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| *Title:* | **CE4 Subtest3: Adaptive De-Quantization Offset** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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| *Source:* | MediaTek Inc. | | |

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# Abstract

This contribution presents experimental results for the proposal on adaptive de-quantization offset (AQO) in Core Experiment 4 Subtest 3. Specifically, a slice level AQO is investigated and proposed. It is observed that on average 1.1% luma BD-rate reduction and over 2% chroma BD-rate reduction were obtained for four inter configurations (RA-HE, RA-LC, LB-HE, and LB-LC) defined in JCTVC-E700. In terms of PCHIP-BD-rate, 0.8% and over 2% rate reduction were achieved. It is also observed that the average encoding and decoding time as well as RVM value of the proposed method is quite similar to those of HM-3.0 anchor.

# Introduction

Adaptive de-quantization offset (AQO) was initially proposed in JCTVC-E091 [1]. The general idea of AQO is to adaptively select de-quantization offset based on input video content.

Compared to JCTVC-E091, the following parts are improved or modified in this contribution:

* Disabling de-quantization offset adaptation at LCU level
* Range limit of de-quantization offset
* Checking model accuracy
* Lambda refinement
* Syntax revisions

All these parts and related implementation details will be described in section 2 and 3.

# Algorithm Description

## De-Quantization Offset Calculation at Slice Level

During slice initialization at encoder, the following steps are performed to derive de-quantization offsets at slice level. Note that AQO is only for inter frames. For intra frames, de-quantization offsets are always set to 0.

Step 0: Initialize de-quantization offsets to zero.

Step 1: Check whether the model assumption (Laplacian distribution of transformed residues) is hold. If not, go to step 3 (see 2.1.1 for details).

Step 2: Calculate de-quantization offsets based on previously coded data (see 2.1.2 for details).

Step 3: Limit the range of de-quantization offsets (see 2.1.3 for details).

Step4: Lambda refinement based on the calculated offsets and input video content (see 2.2 for details)

### Checking Model Accuracy

It is assumed that transformed residues are Laplacian distributed. When this assumption does not hold, the performance of the proposed method may drop. Therefore, it is necessary to check the accuracy of Laplacian model.

Let  and  be the percentage of transformed coefficients which are quantized to {0} and to {-1, 0, 1}, respectively. Based on Laplacian assumption,  (an estimation of ) can be derived by



If calculated  deviates much from the actual , i.e.,



the Laplacian assumption is regarded as “not hold”.

### Offsets Calculation

De-quantization offset is calculated based on Laplacian model [1]. To save computational cost, lookup tables are used as follows.

Step1: Get  information (,  and  are for Y, U, V components, respectively) of previously coded same-type-same-temporal-level frame. If  is not available, it shall be set to 1. That is, the related normalized de-quantization offset  shall be set to 0.

Step2: According to ,  and , get related slice offsets ,  and  for Y, U and V components from lookup tables defined in Table **1** - Table **4**. Note that when , the related  shall be set to 0.47.

Table 1 Lookup Table of  ( 0.99991 )

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 1.00000 | 0.99999 | 0.99998 | 0.99997 | 0.99996 | 0.99995 | 0.99994 | 0.99993 | 0.99992 | 0.99991 |
|  | 0.00 | 0.17 | 0.18 | 0.19 | 0.19 | 0.19 | 0.20 | 0.20 | 0.20 | 0.21 |

Table 2 Lookup Table of  (0.9999  0.9991 )

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0.9999 | 0.9998 | 0.9997 | 0.9996 | 0.9995 | 0.9994 | 0.9993 | 0.9992 | 0.9991 |
|  | 0.21 | 0.22 | 0.23 | 0.24 | 0.24 | 0.24 | 0.25 | 0.25 | 0.25 |

Table Lookup Table of  (0.999  0.981 )

