International Journal of Hybrid Information Technology
Vol.8, No.3 (2015), pp.145-154
http://dx.doi.org/10.14257/ijhit.2015.8.3.14

# Video Compression Algorithm Based on All Phase Biorthogonal Transform and MPEG-2

Baochen Jiang[1,2], Chunxiao Zhang[1], Chengyou Wang[1,*] and Xiaoyan Wang[1]

*[1] School of Mechanical, Electrical and Information Engineering, Shandong University, Weihai 264209, P. R. China*
*[2] School of Electronic Information Engineering, Tianjin University, Tianjin 300072, P. R. China*
*jbc@sdu.edu.cn, sdwhzcx@126.com, wangchengyou@sdu.edu.cn, swwxy00800313@163.com*

***Abstract***

*As the international video coding standard, MPEG-2 has been widely used in today's digital video applications. However, its quantization operation is complex. To simplify this operation, we propose a new algorithm for the intra frame transform-coding in this paper, instead of the conventional algorithm that using discrete cosine transform (DCT). This new algorithm is based on the all phase biorthogonal transform (APBT) theory, which has three kinds of forms in accordance with different transform matrices, referred to as the all phase Walsh biorthogonal transform (APWBT), the all phase discrete cosine biorthogonal transform (APDCBT), and the all phase inverse discrete cosine biorthogonal transform (APIDCBT). Compared with the conventional DCT, APBT reduces the inter-pixel redundancy and the computational complexity using the uniform quantization for the intra frames transform-coding. Experimental results show that the peak signal to noise ratio (PSNR) of the proposed algorithm performs close to the DCT for the tested frames, and there is no difference in visual quality.*

***Keywords:*** *video compression, all phase biorthogonal transform (APBT), uniform quantization, MPEG-2*

## 1. Introduction

The MPEG-2 video coding standard [1] has been widely used in today's digital video applications [2], in which discrete cosine transform (DCT) is adopted because of its better coding performance. Since the complexity of quantization table, the amount of calculation of the existing standard is considerable.

To enhance the performance of MPEG-2, a lot of video compression schemes have been proposed. Reference [3] proposed a new block-based technique for image pre-filtering to overcome some limits of the MPEG-2 system at low bit rate. In [4], based on the operational rate-distortion framework, the unimportant data was largely reduced before encoding, and better performance was achieved. Segall and Katsaggelos [5] surveyed the fields of pre- and post-processing techniques for video compression, and applied them to the compression standard. Obviously, all these algorithms had achieved better compression quality, but the complexity of the algorithm was also increased.

In order to simplify the algorithm and obtain better coding performance, the "all phase digital filtering" theory was proposed [6]. On this basis, [7] proposed the concepts of all phase biorthogonal transform (APBT), which can be divided into the all phase Walsh biorthogonal transform (APWBT), the all phase discrete cosine biorthogonal transform (APDCBT) and the all phase inverse discrete cosine

ISSN: 1738-9968 IJHIT

biorthogonal transform (APIDCBT), and then proposed a new APBT-based still image compression algorithm. From the algorithm, it was concluded that APBT-based algorithm behaved better than the DCT-based algorithm at low bit rate and the amount of calculation decreases.

Therefore, we propose a new algorithm for the frame transform-coding, which introduces APBT theory instead of the conventional DCT. For the intra frame, APBT is applied to the original image data to obtain the 8×8 transform coefficients [8] followed by the quantization operation. In the proposed algorithm, uniform quantization is applied to the APBT coefficients. Therefore, the advantage of the proposed algorithm is that the quantization procedure is simple, and the computational complexity is reduced obviously. Experimental results also show that the peak signal to noise ratio (PSNR) of the proposed algorithm performs close to the DCT, and the visual quality has no obvious difference for these two algorithms.

The rest of the paper is organized as follows. Section 2 introduces the image coding algorithm based on APBT. Section 3 presents the coding scheme of MPEG-2. The proposed video compression scheme is introduced in Section 4. Experimental results and comparisons with the conventional DCT-based algorithm are presented in Section5. Conclusions and remarks on possible further work are given finally in Section 6.

