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Analysis of Screen Content Coding Based on HEVC

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** Short Paper: This paper reviews the recent progress, possibly including previous works in a particular research topic, and has been accepted by the editorial board through the regular reviewing process.*

Abstract: In this paper, the technical analysis and characteristics of screen content coding (SCC) based on High efficiency video coding (HEVC) are presented. For SCC, which is increasingly used these days, HEVC SCC standardization has been proceeded. Technologies such as intra block copy (IBC), palette coding, and adaptive color transform are developed and adopted to the HEVC SCC standard. This paper examines IBC and palette coding that significantly impacts RD performance of SCC for screen content. The HEVC SCC reference model (SCM) 4.0 was used to comparatively analyze the coding performance of HEVC SCC based on the HEVC range extension (RExt) model for screen content.

Keywords: HEVC SCC, Screen content coding

1. Introduction

High efficiency video coding (HEVC) is the latest video compression standard of the Joint Collaborative Team on Video Coding (JCT-VC), which was established by the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG). Several extensions and profiles of HEVC have been developed according to application areas and objects to be coded [1]. The standardization of HEVC version 1 for major applications such as ultra-high definition (UHD) content was completed in January 2013. Furthermore, the standardization of HEVC version 2 for additional applications, such as high-quality, scalable, and 3D video services, was released in October 2014. HEVC version 2 includes 21 range extension profiles, two scalable extension profiles, and one multi-view extension profile [2]. First, the HEVC range extension (RExt) standard aims to support the extended color formats and high bit depths equal to or higher than 12 bits, which HEVC version 1 does not support. In addition, the HEVC scalable extension (SHVC) standard supports multi-layer video coding according to consumer communications and market environments, and the HEVC multi-view extension (MV-HEVC) aims to support multi-view video services. Recently, emerging requirements for screen content coding have been issued, and the extension for SCC was kicked off based on HEVC [3]. In addition, the HEVC HDR/WCG extension for high-dynamic-range (HDR) and wide-color-gamut (WCG) coding is being discussed [4].

The HEVC SCC extension is designed for mixed content that consists of natural videos, computer-generated graphics, text, and animation, which are increasingly being used. The HEVC SCC extension has been discussed since the 17th JCT-VC meeting in March 2014, and it is being standardized with the goal of completion in February 2016. HEVC is known to be efficient for natural video but not for computer-generated graphics, text, and so on. That content has high-frequency components due to sharp edges and lines. Conventional video coders, in general, remove high-frequency components for compression purposes. However, HEVC SCC includes all coding techniques supported by HEVC RExt, and additionally, has IBC, palette coding, and adaptive color space transform. In this study, IBC and palette coding are explained in detail in relation to screen content, among the newly added coding techniques. In addition, the HEVC SCC reference model (SCM) is used to present and analyze the coding performance for screen content. The result of the formal subjective assessment and objective testing showed a clear improvement in comparison to HEVC RExt [5].

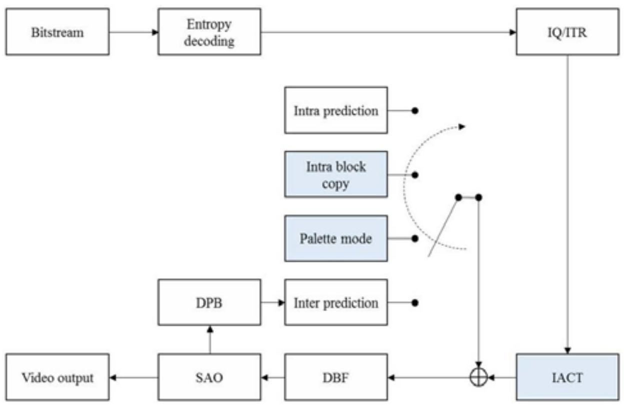


Fig. 1. HEVC SCC decoder block diagram.

This paper is organized as follows. Chapter 2 explains IBC and palette coding, which are the coding techniques added to HEVC SCC. Chapter 3 presents and analyzes the coding performance of HEVC SCC for screen content. Finally, Chapter 4 concludes this study.

2. HEVC Screen Content Coding Techniques

HEVC SCC employs new coding techniques in addition to all the techniques adopted to HEVC RExt. Fig. 1 shows the block diagram for the HEVC SCC decoder, which includes newly adopted IBC, palette mode, and adaptive color transform (ACT). This chapter explains IBC mode coding and palette mode coding, considering the characteristics of screen content.

