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Versatile Video Coding (VVC) Going Beyond HEVC

R&I Core Video Coding team

interdigital™

Outline

- **Overview**
- VVC Architecture and New Tools
- Performance
- Deployment Status
- VVC For Streaming

What is VVC?

- VVC is a Hybrid Video Coding based on HEVC
  - Refined existing techniques
  - Added novel coding tools

Coding Efficiency

35% objective(PSNR)over HEVC

40+% subjective over HEVC

HD/UHD/8K resolutions

10-12 bit depth

Versatility

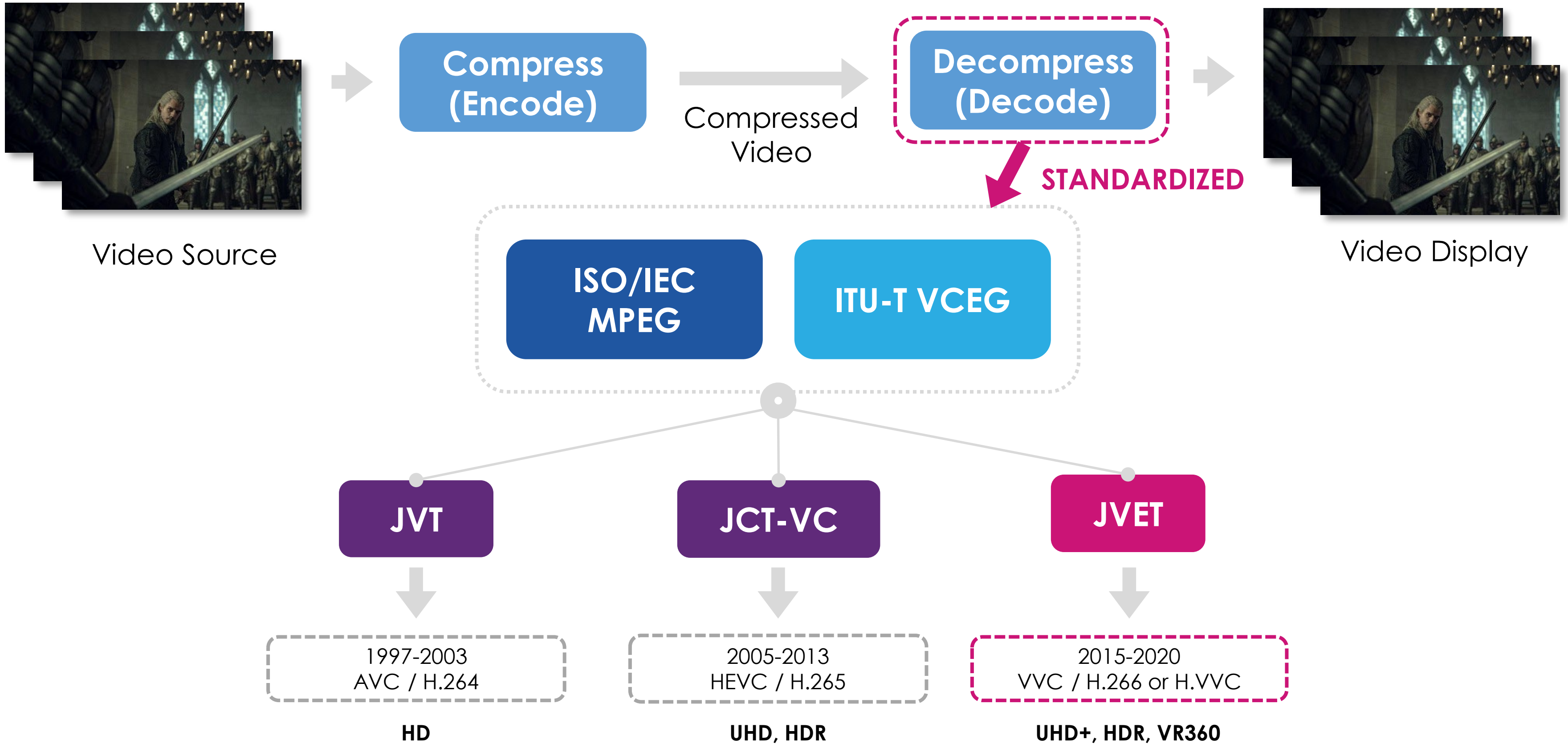
