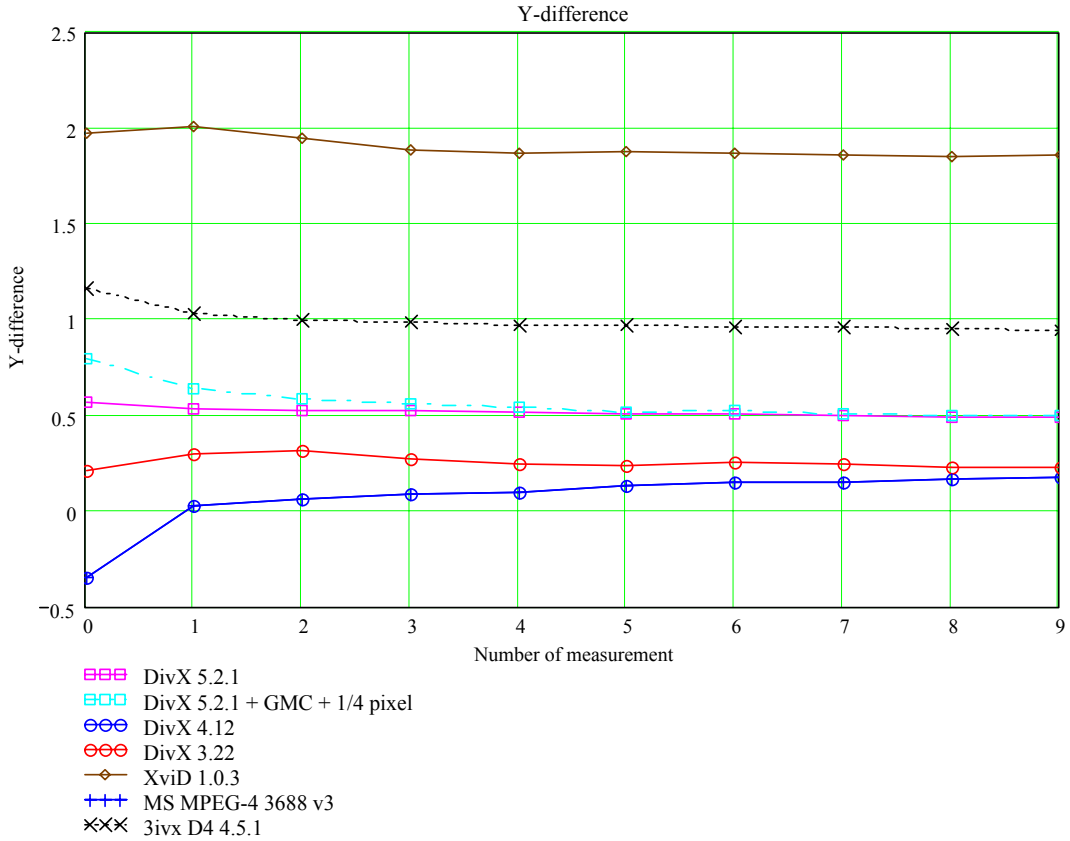
Picture 38. Y-difference. Sequence battle

Bbc3di sequence



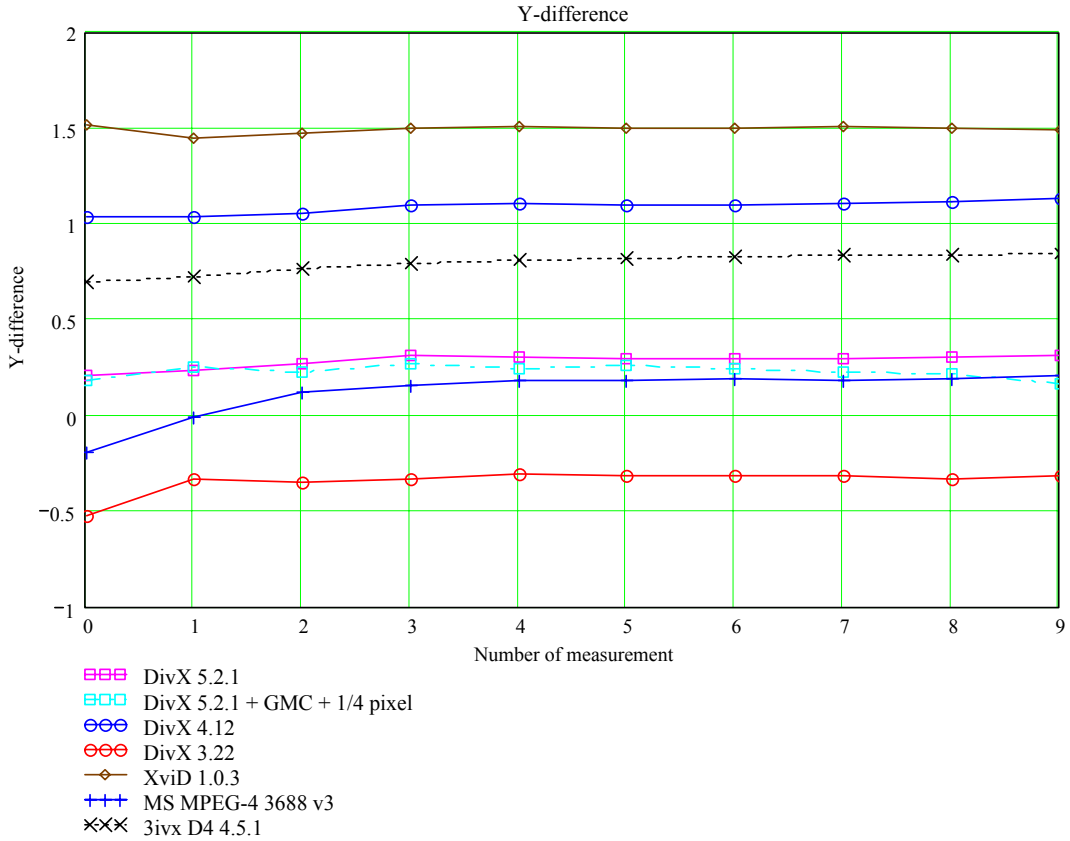
Picture 39. Y-difference. Sequence bbc3di

Foreman sequence



Picture 40. Y-difference. Sequence foreman

Susidi sequence



Picture 41. Y-difference. Sequence susidi

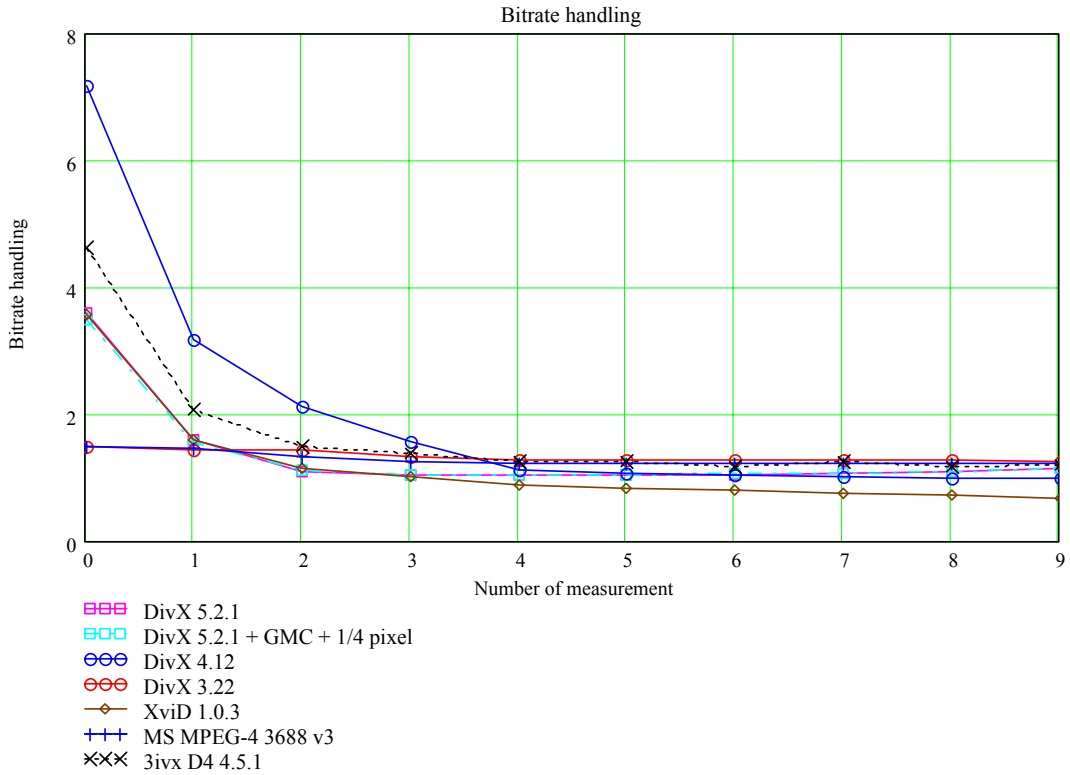
Conclusions:

- DivX 5.2.1 keeps brightness better than others.
- DivX3 and MS MPEG-4 keep it rather well on high bit rates but often decrease on low ones.
- XviD increases brightness more than others. That explains the difference between U/V-PSNR and Y-PSNR diagrams in the previous section.
- DivX 4.12 increases brightness a bit less than XviD.
- OpenDivX greatly increased brightness value on the battle sequence, which is the reason of its poor PSNR results. Perhaps this feature has been included in the codec advisedly by its developers.

Bitrate handling diagrams

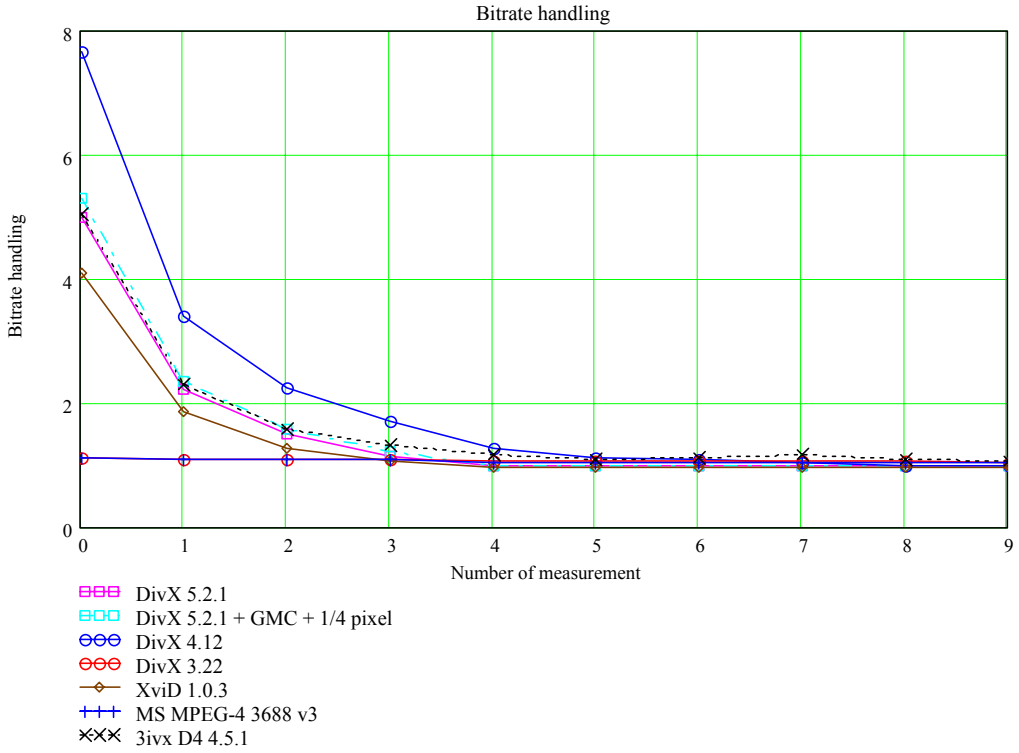
These diagrams show how codecs handle different bitrates. Every branch consists of ten points that correspond to different bitrates. Value “1” means that the codec keeps the specified bitrate; value more than “1” means that the codec actually compresses with the higher bitrate than was specified.

Bankomatdi sequence



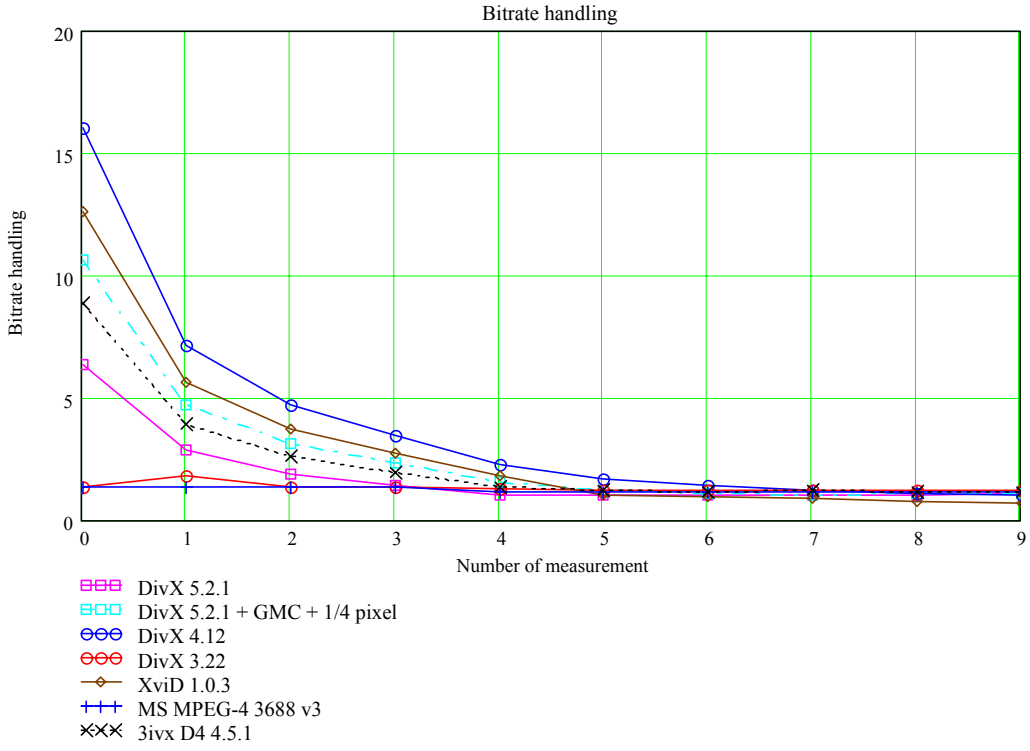
Picture 42. Bit rate handling. Sequence bankomatdi

