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| *Title:* | **AHG7: In-loop color-space transformation of residual signals for range extensions** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This contribution proposes the in-loop color-space transformation of residual signals for HEVC range extensions. This approach transforms prediction error signals in 4:4:4 chroma format into those in a sub-optimal color space. As a result, redundancy of sample value between planes is reduced. The transformation matrix is derived from pixel domain for each coding unit by a singular-value-decomposition (SVD). The color-space transformation is applied to prediction error of both intra and inter mode. Simplified SVD is realized by integer multiplication, addition, and shift operations with limited iterations. No additional information is necessary because residual signals are always transformed. The YUV/RGB BD-rate gains of the All Intra / Random Access / Low delay B are 14.3% / 14.6% / 13.4% for the HE Main-tier and 10.7% / 8.7% / 8.1% for the High-tier, respectively.

# Introduction

This contribution proposes new in-loop color-space transformation for 4:4:4 chroma format. Transformed target is intra / inter residual signals. Transformation matrices are derived from neighboring samples / reference samples by using simplified singular-value-decomposition with limited iterations.

# Proposed method

## Overview

Block diagram of the proposed in-loop color-space transformation is illustrated in Fig. 1. Compared to the existing HEVC architecture, matrix derivation and color-space transformation / inverse transformation are added. The input of the matrix derivation is either local decoded image or frame buffer. The output of the matrix derivation is a transformation matrix for each coding unit. After intra / inter prediction, residual signals are transformed by the derived matrix. Resulting signals are coded by the existing tools in the HEVC. In the following section, we describe the each component in Fig. 1.



Figure Block diagram of the proposed in-loop color-space transformation. Matrix derivation is applied to signals in pixel domain. Resulting matrix is applied to signals in residual domain.

## Transform and inverse transform

In the forward operation, color-space transformation matrix is applied to three planes G, B, and R as follows,

.

Resulting values are clipped within the range of the HEVC specification because values are enlarged of times in the worst case.

In the inverse operation, color-space transformation matrix is applied the three components P’, Q’, and R’ as follows,

.

## Derivation algorithm of transformation matrix

Transform matrix is derived from the reference sample values. Difference reference samples are utilized for the intra case and inter case.

For the case of intra block, target block and reference samples are shown in Fig. 2. In this figure, target block consists of 8x8 gray samples and references are orange and purple samples.



Figure An example of the target block and reference sample for the case of intra 8x8 block.

Actual reference samples depend on the intra prediction mode. Orange pixels are referred to when the intra prediction mode is the range from two to ten, while purple pixels are referred to when the intra prediction mode is in the rage from 26 to 34. Otherwise, both orange and purple pixels are referred to. In any case, the number of reference samples becomes the power-of-two. Therefore upper left region is not included due to the violation of shift operation to compute an average.

For the case of inter block, reference samples for the matrix derivation is the same as that for motion compensation. In order to realize the shift operation, reference samples in the AMP block is sub-sampled such that the number of samples becomes the power-of-two. For example, the number of reference samples in a 12x16 block is reduced to 2/3.

After getting the reference samples, an average of sample values in the same plane is subtracted from the reference sample values. A covariance matrix of three planes is computed from the subtracted values. For example, when the number of reference pixels is 32, a covariance matrix is computed by . The covariance matrix is then normalized by the shit operation so that maximum value of diagonal elements become within the range from 4096 to 8191.

After generating normalized covariance matrix, SVD is applied based on Jacob algorithm. The maximum number of main iterations is decided to three. A square root computation of arbitrary number is also realized by integer operation with two iterations. Finally, each column is sorted so that values of diagonal elements are decreased and then transposed. The obtained matrix is named . When the reference samples are not available, is a unit matrix.

## Coding structure restriction and syntax

Coding structure is required to be identical among all planes because of the color space transformation. For instance, following items need the same properties; the type of prediction unit, the mode of intra prediction. Although this restriction can reduce the some syntax elements, such syntax modification is not applied in order to keep the existing syntax. As a result, any syntax modification is not required for this scheme.

# Experimental results

The proposed mode is implemented to HM-range-extensions (r3055). A test condition follows the common test condition for HEVC range extensions [2]. Following tables show the summary of BD-rate gain and codec runtime.