Camera generated content

HDR/WCG

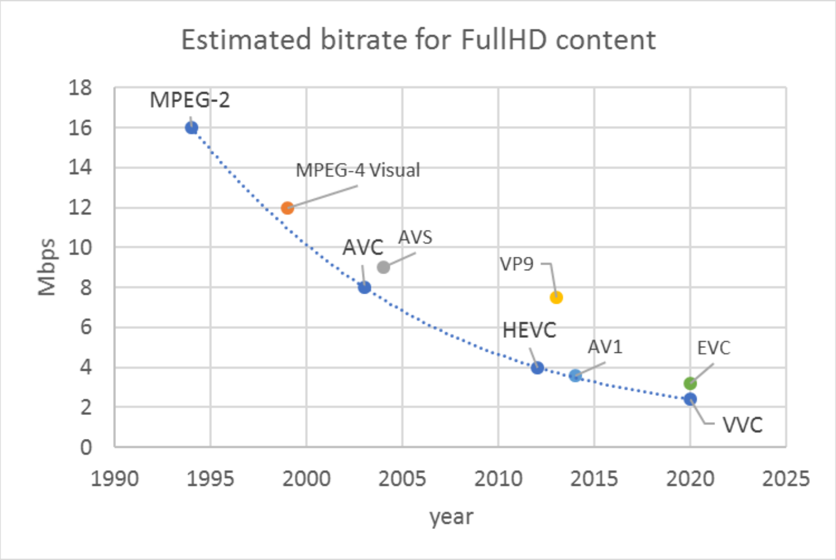
Computer generated content

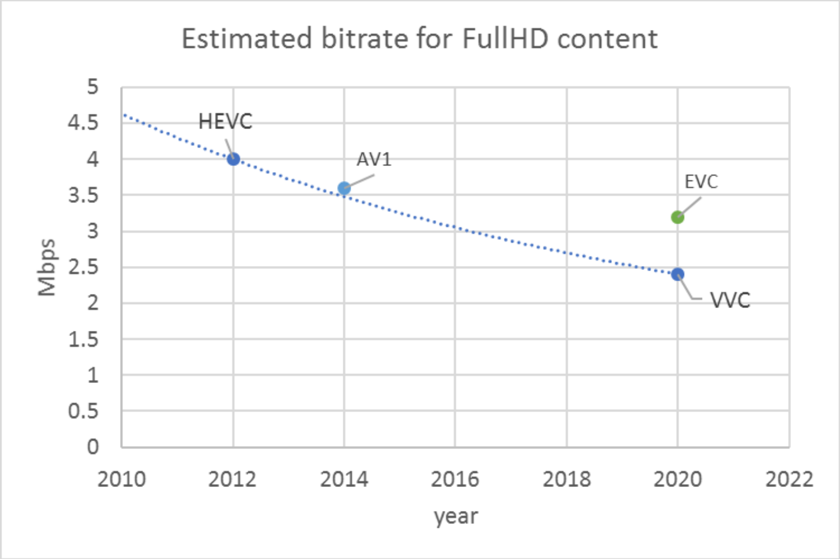
360° VR video

Versatile Video Coding (VVC): How Did We Get Here?



Compression Progress, MPEG-2 to VVC





inspired from Karwowski et al 2017, 20 Years of Progress in Video Compression – from MPEG-1 to MPEG-H HEVC. General View on the Path of Video Coding Development, ICIP2017

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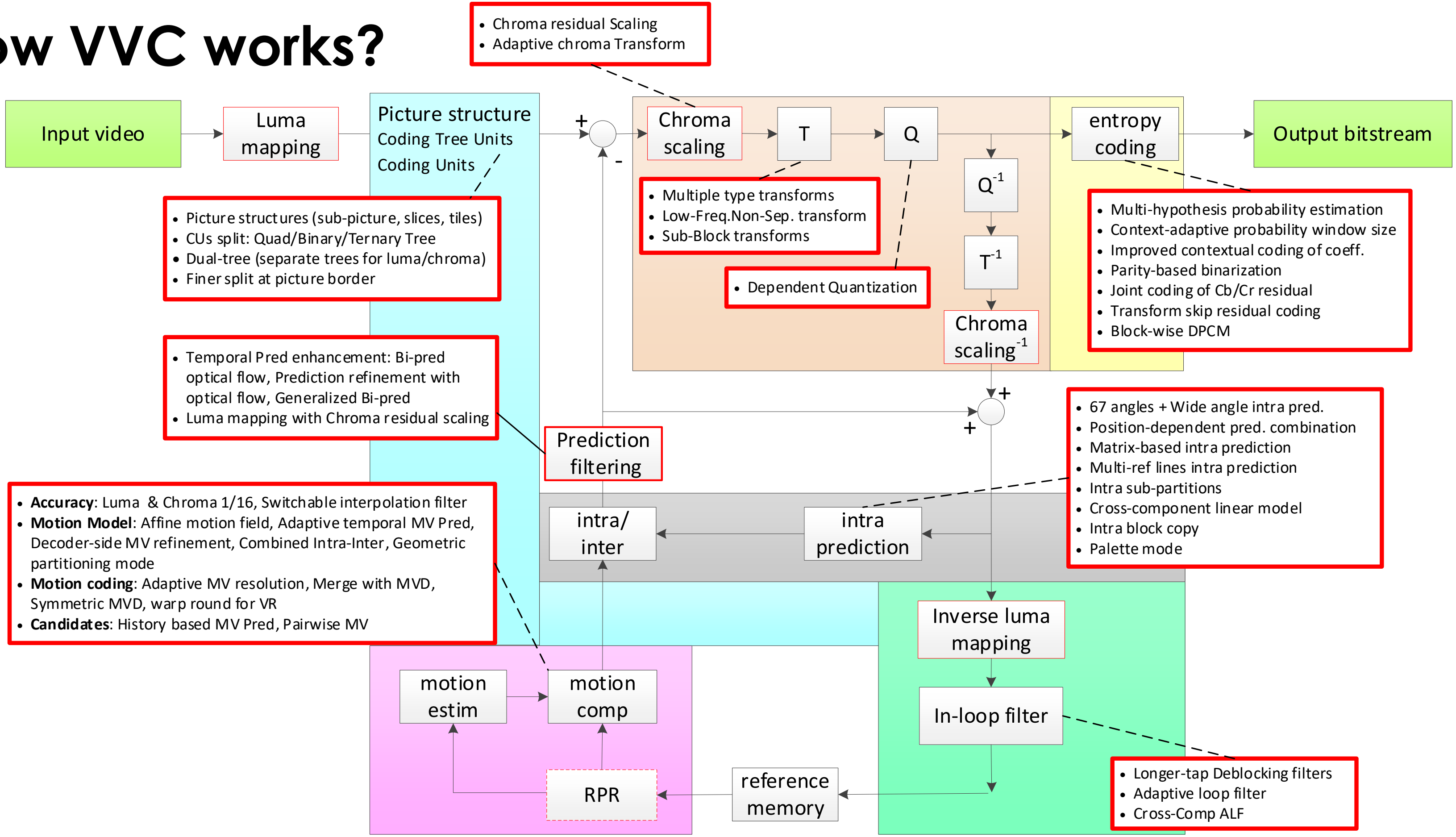
How VVC works?



