MPEG-4
AVC/H.264
Video Codecs
Comparison

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Marat Arsaev

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Codecs:

- H.264
  - DivX H.264
  - Elecard H.264
  - Intel SandyBridge Transcoder (GPU encoder)
  - MainConcept H.264 (software)
  - MainConcept H.264 (CUDA based encoder)
  - Microsoft Expression Encoder
  - DiscretePhoton
  - x264

- Non H.264
  - VP8 (WebM project)
  - XviD (MPEG-4 ASP codec)

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- Elecard Ltd
- Intel Corporation
- MainConcept GmbH
- x264 Development Team
- WebM project team
- DiscretePhoton team
- Microsoft Expression Encoder

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

2.1 Sequences

Table 1. Summary of video sequences.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Number of frames</th>
<th>Frame rate</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>VideoConference</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Videoconference CIF</td>
<td>1374</td>
<td>30</td>
<td>352x288</td>
</tr>
<tr>
<td>2. VideoConference 4CIF</td>
<td>3600</td>
<td>30</td>
<td>640x480</td>
</tr>
<tr>
<td>3. VideoConference 720p</td>
<td>1500</td>
<td>30</td>
<td>1280x720</td>
</tr>
<tr>
<td>Movies (SD sequences)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Ice Age</td>
<td>2014</td>
<td>24</td>
<td>720x480</td>
</tr>
<tr>
<td>5. City</td>
<td>600</td>
<td>60</td>
<td>704x576</td>
</tr>
<tr>
<td>6. Crew</td>
<td>600</td>
<td>60</td>
<td>704x576</td>
</tr>
<tr>
<td>7. Indiana Jones</td>
<td>5000</td>
<td>30</td>
<td>704x288</td>
</tr>
<tr>
<td>8. Harbour</td>
<td>600</td>
<td>60</td>
<td>704x576</td>
</tr>
<tr>
<td>9. Ice Skating</td>
<td>480</td>
<td>60</td>
<td>704x576</td>
</tr>
<tr>
<td>10. Soccer</td>
<td>600</td>
<td>60</td>
<td>704x576</td>
</tr>
<tr>
<td>11. Race Horses</td>
<td>300</td>
<td>30</td>
<td>832x480</td>
</tr>
<tr>
<td>12. State Enemy</td>
<td>6500</td>
<td>24</td>
<td>720x304</td>
</tr>
<tr>
<td>13. Party Scene</td>
<td>500</td>
<td>50</td>
<td>832x480</td>
</tr>
<tr>
<td>HDTV sequences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Park Joy</td>
<td>500</td>
<td>50</td>
<td>1280x720</td>
</tr>
<tr>
<td>15. Riverbed</td>
<td>250</td>
<td>25</td>
<td>1920x1080</td>
</tr>
<tr>
<td>16. Rush Hour</td>
<td>500</td>
<td>25</td>
<td>1920x1080</td>
</tr>
<tr>
<td>17. Blue Sky</td>
<td>217</td>
<td>25</td>
<td>1920x1080</td>
</tr>
<tr>
<td>18. Station</td>
<td>313</td>
<td>25</td>
<td>1920x1080</td>
</tr>
<tr>
<td>19. Stockholm</td>
<td>604</td>
<td>50</td>
<td>1280x720</td>
</tr>
<tr>
<td>20. Sunflower</td>
<td>500</td>
<td>25</td>
<td>1920x1080</td>
</tr>
<tr>
<td>21. Tractor</td>
<td>690</td>
<td>25</td>
<td>1920x1080</td>
</tr>
<tr>
<td>22. Bunny</td>
<td>600</td>
<td>24</td>
<td>1920x1080</td>
</tr>
<tr>
<td>23. Dream</td>
<td>600</td>
<td>24</td>
<td>1920x1080</td>
</tr>
<tr>
<td>24. Troy</td>
<td>300</td>
<td>24</td>
<td>1920x1072</td>
</tr>
</tbody>
</table>

Brief descriptions of the sequences used in our comparison are given in Table 1. More detailed descriptions of these sequences can be found in Appendix 5. Test Set of Video Sequences.
2.2 Codecs

Table 2. Short codec descriptions

<table>
<thead>
<tr>
<th>Codec</th>
<th>Developer</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DivX AVC/H.264 Video Encoder</td>
<td>DivX, Inc.</td>
<td>1.1.1.9</td>
</tr>
<tr>
<td>2. Elecard AVC Video Encoder 8-bit edition</td>
<td>Elecard Ltd</td>
<td>2.1.022202.091207</td>
</tr>
<tr>
<td>3. MainConcept AVC/H.264 Video Encoder Console Application</td>
<td>MainConcept GmbH</td>
<td>1.5.0</td>
</tr>
<tr>
<td>4. Microsoft Expression Encoder 4</td>
<td>Microsoft Corp.</td>
<td>encoder_core.dll version 4.0.3205.0 mc_enc_avc.dll version 8.7.0.37256</td>
</tr>
<tr>
<td>5. x264</td>
<td>x264 Development Team</td>
<td>x264 core:114 r1900 60ef1f8</td>
</tr>
<tr>
<td>6. XviD raw mpeg4 bitstream encoder</td>
<td>XviD Development Team</td>
<td>xvid-1.3.0-dev</td>
</tr>
<tr>
<td>7. Discrete Photon</td>
<td>Discrete Photon Development Team</td>
<td>unversioned</td>
</tr>
<tr>
<td>8. WebM vp8 Codec</td>
<td>WebM</td>
<td>v0.9.2-522-gddd260e</td>
</tr>
</tbody>
</table>

Brief descriptions of the codecs used in our comparison are given in Table 2. XviD was used as a good quality MPEG-4 ASP reference codec for comparison purposes. Detailed descriptions of all codecs used in our comparison can be found in Appendix 6. Tested Codecs.
3 Objectives and Testing Rules

3.1 H.264 Codec Testing Objectives

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

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

3.2 Testing Rules

- The entire test set was divided into two primary types of applications. These applications differ by resolution, bitrate and encoding speed requirements:
  - VideoConference (one pass only)
  - Movies (bitrates of 500-2000 kbps)
  - High-definition television (“HDTV”; bitrates of 0.7-10 mbps)

- There are special presets and speed limitations for every type of application:
  - Video Conference (one pass only, good local bitrate handling)
    - Minimum 60 fps at 4CIF sequence
  - Movies (speed requirements for 750 kbps 4CIF sequences):
    - Minimum 120 fps for "High Speed" preset
    - Minimum 80 fps for "Normal" preset
    - Minimum 40 fps for "High Quality" preset
  - HDTV (speed requirements for 3 mbps 1280x720 sequences):
    - Minimum 100 fps for "High Speed" preset
    - Minimum 50 fps for "Normal" preset
    - Minimum 20 fps for "High Quality" preset

- Each codec’s developer provided settings for each type of application. Each setting’s individual parameters were, to a large extent, chosen by the developers, except the following:
  - DivX H.264
  - XviD (last year presets were used)

- Each codec was tested for speed three times; the minimum score was then used as the representative time.

- During the testing process, source video sequences were in the YV12 format (.yuv file extension) for all codecs.
For all measurements the PRO version of the YUVsoft Video Codec Scoring System was used (http://www.yuvsoft.com/technologies/vicos/index.html).

The following computer configuration was used for the main tests:
- 4-cores processor: Intel Core i7 920, 2.67GHz
- OS Name: Microsoft Windows 7 Professional 64-bit
- Total Physical Memory: 12 GB

During the evaluation the following measures were used:
- SSIM (Y component)
- PSNR (Y component)

Enterprise version of report contains:
- SSIM, Y-SSIM, U-SSIM, V-SSIM
- PSNR, Y-PSNR, U-PSNR, V-PSNR
- MSE
- 3-SSIM
- MS-SSIM

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

4 Comparison Results

4.1 Video Conferences

4.1.1 RD Curves

Next figures show RD curves for three video conference sequences. The leader by quality is x264. DivX H.264 is typically second.

![RD Curves for Video Conferences](image)

Figure 1. Bitrate/quality—usage area “Video Conference,” CIF sequence, Y-SSIM metric

http://www.compression.ru/video/
Figure 2. Bitrate/quality—usage area “Video Conference,” 720p sequence, Y-SSIM metric
4.1.2 Encoding Speed

Absolute speed results are presented in Figure 3 through Figure 5. All the encoders have a similar growth rate for encoding time as the bitrate is increased. Discrete Photon is the fastest.

Figure 3. Encoding speed—usage area “Video Conference”
CIF sequence

Figure 4. Encoding speed—usage area “Video Conference”
4CIF sequence
4.1.3 Speed/Quality Trade-Off

Detailed descriptions of the speed/quality trade-off graphs can be found in Appendix 7. Figures Explanation. Sometimes, codec results are not present in the particular graph owing to the codec’s extremely poor performance. The codec’s RD curve has no intersection with the reference’s RD curve.

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

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

The three best codecs (no codec performs faster with higher quality) in terms of speed/quality are DiscretePhoton, Elecard and x264 at average.
Figure 6. Speed/quality trade-off—usage area “Video Conference,” CIF sequence, Y-SSIM metric

Figure 7. Speed/quality trade-off—usage area “Video Conference,” 4CIF sequence, Y-SSIM metric
Figure 8. Speed/quality trade-off—usage area “Video Conference,” 720p sequence, Y-SSIM metric

Figure 9. Speed/quality trade-off—usage area “Video Conference,” all sequences, Y-SSIM metric

http://www.compression.ru/video/
4.1.4 Bitrate Handling

Encoders with High Speed presets, except the XviD encoder, demonstrate good bitrate handling for all sequences. There are some issues with bitrate handling for DiscretePhoton encoders for CIF sequence.
4.1.5 Local Bitrate Handling

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

\[
LBH = \frac{\max(mfps) \cdot 8 \cdot fps}{1024 \cdot \text{target_bitrate}}
\]

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

And overall results is maximal value of LBH for sequence.

Elecard shows best result for this analysis. And x264 shows lowest result.
Figure 14. Bitrate handling—usage area “Video Conference,” CIF sequence

Figure 15. Bitrate handling—usage area “Video Conference,” 4CIF sequence
4.1.6 Relative Quality Analysis

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

Note that each number in the tables below corresponds to some range of bitrates (see Appendix 7. Figures Explanation for more details). Unfortunately, these ranges can differ significantly because of differences in the quality of compared encoders. This situation can lead to some inadequate results when three or more codecs are compared.

Consider the Y-SSIM results in Table 5 and Y-PSNR results in Table 4. On average, the leader is the x264 encoder followed by DivX H.264 encoder.

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

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>MSE encoder</th>
<th>Discrete Photon</th>
<th>Webm</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>110%</td>
<td>129%</td>
<td>117%</td>
<td>193%</td>
<td>141%</td>
<td>69%</td>
<td>157%</td>
</tr>
<tr>
<td>Elecard</td>
<td>91%</td>
<td>100%</td>
<td>119%</td>
<td>105%</td>
<td>167%</td>
<td>127%</td>
<td>64%</td>
<td>144%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>77%</td>
<td>84%</td>
<td>100%</td>
<td>89%</td>
<td>134%</td>
<td>107%</td>
<td>55%</td>
<td>123%</td>
</tr>
<tr>
<td>MSE encoder</td>
<td>86%</td>
<td>96%</td>
<td>113%</td>
<td>100%</td>
<td>174%</td>
<td>125%</td>
<td>58%</td>
<td>137%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>52%</td>
<td>60%</td>
<td>75%</td>
<td>57%</td>
<td>100%</td>
<td>69%</td>
<td>35%</td>
<td>89%</td>
</tr>
<tr>
<td>Webm</td>
<td>71%</td>
<td>79%</td>
<td>93%</td>
<td>80%</td>
<td>144%</td>
<td>100%</td>
<td>47%</td>
<td>113%</td>
</tr>
<tr>
<td>x264</td>
<td>145%</td>
<td>157%</td>
<td>182%</td>
<td>172%</td>
<td>286%</td>
<td>213%</td>
<td>100%</td>
<td>223%</td>
</tr>
<tr>
<td>XviD</td>
<td>64%</td>
<td>70%</td>
<td>81%</td>
<td>73%</td>
<td>113%</td>
<td>89%</td>
<td>45%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Table 4. Average bitrate ratio for the same quality. Usage area “Video Conference”. Y-PSNR.

