Intra Prediction Efficiency and Performance Comparison of HEVC and VP9

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List of Abbreviations

AVC  Advanced Video Coding
CABAC  Context Adaptive Binary Arithmetic Coding
CTB  Coding Tree Blocks
CTU  Coding Tree Units
HEVC  High Efficiency Video Coding
ISO  International Organization for Standardization
ITU-T  International Telecommunication Union - Telecommunication Standardization Sector
JCT-VC  Joint collaborative team on video coding
JM  Joint model software
MC  Motion Compensation
MI  Mode Info
MPEG  Moving Picture Experts Group
MSE  Mean square error
MV  Motion Vector
NAL  Network Abstraction Layer
PSNR  Peak signal to noise ratio
SSIM  Structural similarity index
TU  Transformation Units
TM  True Motion
VCEG  Video Coding Experts Group
Abstract

The rapid growth and insatiable demand for consumption of video over the internet continues to stress the limits of the available bandwidth [9]. The emerging of a more efficient next generation video coding standard is of a high demand at present. To address this, ISO/IEC/MPEG/ITU-T VCEG developed a next generation video coding standard called HEVC (High Efficiency Video Coding) starting from current generation codec H.264/AVC [8]. Likewise Google embarked on a project in the late 2011 to develop next generation open source video codec VP9 starting from its predecessor VP8 as the baseline [8]. They seem to be two main contenders for the position of the next state-of-the-art video compression standard. The announced aim of HEVC is to achieve twice more efficient compression compared to H.264/AVC, at the same visual quality and VP9 was developed to get half the bit-rate of VP8 with royalty-free video codec [10]. Intra-prediction is one of the main features which determines the compression efficiency of the entire codec. This proposal is a detailed comparison of intra-prediction modes in HEVC and VP9. Experiments will be carried out using JCT-VC HM [16] [17] and WebM VP9 [19] encoders. The analysis will focus on the intra frame coding and different image performance metrics like MSE, PSNR, bit rate, SSIM [22][23][24][25] and hence video quality will be evaluated for high resolution videos.

Overview of HEVC

HEVC is a new standard for video compression that has the potential to deliver better performance than the earlier standards such as H.264/AVC. Source video, consisting of a sequence of video frames, is encoded or compressed by an HEVC video encoder (Figure 1) to create a compressed video bit stream. The compressed bit stream is stored or transmitted. A video decoder decompresses the bit stream to create a sequence of decoded frames. HEVC decoder block diagram is shown in the Figure 2. HEVC has the same basic structure as previous standards such as MPEG-2 Video and H.264/AVC [26]. HEVC is a video coding standard that can enable better compression, at the cost of potentially increased processing power [2].
Figure 1: HEVC encoder block diagram [11]

Figure 2 HEVC decoder block diagram [11]
HEVC intra frame coding

Like H.264/AVC, HEVC uses block-based intra prediction to take advantage of spatial correlation within a picture. HEVC follows the basic idea of H.264/AVC intra prediction but makes it far more flexible. For example, H.264 could grab a 16x16 ‘macroblock’ of pixels and perform nine ‘intra-prediction directions’ - that allowed the pixels to be rebuilt within each block (Figure 4) HEVC can grab 64x64 ‘superblocks’ and perform 35 infra-prediction directions to rebuild them. The 33 luma intra prediction modes for HEVC are as shown in Figure 3. HEVC also includes a planar intra prediction mode, which is useful for predicting smooth picture regions. In planar mode, the prediction is generated from the average of two linear interpolations (horizontal and vertical).

Figure 3: Available prediction directions in the unified intra prediction in HM 1.0 [11]
Furthermore, intra prediction can be implemented at different block sizes, ranging from 4X4 to 64X64 (whatever size the PU has) (Figure 5).