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | -- | 0.999 | 0.998 | 0.997 | 0.996 | 0.995 | 0.994 | 0.993 | 0.992 | 0.991 |
|  | -- | 0.26 | 0.28 | 0.29 | 0.29 | 0.30 | 0.31 | 0.31 | 0.32 | 0.32 |
|  | 0.990 | 0.989 | 0.988 | 0.987 | 0.986 | 0.985 | 0.984 | 0.983 | 0.982 | 0.981 |
|  | 0.32 | 0.33 | 0.33 | 0.33 | 0.33 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |

Table 4 Lookup Table of  (0.98  0.51 )

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | -- | 0.98 | 0.97 | 0.96 | 0.95 | 0.94 | 0.93 | 0.92 | 0.91 | 0.90 |
|  | -- | 0.35 | 0.36 | 0.37 | 0.38 | 0.39 | 0.39 | 0.40 | 0.40 | 0.41 |
|  | 0.89 | 0.88 | 0.87 | 0.86 | 0.85 | 0.84 | 0.83 | 0.82 | 0.81 | 0.80 |
|  | 0.41 | 0.41 | 0.42 | 0.42 | 0.42 | 0.42 | 0.43 | 0.43 | 0.43 | 0.43 |
|  | 0.79 | 0.78 | 0.77 | 0.76 | 0.75 | 0.74 | 0.73 | 0.72 | 0.71 | 0.70 |
|  | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.45 | 0.45 | 0.45 | 0.45 |
|  | 0.69 | 0.68 | 0.67 | 0.66 | 0.65 | 0.64 | 0.63 | 0.62 | 0.61 | 0.60 |
|  | 0.45 | 0.45 | 0.45 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 | 0.46 |
|  | 0.59 | 0.58 | 0.57 | 0.56 | 0.55 | 0.54 | 0.53 | 0.52 | 0.51 | - |
|  | 0.46 | 0.46 | 0.46 | 0.47 | 0.47 | 0.47 | 0.47 | 0.47 | 0.47 | - |

Let  denote the  information of the previously coded same-type frame at temporal level *T*. When the condition defined in is met, the de-quantization offsets shall be set to no less than that of the previously coded same-type frame at temporal level *T*-1.



### Range Limit

Considering different temporal levels are with different importance in motion compensation, the range of de-quantization offsets is limited as follows.



Where *T* indicates the temporal level of the current slice.

## Lambda Calculation at Slice Level

During slice initialization at encoder, the following steps are performed to determine lambda at slice level.

Define  as normalized motion magnitude of one inter frame as



Where  and  are motion vector components of block ,  denotes the temporal distance between the reference and current frame,  indicates the size of the block. Note that motion vector is regarded as 0 for intra blocks.

When  of reference list 0 in the previously coded same-type-same-temporal-level frame is no larger than 22, lambda is refined based on the default lambda in HM-3.0 and de-quantization offsets, i.e.,



Otherwise, default lambda in HM-3.0 is kept unchanged.

## Modified De-Quantization

Let  and  represent un-quantized and quantized transformed coefficients, respectively, the proposed offset  is included in de-quantization process as follows



## Modified RDOQ

Since the de-quantization process is modified when  is non-zero, the distortion calculation in RDOQ has to be modified accordingly. Without de-quantization offset  (or =0), the distortion in RDOQ is calculated as



where *c* is transformed coefficient before quantization.

When including a non-zero , the distortion shall be calculated as



# Simulation and Discussions

To verify the performance of the proposed algorithm, simulations defined in JCTVC-E700 [2] and JCTVC-E704 [3] are conducted. Detailed results can be found in attached excel files. Note that recent investigation showed that BD-rate may not be reliable due to occasional fitting failure such as that for sequence Nebuta.