## 2. Image Coding Algorithm Based on APBT

On the basis of all phase digital filtering [6], three kinds of all phase biorthogonal transforms based on the Walsh-Hadamard transform (WHT), DCT and inverse DCT (IDCT) were proposed and the matrices of APBT were deduced in [7]. For example, the matrix $V$ of all phase inverse discrete cosine biorthogonal transform (APIDCBT) is

$$V(m,n)=\begin{cases}\dfrac{1}{N}, & m=0,\ n=0,1,\cdots,N-1,\\ \dfrac{N-m+\sqrt{2}-1}{N^2}\cos\dfrac{m(2n+1)\pi}{2N}, & m=1,2,\cdots,N-1,\ n=0,1,\cdots,N-1.\end{cases} \quad (1)$$

The matrix $V$ of all phase discrete cosine biorthogonal transform (APDCBT) is

$$V(m,n)=\begin{cases}\dfrac{N-m}{N^2}, & m=0,1,\cdots,N-1, n=0,\\ \dfrac{1}{N^2}\left[(N-m)\cos\dfrac{mn\pi}{N}-\csc\dfrac{n\pi}{N}\sin\dfrac{mn\pi}{N}\right], & m=0,1,\cdots,N-1,\\ & n=1,2,\cdots,N-1.\end{cases} \quad (2)$$

Similar to the DCT matrix, they can be used in image compression transforming the image from spatial domain to frequency domain too.

Figure 1 shows the main procedures for encoding and decoding processes of JPEG-like image compression algorithm based on the APBT [7]. It illustrates the special case of a single-component image; for color image, all processes operate on each image component independently. Substantially the same as basic steps of the baseline JPEG image compression algorithm, there are only differences in the transform step and quantization process.

In the encoding process, the input image data are grouped into 8×8 blocks, and each block is transformed by the forward APBT into 64 APBT coefficients. One is the DC coefficient and the other 63 are the AC coefficients. Reference [7] indicated that the transform coefficients of APBT have the high-frequency attenuation characteristics, that is to say, the APBT coefficients have different frequency weight during the transform process. Therefore, the uniform quantization interval can be applied to the APBT coefficients. After quantization, the APBT coefficients are prepared by Zig-zag scan for entropy encoding. The quantized coefficients are then passed to an entropy encoding procedure which compresses the data further. Here, Huffman encoding is used and Huffman table must be provided to the encoder.

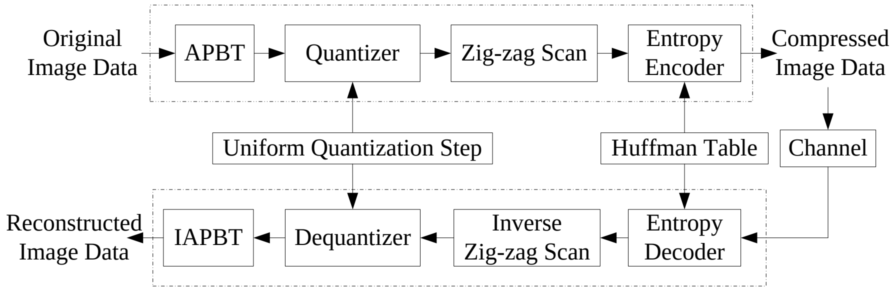



**Figure 1. Diagram of the APBT-JPEG Image Compression Algorithm**

In contrast to the encoder, each step of decoding processes performs essentially the inverse of its corresponding main procedure within the encoder. The entropy decoder decodes the Zig-zag sequence of quantized APBT coefficients. After dequantization the APBT coefficients are transformed to an 8×8 block of samples by the inverse APBT (IAPBT).

## 3. MPEG-2

The conventional MPEG-2 system uses DCT in the transform domain, with which the motion estimation (ME) and motion compensation (MC) are combined, as shown in Figure 2. In the system, there are usually three types of pictures defined, referred to as intra coded pictures (I-Pictures), predictive coded pictures (P-Pictures) and bidirectionally-predictive coded pictures (B-Pictures). Each picture type decides which prediction mode may be used to code the image data. Wherein, the intra frame mode is used for I pictures, and the inter frame mode is used for B pictures and P pictures of the video sequences.

