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| *Title:* | **Color gamut scalable video coding with piecewise linear predictions and shift-offset model** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
| *Author(s) or Contact(s):* | Cheung Auyeung  1730 N. First Street San Jose, CA 95112, USA  Kazushi Sato Sony City Osaki 9F 2-10-1 Osaki, Shinagawa, 141-8610 Tokyo, Japan | Tel: Email: | +1-408-352-4086 [Cheung.Auyeung@am.sony.com](mailto:Cheung.Auyeung@am.sony.com)  +81 50 3750 2741 [Kazushi.Sato@jp.sony.com](mailto:Kazushi.Sato@jp.sony.com) |
| *Source:* | Sony Electronics Inc. / Sony Corp. | | |

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# Abstract

JCTVC-L0334 provided results for color gamut scalability with SMuC-0.1.1 where the input of the base layer is in BT.709 with 8 bits and the input of the enhancement layer is in BT.2020 with 10 bits. This contribution compares the color space linear predictor called Gain-Offset Sequence Adaptive (GO-SA) in JCTVC-L0334 with the proposed piece-wise linear predictor for color gamut scalable video coding. The overall luma BDRs for AI-2x, RA-2x, and SNR scalability are -0.8%, -0.7%, and -0.9%, respectively. There were some losses in BDR for SNR scalability at 0.5% and 1.1% for Cb and Cr. The coding loss in Cb and Cr in piece-wise linear prediction is likely to be caused by lack of QP and configuration adaptation implemented in the Gain-Offset prediction.

This contribution also introduces shift-offset model for color gamut prediction, which is simple and yet can provide better coding efficiency than bit-increment model as proposed by JCTVC-L0334.

# Introduction

JCTVC-L0334 [1] provided results for color gamut scalability where the input of the base layer is in BT.709 with 8 bits and the input of the enhancement layer is in BT.2020 with 10 bits. As shown in Figure 1, a color space predictor is inserted between the base layer reference and the enhancement layer encoding loop to provide color gamut scalability.



Figure 1: Color Space Scalable Coder

JCTVC-L0334 [1] presented results for several color space prediction methods based on linear prediction. In particular, each color channel is predicted independent from other channel. The prediction Pred[c][x][y] of a channel c is given by

Pred[c][x][y] = (gain[c]\*In[c][x][y] + offset[c] + (1<<(numFractionBits-1))) >> numFractionBits

where **numFractionBits** is the number of fraction bits used in the calculation, and In[c][x][y] is the base layer reference. The gain[c] and offset[c] are the parameters of the linear predictor.

JCTVC-L0334 [1] presented results of three parameter design methods: Bit Increment (BI), Gain Offset Sequence Adaptive (GO-SA), and Gain Offset NonAdaptive (GO-NA). The Gain Offset Sequence Adaptive method provided the best coding gain among the three methods.

The GO-SA design uses the first frame of the sequence to design the prediction parameters as follows. First, the base layer frame is reconstructed and up sampled as appropriate to match the resolution of the enhancement layer frame. Then the GO-SA prediction parameters are obtained by minimizing the MSE between the input EL frame and the reference constructed from the BL. This is done once for the first frame of the sequence. Therefore, the prediction parameters depend on the sequence, the QP, and the configuration for AI, RA, LD, spatial scalability, and SNR scalability, etc.

# Proposal –Piecewise-Linear Prediction

To improve coding efficiency, this contribution proposes to extend the gain-offset prediction model in JCTVC-L0334 by piece-wise linear prediction as follows.

Let d[c][x][y] = In[c][x][y] - knot[c]. If d[c][x][y] <= 0

Pred[c][x][y] = (gain1[c]\*d[c][x][y] + offset[c] + (1<<(numFractionBits-1))) >> numFractionBits

else

Pred[c][x][y] = (gain2[c]\*d[c][x][y] + offset[c] + (1<<(numFractionBits-1))) >> numFractionBits

The prediction parameters knot[c], offset[c], gain1[c], and gain2[c] are encoded in the bitsream in the same manner as in JCTVC-L0334 for the GO-SA method.

The prediction parameters in this proposal are computed by minimizing the sum of square prediction error between the first frame of the BT.709 and the first frame of the BT.2020 input. The piece-wise linear parameters was computed off-line by the multivariate adaptive regression splines algorithm [2], and the parameters are passed to the encoder inside the per-sequence configuration files. Consequently the prediction parameters are sequence dependent and are independent on other coding configurations.

## Results

The piece-wise linear prediction was integrated into the SMuC-0.1.1 based JCTVC-L0334 software to compare the coding gain with the GO-SA prediction in JCTVC-L0334. To perform the experiment, the Class A and Class B test sequences are converted into BT.2020 format with 10 bits by the conversion program provided by the proponent of JCTVC-L0334.

Table 1 is the BDR results of the proposed piecewise-linear prediction using the GO-SA prediction [1] as reference with the luminance QPs from the SHM2.0 common test conditions. As in JCTVC-L0334, the chrominance QPs for Cb and Cr are offset by -2 and -6 respectively.

