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| *Title:* | **3D-CE1.a Summary Report: View Synthesis and Inter-view Prediction** | | |
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# Abstract

This document is the summary report of Core Experiment 3. The Core Experiment was established at the 100th MPEG Meeting in Geneva, Switzerland to evaluate depth map resampling and filtering solution for improving 3DV coding efficiency and to resolve the problem of visual artifacts introduced to synthesized views due to resampling of the depth map data. CE3 evaluation procedure includes evaluation of subjective and objective qualities as well as complexity of proposed tools.

# Participants

The following institutions participated in CE3 as proponents or cross-checkers:

* GIST
* Nokia
* Samsung
* ETRI
* FastVDO

Table 1 Proposals registered for CE evaluation and assigned cross-checkers

|  |  |
| --- | --- |
| **Proponent** | **Cross Checker** |
| Normative H.264/AVC deblocking  (JCT2-A0108 /m26070 | GIST, Nokia, Samsung (No documents) |
| Samsung In-loop (JCT2-A0037/m25884) | ETRI(JCT2-A0147/m26165) |
| GIST Post-           (JCT2-A0060/m25967) | Samsung (JCT2-A0066/m25990) |
| Nokia Post-          (JCT2-A0109/ m26071) | Samsung (JCT2-A0064/m25988) |
| Nokia Pre/Post     (JCT2-A0110/m26072) | Samsung (JCT2-A0065/m25989) |
| Samsung Post-     (JCT2-A0038/m25885) | Nokia (JCT2-A0136/m26134) |

Tables 2 provides list of CE-3 related contributions and possible cross-checkers

|  |  |
| --- | --- |
| **Proponent** | **Cross Checker** |
| Samsung Post-     (JCT2-A0039/m25887) | N/A |
| FastVDO              (JCT2-A0155/m26188) | N/A |

# Evaluation procedure

The following evaluation procedure was agreed for CE3.

Decision on in-loop processing to be based on evaluation of the following factors in priority order:

1. Objective results (coding gain) produced with total bitrate and PSNR of **decoded** views
2. Objective results (coding gain) produced with total bitrate and PSNR of **synthesized** views
3. Complexity of the tool: **number of operations** per pixel and decoding time estimates
4. Subjective evaluation of 2D quality of synthesized views

Decision on non-normative processing to be done based on evaluation of the following factors in priority order:

1. **Subjective evaluation** of 2D quality of synthesized views
2. Objective results (coding gain) produced with total bitrate and PSNR of **synthesized** views
3. Objective results (coding gain) produced with total bitrate and PSNR of **decoded** views
4. Subjective evaluation of 3D quality of synthesized views (?)

# Tool Description

Proposals to CE3 evaluation are classified in two major group: Normative and non-normative tools.

## Normative Tools

**Contribution JCT2-A0037** [1] presents an adaptive range filter at the in-loop structure to improve coding efficiency. This filter replaces current deblocking of H.264/AVC. Reported results are -0.6% of dB on average for coded views, 6% of dBR for depth map data and -1.7% of dBR on average for synthesized. Estimated decoding time of proposed method is 104-110% of the CE3 anchor decoding time (deblocking OFF).

**Contribution JCT2-A0108** [2] proposes to enable normative H.264/AVC deblocking filter for depth map coding. Reported results are -0.2% of dB on average for coded views, 6.8% of dBR for depth map and -0.7% of dBR on average for synthesized. Estimated decoding time of proposed method is 104% of the CE3 anchor decoding time.

Table 3 Normative tools for depth map coding evaluated in CE3, CE3 anchor deblocking OFF

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Proponent** | **Cross Checker** | **Texture** | **Depth** | **Synthesied** | **Complexity Decoder** | **Subjective Ranking** | **Total bitrate** |
| Normative H.264/AVC deblocking  (JCT2-A0108 /m26070 | GIST, Nokia, Samsung (No documents) | -0.3% | -6.8% | -0.72% | 104% | TBD | -0.44% |
| Samsung In-loop (JCT2-A0037/m25884) | ETRI(JCT2-A0147/m26165) | -0.6% | -6.1% | -1.7% | 104% - 110% | TBD | -0.6% |
| **Combinations (Editor’s notes)** | | | | | | |
| Samsung In-loop & Post  (JCT2-A0037/m25884) | Not-cross  Checked (?) | -0.6% | -6.1% | -6.8% | 110% - 120% | TBD |
| Nokia: In-loop & Pre/Post  (JCT2-A0037/m25884) | Samsung (JCT2-A0065/m25989) | -0.5% | 5.3% | -6.6% | 111% - 112% | TBD |

Based on objective results provided, and complexity evaluation, it is proposed to **adopt proposal JCT2-A0108 /m26070** and enable H.264/AVC deblocking for depth map in Common Test Conditions.

