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View-Adaptive Streaming of Dynamic Point Clouds

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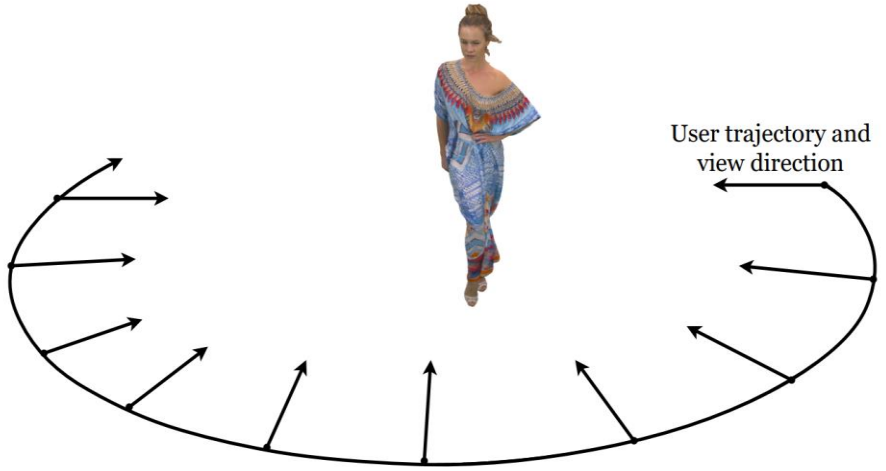
Introduction

- „Traditional“ videos are a big business
- **360-degree videos** have gained popularity in recent years
  - The video is projected on a sphere with the user in it‘s center
  - Users decide which part of the video they watch
  - ➢ **3 Degrees of Freedom**
- The next big step: **Fully Immersive Experiences**
  - Users can navigate through the content
  - ➢ **6 Degrees of Freedom**
  - ➢ Which **media format** to use?

#TheBuggles #VideoKilledTheRadioStar #Remastered
The Buggles - Video Killed The Radio Star (Official Music Video)



[1] Youtube (2022, 23. Sep). https://www.youtube.com/watch?v=W8r-tXRLazs

Point Clouds

Point Clouds

- For dynamic scenes, we have **a sequence of m Point Clouds**

$$(P_1, P_2, \dots, P_m)$$

with n_i points per set

$$P_i = \{(x_j, y_j, z_j, r_j, g_j, b_j) \mid j = 1, \dots, n_i\}$$

- Easy to record and render
- Allow to represent any kind of volumetric content
- **But**: A lot of data! (Longdress [2]: 10s Sequence @ 30 fps: 1.5 GB)

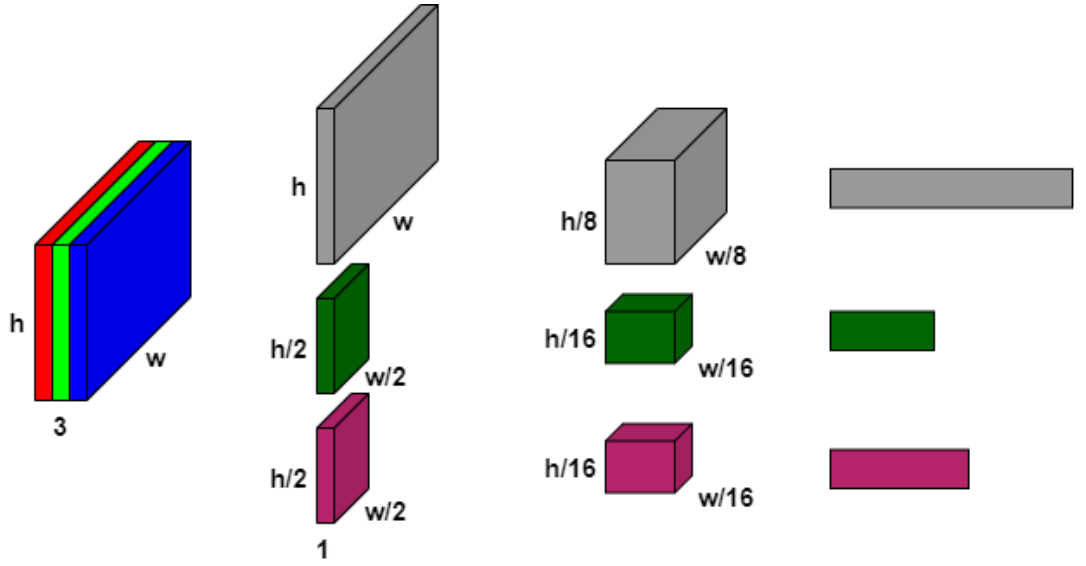
[2] Eugene d'Eon, Bob Harrison, Taos Myers, and Philip A. Chou. 2017. 8i Voxelized Full Bodies - A Voxelized Point Cloud Dataset. ISO/IEC JTC1/SC29 Joint WG11/WG1 (MPEG/JPEG) input document WG11M40059/WG1M74006 (2017)

