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| *Title:* | **CE3: 7 taps interpolation filters for quarter pel position MC from Samsung and Motorola Mobility.** | | |
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| *Purpose:* | Proposal | | |
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# Abstract

Two variants of 7 taps interpolation filter for quarter-pel position are tested here. Both resolves visual artifacts problem is LD(P)-LC, SAO off test. Both show performance improvement compare to HM4.0. An average BD-rate for Y/U/V components across 6 test cases required in CE3: -0.1%/ -0.1%/-0.2% for variant A and -0.4%/0.0%/0.0% for variant B. Two variants of proposed 7 taps filters use different phase shift (1/4 for variant A and 3/16 for variant B) which results in the same worst case computational complexity and memory access while different hit-ration for fractional position in MC process and so different statistical computation complexity was observed. For variant A the number of computations according to CE3 measure is 5-6% smaller compare to HM4.0. Variant B shows 1-2% higher computational complexity compare to HM4.0

# Introduction

HM4.0 uses 8 taps 2D separable interpolation filter proposed in [1-2]. In [3] and [4] was shown that if 7 taps interpolation filter is used for quarter pel position in MC then it allows to improve the compression efficiency for HD contents as well as all content sizes for LD(P) HE and LC test cases.

Several times before both Samsung and Motorola mobility propose solid (non-switchable) interpolation filter solution for HEVC. After internal discussion of variants previously proposed in [1-7] Samsung and Motorola have chosen following two variants of solid (non-switchable) interpolation filters for HEVC:

1. “7q(1/4)+8h”

* Luma:

1/4 : {-1,   4, -10,  58,  17,  -5,   1,   0}  
1/2 : {-1,   4,  -11,  40,  40, -11,   4,  -1}

* Chroma:

1/8: {-2, 58, 10,-2}   
1/4: {-4,  54,  16,  -2}  
3/8: {-6, 46, 28, -4}   
1/2: {-4,  36,  36,  -4}

1. “7q(3/16)+8h”

* Luma:

1/4 : {-1,   3,  -8,  60,  13,  -4,   1,   0}  
1/2 : {-1,   4,  -11,  40,  40, -11,   4,  -1}

* Chroma:

1/8: {-2,  61,   6,  -1}  
1/4: {-4,  54,  16,  -2}  
3/8: {-5,  44,  29,  -4}  
1/2: {-4,  36,  36,  -4}

In both variants half-pel position filter is unchanged compare to HM4.0. Variant A was designed assuming phase shift 1/4 for quarter-pel fractional position but in variant B efficient phase shift is 3/16.

As it was shown in [7],[8] Chroma interpolation filter need to be synchronized with Luma. If down sampled Chroma shares the same MV with Luma then the phase shift in Chroma Interpolation Filter should be twice smaller than for Luma. Due to this reason 1/8-pel Chroma interpolation filters were modified compare to HM4.0 in both variants.

Chroma interpolation filter in HM4.0 [2] was designed assuming symmetric phase shift: 1/8 and 3/8, but efficient phase shift is slightly different form assumption due to rounding error. This was corrected in variant A chroma filter.

Because Luma quarter-pel filter was designed assuming 3/16 phase shift in variant B Chroma interpolation filter for positions 1/8 and 3/8 should be re-designed assuming phase shifts 3/32 and 13/32 correspondently. This synchronization explains changes of 1/8 and 3/8 position Chroma filter in variant B.

# Test results

We implemented both variants of proposed interpolation filters in HM4.0 and tested according to CE3 test description [9] under common test conditions [10]. Attached excel spreadsheets provide detail information of our tests.

We would like to thank e-Brisk and Nokia for cross-check of these tests.

## Variant A

Performance results are presented in Table 1.

