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Source	**Poznań University of Technology (PUT), Poznań, Poland** **Electronics and Telecommunications Research Institute (ETRI), Daejeon, Republic of Korea**
Status	**Input**
Title	**CE3-related: Color-based patch splitting and sorting**
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1 Introduction

This document presents a technical description of PUT/ETRI experiments on the atlas preparation (Immersive Video CE3.1 and CE3.2). In the proposed solution, patches are being packed into atlases basing on their texture.

2 Overview of the proposed technique

In the experiments, we have tested several techniques of color-based patch analysis within atlas constructor.

In TMIV4, all patches are being created basing on their shape (irregular clusters are split) and inserted into atlases based on their size (largest first). We decided to additionally analyze their texture.

2.1 Color-based patch splitting (CE3.1)

The first proposed technique is color-based patch splitting. If a cluster contains vertical or horizontal edge in luma (or depth), it is being split into two parts, along that edge.

If used alone, it cannot provide any gains because of creating additional patch thus introducing additional edges at patch boundaries. However, we used this tool in CE3.2 experiment.

2.2 Color-based patch sorting (CE3.2)

In TMIV4, an atlas is created by copying clusters from the clusterToPack list. All patches in the list are sorted according to their area in the descending order. We propose to sort the clusterToPack list by the mean luma (or depth) of the cluster. In this approach, the brightest patches are inserted first, regardless of their size (with the exception for basicViews, because they are inserted firstly).

When patches are big and heterogenous, such sorting does not work efficiently, but when combined with color-based patch splitting, the efficiency of color-based sorting increases.

2.3 Color-based patch packing (CE3-related)

The idea of the color-based patch packing method is to group similar patches while maintaining the area-based patch sorting (largest patches are placed in the atlases firstly).

For each patch, the same algorithm is performed. At first, it is checked, whether the patch can be stuck to patches already placed in the atlas (occupied-space patch packing). If not, it is placed in some non-occupied region of the atlas (free-space patch packing).

2.3.1 Occupied-space patch packing

The position, rotation and flip of each patch are chosen to maximize the similarity of the common edge between patches already in the atlas and the current patch.

Each patch can be placed in any position within an alignment grid, however, two conditions should be met:

1. the area under the whole patch should be unoccupied,
2. patch placed in such positions should have at least 32-pixel wide (4× alignment) common edge with patches already packed.

If both requirements are met, different rotations and flips (8 in total, Fig. 1) are being tried. In all the cases the mean luma error along the whole edge is being calculated.

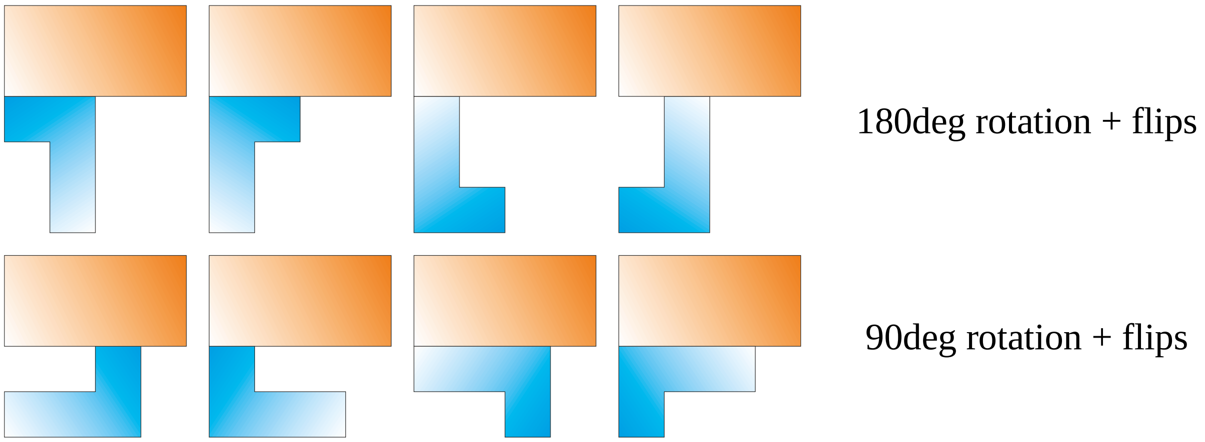

Fig. 1. Edge similarity analysis within occupied-space patch packing (orange: patch already in atlas, blue: patch being currently packed)

The same operations are performed for any possible patch position to find the optimal position, rotation and flip of the patch.