<table>
<thead>
<tr>
<th>Codec</th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>MSE encoder</th>
<th>Discrete Photon</th>
<th>Webm</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>109%</td>
<td>252%</td>
<td>109%</td>
<td>185%</td>
<td>125%</td>
<td>88%</td>
<td>157%</td>
</tr>
<tr>
<td>Elecard</td>
<td>92%</td>
<td>100%</td>
<td>214%</td>
<td>99%</td>
<td>165%</td>
<td>115%</td>
<td>81%</td>
<td>144%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>40%</td>
<td>47%</td>
<td>100%</td>
<td>41%</td>
<td>74%</td>
<td>41%</td>
<td>31%</td>
<td>123%</td>
</tr>
<tr>
<td>MSE encoder</td>
<td>92%</td>
<td>101%</td>
<td>246%</td>
<td>100%</td>
<td>177%</td>
<td>117%</td>
<td>80%</td>
<td>137%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>54%</td>
<td>60%</td>
<td>135%</td>
<td>57%</td>
<td>100%</td>
<td>62%</td>
<td>45%</td>
<td>89%</td>
</tr>
<tr>
<td>Webm</td>
<td>80%</td>
<td>87%</td>
<td>244%</td>
<td>86%</td>
<td>161%</td>
<td>100%</td>
<td>68%</td>
<td>113%</td>
</tr>
<tr>
<td>x264</td>
<td>113%</td>
<td>123%</td>
<td>326%</td>
<td>124%</td>
<td>224%</td>
<td>148%</td>
<td>100%</td>
<td>223%</td>
</tr>
<tr>
<td>XviD</td>
<td>63%</td>
<td>68%</td>
<td>138%</td>
<td>67%</td>
<td>112%</td>
<td>78%</td>
<td>53%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 17 and Figure 18 depict the data from the tables above. Each line in the figures corresponds to one codec. Values on the vertical axis are the average relative bitrates compared with the codecs along the horizontal axis. A lower bitrate indicates better relative results.
Average bitrate ratio for the same quality. Usage area “Video Conference,” Y-PSNR

Figure 18. Average bitrate ratio for a fixed quality—usage area “Video Conference,” Y-PSNR metric

4.2 Movies

4.2.1 RD Curves

4.2.1.1 High Speed Preset

Figure 19 and Figure 20 show typical situation for all encoders (except some sequences). Figure 19 shows all encoders results and Figure 20 – only for encoders that fit encoding speed requirements. For quality analysis we used only encoders that fit encoding speed requirements encoders. The leader for almost all video sequences (except Crew and Harbour) is x264. MainConcept is typically second. Third place is for Elecard. Discrete Photon exhibited the poorest result (even lower than XviD sometimes).

PSNR results are shown at Figure 21 and Figure 22. PSNR usage as main metric changes results strongly for example, MainConcept shows lower quality and MSE shows better quality at average.

MSE and WebM High Speed presets does not fit the encoding speed requirements.

Results for all the sequences, all metrics and all encoders are available in Enterprise version report only.
Figure 19. Bitrate/quality—usage area “Movies,” “Ice Skating” sequence, High Speed preset, Y-SSIM metric. All encoders.

Figure 20. Bitrate/quality—usage area “Movies,” “Ice Skating” sequence, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Figure 21. Bitrate/quality—usage area “Movies,” “Ice Age” sequence, High Speed preset, Y-PSNR metric. All encoders.

Figure 22. Bitrate/quality—usage area “Movies,” “Ice Age” sequence, High Speed preset, Y-PSNR metric. Encoders that fit encoding speed requirements.

4.2.1.2 Normal Preset

The Normal preset results for each sequence are presented in Figure 23 through Figure 28. The first two figures show the Y-SSIM results, and the last two figures show the Y-PSNR results. The results depend on the metric used.

SSIM metric: The leader is x264; three encoders (MainConcept, DivX H.264 and Elecard) placed second – the position depends on sequence tested.

PSNR metric: Results differ strongly, for example Elecard shows better results as for SSIM and MainConcept shows lower results.
MSE and WebM Normal presets does not fit the encoding speed requirements.

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

**Figure 23.** Bitrate/quality—usage area “Movies,” “Race Horses” sequence, Normal preset, Y-SSIM metric. All encoders

**Figure 24.** Bitrate/quality—usage area “Movies,” “Race Horses” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Figure 25. Bitrate/quality—usage area “Movies,” “Ice Age” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 26. Bitrate/quality—usage area “Movies,” “Harbour” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
4.2.1.3 High Quality Preset

The High Quality preset results for each sequence are presented in Figure 29 through Figure 34. The first four graphs show the Y-SSIM results, and the last two graphs show the Y-PSNR results. The results change depending on the metric used.

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

**PSNR metric:** The leader is the same, but encoders at second place exchange their places.

**MSE and WebM High Quality presets do not fit the encoding speed requirements.**

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

Figure 29. Bitrate/quality—usage area “Movies,” “Soccer” sequence, High Quality preset, Y-SSIM metric. All encoders

Figure 30. Bitrate/quality—usage area “Movies,” “Soccer” sequence, High Quality preset, Y-SSIM metric. Encoders that fit encoding speed
Figure 31. Bitrate/quality—usage area “Movies,” “Party Scene” sequence, High Quality preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 32. Bitrate/quality—usage area “Movies,” “State Enemy” sequence, High Quality preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Figure 33. Bitrate/quality—usage area “Movies,” “Party Scene” sequence, High Quality preset, Y-PSNR metric. Encoders that fit encoding speed requirements.

Figure 34. Bitrate/quality—usage area “Movies,” “State Enemy” sequence, High Quality preset, Y-PSNR metric. Encoders that fit encoding speed requirements.
4.2.2 Encoding Speed

4.2.2.1 High Speed Preset

Absolute speed results are presented in Figure 35 through Figure 36. All the encoders except MSE have a similar growth rate for encoding time as the bitrate is increased. XviD is the fastest.

![Figure 35. Encoding speed—usage area “Movie” “City” sequence, “High Speed” preset](image1)

![Figure 36. Encoding speed—usage area “Movies” “Race Horses” sequence, High Speed preset](image2)

4.2.2.2 Normal Preset

Absolute speed results are presented in Figure 37 through Figure 39. All the encoders except MSE and WebM have a similar growth rate for encoding...
time versus increasing bitrate. DiscretePhoton is the fastest encoder at almost all the sequences.

Figure 37. Encoding speed—usage area “Movies”
“Ice Age” sequence, Normal preset

Figure 38. Encoding speed—usage area “Movies”
“Ice Skating” sequence, Normal preset
4.2.2.3 High Quality Preset

Absolute speed results are presented in Figure 40 through Figure 41. The situation is close to Normal Speed preset at average.

Figure 40. Encoding speed—usage area “Movies”
“Ice Age” sequence, High Quality preset
4.2.3 Speed/Quality Trade-Off

Detailed descriptions of the speed/quality trade-off graphs can be found in Appendix 7. Figures Explanation. Sometimes, codec results are not present in the particular graph owing to the codec's extremely poor performance. The codec's RD curve has no intersection with the reference's RD curve.

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

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

4.2.3.1 High Speed Preset

Figure 42 through Figure 48 show results for the High Speed preset. The chosen metric has an influence on results.

The five best codecs (no codec performs faster with higher quality) in terms of speed/quality are XviD, DivX H.264, Elecard, MainConcept and x264 at average. But there are sequences where it is not true, for example at City sequence MainConcept is better than x264 and Elecard. PSNR metric usage changes the result: Elecard and DivX H.264 exhibited better results on average than did MainConcept.

Results for all the sequences, all metrics and all encoders are available in Enterprise version report only.
Figure 42. Speed/quality trade-off—usage area “Movies,” “City” sequence, High Speed preset, Y-SSIM metric.

Figure 43. Speed/quality trade-off—usage area “Movies,” “City” sequence, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Figure 44. Speed/quality trade-off—usage area “Movies,” “Ice Skating” sequence, High Speed preset, Y-SSIM metric

Figure 45. Speed/quality trade-off—usage area “Movies,” “Ice Skating” sequence, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Figure 46. Speed/quality trade-off—usage area “Movies,” All “Movie” sequences, High Speed preset, Y-SSIM metric

Figure 47. Speed/quality trade-off—usage area “Movies,” All “Movie” sequences, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
4.2.3.2 Normal Preset

Figure 49 through Figure 62 show results for the Normal preset. The results differ depending on the chosen metric.

All codecs that fit requirements except DivX H.264 are best (no codec performs faster with higher quality) in terms of speed/quality at average. But there are sequences where it is not true, for example at Indiana Jones sequence codecs change their places. PSNR metric usage changes the result: there are only three best codecs: XviD, Elecard and x264.
Figure 50. Speed/quality trade-off—usage area “Movies,” “Crew” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 51. Speed/quality trade-off—usage area “Movies,” “Indiana Jones” sequence, Normal preset, Y-SSIM metric
Figure 52. Speed/quality trade-off—usage area “Movies,” “Indiana Jones” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 53. Speed/quality trade-off—usage area “Movies,” All “Movie” sequences, Normal preset, Y-SSIM metric
Figure 54. Speed/quality trade-off—usage area “Movies,” All “Movie” sequences, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 55. Speed/quality trade-off—usage area “Movies,” All “Movie” sequences, Normal preset, Y-PSNR metric

4.2.3.3 High Quality Preset

Figure 56 through Figure 62 show results for the High Quality preset. The results depend on the chosen metric.

The four best codecs (no codec performs faster with higher quality) in terms of speed/quality are DiscretePhoton, Elecard and x264 at average. But there are sequences where results differ to average. PSNR metric usage changes the result: XviD became one of the best codecs too.
Figure 56. Speed/quality trade-off—usage area “Movies,” “Ice Age” sequence, High Quality preset, Y-SSIM metric.

Figure 57. Speed/quality trade-off—usage area “Movies,” “Ice Age” sequence, High Quality preset, Y-SSIM metric. Encoders that fit encoding speed requirements
Figure 58. Speed/quality trade-off—usage area “Movies,” “Soccer” sequence, High Quality preset, Y-SSIM metric

Figure 59. Speed/quality trade-off—usage area “Movies,” “Soccer” sequence, High Quality preset, Y-SSIM metric. Encoders that fit encoding speed requirements
Figure 60. Speed/quality trade-off—usage area "Movies," All "Movie" sequences, High Quality preset, Y-SSIM metric

Figure 61. Speed/quality trade-off—usage area "Movies," All "Movie" sequences, High Quality preset, Y-SSIM metric. Encoders that fit encoding speed requirements
**4.2.4 Bitrate Handling**

**4.2.4.1 High Speed Preset**

Encoders with High Speed presets, except the XviD encoder, demonstrate good bitrate handling for all sequences. There are some issues with bitrate handling for DiscretePhoton encoder for some sequences (for example City and Race Horses sequences).
Figure 64. Bitrate handling—usage area “Movies,” “Race Horses” sequence, High Speed preset

Figure 65. Bitrate handling—usage area “Movies,” “Ice Age” sequence, High Speed preset
Figure 66. Bitrate handling—usage area “Movies,” “Harbour” sequence, High Speed preset

4.2.4.2 Normal Preset

Results are close to HighSpeed results: encoders with High Speed presets, except the XviD encoder, demonstrate good bitrate handling for all sequences. There are some issues with bitrate handling for DiscretePhoton encoder for some sequences (for example, Race Horses sequence).

