Versatile Video Coding (VVC)

The emerging new standard

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Versatile Video Coding (VVC)

Outline

- Exploration Phase
- Call for Proposals
- VVC Test Model
Exploration Phase

History of Video Coding Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Year</th>
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</thead>
<tbody>
<tr>
<td>JPEG</td>
<td>1990</td>
</tr>
<tr>
<td>H.261</td>
<td>1991</td>
</tr>
<tr>
<td>H.262 / MPEG-2</td>
<td>1995</td>
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<tr>
<td>H.264 / MPEG-4 AVC</td>
<td>2003</td>
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<tr>
<td>H.265 / MPEG-HEVC</td>
<td>2013</td>
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</tbody>
</table>

Bit-rate Reduction: 50%

PSNR (dB)

0 100 200 300 350 400

bit rate (kbit/s)

Foreman
10 Hz, QCIF
100 frames
Exploration Phase

History of Video Coding Standards

Do we need more efficient video coding?

- Foreman 10 Hz, QCIF 100 frames

<table>
<thead>
<tr>
<th>PSNR (dB)</th>
<th>bit rate (kbit/s)</th>
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<tbody>
<tr>
<td>40</td>
<td>H.265 / MPEG-HEVC (2013)</td>
</tr>
<tr>
<td>34</td>
<td>H.261 (1991)</td>
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<tr>
<td>32</td>
<td>JPEG (1990)</td>
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<tr>
<td>30</td>
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<tr>
<td>28</td>
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H.261 (1991)
JPEG (1990)
Exploration Phase

Jevons Paradox

"The efficiency with which a resource is used tends to increase (rather than decrease) the rate of consumption of that resource."
Exploration Phase

Work beyond HEVC already started 2015

• **Joint Video Exploration Team (JVET)**
  - of ITU-T VCEG and ISO/IEC MPEG
  - established October ’15 in Geneva

• **Joint Video Exploration Model (JEM)**
  - software playground to explore new coding tools

• **34% bitrate savings** for JEM relative to HEVC
  - provided evidence to start a new joint standardization activity with a…

**Joint Call for Proposals** on Video Compression with Capability beyond HEVC
Call for Proposals

Timeline

2017 Oct. – Final CfP

• Submit bitstreams and decoded video for proposed video coding technology
• Compare submission with HEVC anchor for given sequences, bitrates and coding conditions

2018 Apr. – CfP results

• Subjective evaluation results of submitted CfP responses and HEVC anchor
• Description of proposed video coding technology

First Test Model:

• Initial starting point of standard development

2020 Jul. – Final Standard
Call for Proposals

Target for the final VVC standard

PSNR (dB)

H.??? / MPEG-VVC
(2013)

H.265 / MPEG-HEVC
(2013)

H.264 / MPEG-4 AVC
(2003)

H.262 / MPEG-2
(1995)

H.261
(1991)

JPEG
(1990)

Bit-rate Reduction Target: 50%

Foreman
10 Hz, QCIF
100 frames
Call for Proposals

Three categories

• **SDR**
  • 5 HD sequences with bitrates from 400 kbit/s to 3.8 Mbit/s
  • 5 UHD sequences with bitrates from 950 kbit/s to 10 Mbit/s

• **HDR**
  • 4 HD sequences using PQ curve, bitrates from 350 kbit/s to 3 Mbit/s
  • 3 UHD sequences using HLG curve with bitrates from 640 kbit/s to 10 Mbit/s

• **360-degree**
  • 1 sequence 6K x 3K, 2 Mbit/s to 10 Mbit/s
  • 4 sequences 8K x 4K, 400 kbit/s to 7 Mbit/s
Results

• JVET received submissions from 33 organizations.

• 40% or more bitrate savings in terms of PSNR over HEVC were shown.

• All submissions were superior in terms of subjective quality than...
  • HEVC (in most test cases).
  • JEM (in a relevant number of test cases).