Compression
From Images to Point Cloud Sequences

Image Compression

JPEG is a lossy image compression method

- Color transformation from RGB to **YUV**
- **Discrete Cosine Transformation** (DCT) on 8x8 blocks
- **Quantisation**
  - Divide DCT coefficients by Quantisation Matrix and round to Integer
  - This is the **lossy part**!
- **Huffman Coding**



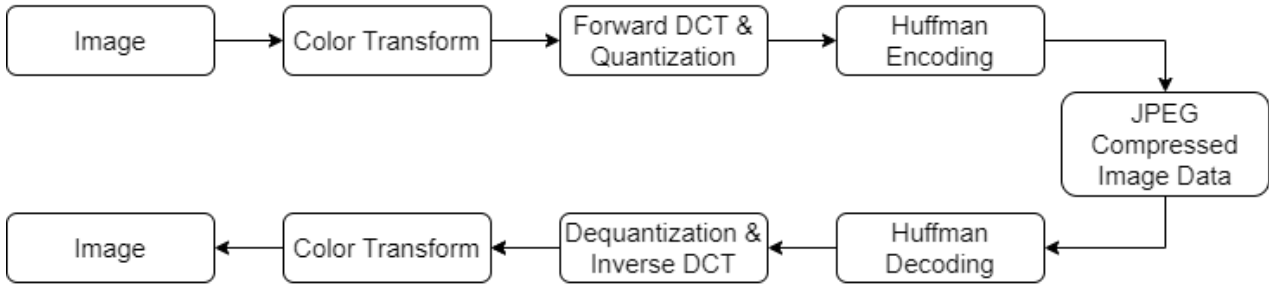


Fig.: JPEG compression pipeline, based on [3]

[3] dos Santos, Samuel Felipe, Nicu Sebe, and Jurandy Almeida. "The good, the bad, and the ugly: Neural networks straight from jpeg." 2020 IEEE International Conference on Image Processing (ICIP). IEEE, 2020.

Video Compression – Intra Prediction

- Videos are **a sequence of frames**
- On frame level, video codecs use **intra prediction**
  - **Predict image blocks** from previously coded blocks in the same frame.
  - Encode only **the residual** after prediction
  - H.264/H.265 allow a plethora of prediction modes
- So called **I-Frames** (Intra-Frames)
  - Very similar to JPEG
  - Can be decoded directly

