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| *Title:* | **Non-CE Simplification of illumination compensation** | | |
| *Status:* | Input Document | | |
| *Purpose:* | Proposal | | |
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# Abstract

In the last meeting, Illumination Compensation(IC) was adopted for improving performance of inter-view prediction. It had significant benefits for correction of luminance/chrominance mismatch between views. However, the method had relatively high complexity. To solve least square solution, multiplications between arbitrary sample values were necessary. In this proposal, simplification of IC is presented. Using only offset model, IC can be carried out by multiplication-free process. It has BD-rate coding change 0.0% compared to current IC model on video only result with 100.3% encoding time, and 98.0% decoding time. Compared to disabling IC on HTM-5.0.1, coding gain -0.6% is maintained on video only.

# Introduction

In JCV3V-B0045[1], linear model compensation was applied to correct inter-view luminance / chrominance mismatches. When the IC flag on CU was turned on, each pixel on disparity compensated block were compensated the below equations.

Where, is compensated prediction samples in a block and is prediction samples in a block before compensation is applied.

Parameter can be derived from reconstructed samples around ,. Both encoder and decoder should solve the linear least square equations to estimate . The below equations presents the linear least square solution. To reduce computing complexity, the division was replaced by multiplication, shift, and look-up-table. But, It has still multiplications of arbitrary sample values for computing cross-correlation of samples.

Where, , are left and top neighbor pixels by ,, respectively.

# Proposed Method

For the complexity reduction of current IC, Only offset model is applied to compensate luminance/chrominance mismatches. IC can be carried out using only additions and shifts without multiplications. The compensation model is just adding an offset as the below equation.

The parameter can be calculated by the below equation.

There are some coding loss on the average with respect to reduce the estimation order. However, It has the advantage removing multiplications of arbitrary numbers on IC process.

# Complexity Analysis

Table1. comparison of operation number of current and proposed IC (per pixel)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Prediction step | Current IC | | | Proposed IC | | |
| Mul | Add | Shift | Mul | Add | Shift |
| Calculation of and for one block | ~=4·*N* +6 | ~=8·*N* +4 | ~=6 | 0 | ~=4·*N* +1 | ~=1 |
| Prediction for each pixel | 1 | 1 | 1 | 0 | 1 | 1 |
| Total operation number for each pixel prediction | 1+4/ *N +*6/ *N2* | 1+8/ *N +4*/ *N2* | 1+6/ *N2* | 0 | 1+4/ *N +*1/ *N2* | 1+1/*N2* |

Table2. comparison of operation number of current and proposed IC (16x16 block example )

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Prediction step | Current IC | | | Proposed IC | | |
| Mul | Add | Shift | Mul | Add | Shift |
| Calculation of and for 16x16 block | ~=70(34) | ~=132 | ~=6 | 0 | ~=64 | ~=1 |
| Prediction for each pixel | 1 (1) | 1 | 1 | 0 | 1 | 1 |
| Total operation number for a 16x16 block | 71(35) | 133 | 7 | 0 | 65 | 2 |

\* The numbers (\*) are the multiplications of cross-correlation (arbitrary samples)

# Experimental results

The offset model is integrated into HTM-5.0.1. The configuration of common test condition is applied. Table1 and Table2 reportedly shows the experimental results. In this contribution, the bug fix on JCT3V-C0046[2] is also applied.

Table3. BD-rate change of proposed method, Anchor : JCT3V-C0046[2] (bug fix part)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | video 0 | video 1 | video 2 | video only | synthesized only | coded & synthesized | enc time | dec time |
| Balloons | 0.0% | -0.8% | -0.4% | -0.2% | -0.2% | -0.2% | 101.4% | 102.5% |
| Kendo | 0.0% | 1.5% | 1.2% | 0.6% | 0.5% | 0.5% | 100.3% | 96.9% |
| Newspapercc | 0.0% | 0.0% | 0.1% | 0.0% | 0.1% | 0.1% | 100.3% | 94.8% |
| GhostTownFly | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% | 95.6% |
| PoznanHall2 | 0.0% | -0.3% | -1.7% | -0.5% | -0.3% | -0.4% | 100.3% | 98.3% |
| PoznanStreet | 0.0% | -0.3% | -0.1% | -0.1% | 0.0% | -0.1% | 100.0% | 102.9% |
| UndoDancer | 0.0% | 0.2% | 0.0% | 0.0% | 0.0% | 0.0% | 99.9% | 95.1% |
| 1024x768 | 0.0% | 0.2% | 0.3% | 0.1% | 0.1% | 0.1% | 100.7% | 98.0% |
| 1920x1088 | 0.0% | -0.1% | -0.4% | -0.1% | -0.1% | -0.1% | 100.0% | 97.9% |
| **average** | **0.0%** | **0.1%** | **-0.1%** | **0.0%** | **0.0%** | **0.0%** | **100.3%** | **98.0%** |

