A Novel Research of Bit-plane Coding Scheme of FGS

Wang Feng Yu Li Guangxi Zhu Yejun He Zhenming Zhang

(Dept. of Electronics and Information Engineering, Huazhong University of Science & Technology,

Wuhan 430074, Hubei, P.R.China)

ABSTRACT

In the paper, authors propose a novel bit-plane coding scheme of the DCT coefficients residues which divides an 8×8 block of the DCT coefficients residues into a positive coefficients block and a negative coefficients block, and subsequently encodes the two coefficients blocks with bit-plane coding. The number of (RUN,EOP) symbols in each bit-plane remains the same in proposed and original schemes. As the number of non-zero coefficients does not change in the two schemes, to differentiate the positive and negative bit-plane coefficients, only one flag bit must be inserted between the positive bit-plane and the negative bit-plane. Therefore, at most six flag bits are used in a block. As a result, the total coding bits using the signs of all DCT coefficients residues are decreased, thus improving coding efficiency.

Key words: bit-plane coding, DCT coefficients residues, signs of the residues

I. INTRODUCTION

In the current fine granularity scalable (FGS) coding scheme, an encoder using the motion-compensated DCT transform coding compatible to other standards, such as MPEG-2, MPEG-4, and H.263, etc., generates a base-layer video as the lowest quality layer. Generally, the base-layer video can be transmitted in a well-controlled channel to minimize errors or packet-losses. In another word, the base layer can be encoded in a way to fit in the minimum channel bandwidth. The residues between original DCT coefficients and de-quantized DCT coefficients of the base layer form the enhancement bitstream with the bit-plane coding technology, which can provide an embedded bitstream and fine granularity scalability. Fine granularity means that the enhancement bitstream can be decoded at any length. The number of enhancement layers produced by the FGS coding scheme is not fixed, but based on the number of bit planes needed to represent the residues in binary format. Each of these enhancement layers contains increasingly more detailed video data to enhance the base layer. As a result, the quality of video greatly improves.

Initially, three types of techniques were proposed for FGS, namely bit-plane coding of the DCT residue[1], wavelet coding of image residue[2,3,4], and matching pursuit of image residue[5]. Later, trading off the two factors of coding complicacy and coding efficiency, Li et. all[1] proposed bit-plane coding of the DCT residue which was chosen for the working draft of MPEG-4 FGS Amendment.

One major feature of FGS coding scheme is, however, that the base layer and all the enhancement layers in a predicted frame are always predicted from the reconstructed version of the base layer in the reference frame. Therefore, the FGS coding scheme provides excellent error recovery from occasional data losses or errors in enhancement layers. By predicting all enhancement layers from the base layer, losses or corruptions of one or more enhancement layers during transmission have no effect on the frames followed. However, since the prediction is always based on the lowest quality base layer, the coding efficiency of the FGS scheme is not as good as, and sometimes is even much worse than, traditional SNR scalability schemes, such as in [6]. Li's experiment indicated that the coding efficiency of FGS was 2-dB~3-dB lower than non-scalable coding scheme at the same rate. In order to improve coding efficiency, Wu et. all[7] proffered progressive fine granular scalable(PFGS) coding scheme which, compared with the FGS scheme in MPEG-4, is a highly efficient scalable video-coding framework. To improve the coding efficiency, the proposed PFGS framework tries to use some higher quality references, to make the motion predictions more accurate. In this way, the PFGS framework provides about 1 dB coding efficiency gain. However 1~2 dB differences exist between PFGS and non-scalable coding scheme with coding efficiency.

In this paper, a new bit-plane coding scheme of the DCT coefficients residues is proposed. The scheme improves the coding method of the sign of DCT coefficients residues, thus increases the coding efficiency for FGS and PFGS. The rest of this paper is arranged as follows. Section II simply introduces the basic idea to build the FGS bit-plane coding. Section III shows the results of experiments that compare enhancement layer's total bits with the bits used coding the signs of DCT coefficients residues in FGS bit-plane coding. An improved technique coding the signs of DCT coefficients residues is proposed in Section IV. Experimental results presented in Section V demonstrate the advantages of the proposed new technique. Finally, Section VI draws a conclusion to this paper.