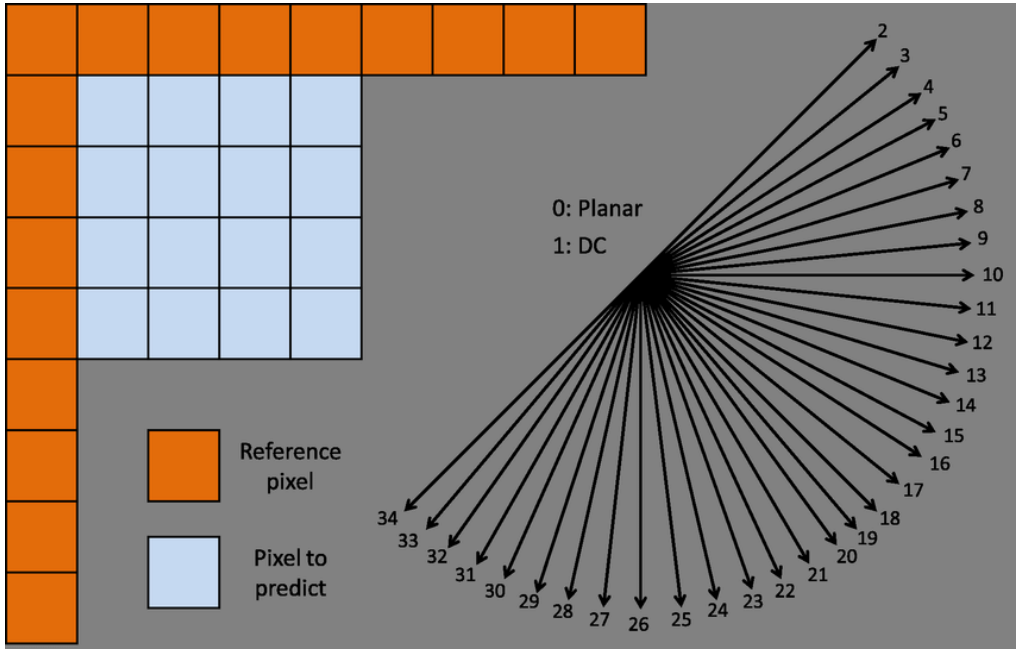


Fig.: Prediction modes in HEVC [3]

[3] Bichon, Maxime, et al. "Inter-block dependencies consideration for intra coding in H. 264/AVC and HEVC standards." 2017 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). IEEE, 2017.

Video Compression – Inter Prediction

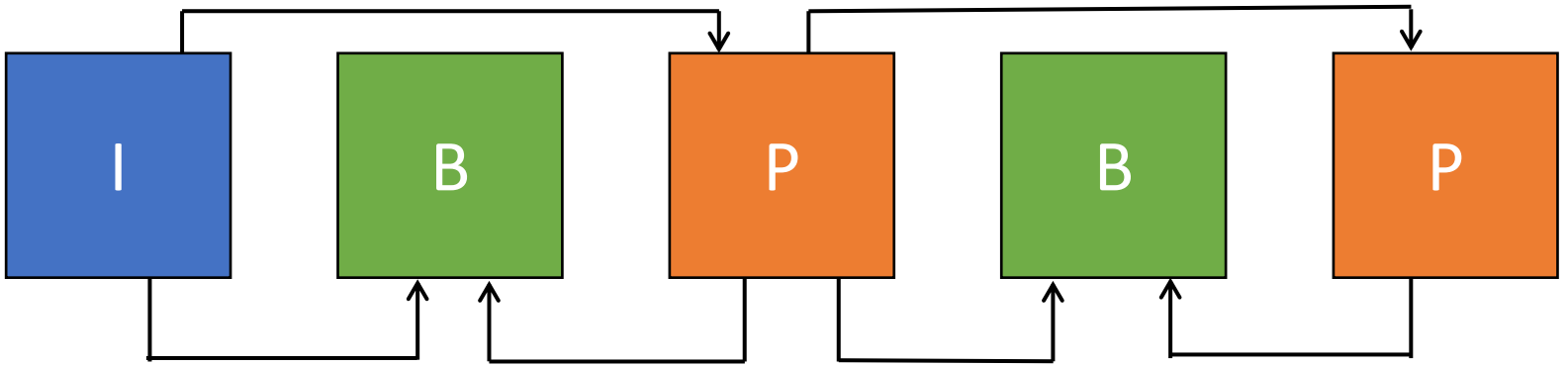
- Subsequent frames are **very similar**
  - Use previous frame to **predict the next frame**
  - Called **P-Frames**
- Compute **residual image** by substracting the frame from the previous frame
  - Less information to compress
  - But: Dynamicity causes large differences
- We need **Motion Compensation**
  - Compensate motion in the reference frame