Although the piece-wise linear prediction is *not* QP and configuration dependent and the GO-SA is both QP and configuration dependent, the piece-wise linear prediction performs better than GO-SA in terms of BDR. Using the GO-SA as reference, the piece-wise linear prediction resulted in overall luma BDRs of -0.8%, -0.7%, and -0.9%, for AI-2x, RA-2x, and SNR scalability respectively.



|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **AI HEVC 2x** | | |  |  |  |
|  | Y | U | V |  |  |  |
| Class A | -1.0% | -0.4% | 0.0% |  |  |  |
| Class B | -0.8% | -0.4% | -0.1% |  |  |  |
| **Overall (Test vs Ref)** | -0.8% | -0.4% | -0.1% |  |  |  |
| **Overall (Test vs single layer)** | 15.4% | 10.7% | 13.2% |  |  |  |
| **Overall (Ref vs single layer)** | 16.4% | 11.2% | 13.2% |  |  |  |
| **Overall (Test EL+BL vs single EL+BL)** | -20.2% | -23.5% | -21.9% |  |  |  |
| **Overall (Ref EL+BL vs single EL+BL)** | -19.6% | -23.2% | -21.8% |  |  |  |
| **EL only (Test vs Ref)** | -1.4% | -0.9% | -0.5% |  |  |  |
| Enc Time[%] | 100.8% | | |  |  |  |
| Dec Time[%] | 99.0% | | |  |  |  |
| Enc Mem[%] | #DIV/0! | | |  |  |  |
| BL Match | Matched | | |  |  |  |
|  |  |  |  |  |  |  |
|  | **RA HEVC 2x** | | | **RA HEVC SNR** | | |
|  | Y | U | V | Y | U | V |
| Class A | -0.8% | 0.0% | -3.8% | -1.2% | -0.7% | -1.4% |
| Class B | -0.7% | 0.0% | 0.2% | -0.8% | 1.0% | 2.1% |
| **Overall (Test vs Ref)** | -0.7% | 0.0% | -0.9% | -0.9% | 0.5% | 1.1% |
| **Overall (Test vs single layer)** | 23.3% | 29.0% | 32.0% | 20.4% | 26.8% | 31.3% |
| **Overall (Ref vs single layer)** | 24.3% | 29.0% | 33.4% | 21.5% | 26.3% | 30.1% |
| **Overall (Test EL+BL vs single EL+BL)** | -13.7% | -9.9% | -7.8% | -17.1% | -12.9% | -10.1% |
| **Overall (Ref EL+BL vs single EL+BL)** | -13.0% | -9.9% | -6.9% | -16.3% | -13.2% | -10.9% |
| **EL only (Test vs Ref)** | -1.3% | -0.5% | -1.4% | -1.5% | 0.0% | 0.6% |
| Enc Time[%] | 102.0% | | | 102.1% | | |
| Dec Time[%] | 104.2% | | | 103.2% | | |
| Enc Mem[%] | #DIV/0! | | | #DIV/0! | | |
| BL Match | Matched | | | Matched | | |

Table 2: BDR of piese-wise linear preduction with gain-offset prediction as reference.

# Proposal –Shift-Offset Model

JCTVC-L0334 proposes two models for color gamut prediction as:

Bit-increment: Pix2020 = Pix709 << 2

Gain-offset: Pix2020=G\*Pix709+O; where G and O are optimized either on-line or off-line.

This contribution proposes the following model, which requires less complexity than Gain-offset, and provides better coding efficiency than Bit-increment as:

Shift-offset: Pix2020 = Pix709 << 2+O; where O are optimized either on-line or off-line.

With Gain-offset model, there are 2 variables to be optimized. With Shift-offset model, only 1 variable needs to be optimized. As SAO is already included in HEVC, offset optimization functionality should be already implemented in typical HEVC encoders. Additional implementation cost will be smaller with Shift-offset model than Gain-offset model.

## Results

Fig 3.1.1(a) is 10-bit image generated from BT.709 image with 8-bit depth just by shifting. (b) is 10-bit image by shifting and offset. Optimized offset for one picture is calculated for Y/Cb/Cr components independently. (c) is BT.2020 image.



1. BT.709 + Shift



1. BT.709 + Shift + Offset



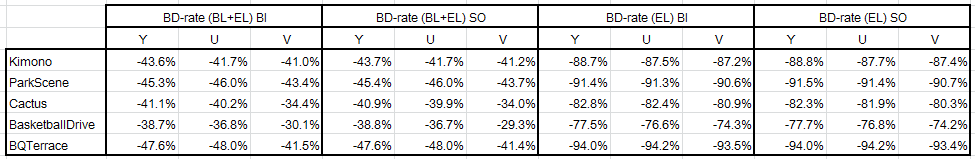
1. BT.2020

Fig 3.1.1

The proposed method is implemented on the source code of JCTVC-L0334, which is based on SMuC-0.1.1. Class B sequences are tested with AI\_SNR condition. Optimized offset is calculated with the first picture and applied for the whole sequence. Summary of the result is shown in Table 3.1.1. Anchor is simulcast coding with HM-8.1.

It is expected that coding efficiency can be improved by

* Offset optimization for each picture, or
* Optimized offset with finer granularity, e.g. block-based or range-based.



# Conclusion

This contribution proposes to use piecewise-linear prediction and shift-offset model for color space prediction in SHVC for color gamut scalability.

# Reference

1. Louis Kerofsky, Andrew Segall, Seung-Hwan Kim, and Kiran Misra, “Color Gamut Scalable Video Coding: New Results”, JCTVC-L0334, 12th Meeting: Geneva, CH, 14–23 Jan. 2013.
2. [Earth - Multivariate adaptive regression splines in Orange (Python machine learning library)](http://orange.biolab.si/blog/2011/12/20/earth-multivariate-adaptive-regression-splines/).

# Patent rights declaration(s)

**Sony Corp. and Sony Electronics Inc. may have current or pending patent rights relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**