## Performance of AQO

summarizes the performance of the proposed AQO. On average, 1.3%, 1.6%, 0.7% and 0.9% luma BD-rate reduction were obtained for RA-HE, RA-LC, LB-HE and LB-LC, respectively. Moreover, average chroma BD-rate reduction was over 2% for the four inter cases. The encoding and decoding time of AQO is almost the same as that of the anchor HM-3.0, which demonstrates the low computational complexity of AQO. Although de-quantization offset is adaptively selected, AQO does not increase bitrate fluctuation at frame level. In fact, RVM [6] of AQO is even slightly smaller than that of the anchor HM-3.0, as shown in Table 8.

Table Performance of AQO (HM30\_CE4SubTest3\_AQO\_11.xls)



## Impacts of Lambda Refinement

In proposed AQO, lambda is refined under a given condition. To study the impact of the lambda refinement on overall coding performance, the following two tests were conducted.

* QO only: AQO with lambda refinement disabled
* Lambda only: AQO with QO suppressed to zero (De-quantization offset is suppressed to zero after lambda is refinement)

The simulation results of the two tests are summarized in Table 10 and Table 11, respectively. For convenience, a simple performance comparison of luma component is presented in Table 9.

Table Performance Comparison of Luma Component

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | RA-HE | RA-LC | LB-HE | LB-LC | Average |
| QO only | -0.5% | -0.7% | -0.4% | -0.8% | -0.6% |
| Lambda only | -0.6% | -0.7% | 0.0% | **+0.5%** | -0.2% |
| AQO | -1.3% | -1.6% | -0.7% | -0.9% | -1.1% |

On average, “QO only” provides 0.6% luma BD-rate reduction for the four inter cases. In contrast, the average gain by “Lambda only” is 0.2%. Interestingly, the gain of AQO (QO+Lambda) is 1.1% which is larger than the sum of individual gain by “QO only” and “Lambda only”. In fact, this is in line with observation in the literature of rate-distortion optimization [4][5]: Lambda selection should be harmonized with quantization process.

Table Performance of AQO without Lambda Refinement (HM30\_CE4SubTest3\_AQO\_10.xls)



Table Performance of AQO with QO Suppressed to Zero (HM30\_CE4SubTest3\_AQO\_12.xls)



## AQO Performance with RDOQ off

Table Performance of AQO with RDOQ off (HM30\_CE4SubTest3\_AQO\_RDOQOff.xls)



In this test, the performance of AQO is studied in the environment of RDOQ off. Table 12 summarizes the simulation results. On average, 1.8% luma BD-rate reduction was obtained for the four inter cases. Compared to the case of RDOQ on, AQO performs better when RDOQ is off. This makes sense since RDOQ is also an optimization method for quantization. There is overlap between these two techniques though the overlap is not much. In general, AQO cannot replace RDOQ since the optimization focuses of the two methods are different. The gain by the two methods is partially additive.

## AQO Performance with SAO off

summarizes the performance of AQO when SAO is off. Compared to , average performance of AQO is quite similar for the cases of SAO on and off, which verifies that the gain of SAO and AQO is almost orthogonal.

Table Performance with SAO off (HM30\_CE4SubTest3\_AQO\_SAOOff.xls)



# Additional results in PCHIP-BD-rate

It is noted that BD-rate is sometimes not reliable, especially for sequence Nebuta. To solve the problem, PCHIP-BD-rate was proposed. In terms of PCHIP-BD-rate, simulation results are summarized as follows. Generally, the overall performance in PCHIP-BD-rate is in line with that in BD-rate though numbers are not exactly match.

## AQO and lambda refinement

Table AQO with lambda refinement (PCHIP-BD-rate)



Table AQO without lambda refinement (PCHIP-BD-rate)



Table Lambda refinement only by suppresing offsets to zero (PCHIP-BD-rate)



## Performance of AQO when RDOQ is off

Table Performance of AQO when RDOQ is off (PCHIP-BD-rate)



## Performance of AQO when SAO is off

Table Performance of AQO when SAO is off (PCHIP-BD-rate)



# Conclusions

In this contribution, adaptive de-quantization offset (AQO) is proposed. For the four inter cases, average BD-rate reduction of 1.1%, 2.0%, and 2.4% is obtained for Y, U, and V components, respectively. The computational complexity of AQO is quite low. Moreover, AQO will not increase bitrate fluctuation at frame level. Simulations also demonstrate that lambda refinement has to be harmonized with quantization process, as suggested in this proposal. Otherwise, the gain of lambda refinement is marginal.

