Fast Algorithm with Palette Mode Skipping and Splitting Early Termination for HEVC Screen Content Coding

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***Abstract*—Screen content videos have special features such as frequently repeated patterns, limited number of colors and non-noisy regions. It differs from the natural scene sequences which require more proper coding tools. New modes were incorporated into the High Efficiency Video Coding (HEVC) standard such as Palette mode (PLT) and Intra Block Copy (IBC) to target the special nature of theses videos. The new tools achieve higher coding performance, however, they bring remarkable computational complexity. In this paper, a new fast scheme is proposed to reduce the HEVC encoding time for the screen content videos. It depends on the number of distinct colors inside the current block. The new approach is implemented and simulated using HEVC screen content extension software HM 16.7+SCM 6. The results show that our scheme reduces the encoding time by 24.46 % with small increment of 2.1 % in the bitrate.**

I. Introduction

With the widespread of the portable devices, such as Computers, Laptops and Mobile phones, huge amount of data is transmitted for video broadcasting. The need for high quality video compression techniques has become a serious demand to enable high quality video transmission through the communication networks. HEVC (High Efficiency Video Coding) [1] is the latest video coding standard, which was launched in 2013. It provides about 50% bitrate saving with respect to the predecessor standard.

There are prevalent types of video contents that are used today, such as camera-capture content, computer-generated graphics and text. Camera-Capture content (CC) videos have the feature of smooth regions and they contain large number of colors, while the Screen-Content (SC) videos have different characteristics such as having regions with limited number of colors, sharp edges, non-noisy regions and repeated patterns. Because of the special nature of the screen content videos, the Joint Collaborative Team on Video Coding (JCT-VC) called for proposals in 2014 [2] for a screen-content extension to the HEVC.

Several coding tools have been included in the HEVC screen content extension to handle the complex structure of the screen-content videos. Palette mode (PLT) [3] is an efficient technique in HEVC screen content, it is used to represent the blocks that have small number of colors without applying the prediction and the transformation steps. A palette table is formed to contain a set of colors from the Coding Unit (CU) and the pixels in the CU are classified into major color and escape colors. If the pixel color is contained in the palette table, it is represented by a map index inside a map table, otherwise the pixel is considered as an escape color, eventually, only the indices are encoded.

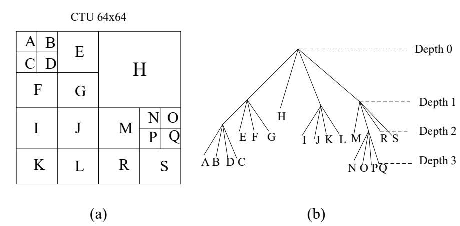

Fig. 1: an example of CTU partitioning. (a) The partitions of the CTU, (b) Its quadtree structure .

Intra Block Copy (IBC) [4] is a new coding tool similar to the motion compensation prediction tool in the conventional HEVC. The difference here is that the IBC uses the current frame as a reference frame to locate the best matching block.

The screen content extension handles the same quadtree block partitioning scheme used in the traditional HEVC. In which, the frame is divided into square blocks called Coding Tree Unit (CTU) which is 64x64 pixels in default, it can be further split into four equal parts. The basic unit is the CU in which the mode decision is taken and it can be further segmented into small parts called Prediction Unit (PU). Fig. 1 illustrates the quadtree structure of the HEVC. The encoder employs a Rate-Distortion Optimization (RDO) process for all combinations and compares the cost of the different modes to reach the best CTU structure, this process is done recursively from 64x64 (depth 0) to 8x8 (depth 3).

Despite of the higher performance that the SC extension brings, the new tools affect the encoding time clearly. In the *All Intra* profile, the regular intra mode includes 35 rough mode decision process that are checked firstly followed by

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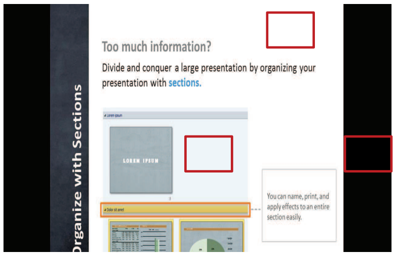


Fig. 2: Picture from the slideshow sequence with a regions have unique color pixel value (highlighted by red squares).

the new modes (IBC and PLT).