## Non-Normative Tools

Non-normative tools and their performance are given in Tables 5 and 6. Table 5 show experiment results with H.264/AVC Deblocking for depth OFF settings, and Table 6 show results with Deblocking ON.

**Contribution JCT2-A0060/m25967 [3]:** presents an adaptive depth boundary filtering as post-processing for 3DV-ATM. The simulation results show the proposed method provides about -3.5% of dBR on average for synthesized views. Estimated decoding time is about 200% -400% of decoding time of anchor.

**Contribution JCT2-A0038** [4] proposes dilation filter for depth post processing. Reported results show that proposed technique provides -4.5% BD-rate gain in terms of synthesized texture PSNR with deblocking filter turned on. When estimated with deblocking OFF, the reported gain is -4.4% BD-rate gain. Reported and cross-checked complexity is 108-120% of the anchor’s decoding time.

**Contribution JCT2-A0109** [5] proposes an adaptive non-linear up-sampling for depth map post-processing. Reported results show that proposed technique provides -1.1% BD-rate gain in terms of synthesized texture PSNR with deblocking filter turned on. When estimated with deblocking OFF, the reported gain is -1.0% BD-rate gain. Reported and cross-checked complexity is 111-112% of the anchor’s decoding time.

**Contribution JCT2-A0110 [6]** proposes an adaptive non-linear downsampling. Reported results show that proposed technique provides -4.5% dBR reduction for synthesized texture PSNR. Reported and cross-checked complexity is 110-112% of the anchor’s decoding time. Simulation results for combined pre-/ and post- processing show that proposed technique provides -5.6% / -5.8% dBR on average for synthesized texture PSNR.

Table 4 Non-Normative tools for depth map coding evaluated in CE3. Experiment with deblocking OFF.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Proponent** | **Cross Checker** | **Texture** | **Coded** | **Synthesied** | **Complexity Decoder** | **Subjective Ranking** |
| GIST Post- (JCT2-A0060/m25967) | Samsung (JCT2-A0066/m25990) | 0.0 | 0.0 | -3.53% | 200% -350% | TBD |
| Nokia Post- (JCT2-A0109/ m26071) | Samsung (JCT2-A0064/m25988) | 0.0 | 0.0 | -1.0% | 108%  -113% | TBD |
| Nokia Pre    (JCT2-A0110/m26072) | Samsung (JCT2-A0065/m25989) | -0.2% | 0.7% | -4.5% | 100% | TBD |
| Nokia Pre/Post    (JCT2-A0110/m26072) | Samsung (JCT2-A0065/m25989) | -0.2% | 0.7% | -5.8% | 104% -110% | TBD |
| Samsung Post-     (JCT2-A0038/m25885) | Nokia (JCT2-A0136/m26134) | 0.0 | 0.0 | -4.5% | 110%  -120% | TBD |

Table 5 Non-Normative tools for depth map coding evaluated in CE3. Experiment with deblocking ON

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Proponent** | **Cross Checker** | **Texture** | **Coded** | **Synthesied** | **Complexity Decoder** | **Subjective Ranking** |
| GIST Post- (JCT2-A0060/m25967) | Samsung (JCT2-A0066/m25990) | 0.0 | 0.0 | -3.18% | 200% -400% | TBD |
| Nokia Post- (JCT2-A0109/ m26071) | Samsung (JCT2-A0064/m25988) | 0.0 | 0.0 | -1.1% | 111%  -112% | TBD |
| Nokia Pre    (JCT2-A0110/m26072) | Samsung (JCT2-A0065/m25989) | -0.2% | 0.6% | -4.5% | 100% | TBD |
| Nokia Pre/Post    (JCT2-A0110/m26072) | Samsung (JCT2-A0065/m25989) | -0.2% | 0.6% | -5.9% | 111%- 112% | TBD |
| Samsung Post-     (JCT2-A0038/m25885) | Nokia (JCT2-A0136/m26134) | 0.0 | 0.0 | -4.4% | 110%  -120% | TBD |

