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Author Ohji Nakagami, Satoru Kuma

Abstract

This document provides G-PCC Core Experiment 13.15 report on LoD generation for the spatial scalability.

1 Introduction

The goal of Core Experiment 13.15 is to evaluate the Level of Details generation method for the lifting scheme for the spatial scalability.
The performance of the technique [2] is evaluated in the scope of the CE 13.15, in terms of RD performance and computational complexity. The performance is also evaluated in the simultaneous coding scenario.

2 Mandates

The mandates for CE are as follows:

1. To study the coding performance (e.g. the End-to-End BD Total Rate) compared to the anchor algorithm
2. To study the complexity (e.g. decoding time) of the proposed method for the spatial scalability
3. To evaluate the visual quality for the lower resolution point cloud with the common rendering software

3 Participants

Participant	*Contact*	*Email*	*Type*
Sony	Ohji Nakagami Satrou Kuma	ohji.nakagami@sony.com satoru.kuma@sony.com	P
Apple	Khaled Mammou	kmammou@apple.com	P/C
Hanyang University	Euee S. Jang	esjang@hanyang.ac.kr	C

LG Electronics Inc.	Sejin Oh	sjin.oh@lge.com	C
Panasonic	Toshiyasu Sugio	sugio.toshiyasu@jp.panasonic.com	C

(P=proponent, C=crosss checker)

4 CE activity

4.1 Code preparation

The proposal is implemented on top of tmc13-version 6.0 software. The code is submitted to MPEG Git on 31 May 2019. A tool for the simulcast anchor 2 (See 5.3) is provided as patch 'subsampleLod123.patch' in the CE branch.

4.2 Cross check activity

The cross check is conducted as described in Table 4-1.

Table 4-1 Test conditions

Test	Proponent	Crosschecker
Single coding anchor	CTC	
Simulcast anchor 1 quantization based approach	Sony	Hanyang University
Simulcast anchor 2 sub-sampled based approach	Sony, Apple	Panasonic
CE13.15 Proposal	Sony	LG

5 Test setting

5.1 Single coding anchor

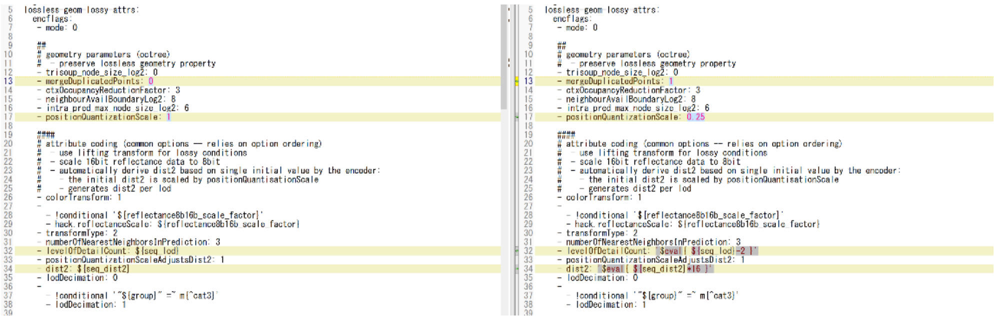
Same as CTC.

5.2 Simulcast anchor 1: quantization based approach

Three resolution are encoded using the anchor tmc13-version 6.0 software.

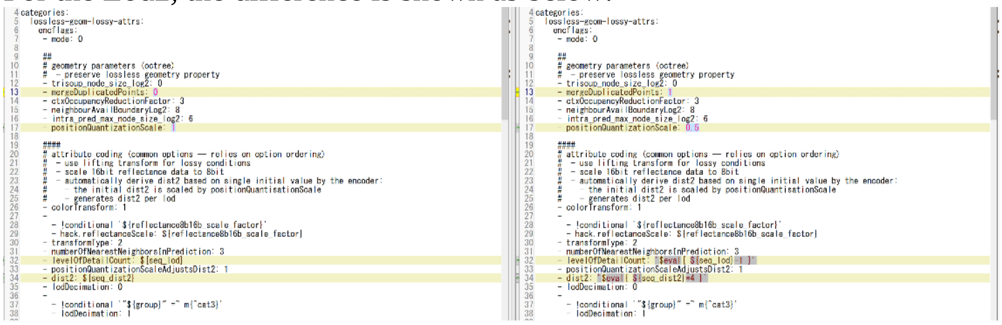
The config for Lod3 is same as the CTC.
The config for Lod1 and 2 are modified to compress with the lower resolution.

