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Title:	**Throughput Improvement on CABAC for Depth Videos with Modified Level Coding**
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Author(s) or Contact(s):	Jung-Ah Choi, Cheon Lee, Yo-Sung Ho 123 Cheomdan gwagi-ro Buk-gu Gwangju, Korea 500-712	Tel: Email:	+82-62-715-2258 jachoi@gist.ac.kr leecheon@gist.ac.kr hoyo@gist.ac.kr
Source:	Gwangju Institute of Science and Technology (GIST)		

Abstract

In this contribution, a modified level coding for depth videos to improve CABAC throughput is presented. Due to the arithmetic coding engine and sophisticated context modeling, CABAC is regarded as the bottleneck of the high throughput codec system. In order to improve the throughput efficiency, this contribution reduces the number of context-coded bins, keeping easy compatibility with the existing CABAC. Especially, context-coded bin coding through regular mode in CABAC is a main factor of the limitation of throughput. In level coding, two flags, *coeff_abs_level_greater1_flag* and *coeff_abs_level_greater2_flag* are coded before encoding the remaining absolute level value. In current HTM, these flags require 8 and 1 contexts, respectively.

These flags are empirically determined to improve CABAC throughput; however, they are originally designed for texture videos. It can be observed that often a given texture transform unit (TU) has a lot of quantized transform coefficients than its collocated depth TU. Thus, the proposed scheme is asserted to reduce maximum number of context coded bins for these flags in depth coding.

There is almost no coding efficiency loss (maximum 0.1% BD-Rate loss on average), compared to the current HTM software in common test condition. The proposed scheme reduces 36% of context-coded bins of CABAC level coding in depth video coding. It is further reported that all the modules and processes of current CABAC are kept unchanged and no additional module is needed in the proposed scheme.

1 Introduction

In current HTM residual coding, significance map and level information are coded as a sub-block unit. A sub-block consists of 16 coefficients in the inverse scan order. For 16×16 and 32×32 TUs, a TU is divided into 4×4 subsets and each subset corresponds to a sub-block. When a sub-block has one or more non-zero quantized transform coefficients, following five syntax elements are signaled to represent the coefficients level information within the sub-block.

a) ***significant_coeff_flag***: indicates whether the coefficient is non-zero or not.

b) ***coeff_abs_level_greater1_flag***: indicates whether the coefficient amplitude is larger than one for each non-zero coefficient (i.e. with *significant_coeff_flag* as 1).

c) ***coeff_abs_level_greater2_flag***: indicates whether the coefficient amplitude is larger than two for each coefficient with amplitude larger than one (i.e. with *coeff_abs_level_greater1_flag* as 1).

d) *coeff_sign_flag*: indicates sign information of the non-zero coefficients.

e) *coeff_abs_level_remaining*: indicates remaining absolute level value.

Among five syntax elements, the bins of *significant_coeff_flag*, *coeff_abs_level_greater1_flag*, and *coeff_abs_level_greater2_flag* are encoded with adaptive context models through regular mode; *coeff_sign_flag* and binarized bins of *coeff_abs_level_remaining* are encoded with fixed equal probability model through bypass mode. The former is referred to as context-coded bins and the latter is referred to as bypass bins. Context-coded bin coding is one of the main bottlenecks of HTM throughput.

Table 1 shows an example of residual coding in a sub-block. In the HEVC standardization, it was asserted to encode *coeff_abs_level_greater1_flag* and *coeff_abs_level_greater2_flag* only for a few starting non-zero coefficients in inverse scan order [1]. Note that in Table 1, *coeff_abs_level_greater1_flag* and *coeff_abs_level_greater2_flag* are encoded only for the first 8 and 1 non-zero coefficients in a sub-block, respectively. This is for improving CABAC throughput by reducing context-coded bins and it is applied for both texture and depth videos in the current HTM. Although these flags are designed by considering trade-off coding performance and throughput improvement, it is optimized for texture videos. Thus, in this proposal, we targets on improving the CABAC throughput in depth video coding.

