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Title: **Internal bit depth increase for coding efficiency**

Purpose: Proposal

1. Introduction

In the field of digital signal processing, it is known that better results are generally able to be achieved by increasing the internal arithmetic precision to a higher level than the external arithmetic precision. This contribution shows that the coding efficiency can be improved by increasing the internal bit depth so that it is greater than the external bit depth of the video codec. Although there were similar contributions [1], [2] when the current specification for over 8-bit sample depth was decided, it is discussed from the viewpoint of coding efficiency in this contribution.

Several experimental results indicate that by using 12 bits of internal bit depth for 8-bit source, on average, 6.14% of bitrate saving for 720p sequences as compared with the anchor based on High profile is achieved on the common condition [3]. In particular, this scheme is more effective for high- resolution sources.

2. Internal bit depth increase in video codec

In digital filter processing, generally, ideal results are achieved by increasing arithmetic precision. For instance, the processing of the interpolation filter, the de-blocking filter and the weighted prediction in the video codec would depend on the arithmetic precision. Therefore, we tried to implement the method, which increases the internal bit depth so that it is greater than the external bit depth of the video codec as shown in Figure 1, and conduct experiments on it from two viewpoints.

In Figure 1, firstly, M-bit source is shifted N bits to the left, and N-bit left-shifted source is processed by (M+N)-bit codec. Then, output video signal is rounded to M bits. Although it is possible to process several methods for input-output bit operation, there were no differences in term of experimental results. Incidentally, an M-bit depth of MSE and a lambda for M bits are used for the mode decision based on the rate-distortion optimization in (M+N)-bit codec.

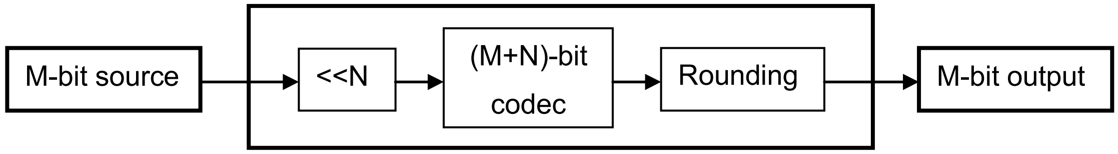

Figure 1 Internal bit depth increase in video codec

1) How many bits should we increase the internal bit-depth?

We examined the internal bit depth from 9 bits to 12 bits for 8-bit sources. Figure 2 shows the relationship between the internal bit depth and the average bitrate saving (ΔBitrate) [4] of five 720p sequences.

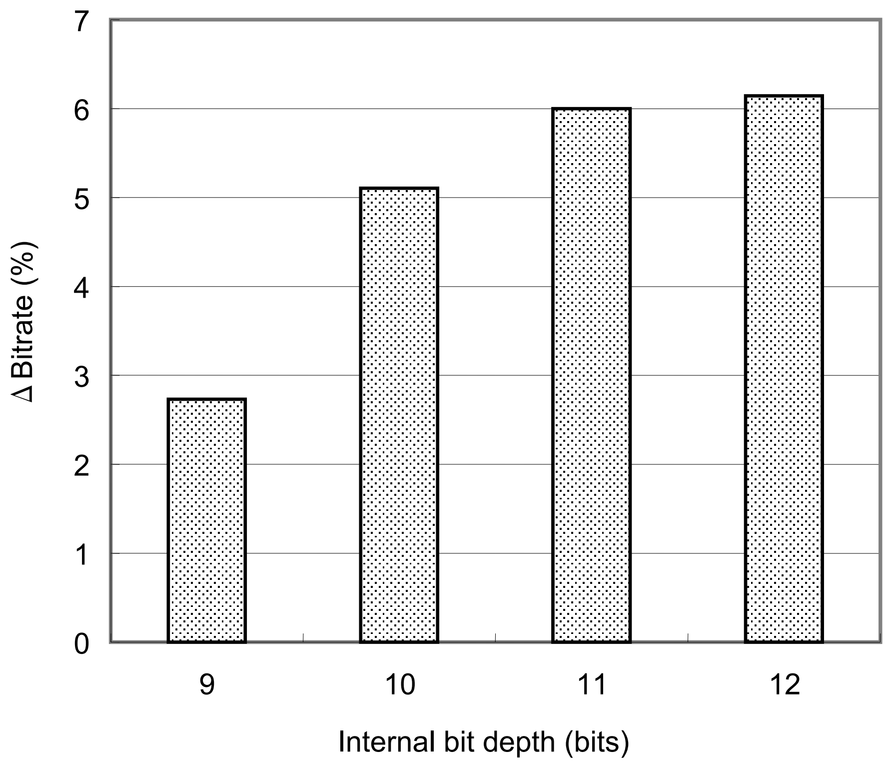

Figure 2 Relationship between the internal bit-depth and the average bitrate saving of five 720p60 sequences

As a result, although the performance is improved by increasing internal bit depth, it is saturated with about 12 bits for 8-bit sources.