For the Lod1, the difference from CTC is shown as below.



The left is a configuration for CTC, the right is for the Lod1.
The setting file is uploaded to the CE branch as “octree-liftt-ctc-lossless-geom-lossy-attrs-MaxMinus2.yaml”.

For the Lod2, the difference is shown as below.



The setting file is “octree-liftt-ctc-lossless-geom-lossy-attrs-MaxMinus1.yaml”.

5.3 Simulcast anchor 2: sub-sample based approach

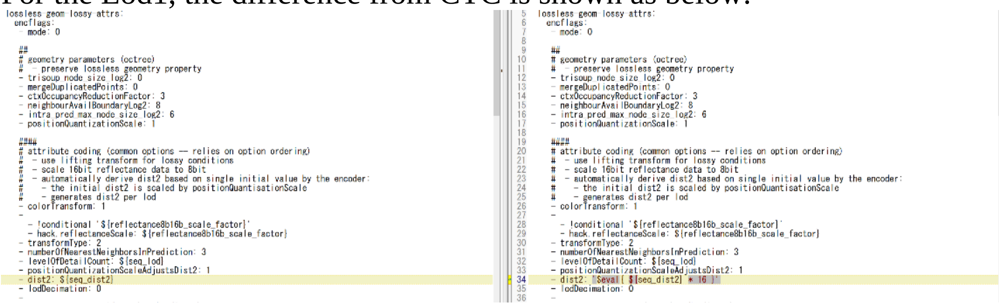
Three sub-sampled point cloud are encoded using the anchor.

This sub-sampled point cloud for the Lod1, 2 and 3 are generated by a dump tool (See the usage in Annex A).

The configuration setting for the Lod3 is same as the CTC.

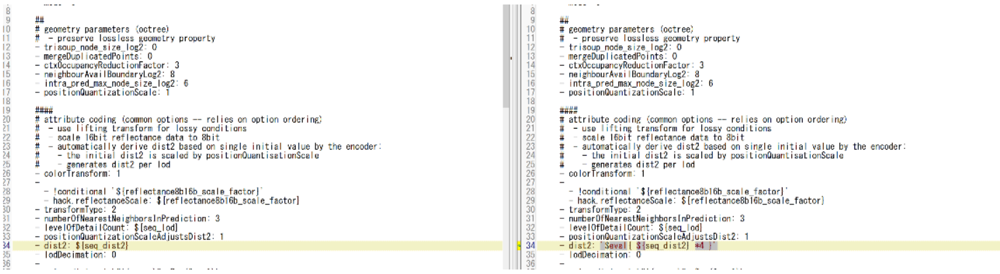
The configuration for Lod1 and 2 are modified.

For the Lod1, the difference from CTC is shown as below.



The left is a configuration for CTC, the right is for the Lod1. The setting file is uploaded to the CE branch as “octree-liftt-ctc-lossless-geom-lossy-attrs_Lod1.yaml”.

For the Lod2, the difference from CTC is shown as below.



The setting file for Lod2 is contained in CE branch as “octree-liftt-ctc-lossless-geom-lossy-attrs_Lod2.yaml”.

5.4 Proposal

Git repository: http://mpegx.int-evry.fr/software/MPEG/PCC/CE/mpeg-pcc-tmc13.git
Branch: /mpeg126/ce13.15/scalableLifting_r1

Configuration: The config files same as the CTC are used except for Cat3. Cat3 is executed with option “--lodDecimation=0”

6 Results

The results are provided in the attached xls files. The file name for each test condition is as follows.

