|  |  |
| --- | --- |
| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11**  6th Meeting: Torino, 14-22 July, 2011 | Document: JCTVC-F248 |

|  |  |  |  |
| --- | --- | --- | --- |
| *Title:* | **CE3: Interpolation filter with shorter tap-length for small PU's** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
| *Author(s) or Contact(s):* | Kemal Ugur, Jani Lainema, Oguz Bici Visiokatu 1, Tampere, Finland | Tel: Email: | +358 50 4860857 [kemal.ugur@nokia.com](mailto:kemal.ugur@nokia.com) [jani.lainema@nokia.com](mailto:jani.lainema@nokia.com)  ext-oguz.bici@nokia.com |
| *Source:* | Nokia | | |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Abstract

This contribution presents Nokia’s response to the Core Experiment-3. In this proposal instead of the HM 8-tap filter, a 4-tap filter is used for bi-predicted small PU’s. The main goal of the proposal is to reduce the peak memory bandwidth of HEVC without impacting the coding efficiency. Experimental results show that coding efficiency changes negligibly (by around 0.03% on average) using this technique.

# Introduction

HM3.0 defines an 8-tap separable filter to interpolate luma samples. For small motion blocks, utilizing the 8-tap filter brings a significant overhead in terms of memory bandwidth. For example if the PU size is 4x4, then the decoder needs to load 11x11 = 121 samples (assuming MV points one of the sub-pixels that are not horizontally or vertically aligned with the integer samples). This is around 7.5 times the prediction block and significantly increase, especially, the worst case memory bandwidth.

In order to reduce the memory bandwidth overhead we propose the following:

* For bi-predicted blocks of PU size < 8x8, use 4-tap filter.
* For other cases, use 8-tap filter as defined in HM3.0.

The main reason to limit the usage of bilinear filter for small block sizes is that memory bandwidth is more problematic when the block size is small. For example, for a 16x16 block size, decoder needs to load a 23x23 block (which is around 2 x the prediction block size), but for a 4x4 block size, decoder needs to load a 11x11 block (which is around 7.5 x prediction block size).

In addition to reducing the peak memory bandwidth, the average memory bandwidth and average interpolation complexities are also reduced.

The utilized 4-tap filter has the following taps (it is designed to have a sharp frequency response as it is only used for bi-prediction):

½ pel : [-6 38 38 -6]

¼ pel : [-6 56 18 -4]

In order to avoid supporting an additional 4-tap filter in the HEVC design, the chroma 4-tap filter could be re-used. The results for that case will also be provided.

# Experimental Results

The proposal is implemented in HM3.0. It should be noted that the motion estimation stage utilizes an 8-tap filter, but during motion compensation the prediction block is generated using the 4-tap filter. (Results for low-delay with P pictures are not presented as they are identical to the anchor)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | Random access |  |  | Random access LC |  |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | -0.1 | -0.2 | 0.0 | 0.0 | 0.0 | 0.2 |
| Class B | 0.0 | 0.0 | 0.0 | -0.1 | 0.0 | 0.0 |
| Class C | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | -0.1 |
| Class D | 0.3 | 0.1 | 0.1 | 0.3 | 0.2 | 0.1 |
| Class E |  |  |  |  |  |  |
| All | 0.06 | 0.0 | 0.0 | 0.05 | 0.0 | 0.1 |
| Enc Time[%] | 101% | | | 101% | | |
| Dec Time[%] | 96% | | | 100% | | |
|  |  |  |  |  |  |  |
|  | Low delay | | | Low delay LC | | |
|  | Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A |  |  |  |  |  |  |
| Class B | 0.0 | 0.2 | 0.3 | -0.1 | -0.1 | -0.3 |
| Class C | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 | -0.1 |
| Class D | 0.1 | 0.4 | 0.4 | 0.0 | 0.2 | 0.1 |
| Class E | 0.1 | -0.2 | -0.3 | -0.1 | -0.2 | -0.6 |
| All | 0.05 | 0.2 | 0.2 | -0.04 | 0.0 | -0.2 |
| Enc Time[%] | 101% | | | 101% | | |
| Dec Time[%] | 99% | | | 100% | | |

In CE3, various other filter coefficients are presented. Some variations of this proposal together with other proposals are presented below as supplementary experimental data

**Using the same 4-tap chroma filter**

This test reuses the same 4-tap filter coefficients used for chroma sample interpolation instead of the ones defined in previous subsection. The aim of this is to improve the spec. cleanliness and help in implementation complexity. On average the coding efficiency loss is 0.05%