Figure 67. Bitrate handling—usage area “Movies,” “Crew” sequence, Normal preset
Figure 68. Bitrate handling—usage area “Movies,” “Ice Skating” sequence, Normal preset

Figure 69. Bitrate handling—usage area “Movies,” “Party Scene” sequence, Normal preset
4.2.4.3 High Quality Preset

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

Figure 70. Bitrate handling—usage area “Movies,” “Race Horses” sequence, Normal preset

Figure 71. Bitrate handling—usage area “Movies,” “City” sequence, High Quality preset
Figure 72. Bitrate handling—usage area “Movies,” “Ice Age” sequence, High Quality preset

Figure 73. Bitrate handling—usage area “Movies,” “Race Horses” sequence, High Quality preset
4.2.5 Relative Quality Analysis

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

Note that each number in the tables below corresponds to some range of bitrates (see Appendix 7. Figures Explanation for more details). Unfortunately, these ranges can differ significantly because of differences in the quality of compared encoders. This situation can lead to some inadequate results when three or more codecs are compared.

Consider the High Speed preset (Y-SSIM results in Table 5 and Y-PSNR results in Table 6). On average, the leader is the x264 encoder and MainConcept with DivX H.264 encoders are second (MainConcept is better than DivX H.264).

Table 7 and Table 8 present the Normal preset results for the Y-SSIM and Y-PSNR quality metrics, respectively. The results are similar to those of the High Speed preset: the leader is the x264 encoder and MainConcept with DivX H.264 encoders are second (DivX H.264 is better than MainConcept).

Table 9 and Table 10 present the High Quality preset results for the Y-SSIM and Y-PSNR quality metrics, respectively. The results are very similar to those of the Normal preset: the leader is the x264 encoder and MainConcept with DivX H.264 encoders are second (DivX H.264 is better than MainConcept).
Table 5. Average bitrate ratio for the same quality. Usage area “Movie”. “High Speed” preset, Y-SSIM.

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>88%</td>
<td>78%</td>
<td>139%</td>
<td>70%</td>
<td>142%</td>
</tr>
<tr>
<td>Elecard</td>
<td>114%</td>
<td>100%</td>
<td>89%</td>
<td>161%</td>
<td>80%</td>
<td>161%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>128%</td>
<td>112%</td>
<td>100%</td>
<td>178%</td>
<td>90%</td>
<td>181%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>72%</td>
<td>62%</td>
<td>56%</td>
<td>100%</td>
<td>50%</td>
<td>102%</td>
</tr>
<tr>
<td>x264</td>
<td>142%</td>
<td>125%</td>
<td>111%</td>
<td>198%</td>
<td>100%</td>
<td>198%</td>
</tr>
<tr>
<td>XviD</td>
<td>70%</td>
<td>62%</td>
<td>55%</td>
<td>98%</td>
<td>50%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>91%</td>
<td>105%</td>
<td>141%</td>
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<td>141%</td>
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<tr>
<td>Elecard</td>
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<td>118%</td>
<td>157%</td>
<td>92%</td>
<td>155%</td>
</tr>
<tr>
<td>MainConcept</td>
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<td>85%</td>
<td>100%</td>
<td>140%</td>
<td>76%</td>
<td>136%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>71%</td>
<td>64%</td>
<td>72%</td>
<td>100%</td>
<td>59%</td>
<td>101%</td>
</tr>
<tr>
<td>x264</td>
<td>119%</td>
<td>109%</td>
<td>131%</td>
<td>170%</td>
<td>100%</td>
<td>167%</td>
</tr>
<tr>
<td>XviD</td>
<td>71%</td>
<td>65%</td>
<td>73%</td>
<td>99%</td>
<td>60%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
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<td>98%</td>
<td>180%</td>
<td>82%</td>
<td>147%</td>
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<td>Elecard</td>
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<td>89%</td>
<td>161%</td>
<td>74%</td>
<td>133%</td>
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<tr>
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<td>100%</td>
<td>181%</td>
<td>84%</td>
<td>150%</td>
</tr>
<tr>
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<td>62%</td>
<td>55%</td>
<td>100%</td>
<td>45%</td>
<td>84%</td>
</tr>
<tr>
<td>x264</td>
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<td>135%</td>
<td>119%</td>
<td>220%</td>
<td>100%</td>
<td>163%</td>
</tr>
<tr>
<td>XviD</td>
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<td>75%</td>
<td>67%</td>
<td>119%</td>
<td>61%</td>
<td>100%</td>
</tr>
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</table>
Table 8. Average bitrate ratio for the same quality. Usage area “Movie”. “Normal” preset, Y-PSNR.

<table>
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<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
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<td>134%</td>
<td>177%</td>
<td>94%</td>
<td>141%</td>
</tr>
<tr>
<td>Elecard</td>
<td>88%</td>
<td>100%</td>
<td>118%</td>
<td>157%</td>
<td>83%</td>
<td>126%</td>
</tr>
<tr>
<td>MainConcept</td>
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<td>85%</td>
<td>100%</td>
<td>142%</td>
<td>77%</td>
<td>112%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>56%</td>
<td>64%</td>
<td>71%</td>
<td>100%</td>
<td>52%</td>
<td>81%</td>
</tr>
<tr>
<td>x264</td>
<td>106%</td>
<td>120%</td>
<td>130%</td>
<td>192%</td>
<td>100%</td>
<td>152%</td>
</tr>
<tr>
<td>XviD</td>
<td>71%</td>
<td>80%</td>
<td>89%</td>
<td>123%</td>
<td>66%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Codec</th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>111%</td>
<td>95%</td>
<td>189%</td>
<td>76%</td>
<td>144%</td>
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<tr>
<td>Elecard</td>
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<td>100%</td>
<td>86%</td>
<td>168%</td>
<td>69%</td>
<td>130%</td>
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<tr>
<td>MainConcept</td>
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<td>116%</td>
<td>100%</td>
<td>197%</td>
<td>81%</td>
<td>151%</td>
</tr>
<tr>
<td>Discrete Photon</td>
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<td>60%</td>
<td>51%</td>
<td>100%</td>
<td>42%</td>
<td>80%</td>
</tr>
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<td>x264</td>
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<td>124%</td>
<td>237%</td>
<td>100%</td>
<td>171%</td>
</tr>
<tr>
<td>XviD</td>
<td>69%</td>
<td>77%</td>
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<td>125%</td>
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<td>100%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Codec</th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>112%</td>
<td>136%</td>
<td>191%</td>
<td>91%</td>
<td>140%</td>
</tr>
<tr>
<td>Elecard</td>
<td>89%</td>
<td>100%</td>
<td>120%</td>
<td>169%</td>
<td>81%</td>
<td>125%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>73%</td>
<td>83%</td>
<td>100%</td>
<td>152%</td>
<td>73%</td>
<td>110%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>52%</td>
<td>59%</td>
<td>66%</td>
<td>100%</td>
<td>47%</td>
<td>76%</td>
</tr>
<tr>
<td>x264</td>
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<td>136%</td>
<td>214%</td>
<td>100%</td>
<td>155%</td>
</tr>
<tr>
<td>XviD</td>
<td>72%</td>
<td>80%</td>
<td>91%</td>
<td>132%</td>
<td>65%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 75 through Figure 80 depict the data from the tables above. Each line in the figures corresponds to one codec. Values on the vertical axis are the average relative bitrates compared with the codecs along the horizontal axis. A lower bitrate indicates better relative results.
Figure 75. Average bitrate ratio for a fixed quality—usage area “Movies,” High Speed preset, Y-SSIM metric

Average bitrate ratio for the same quality. Usage area “Movie”. “High Speed” preset, Y-SSIM metric

Figure 76. Average bitrate ratio for a fixed quality—usage area “Movies”. High Speed preset, Y-PSNR metric.

http://www.compression.ru/video/
Figure 77. Average bitrate ratio for a fixed quality—usage area “Movies”. Normal preset, Y-SSIM metric.

Figure 78. Average bitrate ratio for a fixed quality—usage area “Movies”. Normal preset, Y-PSNR metric.
Figure 79. Average bitrate ratio for a fixed quality—usage area “Movies”. High Quality preset, Y-SSIM metric.

Figure 80. Average bitrate ratio for a fixed quality—usage area “Movies”. High Quality preset, Y-PSNR metric.
4.3 HDTV

4.3.1 RD Curves

4.3.1.1 High Speed Preset

The High Speed preset results for each sequence are presented in Figure 81 through Figure 87. The first six figures show the Y-SSIM results, and the last figure shows the Y-PSNR results. The leader is x264 followed by DivX H.264 and Elecard encoders at average but there are some video sequences (for example, Riverbed), where the situation changes strongly – the leader is Elecard and x264 shows lower quality than even XviD. PSNR metric usage changes the results: for some sequences Elecard shows better quality and x264 shows lower quality.

MSE and WebM High Speed presets do not fit the encoding speed requirements.

![Figure 81. Bitrate/quality—usage area “HDTV,” “Blue sky” sequence, High Speed preset, Y-SSIM metric](http://www.compression.ru/video/)
Figure 82. Bitrate/quality—usage area “HDTV,” “Blue Sky” sequence, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements

Figure 83. Bitrate/quality—usage area “HDTV,” “Park Joy” sequence, High Speed preset, Y-SSIM metric
Figure 84. Bitrate/quality—usage area “HDTV,” “Park Joy” sequence, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements

Figure 85. Bitrate/quality—usage area “HDTV,” “Riverbed” sequence, High Speed preset, Y-SSIM metric
4.3.1.2 Normal Preset

The Normal preset results for each sequence are presented in Figure 88 through Figure 94. The first six figures show the Y-SSIM results, and last figure show the Y-PSNR results.

The situation is close to High Speed preset, but MainConcept shows good results and is among the leaders for this preset. x264 is the leader by quality at average.

*MSE and WebM Normal presets do not fit the encoding speed requirements.*
Figure 88. Bitrate/quality—usage area “HDTV,” “Big Buck Bunny” sequence, Normal preset, Y-SSIM metric

Figure 89. Bitrate/quality—usage area “HDTV,” “Big Buck Bunny” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements
Figure 90. Bitrate/quality—usage area “HDTV,” “Station” sequence, Normal preset, Y-SSIM metric

Figure 91. Bitrate/quality—usage area “HDTV,” “Station” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements
VIDEO MPEG-4 AVC/H.264 CODECS COMPARISON
CS MSU GRAPHICS & MEDIA LAB VIDEO GROUP

MOSCOW, MAY 2011

Figure 92. Bitrate/quality—usage area “HDTV,” “Stockholm” sequence, Normal preset, Y-SSIM metric

Figure 93. Bitrate/quality—usage area “HDTV,” “Stockholm” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements
Figure 94. Bitrate/quality—usage area “HDTV,” “Stockholm” sequence, Normal preset, Y-PSNR metric

4.3.1.3 High Quality Preset

The High Quality preset results for each sequence are presented in Figure 95 through Figure 101. The leader in this use case is x264. Three encoders are the second: MainConcept, DivX H.264 and Elecard. The DiscretePhoton encoder demonstrates the poorest results as for High Speed and Normal presets.