Battle sequence



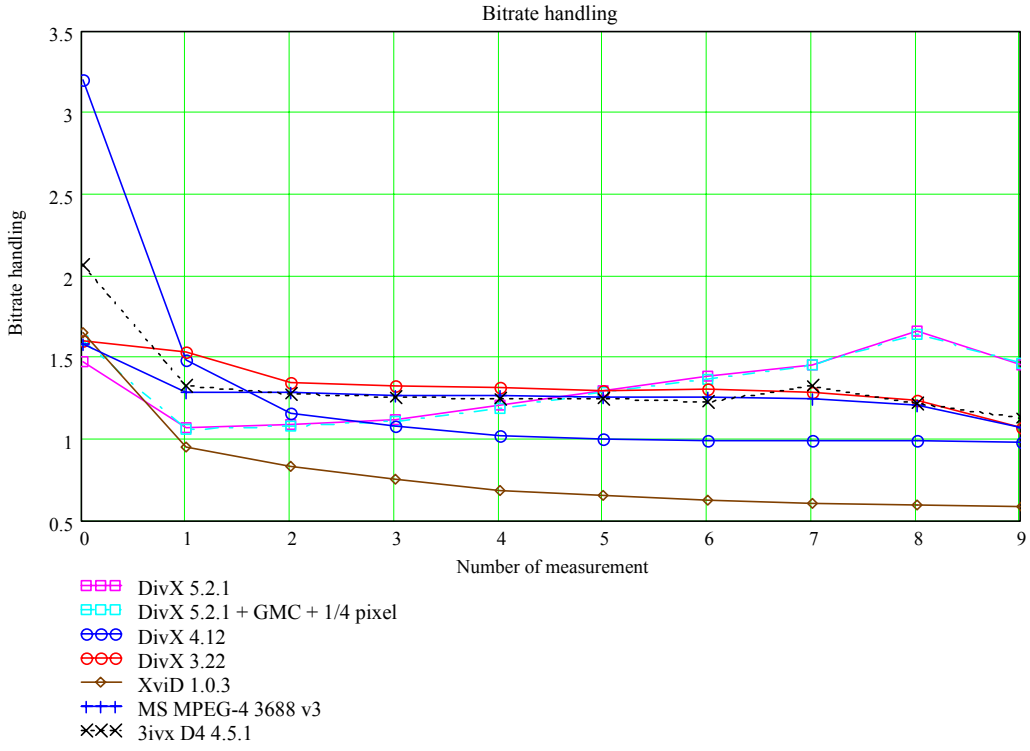
Picture 43. Bit rate handling. Sequence battle

Bbc3di sequence



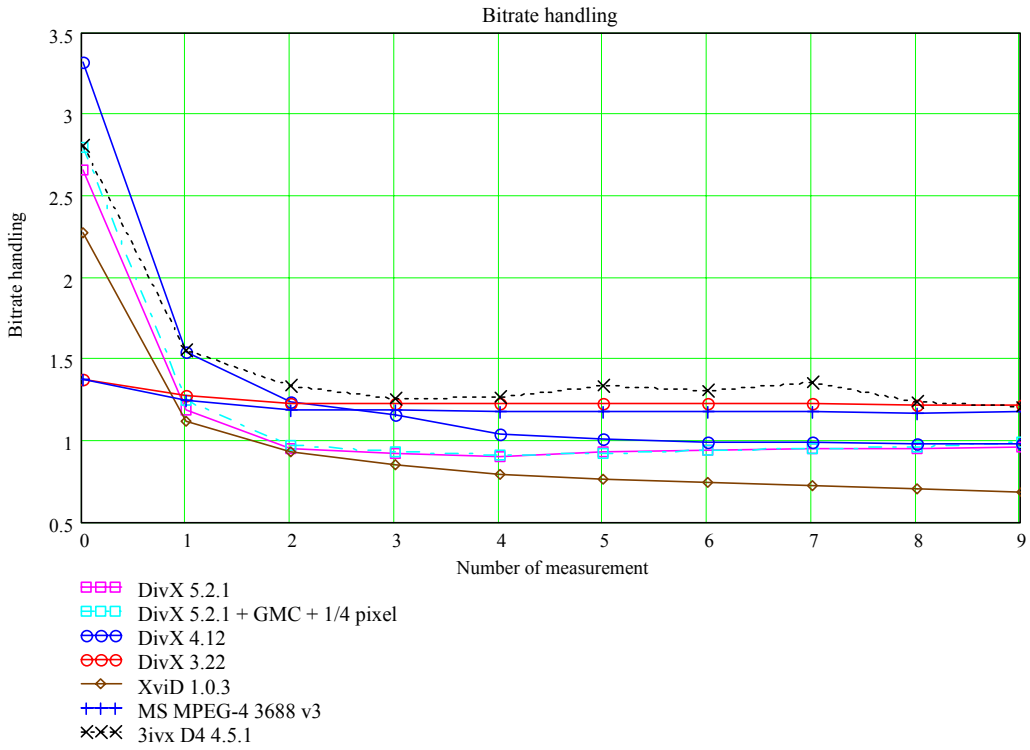
Picture 44. Bit rate handling. Sequence bbc3di

Foreman sequence



Picture 45. Bit rate handling. Sequence foreman

Susidi sequence



Picture 46. Bit rate handling. Sequence susidi

Conclusions:

- DivX3.22 and MS MPEG-4 are the only ones that try to keep low bit rates.
- DivX 4.12 is the worst by this criterion.
- XviD sometimes lowers the bitrate specified.
- DivX 5.2.1 significantly increased specified bit rate higher than 1000 KBps on the foreman sequence.

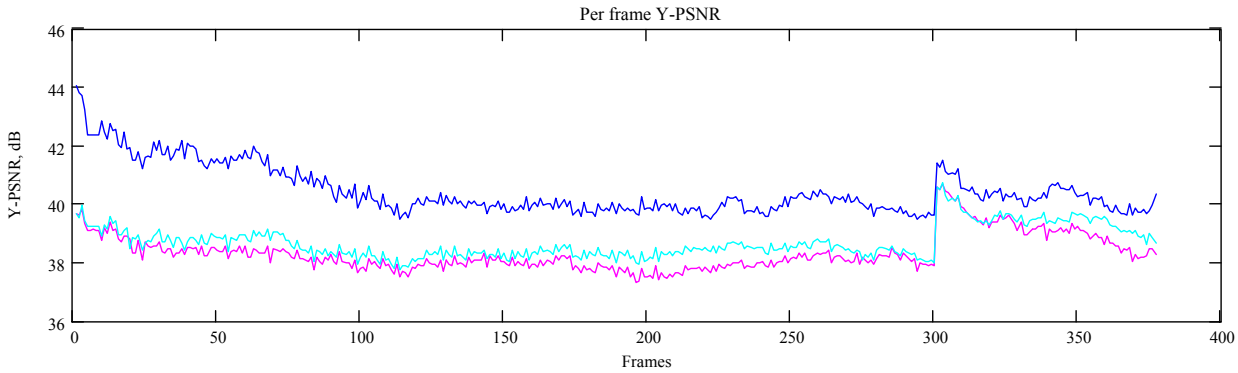
Per frame sequences comparison

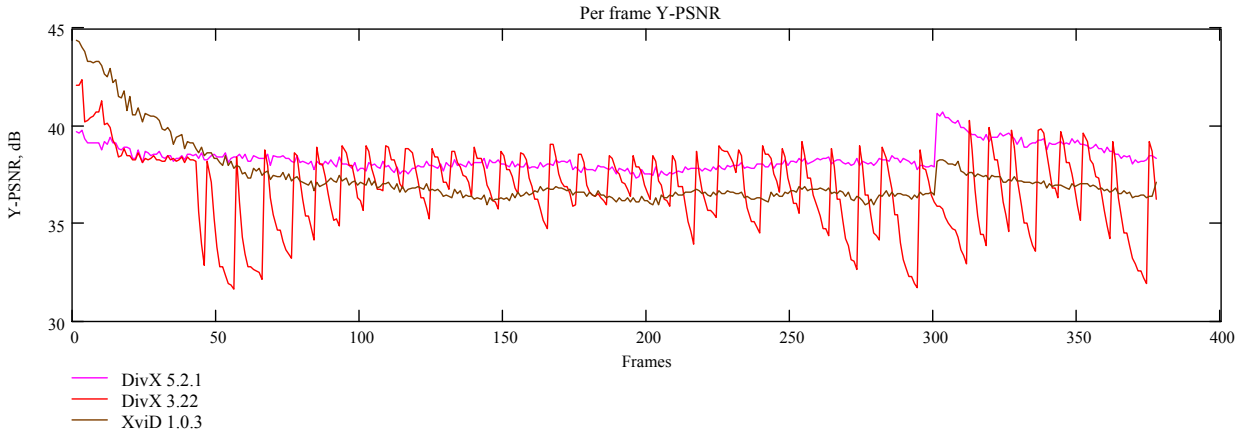
These diagrams show how compression quality changes from frame to frame. X-axis coordinate represents the number of the frame and Y-axis coordinate represents PSNR-value for this frame. Significant constant difference on the susidi diagram is caused by the noise suppression in every second frame (B-frames options in MPEG-2 coder).

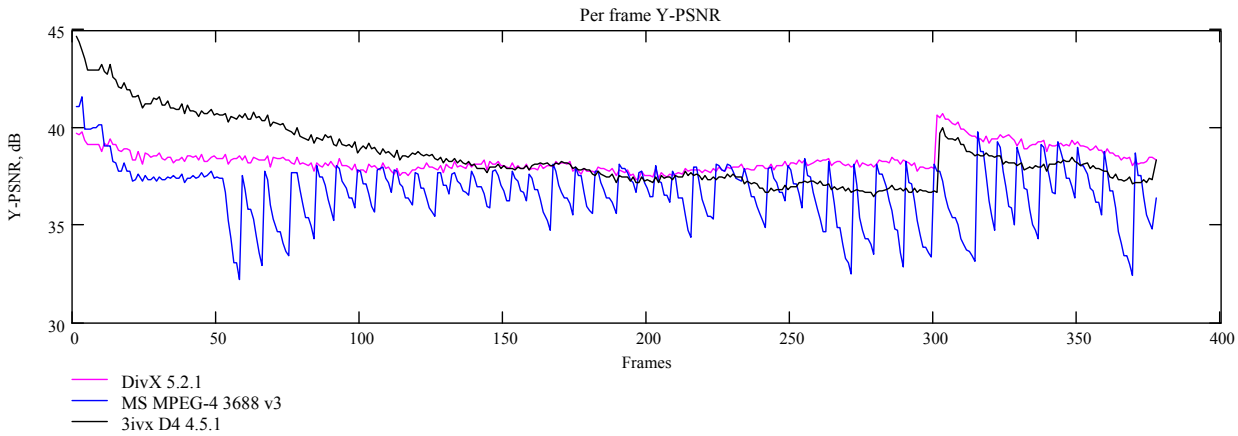
Bit rate that has been set in the codecs options is specified before each diagram. Actual bit rate however can be different (sometimes significantly). So one shouldn`t compare branches that correspond to different codecs; they are located on the same diagram to save space economy and provide better visual perception.