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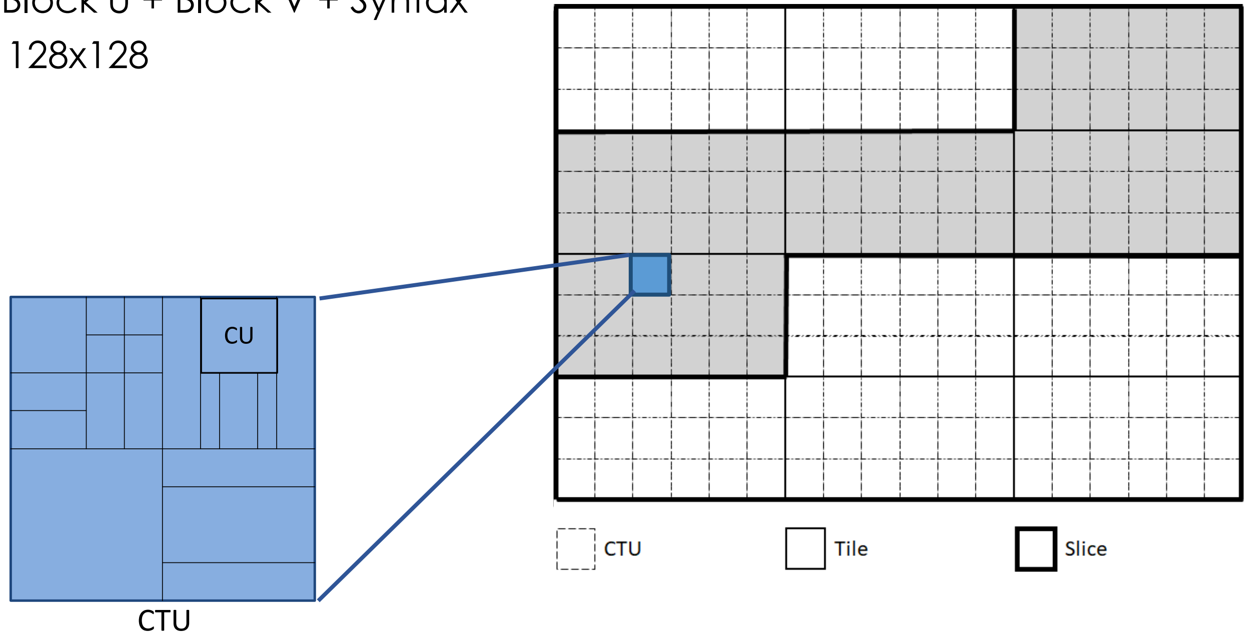
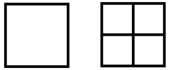
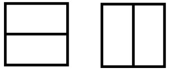
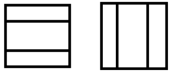
	Main new elements compared to HEVC
Partitioning	• Coding units splitting: Binary Tree + Ternary Tree • Dual-tree (separate trees for luma/chroma) • Finer split at picture border • Picture structures (sub-pictures, slices, tiles)
Transform	• Multiple type transforms • Low-frequency non-separable transform • Sub-block Transforms
Quantization	• Dependent quantization
Residual Coding	• Improved contextual coding of transform coefficients • Parity-based binarization for dependent quantization • Transform skip residual coding • Joint coding of chroma residual
Entropy Coding	• Multi-hypothesis probability estimation • Context-adaptive probability window size
Intra Prediction	• 67 angles and wide angle intra prediction • Position-dependent prediction combination • Matrix-based intra prediction • Multi-reference lines intra prediction • Intra sub-partitions • Cross-component linear model
Inter Prediction	• Affine motion field, combined intra-inter, decoder-side MV refinement and adaptive temporal MV prediction, geometric partitioning mode • Motion coding for adaptive MV resolution, MVD, and symmetric MVD, warp round for VR • Candidates include history based MV prediction, pairwise MV and sub-block based temporal motion prediction • Accuracy: Luma & Chroma 1/16; and switchable interpolation filter is applied
Prediction Filtering	• Temporal prediction enhancement include bi-directional optical flow, prediction refinement with optical flow, and bi-prediction with coded weights • Luma mapping with Chroma residual scaling
Loop Filters	• Adaptive loop filter • Cross-component adaptive loop filter • Longer-tap deblocking filters
SCC & Others	• Intra block copy • Palette mode • Adaptive chroma transform • Adaptive resolution coding