2) If the bit depth of the frame memory is limited to the external bit depth, what is the result?

Since the bit depth of the frame memory has an impact on memory access, we tried to examine the influence of the bit depth of the frame memory. In this examination, for 8-bit sources, the bit depth of the frame memory is 8 bits and the internal bit depth of the other part of the codec is 12 bits.

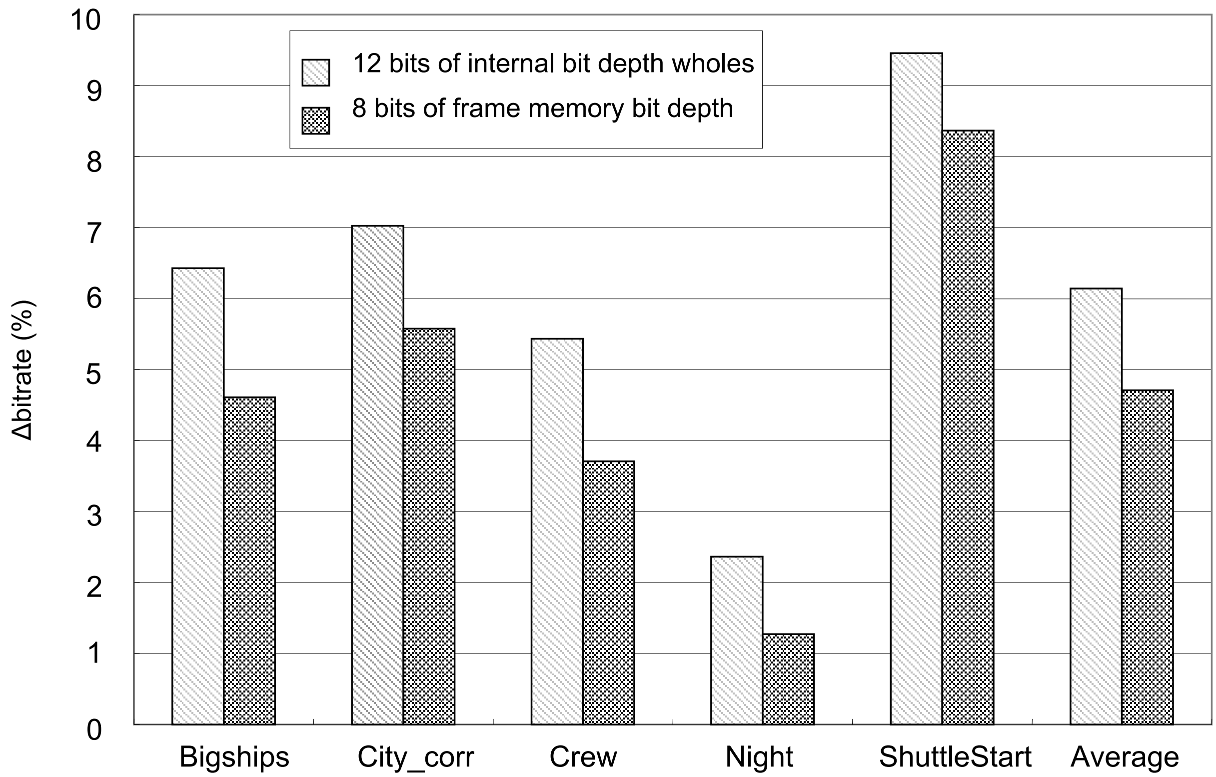

Figure 3 Comparison of bit rate saving between 8 bits of frame memory bit depth and 12 bits of internal bit depth wholes

Experimental results indicate that if the bit depth of the frame memory is limited to 8 bits in the case of internal12-bit depth, the bitrate saving becomes about 3/4 as compared with the bitrate saving of 12 bits of internal depth wholes. It is found that even if the bit depth of frame memory is restricted in consideration of computational complexity, the internal bit depth increase is still effective.