WebM HighQuality preset does not fit encoding speed requirements.

Figure 95. Bitrate/quality—usage area “HDTV,” “Elephants Dream” sequence, High Quality preset, Y-SSIM metric
Figure 96. Bitrate/quality—usage area “HDTV,” “Elephants Dream” sequence, High Quality preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 97. Bitrate/quality—usage area “HDTV,” “Sunflower” sequence, High Quality preset, Y-SSIM metric.
Figure 98. Bitrate/quality—usage area “HDTV,” “Sunflower” sequence, High Quality preset, Y-SSIM metric. All encoders except Discrete Photon (to improve readability of the graph)

Figure 99. Bitrate/quality—usage area “HDTV,” “Troy” sequence, High Quality preset, Y-SSIM metric
4.3.2 Encoding Speed

4.3.2.1 High Speed Preset

Absolute speed results are presented in Figure 102 through Figure 104. All the encoders, except Microsoft Expression for all sequences and Elecard for Riverbed sequence, have a similar growth rate for encoding time versus increasing bitrate.
Figure 102. Encoding speed—usage area “HDTV,” “Blue Sky” sequence, High Speed preset

Figure 103. Encoding speed—usage area “HDTV,” “Riverbed” sequence, High Speed preset
4.3.2.2 Normal Preset

Absolute speed results are presented in Figure 105 through Figure 108. All the encoders, have similar growth rate for encoding time versus increasing bitrate. Elecard and DiscretePhoton are the fastest.
**Figure 106.** Encoding speed—usage area “HDTV,” “Park Joy” sequence, Normal preset

**Figure 107.** Encoding speed—usage area “HDTV,” “Station” sequence, Normal preset
4.3.2.3 High Quality Preset

Absolute speed results are presented in Figure 109 through Figure 112. All the encoders, except Elecard at Riverbed sequence, have a similar growth rate for encoding time versus increasing bitrate. DiscretePhoton is the fastest.
Figure 110. Encoding speed—usage area “HDTV,” “Riverbed” sequence, High Quality preset

Figure 111. Encoding speed—usage area “HDTV,” “Station” sequence, High Quality preset
4.3.3 Speed/Quality Trade-Off

Detailed descriptions of the speed/quality trade-off graphs can be found in Appendix 7. Figures Explanation. Sometimes, codec results are not present in the particular graph owing to the codec’s extremely poor performance. The codec’s RD curve has no intersection with the reference’s RD curve.

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

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

4.3.3.1 High Speed Preset

Figure 113 through Figure 119 show results for the High Speed preset. For the speed/quality trade-off using fast presets, the leaders are the x264 and Elecard encoders. For Y-PSNR metric only Elecard remains a leader.
Figure 113. Speed/quality trade-off—usage area “HDTV,” “Blue Sky” sequence, High Speed preset, Y-SSIM metric.

Figure 114. Speed/quality trade-off—usage area “HDTV,” “Blue Sky” sequence, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Figure 115. Speed/quality trade-off—usage area “HDTV,” “Elephants Dream” sequence, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 116. Speed/quality trade-off—usage area “HDTV,” “Station” sequence, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Average relative bitrate, Y-SSIM, 11 sequences (Blue Sky, Big Buck Bunny, Elephants Dream, …)

Figure 117. Speed/quality trade-off—usage area “HDTV,” all sequences, High Speed preset, Y-SSIM metric.

Figure 118. Speed/quality trade-off—usage area “HDTV,” all sequences, High Speed preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Figure 119. Speed/quality trade-off—usage area “HDTV,” all sequences, High Speed preset, Y-PSNR metric

4.3.3.2 Normal Preset

Figure 120 through Figure 126 show results for the Normal preset. On average, the MainConcept, DivX H.264, Elecard and x264 codecs demonstrate best speed-quality trade-off. PSNR metric usage excludes MainConcept form leaders list.

Figure 120. Speed/quality trade-off—usage area “HDTV,” “Big Buck Bunny” sequence, Normal preset, Y-SSIM metric
Figure 121. Speed/quality trade-off—usage area “HDTV,” “Big Buck Bunny” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 122. Speed/quality trade-off—usage area “HDTV,” “Riverbed” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Figure 123. Speed/quality trade-off—usage area “HDTV,” “Station” sequence, Normal preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 124. Speed/quality trade-off—usage area “HDTV,” all sequences, Normal preset, Y-SSIM metric
4.3.3.3 High Quality Preset

Figure 127 through Figure 131 show results for the High Quality preset. All encoders except MSE and XviD are Pareto-optimal for this preset. The fastest codec is DiscretePhoton; x264 demonstrates the best quality. Y-PSNR usage removes MainConcept from Pareto-optimal codecs list.
Figure 127. Speed/quality trade-off—usage area “HDTV,” “Blue Sky” sequence, High Quality preset, Y-SSIM metric

Figure 128. Speed/quality trade-off—usage area “HDTV,” “Blue Sky” sequence, High Quality preset, Y-SSIM metric. Encoders that fit encoding speed requirements.
Figure 129. Speed/quality trade-off—usage area “HDTV,” “Rush Hour” sequence, High Quality preset, Y-SSIM metric. Encoders that fit encoding speed requirements.

Figure 130. Speed/quality trade-off—usage area “HDTV,” all sequences, High Quality preset, Y-SSIM metric

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4.3.4 Bitrate Handling

4.3.4.1 High Speed Preset

Most codecs demonstrate problems maintaining steady low bitrate using fast presets. The XviD encoder provides the largest increase in bitrate—by more than five times.
Figure 133. Bitrate handling—usage area “HDTV,” “Park Joy” sequence, High Speed preset

Figure 134. Bitrate handling—usage area “HDTV,” “Station” sequence, High Speed preset
Figure 135. Bitrate handling—usage area “HDTV,” “Troy” sequence, High Speed preset

4.3.4.2 Normal Preset

The codecs' behavior for the Normal preset is similar to that for the Fast preset. The XviD exhibits the worst bitrate handling. Interestingly, the MainConcept and XviD shows very bad bitrate handling mechanism in the case of the “Station” sequence. The leaders demonstrated good bitrate handling.

Figure 136. Bitrate handling—usage area “HDTV,” “Big Buck Bunny” sequence, Normal preset
Figure 137. Bitrate handling—usage area “HDTV,” “Park Joy” sequence, Normal preset

Figure 138. Bitrate handling—usage area “HDTV,” “Station” sequence, Normal preset
4.3.4.3 High Quality Preset

Most codecs, except XviD, maintain bitrate rather well. At some sequences MainConcept and Discrete Photon decrease target bitrate.
Figure 141. Bitrate handling—usage area “HDTV,” “Rush Hour” sequence, High Quality preset

Figure 142. Bitrate handling—usage area “HDTV,” “Stockholm” sequence, High Quality preset
Figure 143. Bitrate handling—usage area “HDTV,” “Tractor” sequence, High Quality preset

4.3.5 Relative Quality Analysis

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

Note that each number in the tables below corresponds to some range of bitrates (see Appendix 7. Figures Explanation for more details). Unfortunately, these ranges can differ significantly because of differences in the quality produced by the encoders under comparison. This situation can lead to some inadequate results when comparing three or more codecs.

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

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>95%</td>
<td>166%</td>
<td>204%</td>
<td>88%</td>
<td>144%</td>
</tr>
<tr>
<td>Elecard</td>
<td>105%</td>
<td>100%</td>
<td>187%</td>
<td>230%</td>
<td>92%</td>
<td>152%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>60%</td>
<td>53%</td>
<td>100%</td>
<td>127%</td>
<td>49%</td>
<td>83%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>49%</td>
<td>43%</td>
<td>79%</td>
<td>100%</td>
<td>41%</td>
<td>67%</td>
</tr>
<tr>
<td>x264</td>
<td>114%</td>
<td>109%</td>
<td>204%</td>
<td>246%</td>
<td>100%</td>
<td>165%</td>
</tr>
<tr>
<td>XviD</td>
<td>70%</td>
<td>66%</td>
<td>121%</td>
<td>148%</td>
<td>61%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>93%</td>
<td>196%</td>
<td>218%</td>
<td>113%</td>
<td>135%</td>
</tr>
<tr>
<td>Elecard</td>
<td>107%</td>
<td>100%</td>
<td>226%</td>
<td>245%</td>
<td>122%</td>
<td>145%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>51%</td>
<td>44%</td>
<td>100%</td>
<td>120%</td>
<td>51%</td>
<td>74%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>46%</td>
<td>41%</td>
<td>84%</td>
<td>100%</td>
<td>46%</td>
<td>65%</td>
</tr>
<tr>
<td>x264</td>
<td>88%</td>
<td>82%</td>
<td>195%</td>
<td>215%</td>
<td>100%</td>
<td>122%</td>
</tr>
<tr>
<td>XviD</td>
<td>74%</td>
<td>69%</td>
<td>135%</td>
<td>155%</td>
<td>82%</td>
<td>100%</td>
</tr>
</tbody>
</table>

http://www.compression.ru/video/
Table 13. Average bitrate ratio for a fixed quality—usage area “HDTV”.
Normal preset, Y-SSIM metric.

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>99%</td>
<td>94%</td>
<td>187%</td>
<td>75%</td>
<td>133%</td>
</tr>
<tr>
<td>Elecard</td>
<td>101%</td>
<td>100%</td>
<td>93%</td>
<td>179%</td>
<td>76%</td>
<td>132%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>106%</td>
<td>107%</td>
<td>100%</td>
<td>208%</td>
<td>81%</td>
<td>144%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>53%</td>
<td>56%</td>
<td>48%</td>
<td>100%</td>
<td>43%</td>
<td>73%</td>
</tr>
<tr>
<td>x264</td>
<td>134%</td>
<td>131%</td>
<td>124%</td>
<td>232%</td>
<td>100%</td>
<td>171%</td>
</tr>
<tr>
<td>XviD</td>
<td>75%</td>
<td>76%</td>
<td>69%</td>
<td>136%</td>
<td>58%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>104%</td>
<td>139%</td>
<td>187%</td>
<td>98%</td>
<td>131%</td>
</tr>
<tr>
<td>Elecard</td>
<td>97%</td>
<td>100%</td>
<td>129%</td>
<td>178%</td>
<td>94%</td>
<td>125%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>72%</td>
<td>78%</td>
<td>100%</td>
<td>150%</td>
<td>70%</td>
<td>112%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>53%</td>
<td>56%</td>
<td>67%</td>
<td>100%</td>
<td>51%</td>
<td>73%</td>
</tr>
<tr>
<td>x264</td>
<td>103%</td>
<td>106%</td>
<td>144%</td>
<td>195%</td>
<td>100%</td>
<td>135%</td>
</tr>
<tr>
<td>XviD</td>
<td>76%</td>
<td>80%</td>
<td>89%</td>
<td>138%</td>
<td>74%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>99%</td>
<td>95%</td>
<td>197%</td>
<td>64%</td>
<td>137%</td>
</tr>
<tr>
<td>Elecard</td>
<td>101%</td>
<td>100%</td>
<td>93%</td>
<td>185%</td>
<td>66%</td>
<td>137%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>106%</td>
<td>108%</td>
<td>100%</td>
<td>220%</td>
<td>68%</td>
<td>149%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>51%</td>
<td>54%</td>
<td>45%</td>
<td>100%</td>
<td>34%</td>
<td>75%</td>
</tr>
<tr>
<td>x264</td>
<td>157%</td>
<td>151%</td>
<td>146%</td>
<td>294%</td>
<td>100%</td>
<td>205%</td>
</tr>
<tr>
<td>XviD</td>
<td>73%</td>
<td>73%</td>
<td>67%</td>
<td>133%</td>
<td>49%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>DivX H.264</th>
<th>Elecard</th>
<th>MainConcept</th>
<th>Discrete Photon</th>
<th>x264</th>
<th>XviD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>100%</td>
<td>104%</td>
<td>139%</td>
<td>198%</td>
<td>88%</td>
<td>133%</td>
</tr>
<tr>
<td>Elecard</td>
<td>96%</td>
<td>100%</td>
<td>128%</td>
<td>188%</td>
<td>84%</td>
<td>127%</td>
</tr>
<tr>
<td>MainConcept</td>
<td>72%</td>
<td>78%</td>
<td>100%</td>
<td>159%</td>
<td>55%</td>
<td>100%</td>
</tr>
<tr>
<td>Discrete Photon</td>
<td>51%</td>
<td>53%</td>
<td>63%</td>
<td>100%</td>
<td>41%</td>
<td>70%</td>
</tr>
<tr>
<td>x264</td>
<td>114%</td>
<td>120%</td>
<td>180%</td>
<td>242%</td>
<td>100%</td>
<td>154%</td>
</tr>
<tr>
<td>XviD</td>
<td>75%</td>
<td>79%</td>
<td>100%</td>
<td>142%</td>
<td>65%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Figure 144 through Figure 149 depict the data in the tables above. Each line in these figures corresponds to one codec. Values along the vertical axis are average relative bitrates as compared with the codecs along the horizontal axis. A lower bitrate indicates better relative results.
Average bitrate ratio for the same quality. Usage area “HDTV”.
“Normal” preset, Y-SSIM