In the end, the patch is being placed in the optimal position, however, only if the mean luma error for the optimal placement is smaller than a threshold (in the experiment we set this threshold to 40 for 10-bps texture). If not, a patch is placed in the free space. The luma comparison is performed for texture from the first frame of the GOP.

Using the proposed approach, similar patches are placed side-by-side. However, due to the temporal redundancy removal technique in TMIV4, some blocks of the patch are empty. If such an empty area is small enough (up to 2×2 alignment blocks), we fill the texture using the weighted average.

2.3.2 Free-space patch packing

In order to ensure, that area around each patch is large enough for sticking similar patches, we decided to change the patch positioning order (Fig. 2). In the proposed method, this order decreases recursively, allowing to preserve large spaces between larges patches.

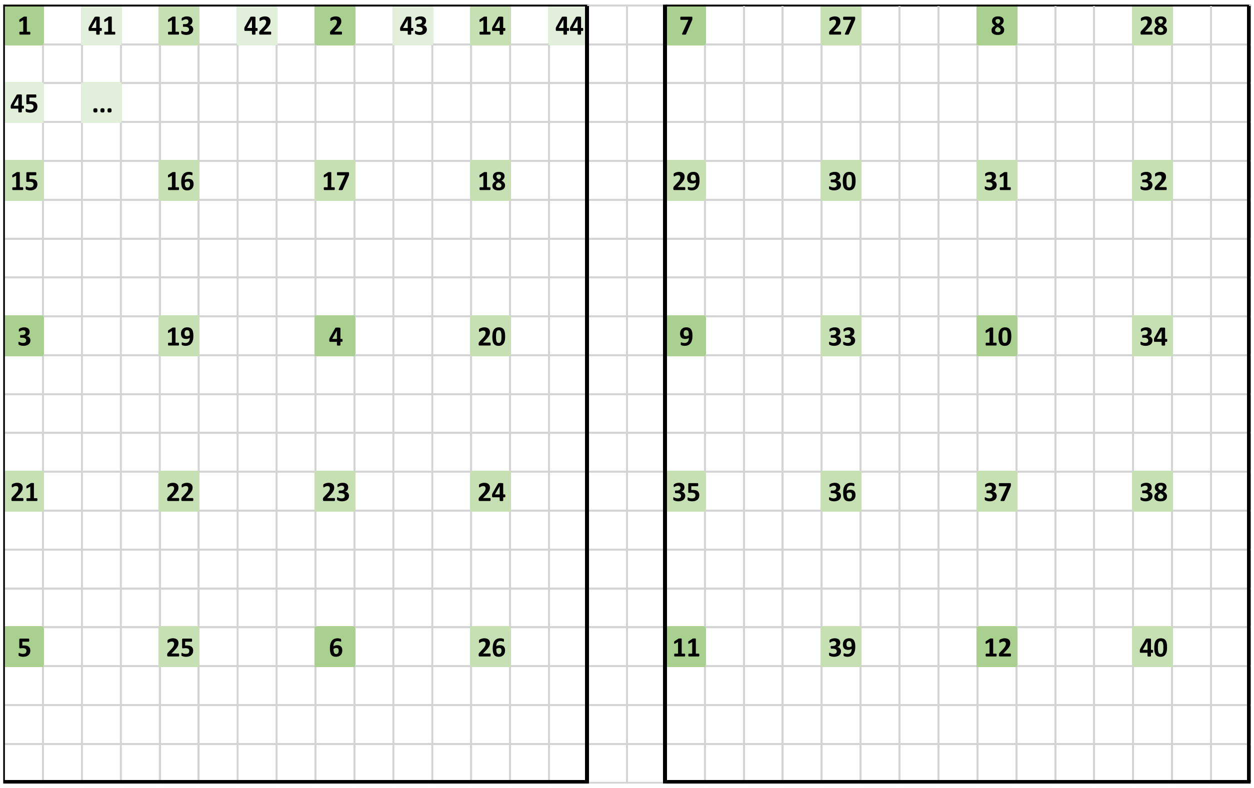

Fig. 2. Free-space patch positioning order in two-atlas case

The very first patch (i.e. the basic view) is being placed in the top-left corner (position 1 in Fig. 2).