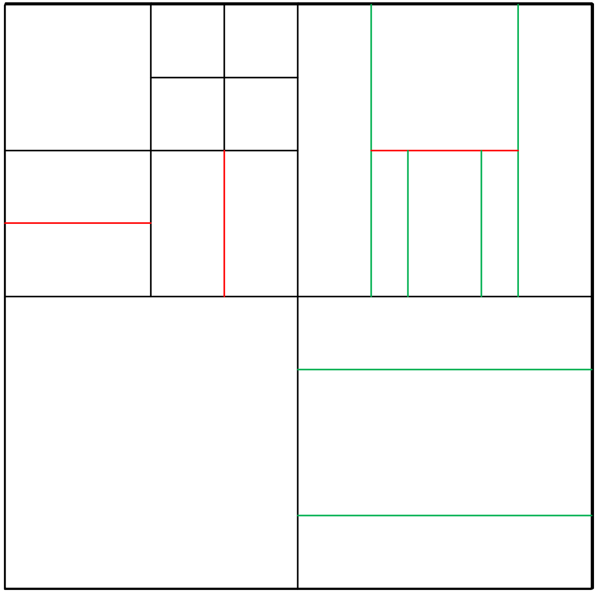
Picture Partitioning

- Partition of a picture into subpictures, slices, tiles and CTUs
  - **CTU**: Coding Tree Unit
    - CTU = Block Y + Block U + Block V + Syntax
    - CTU size is up to 128x128



Block Partitioning

- A CTU is split into CUs using the coding tree
- 1st tree
  - **Quad split** 
- 2nd tree
  - Quad split
  - **Binary split** 
  - **Tenary split** 
- CU can be square or rectangular

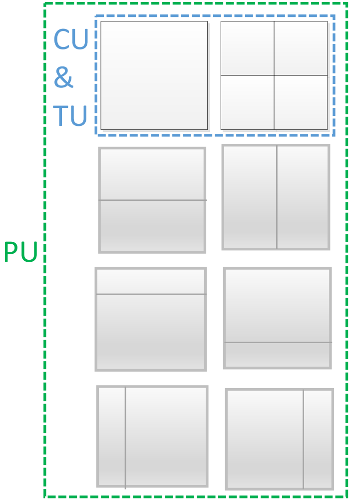


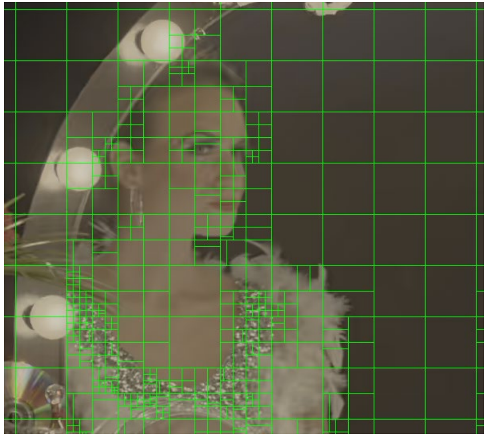
- Support Dual-Tree in I-slices
  - Separated coding trees for Luma and Chroma

Highly flexible partitioning

HEVC

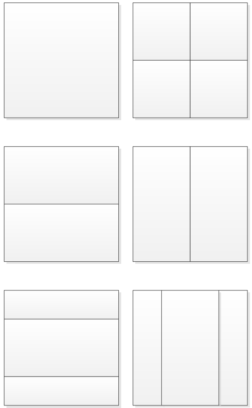
- CTU 64x64
- CU & TU Partitioning: No Split/Quad-Tree
- PU Partitioning: No Split / Quad-Tree / Binary-T / Asymmetric





VVC

- CTU 128x128
- CU Partitioning: No Split / Quad-Tree / Binary-T / Ternary-T
- Most cases: a CU is no more divided into PU or TU