Bankomatdi sequence

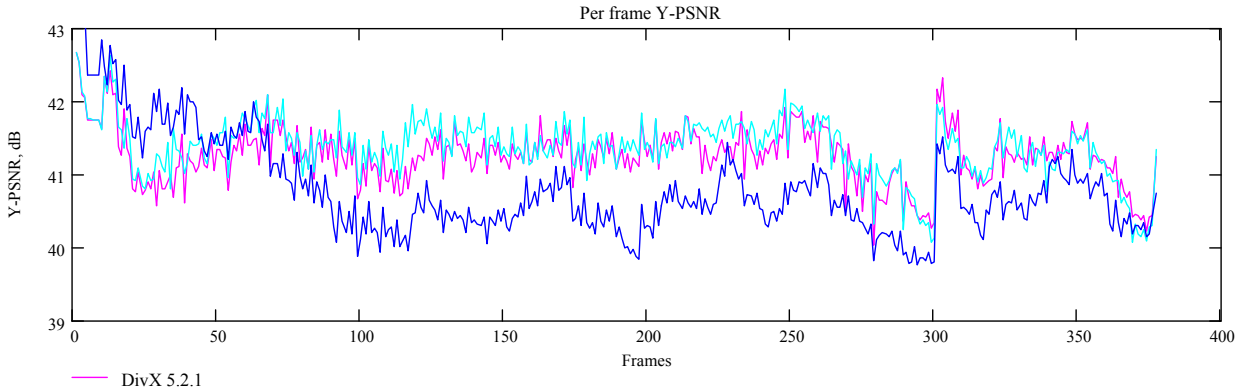
Bitrate = 100 Kb/sec

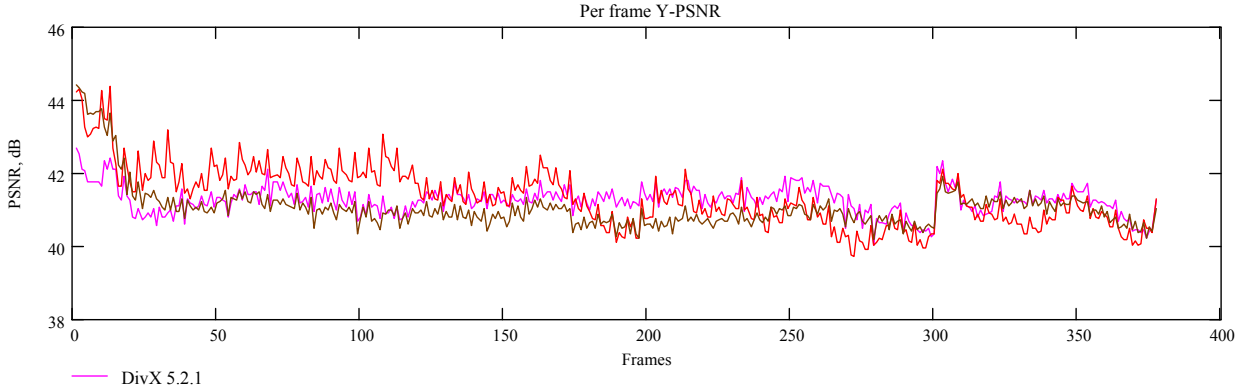


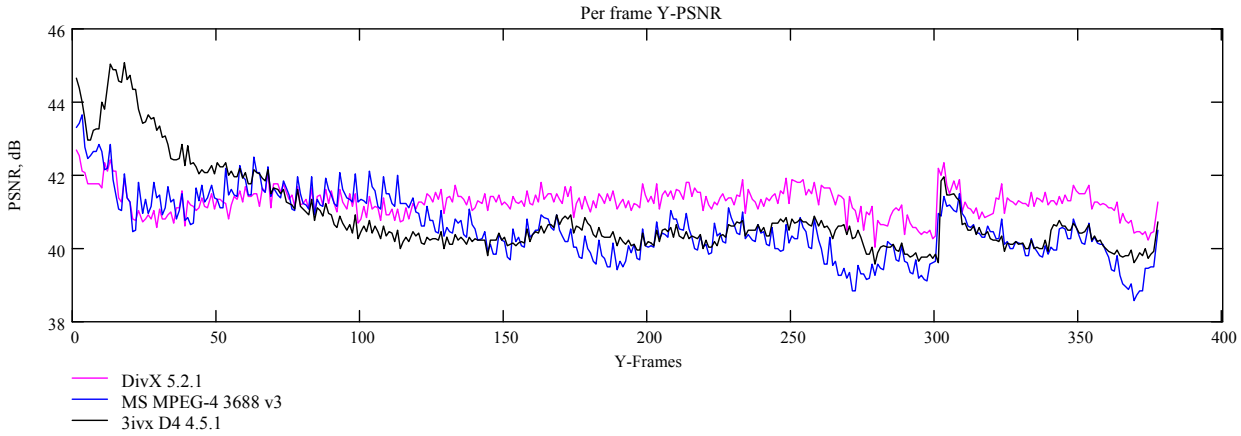




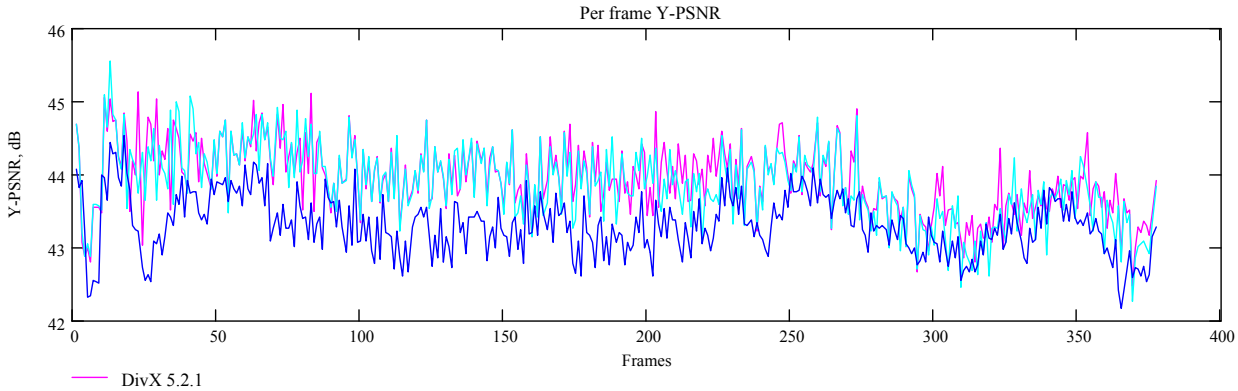
Bitrate = 700 Kb/sec

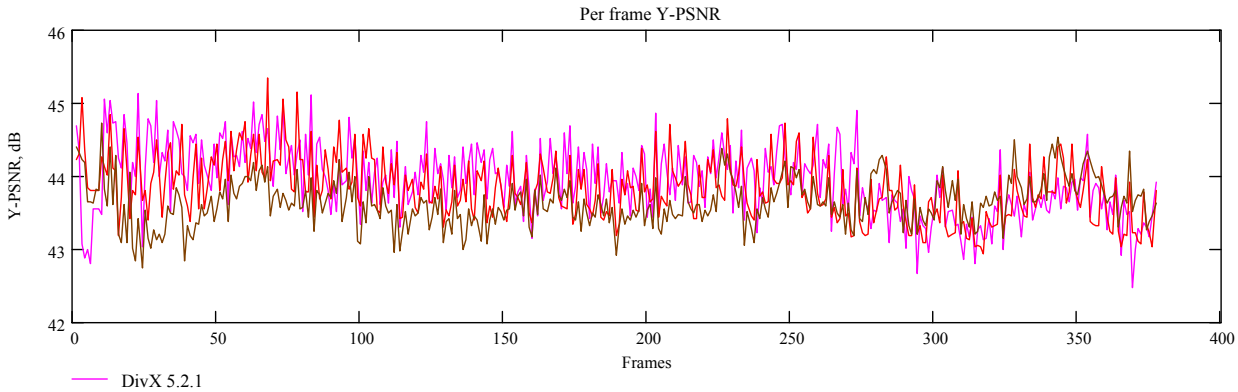


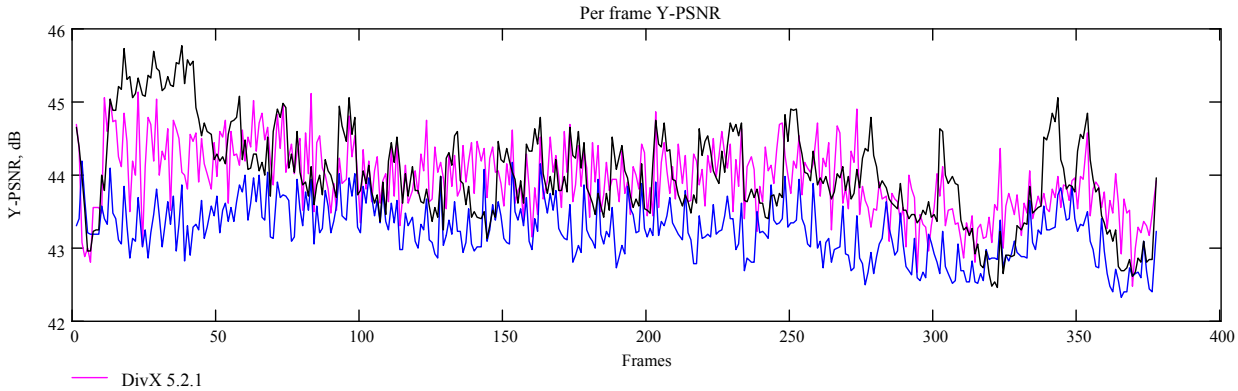




Bitrate = 2340 Kb/sec

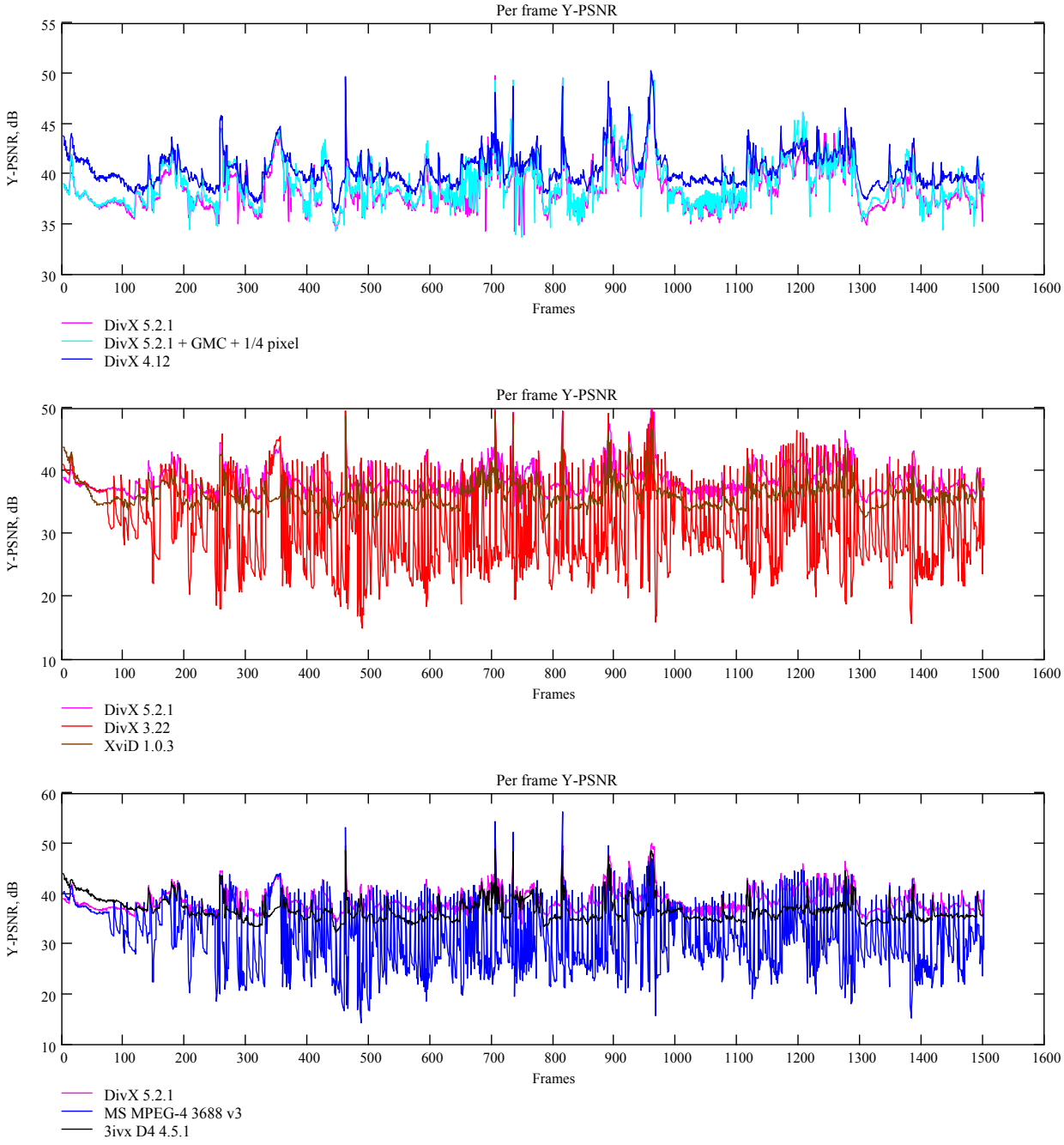




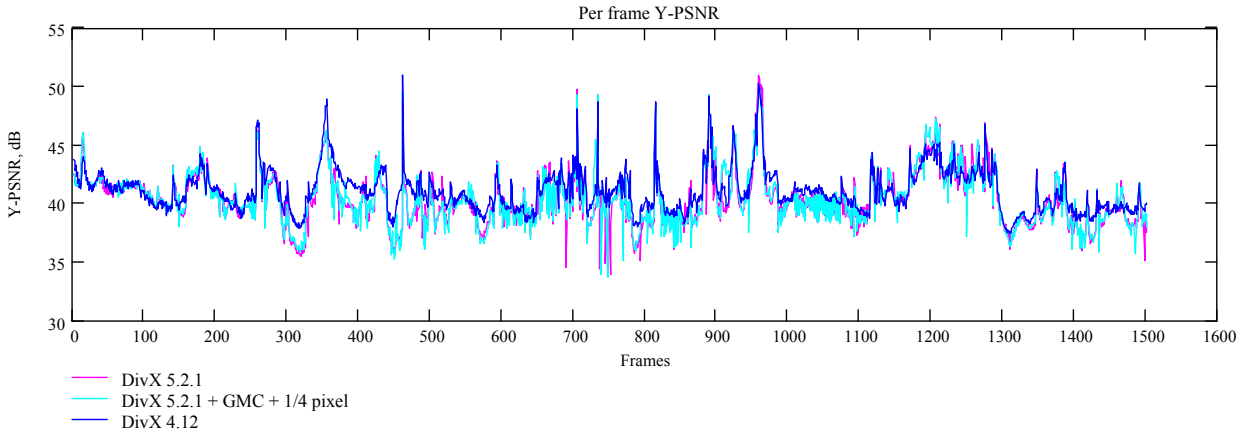


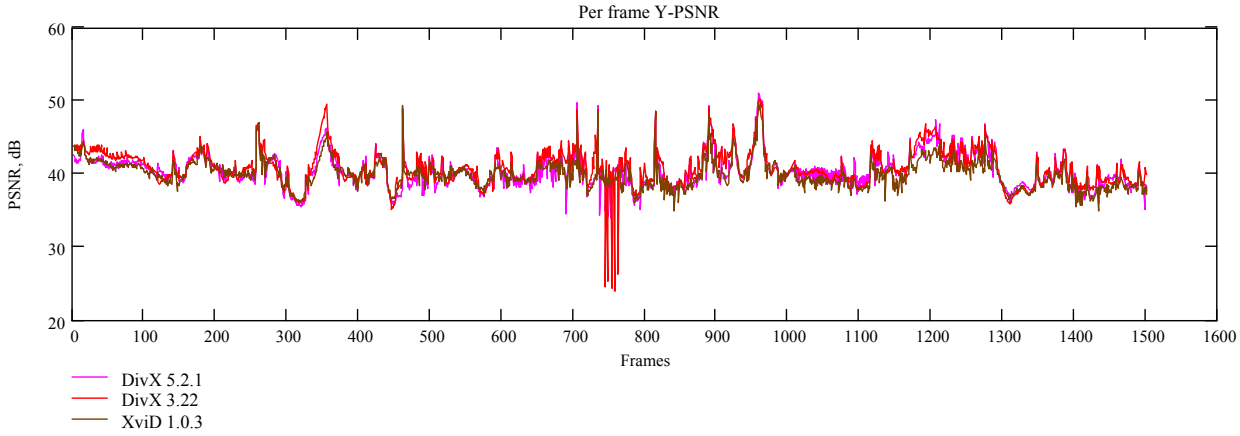
Battle sequence

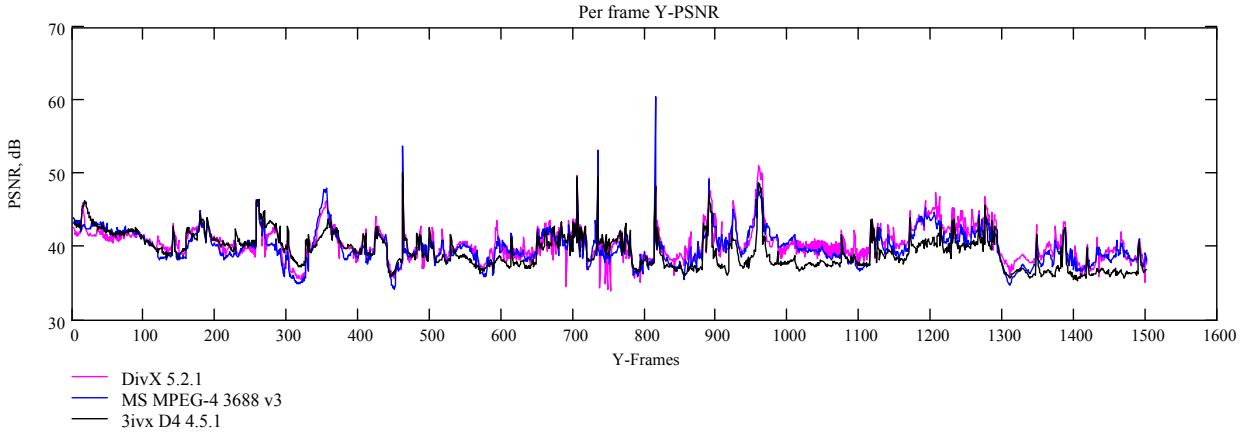