In this paper, a new fast scheme is proposed to reduce the encoding time for screen content sequences. The paper is organized as follows. The previous work is reviewed in Section II. Next, Section III presents the proposed algorithm. Later, the simulation results are discussed in Section IV. Finally, the paper is concluded in Section V.

II. Related Work

Several studies have been done to tackle the large encoding time associated with the new screen content tools. In [5], the authors presented three fast search methods, where the cost of the regular intra mode and the CU activity information are used to limit the search range of the IBC or to completely skip the IBC process. The search areas are restricted to 1-D or 2-D (including the current and left CTUs). IBC also is limited to blocks with sizes of 16X16 (2Nx2N) and 8x8 (2Nx2N, 2NxN, Nx2N). Tsnag et al. [6] suggested to use the hash search method to locate the best matching blocks along the local search areas in 1-D and 2-D. They also presented new formulas to estimate the hash value for the different block sizes.

In [7], a fast intra method was presented based on the analysis of the content property, the CUs are classified into Natural Content NC or Screen Content SC based on the CU characteristics. For NC, the new tools (IBC and PLT) are skipped if the best mode of the previous test for regular intra mode is DC or planar. For SC, the splitting process is terminated based on the rank value. In addition, the bit per pixel (bpp) and the depth information of the neighbor CUs are used to detect the proper depth.

In [8], a fast method was presented to reduce the complexity. The exactness value along the horizontal and the vertical directions is used to stop the splitting process, also early pruning termination was suggested based on the RDO cost since the PLT and IBC order is swapped and the IBC is skipped based on the cost of the PLT checking.

III. The Proposed Algorithm

A. Statistical analysis

As mentioned before, screen content sequences have limited number of colors opposed to the camera captured videos [7]. We propose here to apply a fast scheme based on the number of colors of the coded CU, where the color number is estimated by counting the number of distinct luminance (Y) values inside the CU. Fig. 2 shows a picture from Slideshow sequence, the regions marked by the red squares are smooth regions with single color denoted as Single Color Blocks (SCBs) here. Such type of regions is popular in the screen content sequences with a low probability to be split. In Table I, statistics collected from the first 100 frames of the Webbrowsing sequence [9] are shown. The table shows the percentage of Single Color Blocks (SCBs), also it gives the percentage of SCBs which have RD cost less than the sum of RD costs of their sub CU blocks (CUs are from 64x64 to 16x16, since 8x8 is the largest CU size), which is approximately equals 100%. Therefore, we suggest to check the color number of the current CU then the recursive splitting is terminated if the color number is one.

TABLE I: Statistics of Webbrowsing screen content sequence

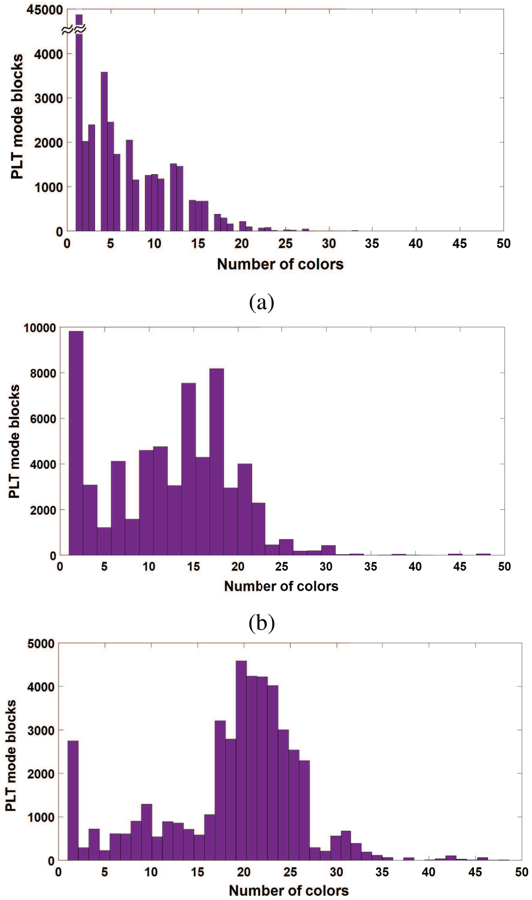
	CU 64x64	CU 32x32	CU 16x16
SCB percentage	**5.6%**	**22.25%**	**25.4%**
SCBs percentage with RD cost less than the sum of RD costs of their sub blocks	**100%**	**99.97%**	**99.99**

Based on our observations, most of the CU blocks that have large number of colors are not coded using PLT mode. Since with large number of colors, there are more indices to be encoded which increases the encoding cost. To validate our observations, the data of the CU coded by the PLT mode as the best mode are collected from Webbrowsing sequence using Quantization Parameter QP=22. Fig. 3 shows the histogram of these blocks versus the number of colors for CU sizes 8x8, 16x16 and 32x32 (PLT mode is not conducted for blocks of size 64x64 in the HM+SCM by default), the number of colors is limited to 50, since with higher numbers, the observed number of coded blocks approximately equals zero. From the figure we can conclude that the PLT mode rarely chosen when the number of colors inside the blocks is large.