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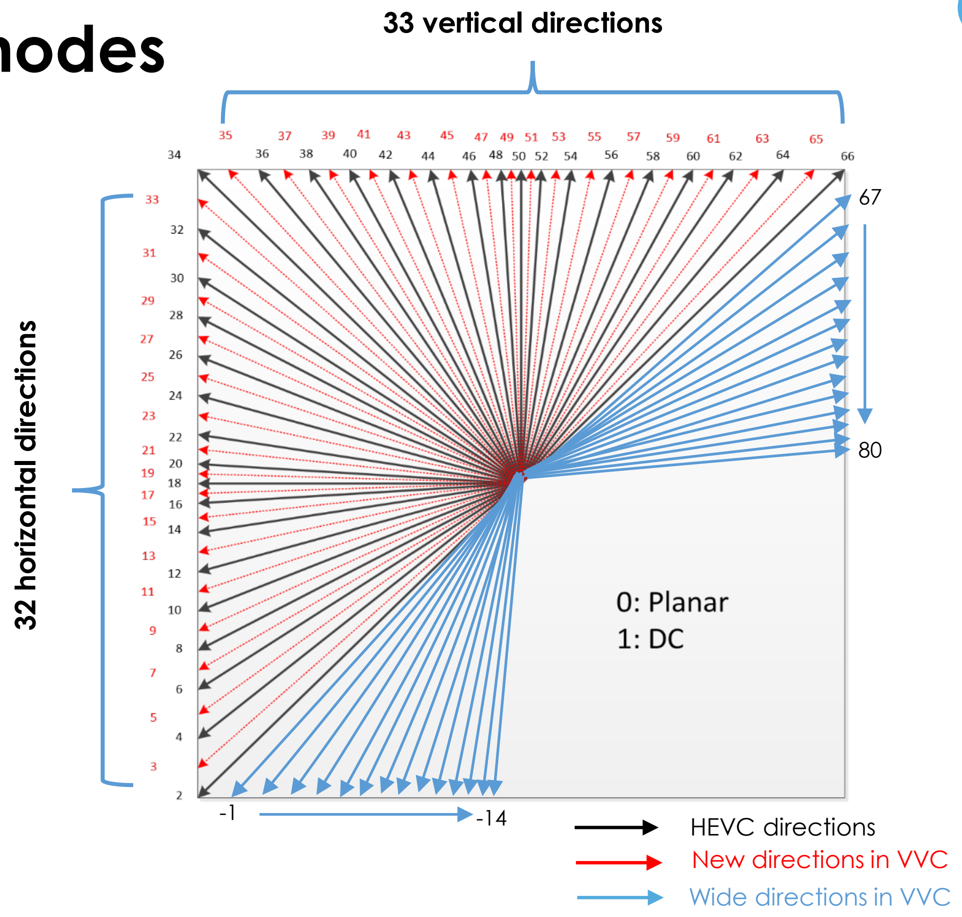
Intra Prediction-angular modes

- **65 angular modes**
  - 33 directions in HEVC + 32 new intermedia directions
- **28 wide angular modes**
  - rectangular only
  - some regular modes are replaced by equal number of wide angular modes



(Arrows point to the opposite direction of prediction angle)

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Metadata for VVC - VSEI

Versatile Supplemental Enhancement Information

- VVC standard only defines processes required for conforming video decoders.
- Information about how video is intended to be post-processed, displayed, or otherwise used is specified mostly in the VSEI standard.
- VUI parameters provide information for the correct display of coded video: scanning format, transfer function, colour gamut, aspect ratio, etc.
- SEI messages provide additional information that can assist decoders, displays, and other video receivers perform as desired by the content producer.
- Several SEI messages such as MDVC, CLLI or ATC were developed for deployment of HDR video serivces.

Film grain synthesis

- Film grain synthesis (FGS) characteristics SEI message is increasingly important due to interest in film grain synthesis in high-value streaming services.
- FGS characteristics SEI message supported in AVC, HEVC and VVC
- A Technical Report on use of film grain technologies is currently in development in ITU-T and ISO/IEC.
- 2 main FGS use cases: preserving artistic intent and masking compression artefacts.

Neural-network post filter

- NNPF SEI messages enable use of neural networks for post-processing operations (e.g, super-resolution, frame rate upsampling)
- NNPFC SEI message signals NN weights.
- NNFPA SEI message signals a specific NN that is invoked.

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VVC Performance

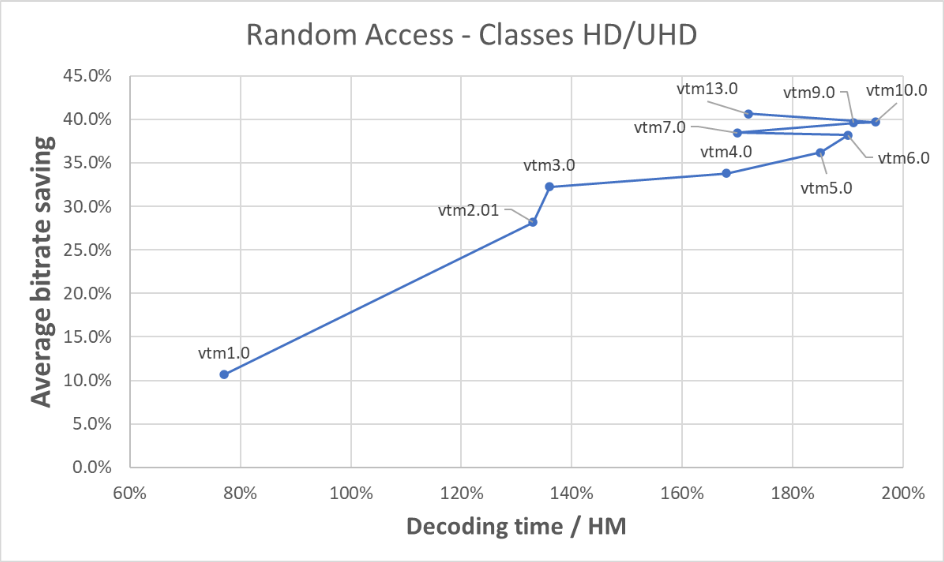
VTM 13.0 (July 2021)