![Figure 5: Subdivision of a CTB into CBs [and transform block (TBs)]. Solid lines indicate CB boundaries and dotted lines indicate TB boundaries (a) CTB with its partitioning. (b) Corresponding quad tree [3].](image)

**VP9 Intra-prediction**

VP9 is similar on the surface. It can also take 64x64 superblocks, but unlike H.265 these do not need to be square so it can sample 64x32 or 4x8 blocks for greater efficiency. On the flip side it only has 10 prediction modes to rebuild them. Cynics argue VP9 [19] changes H.265 just enough for it to avoid copyright infringement. Needless to say both standards require more computational power than H.264 and VP8 for all this rebuilding [8]. The encoder block diagram for VP6 is shown in Figure 6.
Figure 6: VP6 Encoder Block Diagram [21]

Figure 7: VP9 Intra prediction [13]
At block-size 4x4, VP9 supports ten intra prediction modes: DC, Vertical, Horizontal, TM (True Motion), Horizontal Up, Left Diagonal, Vertical Right, Vertical Left, Right Diagonal, and Horizontal Down (the same set defined by VP8). For blocks from 8x8 to 64x64 there is also support for ten intra modes: DC, Vertical, Horizontal, TM, and six angular predictors corresponding, approximately, to angles of 27, 45, 63, 117, 135, and 153 degrees. Furthermore, there is additionally the option of applying a low-pass filter to the prediction that can be signaled in the bitstream [15].

Figure 8: VP9 Superblock splitting example with solid lines for block split: a) with prediction splitting depicted as dotted lines; b) with transform splitting depicted as dotted lines [10]

Figure 9: VP9 Intraprediction block [10]

Figure 10: VP9 Angular Intra Prediction modes [10]
Experiments

Analysis will be performed on the various image quality measurements such as:-
- Objective quality measures-MSE,PSNR [23][24]
- Subjective quality measures- SSIM [25]
- BD-PSNR [25]
- BD-Bit Rate [25]
- Computational Complexity

MSE and PSNR[23][24]

MSE and PSNR for a NxM pixel image are defined as

\[
MSE = \frac{1}{M \times N} \sum_{m=1}^{M} \sum_{n=1}^{N} [o(m,n) - r(m,n)]^2
\]

\[
PSNR = 10 \log_{10} \left( \frac{L^2}{MSE} \right)
\]

where ‘o’ is the original image and ‘r’ is the reconstructed image. M and N are the width and height of an image and \( L \) is the maximum pixel value in the NxM pixel image.

Video Test Sequences [9]

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Resolution</th>
<th>Freame Rate(fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BlowingBubbles</td>
<td>416x240</td>
<td>30</td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>VP9</th>
<th>QP=22</th>
<th>QP=27</th>
<th>QP=32</th>
<th>QP=37</th>
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</thead>
<tbody>
<tr>
<td>PSNR (db)</td>
<td>43.839</td>
<td>43.839</td>
<td>42.868</td>
<td>40.992</td>
</tr>
<tr>
<td>Bitrate (kbps)</td>
<td>9753.64</td>
<td>7384.384</td>
<td>6861.776</td>
<td>5969.36</td>
</tr>
<tr>
<td>Time (sec)</td>
<td>137.60</td>
<td>126.30</td>
<td>104.22</td>
<td>117.48</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>HEVC</th>
<th>QP=22</th>
<th>QP=27</th>
<th>QP=32</th>
<th>QP=37</th>
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</thead>
<tbody>
<tr>
<td>PSNR (db)</td>
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<td>37.69</td>
<td>34.38</td>
<td>31.567</td>
</tr>
<tr>
<td>Bitrate (kbps)</td>
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<td>9227.45</td>
<td>8441.844</td>
<td>6992.448</td>
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<tr>
<td>Time (sec)</td>
<td>17.38</td>
<td>14.50</td>
<td>11.94</td>
<td>10.144</td>
</tr>
</tbody>
</table>
Conclusions

This report is the intermediate stage of implementation of the project and further test cases and analysis follow to come to a better conclusion of the comparison of the codecs.

The aim of this project is to experiment and present a thorough study, implementation and exhaustive comparison of intra-frame only of the contending video coding standards HEVC and VP9 based on different performance metrics like MSE, PSNR etc. for different video coding sequences [9]. Based on the values of these performance metrics, conclusions will be drawn as to which video coding standard is best suited for high definition video compression.
REFERENCES


[2] Iain Richardson/Vcodex.com “HEVC An Introduction to High Efficiency Video Coding” 2013


[16] HEVC JCT-VC HM reference software https://hevc.hhi.fraunhofer.de/svn/svn_TMuCSoftware/tags/HM-1.0_HM-1.0


[23] MSE http://en.wikipedia.org/wiki/Mean_squared_error


Special Issues on HEVC


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