For the intra frame, the original image data is directly operated by DCT, quantization, variable-length coder (VLC), inverse quantization and inverse DCT to reconstruct the current frame, which is a reference frame to the next frame. However, the inter frame is different from the intra frame, which needs to be operated by the motion estimation and motion compensation prediction. According to the reference frame, the current frame subtracts the prediction frame through motion vectors (MV) to form the residual image. Then the residual image is transformed with DCT, and the transform coefficients are quantized and coded by a VLC. Finally, combined with the prediction frame by motion estimation, the reconstructed image of the current frame is formed.

Opposite to the process of the coder, the decoder transforms the quantized DCT coefficients by a variable-length decoder (VLD), inverse quantization (IQ) and IDCT to reconstruct the residual image. Finally the residual image is added to the previously reconstructed motion estimation prediction to generate the reconstructed frame.

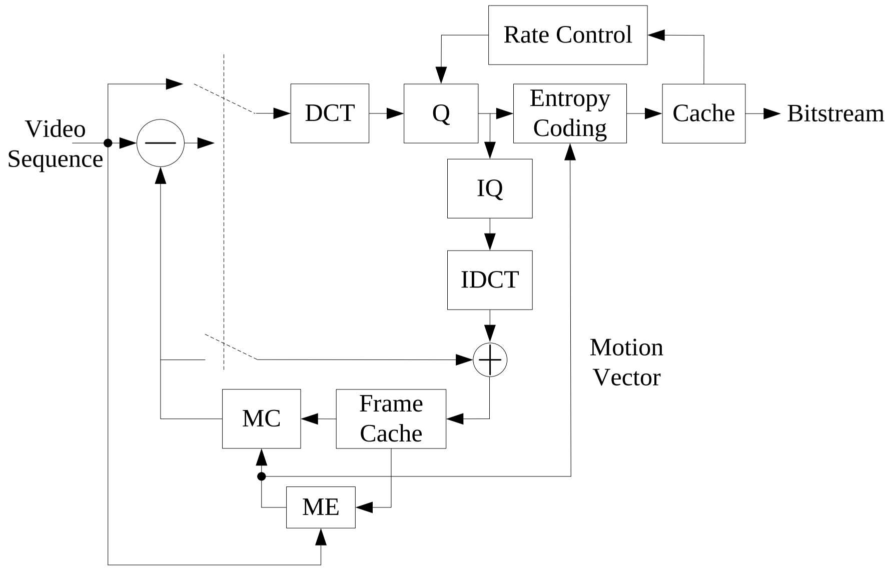
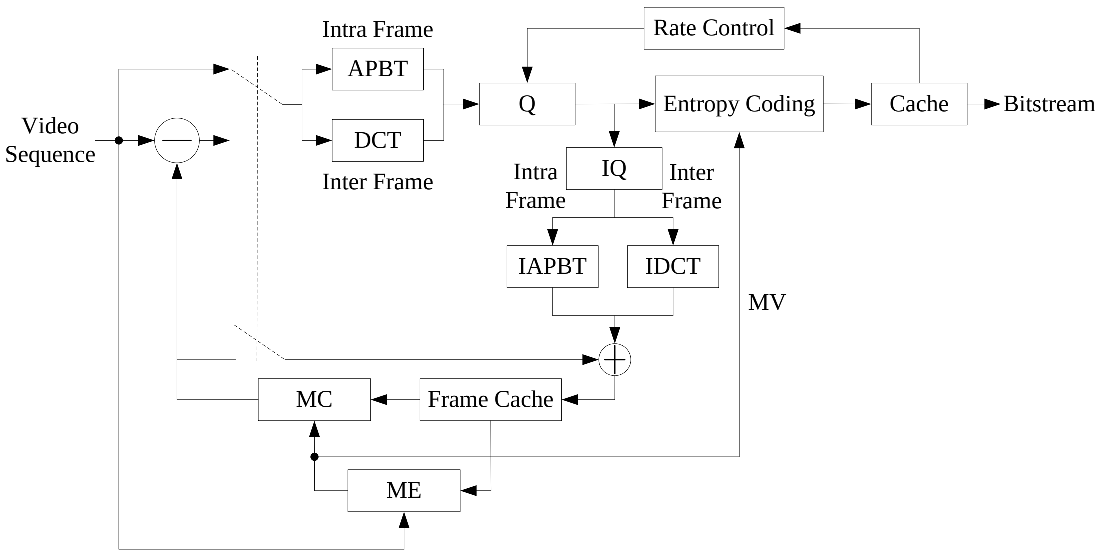