Performance gain over HEVC
HM16.24rc1, Random Access

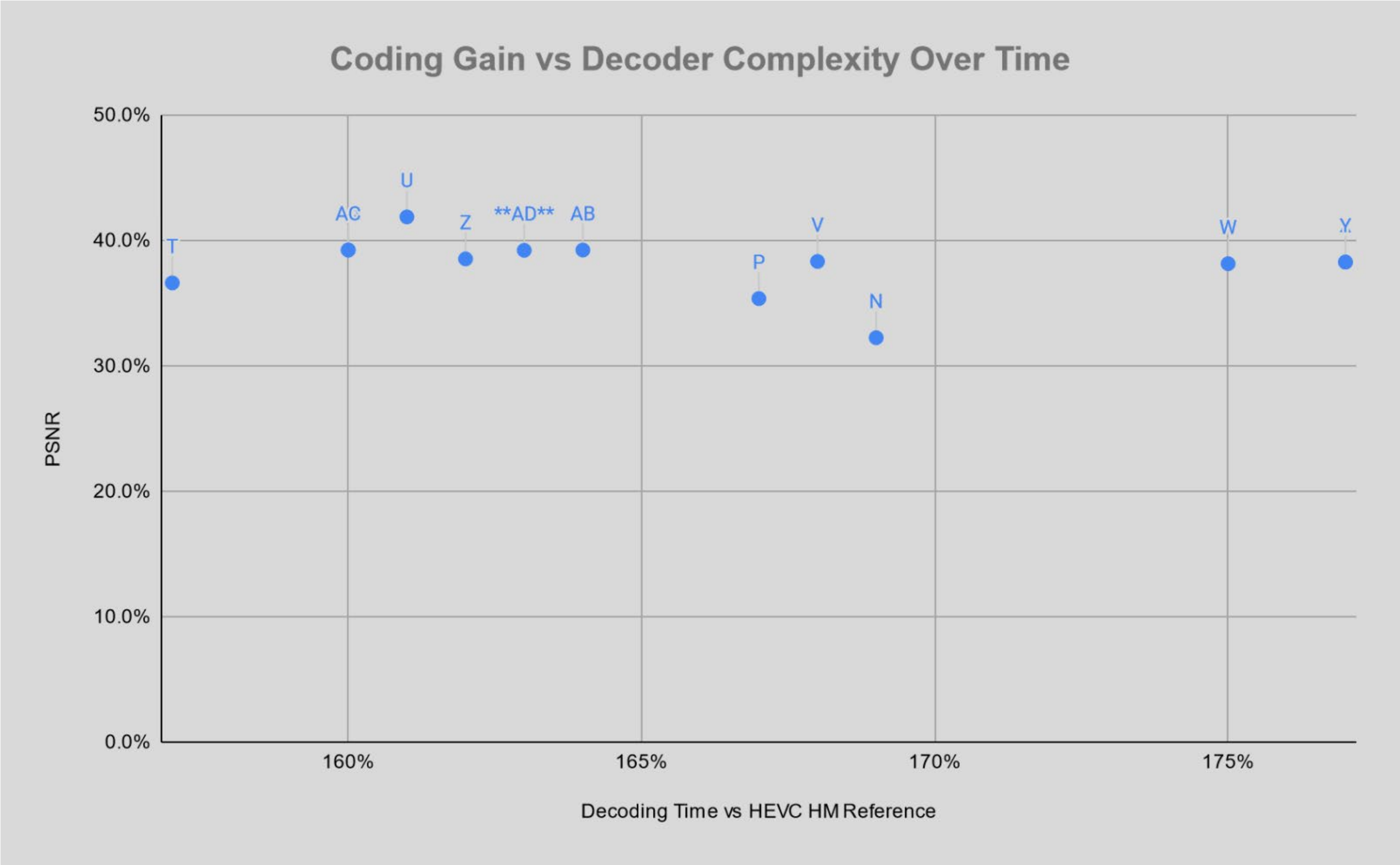
SDR	psnrY	psnrU	psnrV
Class A1 (4K)	-39.74%	-39.41%	-46.15%
Class A2 (4K)	-43.15%	-40.53%	-39.75%
Class B (1080p)	-36.20%	-48.61%	-47.19%
Class C (WGA)	-32.85%	-34.70%	-36.64%
Overall	-37.41%	-41.45%	-42.68%

HDR	(w)psnr Y	(w)psnr U	(w)psnrV
Class PQ (HD)	-38.29%	-53.90%	-47.15%
Class HLG (4K)	-32.44%	-66.33%	-60.54%