For proposed scalable lifting:

1. pcc-tmc3v6.0_octree_predlift_vs_CE13.15.xlsm

For simulcast anchor 1:

1. SimulcastAnchor_QuantizatinBased_LodMinus2.xlsm
2. SimulcastAnchor_QuantizatinBased_LodMinus1.xlsm

For simulcast anchor 2:

1. SimulcastAnchor_SubsampleBased_Lod1.xlsm
2. SimulcastAnchor_SubsampleBased_Lod2.xlsm
3. SimulcastAnchor_SubsampleBased_Lod3.xlsm

For the End-to-End BD-rate evaluation:

1. pcc-tmc13-tmc3v6.0-ce13.15proposed_vs_anchor1.xlsm
   In the evaluation, the reference PSNR is same as the CTC anchor. The reference bit size is summation of anchor CTC, QuantizatinBased_LodMinux1 and QuantizatinBased_LosMinux2 bit size.
2. pcc-tmc13-tmc3v6.0-ce13.15proposed_vs_anchor2.xlsm
   In the evaluation, the reference PSNR is calculated by SubsampleBased_Lod1,2,3 combined point cloud. The reference bit size is summation of SubsampleBased_Lod1, Lod2 and lod3 bit size.

6.1 BD rate

Table 6-1 shows the BD rate of proposal compared to the simulcast anchor. The proposal has gain about 35% to 59% compared with the quantization based anchor, and 8% to 24% compared with the sub-sample based anchor.

Table 6-2 and Table 6-3 show the BDrate of the proposal for each sequences over the simulcast anchor1 and anchor2, respectively.

Overall average End-to-End BD-TotalRate [%]

	Luma	Chroma Cb	Chroma Cr	Reflectance
CE13.15 vs anchor1 (quantization based)	-36.1%	-35.3%	-35.3%	-59.4%
CE13.15 vs anchor2 (subsample based)	-24.0%	-24.2%	-24.2%	-8.9%