**Figure 2. MPEG-2 Encoding Framework**

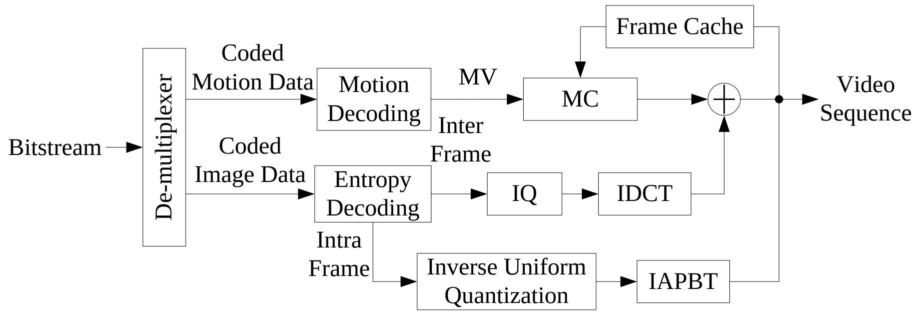
## 4. The Proposed Video Compression Scheme

As shown in Figure 3(a), the proposed video compression scheme is substantially similar to the conventional MPEG-2 compression scheme. In the encoding part, APBT is adopted for the intra frame considering the advantages of the APBT-JPEG algorithm. Then the APBT coefficients are quantized by the uniform quantization value defined by us.