Bitrate = 100 Kb/sec



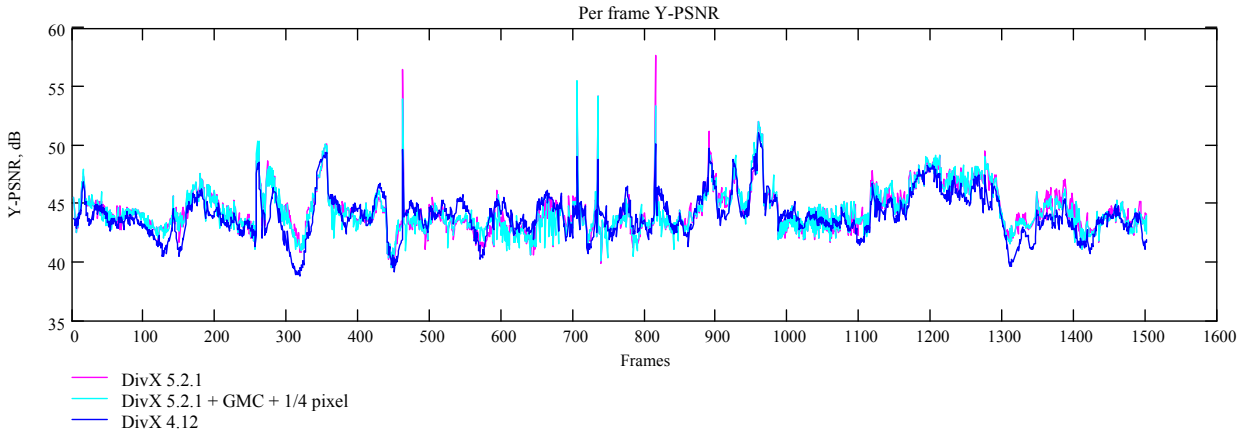
Bitrate = 700 Kb/sec

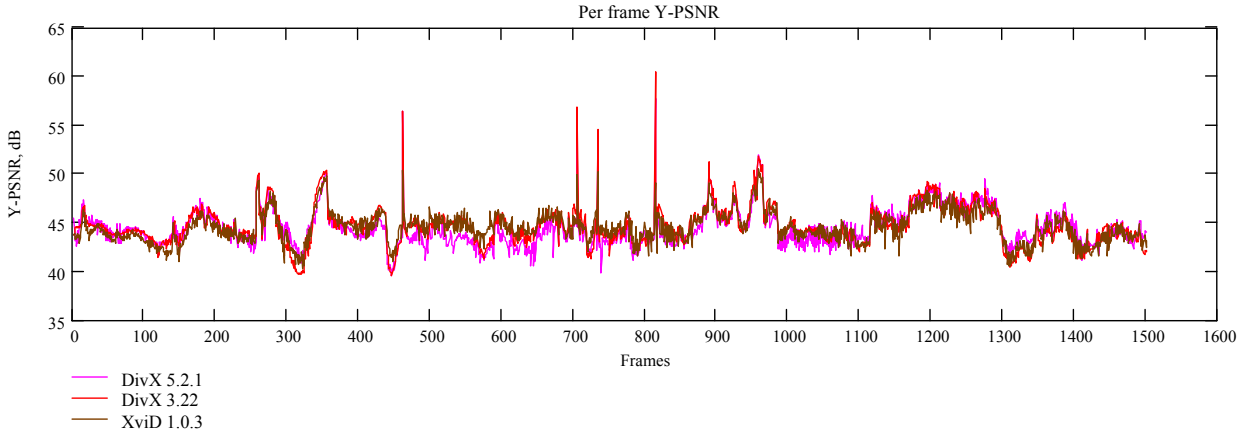


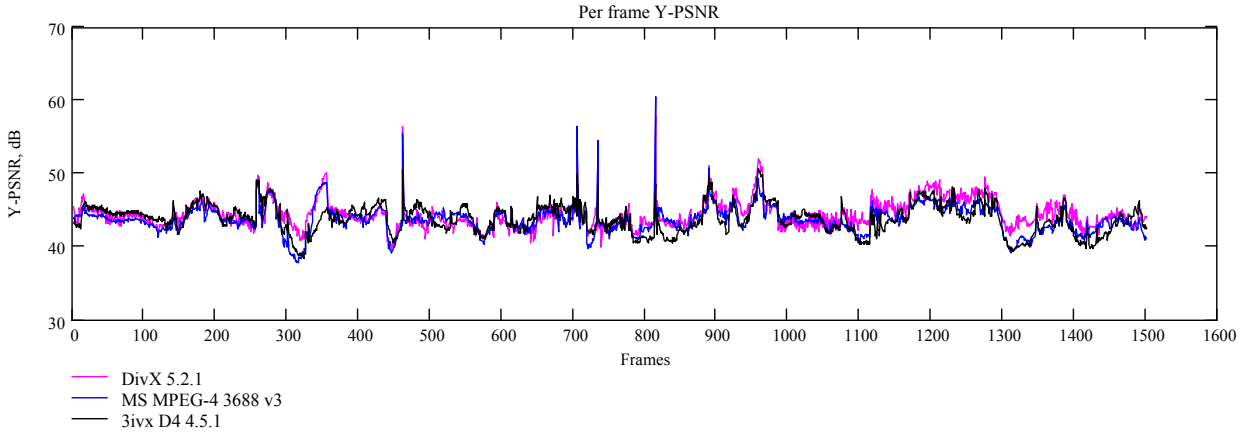




Bitrate = 2340 Kb/sec

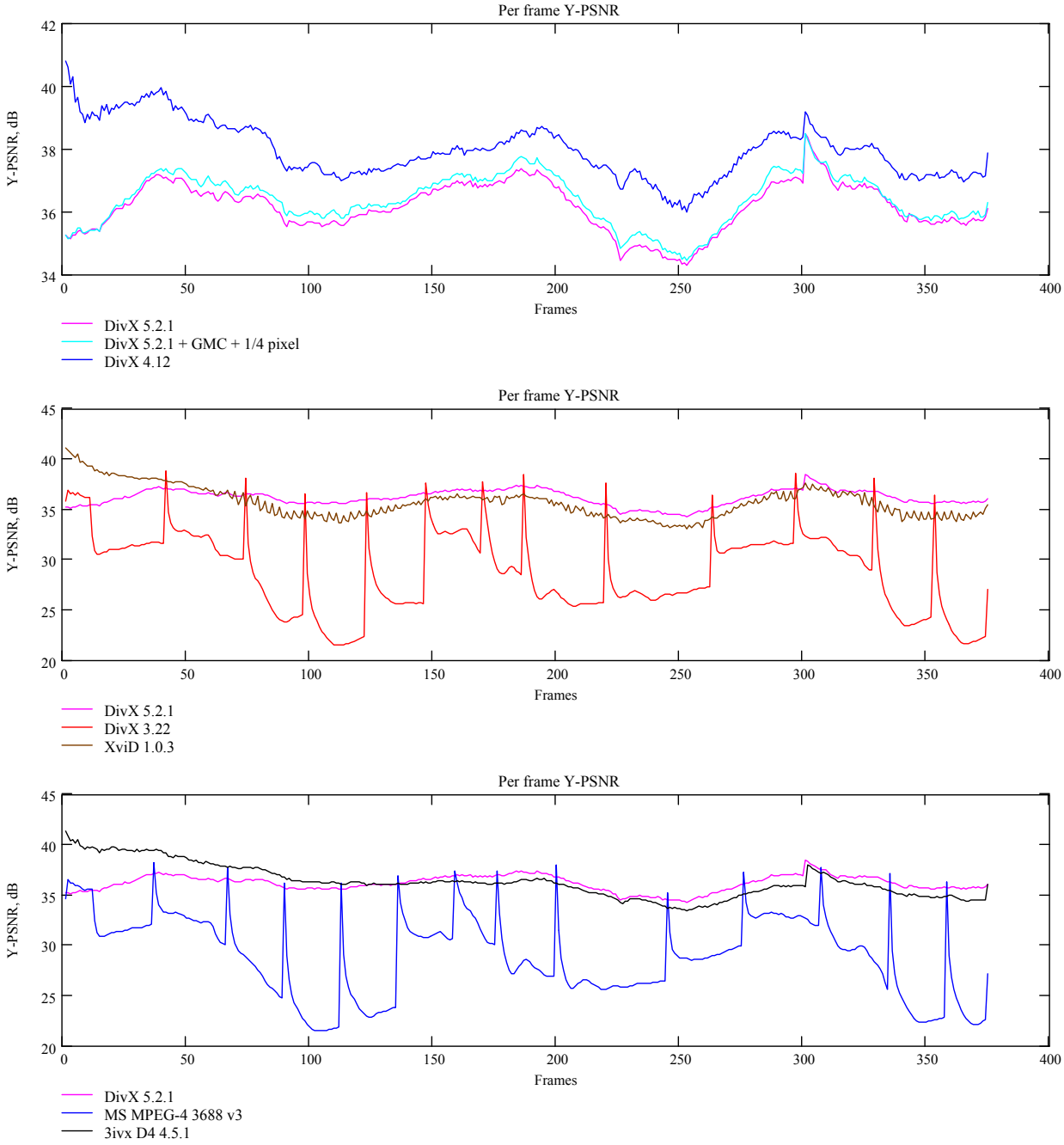




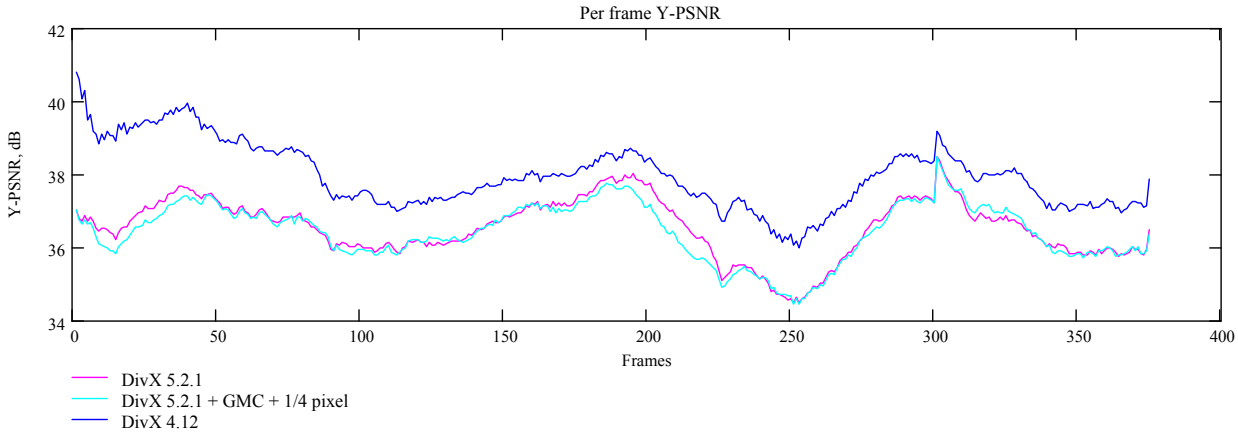


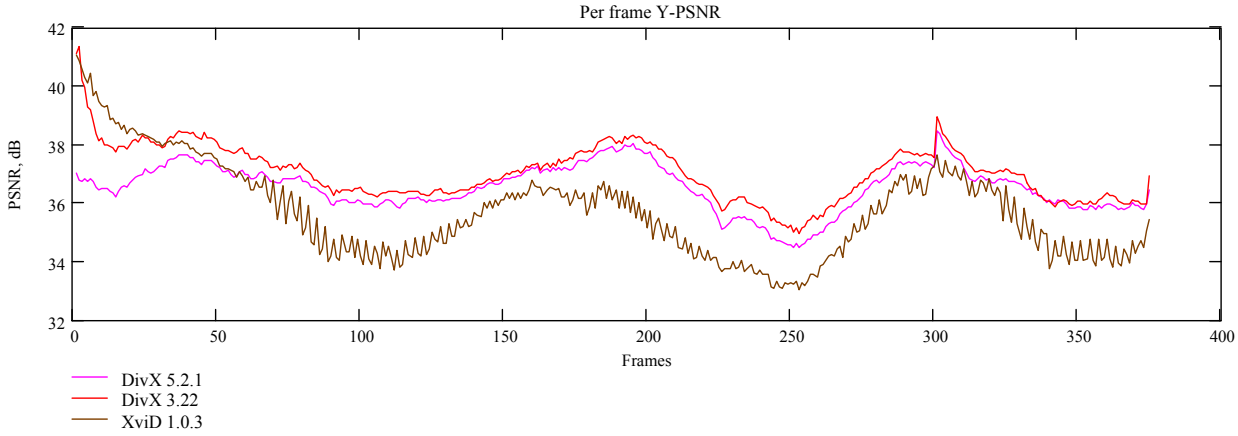
Bbc3di sequence

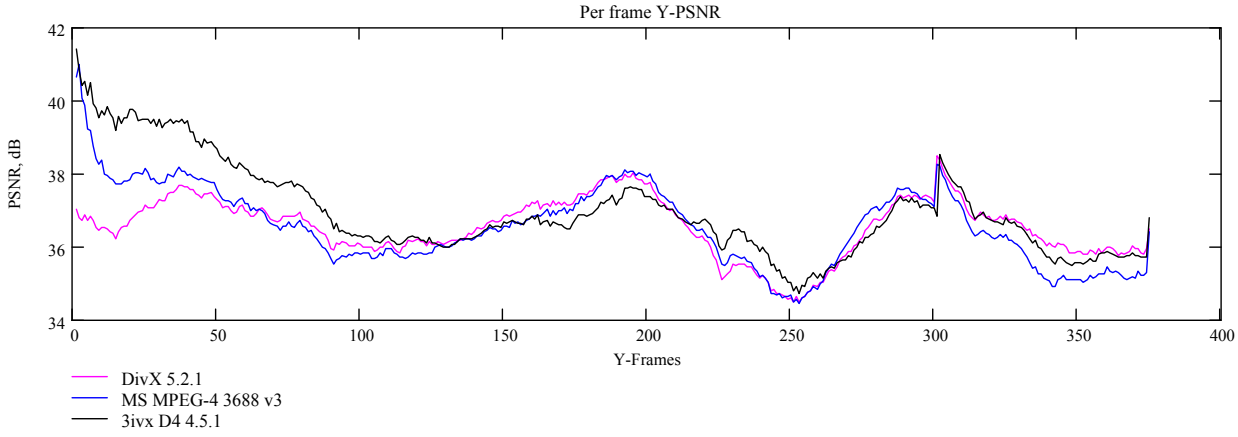
Bitrate = 100 Kb/sec



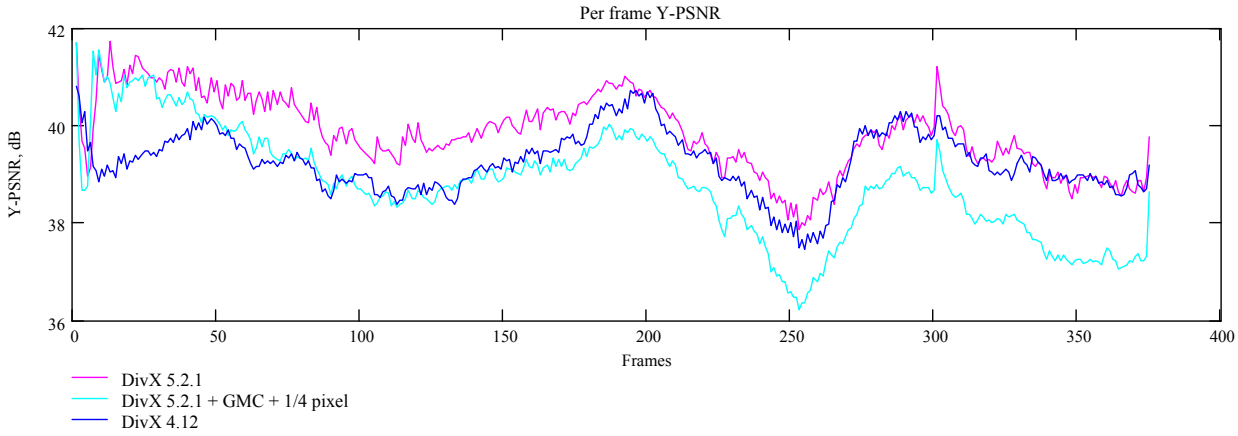
Bitrate = 700 Kb/sec

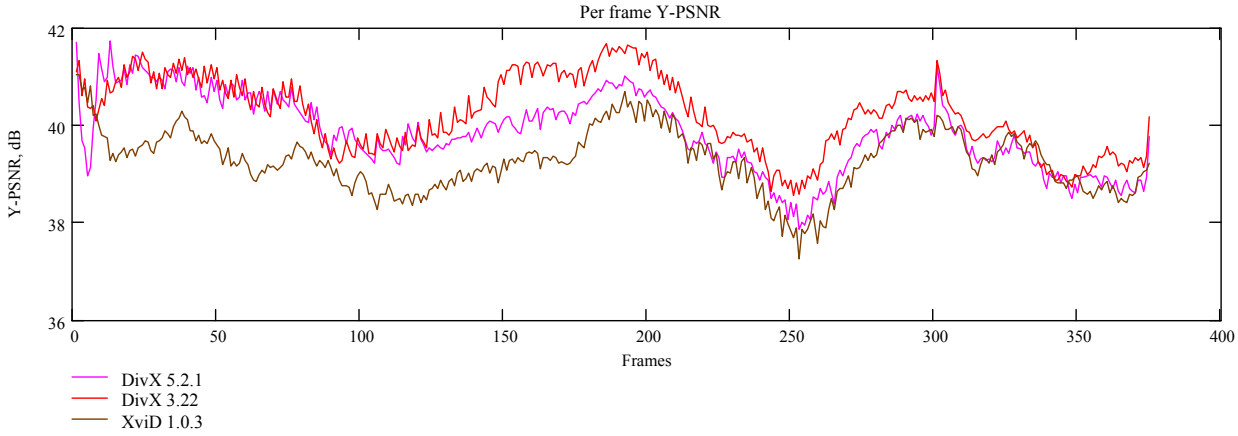