3. Experimental Results

We have conducted simulation for all VCEG sequences of QCIF, CIF and 720p60 based on the recommended simulation common conditions, VCEG-AA10 [3].
The encoder configurations are as follows:

- KTA software (jm11.0kta1.2)
- Search range ±32 pels for QCIF and CIF, ±64 pels for 720p
- Rate-Distortion Optimization
- Reference picture number 4
- Weighted prediction (Picture level RDO)
- Adaptive Rounding Offset
- The thresholding of transform coefficient
- Fixed QP(I)= (22, 27, 32, 37), QP(P)= QP(I) + 1, QP(B) = QP(P) + 1

The PSNR gain (ΔPSNR) and the bitrate saving (ΔBitrate) were calculated based on BD-SNR (VCEG-M33 [4]). Tables 1, 2, and 3 show the results of the internal 12-bit depth without the limitation of the bit depth of the frame memory.

Table 1 Coding efficiency of internal 12-bit depth (IPP, CALVC, anchor based on Baseline Profile)

Test Sequence	Size	Frame Rate	Frames	ΔBitrate (%)	ΔPSNR (dB)
BigShips	1280x720	60	73	10.78	0.454
City	1280x720	60	73	15.17	0.781
Crew	1280x720	60	73	2.98	0.096
Night	1280x720	60	73	3.77	0.175
ShuttleStart	1280x720	60	73	7.92	0.316
Total average of 720p60				**8.12**	**0.364**
foreman_cif	352x288	30	300	3.08	0.143
mobile_cif	352x288	30	300	1.61	0.097
tempete_cif	352x288	30	260	2.40	0.143
paris_cif	352x288	15	150	0.78	0.046
container_qcif	176x144	15	150	3.76	0.179
foreman_qcif	176x144	15	150	1.30	0.069
silent_qcif	176x144	15	150	1.20	0.061
Total average of CIF, QCIF				**2.02**	**0.105**

Table 2 Coding efficiency of internal 12-bit depth (IBBP, CABAC, anchor based on High Profile)

Test Sequence	Size	Frame Rate	Frames	ΔBitrate (%)	ΔPSNR (dB)
BigShips	1280x720	60	73	6.43	0.239
City	1280x720	60	73	7.03	0.284
Crew	1280x720	60	73	5.44	0.166
Night	1280x720	60	73	2.37	0.100
ShuttleStart	1280x720	60	73	9.46	0.365
Total average of 720p60				**6.14**	**0.231**
foreman_cif	352x288	30	298	1.22	0.052
mobile_cif	352x288	30	298	0.54	0.033
tempete_cif	352x288	30	259	1.55	0.083
paris_cif	352x288	15	148	0.95	0.050
container_qcif	176x144	15	148	3.50	0.164
foreman_qcif	176x144	15	148	1.22	0.052
silent_qcif	176x144	15	148	0.75	0.037
Total average of CIF, QCIF				**1.36**	**0.067**

Since the names of parameters for hierarchy B structure in JM11.0 have been changed, the following parameters are used based on VCEG-AA10. Other parameters are the same.

HierarchicalCoding = 3

ExplicitHierarchyFormat = "b3r0b1r1b0e2b2e2b5r1b4e2b6e2"

Table 3 Coding efficiency of internal 12-bit depth (anchor based on Hierarchy B structure)

Test Sequence	Size	Frame Rate	Frames	ΔBitrate (%)	ΔPSNR (dB)
BigShips	1280x720	60	73	6.89	0.244
City	1280x720	60	73	5.55	0.242
Crew	1280x720	60	73	4.69	0.141
Night	1280x720	60	73	2.04	0.086
ShuttleStart	1280x720	60	73	10.37	0.366
Total average of 720p60				**5.91**	**0.216**
foreman_cif	352x288	30	297	1.82	0.075
mobile_cif	352x288	30	297	1.15	0.063
tempete_cif	352x288	30	257	2.42	0.120
Total average of CIF				**1.80**	**0.086**

