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Title **3D-CE2a results on Nonlinear Depth Representation**
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1 Introduction

This documents presents Core Experiment results attained by Poznan University of Technology. The goal of this Core Experiment (CE) was to further investigate and develop depth representation tools applied AVC-compatible 3D video coding (3D-ATM). This core experiment CE was defined in [N12561, Section 2a].

2 Experiment conditions

Software

The 3D-AVC-Test Model under Consideration 0.3 was used in the experiments.

Test Sequences

Test sequences were used according to Common Test Conditions.

Coding Configurations

Table 1: Tool configurations

Case name	Short name	Extended tools (EHP)	Non-linear Depth Representation
Nonlinear Depth Representation – 3D-ATM in HP cfg.	NDR-HP	-	+
Nonlinear Depth Representation - 3D-ATM in EHP cfg.	NDR-EHP	+	+

3 Non-linear Depth Representation tools [M22697] description

M22697 describes a normative tool named non-linear depth representation. The depth is internally represented in such a way that the closer objects are represented more accurately than distant ones.

In the original proposal, internal depth sample values were defined by the following power-law expressions, similar as in the case of well known gamma correction:

$$depth\ value\ internal = \left(\frac{depth\ value\ external}{maximum\ value\ external}\right)^{exponent} \cdot maximum\ value\ internal$$

Where “maximum value” field represents range of used disparity values.

Such approach unfortunately cannot be seamlessly implemented with integer-only operations.
The exact shape of curves for non-linear representation is defined by means of line-segment-approximation. The first (0,0) and the last (255,255) nodes are predefined. Additional nodeds can be transmitted in SPS in form of deviations from straight-line curve (linear representation).
Nodes are defined in configuration file with “NonlinearDepthModel” parameter.
Additionally, this allows experimentation with other non-linear curves that the above-mentioned exp-based curve.

In most of places, linear-to-non-linear conversion is done through LUT tables, and in some cases (view synthesis etc) non-linearity has been incorporated into existing LUT tables.