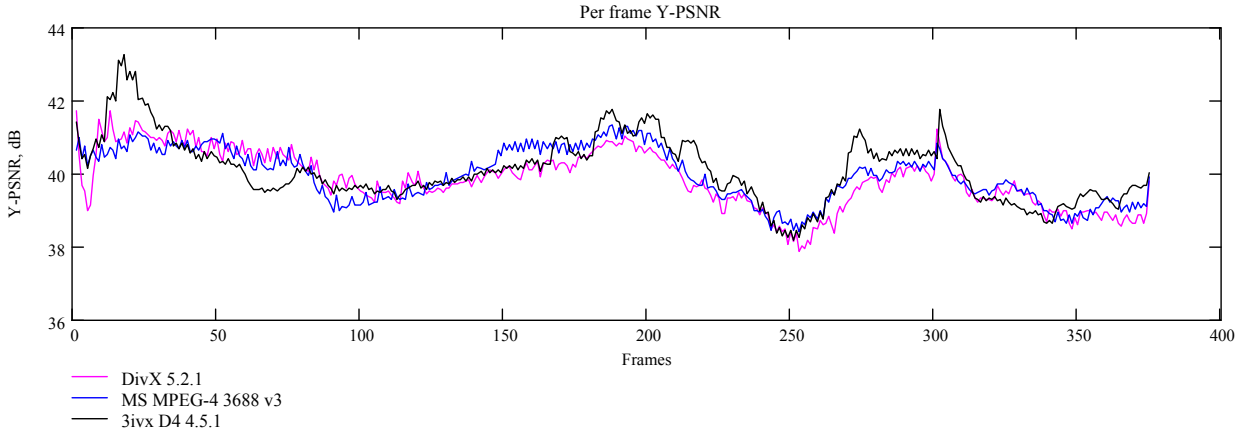




Bitrate = 2340 Kb/sec

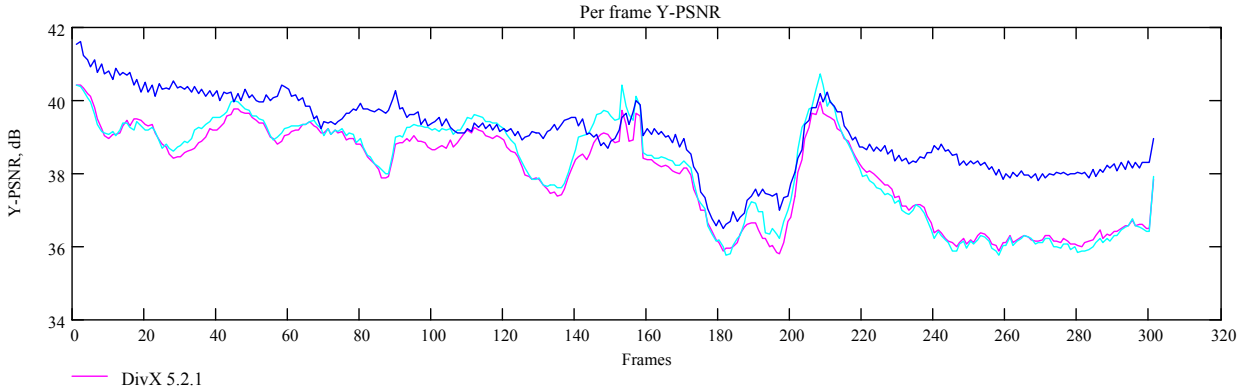


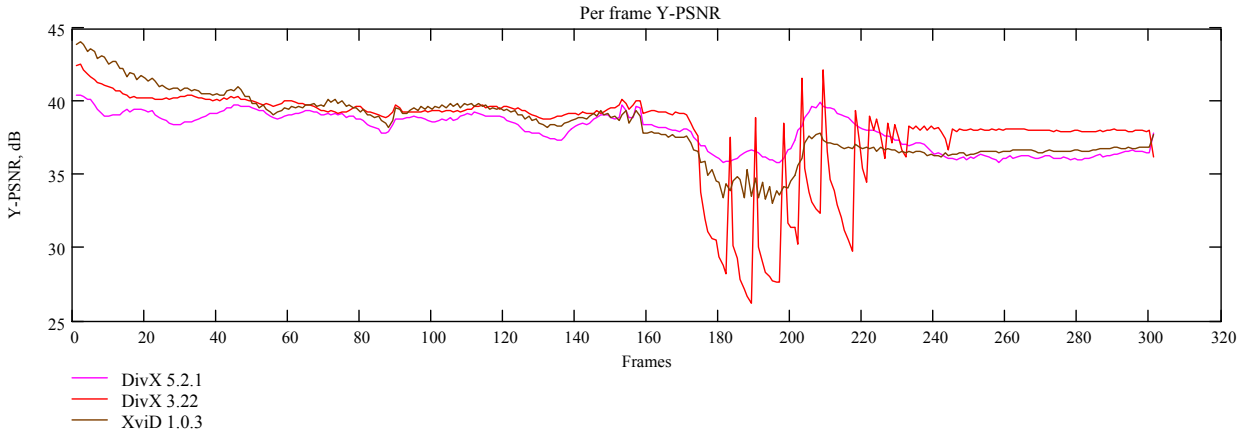


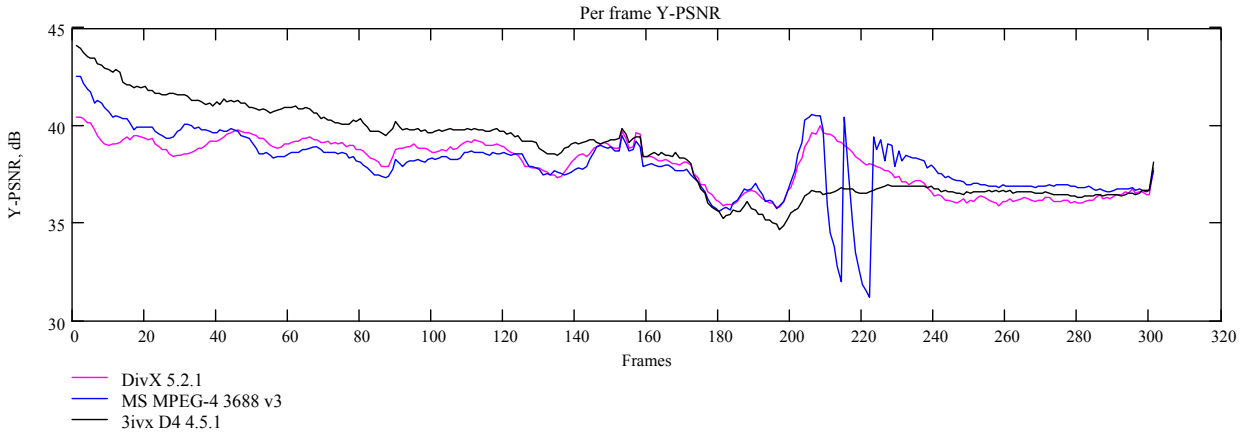


Foreman sequence

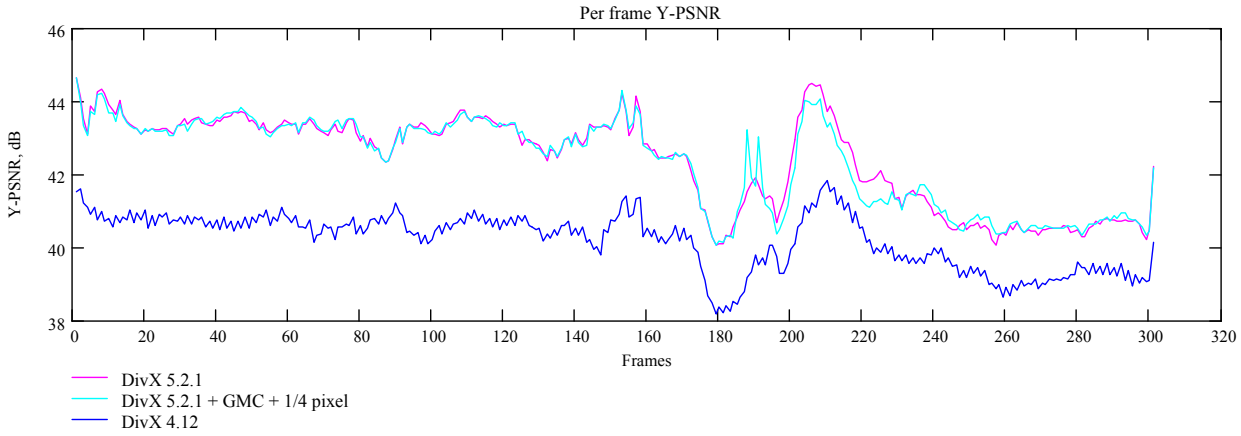
Bitrate = 100 Kb/sec

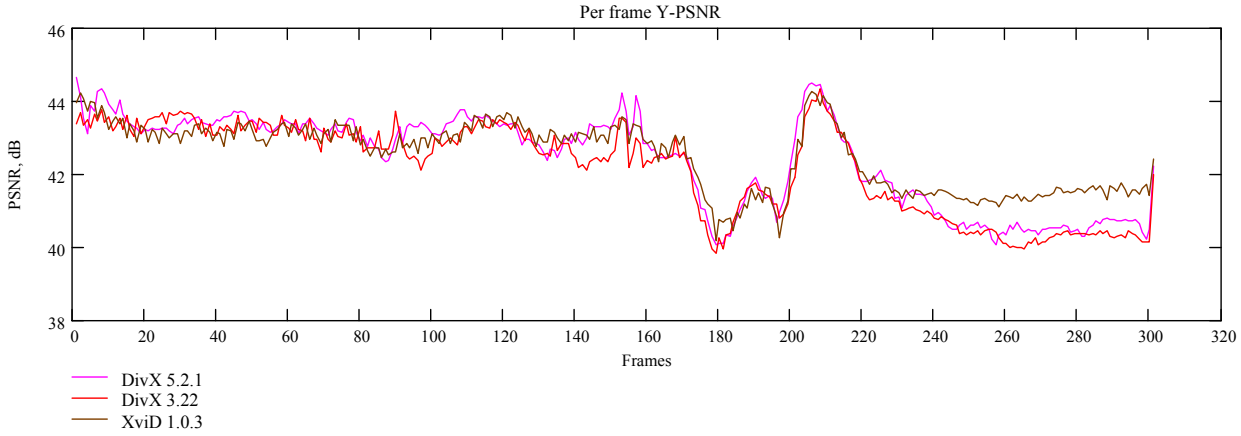


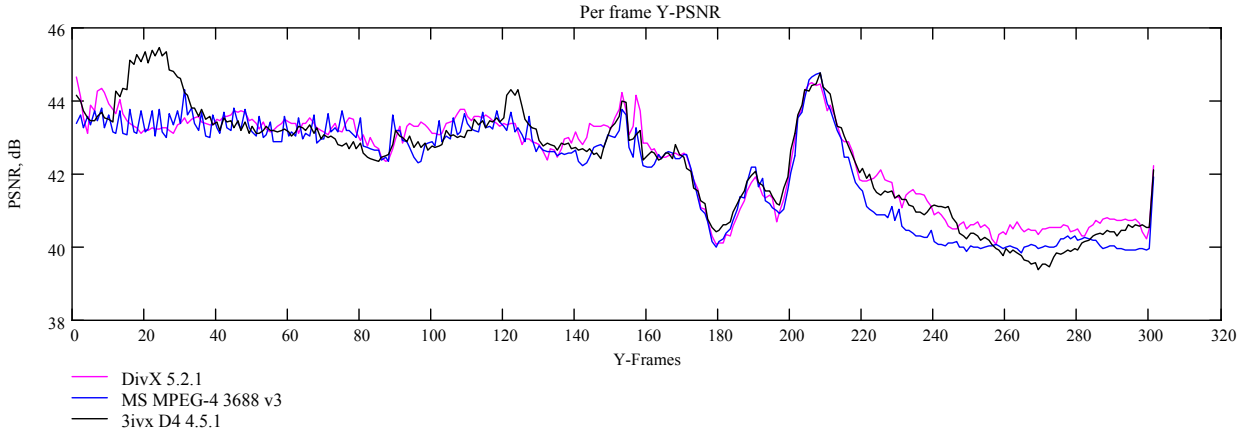




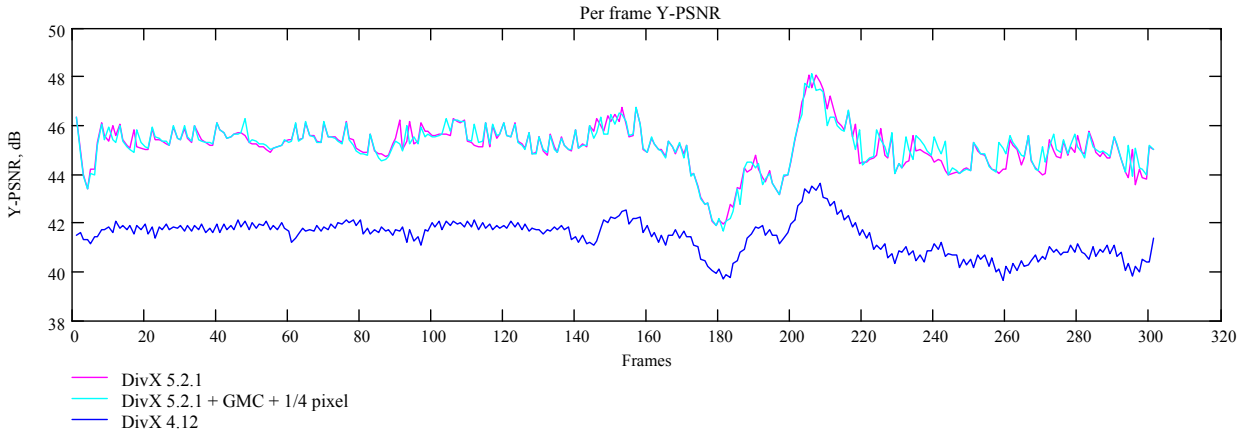
Bitrate = 700 Kb/sec

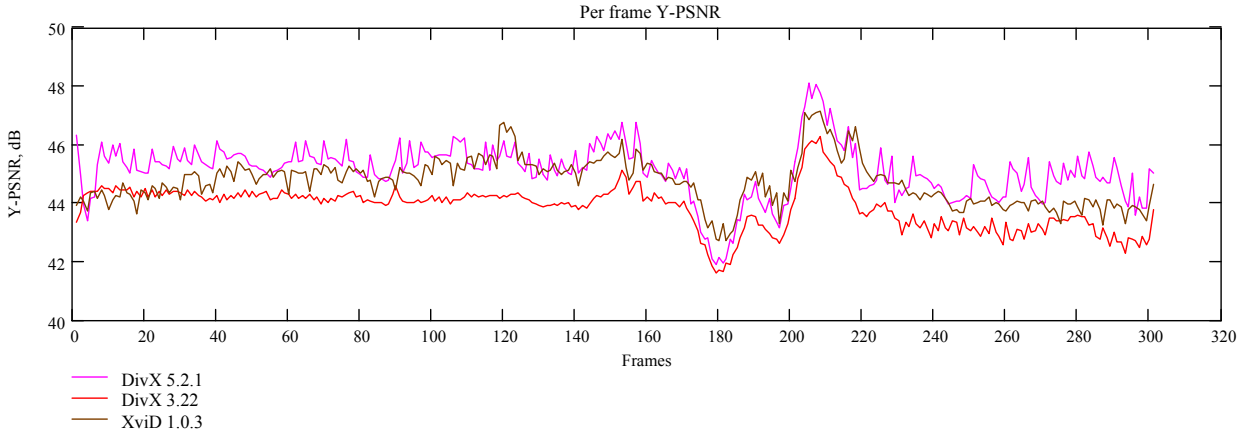


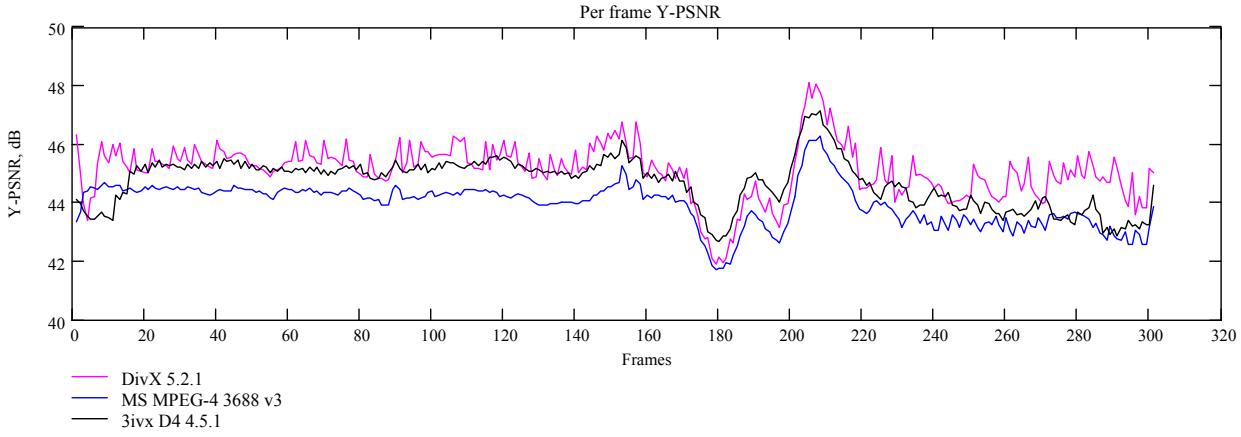