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | Random access |  |  | Random access LC |  |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | 0.06 | 0.04 | 0.07 | 0.00 | -0.02 | 0.19 |
| Class B | 0.00 | -0.04 | 0.00 | -0.02 | 0.03 | 0.04 |
| Class C | 0.11 | 0.08 | 0.08 | 0.12 | 0.04 | 0.02 |
| Class D | 0.36 | 0.19 | 0.13 | 0.38 | 0.19 | 0.21 |
| Class E |  |  |  |  |  |  |
| All | 0.12 | 0.06 | 0.07 | 0.11 | 0.06 | 0.11 |
| Enc Time[%] |  | | |  | | |
| Dec Time[%] |  | | |  | | |
|  |  |  |  |  |  |  |
|  | Low delay | | | Low delay LC | | |
|  | Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A |  |  |  |  |  |  |
| Class B | -0.04 | 0.05 | 0.24 | -0.07 | -0.02 | -0.16 |
| Class C | 0.00 | 0.11 | 0.08 | 0.00 | 0.15 | -0.02 |
| Class D | 0.12 | 0.15 | -0.06 | 0.09 | 0.00 | -0.01 |
| Class E | 0.05 | -0.20 | 0.06 | -0.36 | -0.20 | 0.11 |
| All | 0.03 | 0.04 | 0.09 | -0.07 | 0.00 | -0.04 |
| Enc Time[%] |  | | |  | | |
| Dec Time[%] |  | | |  | | |

**Using with Samsung’s coefficients**

This test reuses the same 4-tap filter coefficients used for chroma sample interpolation and implements the idea on top of Samsung’s 7H6Q proposal. On average the coding efficiency loss is 0.09%

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | Random access |  |  | Random access LC |  |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | 0.08 | 0.27 | 0.10 | 0.04 | 0.04 | 0.06 |
| Class B | 0.01 | 0.05 | -0.05 | 0.00 | 0.02 | 0.04 |
| Class C | 0.15 | 0.07 | 0.16 | 0.15 | 0.04 | 0.09 |
| Class D | 0.36 | 0.33 | 0.28 | 0.39 | 0.22 | 0.27 |
| Class E |  |  |  |  |  |  |
| All | 0.14 | 0.17 | 0.11 | 0.14 | 0.08 | 0.11 |
| Enc Time[%] |  | | |  | | |
| Dec Time[%] |  | | |  | | |
|  |  |  |  |  |  |  |
|  | Low delay | | | Low delay LC | | |
|  | Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A |  |  |  |  |  |  |
| Class B | -0.01 | 0.09 | 0.20 | -0.03 | 0.19 | 0.10 |
| Class C | 0.02 | 0.07 | -0.08 | 0.04 | 0.27 | 0.00 |
| Class D | 0.24 | 0.65 | 0.25 | 0.23 | 0.74 | 0.07 |
| Class E | -0.06 | 0.30 | 0.47 | -0.25 | -0.18 | 0.19 |
| All | 0.05 | 0.26 | 0.19 | 0.01 | 0.28 | 0.09 |
| Enc Time[%] |  | | |  | | |
| Dec Time[%] |  | | |  | | |

**Using with Motorola’s coefficients**

This test reuses the same 4-tap filter coefficients used for chroma sample interpolation and implements the idea on top of Motorola’s 8H8Q proposal. On average the coding efficiency loss is 0.08%

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | Random access |  |  | Random access LC |  |
| Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A | 0.08 | 0.05 | -0.06 | -0.03 | 0.01 | 0.02 |
| Class B | 0.01 | -0.04 | 0.03 | 0.00 | -0.03 | 0.00 |
| Class C | 0.17 | 0.09 | 0.28 | 0.15 | 0.05 | 0.08 |
| Class D | 0.38 | 0.33 | 0.29 | 0.43 | 0.13 | 0.23 |
| Class E |  |  |  |  |  |  |
| All | 0.15 | 0.10 | 0.13 | 0.13 | 0.04 | 0.08 |
| Enc Time[%] |  | | |  | | |
| Dec Time[%] |  | | |  | | |
|  |  |  |  |  |  |  |
|  | Low delay | | | Low delay LC | | |
|  | Y BD-rate | U BD-rate | V BD-rate | Y BD-rate | U BD-rate | V BD-rate |
| Class A |  |  |  |  |  |  |
| Class B | -0.01 | 0.00 | -0.04 | -0.09 | 0.13 | 0.18 |
| Class C | 0.00 | -0.13 | 0.24 | -0.07 | -0.11 | -0.11 |
| Class D | 0.17 | 0.25 | 0.27 | 0.16 | 0.02 | 0.74 |
| Class E | 0.08 | 0.30 | -0.30 | -0.14 | -0.61 | 0.14 |
| All | 0.05 | 0.09 | 0.06 | -0.03 | -0.10 | 0.24 |
| Enc Time[%] |  | | |  | | |
| Dec Time[%] |  | | |  | | |

# Memory bandwidth analysis

Below table compares the memory bandwidth reduction by using 4-tap filter instead of 8-tap filter for small block sizes.

|  |  |  |  |
| --- | --- | --- | --- |
| PU Size | 8-tap filter | 4-tap filter | Percent reduction in memory bandwidth |
| 4x4 | 11x11 = 121 | 7x7 = 49 | 59% |
| 4x8 | 11x15 = 165 | 7x11 = 77 | 53% |
| 8x4 | 15x11 = 165 | 11x7 = 77 | 53% |

# Complexity analysis

The following chart depicts the complexity summary of the proposal as measured in CE3.

# 

# 

# Patent rights declaration(s)

**Nokia may have IPR 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).**