Evolution VTM (SDR)



VVC: 40% Gain,1.6x Decode Complexity vs HEVC



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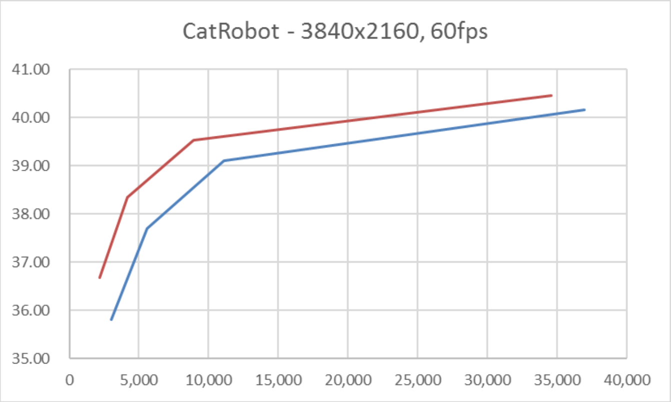
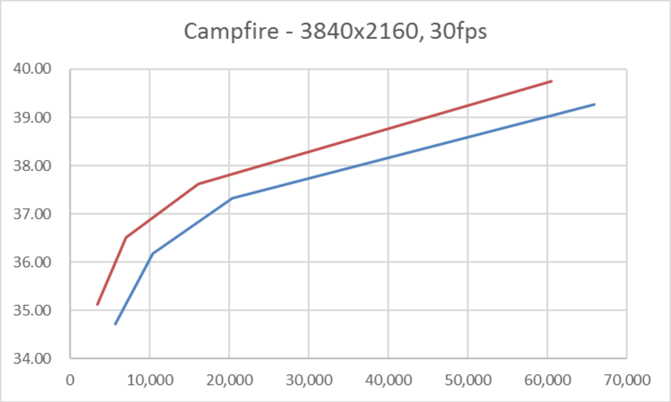
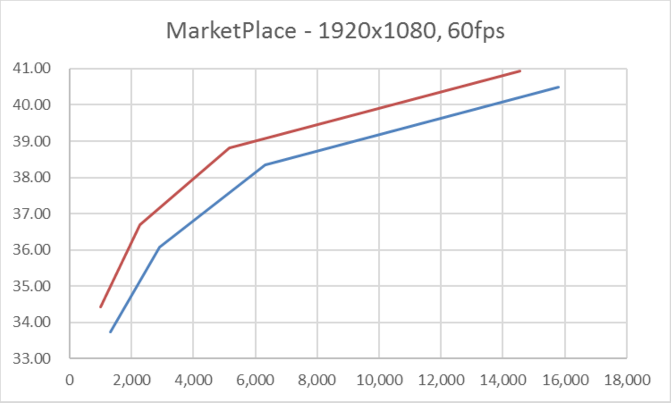
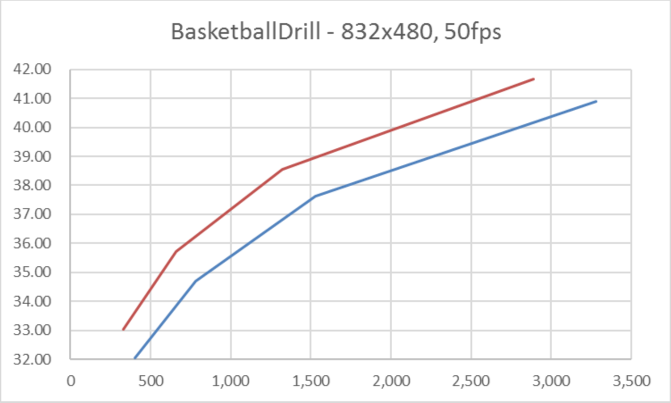
VVC vs HEVC, SDR content