Bitrate = 2340 Kb/sec

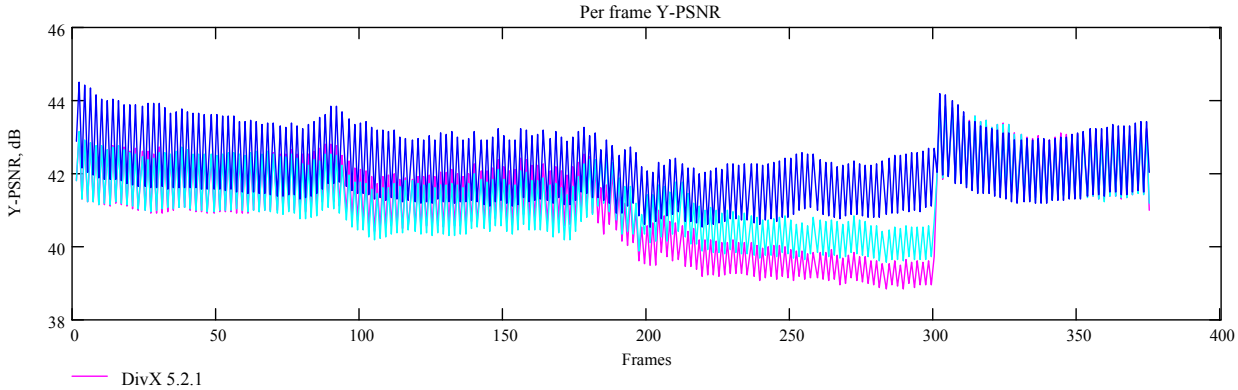


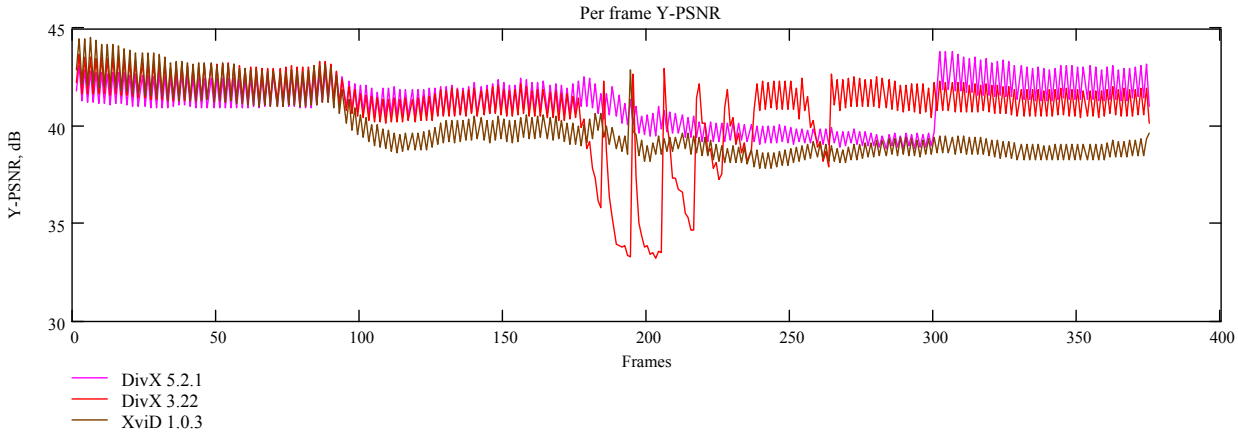


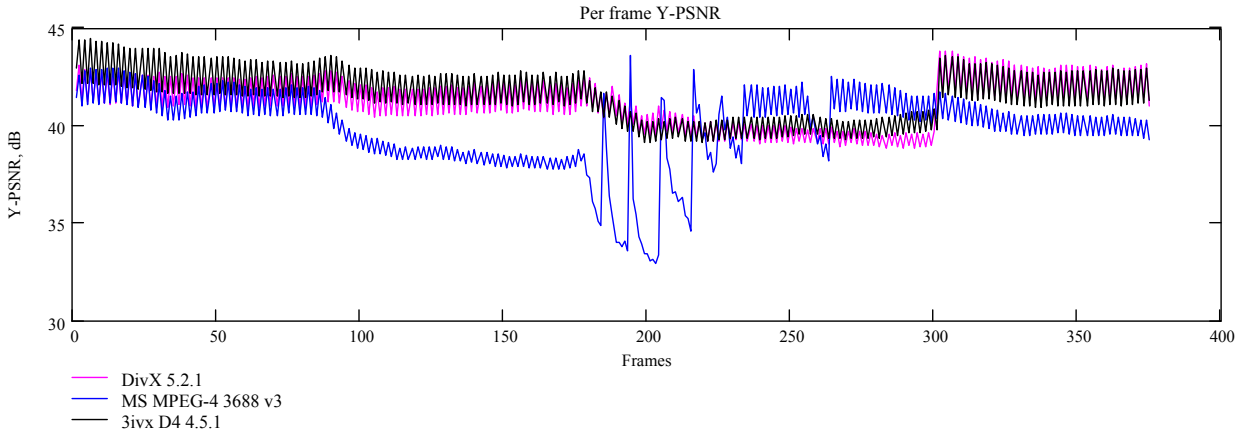


Susidi sequence

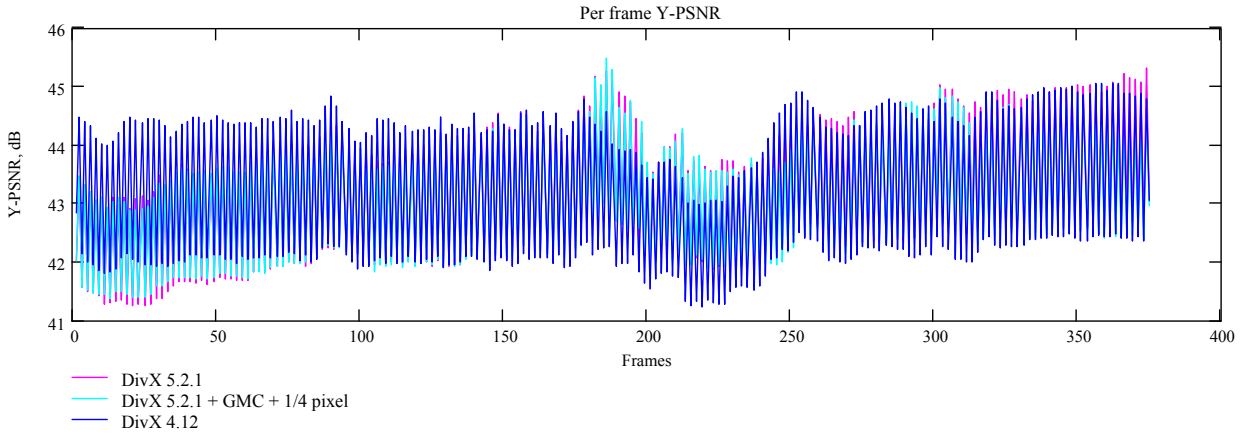
Bitrate = 100 Kb/sec

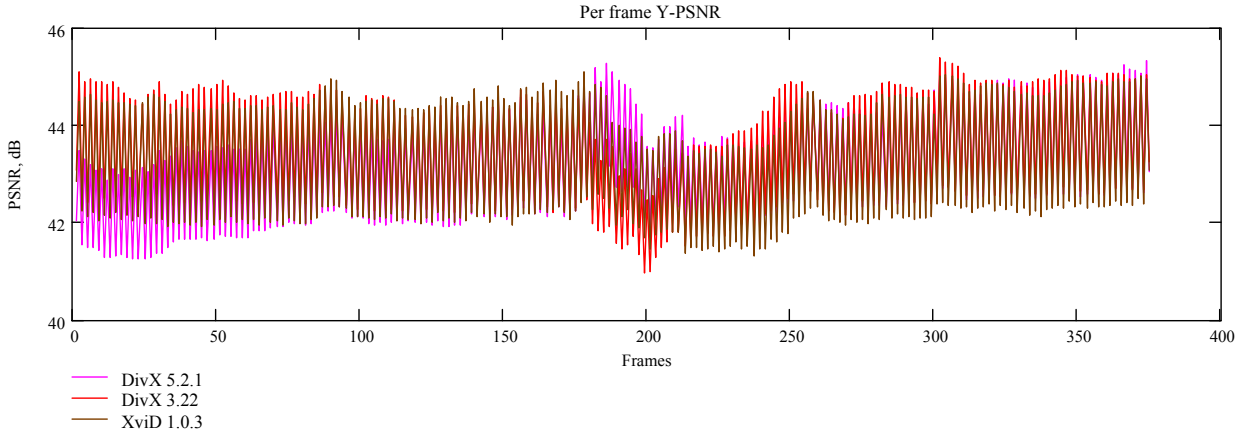


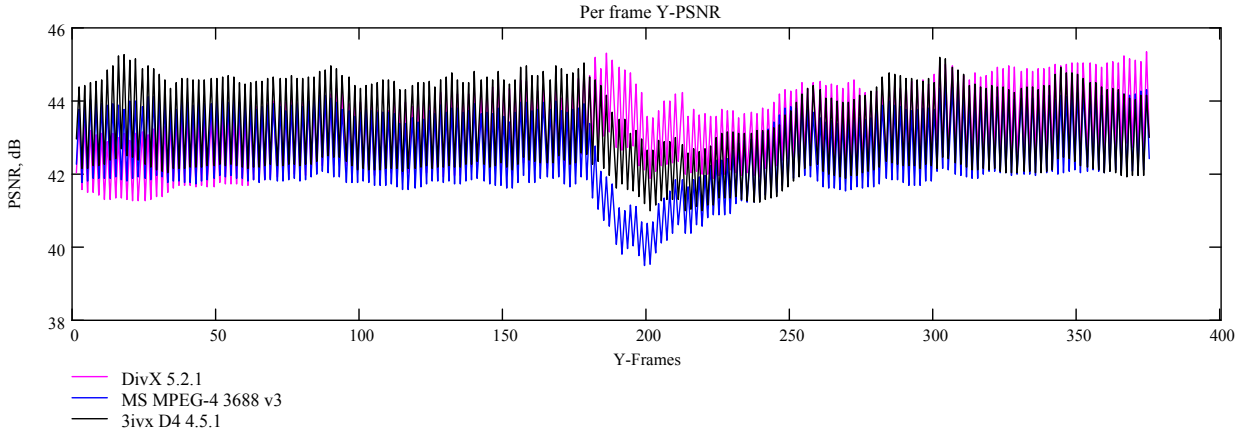




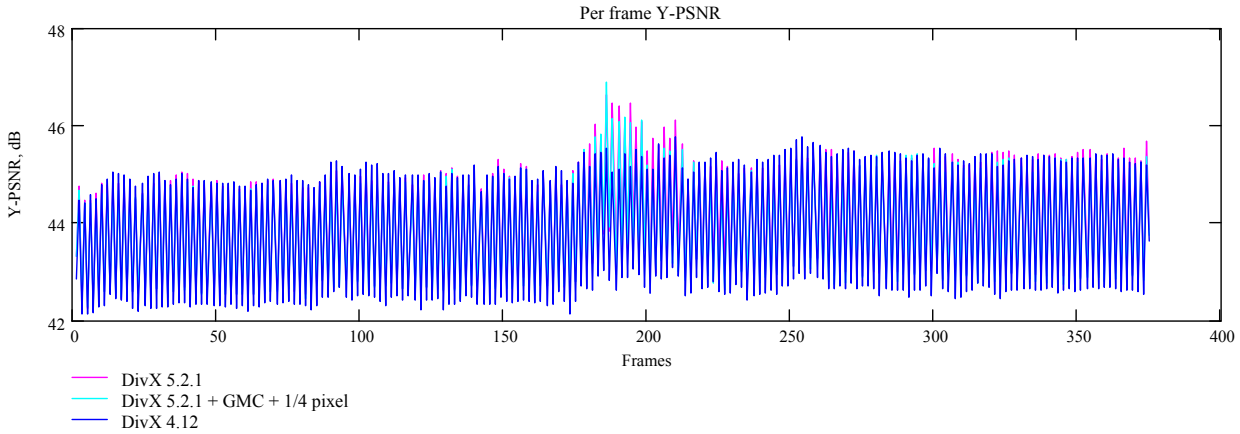
Bitrate = 700 Kb/sec

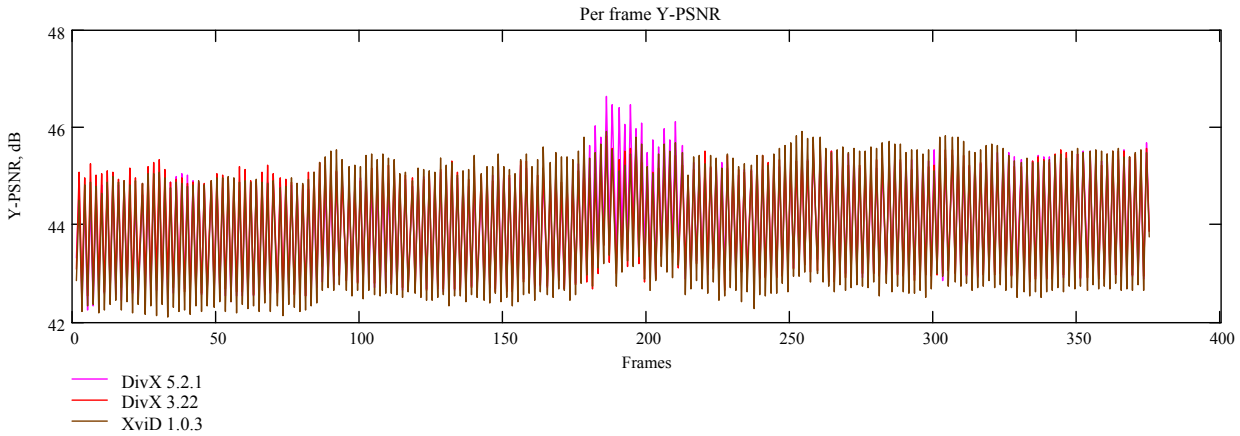


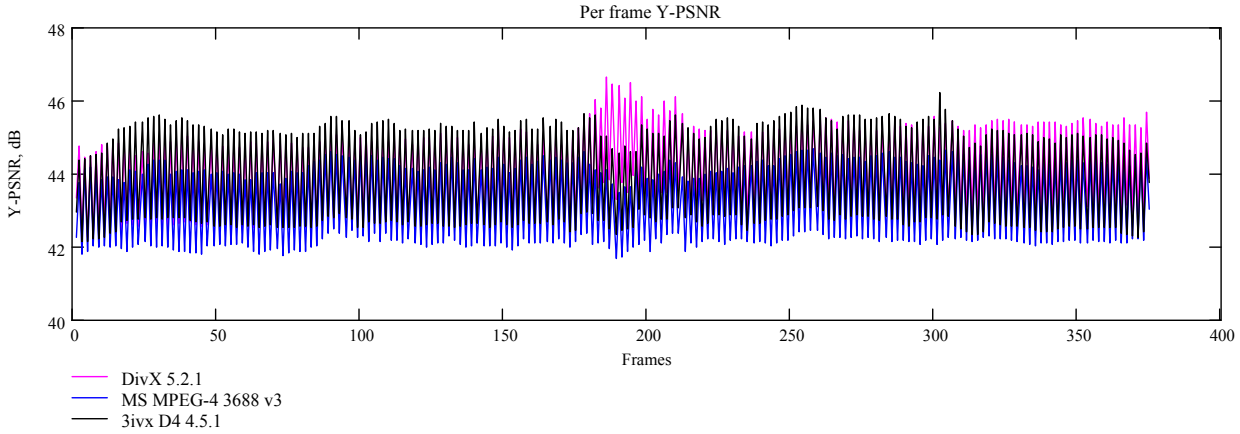




Bitrate = 2340 Kb/sec







Conclusions:

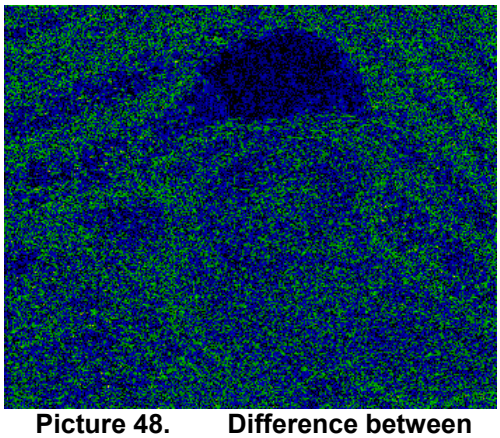
- DivX 3.12 and MS MPEG-4 diagrams are very similar.
- The diagrams clearly reflect drop frames usage on low bit rates by DivX 3.12 and MS MPEG-4.

Visual comparison

Foreman sequence, frame 8, bit rate 700 KBps.

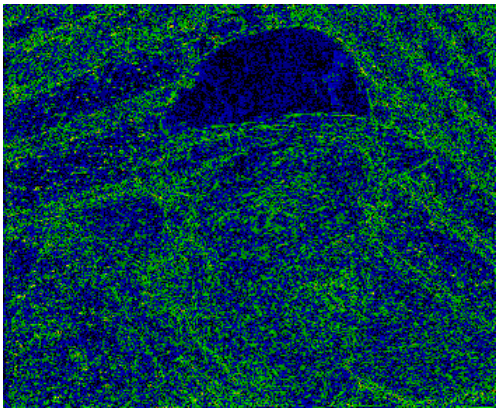
Examples below are single frames from the compressed foreman sequence. They demonstrate the visual difference among the codecs produced by DivXNetworks, Inc. The 5th version shows significant quality improvement in comparison with the 4th one.

Picture 47. DivX 5.2.1, foreman, frame 8



Picture 48. Difference between DivX 5.2.1 and original, foreman, frame 8

Picture 49. DivX 4.12, foreman, frame 8

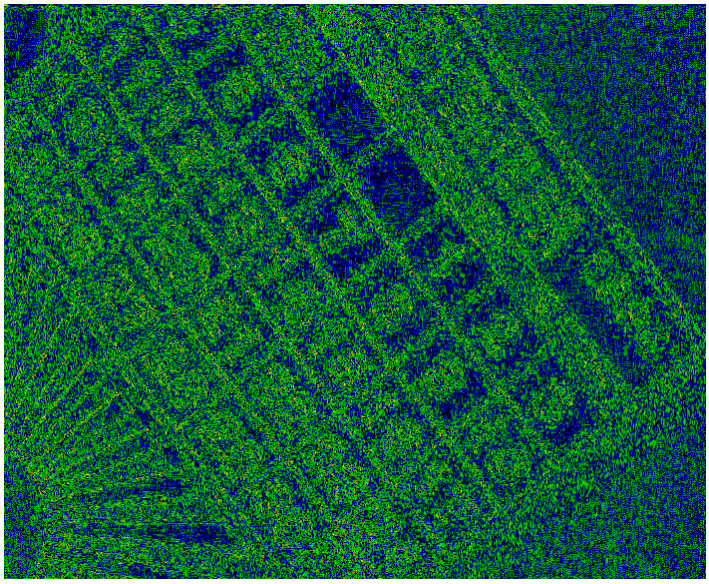


Picture 50. Difference between DivX 4.12 and original, foreman, frame 8

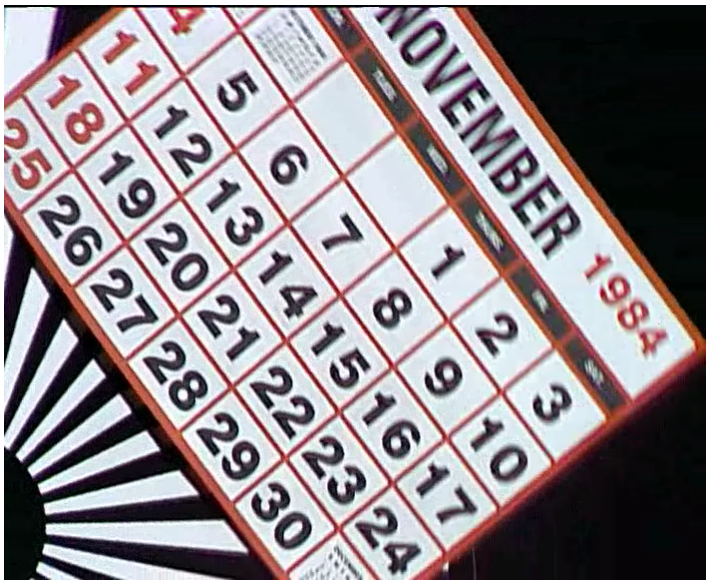
Bbc3di sequence, frame 251, bit rate 2340 KBps.

This sequence contains strong rotation of the whole frame. PSNR diagrams have shown that enabling of the GMC (Global Motion Compensation) and Quarter Pixel options in the DivX codec causes significant PSNR decrease. The following example demonstrates that quality in this case is affected as well.

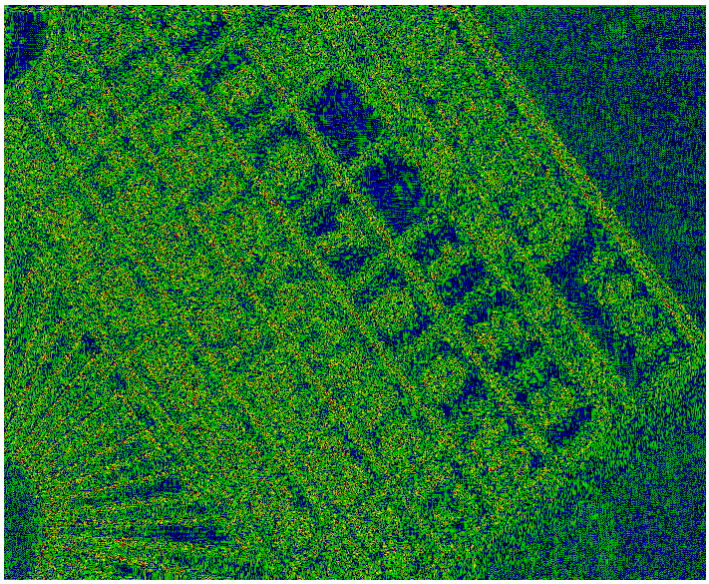
Picture 51. DivX 5.2.1, bbc3di, frame 251



Picture 52. Difference between DivX 5.2.1 and original, bbc3di, frame 251



Picture 53. DivX 5.2.1 + GMC, bbc3di, frame 251



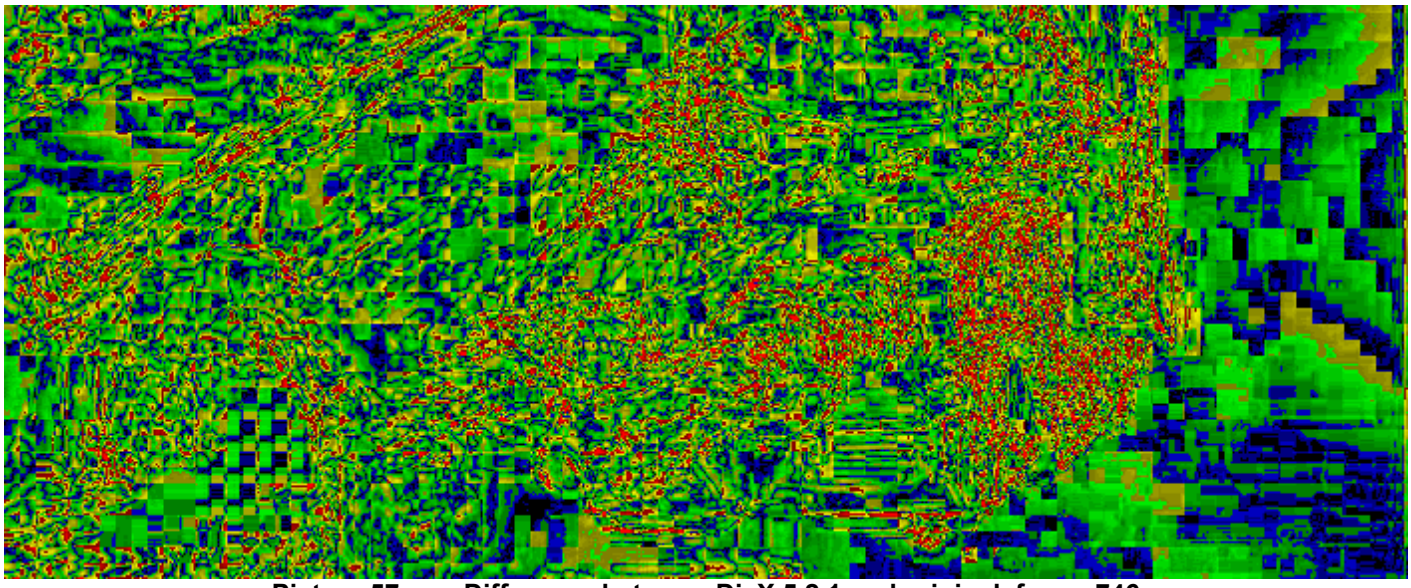
Picture 54. Difference between DivX 5.2.1 + GMC and original, bbc3di, frame 251

Battle sequence, frame 746.

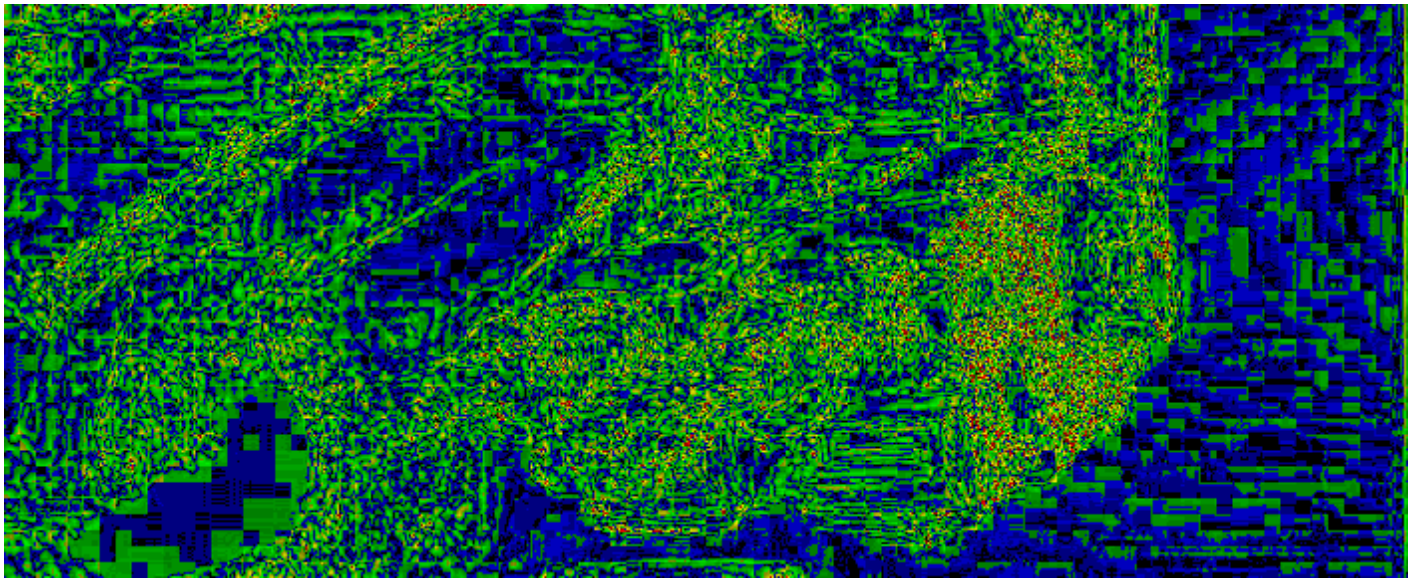
Frames below demonstrate much better quality of XviD than DivX 5.2.1.

