Patch Decoder-Side Depth Estimation in MPEG Immersive Video

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Outline

- MPEG Immersive Video
- Test Model for Immersive Video
- Proposed Method
- Results
- Discussion and Summary

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MPEG Immersive Video (MIV)

- ISO/IEC 23090-12 MPEG Immersive Video (MIV) specification
- Standard for **streaming** and **storage** of immersive content
- Aims to provide the 6 DoF (degrees of freedom) user experience
- MIV does not utilize specialized depth coding tools
- **MIV constraints:** bitrate, pixel rate, number of simultaneous 2D decoders
- Variety of use cases and devices: head mounted displays, light field displays, tablets, laptops…

https://mpeg-miv.org/
https://venturebeat.com/2019/05/05/how-virtual-reality-positional-tracking-works/

MPEG Immersive Video (MIV)

- Input format: Multiview video plus depth (MVD)
- 3D scene is captured by multiple real or virtual cameras
- Depth maps can be computer generated or natural
- Computer generated depth maps are obtained using mathematical models of a 3D scene
- Natural depth maps are obtained by a sensor or some depth estimation algorithm (not perfect)
- Output format: texture and depth atlases
- These video data streams are compressed by 2D video codecs

https://mpeg-miv.org/index.php/content-database-2/

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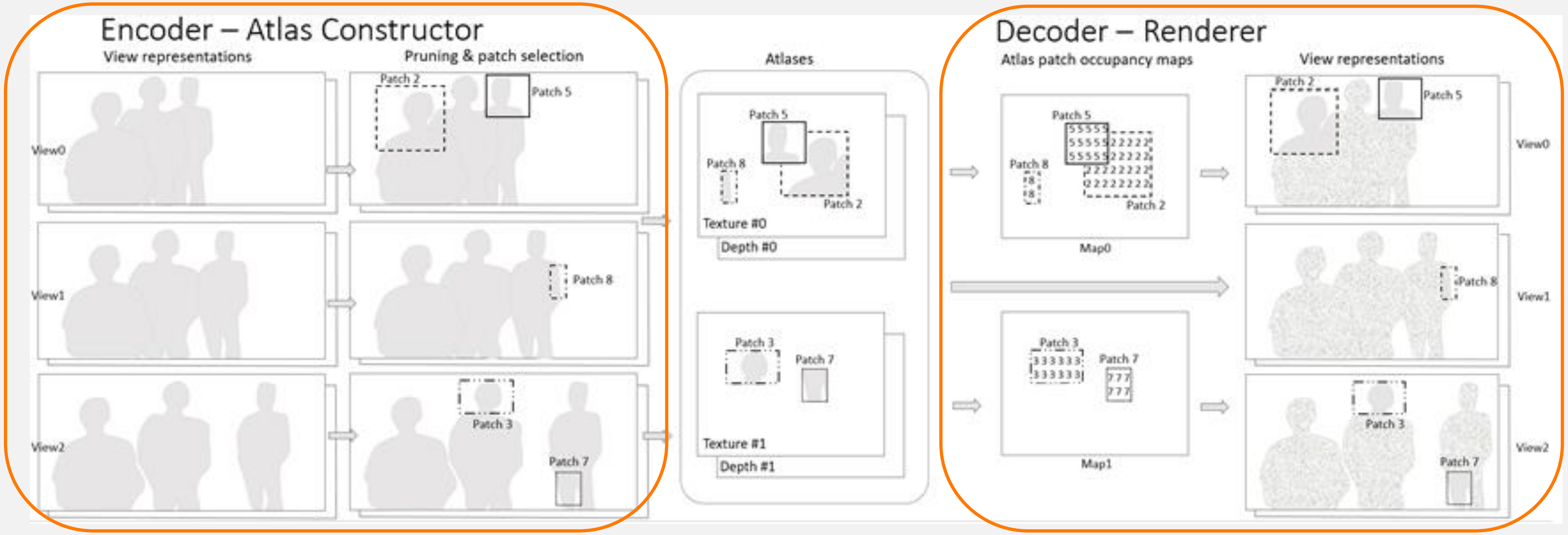
Test Model for Immersive Video (TMIV)