Figure 146. Average bitrate ratio for a fixed quality—usage area “HDTV”.
Normal preset, Y-SSIM metric.

Average bitrate ratio for the same quality. Usage area “HDTV”.
“Normal” preset, Y-PSNR

Figure 147. Average bitrate ratio for a fixed quality—usage area “HDTV”.
Normal preset, Y-PSNR metric.
Average bitrate ratio for the same quality. Usage area “HDTV”. "High Quality" preset, Y-SSIM

Figure 148. Average bitrate ratio for a fixed quality—usage area “HDTV”. High Quality preset, Y-SSIM metric.

Average bitrate ratio for the same quality. Usage area “HDTV”. "High Quality" preset, Y-PSNR

Figure 149. Average bitrate ratio for a fixed quality—usage area “HDTV”. High Quality preset, Y-PSNR metric.
4.4 Conclusions

4.4.1 Video Conference

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

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

But the x264 encoder demonstrates the lowest quality of local bitrate handling (see 4.1.5 Local Bitrate Handling), so analyzed preset could be hardly used for video conference encoding.

![Chart: Average relative bitrate for the same quality for usage area "Video Conference"]

Figure 150. Average bitrate ratio for a fixed quality—usage area “Video Conference,” Y-SSIM.

4.4.2 Movies

The leading encoder in this usage area is x264, followed by MainConcept, DivX H.264 and Elecard.

4.4.2.1 High Speed Preset

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

1. x264
2. MainConcept
3. Elecard

4.4.2.2 Normal Preset

The results for the Normal preset differ from those for the High Speed presets in second and third places. The x264 encoder demonstrates better quality on average, and MainConcept and Divx H.264 show slightly lower quality. The Elecard encoder holds third place. The top four codecs for this preset are the following:
4.4.2.3 High Quality Preset
The results for this preset are similar to those of the Normal preset. The leader is the x264, followed by three codecs. The top four codecs for this preset are the following:

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

Average relative bitrate for the same quality for usage area "Movie"

![Graph showing average relative bitrate for different codecs]

Figure 151. Average bitrate ratio for a fixed quality—usage area “Movies,” all presets, Y-SSIM.

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

4.4.3.1 High Speed Preset
The x264 encoder demonstrates better quality on average, and Elecard and DivX H.264 show slightly lower quality. The top three codecs for this preset are the following:

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

4.4.3.2 Normal Preset
The results for the Normal preset differ from those of the High Speed presets. x264 shows best result, MainConcept shows better results than for High Speed preset; DivX H.264 and Elecard share third place (their quality results are very similar). The top four codecs for this preset are the following:

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

4.4.3.3 High Quality Preset

The results for the High Quality preset are very close to Normal preset results: x264 held first place, MainConcept is in second place, and two codecs (DivX H.264 and Elecard) share third place (their quality results are very close). The top four codecs for this preset are the following:

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

Figure 152. Average bitrate ratio for a fixed quality—usage area “HDTV,” all presets, Y-SSIM.
4.4.4 Overall Conclusions

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

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

1. x264
2. DivX H.264
3. Elecard
4. MainConcept
5. XviD
6. DiscretePhoton

WebM and Microsoft Expression encoders could not be placed in this list because of their longer encoding time compared with other encoders.

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

The difference between the Elecard and DivX H.264 encoders is almost nothing, and between these encoders and MainConcept is not overly significant, so these encoders tied for second and third in this comparison.

This rank is based only on the encoders’ quality results (see Figure 153). Encoding speed is not considered here.

4.4.5 Codec Conclusions

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

• **Microsoft Expression Encoder**—encoder with good encoding quality but due to the fact of long initial loading time, the encoding time for Microsoft Expression Encoder is significantly higher than for other encoders.

• **MainConcept**—good balanced encoder; has many encoding settings that can be adjusted. The results for Movie use-case was second, so this codec has a good potential to be one of comparison leaders

• **x264**—one of the best codecs by encoding quality; has very user-friendly predefined presets, as well as many adjustable encoding settings.

• **XviD**—an MPEG-4 ASP codec; its quality could be very close to or even higher than that of some commercial H.264 standard implementations, especially for encoding “Movie” sequences, but not for “HDTV” sequences.

• **WebM**—good new non H.264 encoder, it shows good quality but due to the low encoding speed it is not presented in encoders list by quality

4.4.6 Comments from Developers

4.4.6.1 DiscretePhoton

*DiscretePhoton encoder is basically targeted to real-time / low-latency encoding scenarios.*

*It's quite constrained 1-pass CBR rate-control and baseline profile features might have hurt quality measurements.*

Anyway, MSU's test is a very precious experience for us. Thank you.

4.4.6.2 Microsoft Expression Encoder

*Microsoft Expression Encoder 4, unlike its previous versions, no longer uses a Microsoft-developed H.264 codec. It uses the MainConcept H.264/AVC Encoder SDK for both its H.264 and AAC encoding. The latest version of Expression Encoder 4 (SP1) also supports CUDA-accelerated H.264 encoding, also through the MainConcept CUDA H.264/AVC Encoder SDK. Consequently, any differences in results presented in this paper between the MainConcept H.264 Encoder and Microsoft Expression Encoder are actually due to the differences in encoding presets (as Microsoft and MainConcept were each asked to supply their own presets), rather than in the underlying compression engine. When configured the same, both encoders should produce nearly identical results.*

The long startup times noted in this paper are due to the fact that Microsoft Expression Encoder, both its frontend application and its SDK, are built on the .NET framework. The advantage of a managed code (e.g. C#) SDK, as opposed to a native code (e.g. C++) SDK, is that it allows easy development and quick deployment of applications. For example, Expression Encoder 4 comes with a number of sample C# and VB.NET applications which demonstrate how to automate various encoding scenarios - and most of them can be modified, compiled and deployed in a matter of minutes. A known
The downside of managed code applications, however, is their longer startup time. The command-line Expression Encoder app provided to MSU for testing took an average of 5-6 seconds to initialize and start encoding. Due to the short length of most MSU test sources (many were only 10 seconds long), the long startup times added a significant overhead to these short encoding times. It should be noted that in a typical encoding scenario where the source content is several minutes or hours long, a startup time of 5-6 seconds would actually represent a negligible overhead to the total encoding time.

### 4.4.6.3 WebM vp8 Codec

In a typical videoconferencing setup, video is captured from a device (typically a camera) with video frames being captured in fixed time intervals. For example, capturing a video at 10 frame/second means that video frames are coming from capturing device at time sequences of 0ms, 100ms, 200ms, 300ms, and so on.

To maintain audio video sync (AV-sync) in video conference, latency has to be kept very low at all time in the encoding process. Encoding speed is important in keeping the latency low, but high encoding speed only is not enough. For example:

1. No frame reordering in encoder is allowed: An H.264 encoder using 3 B-frames will require encoder/decoder reorder input frames and therefore cause at least a 4 frame delay no matter how fast the encoding speed is.

2. No forced delay in encoder is allowed: While frame-level parallel processing is helpful for offline transcoding, it is useless for video conferencing due to the low latency requirement. For example, even if an encoder can speed up encoding by 8X on an 8 core machine, video conferencing applications can not wait for 8 input frames of latency to make use of the parallel processing.

Most of the H.264 encoder settings used in the videoconferencing test use B frames, and some even include frame-level parallel encoding. Those settings are invalid for a videoconferencing usage case.

In contrast, VP8 does not have B frames, therefore no frame reordering is ever required in encoding. Also, a VP8 encoder can use parallel processing at the macroblock row level, which improves encoding speed and keeps latency low at the same time.
5 Appendix 1. Hardware and Software Encoders Comparison

5.1 Brief Description

In this work, we analyzed not only software video, but also video codecs that used hardware acceleration. There are two main directions for this type of acceleration: using discrete GPU (basically with help of CUDA) and using SandyBridge Platform.

There were two different use-cases for this comparison:

- HDTV encoding at low bitrates 1-10Mbps
- HDTV encoding at high bitrates 6-18Mbps

In this part of the comparison we have analyzed next encoders:

1. Intel Sandy Bridge Transcoder (hardware)
2. MainConcept CUDA based encoder (hardware)
3. x264
4. Elecard
5. DivX H.264
6. XviD (only for low bitrates)

5.1.1 Hardware Description

During tests we have used next hardware:

- CPU: Intel Core i7-2600 @ 3.4GHz, 4 Cores 8 Threads
- GPU:
  - Geforce GTX 580 (for MainConcept CUDA based encoder)
  - Intel GT1 (for Intel Sandy Bridge Transcoder)
- Memory: 8 Gb RAM
- OS: Windows7 Ultimate 64-bit edition, Service Pack 1

5.2 Results for Low Bitrates Encoding

The following graphs show results for this comparison. RD-curves analysis is not very interesting because of different encoding speed and because of it speed/quality graphs have more information.
5.2.1 RD-curves and Speed/Quality Graphs

Figure 63. Bitrate/quality, “Rush Hour” sequence, Y-SSIM metric

Figure 96. Speed/quality trade-off, “Blue Sky” sequence, Y-SSIM metric
Figure 154. Speed/quality trade-off, “Big Buck Bunny” sequence, Y-SSIM metric

Figure 155. Speed/quality trade-off, “Elephants Dream” sequence, Y-SSIM metric
Figure 156. Speed/quality trade-off, “Park Joy” sequence, Y-SSIM metric

Figure 157. Speed/quality trade-off, “Riverbed” sequence, Y-SSIM metric
Figure 158. Speed/quality trade-off, “Rush Hour” sequence, Y-SSIM metric

Figure 159. Speed/quality trade-off, “Station” sequence, Y-SSIM metric
Figure 160. Speed/quality trade-off, “Stockholm” sequence, Y-SSIM metric

Figure 161. Speed/quality trade-off, “Sunflower” sequence, Y-SSIM metric
Figure 162. Speed/quality trade-off, “Tractor” sequence, Y-SSIM metric

Figure 163. Speed/quality trade-off, “Troy” sequence, Y-SSIM metric
Figure 164. Speed/quality trade-off, all sequences, Y-SSIM metric

Figure 165. Speed/quality trade-off, all sequences, Y-PSNR metric
5.2.2 Encoding Speed

Figure 166. Encoding speed, “Blue Sky” sequence

Figure 167. Encoding speed, “Big Buck Bunny” sequence
Figure 168. Encoding speed, “Elephants Dream” sequence

Figure 169. Encoding speed, “Park Joy” sequence
Figure 170. Encoding speed, “Riverbed” sequence

Figure 171. Encoding speed, “Rush Hour” sequence
Figure 172. Encoding speed, “Station” sequence

Figure 173. Encoding speed, “Stockholm” sequence
Figure 174. Encoding speed, “Sunflower” sequence

Figure 175. Encoding speed, “Tractor” sequence
5.3 Results for High Bitrates Encoding

The following graphs show results for this comparison. Some presets are missing on some speed/quality graphs due to its low encoding quality and low RD-curve.

