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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	**Color correction in TMIV**
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1 Introduction

This document presents a technical description of the PUT/ETRI experiment on color correction within TMIV. In the proposed solution, color characteristics of patches from different input views are aligned in order to provide better video compression and higher inter-view consistency. At the decoder side, the global luma offset between input views (which is sent within metadata) is analyzed to recover the natural brightness of the scene in the viewport.

2 Proposed technique

In the proposed technique, color characteristics of patches from different input views is aligned to color characteristics of the reference view. In the first step, the reference view is chosen. The reference view is the one captured by a camera closest to the center of the camera rig.

Then, all the pixels from other views are reprojected to the reference view. For each pixel, the difference between pixel's value and value of corresponding pixel in the reference view is calculated (separately for luma and both chromas).

During packing operation, these differences are averaged within entire patch. Then, all the pixels in the patch are modified by subtracting the mean value for all the color components.

In order to restore initial, global brightness of the scene (which could be different in various cameras, e.g. because of different lighting conditions or non-lambertian reflections), the color (luma) difference between reference view and each other view are also averaged over entire view. This information have to be sent within metadata.

At the decoder side, luma of each pixel of the rendered view is modified by adding the offset o. This offset is calculated as a weighted average:

$$o = \frac{\sum_{v=0}^{V}\left(\frac{o_v}{d_v^2}\right)}{\sum_{v=0}^{V}\left(\frac{1}{d_v^2}\right)},$$

where V is the number of views, o_v the offset of v-th view and d_v^2 is the squared distance between a camera which captures rendered view and camera capturing v-th view.

3 Experimental results

Table 1. Objective quality evaluation.

Mandatory content - Proposal vs. Low/High-bitrate Anchors

Sequence		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
ClassroomVideo	SA	-1.5%	-0.7%	1.97	-0.7%	-0.3%	-0.2%	-0.1%
Museum	SB	-0.1%	-0.0%	16.71	-0.1%	-0.1%	-0.0%	-0.0%
Hijack	SC	-0.6%	-0.2%	9.80	0.0%	-0.0%	-0.2%	-0.1%
Chess	SN	-0.3%	-0.2%	16.62	-0.1%	-0.1%	-0.0%	-0.1%
Kitchen	SJ	0.9%	0.3%	16.82	0.2%	0.0%	0.8%	0.4%
Painter	SD	-1.8%	-0.8%	8.23	-0.2%	-0.2%	-0.4%	-0.2%
Frog	SE	0.0%	0.0%	6.00	0.0%	-0.0%	0.0%	0.0%
Carpark	SP	0.1%	0.1%	7.51	0.1%	-0.0%	0.1%	-0.1%
MIV		**-0.4%**	**-0.2%**	**10.46**	**-0.1%**	**-0.1%**	**0.0%**	**-0.0%**

Optional content - Proposal vs. Low/High-bitrate Anchors

Fencing	SL	-3.1%	-1.2%	12.93	-0.2%	0.0%	-2.0%	-0.7%
Hall	ST	-7.6%	-3.8%	12.93	-0.2%	-0.6%	-0.8%	-0.4%
Street	SU	0.2%	0.1%	10.58	0.1%	0.0%	0.1%	0.0%
Group	SR	-0.0%	-0.0%	11.88	0.3%	0.1%	-0.0%	-0.1%
Fan	SO	0.1%	0.1%	9.05	-0.0%	-0.0%	0.0%	0.0%
MIV		**-2.1%**	**-1.0%**	**11.47**	**-0.0%**	**-0.1%**	**-0.5%**	**-0.2%**

As results from Table 1 show, the proposal provides the highest gain for challenging natural content – SL and ST sequences. This is the result of color inconsistencies that occur between input views. Therefore, when the proposal is used, the synthesized views are more intra-view consistent – see the example for SL shown below.

For most other sequences there are also BD-rate gains, even for CGI content. The gain mostly visible for Y-PSNR, what shows that synthesized views are more pixel-wise similar to input views, with a very small amount with additional metadata required to be sent.