Table 1. Example of residual coding in HTM

Coding order →

Scanning Position	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Coefficient	**0**	**1**	**-1**	**0**	**2**	**4**	**-1**	**-4**	**4**	**2**	**-6**	**4**	**7**	**6**	**-12**	**18**
significant_coeff_flag	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
coeff_abs_level_greater1_flag		0	0		1	1	0	1	1	1						
coeff_abs_level_greater2_flag					0											
coeff_sign_flag		0	1		0	0	1	1	0	0	1	0	0	0	1	0
coeff_abs_level_remaining						2		2	2	0	5	3	6	5	10	17

2 Proposed method

To find the best trade-off performance and throughput improvement for depth videos, we tested different N (0, 2, and 4) values. Comparing experimental results, in the proposed method, we set N to 0, i.e., we do not encode both *coeff_abs_level_greater1_flag* and *coeff_abs_level_greater2_flag* for depth videos. Table 2 shows an example of the proposed scheme. Compared with the coded symbols in Table 1 (the HTM method), 8 *coeff_abs_level_greater1_flag*s and 1 *coeff_abs_level_greater2_flags* are removed in depth coding. The value of *coeff_abs_level_remaining* is adjusted appropriately for the values of *coeff_abs_level_greater1_flag and coeff_abs_level_greater2_flag*.

Table 2. Example of residual coding in the proposed scheme

Coding order →

Scanning Position	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Coefficient	**0**	**1**	**-1**	**0**	**2**	**4**	**-1**	**-4**	**4**	**2**	**-6**	**4**	**7**	**6**	**-12**	**18**
significant_coeff_flag	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
coeff_abs_level_greater1_flag																
coeff_abs_level_greater2_flag																
coeff_sign_flag		0	1		0	0	1	1	0	0	1	0	0	0	1	0
coeff_abs_level_remaining		0	0		1	3		3	3	1	5	3	6	5	10	17

Table 3 shows the number of context-coded bins for a 4×4 sub-block in worst-case scenario. As shown, the proposed scheme reduces the maximum numbers of context-coded bins from 25 to 16. This rate is 36% of context-coded bins in CABAC level coding.

Table 3. Comparison of maximum number of context-coded bins in worst-case scenario

	HTM 4.0	Proposed Method
significant_coeff_flag	16	16
coeff_abs_level_greater1_flag	8	0
coeff_abs_level_greater2_flag	1	0
Total	**25**	**16**

3 Simulation Results

We implemented the proposed high throughput CABAC method into the HTM 4.0.1 software [2]. Simulations were performed using common test conditions [3]. Table 4, Table 5, and Table, 6 show the results of the proposed scheme. From these results, we determine N = 0. As shown, there is maximum 0.1% BD-Rate loss on average. Table 7, Table 8, and Table 9 are 2 views test cases. In this experiment, we did not check processing time. However, since no complex process is added for the proposed scheme, we expect that there is no significant processing time increase.

Table 4. Experimental results - 3 views test case (coeff_abs_level_greater1_flag = 4)

	video 0	**video 1**	**video 2**	**video only**	**synthesized only**	**coded & synthesized**
Balloons	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Kendo	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Newspapercc	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GhostTownFly	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PoznanHall2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PoznanStreet	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UndoDancer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1024x768	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1920x1088	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Average	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Table 5. Experimental results - 3 views test case (coeff_abs_level_greater1_flag = 2)

	video 0	**video 1**	**video 2**	**video only**	**synthesized only**	**coded & synthesized**
Balloons	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Kendo	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Newspapercc	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GhostTownFly	0.0%	0.0%	0.0%	0.0%	0.6%	0.3%
PoznanHall2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PoznanStreet	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

UndoDancer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1024x768	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1920x1088	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
Average	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.1%**	**0.1%**

Table 6. Experimental results - 3 views test case (coeff_abs_level_greater1_flag = 0, coeff_abs_level_greater2_flag = 0)

	video 0	**video 1**	**video 2**	**video only**	**synthesized only**	**coded & synthesized**
Balloons	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Kendo	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Newspapercc	0.0%	0.0%	0.0%	0.0%	0.2%	0.1%
GhostTownFly	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
PoznanHall2	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
PoznanStreet	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
UndoDancer	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1024x768	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
1920x1088	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Average	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.1%**	**0.1%**

