Abstract—High Efficiency Video Coding (HEVC) is a recently developed video coding standard by Joint Collaborative Team on Video Coding (JCT-VC). It proves coding efficiency about half in point of bit rate reduction compared with H.264/MPEG-4 AVC. In transform process of HEVC, there is skip mode only for 4x4 transform blocks; however, for screen contents, it is helpful to extend transform block size for transform skip and has great coding performance. In this paper, we proposed early termination scheme for transform skip mode and scan order modification for computational time. The experimental results show 9% ~ 16% of saving time with small BD-PSNR loss.

Keywords—Transform skip mode, discrete cosine transform, high efficiency video coding, HEVC.

I. INTRODUCTION

With the popularity and the demand of high resolution video increased rapidly, new video codec technologies which has better coding efficiency than H.264/MPEG-4 AVC [1] proposed for past few years. Finally, as the successor of H.264/MPEG-4 AVC, the high efficiency video coding (HEVC) [2] was recently finalized by the Joint Collaborative Team on Video Coding (JCT-VC) consists of members in ISO/IEC MPEG and ITU-T VCEG. HEVC performs half bit-rate reduction compared to H.264/MPEG-4 AVC High Profile with the similar subjective video quality. The main difference between H.264/MPEG-4 AVC and HEVC is the basic unit of coding structure. H.264/MPEG-4 AVC utilize only 16x16 blocks which has fixed block size regardless of video characteristics. However, HEVC uses basic units with variable block size (8x8 to 64x64) which can adaptively encode the high resolution video [3]. A coding tree unit (CTU) has three coding tree blocks (CTBs) that are one luma and two chroma components and has the related syntax elements. HEVC divide CTU to coding units (CUs) employed quadtree structure, and CUs also can be separated into multiple prediction units (PUs) and transform units (TUs). PU is basic unit of prediction (intra-picture prediction and inter-picture prediction) and it is specified by splitting types. For each TU, integer transform based on DCT (discrete cosine transform) and quantization is applied. TU can be divided into half size of TUs followed by residual quadtree (RQT). The best sizes and modes for each CTU are determined by rate-distortion cost (RD cost), and HEVC finally can get bit-streams to binarize and entropy-code with transform coefficients.

The remainder part of this paper is organized as follows. Section II describes properties of DCT and technologies for transform skip mode (TSM). The proposed algorithm for TSM is specified in Section III. Experimental results and analysis are shown in Section IV. Finally, we conclude our proposed algorithms in Section V.

II. BACKGROUNDS

A. Properties of Discrete Cosine Transform

For signal processing and image compression, one of the most commonly used transform method is DCT. Since the cosine transform has outstanding energy compaction for highly correlated signals like images and video sequences, DCT yields great coding performance with video codec [4].

As shown in Fig. 1, a basis function of left-upper position represents direct current (DC) component and right-bottom bases of DCT are high-frequency components in 8x8 block image. Also, first row of basis function represents vertical edges and first column shows horizontal edges. If the most of DCT coefficients congregate at nearby DC component, we can easily compress images with quantization which removes relatively...
small amount of high-frequencies.

It is applied only for 4x4 TU and there are no changes in motion estimation and compensation, quantization, de-blocking filter and entropy coding. For Class F, they obtained gains about 1.8% for random access and 3.0% for low delay.

For HEVC range extension, X. Peng contributes a technique to transform skip at large size TU [8]. The author experiments transform skip for large size TU, i.e., 8x8, 16x16 and 32x32 at HM10.1_RExt3.0 anchor. For Class F and screen contents of 4:4:4 color format, the technique led to 0.9% ~ 2% BD-BR gain. Although there is coding efficiency; however, it is inevitable increasing encoding time. Since the time consumption of HM encoder and decoder has been one of the important issues of HEVC standardization, we study a novel attempt for early termination of TSM.

III. PROPOSED ALGORITHMS

A. Early Termination of Transform Skip Mode

The main idea is based on the assumption that if the magnitude of high frequency coefficients is larger than low frequency coefficients, the traditional transform technique for the video codec is not efficient to compress video sequences, as we mentioned in Section II-A.