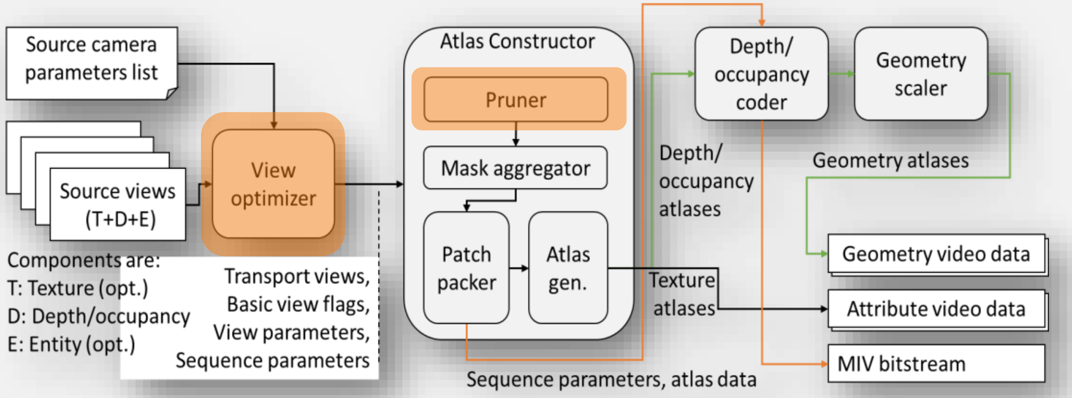
Representing source views using patch atlases

Pruned view reconstruction

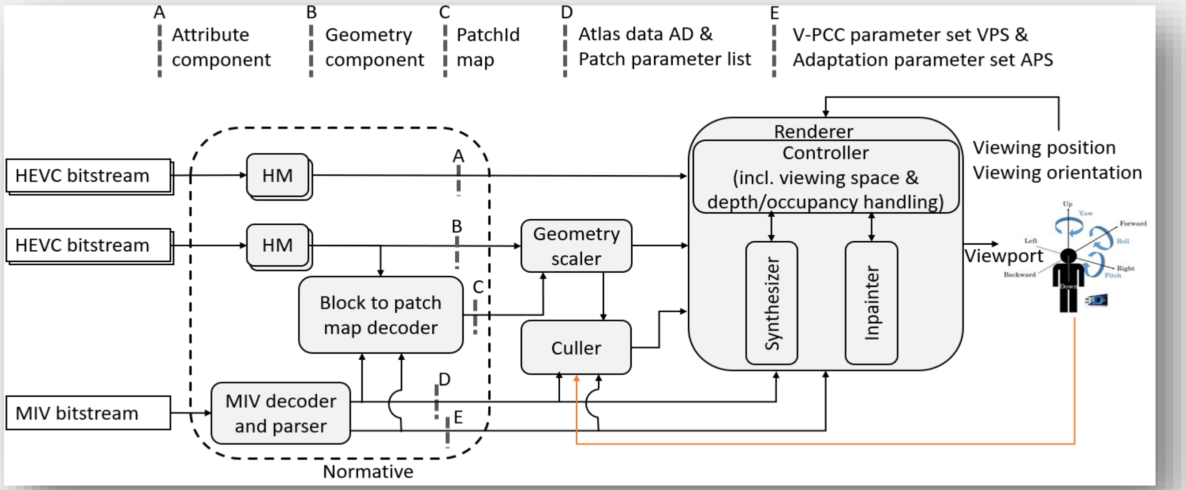
Basel Salahieh, Bart Kroon, Joel Jung, and Marek Domanski,
"Test Model 4 for Immersive Video," ISO/IEC JTC 1/SC29/WG 11 N19002, Feb. 2020.