5.3.1 RD-curves and Speed/Quality Graphs

Figure 177. Bitrate/quality, “Blue Sky” sequence, Y-SSIM metric
Figure 178. Bitrate/quality, “Big Buck Bunny” sequence, Y-SSIM metric

Figure 179. Bitrate/quality, “Elephants Dream” sequence, Y-SSIM metric
Figure 180. Bitrate/quality, "Park Joy" sequence, Y-SSIM metric

Figure 181. Bitrate/quality, "Riverbed" sequence, Y-SSIM metric
Figure 182. Bitrate/quality, “Rush Hour” sequence, Y-SSIM metric

Figure 183. Bitrate/quality, “Stattion” sequence, Y-SSIM metric
Figure 184. Bitrate/quality, “Stockholm” sequence, Y-SSIM metric

Figure 185. Bitrate/quality, “Sunflower” sequence, Y-SSIM metric
Figure 186. Bitrate/quality, “Tractor” sequence, Y-SSIM metric

Figure 187. Bitrate/quality, “Troy” sequence, Y-SSIM metric
Figure 96. Speed/quality trade-off, “Blue Sky” sequence, Y-SSIM metric

Figure 188. Speed/quality trade-off, “Big Buck Bunny” sequence, Y-SSIM metric
Average relative bitrate, Y-SSIM, 1 sequence (Elephants Dream)

Average relative bitrate

Relative Encoding Time

DivX H.264, High-Speed preset
Elecard, High-Speed preset
Intel SandyBridge Transcoder, TU_1
Intel SandyBridge Transcoder, TU_4
Intel SandyBridge Transcoder, TU_7
MainConcept CUDA Encoder, High-Speed preset
MainConcept CUDA Encoder, High-Quality preset
MainConcept CUDA Encoder, Normal preset
x264, super-very preset #2
x264, superfast 1-pass preset
x264, ultra-super preset #2
x264, ultra-super preset #4

Figure 189. Speed/quality trade-off, “Elephants Dream” sequence, Y-SSIM metric

Average relative bitrate, Y-SSIM, 1 sequence (Park Joy)

Average relative bitrate

Relative Encoding Time

DivX H.264, High-Speed preset
Elecard, High-Speed preset
Intel SandyBridge Transcoder, TU_1
Intel SandyBridge Transcoder, TU_4
Intel SandyBridge Transcoder, TU_7
MainConcept CUDA Encoder, High-Speed preset
MainConcept CUDA Encoder, High-Quality preset
MainConcept CUDA Encoder, Normal preset
x264, super-very preset #2
x264, superfast 1-pass preset
x264, ultra-super preset #2
x264, ultra-super preset #4

Figure 190. Speed/quality trade-off, “Park Joy” sequence, Y-SSIM metric
Figure 191. Speed/quality trade-off, “Riverbed” sequence, Y-SSIM metric

Figure 192. Speed/quality trade-off, “Rush Hour” sequence, Y-SSIM metric
VIDEO MPEG-4 AVC/H.264 CODECS COMPARISON
CS MSU GRAPHICS & MEDIA LAB VIDEO GROUP

MOSCOW, MAY 2011

http://www.compression.ru/video/
Figure 195. Speed/quality trade-off, “Sunflower” sequence, Y-SSIM metric

Figure 196. Speed/quality trade-off, “Tractor” sequence, Y-SSIM metric
Figure 197. Speed/quality trade-off, “Troy” sequence, Y-SSIM metric

Figure 198. Speed/quality trade-off, all sequences, Y-SSIM metric
5.3.2 Encoding Speed

Figure 199. Speed/quality trade-off, all sequences, Y-PSNR metric

Figure 200. Encoding speed, “Blue Sky” sequence
Figure 201. Encoding speed, “Big Buck Bunny” sequence

Figure 202. Encoding speed, “Elephants Dream” sequence
Figure 203. Encoding speed, “Park Joy” sequence

Figure 204. Encoding speed, “Riverbed” sequence
Figure 205. Encoding speed, “Rush Hour” sequence

Figure 206. Encoding speed, “Station” sequence
Figure 207. Encoding speed, “Stockholm” sequence

Figure 208. Encoding speed, “Sunflower” sequence
5.4 Conclusion

Analyzing the graphs for High bitrate and Low bitrate HDTV encoding we could make a conclusion:

1. Software x264 and Intel SandyBridge transcoder are very close to each other
   a. For High Bitrates: software x264 and Intel SandyBridge transcoder are very close to each other, but Intel shows slightly better results than x264 in speed/quality trade-off.
   b. For low Bitrates: at present time software x264 could be best encoder even comparing to hardware-based encoder solution

2. Among hardware solutions Intel SandyBridge transcoder is best.

3. Most software encoders are slower and produce lower quality than Intel SandyBridge transcoder and x264 at very high encoding speed.
5.5 Presets

<table>
<thead>
<tr>
<th>Codec</th>
<th>Preset Name</th>
<th>Preset</th>
</tr>
</thead>
<tbody>
<tr>
<td>x264</td>
<td>Ultra-super #2</td>
<td>--tune ssim --keyint 500 --preset superfast --weightp 0 --partitions none --no-cabac --no-8x8dct --bframes 0</td>
</tr>
<tr>
<td></td>
<td>Ultra-super #4</td>
<td>--tune ssim --keyint 500 --preset superfast --weightp 0 --partitions none --no-cabac</td>
</tr>
<tr>
<td></td>
<td>Superfast</td>
<td>--tune ssim --keyint 500 --preset superfast</td>
</tr>
<tr>
<td></td>
<td>Super-very #2</td>
<td>--tune ssim --keyint 500 --preset veryfast --partitions i8x8,i4x4</td>
</tr>
<tr>
<td></td>
<td>veryfast</td>
<td>--tune ssim --keyint 500 --preset veryfast</td>
</tr>
<tr>
<td>Intel Sandy Bridge Transcoder</td>
<td>Use-case 1</td>
<td>-h264 -hw -d3d -async 10 -s 0 -l 1-u 1 -i:yv12</td>
</tr>
<tr>
<td></td>
<td>Use-case 2</td>
<td>-h264 -hw -d3d -async 10 -s 0 -l 1-u 4 -i:yv12</td>
</tr>
<tr>
<td></td>
<td>Use-case 3</td>
<td>-h264 -hw -d3d -async 10 -s 0 -l 1-u 7 -i:yv12</td>
</tr>
</tbody>
</table>

6 Appendix 2. x264 and WebM Comparison Over Time

6.1 x264 Comparison Over Time

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

Figure 211 shows the RD curve for the “Battle” sequence using x264 encoders from different years. The best encoder is this year’s x264; the worst is the 2005 version. Using SSIM, the codecs can be ranked as follows:

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

These results are shown in Figure 212. This figure indicates that the overall progress is very good, and that the x264 encoder has increased in speed and quality over recent years. But the old x264 does not use multithreading, so encoding speed varies considerably.
Figure 211. Bitrate/quality for different x264 encoder versions—usage area “Movies,” “Battle” sequence, High Quality preset, Y-SSIM metric

Figure 212. Progress of the x264 encoder over several years—Y-SSIM metric

6.2 WebM Comparison Over Time
WebM encoder participates comparison only for two years so next graphs show progress for WebM encoder for 2010 and 2011 years.
**Figure 213.** Speed/quality trade-off, “Battle” sequence, Y-SSIM metric

**Figure 214.** Speed/quality trade-off, “Elephant’s Dream” sequence, Y-SSIM metric
Figure 215. Speed/quality trade-off, “Riverbed” sequence, Y-SSIM metric

Figure 216. Speed/quality trade-off, “Station” sequence, Y-SSIM metric
Figure 217. Speed/quality trade-off, “Sunflower” sequence, Y-SSIM metric

Figure 218. Speed/quality trade-off, 5 sequences, Y-SSIM metric
7 Appendix 3. Another Quality Metrics

To analyze quality results Y-SSIM metrics was used as main metric, but this appendix contains results for other quality metrics (MS-SSIM and 3-SSIM).

MS-SSIM and 3-SSIM descriptions could be found here:
http://compression.ru/video/quality_measure/info_en.html#msssim
http://compression.ru/video/quality_measure/info_en.html#3ssim

7.1 Movies

![Graph showing speed/quality trade-off for Movies, High-Speed preset, all sequences, Y-SSIM metric]

Figure 219. Speed/quality trade-off, Movies, High-Speed preset, all sequences, Y-SSIM metric

![Graph showing speed/quality trade-off for Movies, High-Speed preset, all sequences, 3SSIM metric]

Figure 220. Speed/quality trade-off, Movies, High-Speed preset, all sequences, 3SSIM metric
Figure 221. Speed/quality trade-off, Movies, High-Speed preset, all sequences, MS-SSIM metric

Figure 222. Speed/quality trade-off, Movies, Normal preset, all sequences, Y-SSIM metric
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MOSCOW, MAY 2011

Figure 223. Speed/quality trade-off, Movies, Normal preset, all sequences, 3SSIM metric

Figure 224. Speed/quality trade-off, Movies, Normal preset, all sequences, MS-SSIM metric
Figure 225. Speed/quality trade-off, Movies, High Quality preset, all sequences, Y-SSIM metric

Figure 226. Speed/quality trade-off, Movies, High Quality preset, all sequences, 3SSIM metric
Fig. 227. Speed/quality trade-off, Movies, High Quality preset, all sequences, MS-SSIM metric

7.2 HDTV

Fig. 228. Speed/quality trade-off, HDTV, High-Speed preset, all sequences, Y-SSIM metric
Figure 229. Speed/quality trade-off, HDTV, High-Speed preset, all sequences, 3SSIM metric

Figure 230. Speed/quality trade-off, HDTV, High-Speed preset, all sequences, MS-SSIM metric
Figure 231. Speed/quality trade-off, HDTV, Normal preset, all sequences, Y-SSIM metric

Figure 232. Speed/quality trade-off, HDTV, Normal preset, all sequences, 3SSIM metric

http://www.compression.ru/video/
Figure 233. Speed/quality trade-off, HDTV, Normal preset, all sequences, MS-SSIM metric

Figure 234. Speed/quality trade-off, HDTV, High Quality preset, all sequences, Y-SSIM metric
7.3 Conclusion on Different Metric Usage