**(a)**



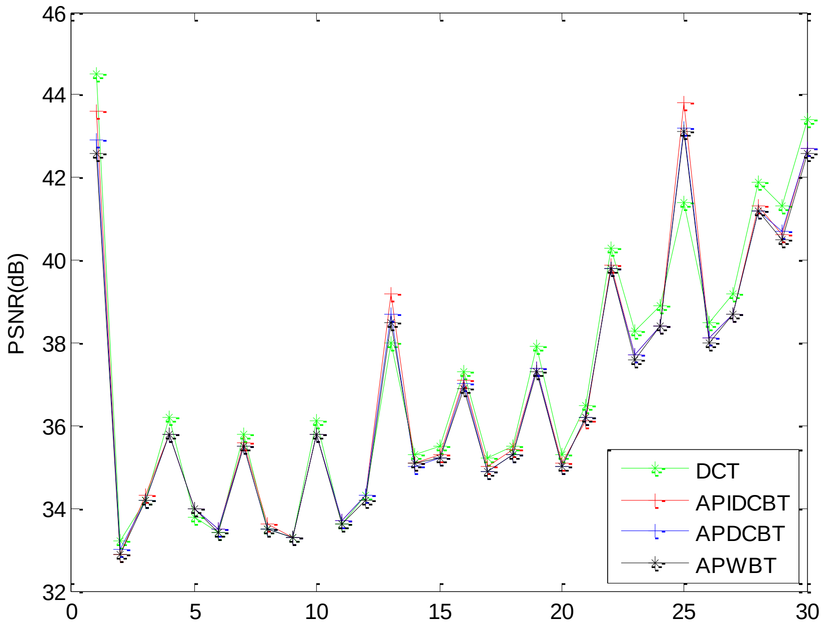

**(b)**

**Figure 3(a). Modified MPEG-2 Coder, (b) Modified MPEG-2 Decoder**

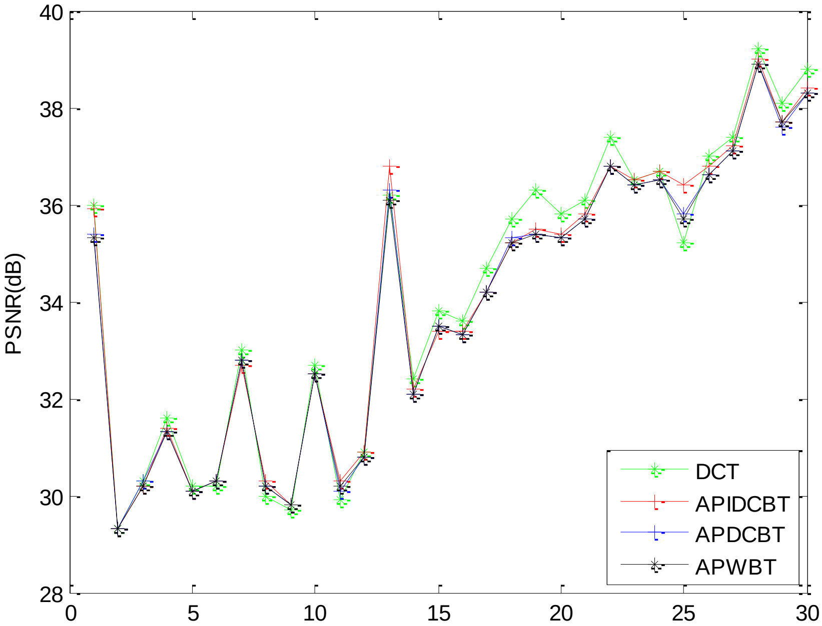
The similar situation appears in the decoder as shown in Figure 3(b). The coded bit stream is firstly operated by a VLD. The decoded data is inverse quantized and inverse transformed to reconstructed the residual image, which is decided by the type of the original image. Finally the residual image is added to the previously reconstructed motion-estimated prediction to generate the reconstructed frame.

## 5. Experimental Results

In order to test the performance of the proposed algorithm, simulation is conducted by applying the algorithm to two different video sequences: Football, Stefan. The format of the video sequences is CIF, of which the output bit rate is 3Mbps (25 frames/sec).The distance between I frame is 12, and B frames are between two P frames or I frame and a P frame. The quantization step of intra frame is 30. The rest parameters are set as default values. Figure 4 gives the PSNR of two video sequences in DCT and APBT algorithms.




**(a)**




**(b)**

**Figure 4. PSNR of 30 Frames for Different Sequences: (a) Football, (b) Stefan**

To evaluate the subjective quality of the reconstructed images, Figure 5 gives the reconstructed image of the frame 11 in the Football sequences using DCT and APIDCBT algorithms respectively. Figure 6 gives the reconstructed image of the frame 17 in the Stefan sequence using DCT and APDCBT algorithms.

From the PSNR shown in Figure 4, the sequence with intra frame using APBT algorithm performs close to that using DCT. From the reconstructed images by DCT and APBT algorithms, it can be concluded that the visual quality of the proposed algorithm has no difference with the DCT for different tested sequences. In particular, for I frame, quantization table adopts uniform value, so that the complexity of calculation reduces obviously.

**(a)**


(b)

**Figure 5. Reconstructed Images of Football Sequence (No. 11): (a) DCT, (b) APIDCBT**


(a)


(b)

**Figure 6. Reconstructed Images of Stefan Sequence (No. 17): (a) DCT, (b) APDCBT**

## 6. Conclusion

In this paper, a new algorithm for the intra frames transform-coding was proposed. Instead of the conventional DCT, APBT was applied for the frame coding. In the quantization procedure, the uniform quantization was also used in the algorithm. Compared with the conventional DCT, APBT reduces the inter-pixel redundancy and the computational complexity using the uniform quantization for the intra frame transform-coding. Experimental results show that the visual quality of the proposed algorithm has no difference with that using DCT for video sequences.

Although acceptable performance has been achieved, the PSNR of proposed algorithm is not higher than DCT. Furthermore, possible improvements can be gained by considering modifying the rate control in MPEG-2, making it more suitable for APBT algorithm. Additionally, considering that directional edges exist in images, the directional APBT [9] could be used in MPEG-2 to improve performance of compression. These issues are left for future research.