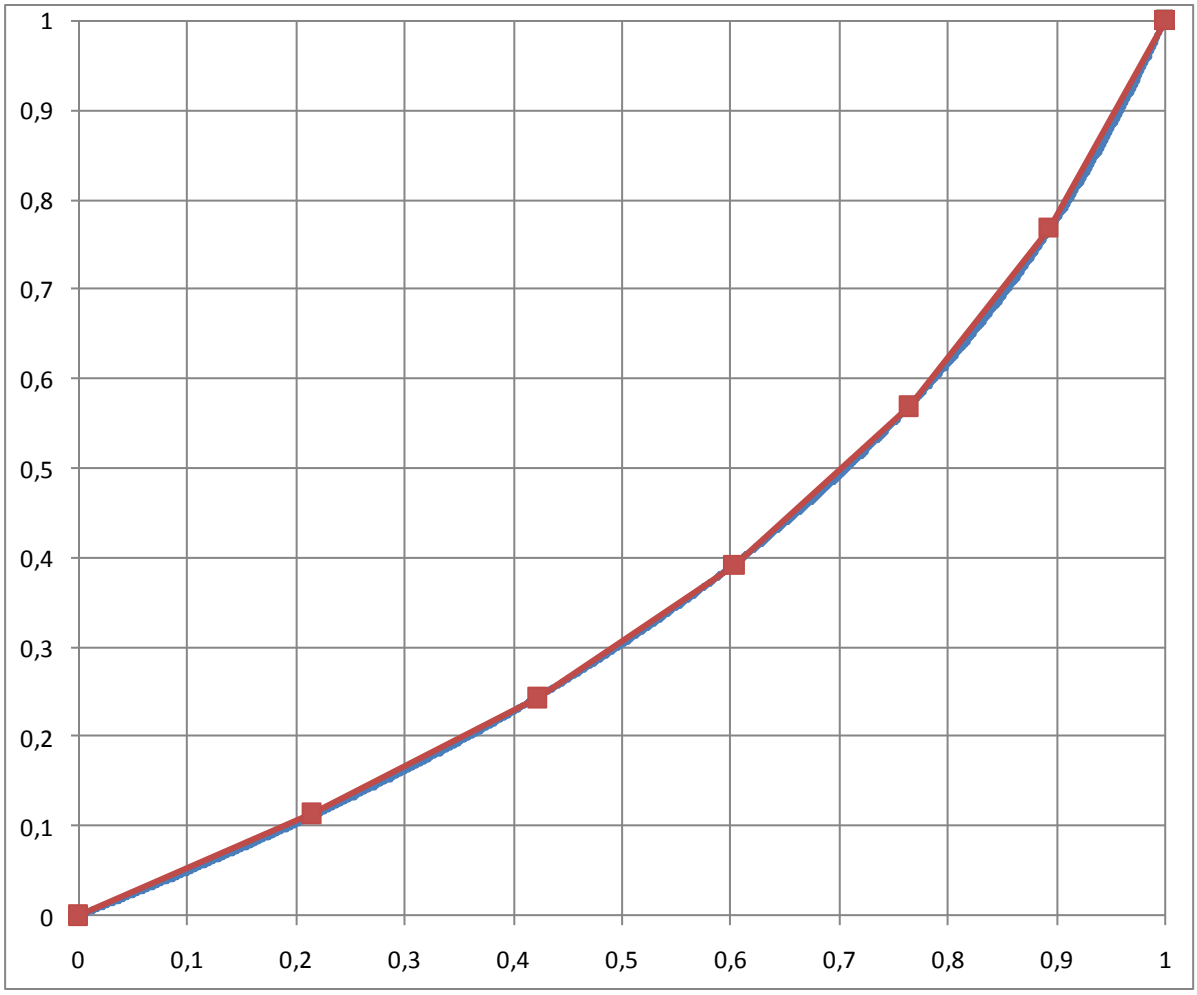

Fig 1. An exemplary approximation of non-linear curve with 5 values being sent in SPS.

As previous experiments has shown, Non-linear Depth Representation gives subjective gains but sometimes imposes objective losses.
We have performed some experiments that shown, that the objective losses can be reduced if this tool is turned off in some sequences. Specifically, this tools is turned off, if weighted average of depth map of the center view (the center of the scene) is in low disparity ranges. Experimentally, we have found, that selection can be automatically done with use of the following value:

$$center\_disparity = \frac{\sum_{i=0..255} disparity\_histogram(i) \cdot i}{\sum_{i=0..255} disparity\_histogram(i)}$$

where $disparity\_histogram(i)$ is a histogram of the first frame of depth map in center view.

If $center\_disparity$ is lesser that some threshold (in this CE set to 100), then Non-linear Depth Representation tool is turned off.
The rationale behind such approach is that low disparity values are highly distorted.

4 Tool configuration

The tools was tested in two configurations:

a) 7-node approximation

NonlinearDepth=1
NonlinearDepthModel="10;19;24;27;26;22;13'"
NonlinearDepthThreshold=100

b) 7-node approximation, which was introduced as an update during the last CE experimentation phase

NonlinearDepth=1
NonlinearDepthModel="2;4;7;8;10;12;14;16;17;19;20;21;22;23;24;25;26;26;27;27;27;27;27;27;26;26;25;24;23;22;20;19;17;15;13;11;9;6;3'"
NonlinearDepthThreshold=100

5 Results

NDR-HP

	Texture Coding		Depth Coding		Total (Coded PSNR)		Total (Synthesed PSNR)	
	dBR, %	dPSNR,dB	dBR, %	dPSNR,dB	dBR, %	dPSNR,dB	dBR, %	dPSNR,dB
S01	0,00	0,00	0,00	0,00	0,00	0,00	-0,06	0,00
S02	-0,04	0,00	-0,02	0,00	-0,04	0,00	0,01	0,00
S03	0,01	0,00	-0,01	0,00	0,01	0,00	0,00	0,00
S04	0,00	0,00	-21,93	1,37	-1,25	0,05	-0,11	0,00
S05	0,00	0,00	-25,76	1,64	-5,28	0,28	-4,13	0,20
S06	-0,01	0,00	-25,87	1,34	-3,27	0,17	-2,59	0,13
S08	0,01	0,00	0,04	0,00	0,01	0,00	0,00	0,00
Average	0,00	0,00	-10,51	0,62	-1,40	0,07	-0,98	0,05

