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Performance Comparison between DWT-based and DCT-based Encoders

Xin Lu[1] and Xuesong Jin[2*]

[1] School of Electronics and Information Engineering,
Harbin Institute of Technology, Harbin, China
luxin5321@163.com

[2] School of Computer and Information Engineering,
Harbin University of Commerce, Harbin, China
jinxuesong@163.com

Abstract. The scalable extension to the H.264/AVC has been established as a Scalable Video Coding (SVC) standard, and JPEG2000 is a state of the act still image coding standard. SVC is based on the Discrete Cosine Transform (DCT) and JPEG2000 is based on Discrete Wavelet Transform (DWT). Despite the DWT has been successfully employed in still image coding, the latest video coding standard keeps on ultilising DCT and the relevant techniques as its coding tools. In this paper, we investigate SVC for intra frame coding and JPEG2000 for still image coding, on video sequences with different resolutions and features. We intend to gain deeper insight into the application scenarios of these two transform techniques. The experiments results demonstrate that at high bitrates, JPEG2000 outperforms SVC, and it is vice versa. We also note that the PSNR difference between SVC and JPEG2000 decreases with increasing the picture resolution.

Keywords: Scalable Video Coding(SVC), JPEG2000, DCT, DWT, Still Image Coding

1 Introduction

SVC is the scalable video coding extension based on H.264/AVC for supplying temporal, spatial and SNR scalability. It has been finalised as the video standard in July 2007 [1]. Compared with its predecessors, SVC achieves better compression performance in coding intra frame. In intra frame coding, SVC employs the spatial prediction within one frame, various block-size integer DCT transformation, and the CABAC for entropy coding [2]. Besides the encoding tools mentioned above, the unique inter layer intra prediction technique is employed in SVC, which exploits the lower layer information for encoding the enhancement layer signal [3].

JPEG2000 is the first international still image compression standard based on wavelet transformation [4]. The predecessor of JPEG2000 is JPEG, which is based on

* Corresponding author

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8×8 block DCT transform. Because of the defect of artificial blocking effect, DCT was discarded in the competition with DWT. The core encoding tools of JPEG2000 include DWT and entropy coding algorithm-Embedded Block Coding with Optimized Truncation (EBCOT). With these tools, JPEG2000 outperforms the JPEG in the term of compression performance by nearly 30% [5]. Besides the compression efficiency, JPEG2000 also provides several features e.g. intrinsic multi-resolution characteristic, which are useful in multimedia applications [6].

2 DCT in SVC Extension of H.264/AVC

DCT has been adopted in the still image compression standard JPEG and the video compression standards such as MPEG-1/2, H.261/263 et al [7]. Similar to the previous video coding standards [8], SVC keeps on utilising DCT as its transformation tool. In order to exploit the spatial correlation in the intra frame coding, H.264 performs intra frame prediction in spatial domain by referring to the neighbouring previously-coded blocks. Subsequently, the residual signal is transformed by using the integer DCT which has the similar properties with DCT.

The integer DCT used in SVC has several features compared with DCT [9]:

(1) Integer transformation (all the operations in the encoder and decoder can be completed in integer arithmetic, without any loss of decoding precision);

(2) Without any mismatch between the transformation in the encoder and the inverse transformation in the decoder;

(3) The core part of the transformation can be implemented using only additions and shifts operation;

(4) Scaling multiplication is removed from the transformation and is incorporated into the quantizer, thus the number of multiplications can be reduced.

A 4×4 forward DCT transformation equation can be written as follows [10]:

$$\mathbf{Y} = (\mathbf{C}_f \mathbf{X} \mathbf{C}_f^{\mathrm{T}}) \otimes \mathbf{E}_f = \left(\begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix} \begin{bmatrix} \mathbf{X} \end{bmatrix} \begin{bmatrix} 1 & 2 & 1 & 1 \\ 1 & 1 & -1 & -2 \\ 1 & -1 & -1 & 2 \\ 1 & -2 & 1 & -1 \end{bmatrix} \right) \otimes \begin{bmatrix} a^2 & ab/2 & a^2 & ab/2 \\ ab/2 & b^2/4 & ab/2 & b^2/4 \\ a^2 & ab/2 & a^2 & ab/2 \\ ab/2 & b^2/4 & ab/2 & b^2/4 \end{bmatrix} \quad (1)$$

3 DWT in JPEG2000

DWT has a better energy compaction capability and a multi-resolution representation, and it is able to get rid of the critical problem arisen in DCT-the blocking artificial. Therefore, DWT has been used in the latest still picture compression standard-JPEG2000. JPEG2000 not only achieves superior compression performance, but also supports various kinds of features, e.g. multi-resolution representation and Region Of Interest (ROI) coding et. al. With the purpose of reducing the correlation between pixels, DWT decomposes the spatial image into a number of frequency sunbands which represent the horizontal and vertical frequency components of the original image. Subsequently, the coefficients in each wavelet subband are quantised and

coded independently with different coding strategies. Compared with DCT which is employed in JPEG codec, DWT provides a better time-frequency localization of a given image. Therefore, wavelet-based image coding has the superior compression performance to its predecessors.