## Acknowledgements

This work was supported by the National Natural Science Foundation of China (Grant No. 61201371) and the promotive research fund for excellent young and middle-aged scientists of Shandong Province, China (Grant No. BS2013DX022). The authors would like to thank Fanfan Yang and Qiming Fu for their help and valuable suggestions. The authors also thank the anonymous reviewers and the editor for their valuable comments to improve the presentation of the paper.

## References

[1] ISO/IEC, "Information Technology—Generic Coding of Moving Pictures and Associated Audio Information", ISO/IEC 13818 Standard, (**1994**).

[2] J. D. Wu and Y. Y. Lin, "MPEG-2 to H.264/AVC intra frame transition coding", Proceedings of the 10th Pacific Conference on Multimedia, (**2009**), pp. 1018-1029.

[3] F. Gottardo, J. Mir, G. Parladori and G. L. Sicuranza, "Nonlinear preprocessing for MPEG-2 video sequences", Proceedings of the IEEE-EURASIP Workshop on Nonlinear Signal and Image Processing, (**1999**), pp. 43-47.

[4] P. V. Karunaratne, C. A. Segall and A. K. Katsaggelos, "A rate-distortion optimal video pre-processing algorithm", Proceedings of the IEEE International Conference on Image Processing, (**2001**), pp. 481-484.

[5] C. A. Segall and A. K. Katsaggelos, "Pre- and post-processing algorithms for compressed video enhancement", Conference Record of the 34th Asilomar Conference on Signals, Systems and Computers, (**2000**), pp. 1369-1373.

[6] Z. X. Hou and X. Yang, "The all phase DFT filter", Proceedings of the 10th IEEE Digital Signal Processing Workshop and the 2nd IEEE Signal Processing Education Workshop, (**2002**), pp. 221-226.

[7] Z. X. Hou, C. Y. Wang and A. P. Yang, "All phase biorthogonal transform and its application in JPEG-like image compression", Signal Processing: Image Communication, vol. 24, no. 10, (**2009**), pp. 791-802.

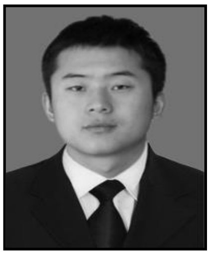
[8] X. G. Liu, K. Y. Yoo and S. W. Kim, "Low complexity intra prediction algorithm for MPEG-2 to H.264/AVC transcoder", IEEE Transactions on Consumer Electronics, vol. 56, no. 2, (**2010**), pp. 987-994.

[9] C. Y. Wang, "Directional APBT and its application in image coding", Proceedings of the 11th IEEE International Conference on Signal Processing, (**2012**), pp. 728-731.

## Authors

**Baochen Jiang** was born in Shandong province, China in 1962. He received his B.S. degree in radio electronics from Shandong University, China, in 1983 and his M.E. degree in communication and electronic systems from Tsinghua University, China, in 1990. Now he is a professor in the School of Mechanical, Electrical and Information Engineering, Shandong University, Weihai, China. His current research interests include signal and information processing, image and video processing, and smart grid technology.



**Chunxiao Zhang** was born was born in Shandong province, China in 1990. He received his B.S. degree in electronic information science and technology from Shandong University, Weihai, China, in 2012. Now he is pursuing his M.E. degree in circuits and systems in Shandong University, Weihai, China. His research interests concentrate on image and video processing.

**Chengyou Wang** was born in Shandong province, China in 1979. He received his B.E. degree in electronic information science and technology from Yantai University, China, in 2004 and his M.E. and Ph.D. degree in signal and information processing from Tianjin University, China, in 2007 and 2010 respectively. Now he is an associate professor in the School of Mechanical, Electrical and Information Engineering, Shandong University, Weihai, China. His current research interests include digital image and video processing, multidimensional signal and information processing, and smart grid technology.

**Xiaoyan Wang** was born in Shandong province, China in 1990. She received her B.S. degree in electronic information science and technology from Shandong University, Weihai, China, in 2012. Now she is pursuing her M.E. degree in circuits and systems in Shandong University, Weihai, China. Her research interests concentrate on image and video processing.