# References

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# Annex A Proposed Specification for the WD

## Revisions in SPS

|  |  |
| --- | --- |
| seq\_parameter\_set\_rbsp( ) { | Descriptor |
| …… |  |
| interpolation\_filter\_flag | u(1) |
| **seq\_adaptive\_dequantization\_offset\_flag** | u(1) |
| rbsp\_trailing\_bits( ) |  |
| } |  |

**seq\_adaptive\_dequantization\_offset\_flag** equal to 1 specifies that the adaptive de-quantization offset is enabled. Otherwise, the feature is disabled.

## Revisions in Slice Header

|  |  |
| --- | --- |
| slice\_header( ) { | Descriptor |
| …… |  |
| slice\_qp\_delta | se(v) |
| if(seq\_adaptive\_dequantization\_offset\_flag) { |  |
| **slice\_adaptive\_dequantization\_offset\_idc** | **u(2)** |
| if(slice\_adaptive\_dequantization\_offset\_idc) **{** |  |
| **slice\_adaptive\_dequantization\_offset\_luma** | **ue(v)** |
| **slice\_adaptive\_dequantization\_offset\_chroma0** | **ue(v)** |
| **slice\_adaptive\_dequantization\_offset\_chroma1** | **ue(v)** |
| **}** |  |
| **}** |  |
| alf\_param() |  |
| …… |  |
| } |  |

**slice\_adaptive\_dequantization\_offset\_idc** specifies the type of the de-quantization offset. The values of slice\_adaptive\_dequantization\_offset\_idc are specified in **Table 11**.

Table 16 slice\_adaptive\_dequantization\_offset\_idc

|  |  |
| --- | --- |
| slice\_adaptive\_dequantization\_offset\_idc | Meaning |
| 0 | Adaptive de-quantization offset is disabled at slice level |
| 1 | De-quantization offsets will be signaled at slice level |

**slice\_adaptive\_dequantization\_offset\_luma** specifiesthenormalized de-quantization offset of luma component in this slice**.** When slice\_adaptive\_dequantization\_offset\_luma is not presented, slice\_adaptive\_dequantization\_offset\_luma shall be inferred as zero.

**slice\_adaptive\_dequantization\_offset\_chroma0** specifiesthenormalized de-quantization offset of the first chroma component in this slice**.** When slice\_adaptive\_dequantization\_offset\_chroma0 is not presented, slice\_adaptive\_dequantization\_offset\_chroma0 shall be inferred as zero.

**slice\_adaptive\_dequantization\_offset\_chroma1** specifiesthenormalized de-quantization offset of the second chroma component in this slice**.** When slice\_adaptive\_dequantization\_offset\_chroma0 is not presented, slice\_adaptive\_dequantization\_offset\_chroma0 shall be inferred as zero.

## Revisions in Scaling Process for Transform Coefficients

In the current HEVC WD , the scaled transform coefficient array dij is derived as follows.

dij = ( cij \* LevelScale(nS)x(nS)[ qP%6 ][ i ][ j ] ) << ( qP/6 + trafoPrecisionExt ), with i, j = 0..nS-1

To incorporate AQO, is modified to .

dij = ( cij \* LevelScale(nS)x(nS)[ qP%6 ][ i ][ j ]+beta\* LevelScale(nS)x(nS)[ qP%6 ][ i ][ j ]/100 )

<< ( qP/6 + trafoPrecisionExt ), with i, j = 0..nS-1