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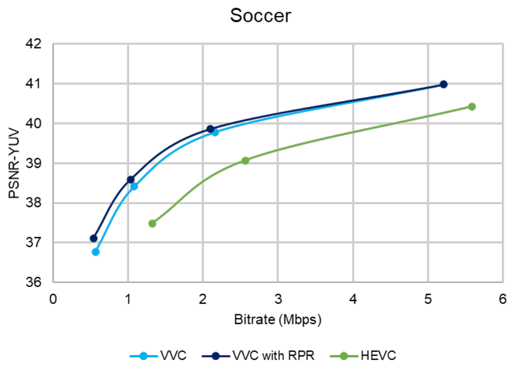
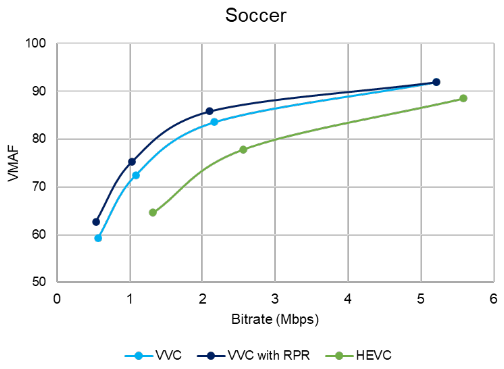
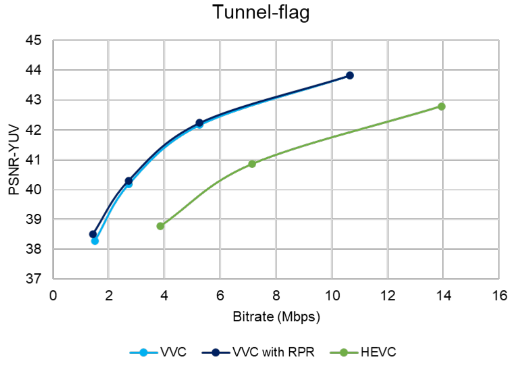
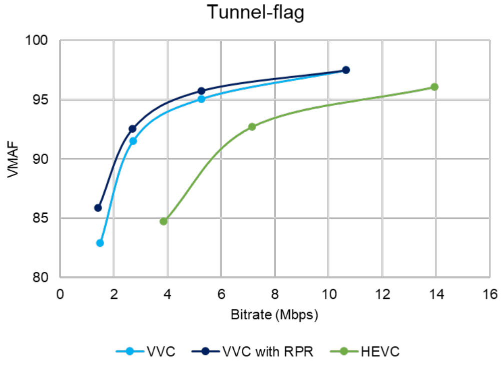
VVC Reference Picture Resampling (RPR) Gains





	BD-rate gains	
Soccer	PSNR-YUV [%]	VMAF [%]
VVC vs. HEVC	39.27%	40.23%
VVC with RPR vs. HEVC	43.02%	48.77%





	BD-rate gains	
Tunnel-flag	PSNR-YUV [%]	VMAF [%]
VVC vs. HEVC	52.64%	55.19%
VVC with RPR vs. HEVC	54.38%	61.55%

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VVC Adoption in Application Standards

ARIB

Investigating VVC Main 10 and Multilayer for next gen digital video broadcasting system.

ATSC

Specifying VVC for inclusion in the ATSC 3.0 suite of standards.

CTA Wave

Added VVC profile to its Web Application Video Ecosystem Content Specification in 2021.

DASH-IF

Added VVC profile to its DASH-IF Interoperability Points in 2022.

DVB

Adopted VVC as Next Generation Video Codec into its codec toolbox in 2022.

SBTVD

Selected VVC as the sole video base layer codec in 2021. Specification drafting is ongoing.

SCTE

Adopted VVC into its standards, SCTE 281-1 and 281-2 in March 2023.

Compression performance requirements

DVB set out a number of performance related commercial requirements to be met by next generation video codecs.

- 8K video over legacy broadcast multiplexes.
- 5x 4K services in a 40Mbps multiplex (3x for HEVC).
- 27% and over 30% efficiency gains over HEVC for live and offline streaming.

In **SBTVD** evaluation, VVC technology was tested on variety of content test cases and gains >30% were reported for:

- Spatial resolutions from 720p to 4320p for HDR HLD and HDR PQ.
- 1080p SDR content with different frate rates.
- Sign language video in portrait mode (540x960 and 360x640)

** Based on publicly available information*

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VVC Commercial Deployment Apr 2023*

Software decoding

- HD playback on Android and iOS mobile plaftorms.
- UHD/4K playback on laptop/desktop grade processors.
- UHD/8K playback on AMD EPYC and Intel Xeon based servers.
- Web browser playback with WebAssembly with Edge, Firefox, Safari and Chrome browsers.

Encoding

- Offline commercial VVC encoders with >30% performance gains over HEVC integrated into cloud-based encoding, transcoding and mobile OTT services.
- Real-time commercial VVC encoders with 15-30% performance gains over HEVC using the same or comparable HW (1-1.5x).

Hardware decoding

- 8Kp120 VVC decoder IP core.
- 4Kp60 SoC decoder for STB.
- 4Kp120 and 8Kp120 SoC decoders for TVs.
- New TV ranges supporting VVC announced for 2023.

Open-source and commercial developer tools

- VVC encoder or decoder integration plugins available for FFMPEG, VLC, GPAC,..
- VVC conformance testing specification developed by JVET, VVC Verification and Validation bitstreams developed by DVB.
- Commercial test bitstreams and bitstream analyzers.

*JVET maintains up to date list of VVC deployments, available from JVET repository: jvet-experts.org

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VVC for Streaming? What's Different From HEVC

- VVEnc/VVDec
  - Open Source code from one of the primary VVC contributing companies, Fraunhofer HHI
  - Optimized, highly performant portable code (x86/Arm/wasm)
  - Webassembly support enables browsers to play VVC (Firefox, ***Chrome***, Edge, Safari), mitigating an issue that plagued HEVC for years
  - Accelerates prototypes and commercial product deployment
  - Keeps parity with non-MPEG codecs such as AV1
- MC-IF
  - Industry Forum with range of ecosystem participants, mission to foster MPEG technology adoption, starting with VVC
  - Developing VVC Commercial Guidelines for Streaming and Broadcast, first release planned for June 2023

Thanks for your attention!

Questions?