4 Experiment Descriptions

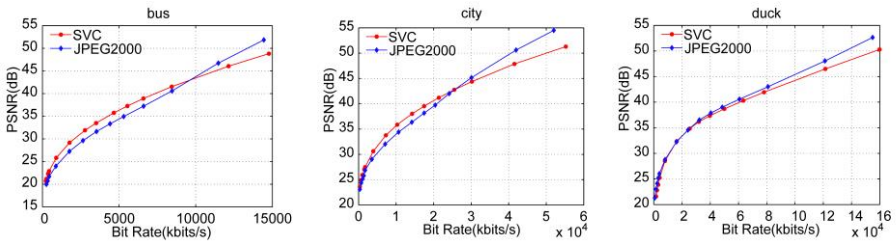
In order to compare the coding efficiency of SVC intra coding and JPEG2000, the Joint Scalable Video Model (JSVM) 9.18 is chosen as the evaluation model for SVC, and Kakadu 2.2.3 is selected for JPEG2000. The performance in terms of PSNR and bitrates are evaluated in our experiments. SVC uses intra-prediction and inter-layer prediction for intra coding. JEPG2000 sets the DWT decomposition levels to 3 for CIF sequence, 4 for 4CIF, 5 for 720P, 6 for 1080P, 7 for 2160P video sequences. The video pictures and resolutions used in the comparison are listed in Table 1.

Table 1. Video sequences used in the evaluation.

Resolution	Video sequence
CIF (352×288)	bus(150f)
4CIF (704×576)	city(300f)
720P (1280×720)	duck(90f)
1080P (1920×1080)	sky(90f)
2160P (3840×2160)	crowd(90f)

5 Experiment Results and Analysis

The performance is measured by PSNR of the Y-component according to various compressed bitrates. For the five sets of testing video sequences, the rate distortion curves are presented and analyzed.



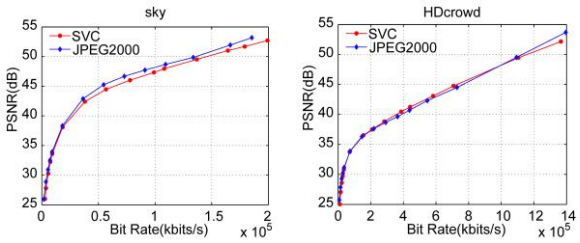


Fig. 1 Rate distortion curves for various video sequences

For the same resolution reconstructed picture, when the bitrates is high, JPEG2000 outperforms SVC in terms of Y-PSNR, but when the bitrates is low, it is vice versa. This result can be found for all the video sequences. It can be seen from the figures, there is an intersection between the RD curves of SVC and JPEG2000. When the bitrates is less than this intersection, SVC gains better performance than JPEG2000. However, when the bitrates surpasses the intersection, JPEG2000 predominates in PSNR. The position of the intersection is closely linked with the resolution and the picture content. For the lower resolution pictures, the value of intersection is relative small, and it is vice versa. We also note that the PSNR difference between SVC and JPEG2000 decreases with increasing the picture resolution. For the CIF video sequences, the difference in PSNR can achieve by up to 3dB. While for the HD video the difference is less than 1 dB. We have investigated the internal reasons caused such phenomenon. DWT is applied to the entire picture, and the picture energy is concentrated into the low frequency subband. At low bitrates, almost all of the high frequency energy, which represents the significant detail information, and parts of the low frequency are lost, which leads to the overall PSNR drops dramatically. However, since DCT in SVC is based on 4×4 block, the information lost is restricted to the local block. Therefore, AVC gains better performance than JPEG2000 at low bitrates. At high bitrates, the information lost is minor, considering DWT is a global transformation, but DCT is a local transformation. DCT cannot avoid the boundary blocking effect, which is introduced by block-based transformation. Based on the above analysis, we can conclude that JPEG2000 is fit for high bitrates picture compression; SVC is more suited for low bitrates transmission. Therefore, JPEG2000 is suitable for high resolution picture compression, which is one of the reasons why digital cinema video selects JPEG2000 instead of AVC as its video coding standard.

6 Conclusion

In this paper, the performance of the DCT-based SVC standard and the wavelet-based JPEG2000 were investigated thoroughly. We compared the coding efficiency using a variety of video pictures with resolutions from CIF to 2160P. The experimental results show that at lower bitrates, SVC can achieve better performance than JPEG2000. However when the bitrates is high, JPEG2000 outperforms SVC for all the pictures. We also noted that the PSNR difference between SVC and JPEG2000 decreases with increasing the picture resolution. Therefore, JPEG2000 is more suited for high definition picture compression.

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