Table4. BD-rate changes of proposed method with IC\_bugfix, Anchor : HTM-5.0.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | video 0 | video 1 | video 2 | video only | synthesized only | coded & synthesized | enc time | dec time |
| Balloons | 0.0% | -1.1% | -0.7% | -0.4% | -0.2% | -0.3% | 102.0% | 102.8% |
| Kendo | 0.0% | 0.4% | 0.2% | 0.1% | 0.2% | 0.2% | 101.3% | 96.0% |
| Newspapercc | 0.0% | -0.5% | -0.4% | -0.2% | -0.1% | -0.1% | 100.8% | 100.5% |
| GhostTownFly | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.1% | 92.5% |
| PoznanHall2 | 0.0% | -0.3% | -1.9% | -0.6% | -0.3% | -0.3% | 100.8% | 95.6% |
| PoznanStreet | 0.0% | -0.5% | -0.3% | -0.1% | -0.1% | -0.s1% | 100.3% | 102.2% |
| UndoDancer | 0.0% | 0.1% | 0.0% | 0.0% | -0.1% | -0.1% | 100.2% | 101.6% |
| 1024x768 | 0.0% | -0.4% | -0.3% | -0.2% | 0.0% | -0.1% | 101.4% | 99.7% |
| 1920x1088 | 0.0% | -0.2% | -0.6% | -0.2% | -0.1% | -0.1% | 100.4% | 97.9% |
| **average** | **0.0%** | **-0.3%** | **-0.5%** | **-0.2%** | **-0.1%** | **-0.1%** | **100.8%** | **98.7%** |

Table5. BD-rate change of offset model, Anchor : HTM-5.0.1, (IlluCompEnable : 0)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | video 0 | video 1 | video 2 | video only | synthesized only | coded & synthesized | enc time | dec time |
| Balloons | 0.0% | -2.6% | -2.3% | -1.1% | -0.7% | -0.8% | 108.5% | 94.3% |
| Kendo | 0.0% | -2.9% | -4.2% | -1.6% | -1.2% | -1.3% | 109.6% | 98.2% |
| Newspapercc | 0.0% | -1.1% | -1.4% | -0.6% | -0.5% | -0.5% | 105.7% | 100.5% |
| GhostTownFly | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.8% | 99.9% |
| PoznanHall2 | 0.0% | -0.5% | -3.2% | -0.9% | -0.5% | -0.6% | 105.6% | 106.0% |
| PoznanStreet | 0.0% | 0.1% | -0.4% | -0.1% | -0.1% | -0.1% | 104.7% | 106.2% |
| UndoDancer | 0.0% | 0.2% | 0.2% | 0.1% | 0.1% | 0.1% | 103.9% | 98.6% |
| 1024x768 | 0.0% | -2.2% | -2.7% | -1.1% | -0.8% | -0.9% | 107.9% | 97.7% |
| 1920x1088 | 0.0% | -0.1% | -0.8% | -0.2% | -0.1% | -0.2% | 103.7% | 102.6% |
| **average** | **0.0%** | **-1.0%** | **-1.6%** | **-0.6%** | **-0.4%** | **-0.5%** | **105.5%** | **100.5%** |

Although the complexity is reduced, there is coding gain in some cases, especially Poznan\_Hall2 video2.

# WD Text

###### 8.5.2.2.3.3.1 Illumination compensation based sample prediction process

Inputs to this process are:

– a location ( xB, yB ) specifying the top-left sample of the current prediction block relative to the top left sample of the current coding block,

– the width and height of this prediction block, nPbW and nPbH,

– two (nPbW)x(nPbH) arrays predSamplesL0 and predSamplesL1,

– prediction list utilization flags, predFlagL0 and predFlagL1,

– the width of current coding unit, nCbW,

– neighboring samples of current coding unit p[ x, y ], with x = -1, y = 0..nCbW−1, and y = -1, x = 0..nCbW−1,

– availability of neighboring samples of current coding unit, avaiAboveRow, avaiLeftCol,

– availability of neighboring samples of reference coding unit, avaiAboveRowRefL0, avaiLeftColRefL0, and avaiAboveRowRefL1, avaiLeftCol RefL1,

– if predFlagL0 is equal to 1, neighboring samples of referenced coding unit of list 0 r0[ x, y ], with x = -1, y = 0..nCbW−1, and y = -1, x = 0..nCbW−1,

– if predFlagL1 is equal to 1, neighboring samples of referenced coding unit of list 1 r1[ x, y ], with x = -1, y = 0..nCbW−1, and y = -1, x = 0..nCbW−1,

Outputs of this process are:

– the (nPbW)x(nPbH) array predSamples of prediction sample values.