Analyzing graphs with SSIM, 3SSIM and MS-SSIM one could make a conclusion – the chosen metric has no strong influence on results analysis, it changes positions of encoders slightly sometimes only.
8 Appendix 5. Test Set of Video Sequences

8.1 Videoconference Sequences

8.1.1 “CIF” (“Deadline”)

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Conference CIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>352x288</td>
</tr>
<tr>
<td>Number of frames</td>
<td>1374</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>30</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

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

Figure 237. Deadline sequence, frame 1
Figure 238. Deadline sequence, frame 190
8.1.2 “4CIF”

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Conference CIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>640x480</td>
</tr>
<tr>
<td>Number of frames</td>
<td>3600</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>30</td>
</tr>
<tr>
<td>Source</td>
<td>HuffYUV, 57Mbps, progressive</td>
</tr>
</tbody>
</table>

Video with some movement and facial expressions in foreground and some very bright movement at background (man in red shirt at background).
### 8.1.3 “720p”

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Sequence title</td>
<td>Conference 720p</td>
</tr>
<tr>
<td>Resolution</td>
<td>1280x720</td>
</tr>
<tr>
<td>Number of frames</td>
<td>1500</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>30</td>
</tr>
<tr>
<td>Source</td>
<td>HuffYUV, 160Mbps, progressive</td>
</tr>
</tbody>
</table>

Figure 240. 720p sequence, frame 750

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

8.2.1 “City”

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>704x576</td>
</tr>
<tr>
<td>Number of frames</td>
<td>600</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>60</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

This sequence is a panorama of New York city. A lot of small details such as building windows. Pretty similar colors all over the frames of the sequence. Camera shakes a little through the sequence.
This sequence is a fragment from the *Indiana Jones* movie. Compression of this sequence is difficult for two main reasons: the presence of low-contrast scenes and the high level of motion in different scenes. Also, several scenes have very different types of motion, ranging from almost static scenes with talking people to scenes with strong motion (for example, the scene where stones fall).
### 8.2.3 “State Enemy”

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>State Enemy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>720x304</td>
</tr>
<tr>
<td>Number of frames</td>
<td>6500</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>24</td>
</tr>
<tr>
<td>Source</td>
<td>MPEG-2 (DVD), FlaskMPEG deinterlace</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Crew</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>704x576</td>
</tr>
<tr>
<td>Number of frames</td>
<td>600</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>60</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Harbour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>704x576</td>
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<tr>
<td>Number of frames</td>
<td>600</td>
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<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>60</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Ice Skating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>704x576</td>
</tr>
<tr>
<td>Number of frames</td>
<td>600</td>
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<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>60</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

Figure 246. Ice Skating sequence, frame 425

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Soccer</th>
</tr>
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<tbody>
<tr>
<td>Resolution</td>
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</tr>
<tr>
<td>Number of frames</td>
<td>600</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>60</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

Figure 247. Soccer sequence, frame 550

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Race Horses</th>
</tr>
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<tbody>
<tr>
<td>Resolution</td>
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</tr>
<tr>
<td>Number of frames</td>
<td>300</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>30</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Party Scene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>832x480</td>
</tr>
<tr>
<td>Number of frames</td>
<td>500</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>30</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Ice Age</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Number of frames</td>
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<tr>
<td>Color space</td>
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<td>Frames per second</td>
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<tr>
<td>Source</td>
<td>MPEG-2 (DVD9), 5.7Mbps</td>
</tr>
</tbody>
</table>

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

8.3.1 “Park Joy”

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Park Joy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1280x720</td>
</tr>
<tr>
<td>Number of frames</td>
<td>500</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>50</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Riverbed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920x1080</td>
</tr>
<tr>
<td>Number of frames</td>
<td>250</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>25</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

Figure 252. Riverbed sequence, frame 125

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Troy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920x1072</td>
</tr>
<tr>
<td>Number of frames</td>
<td>300</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>24</td>
</tr>
<tr>
<td>Source</td>
<td>MPEG-2</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Stockholm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1280x720</td>
</tr>
<tr>
<td>Number of frames</td>
<td>604</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>50</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Rush Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920x1080</td>
</tr>
<tr>
<td>Number of frames</td>
<td>250</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>25</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

Rush-hour in Munich city. Many cars moving slowly, high depth of focus. Fixed camera.
8.3.6 “Blue Sky”

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Blue Sky</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920x1080</td>
</tr>
<tr>
<td>Number of frames</td>
<td>217</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>25</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

Figure 256. Blue Sky sequence, frame 100

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920x1080</td>
</tr>
<tr>
<td>Number of frames</td>
<td>313</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>25</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

![Station sequence, frame 155](image)

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Sunflower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920x1080</td>
</tr>
<tr>
<td>Number of frames</td>
<td>500</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>25</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Tractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920x1080</td>
</tr>
<tr>
<td>Number of frames</td>
<td>690</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
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<tr>
<td>Frames per second</td>
<td>25</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

Figure 259. Tracktor sequence, frame 470

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

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Big Buck Bunny</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920x1080</td>
</tr>
<tr>
<td>Number of frames</td>
<td>600</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>24</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

Figure 260. Big Buck Bunny sequence, frame 110

Scene from a cartoon movie Big Buck Bunny. Contains a lot of movement, very bright colors, different type of motion. The web-site for this movie is [http://www.bigbuckbunny.org/](http://www.bigbuckbunny.org/)
8.3.11 “Elephants Dream”

<table>
<thead>
<tr>
<th>Sequence title</th>
<th>Elephants Dream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920x1080</td>
</tr>
<tr>
<td>Number of frames</td>
<td>600</td>
</tr>
<tr>
<td>Color space</td>
<td>YV12</td>
</tr>
<tr>
<td>Frames per second</td>
<td>24</td>
</tr>
<tr>
<td>Source</td>
<td>Uncompressed, progressive</td>
</tr>
</tbody>
</table>

Figure 261. Elephants Dream sequence, frame 460

Part of a cartoon movie Elephants Dream. Contains a lot of contrast thin lines and motion all over the scenes. Combination of dark colors with very bright small details makes this sequence pretty hard for encoding. The web-site for this movie is [http://www.elephantsdream.org/](http://www.elephantsdream.org/)
9 Appendix 6. Tested Codecs and Presets

9.1 Codecs

9.1.1 DivX AVC/H.264 Video Encoder

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

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

DivX AVC/H.264 Video Encoder (version 1.1.1.9) Copyright © 2010 DivX, Inc.
Usage: Options:

General:

- help This help information
- h Do not display progress information
- version Display version information
- v <0|1> Verbos level

Input/Output:

- i <input file> AVI file or AVI's path script (autofs)
- o <output file> Output format in one of these formats: VO12 IV412 IV012 UVIV VUVU UV412 BPG84 BPG32 or raw yuv (but – for stdin) requires -y
- y <width>x<height> Raw AVC bit stream
- fps <int>/<num> Override input frame rate (e.g. 30 or 30/1.001)
- r <int> Interlaced input, top field first
- b <int> Interlaced input, bottom field first
- sar <width>x<height> Sample Aspect Ratio (1:1)
- start <int> First frame to encode
- frames <int> Maximum number of frames to encode

Rate control:

- br <int> Target bitrate in kbps
- qf <int> Target Quality Factor

Multipass:

- mpass <1|2> Specify multipass mode
- sf <stat file> Specify multipass statistics file name (divx264_stat.dat)

Encoder:

- algo <0|1|2> Algorithm quality optimized for: 0 = Fast encoding, 1 = Balanced performance/quality (default), 2 = Highest quality
- i <int> Group length (seconds) [4]
- fenode <int> Interlaced coding mode
- m <int> Mode
- ref <int> Maximum number of reference frames [4]
- pyramied Enables pyramid encoding (implies -bref)
- bref Enables B as reference
- mb <0|1> Maximum consecutive B-frames [2]
- threads <int> Maximum number of threads [auto]

The following frame rates for DivX Plus are permitted:

- 60 Hz ECA696/1601 Hz
- 50 Hz
- 30 Hz
- 25 Hz
- 24 Hz
- 30000/1001 Hz

This pre-release version will expire on Wed Aug 29 01:30:00 2012
Please check http://labs.divx.com for new versions.
9.1.2 Elecard AVC Video Encoder 8-bit edition,
- Console encoding program version 2.1.026895.110204
- Codec and presets were provided by Elecard Ltd Company specifically for this test

```
Elecard AVC Video Encoder 8-bit edition, vpr. 2.1.026895.110204
usage: eutenc.exe config.cfg [parameters list]
```

Figure 263. Elecard AVC Video Encoder 8-bit edition

9.1.3 MainConcept AVC/H.264 Video Encoder Console Application
- Console encoding version 1.5.0
- Codec and presets were provided by MainConcept AG Company specifically for this test

```
* A.G.E.N.T v1.5.0
* *
* Advanced General Encoding Tool: *
* Console application for testing any available codec.
* *
Usage: agent <config> [company]
   - <config> the configuration file
   - <company> the company prefix to search for (default: 'mc')
   - ? or help display detailed help texts
   There are different sections of interest:
     'agent ?',
     'agent ? input',
     'agent ? fourcc',
     'agent ? codec',
     'agent ? profile',
     'agent ? special'
```

Figure 264. MainConcept H.264/AVC encoder

9.1.4 Microsoft Expression Encoder 4
- CLI version of Microsoft Expression Encoder 4 was provided by Microsoft specifically for this test
- Codec and presets were provided by Microsoft specifically for this test

Remarks: Owing to a long initial loading time, the encoding time for Microsoft Expression Encoder is significantly higher than for other encoders.

```
Microsoft Expression Encoder Command-Line Utility v1.0.1.0
Copyright (c) 2011 Microsoft Corporation
Encoder license installed: Pro
```

Figure 265. Microsoft Expression encoder

http://www.compression.ru/video/
9.1.5 x264

- Console encoding program version core:114 r1900 60ef1f8 was provided by developers specifically for this test
- Codec and presets were provided by developers specifically for this test

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

Figure 266. x264 encoder

9.1.6 XviD raw mpeg4 bitstream encoder

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

- Console encoding program version core:114 r1900 60ef1f8 was provided by developers specifically for this test
- Codec and presets were provided by developers specifically for this test

![Figure 268. Discrete Photon encoder](image)

9.1.8 WebM vp8 Codec

- Encoder, decoder and presets was provided by WebM specifically for this test
- Encoder version: v0.9.2-522-gddd260e

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

![Figure 269. WebM vp8 encoder](image)
## 9.2 Presets

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

<table>
<thead>
<tr>
<th>Codec</th>
<th>Preset Name</th>
<th>Preset</th>
</tr>
</thead>
<tbody>
<tr>
<td>DivX H.264</td>
<td>Movie “High Speed”</td>
<td>-aqo 0 -ref 1 -bf 0</td>
</tr>
<tr>
<td></td>
<td>Movie “Normal”</td>
<td>Default presets</td>
</tr>
<tr>
<td></td>
<td>Movie “High Quality”</td>
<td>1-st pass: -npass 1 2-nd pass: -npass 2</td>
</tr>
<tr>
<td></td>
<td>HDTV “High Speed”</td>
<td>-aqo 0 -ref 1 -bf 0</td>
</tr>
<tr>
<td></td>
<td>HDTV “Normal”</td>
<td>-aqo 0</td>
</tr>
<tr>
<td></td>
<td>HDTV “High Quality”</td>
<td>-bf 3 -pyramid -bref</td>
</tr>
</tbody>
</table>