Table 6-1 BD rate of the proposal

C1_ai ― lossless geometry, lossy att		End-to-End BD-AttrRate [%]				End-to-End BD-TotalRate [%]			
Class	Sequence	Luma	Chroma Cb	Chroma Cr	Reflectance	Luma	Chroma Cb	Chroma Cr	Reflectance
cat1-A	basketball_player_vox11_0000(	-16.7%	-18.5%	-15.0%		-24.1%	-24.2%	-23.9%	
	boxer_viewdep_vox12	-42.0%	-42.5%	-42.1%		-25.5%	-25.4%	-25.3%	
	dancer_vox11_00000001	-17.7%	-19.2%	-17.1%		-24.0%	-24.2%	-23.9%	
	egyptian_mask_vox12	-42.4%	-36.6%	-35.6%		-55.8%	-55.5%	-55.4%	
	facade_00009_vox12	-45.4%	-39.0%	-41.7%		-44.4%	-42.8%	-43.5%	
	facade_00015_vox14	-45.9%	-27.0%	-25.6%		-48.8%	-47.0%	-47.0%	
	facade_00064_vox11	-16.5%	-10.5%	-8.8%		-21.3%	-19.8%	-19.3%	
	frog_00067_vox12	-30.3%	-18.5%	-12.7%		-38.1%	-37.1%	-37.0%	
	head_00039_vox12	-27.7%	-23.3%	-20.2%		-30.0%	-29.2%	-28.9%	
	house_without_roof_00057_vo:	-34.8%	-29.5%	-33.7%		-37.1%	-36.5%	-36.9%	
	longdress_viewdep_vox12	-45.5%	-44.2%	-43.8%		-30.6%	-29.6%	-29.7%	
	longdress_vox10_1300	-22.1%	-17.1%	-17.2%		-25.7%	-23.7%	-23.9%	
	loot_viewdep_vox12	-42.0%	-42.9%	-42.0%		-25.9%	-25.9%	-25.8%	
	loot_vox10_1200	-18.0%	-12.6%	-10.5%		-25.0%	-24.4%	-24.0%	
	queen_0200	-17.2%	-8.1%	-11.1%		-24.2%	-23.1%	-23.4%	
	redandblack_viewdep_vox12	-43.9%	-44.1%	-41.7%		-29.5%	-29.5%	-29.0%	
	redandblack_vox10_1550	-19.6%	-16.5%	-17.9%		-25.1%	-24.2%	-24.7%	
	shiva_00035_vox12	-50.4%	-39.2%	-37.6%		-51.7%	-50.0%	-49.6%	
	soldier_viewdep_vox12	-42.9%	-44.1%	-43.1%		-27.8%	-27.9%	-27.8%	
	soldier_vox10_0690	-18.2%	-15.0%	-15.7%		-25.3%	-24.1%	-24.3%	
	thaidancer_viewdep_vox12	-22.7%	-18.5%	-18.5%		-26.5%	-25.2%	-25.1%	
	ulb_unicorn_vox13	-52.2%	-47.0%	-47.3%		-55.2%	-54.8%	-54.8%	
cat3-fuse	citytunnel_q1mm	-38.6%	-38.7%	-36.6%	-53.2%	-59.0%	-58.5%	-58.4%	-56.7%
	overpass_q1mm	-44.2%	-40.1%	-39.6%	-53.6%	-60.5%	-59.9%	-59.9%	-59.0%
	tollbooth_q1mm	-52.5%	-43.4%	-45.2%	-56.2%	-61.0%	-60.3%	-60.5%	-59.8%
cat3-fram	ford_01_q1mm				-45.7%				-61.3%
	ford_02_q1mm				-46.5%				-61.3%
	ford_03_q1mm				-41.0%				-61.4%
	qnxadas-junction-approach				25.7%				-58.4%
	qnxadas-junction-exit				18.8%				-58.2%
	qnxadas-motorway-join				38.7%				-58.7%
	qnxadas-navigating-bends				56.0%				-59.1%
	Cat1-A average	-32.5%	-27.9%	-27.2%		-32.8%	-32.0%	-32.0%	
	Cat3-fused average	-45.1%	-40.7%	-40.5%	-54.3%	-60.2%	-59.6%	-59.6%	-58.5%
	Cat3-frame average				0.8%				-59.8%
	Overall average	-34.0%	-29.4%	-28.8%	-15.7%	-36.1%	-35.3%	-35.3%	-59.4%

Table 6-2 The proposal vs the anchor (quantization based) in terms of BD bitrate.