2.1 IBC Mode

As mentioned in Chapter 1, screen content is likely to have similar patterns on one screen, unlike natural images. Such a spatial redundancy is different from the removable spatial redundancy under the existing intra prediction schemes. The most significant difference is the distance and shapes from neighboring objects. Removable spatial redundancy with the intra prediction schemes refers to the similarity between the boundary pixels of the block to be coded and the adjacent pixels located spatially within one pixel. The removable spatial redundancy in IBC mode refers to the similarity between the area in the reconstructed picture and the block to be coded [6]. Unlike the conventional intra prediction schemes, a target 2D block is predicted from a reconstructed 2D block that is more than one pixel distant from it. Inter prediction should have the motion information, the so-called motion vector, with respect to the reference block to remove the temporal redundancy in the previously decoded frames. In the same manner, IBC mode also needs the location information for the reference block in the form of a vector in the same frame. Fig. 2 shows the concept of IBC and the block vector.

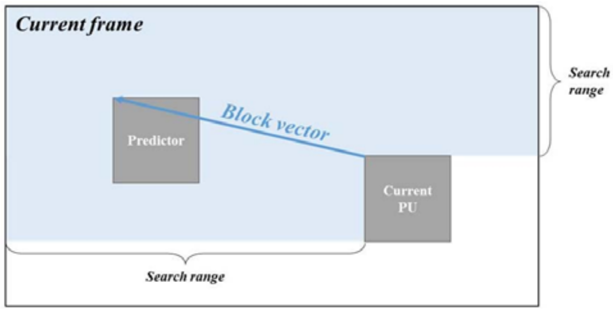


Fig. 2. Intra block copy and block vector.

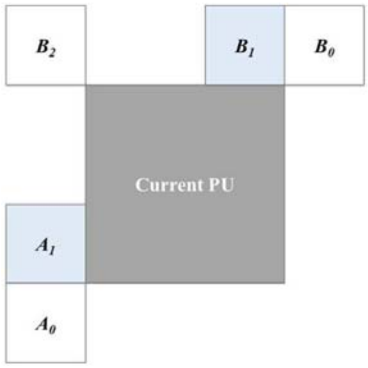


Fig. 3. Candidates of spatial motion vector predictor and block vector predictor.

In HEVC SCC, a vector that locates the reference block is called the block vector (BV) [7]. Conceptually, this is considered to be similar to the motion vector (MV) of inter prediction. The block vector and motion vector have differences and similarities. In terms of the accuracy of the vectors, MV has quarter-pel accuracy to ensure improved prediction accuracy, whereas BV has integer-pel accuracy. This is because of the characteristics of the screen content in IBC mode. In computer-generated graphics, objects are generated pixel by pixel. The key feature of IBC is conducted on the reconstructed area of the current frame not previously coded, or frames decoded different. In addition, the BV should be sent to the decoder side, but the block vector is predicted to reduce the amount of data in a manner similar to the motion vector. During the HEVC SCC standardization process, various algorithms of BV prediction techniques were discussed. They can be classified into a BV prediction method independent from the MV prediction method, and a prediction method working in the same way as the MV prediction method.

In the BV prediction method that is independent of the MV prediction method, the BV of the adjacent block and the BV that is not adjacent, but IBC-coded, is taken for the selection of BV predictor (BVP) candidates, and one of them is selected. Fig. 3 shows the spatial candidates under MV and BV. In the case of MV, the MVs of all prediction units (PUs), A0, A1, B0, B1, and B2, are used as spatial candidates. With the BV, however, only A1 and B1 are used as spatial candidates. When the left adjacent block, A1, of the PU is coded with IBC mode, the BV of A1 is selected as the BVP candidate. Then, when the aforementioned block B1 of the PU is coded with IBC mode, the BV of B1 is also selected as the BVP candidate.

As in the MV prediction method, the BV prediction technique adds the partly reconstructed current picture to the reference picture list, and IBC mode of the current PU could refer the reconstructed area of the current picture. The second method was proposed in the 20th JCT-VC meeting and it was adopted. Although the BV can be predicted, as in the existing MV prediction method, because the current picture is added to the reference list, predictors may exist that do not conform to the characteristics of IBC during the advanced motion vector prediction (AMVP) and merge candidate list creation processes. However, it still has several problems, such as the difference in vector accuracy between MV and BV, optimal BVP candidates, and so on. To address this problem, studies are being conducted to change the zero candidate considering the IBC characteristics and to change the candidate list.

2.2 Palette Mode

HEVC SCC has palette mode in addition to IBC mode. In palette mode, pixel values that frequently appear in the block are expressed in indices and then coded [8]. In HEVC SCC, the index for palette mode coding is defined as the color index, and the mapping information between the pixel value and the color index is defined in the palette table. Palette mode can improve coding efficiency when the prediction does not work due to low redundancy and when the number of pixel values for the block is small. Unlike the existing coding mode, which uses intra-inter prediction to remove the spatial-temporal redundancy, palette mode expresses the pixel values that form the current block with the color index, so coding is possible independent of the already restored adjacent information. In addition, fewer color indexes are required than the total number of pixels in a current block, which improves coding efficiency.

