Title: One-addition dequantization
Status: Input Document to JCT-VC
Purpose: Proposal

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Abstract

Generic set of integer multipliers $\{5, 6, 7, 8, 9\}$ is proposed for dequantization. Multiplication by each value of this set may be performed with no more than 2 shifts and 1 addition or subtraction. This set of multipliers increases bit-depth of dequantized transform coefficient by no more than 4 bits. It is reported that current QP control schemes of common test conditions are compliant with the proposed quantization modification.

1 Introduction

Current HEVC quantizer that was mostly inherited from H.264/AVC [1] has set of only 6 generic dequantization multipliers (or mantissæ), that may be extended by bitwise shifts to 52 different values. Design of [1] was aimed at reducing complexity and bit depth of quantization and dequantization values.

Although split of multiplier to the mantissa and bitwise shift is a very efficient technique itself, we find that it is possible to impose one additional criterion on multiplication by constant dequantization integer. Namely, we can try to use values having representation of form $2^m \pm 2^p$. Multiplication by such values can be replaced with only one addition (or subtraction) operation and with no more than two shifts.

2 Description

In HM-4.0 reference software [2] dequantization is performed via following computation:

```
iAdd = 1 << (iShift - 1);
iCoeffQ = ( piQCoef[n] * scale + iAdd ) >> iShift;
```

First, we propose to remove `iAdd` value from the computation, because rounding fix here gives no effect on performance and simply does one addition in vain.

Second, `scale` value in HM-4.0 may be one of $\{40, 45, 51, 57, 64, 72\}$ mantissæ left-shifted by $\{0..8\}$ bits. This provides periodical and more or less uniform placement of scaling values in log-domain between neighbouring powers of 2.

Attempt to cover the same domain using only those mantissæ multiplication by which may be reduced to computation with only one addition shows that in the range $[32, 64]$ there are only $\{32, 33, 34, 36, 40, 48\}$ (for addition) and $\{48, 56, 60, 62, 63, 64\}$ (for subtraction) sets to choose values from. Worst is the central part where 48 is the only value inside the interval $(40, 56)$. The same is true for other intervals between neighbouring powers of 2, there is lonely $2^k + 2^{k-1}$ value in the empty middle of $[2^k, 2^{k+1}]$. Thus, considering that close enough alternative one-adder integers give us not that much, we can convert the set of constant dequantization values of current HEVC design to $\{40, 48, 56, 64, 72\}$. The latter can be reduced to $\{5, 6, 7, 8, 9\}$, because all the values are multiples of 8. Resulting set of scaling multipliers has 3 bit less bitdepth than the set from HM-4.0 and may simplify design of the transform.

Parameterization by integer number QP for the new design remains almost the same as before. Particularly, range of integer QP values shrinks to $[0, 44]$; derivation of mantissa and shift value uses remainder and integer part after division by 5, not by 6, respectively.

One drawback of one-adder design is worsening of uniformity in the log-domain. According to rate-distortion concept in use [3] one might expect constant bitrate increase with constant decrease of QP parameter, at least in a high bitrate limit. Yet we find low complexity of a dequantizer more important while constant bitrate changes still have to be managed with some additional techniques.

Common test conditions include different QP control schemes for different tests. Potentially, these schemes might be not compliant with new (de)quantizer design. We report below that our design gives no essential difference in performance for existing schemes.

3 Reference software changes and test results

In order to verify new quantizer design we tested it with HM-4.0 software. For the sake of easier implementation dequantization multipliers were set to $\{40, 48, 56, 64, 72\}$ (rather than $\{5, 6, 7, 8, 9\}$) because of presence of downscaling right shift. Further reduction to $\{5, 6, 7, 8, 9\}$ may be done during stabilization of transform design.

Table 1: Test results.

	All Intra HE			All Intra LC		
	Y	U	V	Y	U	V
Class A	-0.4%	-1.8%	-1.7%	0.5%	-1.7%	-1.7%
Class B	-0.2%	-2.0%	-1.9%	0.3%	-1.8%	-1.7%
Class C	0.0%	-2.1%	-2.0%	0.1%	-1.7%	-1.7%
Class D	0.1%	-2.2%	-2.2%	0.1%	-1.6%	-1.5%
Class E	-0.2%	-1.3%	-1.5%	0.5%	-1.3%	-1.5%
Class F	0.0%	-1.7%	-1.7%	0.0%	-1.3%	-1.5%
Overall	-0.1%	-1.9%	-1.9%	0.2%	-1.6%	-1.6%
Enc Time[%]		101%			100%	
Dec Time[%]		100%			100%	