	Deltas				
View	Y-PSNR	U-PSNR	V-PSNR	VMAF	IV-PSNR
v0	0.00	0.00	0.00	0.00	0.00
	0.00	0.01	0.03	-0.03	0.00
	0.00	0.02	-0.04	0.01	0.00
	0.00	0.02	-0.12	0.13	-0.01
	-0.01	-0.10	0.11	0.22	-0.01
v1	0.00	-0.01	-0.01	-0.05	-0.02
	0.00	0.00	0.04	-0.06	-0.01
	0.00	-0.01	0.00	-0.04	-0.02
	-0.02	0.03	-0.13	-0.20	-0.04
	-0.04	-0.05	0.10	-0.01	-0.03
v2	0.00	0.00	-0.01	-0.02	0.00
	0.00	0.03	0.03	-0.01	0.01
	0.00	-0.06	0.05	-0.05	0.00
	0.00	0.02	0.00	0.12	-0.01
	-0.03	-0.10	-0.03	-0.41	-0.04
v3	0.00	0.00	-0.01	-0.01	0.00
	0.00	0.00	0.00	-0.01	-0.01
	0.00	-0.03	0.01	-0.01	0.00
	-0.01	-0.01	-0.03	-0.09	-0.02
	-0.04	-0.03	-0.10	-0.41	-0.03
v4	0.01	0.00	-0.01	0.02	0.02
	0.01	0.00	0.01	0.01	0.02
	0.01	0.00	0.03	-0.02	0.02
	0.02	0.03	-0.12	-0.10	0.00
	0.02	0.06	-0.13	-0.24	0.02
v5	0.03	0.01	0.00	0.08	0.07
	0.03	-0.01	-0.01	0.04	0.06
	0.03	-0.02	0.00	0.06	0.05
	0.03	0.02	-0.08	-0.10	0.03
	0.04	0.02	-0.15	0.09	0.01
v6	0.00	0.00	-0.01	0.01	0.01
	0.00	-0.01	0.00	-0.01	0.00
	-0.01	0.01	0.00	0.03	-0.01
	0.01	0.00	-0.01	-0.13	0.01
	0.02	-0.03	0.01	0.05	-0.02
v7	0.01	0.01	0.00	-0.02	-0.03
	0.01	-0.02	0.01	-0.04	-0.04
	0.02	0.00	0.00	0.00	-0.04
	0.02	-0.02	-0.11	0.03	-0.02
	0.02	0.10	-0.01	-0.11	-0.03
v8	0.68	-0.01	-0.02	0.34	0.65
	0.64	0.02	-0.02	0.33	0.61
	0.47	0.00	0.00	0.25	0.50
	0.23	0.03	-0.04	0.20	0.29
	0.13	-0.23	-0.14	0.63	0.11
v9	0.02	0.01	0.00	0.00	0.00
	0.01	0.00	-0.01	-0.03	0.02
	0.01	0.01	0.00	-0.03	0.00
	0.01	-0.12	0.06	-0.07	-0.02
	0.04	0.03	-0.03	0.53	0.06

v8 anchor:

v8 proposal:

(the contrast of views was increased)

4 Syntax and semantics

4.1 Modify §7.3.6.13.1:

common_atlas_frame_rbsp( ) {	**Descriptor**
caf_atlas_adaptation_parameter_set_id	ue(v)
caf_frm_order_cnt_lsb	u(v)
caf_miv_view_params_list_update_mode	u(3)
if(caf_miv_view_params_list_update_mode == VPL_INITLIST)	
miv_view_params_list( )	
else if(caf_miv_view_params_list_update_mode == VPL_UPD_EXT)	
miv_view_params_update_extrinsics( )	
else if(caf_miv_view_params_list_update_mode == VPL_UPD_INT)	
miv_view_params_update_intrinsics( )	

else if(caf_miv_view_params_list_update_mode == VPL_UPD_DQ)	
miv_view_params_update_depth_quantization( )	
else if(caf_miv_view_params_list_update_mode == VPL_UPD_CC)	
miv_view_params_update_color_characteristics( )	
else if(caf_miv_view_params_list_update_mode == VPL_ALL) {	
miv_view_params_update_extrinsics( )	
miv_view_params_update_intrinsics( )	
miv_view_params_update_depth_quantization( )	
miv_view_params_update_color_characteristics( )	
}	
caf_extension_flag	u(1)
if(caf_extension_flag)	
caf_extension_8bits	u(6)
if(caf_extension_8bits)	
while(more_rbsp_data( ))	
caf_extension_data_flag	u(1)
rbsp_trailing_bits( )	
}	

4.2 Add §7.3.6.13.10:

color_characteristics(v) {	**Descriptor**
cc_offset_Y[v]	u(16)
}	

4.3 Modify §7.4.6.13.1:

Table 4-1 – Updating modes for view parameters list update

caf_miv_view_params_list_update_mode	**Identifier**	**Description**
0	VPL_INITLIST	a new initialized view parameters list is present
1	VPL_UPD_EXT	extrinsic parameters are updated for sub-set of existing views
2	VPL_UPD_INT	intrinsic parameters are updated for sub-set of existing views
3	VPL_UPD_DQ	depth quantization parameters are updated for a sub-set of existing views
4	VPL_UPD_CC	color characteristics parameters are updated for a sub-set of existing views

5	VPL_ALL	extrinsic, intrinsic, ~~and~~ depth quantization and color characteristics parameters are updated for a sub-set of existing views
6 .. 7	Reserved	Reserved for future use by ISO/EC

4.4 Add §7.4.6.13.10:

cc_offset_Y[v] specifies the global offset between average luma component of reference view and v-th view.

5 Acknowledgement

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6 Recommendations

We recommend:

- to include proposed technique into TMIV7,
- to adopt proposed syntax and semantics.

7 References

[N18069] "WS-PSNR Software Manual"
ISO/IEC JTC1/SC29/WG11 MPEG/N19495, October 2018, Macao, China.

[N19495] "Software manual of IV-PSNR for Immersive Video"
ISO/IEC JTC1/SC29/WG11 MPEG/N19495, July 2020, Online.