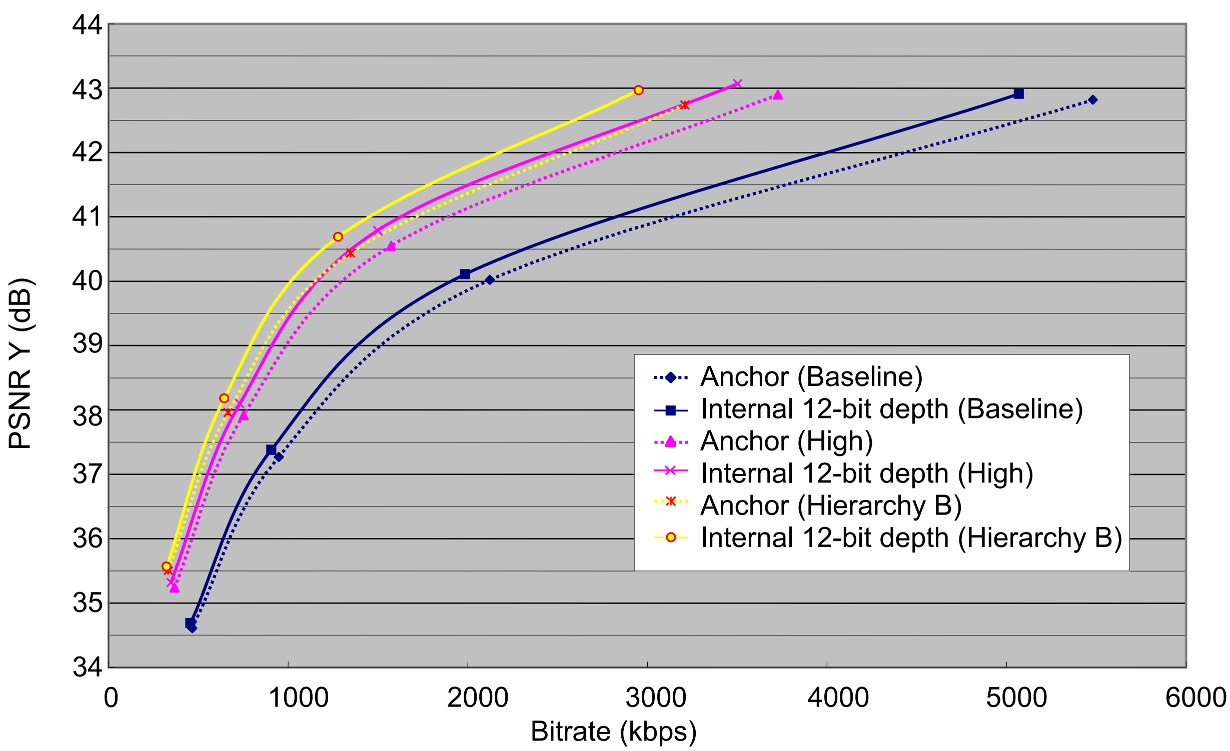

Figure 4 R-D curves (ShuttleStart)

4. Implementation on Software

This contribution includes the software that implemented the proposed tool on KTA1.2. The following two parameters have been added to the configuration file in the KTA section:

```
BitDepthIncrease                 =  0
BitDepthIncreaseExceptFrameMem   =  0
```

`BitDepthIncrease = N` is an integer which has range from 0 to 4. This parameter shows how many bits are increased from the values of input-output bit depth which is defined by BitDepthLuma and BitDepthChroma. The sum of BitDepthIncrease plus Max(BitDepthLuma, BitDepthChroma) is also limited to equal to or less than 12.
`BitDepthIncreaseExceptFrameMem = 0` disable the limitation of bit depth of frame memory, when BitDepthIncrease is greater than 0.
`BitDepthIncreaseExceptFrameMem = 1` enable the limitation of bit depth of frame memory. When BitDepthIncrease is greater than 0, the bit depth of frame memory is equal to the value which is defined by BitDepthLuma and BitDepthChroma.

5. Conclusion

In this contribution, we showed that the improvement of coding efficiency can be achieved by increasing the internal bit depth so that it is greater than the external bit depth. According to the experimental results, this scheme does not cause loss for almost all sequences and does not need special encoding techniques. Although the internal arithmetic precision in the video codec should be discussed in consideration of computational complexity, we would like to suggest that the internal bit depth is important for the improvement of coding efficiency.

6. References

[1] W. Gish, C. Vogt, "10-bit and 12-bit Sample Depth," ISO/IEC JTC1/SC29/WG11 and ITU-T SG16 Q.6 Document, JVT-E048r2, Geneva, October 2002.
[2] W. Gish, H. Yu, "Extended Sample Depth: Implementation and Characterization," ISO/IEC JTC1/SC29/WG11 and ITU-T SG16 Q.6 Document, JVT-H016, Geneva, May 2003.
[3] T. K Tan, G. Sullivan and T. Wedi, "Recommended Simulation Common Conditions for Coding Efficiency Experiments," ITU-T SG16 Q.6 Document, VCEG-AA10, Nice, Oct. 2005.
[4] G. Bjøntegaard, "Calculation of average PSNR differences between RD-Curves," ITU-T SG16 Q.6 Document, VCEG-M33, April 2001.

7. IPR Statement

Toshiba Corporation may have IPR relating to the technology described 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.