C1_ai ― lossless geometry, lossy att		End-to-End BD-AttrRate [%]				End-to-End BD-TotalRate [%]			
Class	Sequence	Luma	Chroma Cb	Chroma Cr	Reflectance	Luma	Chroma Cb	Chroma Cr	Reflectance
cat1-A	basketball_player_vox11_0000(	−26.6%	−26.7%	−30.1%		−57.9%	−57.5%	−59.1%	
	boxer_viewdep_vox12	−33.3%	−32.9%	−33.9%		−36.6%	−36.8%	−36.8%	
	dancer_vox11_00000001	−28.1%	−28.0%	−32.8%		−58.3%	−58.3%	−59.7%	
	egyptian_mask_vox12	−10.5%	−15.5%	−15.2%		−14.7%	−15.0%	−15.0%	
	facade_00009_vox12	−1.6%	0.7%	2.1%		−11.0%	−10.9%	−10.5%	
	facade_00015_vox14	24.5%	47.4%	51.6%		−3.0%	−1.6%	−1.4%	
	facade_00064_vox11	−0.2%	−0.5%	−0.2%		−26.0%	−28.3%	−28.5%	
	frog_00067_vox12	22.2%	25.9%	32.2%		−7.8%	−7.8%	−7.8%	
	head_00039_vox12	19.8%	15.1%	17.8%		−7.2%	−8.2%	−8.4%	
	house_without_roof_00057_vo:	15.4%	12.2%	9.1%		−8.0%	−8.3%	−8.3%	
	longdress_viewdep_vox12	−30.3%	−37.2%	−36.7%		−33.4%	−35.1%	−34.8%	
	longdress_vox10_1300	−2.0%	−5.0%	−5.0%		−28.1%	−30.4%	−30.3%	
	loot_viewdep_vox12	−34.2%	−34.6%	−33.1%		−35.8%	−35.9%	−35.8%	
	loot_vox10_1200	−4.4%	−6.7%	−10.7%		−38.4%	−40.1%	−40.5%	
	queen_0200	−0.7%	−0.2%	−2.9%		−37.1%	−38.9%	−39.1%	
	redandblack_viewdep_vox12	−32.1%	−34.7%	−35.1%		−34.2%	−34.7%	−34.4%	
	redandblack_vox10_1550	−4.0%	−3.8%	−3.9%		−32.2%	−33.0%	−32.6%	
	shiva_00035_vox12	19.7%	33.3%	36.7%		−2.6%	−0.4%	0.1%	
	soldier_viewdep_vox12	−33.5%	−34.2%	−33.9%		−34.6%	−34.9%	−34.9%	
	soldier_vox10_0690	−2.6%	−5.9%	−3.8%		−34.7%	−36.2%	−36.3%	
	thaidancer_viewdep_vox12	−6.8%	−10.6%	−10.8%		−37.8%	−39.5%	−39.5%	
	ulb_unicorn_vox13	4.1%	3.7%	4.2%		−5.7%	−5.7%	−5.7%	
cat3-fuse	citytunnel_q1mm	32.5%	40.3%	45.7%	235.7%	−5.1%	−2.7%	−2.6%	1.3%
	overpass_q1mm	29.6%	48.5%	50.8%	264.0%	−4.0%	−1.1%	−1.2%	0.9%
	tollbooth_q1mm	8.4%	39.3%	32.1%	214.6%	−5.6%	−2.6%	−3.2%	−1.8%
cat3-fram	ford_01_q1mm				27.5%				−8.6%
	ford_02_q1mm				25.5%				−8.7%
	ford_03_q1mm				42.2%				−7.7%
	qnxadas-junction-approach				176.1%				−16.0%
	qnxadas-junction-exit				124.4%				−18.5%
	qnxadas-motorway-join				182.5%				−16.2%
	qnxadas-navigating-bends				228.6%				−13.6%
	Cat1-A average	−6.6%	−6.3%	−6.1%		−26.6%	−27.2%	−27.2%	
	Cat3-fused average	23.5%	42.7%	42.9%	238.1%	−4.9%	−2.2%	−2.3%	0.2%
	Cat3-frame average				115.3%				−12.8%
	Overall average	−3.0%	−0.4%	−0.2%	152.1%	−24.0%	−24.2%	−24.2%	−8.9%

Table 6-3 The proposal vs the anchor (sub-sample based) in terms of BD bitrate.

6.2 Decoding time

The geometry and attribute decoding time is shown as Table 6-4.

		CTC anchor [sec]	Proposal [sec]	Ratio
Basketball_player_vox11 R4	Geometry octree	2.39	2.41	101%
	Attribute color	13.62	14.49	106%

Table 6-4 Decoding time comparison

CE13.15 proposal has three changes (octree harmonized LoD construction, weight derivation, and distance normalization).

	CE13.15	subtest1	subtest2	subtest3	CTC anchor
Octree harmonized Lod	1	1	1	0	0
Weight derivation	1	0	1	1	0
Distance normalization	1	1	0	1	0
attribute[sec]	14.49	15.02	14.58	13.6	13.62

Table 6-5 Performance analysis

Table 6-5 shows the performance impact of each change. Since the decoding time of the subtest3 is same as the CTC anchor, the decoding time is increased by Octree harmonized Lod construction implementation.