For every other patch (if it did not fit to patches already packed) it is tested, whether it has enough free space at the position 2, 3, 4, etc. The patch will be placed in the first free position. It should be noted, that for each position two patch rotations are being checked: no rotation and XY swap.

3 Experimental results

The results for color-based patch packing were compared with A97 anchor. Due to lack of time, techniques 2.1 and 2.2 were compared to A17 only.

3.1 Color-based patch splitting

Fig. 3 presents the example of depth atlas created with and without color-based patch splitting. In this example, patches were split according to the depth component.

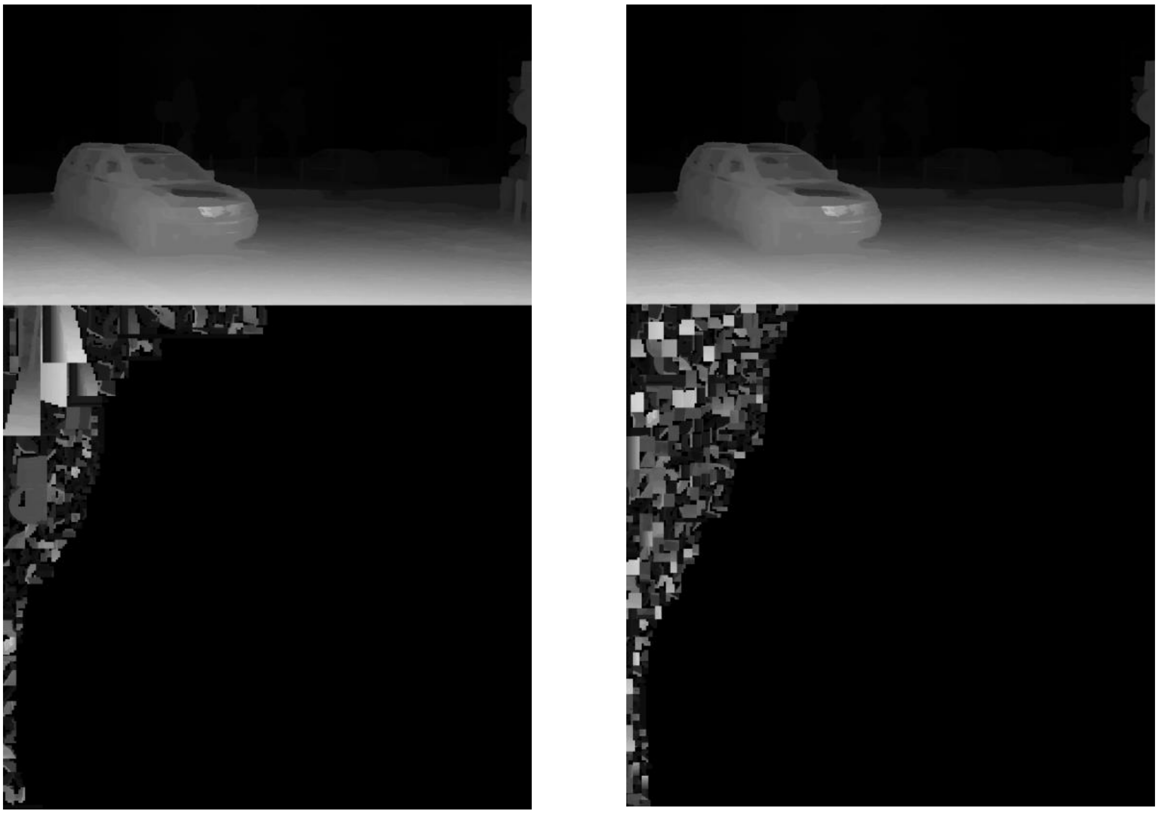

Fig. 3. Anchor vs. color-based splitting

3.2 Color-based patch sorting

Figs. 4 an 5 presents the comparison of anchor depth atlas and atlases created using proposed techniques. As previously, all operations were performed by analyzing depth component.