Picture 55. DivX 5.2.1, battle, frame 746

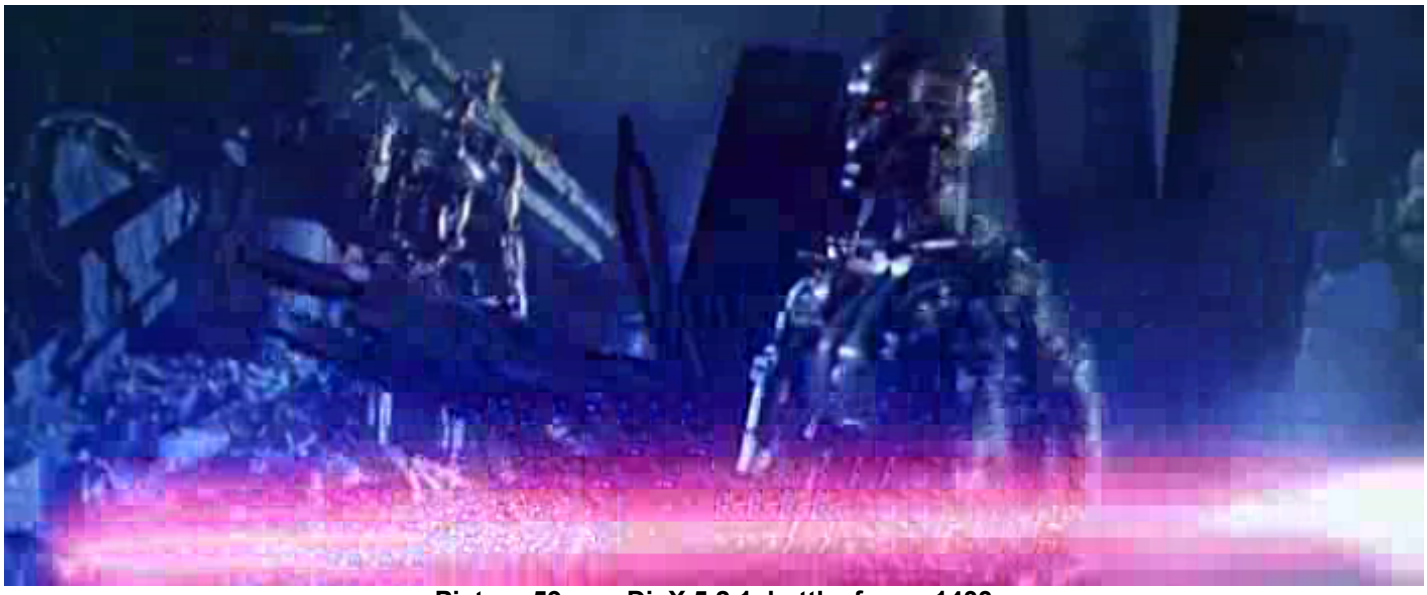
Picture 56. XviD 1.0.3, battle, frame 746



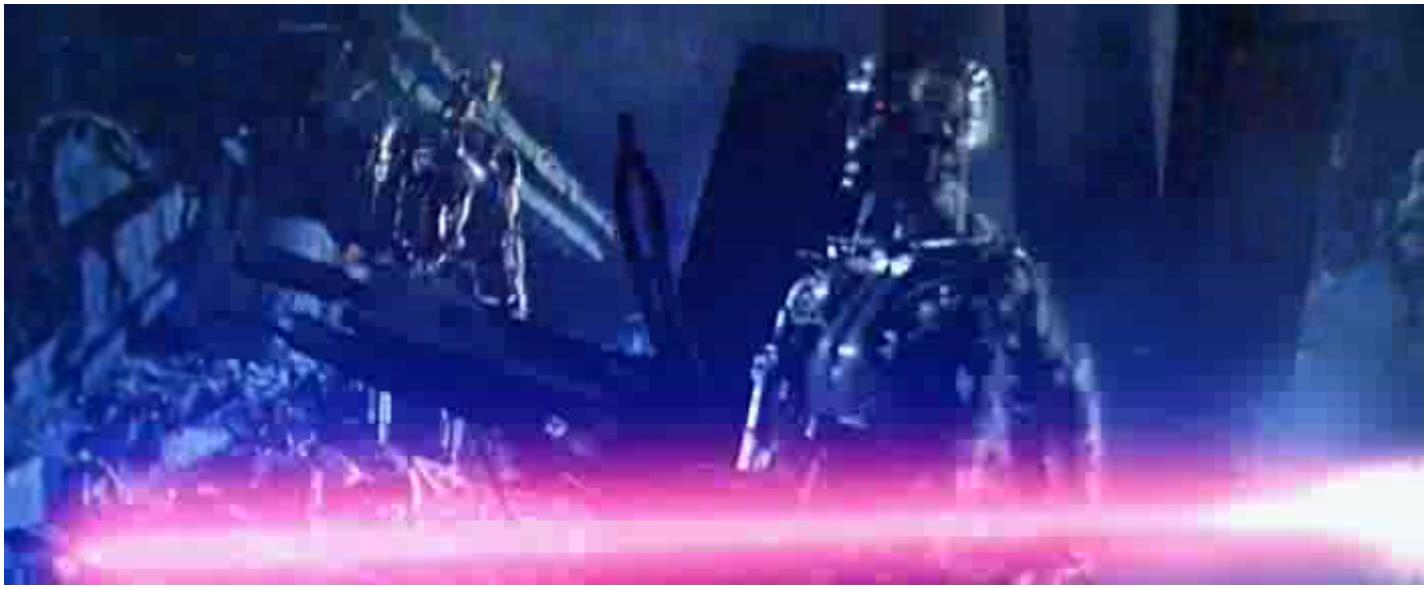
Picture 57. Difference between DivX 5.2.1 and original, frame 746



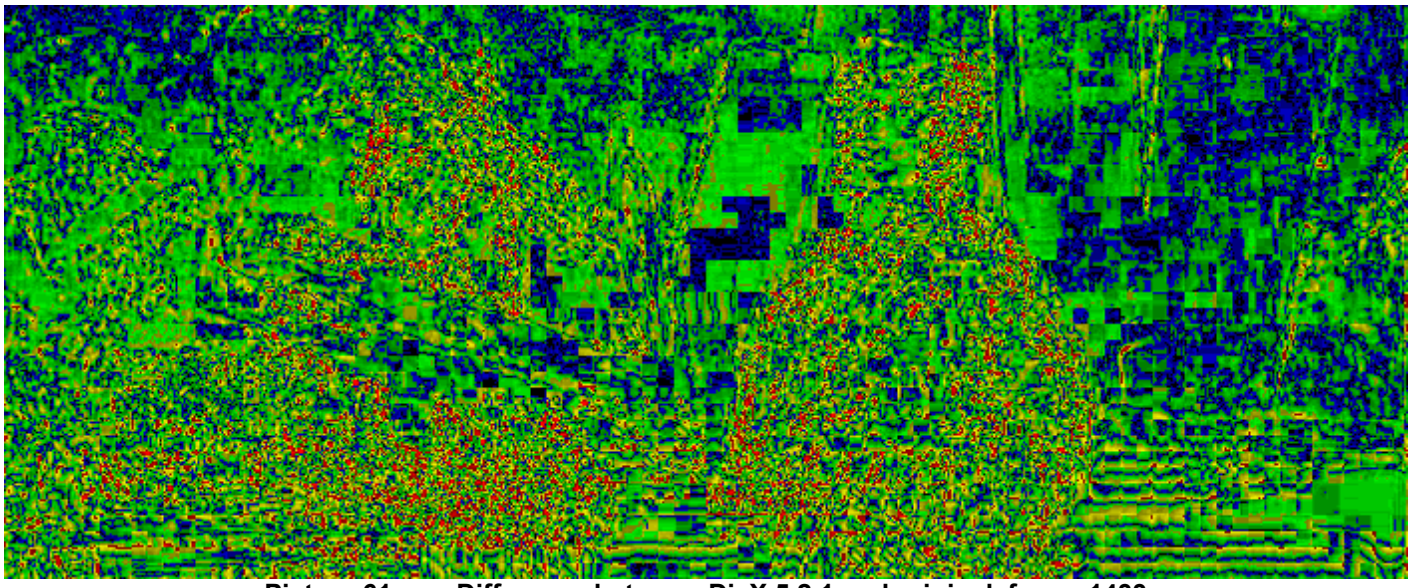
Picture 58. Difference between XviD 1.0.3 and original, battle, frame 746



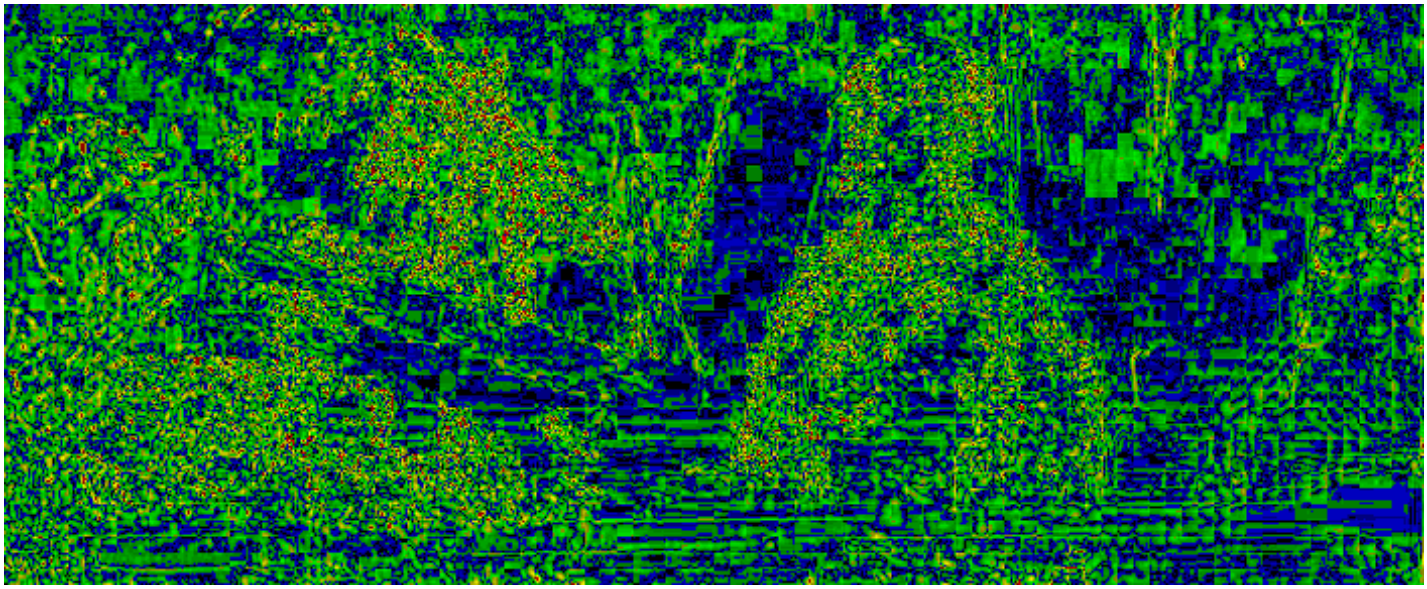
Picture 59. DivX 5.2.1, battle, frame 1433



Picture 60. XviD 1.0.3, battle, frame 1433



Picture 61. Difference between DivX 5.2.1 and original, frame 1433



Picture 62. Difference between XviD 1.0.3 and original, battle, frame 1433

Informal codecs comparison

As one can see on the diagrams above different codecs show significantly different results on different sequences. That happens because all the represented sequences have different character (motion, noise e.t.c.). This fact allows to define which codecs do well with any kind of video sequences and which provide good results only for some class of sequences. However it would be interesting to find out general characteristics of each codec on the whole testing set.

We decided that averaging resulting values for all the sequences won't be correct and suggested an informal estimation where every codec is given some score depending on the results of its measurement.

Informal comparison rules

- If some codec is stably better than all the others in more than one point it is given score 3 regardless of other results.
- If some codec is worse than all the others in more than one point it is given score 1.
- Otherwise it is given score 2.
- Y-PSNR, U-PSNR, and V-PSNR parameters are estimated using this method.
- OpenDivX 0.3 doesn't take part in the informal comparison, because it hasn't been tested on all the sequences.

Informal comparison results

	bankomatdi	battle	bbc3di	foreman	susidi	total	place
DivX 5.2.1	3	3	3	2	3	14	1
DivX 5.2.1 + GMC + 1/4	2	2	1	2	1	8	4,5
DivX 4.12	2	2	1	3	2	10	2
DivX 3.22	1	1	1	2	2	7	6
MS MPEG-4	1	1	1	2	1	6	7
XviD 1.0.3	2	2	1	3	1	9	3
3ivx D4 4.5.1	2	1	2	1	2	8	4,5

Picture 63. Informal comparison results table for Y-PSNR.

	bankomatdi		battle		bbc3di		foreman		susidi		total	place
	U	V	U	V	U	V	U	V	U	V		
DivX 5.2.1	2	2	2	2	3	2	2	2	3	3	23	2
DivX 5.2.1 + GMC + 1/4	3	3	3	3	1	1	2	2	2	2	22	3
DivX 4.12	2	2	2	2	2	2	1	1	2	2	18	5,6
DivX 3.22	2	2	2	2	2	2	2	2	2	2	20	4
MS MPEG-4	1	1	2	2	2	2	2	2	1	1	16	7
XviD 1.0.3	3	3	3	3	1	1	3	3	3	3	26	1
3ivx D4 4.5.1	2	1	1	1	2	3	2	2	2	2	18	5,6

Picture 64. Informal comparison results table for U- and V-PSNR

	Y	UV/2	total	place
DivX 5.2.1	14	11.5	25.5	1
DivX 5.2.1 + GMC + 1/4	8	11	17	4,5,6
DivX 4.12	10	9	19	3
DivX 3.22	7	10	17	4,5,6
MS MPEG-4	6	8	14	7
XviD 1.0.3	9	13	22	2
3ivx D4 4.5.1	8	9	17	4,5,6

Picture 65. General informal comparison results table

General conclusions

- Only MS MPEG-4 and DivX 3.22 should be used for low bit rate compression.
- DivX 5.2.1 proved to be a total leader.
- Leadership of the DivX 5.2.1 codec is often based on the fact that it keeps brightness level in the compressed sequence better than the others.
- GMC and Quarter Pixel options of DivX 5.2.1 mostly do not improve the quality of the compressed sequence. Moreover usage of these options often leads to much worse results.
- XviD is the best in processing U and V components. It could possibly compete with DivX 5.2.1 without its raising brightness in the compressed sequence.
- Although we think that codec developers must keep the initial brightness level in the decompressed video, we plan to complete this comparison with metrics persistent to brightness changes.

Also you can see MSU H.264/MPEG-4 AVC Codecs Comparison. http://www.compression.ru/video/codec_comparison/mpeg-4_avc_h264_en.html

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

MSU Video Quality Measurement Tool

MSU Graphics & Media Lab. Video Group.

GRAPHICS & MEDIA LAB VIDEO GROUP

Main Features

1. 12 Objective Metric + 5 Plugins

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

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

*.AVI,
*. YUV:
YUV,
YV12,
IYUV,
UYVY,
Y,
YUY2,
*.BMP,
*.AVS:
*.MOV,
*.VOB,
*.WMV,
*.MP4,
*.MPG,
*.MKV,
*.FLV,
etc.,

Extended Color Depth:
P010, P014,
P016, P210,
P214, P216,
P410, P414,
P416,
P410_RGB,
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

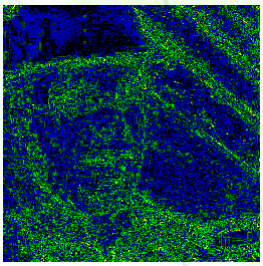
GUI and command line tools

7. Plugins Interface

You can easily develop your own metric

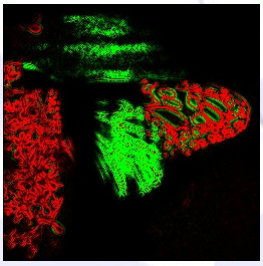
Visualization Examples

Allows easily detect where codec/filter fails

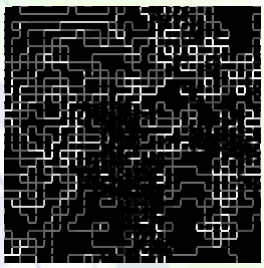


Y-YUV PSNR

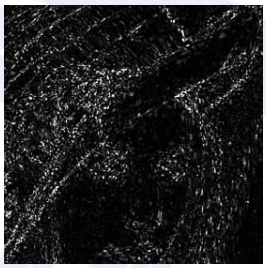
Y-YUV Delta



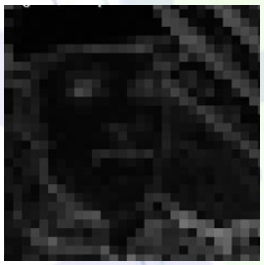
MSU Blurring Metric



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:

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skype
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NASA
DOLBY
CISCO
Sun microsystems
NBC UNIVERSAL
DivX®