Table 7. Experimental results - 2 views test case (coeff_abs_level_greater1_flag = 4)

	video 0	**video 1**	**video only**	**synthesized only**	**coded & synthesized**
Balloons	0.0%	0.0%	0.0%	0.1%	0.0%
Kendo	0.0%	0.0%	0.0%	-0.1%	0.0%
Newspapercc	0.0%	0.0%	0.0%	0.0%	0.0%
GhostTownFly	0.0%	0.0%	0.0%	0.0%	0.0%
PoznanHall2	0.0%	0.0%	0.0%	0.0%	0.0%
PoznanStreet	0.0%	0.0%	0.0%	0.0%	0.0%
UndoDancer	0.0%	0.0%	0.0%	0.1%	0.0%
1024x768	0.0%	0.0%	0.0%	0.0%	0.0%
1920x1088	0.0%	0.0%	0.0%	0.0%	0.0%
Average	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Table 8. Experimental results - 2 views test case (coeff_abs_level_greater1_flag = 2)

	video 0	**video 1**	**video only**	**synthesized only**	**coded & synthesized**
Balloons	0.0%	0.0%	0.0%	0.1%	0.0%
Kendo	0.0%	0.0%	0.0%	-0.1%	0.0%
Newspapercc	0.0%	0.0%	0.0%	0.1%	0.1%
GhostTownFly	0.0%	0.0%	0.0%	0.6%	0.3%

PoznanHall2	0.0%	0.0%	0.0%	0.0%	0.0%
PoznanStreet	0.0%	0.0%	0.0%	0.0%	0.0%
UndoDancer	0.0%	0.0%	0.0%	0.1%	0.0%
1024x768	0.0%	0.0%	0.0%	0.0%	0.0%
1920x1088	0.0%	0.0%	0.0%	0.2%	0.1%
Average	**0.0%**	**0.0%**	**0.0%**	**0.1%**	**0.1%**

Table 9. Experimental results - 2 views test case (coeff_abs_level_greater1_flag = 0, coeff_abs_level_greater2_flag = 0)

	video 0	**video 1**	**video only**	**synthesized only**	**coded & synthesized**
Balloons	0.0%	0.0%	0.0%	0.1%	0.0%
Kendo	0.0%	0.0%	0.0%	0.0%	0.0%
Newspapercc	0.0%	0.0%	0.0%	0.2%	0.1%
GhostTownFly	0.0%	0.0%	0.0%	0.1%	0.1%
PoznanHall2	0.0%	0.0%	0.0%	0.1%	0.0%
PoznanStreet	0.0%	0.0%	0.0%	0.1%	0.0%
UndoDancer	0.0%	0.0%	0.0%	0.1%	0.0%
1024x768	0.0%	0.0%	0.0%	0.1%	0.0%
1920x1088	0.0%	0.0%	0.0%	0.1%	0.0%
Average	**0.0%**	**0.0%**	**0.0%**	**0.1%**	**0.0%**

4 Conclusions

This contribution has presented a simplified CABAC coefficients level coding for depth map. In the proposed method, we do not encode both *coeff_abs_level_greater1_flag* and *coeff_abs_level_greater2_flag*, therefore nine context-coded bins are saved in each sub-block. Note that all the modules and processes of current CABAC are kept unchanged and no additional module is needed in the proposed scheme. We recommend adoption of the proposed scheme in the next version of HTM.

5 References

[1] J. Chen, W. Chien, J. Rajan, J. Sole, and M. Karczewicz, "Non-CE1: throughput improvement on CABAC coefficients level coding," JCTVC-H0554, San Jose, CA, February 2012.

[2] HTM 4.0.1 Software, https://hevc.hhi.fraunhofer.de/svn/svn_3DVCSoftware/tags/HTM-4.0.1/

[3] D. Rusanovskyy, K. Müller, and A. Vetro, "Common Test Conditions of 3DV Core Experiments," JCT2-A1100, Stockholm, SE, July 2012.

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7 Patent rights declaration(s)

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