**Table 1**. Variant A performance test in CE3 format..

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access HE** | | | **Random Access LC** | | |
|  | Y | U | V | Y | U | V |
| Class A | -0.1% | -0.3% | -0.2% | -0.1% | 0.2% | 0.5% |
| Class B | -0.1% | -0.1% | 0.0% | -0.1% | -0.1% | -0.2% |
| Class C | 0.1% | 0.1% | 0.1% | 0.4% | 0.2% | 0.1% |
| Class D | 0.1% | 0.1% | 0.1% | 0.8% | 0.0% | -0.1% |
| Class E |  |  |  |  |  |  |
| **Overall** | 0.0% | -0.1% | 0.0% | 0.2% | 0.1% | 0.1% |
|  | 0.0% | -0.1% | 0.0% | 0.2% | 0.1% | 0.1% |
| Enc Time[%] | 100% | | | 101% | | |
| Dec Time[%] | 100% | | | 102% | | |
| Mult[%] | -5% | | | -6% | | |
| Adds[%] | -6% | | | -7% | | |
| Access[%] | 0% | | | 0% | | |
| MemBand(2D) Ave.[%] | -1% | | | -1% | | |
| MemBand(2D) Max.[%] | 1% | | | 3% | | |
| MemBand(1D) Ave.[%] | -4% | | | 1% | | |
| MemBand(1D) Max.[%] | -1% | | | 6% | | |
|  |  |  |  |  |  |  |
|  | **Low delay B HE** | | | **Low delay B LC** | | |
|  | Y | U | V | Y | U | V |
| Class A |  |  |  |  |  |  |
| Class B | -0.2% | -0.5% | -0.4% | -0.3% | -0.4% | -0.5% |
| Class C | 0.1% | 0.1% | 0.1% | 0.3% | 0.3% | 0.1% |
| Class D | 0.5% | -0.1% | -0.1% | 0.8% | -0.1% | -0.5% |
| Class E | -0.5% | 0.2% | 0.6% | -0.7% | -0.3% | -0.6% |
| **Overall** | 0.0% | -0.1% | 0.0% | 0.0% | -0.1% | -0.4% |
|  | 0.0% | -0.2% | -0.1% | 0.0% | -0.2% | -0.4% |
| Enc Time[%] | 101% | | | 101% | | |
| Dec Time[%] | 101% | | | 102% | | |
| Mult[%] | -5% | | | -5% | | |
| Adds[%] | -6% | | | -6% | | |
| Access[%] | 0% | | | 0% | | |
| MemBand(2D) Ave.[%] | -1% | | | -1% | | |
| MemBand(2D) Max.[%] | 6% | | | 10% | | |
| MemBand(1D) Ave.[%] | -4% | | | 1% | | |
| MemBand(1D) Max.[%] | 1% | | | 11% | | |
|  |  |  |  |  |  |  |
|  | **Low delay P HE** | | | **Low delay P LC** | | |
|  | Y | U | V | Y | U | V |
| Class A |  |  |  |  |  |  |
| Class B | -0.2% | -0.3% | -0.2% | -0.7% | -0.4% | -0.7% |
| Class C | 0.0% | 0.3% | 0.1% | -0.1% | 0.2% | 0.1% |
| Class D | 0.6% | -0.3% | -0.6% | 0.4% | -0.4% | -0.7% |
| Class E | -0.7% | 0.0% | 0.3% | -2.1% | -1.4% | -1.1% |
| **Overall** | -0.1% | -0.1% | -0.1% | -0.5% | -0.5% | -0.6% |
|  | -0.1% | -0.1% | -0.2% | -0.5% | -0.5% | -0.6% |
| Enc Time[%] | 100% | | | 101% | | |
| Dec Time[%] | 101% | | | 102% | | |
| Mult[%] | -5% | | | -5% | | |
| Adds[%] | -6% | | | -6% | | |
| Access[%] | 0% | | | 0% | | |
| MemBand(2D) Ave.[%] | -1% | | | -1% | | |
| MemBand(2D) Max.[%] | 2% | | | 5% | | |
| MemBand(1D) Ave.[%] | -4% | | | 1% | | |
| MemBand(1D) Max.[%] | -2% | | | 8% | | |

|  |  |  |  |
| --- | --- | --- | --- |
| Gain Ave.[%] | -0.07% | -0.13% | -0.18% |
| Gain Min. [%] | -3.60% | -2.05% | -1.89% |
| Gain Max.[%] | 1.84% | 2.26% | 1.69% |
| Enc Time[%] | 100.45% | | |
| Dec Time[%] | 101.41% | | |
| Mult Ave.[%] | -5% | | |
| Mult Worst[%] | 0% | | |
| Adds Ave.[%] | -6% | | |
| Adds Worst[%] | 0% | | |
| Access[%] | 0% | | |
| MemBand(2D) Ave.[%] | -1% | | |
| MemBand(2D) Max.[%] | 5% | | |
| MemBand(2D) Worst[%] | 0% | | |
| MemBand(1D) Ave.[%] | -2% | | |
| MemBand(1D) Max.[%] | 4% | | |
| MemBand(1D) Worst[%] | 0% | | |

## Variant B

Performance results are presented in Table 2.