Accordingly, we propose to skip PLT mode if the color number is higher than a predefined threshold. To determine the threshold value, simulation was conducted using the HEVC screen content extension software tool (HM-16.7+ SCM-6). The Webbrowsing, Kimono and MissionControl3 sequences [9] from different categories were used. Fig. 4 illustrates the average results for different CU sizes within range of colors in terms of Time-saving and BD-rate [10]. Time-saving is estimated as follows:

$$T_S = \frac{T_{conv} - T_{mod}}{T_{conv}} \times 100 \tag{1}$$

Where T_S is the Time-saving, T_{conv} is the encoding time of the conventional encoder without modifications, T_{mod} is the encoding time of the modified encoder. The simulation were conducted at 11 steps along the color range, at each step, the PLT mode is ignored if the color number is larger than the current step color.

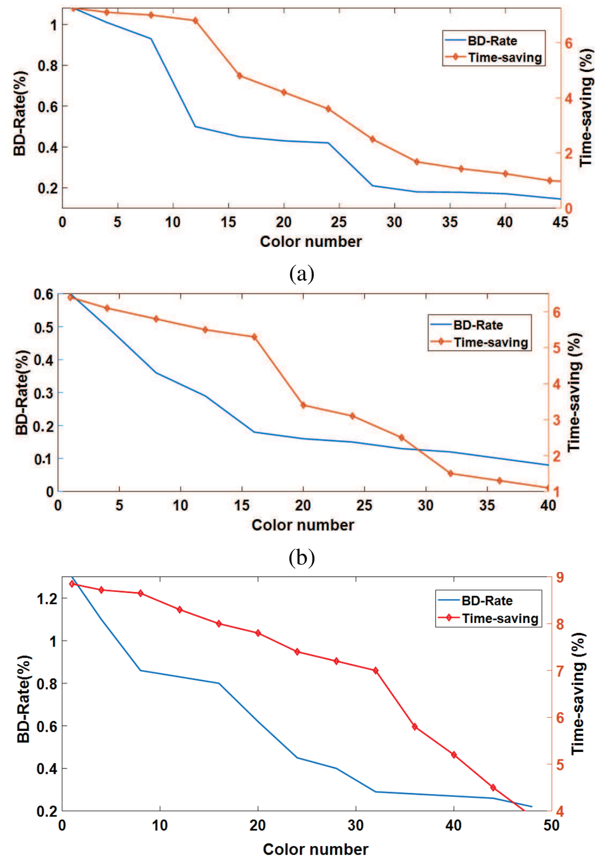


(a)

(b)

(c)

Fig. 3: The histogram of CUs coded by PLT mode vs the number of colors for (a) 8x8, (b) 16x16, and (c) 32x32 CU sizes.



(a)

(b)

(c)

Fig. 4: The average BD-Rate and Time-saving of Webbrowsing, Kimono and MissionControl3 sequences at certain range of color number for (a) 8x8, (b) 16x16, and (c) 32x32 CU sizes.

From Fig. 4, we can observe that the best cases for 8x8, 16x16 and 32x32 are 12,16 and 32 respectively, since at these values, the Time-Saving is the best according to the BD-Rate increment. So, 12,16 and 32 are the Thresholds (THs) for 8x8, 16x16 and 32x32 CU sizes respectively and they are used to terminate the PLT checking if the color number inside the block is greater than them.

B. Algorithm steps

Combining the above two approaches, the full algorithm steps are described in the flow chart shown in Fig 5. Starting with the block of depth k=0, the Number of colors N_C is calculated firstly. Later, the 35 modes of the regular intra-prediction are checked to find the best mode of the current CU. Next, the IBC mode is tested. After finishing the IBC RDO process, a condition is tested to decide if the PLT mode is checked or not. If the depth K is larger than 0 and N_C is less than the predefined threshold TH, the PLT process is performed, otherwise other conditions are checked. After finishing the PLT mode, if K=3 or $N_C = 1$ (smooth region), the splitting process is terminated and the final depth is the current depth K. Otherwise, K is updated to K+1, and the process is repeated. Eventually, the encoder transmits the final structure information to the entropy, then it sends the information to the decoder for the reconstruction process.