[4] Vcodex Ltd. (2022, 23. Sep.). Video Coding Walkthrough, https://www.vcodex.com/video-coding-walkthrough/

Video Compression – Summarized

Split the video into a group of pictures:

- **I-Frames** are coded like still pictures
- **P-Frames** are predicted from I-Frames or P-Frame
- **B-Frames** are predicted from **mutliple frames** (forward and backward)



Point Cloud Compression

Idea: Use video compression for Point Clouds

- So we need a **2D representation**

MPEG's V-PCC:

- Decompose point cloud into **patches with same orientation**
- Project points into a 2D patch
  - Store distance of each point to the plane
  - Store the corresponding point color
  - Keep a binary map of where points are

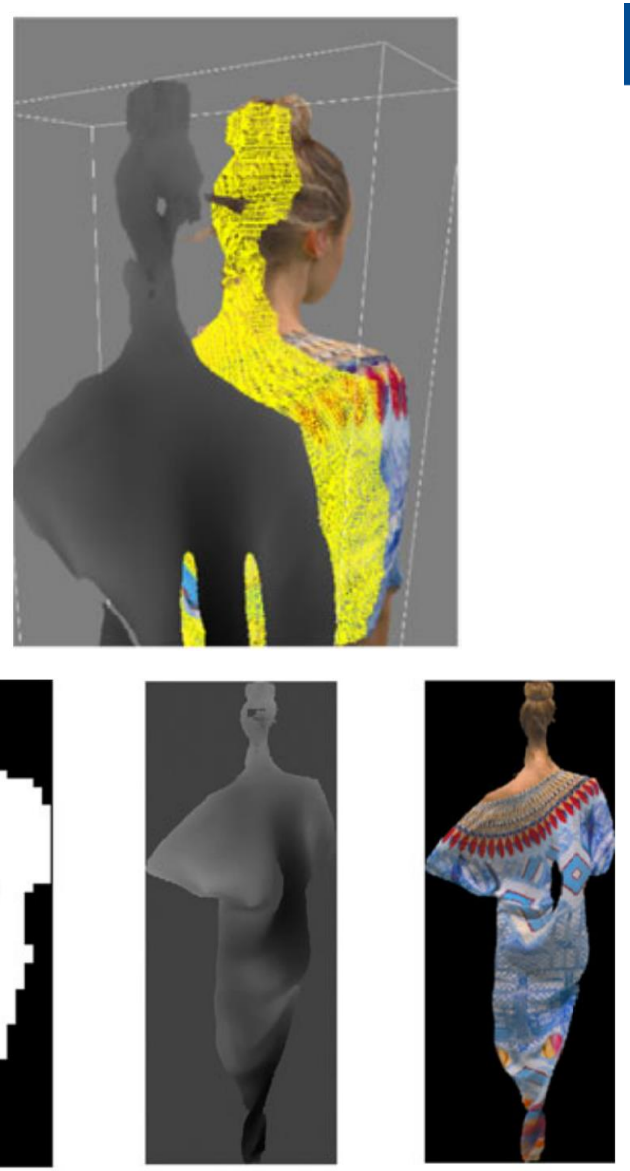


Fig.: Patch projection and patches [5]

[5] Sebastian Schwarz et al. 2018. Emerging MPEG standards for point cloud compression. IEEE Journal on Emerging and Selected Topics in Circuits and Systems 9, 1 (2018), 133–148.