## Combination of Normative and Non-Normative Tools

**Contributions JCT2-A0037/ JCT2-A0037** propose to combine RALF in-loop filtering and dilation filter for depth post processing. Reported results show that proposed technique provides -6.8% BD-rate gain in terms of synthesized texture PSNR. Reported and cross-checked complexity is 108-120% of the anchor’s decoding time (deblocking OFF).

**Contributions JCT2-A0108/ JCT2-A0037/ JCT2-A0109** propose to combine normative H.264/AVC coding with non-linear pre- and post-filtering. Reported results show that proposed technique provides -6.6% BD-rate gain in terms of synthesized texture PSNR. Reported and cross-checked complexity is 104-112% of the anchor’s decoding time (deblocking OFF).

Comparative results for these schemes are shown in Table 5.

## CE3 related contributions

**Proposal JCT2-A0039 [7]** presents a hybrid post filter for depth map data. Reported results show -5.7% of dBR for synthesized views with deblocking ON. Estimated decoding time is about 1.7-1.9x of the anchor’s decoding time. This contributions was not cross-checked, due to lack of time.

**Proposal JCT2-A0155/m26188 [8]** presents initial results for depth map resampling. Dancer test sequence was utilized as a case study.

## Results of Subjective viewing

Four proposals have been evaluated during subjective viewing. The table of subjective results in shown in Table 6.

Table 6. Results of subjective viewing for post-processing techniques proposes for CE3

|  |  |  |
| --- | --- | --- |
| Proposals | Positive | Negative |
| P1 (A0038/m25885) | 11 | -2 |
| P2 (A0110/m26072) | 11 | -7 |
| P3 (A0066/m25990) | 2 | -11 |
| P4 (A0110+A0038) | 11 | -4 |

Results of subjective viewing show proponents P1, P2 and P3 provided equal number of positive scors (better than anchor). However, proposal P1 was ranked as providing less number of negative scores, in comparison to the other techniques.

Based on subjective viewing results, it is recommended to **include post-processing technique proposed in P1 (JCT-A0038)** in 3DV-ATM software and enabling this post-processing in CTC.

# References

[1] JCT2-A0037/m25884 3D-CE3.a results on region based adaptive loop filter [Ilsoon Lim Ho-Cheon Wey Jaejoon Lee Du Sik Park (Samsung)]

[2] JCT2-A0108/m26070 3DV-CE3: Enabling H.264/AVC deblocking for depth map coding in 3DV-ATM [Dmytro Rusanovskyy (Nokia), Payman Aflaki (TUT), Miska M. Hannuksela (Nokia)]

[3] JCT2-A0060/m25967 3D-CE3.a results on depth boundary filtering as post-processing by GIST [Yunseok Song, Cheon Lee, Yo-Sung Ho (GIST)] [late]

[4] JCT2-A0038/m25885 3D-CE3.a results on dilation filter for depth post processing [Seok Lee Seungsin Lee Ho-Cheon Wey Jaejoon Lee Du Sik Park (Samsung)]

[5] JCT2-A0109/m26071 3DV-CE3.a: Non-linear Depth Map Upsampling for 3DV-ATM Coding [Payman Aflaki (TUT), Dmytro Rusanovskyy (Nokia), Miska Hannuksela (Nokia)]

[6] JCT2-A0110/m26072 3DV-CE3: Non-linear Depth Map Downsampling for 3DV-ATM Coding (Pre-processing) [Payman Aflaki (TUT), Dmytro Rusanovskyy (Nokia), Miska M. Hannuksela (Nokia)]

[7]JCT2-A0039/m25887 3D-CE3.a related results on depth hybrid post filter [Seok Lee Seungsin Lee Ho-Cheon Wey Jaejoon Lee Du Sik Park (Samsung)]

[8] JCT2-A0155/m26188 Sampling filters for depth map video for 3DV (CE3 related) [W Dai, M Krishnan, P Topiwala (FastVDO)] [late]