TMIV Encoder & Decoder

Encoder



Decoder

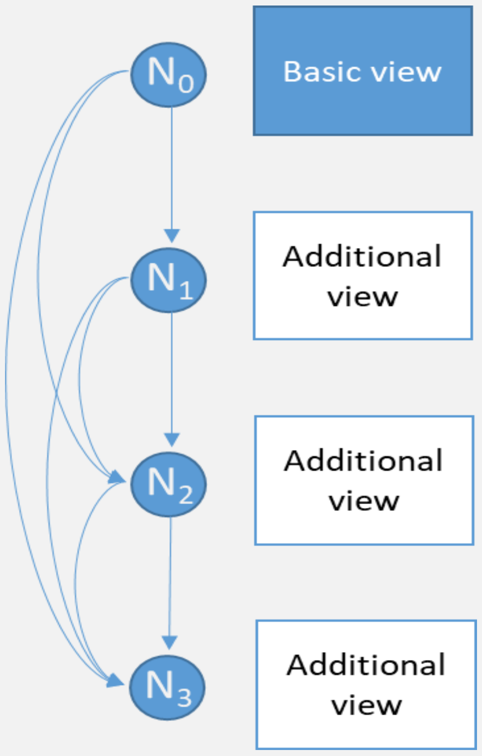


Basel Salahieh, Bart Kroon, Joel Jung, and Marek Domanski,
“Test Model 4 for Immersive Video,”
ISO/IEC JTC 1/SC29/WG 11 N19002,
Feb. 2020.