**Table 2**. Variant B performance test in CE3 format.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access HE** | | | **Random Access LC** | | |
|  | Y | U | V | Y | U | V |
| Class A | -0.1% | 0.0% | 0.0% | -0.2% | 0.3% | 0.2% |
| Class B | -0.2% | 0.0% | 0.0% | -0.2% | 0.0% | 0.0% |
| Class C | 0.0% | 0.0% | 0.2% | 0.4% | 0.3% | 0.3% |
| Class D | 0.1% | 0.2% | 0.3% | 1.0% | 0.3% | 0.5% |
| Class E |  |  |  |  |  |  |
| **Overall** | -0.1% | 0.1% | 0.1% | 0.2% | 0.2% | 0.2% |
|  | -0.1% | 0.1% | 0.1% | 0.2% | 0.2% | 0.2% |
| Enc Time[%] | 101% | | | 100% | | |
| Dec Time[%] | 102% | | | 99% | | |
| Mult[%] | 1% | | | 0% | | |
| Adds[%] | -1% | | | -1% | | |
| Access[%] | 3% | | | 3% | | |
| MemBand(2D) Ave.[%] | 2% | | | 2% | | |
| MemBand(2D) Max.[%] | 9% | | | 10% | | |
| MemBand(1D) Ave.[%] | 2% | | | 2% | | |
| MemBand(1D) Max.[%] | 10% | | | 10% | | |
|  |  |  |  |  |  |  |
|  | **Low delay B HE** | | | **Low delay B LC** | | |
|  | Y | U | V | Y | U | V |
| Class A |  |  |  |  |  |  |
| Class B | -0.3% | 0.1% | -0.2% | -0.5% | 0.3% | 0.3% |
| Class C | -0.1% | 0.3% | 0.3% | 0.1% | 0.5% | 0.4% |
| Class D | 0.4% | 0.6% | 0.8% | 0.7% | 0.8% | 0.8% |
| Class E | -0.5% | -0.3% | 0.0% | -1.0% | -0.2% | -1.1% |
| **Overall** | -0.1% | 0.2% | 0.2% | -0.1% | 0.4% | 0.2% |
|  | -0.1% | 0.1% | 0.1% | -0.1% | 0.4% | 0.1% |
| Enc Time[%] | 101% | | | 101% | | |
| Dec Time[%] | 100% | | | 101% | | |
| Mult[%] | 3% | | | 2% | | |
| Adds[%] | 2% | | | 1% | | |
| Access[%] | 4% | | | 4% | | |
| MemBand(2D) Ave.[%] | 1% | | | 1% | | |
| MemBand(2D) Max.[%] | 12% | | | 6% | | |
| MemBand(1D) Ave.[%] | 0% | | | 1% | | |
| MemBand(1D) Max.[%] | 11% | | | 5% | | |
|  |  |  |  |  |  |  |
|  | **Low delay P HE** | | | **Low delay P LC** | | |
|  | Y | U | V | Y | U | V |
| Class A |  |  |  |  |  |  |
| Class B | -0.6% | -0.4% | -0.4% | -1.2% | 0.1% | -0.3% |
| Class C | -0.9% | -0.2% | -0.2% | -0.8% | 0.0% | 0.0% |
| Class D | -0.6% | -0.3% | -0.2% | -0.6% | 0.1% | 0.0% |
| Class E | -1.4% | -0.8% | -0.6% | -3.0% | -1.5% | -1.1% |
| **Overall** | -0.8% | -0.4% | -0.3% | -1.3% | -0.2% | -0.3% |
|  | -0.8% | -0.4% | -0.4% | -1.3% | -0.3% | -0.4% |
| Enc Time[%] | 100% | | | 101% | | |
| Dec Time[%] | 101% | | | 101% | | |
| Mult[%] | 3% | | | 4% | | |
| Adds[%] | 2% | | | 2% | | |
| Access[%] | 4% | | | 4% | | |
| MemBand(2D) Ave.[%] | 1% | | | 1% | | |
| MemBand(2D) Max.[%] | 6% | | | 7% | | |
| MemBand(1D) Ave.[%] | 1% | | | 1% | | |
| MemBand(1D) Max.[%] | 6% | | | 7% | | |