Point Cloud Compression

- Place all 2D patches in an **image frame**
- Perform **smoothing** on patch borders
  - Better compression
  - Binary map is needed for reconstruction
- Compress with standard **video codecs**

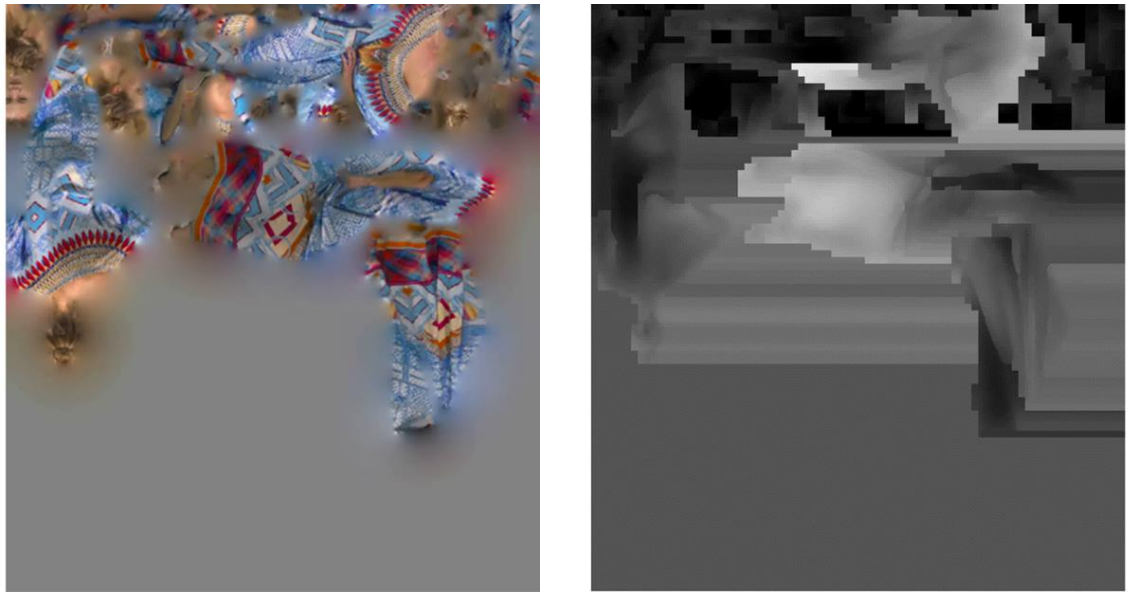


Fig.: Attribute and geometry frame [5]

[5] Sebastian Schwarz et al. 2018. Emerging MPEG standards for point cloud compression. IEEE Journal on Emerging and Selected Topics in Circuits and Systems 9, 1 (2018), 133–148.

View-Adaptive streaming

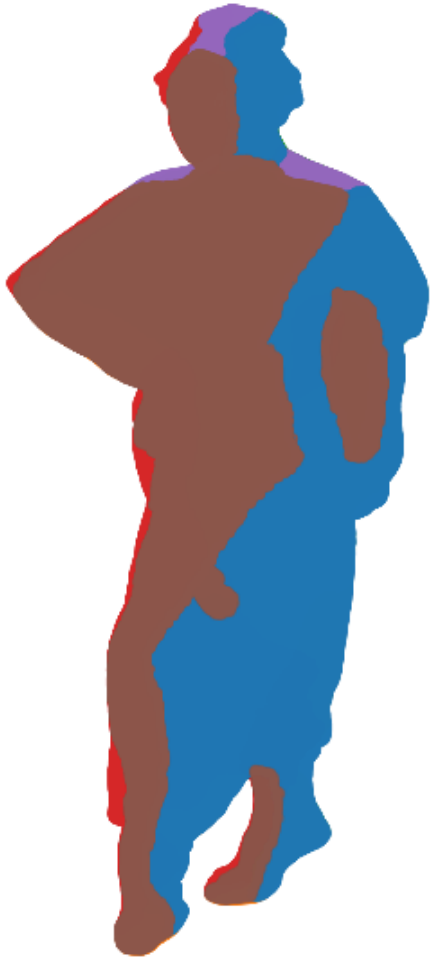
Motivation for view-adaptive streaming

Problem:

- Users only see the part of the point cloud that is facing them.