IV. THE EXPERIMENTAL RESULTS

To evaluate the performance of the proposed scheme, simulation was conducted using the screen content software tool HM-16.7+SCM-6. Recommended screen content video sequences [9] were used, where TGM: Text and graphics with motion, M: mixed content, A: animation, CC: camera-captured content. The test employs **encoder_intra_main_scc** as a coding profile. Four Quantization Parameters (QPs) are used; 22,27,32 and 37. For fair comparison, the results are compared with the results in [8] using the same SCM encoder version. The simulation results are shown in Table II for the sequences that appeared in [8] in terms of BD-rate [10] and Time-saving percentage.

From Table II, we can observe that the proposed scheme achieves higher time saving than the approach in [8] where it

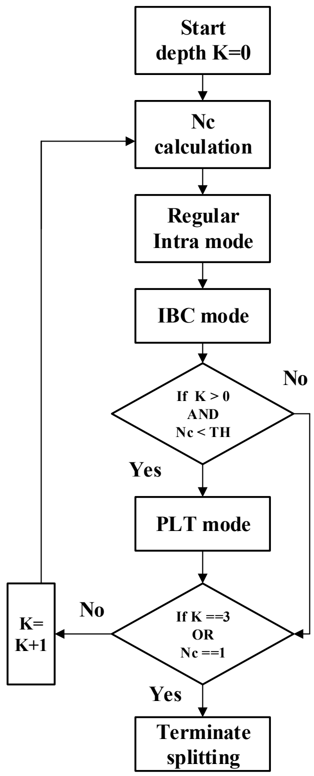


Fig. 5: The proposed algorithm steps.

has in average 24.46% time saving while the approach in [8] saves 17.07% of the encoding time, the difference in BD-Rate equals approximately 0.58 which is a small value. When it comes to the sequence types, for the M+TGM videos classes, the average time saving for the proposed method is higher with 24.1% time saving against 19.05% for about 0.6% difference in the BD-Rate.

For A+CC classes, our approach outperforms the method in [8] with 26.4% and 0.03% time saving and the BD-Rate respectively, while the other method only saves 9.8% of the encoding time with 0.09% increment in the bitrate.

The presented scheme shows different time saving impacts for the different sequences types. For example, the time saving is the highest for the Slideshow sequence, since it contains non-split large smooth areas with a single color. Furthermore, the A+CC sequences have many blocks with large number of colors so the noticed time saving improvement is due to avoiding the PLT mode checking. The proposed algorithm can be integrated with other existing schemes to further increase the time saving.

V. Conclusion

New tools such as Palette mode (PLT) and Intra Block Copy (IBC) are adopted in the conventional HEVC standard to better encode the screen content sequences. The new tools achieve high bitrate reduction with respect to the traditional HEVC.

TABLE II: The simulation results comparison

Sequences	Tsang [8]		Proposed	
	BD-Rate	Time%	BD-Rate	Time%
sc_flyingGraphics	3.41	13.52	2.4	21.6
sc_desktop	2.74	20.58	2.2	15
sc_console	3.40	16.39	1.8	11.2
sc_web_browsing	1.82	20.86	0.8	16.2
sc_map	0.78	13.19	3.7	29
sc_programming	1.43	16.11	4.3	24.3
sc_Slideshow	2.01	43.45	2.4	41.5
Average(M+TGM)	1.91	19.05	2.5	24.1
Average(A+CC)	0.09	9.8	0.03	26.4
Average	**1.52**	**17.07**	**2.1**	**24.46**

However, testing the additional modes increases the encoding time. In this paper, a new fast method is presented to reduce the encoding time. It early terminates the splitting process and skips unnecessary check for PLT mode based on the number of colors. The final results show that the proposed method saves encoding time with 24.46% with a small bitrate sacrifice, where the BD-Rate increment is equal to 2.1% only. In the future work, the Chrominance components will be considered at the estimation of the colors number to improve the bitrate. Also, the proposed algorithm will be integrated with other state-of-art algorithms to further increase the encoding time saving.

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