Table Results of the All Intra HE conditions

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra HE Main-tier** | | | | **All Intra HE High-tier** | | | |
|  | Y | U | V | YUV | Y | U |  | V |
| RGB 4:4:4 | -28.8% | -19.2% | -27.8% | -23.8% | -21.3% | -13.7% | -20.8% | -17.6% |
| YCbCr 4:4:4 | -1.9% | -7.4% | -10.3% | -3.5% | -2.6% | -3.5% | -9.5% | -2.8% |
| YCbCr 4:2:2 |  |  |  |  |  |  |  |  |
| **Overall** | -16.3% | -13.7% | -19.7% | -14.3% | -12.6% | -9.0% | -15.5% | -10.7% |
|  | -16.2% | -14.2% | -19.6% | -14.3% | -12.6% | -9.7% | -15.7% | -10.6% |
| Enc Time[%] | 107.1% | | | | 107.2% | | | |
| Dec Time[%] | 106.5% | | | | 105.9% | | | |

Table Results of the Random Access HE conditions

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access HE Main-tier** | | | | **Random Access HE High-tier** | | | |
|  | Y | U |  | V | Y | U |  | V |
| RGB 4:4:4 | -34.4% | -13.7% | -29.1% | -23.4% | -27.4% | -3.1% | -22.2% | -13.6% |
| YCbCr 4:4:4 | -1.5% | -12.2% | -12.9% | -4.4% | -2.2% | -6.2% | -13.2% | -3.1% |
| YCbCr 4:2:2 |  |  |  |  |  |  |  |  |
| **Overall** | -19.0% | -13.0% | -21.5% | -14.6% | -15.7% | -4.6% | -18.0% | -8.7% |
|  | -18.2% | -15.1% | -21.0% | -12.3% | -17.7% | -7.2% | -18.9% | -10.2% |
| Enc Time[%] | 106.0% | | | | 105.9% | | | |
| Dec Time[%] | 104.4% | | | | 106.5% | | | |

Table Results of the Low delay B HE conditions

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Low delay B HE Main-tier** | | | | **Low delay B HE High-tier** | | | |
|  | Y | U |  | V | Y | U |  | V |
| RGB 4:4:4 | -35.6% | -8.4% | -27.0% | -20.2% | -27.5% | 0.2% | -21.1% | -12.3% |
| YCbCr 4:4:4 | -3.2% | -12.0% | -14.9% | -5.6% | -4.3% | -4.7% | -15.1% | -3.4% |
| YCbCr 4:2:2 |  |  |  |  |  |  |  |  |
| **Overall** | -20.5% | -10.1% | -21.4% | -13.4% | -16.7% | -2.1% | -18.3% | -8.1% |
|  | -18.8% | -6.4% | -18.2% | -2.5% | -17.3% | -3.1% | -18.5% | -7.9% |
| Enc Time[%] | 105.2% | | | | 105.2% | | | |
| Dec Time[%] | 106.6% | | | | 108.3% | | | |

# Conclusion

This contribution proposed in-loop color-space transformation of residual signals. The proposed method reduced the redundancy of color space in 4:4:4 chroma format. Since transformation matrix was derived from reconstructed samples on the both encoder and decoder side, no side information was necessary. On the other hand, actual transformation target is signals in residual domain. Computation of matrix derivation is completely realized by integer multiplication, addition, and shift operation with limited iterations.

Experimental results showed that the proposed method achieved 14.3%, 14.6%, and 13.4% BD-rate reduction respectively for the All Intra, Random Access and Low delay B of HE Main-tier.

Since the in-loop color-space transformation achieves solid coding gain with inter-plane correlation, we recommend adopting it in HEVC range extensions.

# References

1. K. Kawamura et al. “AHG7: Adaptive colour-space transformation of residual signals”, JCTVC-K0193, Shanghai, Oct. 2012.
2. D. Flynn, “Common test conditions and software reference configurations for HEVC range extensions,” JCTVC-K1006, Shanghai, Oct. 2012.

# Patent rights declaration(s)

**KDDI Corporation 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).**