To calculate magnitudes of DC and AC area, we use absolute sum of each coefficients because DCT coefficients can have both of positive and negative number. First, we pre-check energy of AC area as follows:

![Fig. 3 Partition of DC and AC area for 8x8 TU (a) and 16x16 TU (b)]
\[ \text{sum}_\text{abs}_\text{ac} = \sum_{(x,y)\in AC_1, AC_2, AC_3} |\text{coeff}(x,y)|. \]  

(1)

coeff(x,y) means DCT coefficient located (x, y), and (x, y) is relative location of left-upper coefficient of TU. AC_1, AC_2, AC_3 have 4 coefficients respectively and located corner areas as shown in Fig. 3 (a) and (b). The reason why we firstly calculate these areas is that, in complex region, there are tendencies of DCT coefficients are gathered at each corner of ACs, as shown in Fig. 2. If \( \text{sum}_\text{abs}_\text{ac} \) equal to zero, we do not apply transform skip mode to current TU and if it is not, we calculate absolute sum of DC and AC regions by

\[ \text{sum}_\text{abs}_\text{DC} = \sum_{(x,y)\in DC} |\text{coeff}(x,y)| \]  

(2)

\[ \text{sum}_\text{abs}_\text{AC}_i = \sum_{(x,y)\in AC_i} |\text{coeff}(x,y)|. \]  

for \( i = 1, 2, 3 \)  

(3)

If \( \text{sum}_\text{abs}_\text{DC} \) is larger than accumulated \( \text{sum}_\text{abs}_\text{AC}_i \), TSM is not applied for current TU because energy compaction of current block is suitable for DCT. Otherwise, we add TSM as a candidate of DCT mode and determine the best mode by comparing RD-cost.

B. Scan Order Modification

For more speed enhancement, we modify scan patterns when we calculate sum of absolute values, following characteristics of coefficients.

![Scan order for early termination](image)

Fig. 4 Scan order for early termination

The scan order is described in Fig. 4. The order of AC part is AC_3, AC_1 and AC_2, and it is determined experimentally. For each of AC_i, the scan order is followed by arrows; since, the AC_1, AC_2, AC_3 part have larger coefficients than others at edges and text. Finally, we compare \( \text{sum}_\text{abs}_\text{DC} \) with accumulated \( \text{sum}_\text{abs}_\text{AC}_i \) as soon as the calculation of one row or column of AC_i is finished. If \( \text{sum}_\text{abs}_\text{AC}_i \) is larger than \( \text{sum}_\text{abs}_\text{DC} \), TSM is added to DCT of HEVC. The entire procedure of proposed algorithm is described in Fig. 5.

IV. EXPERIMENTAL RESULTS

The proposed early termination method for transform skip mode is implemented in HM 12.0. We utilize the data set used for the HEVC standard development and additionally, for screen contents, we make our test sequences which are ICSP test1 and ICSP test3, as shown in Fig. 6 and Fig. 7. For experiments, all intra (AI) configuration of HEVC Main Profile is used, and largest coding unit size is 64x64 and QP = 22, 27, 32 and 37. As a measure of consuming time, \( \Delta \text{Time} \) is defined as follows,

\[ \Delta \text{Time}(\%) = 1 - \frac{(\text{Time}(\text{HM 12.0}) - \text{Time}(\text{proposed method}))}{\text{Time}(\text{HM 12.0})}. \]  

(4)

![Flowchart for proposed algorithms](image)

Table 1. Experimental results for proposed algorithms

<table>
<thead>
<tr>
<th>Sequences</th>
<th>ET_TSM (MAX_TS = 8)</th>
<th>ET_TSM + SOM (MAX_TS = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BD-BR</td>
<td>BD-PSNR</td>
</tr>
<tr>
<td>BasketballDrillTest</td>
<td>-0.164</td>
<td>0.009</td>
</tr>
<tr>
<td>Chefshow</td>
<td>-0.655</td>
<td>0.060</td>
</tr>
<tr>
<td>ICSP test1</td>
<td>-0.906</td>
<td>0.129</td>
</tr>
<tr>
<td>ICSP test3</td>
<td>-0.934</td>
<td>0.128</td>
</tr>
<tr>
<td>SlideEditing</td>
<td>-1.462</td>
<td>0.235</td>
</tr>
<tr>
<td>SlideShow</td>
<td>-0.616</td>
<td>0.057</td>
</tr>
<tr>
<td>Average</td>
<td>-0.790</td>
<td>0.103</td>
</tr>
</tbody>
</table>
In this paper, we proposed algorithms for TSM of HEVC transform coding. The proposed algorithm consisted of early termination of TSM and scan order modification for speed improvement reduce computation time of HM encoder with extension of TSM. Using characteristics of DCT coefficients, we can efficiently selects whether TSM is applied for HM or not, and by changing scan order of calculating sum of absolute values, we also save computational time of transform process of HM. Therefore, our proposed algorithms are efficient for screen contents and its application.

### V. CONCLUSIONS

In this paper, we proposed algorithms for TSM of HEVC transform coding. The proposed algorithm consisted of early termination of TSM and scan order modification for speed improvement reduce computation time of HM encoder with extension of TSM. Using characteristics of DCT coefficients, we can efficiently selects whether TSM is applied for HM or not, and by changing scan order of calculating sum of absolute values, we also save computational time of transform process of HM. Therefore, our proposed algorithms are efficient for screen contents and its application.

### REFERENCES


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