The coding process in HEVC SCC palette mode consists of two steps: the palette table coding process and the color index map coding process. The palette table coding process is conducted as follows. First, assuming that N peaks exist when pixel values are shown in a histogram, N peak pixel values are defined as major colors. N major colors are mapped as the color indices via quantization, with the colors in the quantization zone as the major colors. The colors that exist outside the quantization zone, which are not expressed as major colors, are defined as escape colors, which are coded not using the color index but the quantization of the pixel values. The table with the generated color indices is defined as the palette table for each coding unit (CU). The palette table conducts prediction coding by referring to the previous CU coded by palette mode. Whether or not the prediction coding is conducted is coded using the previous_palette_entry_flag. Prediction coding uses palette stuffing, which utilizes the predictor of the previous CU [9]. Fig. 4 shows the histogram of the pixel values and the resulting major/escape colors of palette mode.

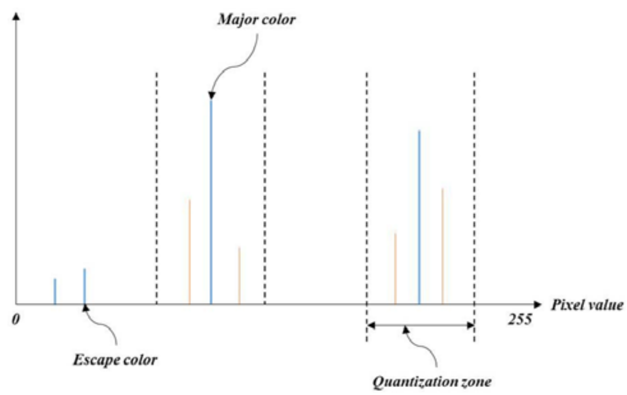


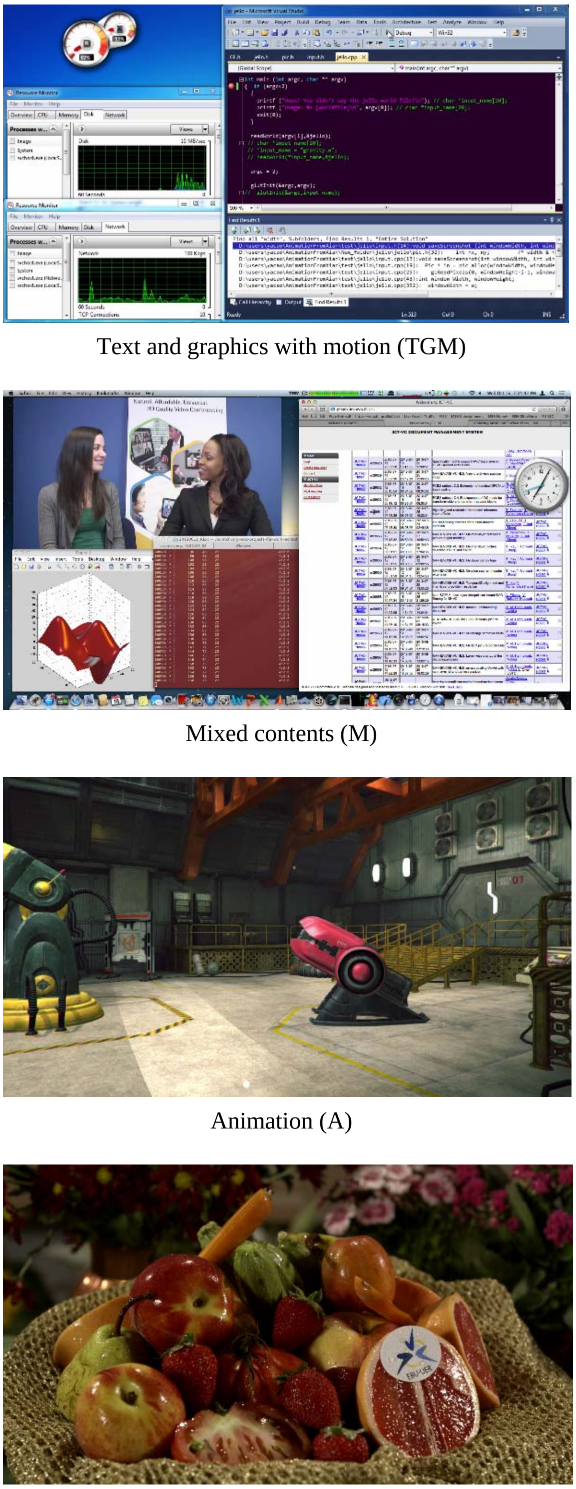
Fig. 4. Histogram of the pixel values and major/escape colors of palette mode.