	Random Access HE			Random Access LC		
	Y	U	V	Y	U	V
Class A	0.4%	-4.3%	-5.2%	1.4%	-4.5%	-4.7%
Class B	0.3%	-3.6%	-3.5%	0.9%	-3.7%	-3.4%
Class C	0.1%	-3.1%	-2.8%	0.2%	-3.2%	-2.7%
Class D	0.2%	-3.9%	-3.9%	0.2%	-3.1%	-2.9%
Class E						
Class F						
Overall	0.3%	-3.7%	-3.8%	0.7%	-3.6%	-3.4%
Enc Time[%]		102%			102%	
Dec Time[%]		101%			102%	

Along with this following minimal changes in the reference software were made:

- quantization table was set to $\{26215, 21846, 18725, 16384, 14564\}$
- QP parameter range was changed from $[0, 51]$ to $[0, 44]$
- denominator in derivaton of mantissa and exponenta was changed from 6 to 5
- `iAdd` was removed from dequantization line
- chroma QP offset table was adjusted to new design:

Table 2: New chroma QP offset table, for $QP > 24$

Y	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
U, V	24	25	26	26	27	28	28	29	30	30	31	31	31	31	31	32	32	32	32	32

- for more adequate λ setting, new QP set was mapped to old one at the encoder side

We used common test conditions [4], including RDOQ set on, for QPs 18, 22, 26, 31, approximately matching the old set of 22, 27, 32, 37. Test results are presented in tables below and in supplementary

Table 3: Test results (continued).

	Lowdelay B HE			Lowdelay B LC		
	Y	U	V	Y	U	V
Class A						
Class B	0.0%	-1.6%	-2.3%	0.6%	-1.5%	-1.5%
Class C	0.0%	-1.4%	-1.8%	0.1%	-0.9%	-1.1%
Class D	-0.1%	-3.0%	-2.7%	0.1%	-1.4%	-1.2%
Class E	-0.9%	-3.8%	-3.5%	-0.3%	-3.5%	-2.7%
Class F	-0.8%	-2.1%	-2.3%	-0.5%	-1.7%	-2.1%
Overall	-0.3%	-2.3%	-2.4%	0.1%	-1.7%	-1.6%
Enc Time[%]		99%			99%	
Dec Time[%]		99%			99%	

	Lowdelay P HE			Lowdelay P LC		
	Y	U	V	Y	U	V
Class A						
Class B	0.2%	-1.6%	-2.2%	1.5%	-1.3%	-1.3%
Class C	0.1%	-1.5%	-1.7%	0.5%	-1.0%	-0.9%
Class D	0.2%	-3.1%	-3.1%	0.3%	-1.5%	-1.5%
Class E	-0.6%	-3.7%	-4.2%	0.8%	-3.9%	-3.3%
Class F	-0.5%	-2.0%	-2.5%	-0.3%	-1.4%	-1.6%
Overall	-0.1%	-2.3%	-2.6%	0.6%	-1.7%	-1.6%
Enc Time[%]		99%			99%	
Dec Time[%]		99%			99%	

spreadsheets as well. We also provide patch with the mentioned software changes.

4 Conclusion

Test results show that using new quantization/dequantization design the same coding performance may be achieved for common test conditions.

New low complexity and low bit-depth dequantization comprises set of mantissæ of dequantization multipliers $\{5, 6, 7, 8, 9\}$; parameterization of dequantization multipliers with integer parameter QP in the range [0,44]; derivation of mantissa and exponenta of dequantization multiplier using remainder and integer part of division of QP by 5, similar to that of H.264/AVC standard. With this design dequantization may be performed by only one addition or subtraction and no more than two shifts, increasing bit-depth of coefficient by no more than 4 bits. The last feature is a benefit for new transform design.

We propose new quantization scheme for adoption into HEVC design.

References

[1] L. Kerofsky and S. Lei, Reduced bit-depth quantization, in JointVideo Team (JVT) of ISO/IEC MPEG and ITU-T VCEG, Sept. 2001, Doc. VCEG-N20.

[2] http://hevc.kw.bbc.co.uk/trac/browser/jctvc-hm/tags/HM-4.0

[3] Gary J. Sullivan and Thomas Wiegand, Rate-Distortion Optimization for Video Compression, IEEE Signal Processing Magazine, vol. 15, no. 6, pp. 74-90, November 1998

[4] F. Bossen, Common test conditions and software reference configurations, Document of Joint Collaborative Team on Video Coding, JCTVC-F900, Jul. 2011.

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