• Fraunhofer HHI among the best performing submissions in all 3 categories.
Call for Proposals

Subjective testing result example

Mean Opinion Score (MOS)

10 Mbit/s
6 Mbit/s
3 Mbit/s
1.5 Mbit/s

HEVC anchor
JEM
HHI

SunsetBeach (UHD, HLG)

JVET-J0080: “Results of Subjective Testing of Responses to the Joint CfP on Video Compression Technology with Capability beyond HEVC”, 10th JVET Meeting, San Diego, April 2018
VVC Test Model

Motivation

• Start off with a clean slate test model

• Add quadtree plus multi-type tree block partitioning (QT+MTT)
  • Fundamental impact on all coding tools to be added
  • Most common partitioning scheme among all CfP submissions

• Use Fraunhofer HHI software with QT+MTT as basis for the test model

• Test promising coding tools from CfP on that basis (efficiency / complexity aspects)

• Agree on adding tested coding tools until sufficient bitrate reduction is achieved
VVC Test Model

New block partitioning

- 128x128 Coding Tree Units (CTU)
- Recursive quadtree partitioning (QT)
VVC Test Model

New block partitioning

- 128x128 Coding Tree Units (CTU)
- Recursive quadtree partitioning (QT)
- Nested recursive multi-type tree partitioning (MTT) with

  - binary split
  - ternary split

  ![Diagram of block partitioning with binary and ternary splits](image)
VVC Test Model

New block partitioning

- 128x128 Coding Tree Units (CTU)
- Recursive *quadtree partitioning* (QT)
- Nested recursive *multi-type tree partitioning* (MTT) with
  - *binary split* or *ternary split*

- Variable size *Coding Units (CU)*
VVC Test Model

New block partitioning
VVC Test Model
Current Version 4.0 improves all blocks of hybrid video coding

- **Block partitioning** with quadtree plus multi-type tree (QT+MTT)
- **Intra**-picture prediction with luma to chroma and improved angular prediction (7 tools)
- **Inter**-picture prediction with improvements mainly in motion vector coding (10 tools)
- Dependent **quantization** adaptively switches between quantizers
- Multiple **transform** selection allows DCT-II, DST-VII and DCT-VIII transform combinations
- **In-loop filtering** with improved de-blocking and new adaptive loop filter
- **CABAC entropy coding** with improved probability estimation and transform coefficient coding
VVC Test Model

Current Intra Main Tools

• 65 prediction angles including wide angles for very narrow blocks
• Prediction filtering using neighboring reference samples
• Cross-component linear model (CCLM) prediction (Y to Cb,Cr)
• Multi-reference line prediction using
• 4-tap interpolation filter for angular prediction
• Intra block copy adaptively switches between quantizers
• Intra sub-partitions enabling 1D intra prediction and transform blocks
VVC Test Model

Current Inter Main Tools

- Affine motion compensation (4x4 subblocks)
- Improved temporal merge MV predictors (8x8 subblocks)
- Adaptive Motion Vector Resolution switches between ¼, 1, 4 sample accuracy for MVD
- Merge Mode plus Motion Vector Difference
- Triangular partitions for prediction
- Combined Intra/Inter prediction
- Weighted bi-prediction with cu-level weight signalling
- Bi-directional optical flow decoder side prediction refinement
- Decoder side motion vector refinement performing lightweight motion search at the decoder
- Symmetrical MVD signalling (MVD for L1 = -MVD for L0)
### VVC Test Results – HD and UHD

<table>
<thead>
<tr>
<th>VTM</th>
<th>BD-Rate YUV</th>
<th>Enc. Speed</th>
<th>Dec. Speed</th>
<th>Complexity / runtime increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>JEM 7.0</td>
<td>-31.1</td>
<td>9.1</td>
<td>6.1</td>
<td>0</td>
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<tr>
<td>VTM-1.0</td>
<td>-30.6</td>
<td>2.2</td>
<td>0.8</td>
<td>-5</td>
</tr>
<tr>
<td>VTM-2.0</td>
<td>-27.5</td>
<td>3.6</td>
<td>1.3</td>
<td>-10.6</td>
</tr>
<tr>
<td>VTM-3.0</td>
<td>-31.8</td>
<td>5.2</td>
<td>1.3</td>
<td>-15.2</td>
</tr>
<tr>
<td>VTM-4.0</td>
<td>-34.2</td>
<td>7.4</td>
<td>1.5</td>
<td>-20.6</td>
</tr>
</tbody>
</table>
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Summary

- New standardization activity started in April 2018
- Fraunhofer HHI among others submitted coding technology with much superior subjective quality compared to HEVC
- VVC Test Model 1.0 (VTM) released in May 2018 based on Fraunhofer HHI software (advanced block partitioning only)
- VVC Test Model 4.0 achieves over HEVC (HM)
  - 34% bitrate reduction
  - 7.5x encoder and 1.5x decoder complexity
- Final Standard by July 2020
Thank you very much!

Further Information:

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