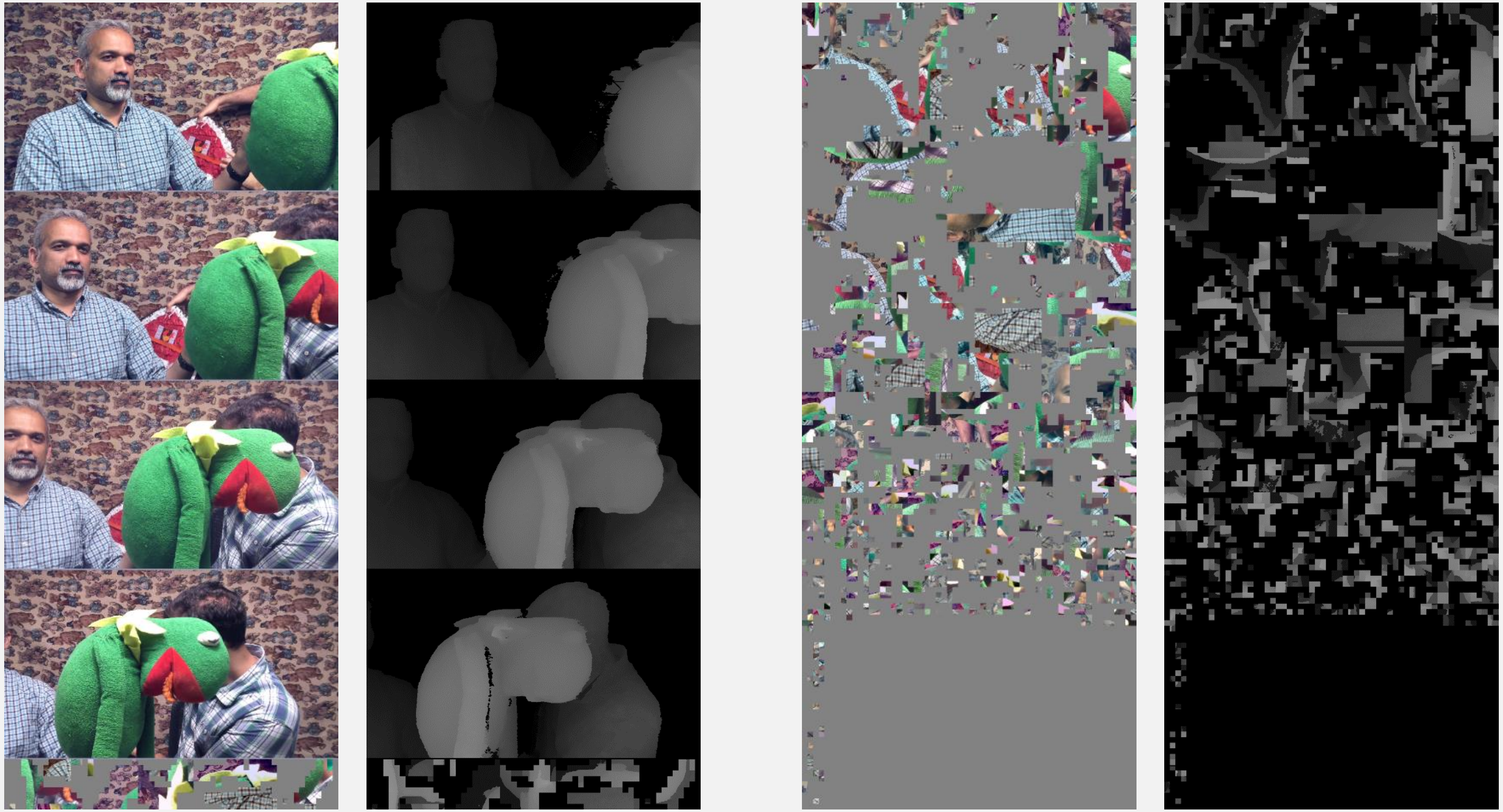
TMIV Pruning

- The pruning process **removes the inter-view redundancy**
- The pruner uses three criteria to determine if a pixel may be pruned:
  - The pixel should be synthesized from the views higher up in the hierarchy
  - The difference between synthesized and source geometry should be less than a threshold
  - The minimum difference between luma of a synthesized pixel and luma of all pixels within a collocated source 3×3 block should be less than a pruning luma threshold
- **Second-pass pruning:** identifying the pixels that are not to be pruned among the pixels that were initially determined to be pruned (global color component differences)
- **Temporal consistency:** the pruning masks are aggregated frame-by-frame and reset at the beginning of each intra period

The pruning graph is created:



TMIV Atlases Demo



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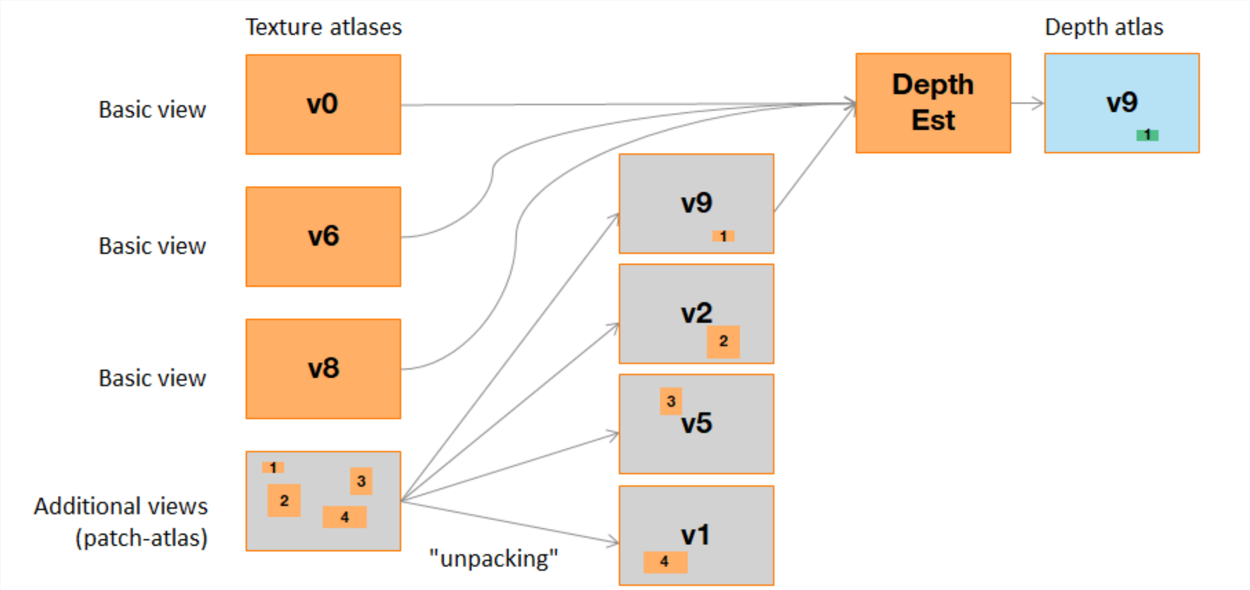
Proposed Method