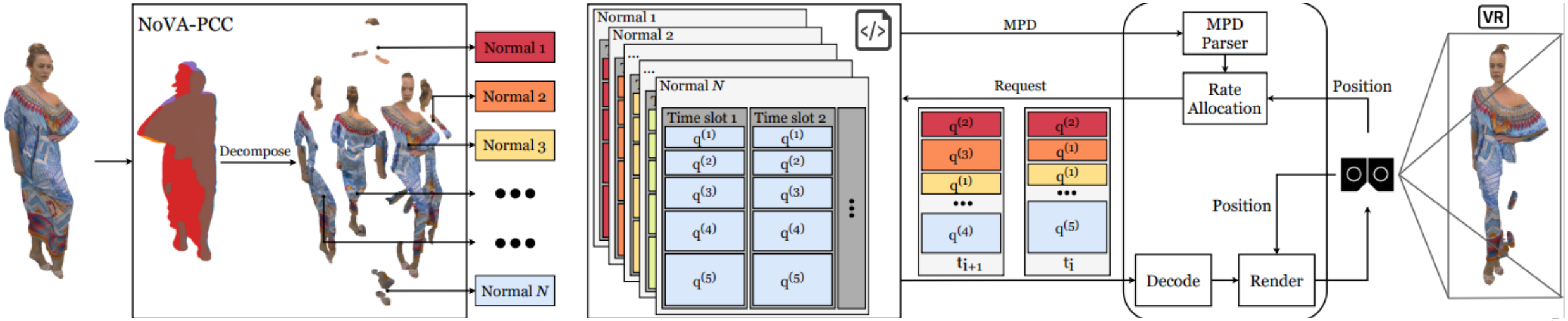
Idea:

- Decompose the Point Cloud to derive independent streams for each view
- Projection direction is a very good indicator for the **visibility** of the patch



Method

- **Modification** of the codec to sort patches into **independent bitstreams**
- Can be streamed with Dynamic Adaptive Streaming (DASH)
  - Server stores different quality representations
  - Client requests **parts of the point cloud** depending on
    - Current **network condition**
    - User **position** and **view direction**



Michael Rudolph and Amr Rizk, 2022, View-Adaptive Streaming of Point Cloud Scenes through combined Decomposition and Video-based Coding, Accepted to the 1st Workshop on Advances in Point Cloud Compression, Processing and Analysis (APCCPA), Lisbon.

Results

Compared to streaming full point clouds, we can utilize available bandwidth more effectively

- **No wasted bandwidth** on **unseen parts** of the Point Cloud
- **Higher quality** for visible parts

But:

- Point Cloud Coding is **not yet real-time**
- Buffering and streaming **delay**
  - User‘s move after requesting a view
  - Future work: **Movement prediction**!

References

These slides are based on:

- Michael Rudolph and Amr Rizk, 2022, View-Adaptive Streaming of Point Cloud Scenes through combined Decomposition and Video-based Coding, Accepted to the 1st Workshop on Advances in Point Cloud Compression, Processing and Analysis (APCCPA), Lisbon.
- Iain E. Richardson. *The H.264 Advanced Video Compression Standard*. 2nd ed., Wiley, 2010.
- Sebastian Schwarz, Marius Preda, Vittorio Baroncini, Madhukar Budagavi, Pablo Cesar, Philip A Chou, Robert A Cohen, Maja Krivokuća, Sébastien Lasserre, Zhu Li, et al. 2018. Emerging MPEG standards for point cloud compression. IEEE Journal on Emerging and Selected Topics in Circuits and Systems 9, 1 (2018), 133–148.
- ISO/IEC MPEG (JTC 1/SC 29/WG 11). 2020. V-PCC Codec Description. Technical Report.