In the current CE code, the proposed Lod construction is implemented on the anchor LoD construction code which uses `attributeSearchRange` for the neighbor point search. In the search code, the octree structure is derived based on the nearest point distance using the distance check function. This implementation is for the simplicity and readability of the proposed algorithm.

It is pointed that the attribute LoD generation process can be skipped by using the geometry octree LoD structure because the proposed attribute lifting LoD is same as the geometry. With such optimized implementation, the decoder runtime of the proposal will be same as the subtest3, accordingly same as the CTC anchor.

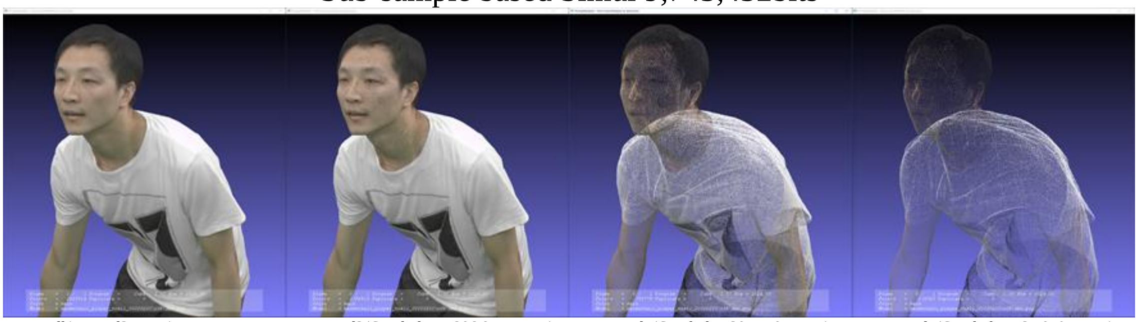
6.3 Visual quality

The visual quality of basketball_player_vox11_00000200 R6 with the rendering cube size 1.0 is shown as Figure 1.
The quantization based simulcast and the proposal are similar for the lower resolution decode result in terms of the number of points and the density of points.
In the sub-sample based simulcast result, the point number is similar, but the geometry accuracy of the decoded points in each Lod1,2,3. is same as the CTC anchor.

Quantization based Simul 6,975,864bits

Geo-lod11 2,925,514point Geo-lod10 796,198point Geo-Lod9 206,818point

Sub-sample based Simul 9,743,432bits



Full(i.e. Lod3+2+1s) Lod3(Goe-lod11 2,396,815 points) Lod2(Goe-lod11 395,779 points) Lod1(Geo-lod11 132,920 points)

Proposal 5,460,712bit

Geo-lod11 2,925,514 points Geo-lod10 796,197 points Geo-Lod9 206,549 points Geo-Lod8 52,497 points

Figure 1 basketball player vox11 (R6) with the rendering cube size 1.0

For the visual quality evaluation, the rendered point cloud image with the cube size 1.0 to 8.33 is shown as Figure 2. The cube size of the quantization based anchor and the proposal can be decide by Lod. The cube size 2 is for Goe-Lod10, the size 4 is for Geo-Lod 9. On the other hand, the cube size for sub-sample based anchor was adjusted while looking at actual gaps in the rendered images. The cube size is 1.8, 3.65, 6.58 for the basketball player sequence. Since sub-sample based anchor has a space and dense region in a frame, the cube size is adjusted by hand tuning.