- **Goal:**
  - Reduce the transmission of the depth data in the context of TMIV
- **Motivation:**
  - MIV constraints (bitrate, pixel rate, number of 2D decoders)
  - Decoder-Side Depth Estimation: transmission of the depth maps is not needed
- **The main idea:**
  - Omit the depth component of some patches that belong to pruned views

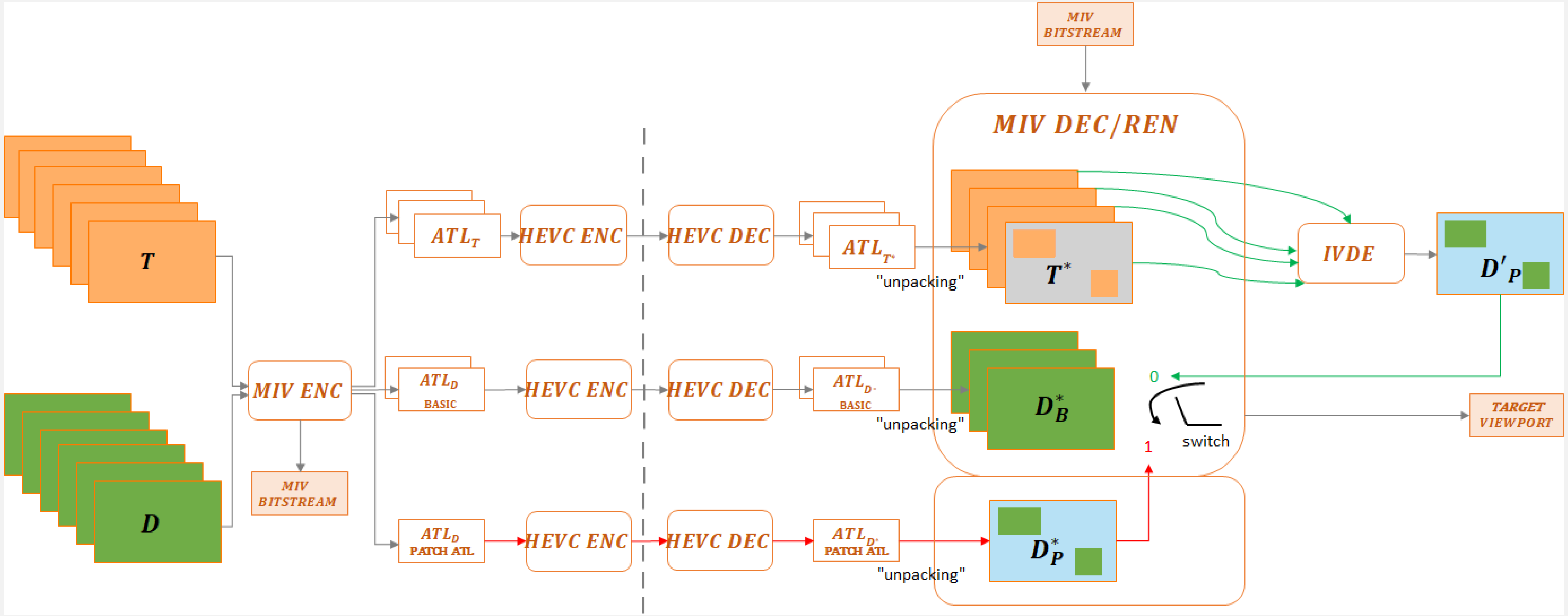
Patrick Garus, Joel Jung, Thomas Maugey, and Christine Guillemot, "Bypassing Depth Maps Transmission For Immersive Video Coding," in *2019 Picture Coding Symposium (PCS)*, Ningbo, China, Nov. 2019, pp. 1–5, IEEE.