Then, the current CU is coded through the color index map coding process. The color index map refers to the block expressed by replacing the pixel value of the current CU with the color index. The information coded during the color index map coding process includes the color index scanning direction and the color index map. The scanning direction of the color index is coded using the palette_transpose_flag by the CU, and three types of color index map, the INDEX mode, COPY_ABOVE mode, and ESCAPE mode, are coded. In INDEX mode, run-length coding is conducted for the color index value, and the mode index, color index, and run-length are coded. In COPY_ABOVE mode, which copies the color index of the aforementioned row, the mode index and run-length are coded. Finally, in ESCAPE mode, which uses the pixel value as it is, the mode index and the quantized pixel value are coded.

3. Analysis and Performance Evaluation of HEVC SCC

In this chapter, the HEVC SCC reference mode (SCM) 4.0 [10] is used to analyze the coding performance of HEVC SCC for the screen content against the reference model for HEVC RExt. All the tests were conducted under the HEVC SCC common test condition (CTC) [11] to achieve the coding performance with HEVC SCC. In addition, the HEVC SCC common test sequences were used in the test, which were classified into four categories. Text and graphics with motion (TGM) have images with text and graphics combined, and best shows the characteristics of the screen content. Mixed contents (M) is an image that contains mixed characteristics of screen content and natural images. In addition, there are categories such as animation (A) and natural image camera-captured content (CC). Fig. 5 shows the four categories of the HEVC SCC common test sequences.

The coding performance and speed were measured in the same test environment. Table 1 lists the details of the test environment. In addition, Bjontegaard distortion- bitrate



Text and graphics with motion (TGM)

Mixed contents (M)

Animation (A)

Camera-captured content (CC)

Fig. 5. Four categories of common test sequences.

Table 1. Test environments.

	Specification
CPU	INTEL CORE I7-3960X 3.30GHZ
Memory	16GB
OS	Windows 7
Compiler	VS 2012

Table 2. BD-BR performance evaluation of SCM 4.0 compared to HM 16.0 in All Intra.

Category	All Intra		
	Y	U	V
TGM, 1080p & 720p	-57.4%	-61.2%	-62.7%
M, 1440p & 720p	-44.9%	-50.3%	-50.4%
A, 720p	0.0%	-8.5%	-5.2%
CC, 1080p	5.4%	8.6%	12.5%
Encoding time (%)	347		
Decoding time (%)	121		

Table 3. BD-BR performance evaluation of SCM 4.0 compared to HM 16.0 in Random Access.

Category	Random Access		
	Y	U	V
TGM, 1080p & 720p	-48.0%	-52.4%	-55.0%
M, 1440p & 720p	-36.3%	-43.6%	-43.7%
A, 720p	1.8%	-5.3%	-2.2%
CC, 1080p	6.0%	15.8%	20.1%
Encoding time (%)	139		
Decoding time (%)	147		

Table 4. BD-BR performance evaluation of SCM 4.0 compared to HM 16.0 in Low delay B.

Category	Low delay B		
	Y	U	V
TGM, 1080p & 720p	-41.4%	-45.3%	-48.0%
M, 1440p & 720p	-23.7%	-32.1%	-32.2%
A, 720p	2.7%	-2.0%	0.6%
CC, 1080p	6.0%	14.2%	17.6%
Encoding time (%)	141		
Decoding time (%)	145		

(BD-BR) was used to compare the coding performance, and the time ratio was used to measure the coding speed.

Tables 2 to 4 show the coding performance when the HEVC SCC common test sequences were coded in HM 16.0 and SCM 4.0. For the screen content, SCM 4.0 had 19.1% Y BD-BR gain, 21.8% U BD-BR gain, and 20.7% V BD-BR gain, compared with HM 16.0. In the TGM category, which has strong screen content characteristics, 48.9% Y BD-BR gain, 53.0% U BD-BR gain, and 55.2% V BD-BR gain were obtained, and the results show that the newly added IBC mode and palette mode performed well. Otherwise, 5.8% Y BD-BR loss, 12.9% U BD-BR loss, and 16.7% BD-BR loss were obtained in the CC category, which has strong natural content characteristics. As shown in Tables 2 to 4, the newly added coding tools, IBC and palette mode, increased encoding time by 347%, 139%, and 141% for All Intra, Random Access, and Low delay B, respectively. In the results, fast encoding algorithms for IBC and palette mode are expected to be widely studied in the future.

4. Conclusion

In this paper, the newly added algorithms of HEVC SCC were introduced, and the HEVC SCC coding performance was also analyzed for screen content. The coding characteristics of the new coding tools that consider the screen content, which are intra block copy (IBC) mode and palette mode, were introduced in detail. As for coding performance of the screen content, HEVC SCC had 19.1% BD-BR gain compared with HEVC RExt. The HEVC SCC standardization will be completed in October 2015 and is expected to be widely used in various screen content applications.

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