### Elecard

**Movie “Normal”**

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMax</td>
<td>3</td>
<td>max number of b-frames</td>
</tr>
<tr>
<td>BMode</td>
<td>2</td>
<td>2 - hierarchical structure</td>
</tr>
<tr>
<td>ModeDecision</td>
<td>1</td>
<td>1 - SATD</td>
</tr>
<tr>
<td>WPredMode</td>
<td>1</td>
<td>1 - explicit mode (for both P- and B-frames)</td>
</tr>
<tr>
<td>NumRefFrames</td>
<td>3</td>
<td>actual size of DPB</td>
</tr>
<tr>
<td>AQMode</td>
<td>0</td>
<td>0 - do not use</td>
</tr>
<tr>
<td>Lookahead</td>
<td>1</td>
<td>lookahead length in seconds</td>
</tr>
<tr>
<td>OffsetCb</td>
<td>1</td>
<td>[-10,+10] i prefer 0 or -1</td>
</tr>
<tr>
<td>OffsetCr</td>
<td>1</td>
<td>[-10,+10] i prefer 0 or -1</td>
</tr>
<tr>
<td>AQMode</td>
<td>0</td>
<td>0 - do not use</td>
</tr>
<tr>
<td>DeblockAlpha</td>
<td>-1</td>
<td>[-6,+6] really depends on source</td>
</tr>
<tr>
<td>DeblockBeta</td>
<td>-1</td>
<td>[-6,+6] really depends on source</td>
</tr>
<tr>
<td>DeblockMode</td>
<td>0</td>
<td>0 - filter whole picture</td>
</tr>
<tr>
<td>intraNewInI</td>
<td>1</td>
<td>enables MB intra in I-slices</td>
</tr>
<tr>
<td>intra8x8InI</td>
<td>1</td>
<td>same for P-slices</td>
</tr>
<tr>
<td>intra4x4InI</td>
<td>1</td>
<td>same for B-slices</td>
</tr>
<tr>
<td>intraNewInP</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>intra8x8InP</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>intra4x4InP</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>intraNewInB</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>intra8x8InB</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>intra4x4InB</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>BlockMode</td>
<td>1</td>
<td>1 - MC down to 8x8</td>
</tr>
<tr>
<td>MaxVectorLen</td>
<td>511</td>
<td>for both horz and vert components</td>
</tr>
</tbody>
</table>

**Movie “High Speed”**

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMax</td>
<td>1</td>
<td>max number of b-frames</td>
</tr>
<tr>
<td>BMode</td>
<td>0</td>
<td>0 - plain vanilla</td>
</tr>
<tr>
<td>ModeDecision</td>
<td>0</td>
<td>0 - SAD</td>
</tr>
<tr>
<td>WPredMode</td>
<td>0</td>
<td>0 - not used</td>
</tr>
<tr>
<td>NumRefFrames</td>
<td>2</td>
<td>actual size of DPB</td>
</tr>
</tbody>
</table>

**Movie “High Quality”**

1-st pass:

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMax</td>
<td>3</td>
<td>max number of b-frames</td>
</tr>
<tr>
<td>BMode</td>
<td>2</td>
<td>2 - hierarchical structure</td>
</tr>
<tr>
<td>ModeDecision</td>
<td>1</td>
<td>1 - SATD</td>
</tr>
<tr>
<td>WPredMode</td>
<td>1</td>
<td>1 - explicit mode (for both P- and B-frames)</td>
</tr>
<tr>
<td>NumRefFrames</td>
<td>3</td>
<td>actual size of DPB</td>
</tr>
</tbody>
</table>

2-nd pass:

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>NumRefFrames</td>
<td>4</td>
<td>actual size of DPB</td>
</tr>
</tbody>
</table>
### HDTV “Normal”

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra8x8InP</td>
<td>0</td>
<td>disables MB intra in corresponding slices</td>
</tr>
<tr>
<td>Intra4x4InP</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IntraNewInB</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Intra8x8InB</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Intra4x4InB</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

### HDTV “High Speed”

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMax</td>
<td>1</td>
<td>max number of b-frames</td>
</tr>
<tr>
<td>BMode</td>
<td>0</td>
<td>0 - plain vanilla</td>
</tr>
<tr>
<td>Intra4x4InI</td>
<td>0</td>
<td>disables 4x4 in I-slices</td>
</tr>
<tr>
<td>ModeDecision</td>
<td>0</td>
<td>0 - SAD</td>
</tr>
<tr>
<td>W/PredMode</td>
<td>0</td>
<td>0 - not used</td>
</tr>
<tr>
<td>NumRefFrames</td>
<td>1</td>
<td>actual size of DPB</td>
</tr>
<tr>
<td>MaxVectorLen</td>
<td>255</td>
<td>for both horz and vert components</td>
</tr>
</tbody>
</table>

### HDTV “High Quality”

**1-st pass:**

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra8x8InP</td>
<td>1</td>
<td>enables MB intra in corresponding slices</td>
</tr>
<tr>
<td>Intra4x4InP</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>IntraNewInB</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Intra8x8InB</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Intra4x4InB</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**2-nd pass:**

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra8x8InP</td>
<td>1</td>
<td>enables MB intra in corresponding slices</td>
</tr>
<tr>
<td>Intra4x4InP</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>IntraNewInB</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Intra8x8InB</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Intra4x4InB</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>NumRefFrames</td>
<td>4</td>
<td>actual size of DPB</td>
</tr>
</tbody>
</table>

### VideoConference

Same as “Movie Normal”

### Microsoft Expression Encoder 4

#### Movie “Normal”

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### Video Codec Comparison

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**"High Quality"**

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#### x264

**Movie**

**"Normal"**

- 1-st pass:
  - --tune ssim --pass 1 --keyint 500 --preset medium
- 2-nd pass:
  - --tune ssim --pass 2 --keyint 500 --preset medium

**Movie**

**"High Quality"**

- 1-st pass:
  - --tune ssim --pass 1 --keyint 500 --preset slow
- 2-nd pass:
  - --tune ssim --pass 2 --keyint 500 --preset slow

#### HDTV

**"Normal"**

- 1-st pass:
  - --tune ssim --pass 1 --keyint 500 --preset faster
- 2-nd pass:
  - --tune ssim --pass 2 --keyint 500 --preset faster

**"High Quality"**

- 1-st pass:
  - --tune ssim --pass 1 --keyint 500 --preset veryfast
- 2-nd pass:
  - --tune ssim --pass 2 --keyint 500 --preset slower

#### VideoConference

- 1-st pass:
  - --tune ssim --pass 1 --keyint 500 --preset slower

#### XviD

**Movie**

**"High Speed"**

- -type 0 -quality 5 -vhqmode 1 -max_bframes 0 -reaction 8 -averaging 50 -smoother 50

**Movie**

**"Normal"**

- 1-st pass:
  - -type 0 -pass1 -quality 6 -vhqmode 1 -ostrength 20 -oimprove 10 -odegrade 10
- 2-nd pass:
  - -type 0 -pass2 -quality 6 -vhqmode 1 -ostrength 20 -oimprove 10 -odegrade 10

**Movie**

**"High Quality"**

- 1-st pass:
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<td>Photon</td>
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Appendix 7. Figures Explanation

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

10.1.1.1 RD curves

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

10.1.1.2 Relative Bitrate/Relative Time Charts

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

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

10.1.1.3 Graph Example

Figure 270 shows a case where these graphs can be useful. In the top left graph, it is apparent that the “Green” codec encodes with significantly better quality than the “Black” codec. On the other hand, the top right graph shows that the “Green” codec is slightly slower. Relative bitrate/relative time graphs can be useful in precisely these situations: it is clearly visible in the bottom graph that one of the codecs is slower, but yields higher visual quality, and that the other codec is faster, but yields lower visual quality.
As a result of these advantages, relative bitrate/relative time graphs are used frequently in this report since they assist in the evaluation of the codecs in the test set, especially when number of codecs is large.

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

### 10.2 Bitrates Ratio with the Same Quality

The first step in computing the average bitrate ratio for a fixed quality is inversion of the axes of the bitrate/quality graph (see Figure 272). All further computations are performed using the inverted graph.

The second step involves averaging the interval over which the quality axis is chosen. Averaging is performed only over those segments for which there are results for both codecs. This limitation is due to the difficulty of developing extrapolation methods for classic RD curves; nevertheless, for interpolation of RD curves, even linear methods are acceptable.
The final step is calculation of the area under the curves in the chosen interpolation segment and determination of their ratio (see Figure 273). This result is an average bitrate ratio for a fixed quality for the two codecs. If more than two codecs are considered, then one of them is defined as a reference codec and the quality of others is compared to that of the reference.

Figure 271. Source Data

Figure 272. Axes’ Inversion and Averaging Interval Choosing

Figure 273. Areas’ under Curves Ratio
11 Appendix 7. Objective Quality Metrics Description

11.1 SSIM (Structural SIMilarity)

11.1.1 Brief Description

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

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

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

- Luminance
- Contrast
- Structure

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

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

where

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

\[
\sigma_x = \left( \sum_{i=1}^{N} \omega_i (x_i - \mu_x)^2 \right)^{1/2}
\]

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

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

\[
C_1 = (K_1 L)^2
\]

\[
C_2 = (K_2 L)^2
\]

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

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

For the implementation used in this comparison, one SSIM value corresponds to two sequences. The value is in the range \([-1, 1]\), with higher values being


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more desirable (a value of 1 corresponds to identical frames). One of the advantages of the SSIM metric is that it better represents human visual perception than does PSNR. SSIM is more complex, however, and takes more time to calculate.

11.1.2 Examples

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

![SSIM example for compressed image](image)

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

![Original image](image) ![Image with added noise](image)
Figure 275. Original and processed images (for SSIM example)
The SSIM values for the Y-plane for these images are given below.

SSIM for image with itself, value = 1
SSIM for image with noisy image, value = 0.552119
11.2 PSNR (Peak Signal-to-Noise Ratio)

11.2.1 Brief Description

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

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

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

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

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

\(m, n\) – frame size \(mxn\)

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

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

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

The values of the PSNR in the LUV color space are in the range \([0, 100]\); the value 100 means that the frames are identical.
11.2.2 Examples
PSNR visualization uses different colors for better visual representation:

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

The following is an example of the PSNR metric:

![Figure 277. PSNR example for two frames](image)

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

![Original image](image) ![Image with added noise](image)
Next are the PSNR values for the Y–plane for these images.

**Figure 278.** Original and processed images (for PSNR example)

<table>
<thead>
<tr>
<th>Image Description</th>
<th>PSNR Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image with itself</td>
<td>0</td>
</tr>
<tr>
<td>Image with noisy image</td>
<td>26.0365</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Image Description</th>
<th>PSNR Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>YUV: original, original</td>
<td>100</td>
</tr>
<tr>
<td>YUV: original, noise 26.0365</td>
<td>26.0365</td>
</tr>
</tbody>
</table>

PSNR for image with itself, value = 0

PSNR for image with noisy image, value = 26.0365
PSNR for image with blurred image, value = 30.7045

PSNR for image with sharpen image, value = 32.9183

Figure 279. PSNR values for original and processed images
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The Graphics & Media Lab Video Group is part of the Computer Science Department of Moscow State University. The Graphics Group began at the end of 1980’s, and the Graphics & Media Lab was officially founded in 1998. The main research avenues of the lab include areas of computer graphics, computer vision and media processing (audio, image and video). A number of patents have been acquired based on the lab’s research, and other results have been presented in various publications.

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

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

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

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

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

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

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

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