Average synthesized gain is 0,98%. The computational complexity is almost unchanged (3% deviation)

NDR-EHP

	Texture Coding		Depth Coding		Total (Coded PSNR)		Total (Synthesed PSNR)	
	dBR, %	dPSNR,dB	dBR, %	dPSNR,dB	dBR, %	dPSNR,dB	dBR, %	dPSNR,dB
S01	0,00	0,00	0,00	0,00	0,00	0,00	0,06	0,00
S02	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,00
S03	0,00	0,00	0,00	0,00	0,00	0,00	-0,03	0,00
S04	1,36	-0,05	0,00	-23,87	0,63	-0,02	0,74	-0,02
S05	0,19	-0,01	0,00	-20,35	-3,41	0,15	-3,13	0,14
S06	0,44	-0,02	0,00	-21,79	-1,35	0,06	-1,18	0,05
S08	0,00	0,00	0,00	0,00	0,00	0,00	-0,02	0,00
Average	0,28	-0,01	0,00	-9,43	-0,59	0,03	-0,51	0,02

Average synthesized gain is 0,51%. The computational complexity is almost unchanged (5% deviation)

6 Subjective evaluation

In order to allow subjective viewing, the tools has also been tested with constant-bitrate condition, apart from constant-QP defined in cTC.
The target bitrates were the same as bitrates of the current anchors.

a) ATM - NDR - HP profile

S1 Poznan Hall2
S2 Poznan Street
S3 Undo Dancer
S4 GT_Fly
R1: I41 P41 B41
R2: I36 P36 B36
R3: I31 P31 B31
R4: I26 P26 B26

S5 Kendo
R1: I40 P40 B41
R2: I35 P35 B36
R3: I30 P30 B31
R4: I25 P25 B26

S6 Balloons
R1: I40 P41 B41
R2: I35 P36 B36
R3: I29 P31 B31
R4: I25 P26 B26

S8 Newspaper
R1: I40 P40 B41
R2: I35 P35 B36
R3: I30 P30 B31
R4: I25 P25 B26

b) ATM - NDR - EHP profile

S1 Poznan Hall2
S2 Poznan Street
S3 Undo Dancer
S4 GT_Fly
R1: I41 P41 B41
R2: I36 P36 B36
R3: I31 P31 B31
R4: I26 P26 B26

S5 Kendo
R1: I39 P41 B41
R2: I34 P36 B36
R3: I29 P31 B31
R4: I24 P26 B26

S6 Balloons
R1: I39 P41 B41
R2: I34 P36 B36
R3: I29 P31 B31
R4: I25 P25 B26

S8 Newspaper
R1: I39 P41 B41
R2: I34 P36 B36
R3: I30 P30 B31
R4: I25 P25 B26

7 Test Platform

The simulations results was generated on a ~80 core cluster system. This cluster platform's processing units have the following specifications:

- Processor: Intel Xeon X5675
- Clock Speed: 3.06 GHz
- Memory: approx. 4 GB per Core
- OS: 64-bit Windows Server 2008
- Compiler: Microsoft Visual Studio 2008 (64 bit)

8 Conclusions and recommendations

- The Nonlinear-Depth-Representation tool has been enhanced to support integer-only operations.
- The tool is now automatically turned-on / turned-off to produce objective gains.
- Computational compelexity is neglible
- Average synthesized gain is 0,98% for HP-configuration.
- Average synthesized gain is 0,51% for EHP-configuration.
- We recommend to integrate NDR in 3D-ATM.
- Subjective evaluation also possible on the meeting – constant-bitrate points are available.