Proposed Method

- Use the information available at the decoder side:
- Recover the pruned views: take the patches from atlases and put them to the correct positions in corresponding views using the metadata information
- Estimate the patch-depth using all textures from available basic views and the corresponding pruned view



Proposed Method



Process diagram for anchor (switch = 1) and proposed method (switch = 0) in TMIV framework

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Synthesis Results

Sequence	CTC - High bitrate	CTC - Medium bitrate	Low bitrate
Shaman (CG)	26.34	8.99	0.73
Kitchen (CG)	66.95	30.33	10.72
Painter (NC)	2.75	-7.81	-12.86
Frog (NC)	3.57	-3.49	-8.01
Fencing (NC)	-12.33	-16.02	-18.35
Carpark (NC)	0.26	-8.33	-12.63
Street (NC)	-6.10	-8.67	-10.65
Hall (NC)	-8.53	-9.48	-10.17
Average (all)	**9.11**	**-1.81**	**-7.65**
Average (NC)	**-3.40**	**-8.97**	**-12.11**

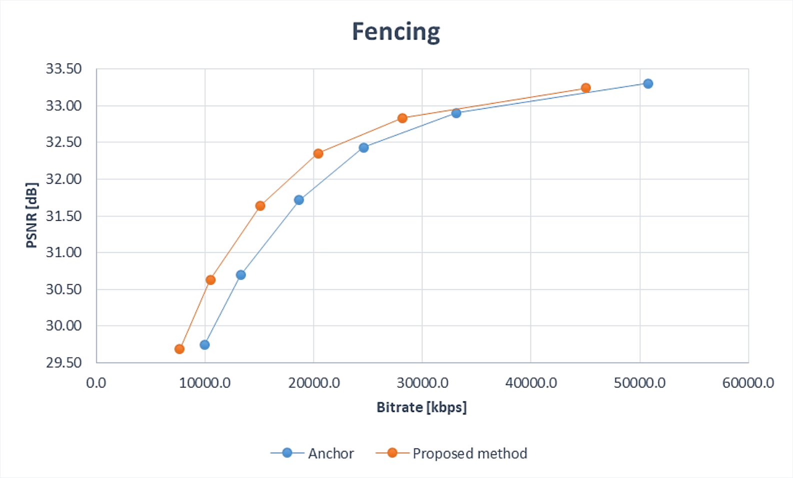
Table 1. BD-rate results per test sequence, in terms of Y-PSNR of synthesized texture [%]. Negative values indicate gains.

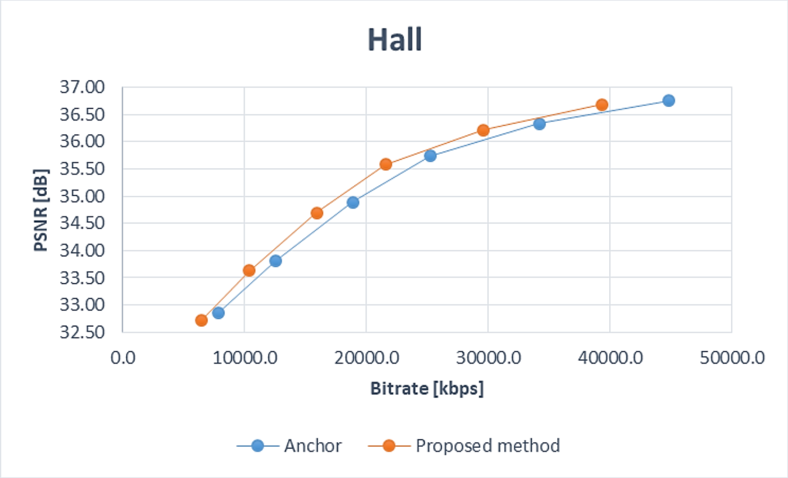
Sequence	VMAF			MS-SSIM		
	High	Med	Low	High	Med	Low
Shaman (CG)	3.44	-6.69	-11.53	20.60	1.54	-6.33
Kitchen (CG)	46.96	12.77	-0.28	20.14	5.08	-3.38
Painter (NC)	-13.04	-18.59	-21.31	-4.21	-13.96	-18.22
Frog (NC)	-3.57	-8.57	-11.13	6.19	-5.49	-10.07
Fencing (NC)	-12.91	-16.87	-19.60	-3.74	-13.29	-17.03
Carpark (NC)	-5.53	-13.14	-16.52	-1.70	-12.27	-16.15
Street (NC)	-7.00	-9.52	-11.32	-6.54	-9.31	-11.29
Hall (NC)	-10.84	-13.35	-15.09	3.93	-5.73	-10.22
Average (all)	**-0.31**	**-9.25**	**-13.35**	**4.33**	**-6.68**	**-11.59**
Average (NC)	**-8.82**	**-13.34**	**-15.83**	**-1.01**	**-10.01**	**-13.83**