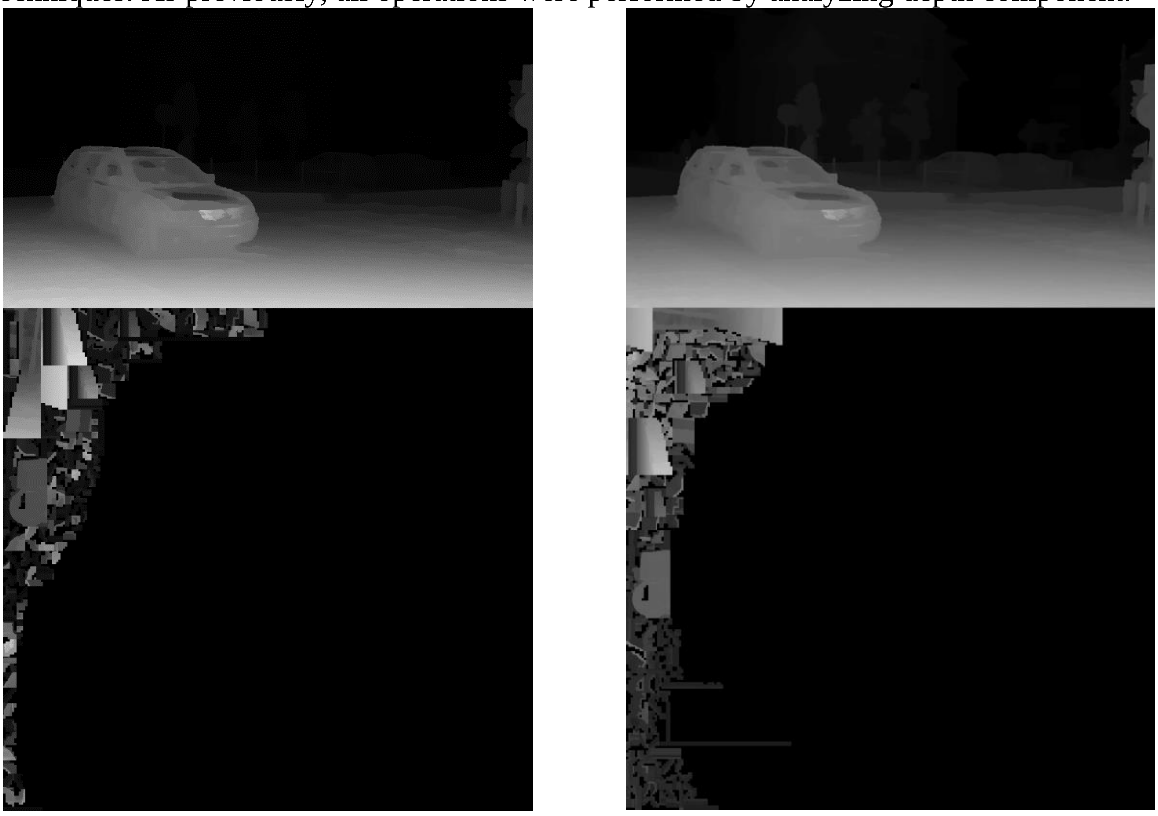

Fig. 4. Anchor vs. sorting

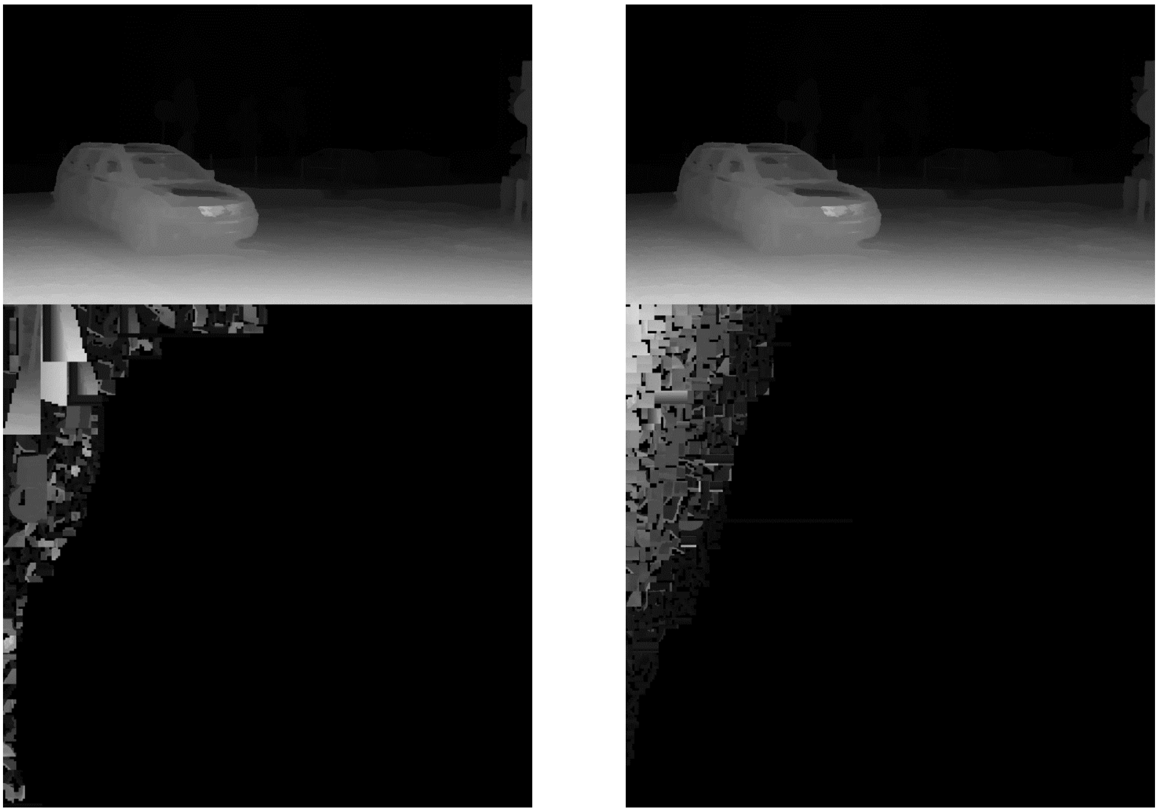

Fig. 5. Anchor vs. splitting+sorting (bottom row)

Table below contains results for combined splitting and sorting of patches according to their luma.

Proposal vs. Low/High-bitrate Anchors

Test class	Sequence	Anchor (rf)	High-BR BD rate Y-PSNR	Low-BR BD rate Y-PSNR	Max delta Y-PSNR	High-BR BD rate VMAF	Low-BR BD rate VMAF	High-BR BD rate IV-PSNR	Low-BR BD rate IV-PSNR	Pixel rate ratio
CG	ClassroomVideo	AA17 (MIV)	0.6%	-0.8%	3.28	#ARG!	#ARG!	1.4%	0.8%	0.59
	TechnicolorMuseum	BA17 (MIV)	4.7%	4.8%	13.77	#ARG!	#ARG!	3.5%	4.0%	0.59
	InterdigitalHijack	CA17 (MIV)	6.5%	3.4%	12.24	#ARG!	#ARG!	3.5%	2.5%	0.59
	OrangeKitchen	JA17 (MIV)	9.2%	6.9%	14.16	#ARG!	#ARG!	8.3%	6.9%	0.70
	NokiaChess (*)	NA17 (MIV)	0.2%	1.9%	15.40	#ARG!	#ARG!	-0.6%	-0.6%	0.59
		MIV	5.2%	3.6%	14.16	#ARG!	#ARG!	4.2%	3.5%	