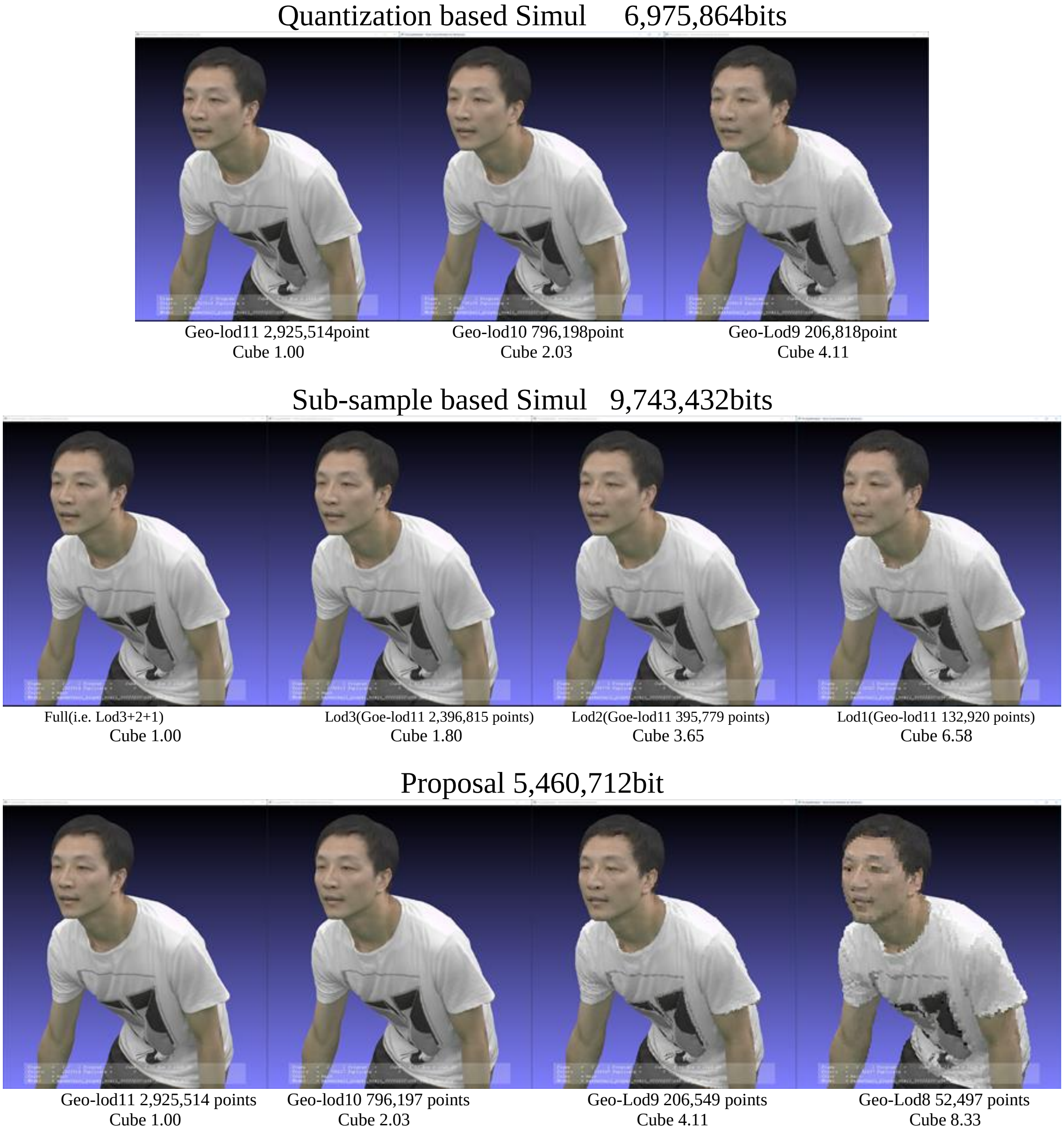


Figure 2 basketball player vox11 (R6) with the adjusted rendering cube size 1.0 to 8.33

The visual quality of the full resolution point cloud for the rate point R2, R4 and R6 is shown in Figure 3.

At the low rates (i.e. R2), the proposal has slightly more block noise than the quantization based simulcast anchor.

It is also pointed that the sub-sample based simulcast anchor has noticeable salt and pepper noise. The noise comes from the combination of separately coded LoD result.