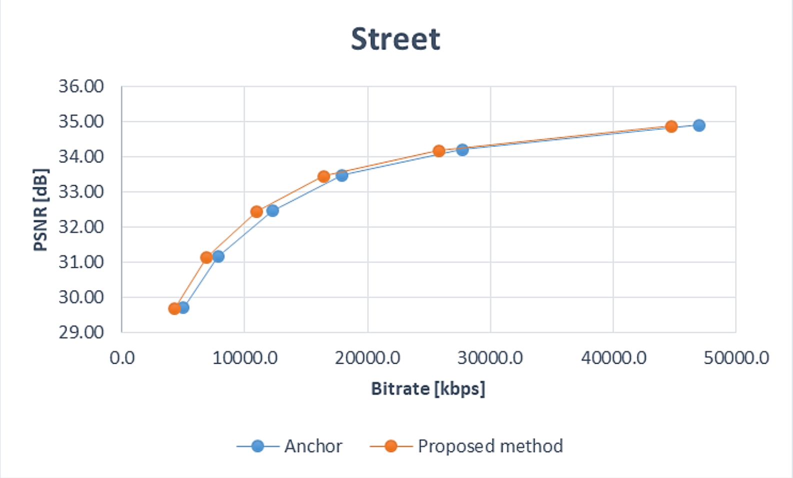
Table 2. BD-rate results per test sequence, in terms of VMAF and MS-SSIM metrics [%]. Negative values indicate gains.

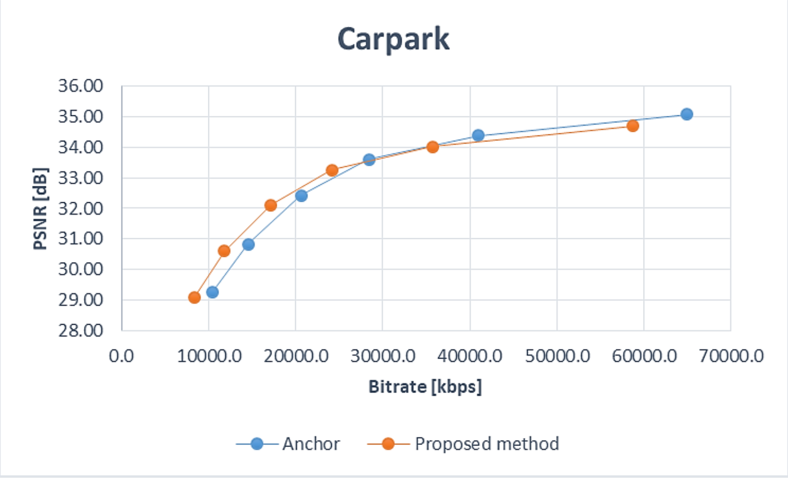
+ pixel rate reduction of 8.3% per sequence

Synthesis Results









Synthesis Results

Anchor

Our proposal

Source

Fencing ~ 10 000 kbps

Marta Milovanović, Félix Henry, Marco Cagnazzo and Joël Jung, "Patch Decoder-Side Depth Estimation in MPEG Immersive Video," in *2021 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, Toronto, ON, Canada, June 2021, pp. 1945-1949, IEEE.

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Discussion and Summary

- **We demonstrate:**
  - Gains measured with objective metrics for natural content:
  - 3.4%, 9.0%, 12.1% Y-PSNR BD-rate gains on high, medium, and low bitrate, respectively
  - Preserved perceptual quality as measured with MS-SSIM and VMAF
  - Pixel rate reduction of 8.3% per sequence
- For CG content, comparison is done with the Blender ground-truth depths!
- **Limitations:**
  - Pruning strategy
  - Local depth estimation on very small patch areas
  - Depth estimation from compressed textures

Discussion and Summary

- **Future work:**
  - Adapt the **pruning strategy** to ensure a reliable patch depth estimation at the decoder side
  - Current tests involve patch level decisions based on depth estimation quality
  - This approach gives new possibilities, *e.g.* sending more textures, instead of depths

Thank you for your attention !

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?

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