NC	TechnicolorPainter	DA17 (MIV)	1.0%	0.7%	7.93	#ARG!	#ARG!	0.0%	0.0%	0.59
	IntelFrog	EA17 (MIV)	2.0%	2.2%	13.05	#ARG!	#ARG!	2.0%	2.2%	0.70
	PoznanFencing	LA17 (MIV)	1.4%	0.6%	13.93	#ARG!	#ARG!	1.0%	1.0%	0.49
	PoznanCarpark (*)	PA17 (MIV)	5.5%	5.3%	12.15	#ARG!	#ARG!	6.7%	6.9%	0.49
	PoznanHall (*)	TA17 (MIV)	1.2%	0.5%	17.31	#ARG!	#ARG!	1.1%	0.7%	0.49
	PoznanStreet (*)	UA17 (MIV)	2.4%	2.6%	10.83	#ARG!	#ARG!	2.0%	2.3%	0.49
		MIV	1.4%	1.2%	13.93	#ARG!	#ARG!	1.0%	1.1%	
All		MIV	3.6%	2.5%	11.20	#ARG!	#ARG!	2.8%	2.5%	

The results show, that anchor slightly outperforms proposed technique, especially for CG content. The main reason for worse performance is introducing of many edges – not only because of color-based splitting but also because of the changed order of atlas packing. When large clusters wait for their placement and the atlas is being filled by smaller ones, they do not have enough place to be inserted integrally thus have to be split.