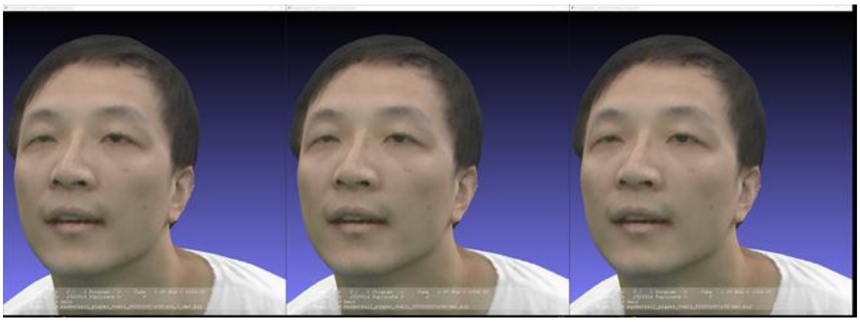
In terms of bit amounts, there is a big different between the proposal and anchor simulcast. It is necessary to compare the results of relatively close generation amounts, not the same rate point. Figure 4 and Figure 5 show the visual comparison at the similar bitstrean size. In the comparison, the proposal looks good visual quality, in terms of the block noise, salt and pepper noise, and texture resolution, compared to the two simul cast anchors. When compared at close bit rates, the proposal quality is better because the QP is lower in the proposal.

R2

Proposal	Quantization based	Sub-sample based
2,737,816 bits	3,655,480bits	6,933,256bits

R4

Proposal	Quantization based	Sub-sample based
3,187,160bits	4,206,144bits	7,400,176bits



R6

Proposal	Quantization based	Sub-sample based
5,460,712bits	6,975,864bits	9,743,432bits

Figure 3 full decode visual quality

Proposal R4 | Quantization based R2
3,187,160bit | 3,655,480bits(total)

Figure 4 full decode visual quality (proposal vs quantization based)

Proposal R6 | Sub-sample based R2
5,460,712bit | 6,933,256bits(total)

Figure 5 full decode visual quality (proposal vs sub-sample based)

The visual quality for the lower resolution point cloud is shown as Figure 6 and Figure 7. Figure 6 and Figure 7 compare the results of scalable decoding with relatively close bit amounts.

The sub-sample based uses Lod3 for comparison because the number of points is larger than that of sub-sample based Lod2, and the cube size for rendering can be smaller. The proposal is good for both block noise and texture resolution.

Proposal R3
Lod10 796,217 points
3,187,160bit

Quantization based R2
Lod10 796,198 points
3,655,480bits(total)

Figure 6 scalable decode visual quality (proposal vs quantization based)

Proposal R6
Lod10 796,217 points
5,460,712bit

Sub-sample based R2
Lod3(Goe-lod11 2,396,815 points)
6,933,256bits(total)

Figure 7 scalable decode visual quality (proposal vs sub-sample based)

7 Conclusion

The proposal has BD bitrate gain compare to the two simulcast anchors. In terms of visual quality of similar bit amounts, the proposal is better for block noise and texture resolution. We propose to adapt scalable lifting in the G-PCC standard.

8 Reference

[1] "G-PCC CE 13.15 on LoD generation for spatial scalability", ISO/IEC JTC1/SC29 WG11 (MPEG) output document w18489, Geneva, CH, March 2019

[2] "[G-PCC] Spatial scalability support for G-PCC," ISO/IEC JTC1/SC29 WG11 (MPEG) input document m47352, Geneva, CH, March 2019

9 Annex A: Sub-sampled point cloud dump tool

The patch “subsampleLod123.patch” is applied to tmc13 test model version 6.0. The software with the patch can dump the three sub-sampled point cloud. To dump the sub-sampled source point cloud, the tool should be used with the lossless geometry setting (octree-liftt-ctc-lossless-geom-lossy-attrs) with “`--colorTransform=0`”.

The options to dump the sub-sampled ply are as follows:

```
("outputLod123Ply",
  "Enable Lod123 which are subsampled for evaluation of CE13.15 scalable")

("lod1DataPath",
  "The sub-sampled Lod1 (low density) ply path")

("lod2DataPath",
  "The sub-sampled Lod2 (middle density) ply path")

("lod3DataPath",
  "The sub-sampled Lod3 (high density) ply path")
```