|  |  |  |  |
| --- | --- | --- | --- |
| Gain Ave.[%] | -0.37% | 0.03% | 0.02% |
| Gain Min. [%] | -4.86% | -2.26% | -2.20% |
| Gain Max.[%] | 2.43% | 1.64% | 2.41% |
| Enc Time[%] | 100.65% | | |
| Dec Time[%] | 100.73% | | |
| Mult Ave.[%] | 2% | | |
| Mult Worst[%] | 0% | | |
| Adds Ave.[%] | 1% | | |
| Adds Worst[%] | 0% | | |
| Access[%] | 4% | | |
| MemBand(2D) Ave.[%] | 1% | | |
| MemBand(2D) Max.[%] | 9% | | |
| MemBand(2D) Worst[%] | 0% | | |
| MemBand(1D) Ave.[%] | 1% | | |
| MemBand(1D) Max.[%] | 8% | | |
| MemBand(1D) Worst[%] | 0% | | |

# Summary of results

Brief summary of test results is following.

Both variants provide performance improvement mainly in LD(P) test case.

Table 4. Summary of both tests.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test | Average BD-rate across RA,LD and LD(P) (HE and LC) | | | Average Complexity across RA,LD and LD(P) (HE and LC) | | | |
| Y | U | V | Mults | Adds | MemBand(2D) Ave.[%] | MemBand(1D) Ave.[%] |
| 7q(1/4)+8h | -0.1% | -0.1% | -0.2% | -5% | -6% | -1% | -2% |
| 7q(3/16)+8h | -0.4% | 0.0% | 0.0% | 2% | 1% | 1% | 1% |

Table 4 reports average performance and complexity shown in both tests. Negative numbers for BD-rate indicate better compression than anchor. In CE3 2 different complexity measure are used: an average number of computations and average Memory Band-Width. Both these parameters are reflected in Table 4. Negative numbers indicate complexity reduction compare to anchor.

We may conclude that both tested variants improve compression. Variant B shows better performance for Luma (0.4% better), variant A is better in terms of Chroma (0.1-0.2% better). Variant A reduces the statistical computational complexity and memory access; variant B is statistically, slightly more complex than anchor. Note that in terms of deterministic worst case computational complexity and memory access both variants are the same.

The difference in compression efficiency and complexity between variants A and B comes from different phase shift they use. Given the observation that the statistical distribution of sub-pixel phase offsets used for MC is more concentrated around the integer position, it makes the variant B with (3/16-pel) more efficient. On the other hand it reduces number of phase offsets which use integer pel offset, therefore the phase shift 3/16 leads to increment of fractional position hit-ratio during MC process (due to reduction of hit-ratio of integer MV).

# Visual quality check

One part of CE3 is visual quality test. Under common test condition there is no problem with visual quality for HM4.0. Under common test conditions both tested variation for interpolation filters shows no visual quality difference with anchor; there is no need to include pictures in this case.

It was noticed that if SAO is disabled in LD(P)-LC test case then in some cases one may see ring artifacts. Fig. 1-2 illustrate this.

Fig 1. 100th frame of PartyScene encoded with QP=37, LD(P)-LC.



Fig 2. 100th frame of PartyScene encoded with QP=37, LD(P)-LC id SAO is disabled.



Fig 3. 100th frame of PartyScene encoded with QP=37, LD(P)-LC id SAO is disabled (variant A).



Fig 4. 100th frame of PartyScene encoded with QP=37, LD(P)-LC id SAO is disabled (variant B).



Corresponding pictures for the same test: LD(P)-LC, SAO off, QP=37 with different interpolation filters are shown on Fig 3(variant A) and Fig 4 (variant B). There is no obvious difference between variants A and B; but both shows better visual quality than anchor.

# Conclusions

Based on test results

* Variant A: performance -0.1% (Y)/ -0.2%(U) /-0.2% (V); 5-6% computation reduction compare to HM, 1-2% memory band-width reduction in avg.;
* Variant B: performance -0.4% (Y)/ 0.0%(U) /0.0% (V); 1-2% computation increment compare to HM, 1% memory band-width increment in avg.;

and visual quality test for PartySciene, LD(P)-LC, QP=37, SAO off we recommend to take into account possibility to change quarter-pel interpolation filter to 7 taps.

.

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# Patent rights declaration(s)

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