3.3 Color-based patch packing

Proposal vs. Low/High-bitrate Anchors

Test class	Sequence	Anchor (ff)	High-BR BD rate Y-PSNR	Low-BR BD rate Y-PSNR	Max delta Y-PSNR	High-BR BD rate VMAF	Low-BR BD rate VMAF	High-BR BD rate IV-PSNR	Low-BR BD rate IV-PSNR	Pixel rate ratio
CG	ClassroomVideo	AA97 (MIV)	2.9%	2.3%	3.36	2.3%	2.2%	2.3%	2.3%	0.59
	TechnicolorMuseum	BA97 (MIV)	0.9%	1.3%	13.99	1.2%	1.4%	1.0%	1.4%	0.59
	InterdigitalHijack	CA97 (MIV)	0.6%	-0.5%	12.47	1.3%	0.0%	1.9%	0.7%	0.59
	OrangeKitchen	JA97 (MIV)	6.0%	4.1%	14.39	5.4%	4.6%	5.4%	3.9%	0.70
	NokiaChess (*)	NA97 (MIV)	2.8%	1.9%	16.98	-0.3%	-0.5%	1.5%	1.1%	0.59
		All MIV Anchor	2.6%	1.8%	14.39	2.6%	2.1%	2.7%	2.1%	

Test class	Sequence	Anchor (ff)	High-BR BD rate Y-PSNR	Low-BR BD rate Y-PSNR	Max delta Y-PSNR	High-BR BD rate VMAF	Low-BR BD rate VMAF	High-BR BD rate IV-PSNR	Low-BR BD rate IV-PSNR	Pixel rate ratio
NC	TechnicolorPainter	DA97 (MIV)	-0.7%	-1.6%	8.29	-0.9%	-1.6%	-0.7%	-1.4%	0.71
	IntelFrog	EA97 (MIV)	0.5%	0.8%	11.33	0.5%	0.8%	0.9%	1.0%	0.70
	PoznanFencing	LA97 (MIV)	1.4%	0.9%	13.85	0.5%	0.8%	0.8%	0.6%	0.49
	PoznanCarpark (*)	PA97 (MIV)	1.3%	0.9%	12.06	1.5%	1.2%	1.4%	1.2%	0.49
	PoznanHall (*)	TA97 (MIV)	0.0%	-0.4%	14.11	0.5%	0.1%	0.2%	-0.1%	0.49
	PoznanStreet (*)	UA97 (MIV)	1.1%	1.0%	10.34	1.2%	1.2%	1.2%	1.2%	0.49
		All MIV Anchor	0.4%	0.1%	13.85	0.0%	0.0%	0.4%	0.1%	

Test class	Sequence	Anchor (ff)	High-BR BD rate Y-PSNR	Low-BR BD rate Y-PSNR	Max delta Y-PSNR	High-BR BD rate VMAF	Low-BR BD rate VMAF	High-BR BD rate IV-PSNR	Low-BR BD rate IV-PSNR	
All		**All MIV Anchor**	1.7%	1.1%	11.10	1.5%	1.2%	1.7%	1.2%	