Derive nS0 and nS1 using following two order steps, with *idx* in the following variables nS*idx*, avaiAboveRowRefL*idx* and avaiLeftColRefL*idx* replaced by 0 and 1:

1. if avaiAboveRowRefL*idx* is equal to 0 or avaiAboveRow is equal to 0, nS*idx* is set to 1; otherwise, if avaiAboveRowRefL*idx* is equal to 1 and avaiAboveRow is equal to 1, nS*idx* is set to 0,

2. if avaiLeftColRefL*idx* is equal to 0 or avaiLeftCol is equal to 0, nS*idx* is set to nS*idx*+1; otherwise, if avaiAboveRowRefL*idx* is equal to 1 and avaiAboveRow is equal to 1, nS*idx* is set to nS*idx*,

The parameters of linear illumination compensation model are derived as the following ordered steps. if predFlagL0 is equal to 1 and nS0 is not equal to 2, (ica0, ick0, icb0) used for list 0 is derived by replacing *idx* in avaiAboveRowRefL*idx*, avaiLeftColRefL*idx*, nS*idx*, r*idx*, ica*idx*, ick*idx* and icb*idx* with 0; otherwise, set ica0 to 1, ick0 to 0 and icb0 to 0. if predFlagL1 is equal to 1 and nS0 is not equal to 2, (ica1, ick1, icb1) used for list 1 is derived by replacing *idx* in avaiAboveRowRefL*idx*, avaiLeftColRefL*idx*, nS*idx*, r*idx*, ica*idx*, ick*idx* and icb*idx* with 1; otherwise, set a1 to 1, k1 to 0 and b1 to 0.

1. Variable k3 is derived as:

k3 = Max( 0, BitDepth + Log2( nCbW >> nS*idx* ) − 14 ) (8‑xxx)

1. Variables R, P and k2 are derived as follows:
   1. If avaiAboveRowRefL*idx* is equal to 1, avaiAboveRow is equal to 1, avaiLeftColRefL*idx* is equal to 1 and avaiLeftCol is equal to 1

R =  (8‑xxx)

P =  (8‑xxx)

* 1. Else, if avaiAboveRowRefL*idx* is equal to 1 and avaiAboveRow is equal to 1, and avaiLeftColRefL*idx* is equal to 0 or avaiLeftCol is equal to 0,

R =  (8‑xxx)

P =  (8‑xxx)

* 1. Else, if avaiAboveRowRefL*idx* is equal to 0 or avaiAboveRow is equal to 0, and avaiLeftColRefL*idx* is equal to 1 and avaiLeftCol is equal to 1,

R =  (8‑xxx)

P =  (8‑xxx)

k2 = Log2( (2\*(nCbW >> nS*idx*)) >> k3 ) (8‑xxx)

1. Variables ica*idx*, icb*idx* and ick*cidx* are derived as:

icb*idx* = ( R – P ) + ( 1 << ( k2 − 1 ) ) ) >> k2 (8‑xxx)

The prediction sample predSamples[ x ][ y ] with x = 0..(nPbW)−1 and y = 0..(nPbH)−1 are derived as follows:

– If the predFlagL0 is equal to 1 and predFlagL1 is equal to 0, the prediction samples are derived by:

predSamples[ x ][ y ] = Clip3( 0, ( 1 << bitDepth ) − 1, ( (predSamplesL0[ x ][ y ] + offset1 ) >> shift1) + icb0 ) (8‑xxx)

– Otherwise, if the predFlagL0 is equal to 0 and predFlagL1 is equal to 1, the final predicted sample values predSamples [ x ][ y ] are derived by

predSamples[ x ][ y ] = Clip3( 0, ( 1 << bitDepth ) − 1, ( ( predSamplesL1[ x ][ y ] + offset1 ) >> shift1) + icb1 ) (8‑xxx)

– Otherwise, the final predicted sample values predSamples[ x ][ y ] are derived by

predSamples[ x ][ y ] = Clip3( 0, ( 1 << bitDepth ) − 1,   
 predSamplesL0[ x ][ y ]   + predSamplesL1[ x ][ y ]  + offset2 +  
 ( (icb0 + icb1 ) << shift1) ) >> shift2 ) (8‑xxx)

# Conclusion

In this contribution, a method to use simple offset model is proposed to simplify IC process. The current method for IC is relatively complex because the process contains multiplications of arbitrary samples. The process to calculate least square solution is replaced with the calculation of the difference of mean values. Although the BD-rate results have little coding loss on the coded & synthesized results, the proposed method has the benefits of multiplication-free and.

It is recommended that proposed method is adopted into 3D-HEVC.

# Reference

1. H. Liu, J. Jung, J. Sung*, etc.*, (LG), "3D-CE2.h : Results of Illumination Compensation for Inter-View Prediction", Joint Collaborative Team on 3D Video Coding Extension Development (JCT-3V) of ITU-T VCEG and ISO/IEC MPEG JCT3V-B0045, Shanghai, China, October, 2012.
2. H. Liu, J. Jung, J. Sung*, etc.*, (LG), "CE5.h related : Bug Fix and Extension of Illumination Compensation", Joint Collaborative Team on 3D Video Coding Extension Development (JCT-3V) of ITU-T VCEG and ISO/IEC MPEG JCT3V-C0046, Geneva, Switzerland, January, 2013.

# Patent rights declaration(s)

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