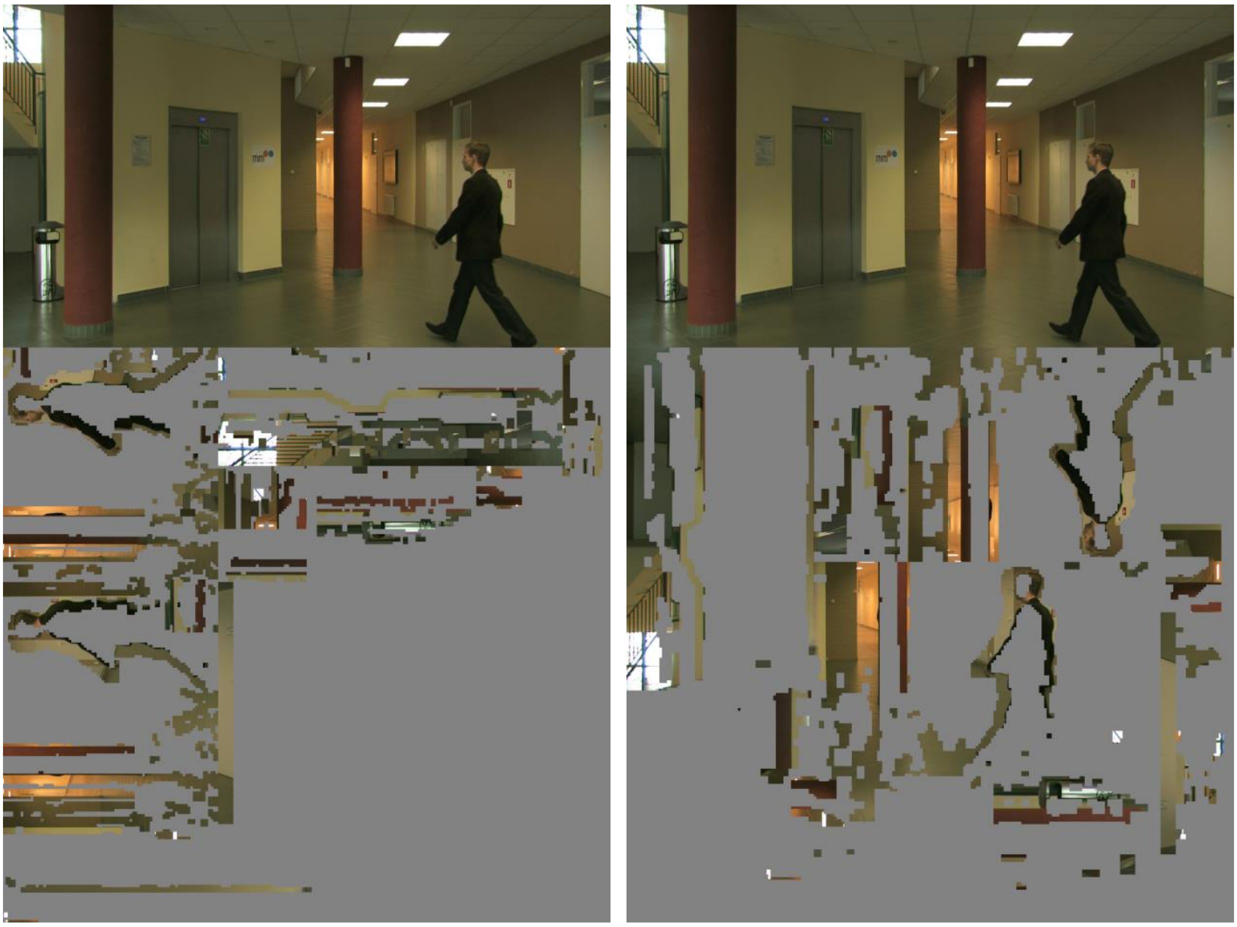

Fig. 6. Anchor vs. proposed, ST: Group 1, frame 64

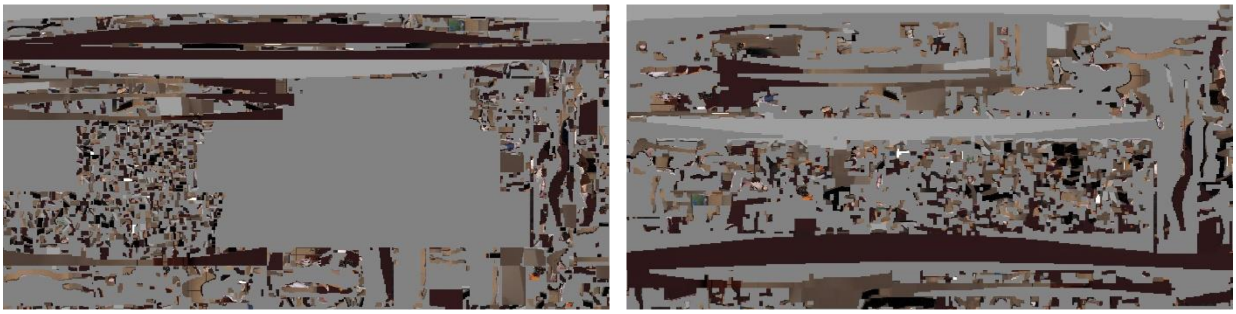

Fig. 7. Anchor vs. proposed, SC: Atlas 1, frame 5

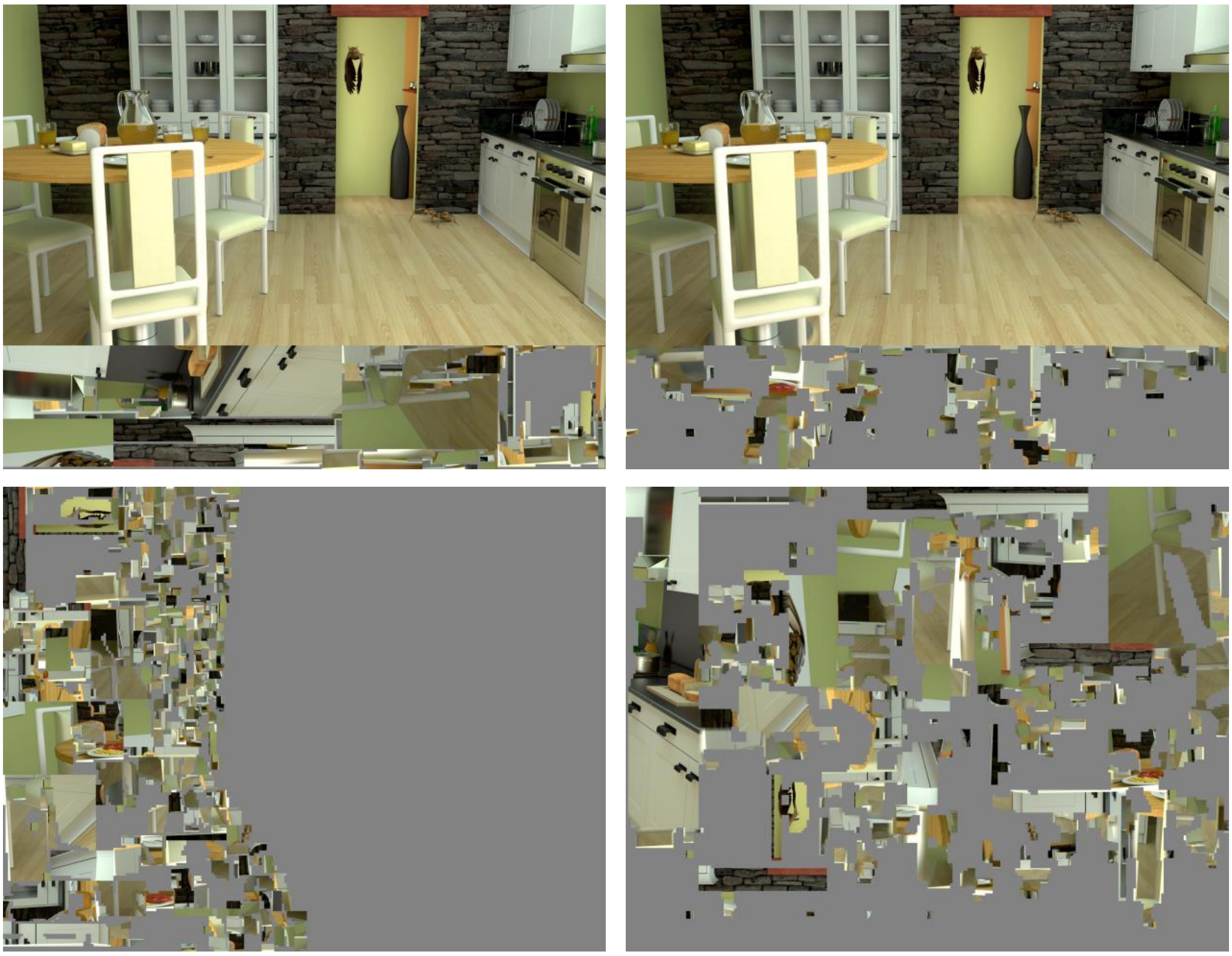

Fig. 8. Anchor vs. proposed, SJ: Group 2, frame 0

4 Acknowledgement

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5 Recommendations

We recommend to continue the Core Experiment 3.

6 References

[1] Renaud Doré, "Description of Immersive Video Core Experiments 3 (Atlas preparation)", ISO/IEC JTC1/SC29/WG11 MPEG/N18934, October 2019, Geneva, CH.