II. ENHANCEMENT LAYERS BIT-PLANE CODING IN FGS

FGS bass layer coding, like MPEG-4 non-scalable coding, is made up of motion-estimating, motion-compensating, DCT transform coding, quantizing, and VLC. With the enhancement layer coding, however, the residues between the original DCT coefficients and the de-quantized DCT coefficients of the base layer form the enhancement bitstream by using the bit-plane coding technology. The following example

$$\begin{bmatrix} 11 & -5 & 3 & -1 & \bullet & 0 & 0 & \bullet \\ 6 & -4 & 2 & 0 & 0 & 0 & 0 & \bullet \\ -2 & -2 & 1 & 0 & 0 & 0 & 0 & \bullet \\ 1 & 2 & 0 & 0 & 0 & 0 & 0 & \bullet \\ -1 & 0 & 0 & 0 & 0 & \bullet & 0 & \bullet \\ 0 & 0 & 0 & 0 & \bullet & 0 & 0 & 0 \\ 0 & 0 & \bullet & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \bullet & 0 & 0 & 0 & 0 & \bullet \end{bmatrix}$$

Fig.1 DCT residues coefficients

illustrates the procedure of bit-plane coding. First the gained 8×8 residues block is shown in Fig.1. Then the absolute values and the sign bits after zigzag ordering are given as follows:

11,5,6,2,4,3,1,2,2,1,1,2,1,0,……,0,0 (absolute)
0,1,0,1,1,0,1,0,1,0,1,0,0,x, ……, x,x (sign bits)

The maximum value in this block is found to be 11 and the number of bits representing 11 in the binary format (1011) is 4. So 4 bit-planes are considered. Writing every value in the binary format, the 4 bit-planes are formed as follows:

1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,……,0,0 (MSB)
0,1,1,0,1,0,0,0,0,0,0,0,0,0,0,0,……,0,0 (MSB-1)
1,0,1,1,0,1,0,1,1,0,0,1,0,0,0,0,……,0,0 (MSB-2)
1,1,0,0,0,1,1,0,0,1,1,0,1,0,0,0,……,0,0 (LSB)

(RUN, EOP) symbols can be obtained through run-coding. Wu at. all[7] presented 2D and 3D coding schemes for run-coding. In this paper, 2D coding is adopted. RUN is the number of consecutive zeros before a 1, and EOP is the end flag of bit-plane indicating whether there are any ones left on this bit-plane, i.e., end-of-plane (EOP). If a bit-plane contains all zeros, a special symbol ALL-ZERO is formed to represent it. Converting the four bit-planes into (RUN, EOP) symbols, we have

(0,1) (MSB)
(1,0),(0,0),(1,1) (MSB-1)
(0,0),(1,0),(0,0),(1,0),(1,0),(0,0),(2,1) (MSB-2)
(0,0),(0,0),(3,0),(0,0),(2,0),(0,0),(1,0),(0,0),(0,1) (LSB)

In this way, 20 (RUN, EOP) symbols are formed in this example. Finally the (RUN, EOP) symbols can be coded into binary sequence through either VLC or direct binary-coding. With VLC, these symbols are encoded by using variable-length code together with the sign bits, as is shown at the bottom of the segment. Each sign bit is put into the bitstream only once and right after the VLC code that contains the MSB of the nonzero absolute value associated with the sign bit. For example, no sign bit follows the first and second VLC codes of the MSB-2 plane because the sign bit has been coded after the VLC code in the MSB-1 plane and the MSB-2 plane.

VLC(0,1),0 (MSB)
VLC(1,0),1,VLC(0,0),0,VLC(1,1),1 (MSB-1)
VLC(0,0),VLC(1,0),VLC(0,0),1,VLC(1,0),0,
VLC(1,0),0,VLC(0,0),1,VLC(2,1),0 (MSB-2)
VLC(0,0),VLC(0,0),VLC(3,1),VLC(0,0),1,
VLC(2,0),0,VLC(0,0),1,VLC(1,1),0 (LSB)

FGS has some characters because of the use of bit-plane coding technique: First, the enhancement layer bitstream can adapt to the range of Internet bandwidth change. Second, the enhancement layer bitstream can be truncated in any positionin in each frame. Finally, decoder reconstructs video quality in direct proportion to bits of the enhancement layer received.

III. EXPERIMENT RESULTS OF THE ENHANCEMENT LAYER'S TOTALBITS AND THE SIGNS BITS IN FGS

We can observe from the procedure of bit-plane VLC in section II that the number of bits for the signs inserted is the same as the number of signs of non-zero DCT coefficients residue. The bigger the number of non-zero coefficients in a 8×8 residues block, the more sign bits are needed to be inserted. By using TML9.0 software, we widely tested video sequences, and coded them into IPPP, at the frame rate of 30f/s. One predicted reference frame is used for P-Frame. Also used is 1/4 pels motion-compensating. The I-Frame and the P-Frame quantized sizes are up to 20 and 24 respectively. The

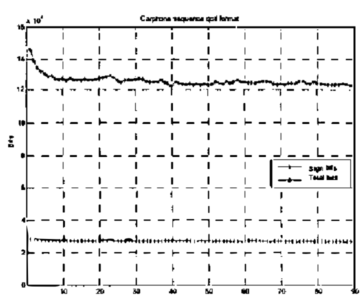

Fig.2 Carphone enhancement layer bits and the signs bits

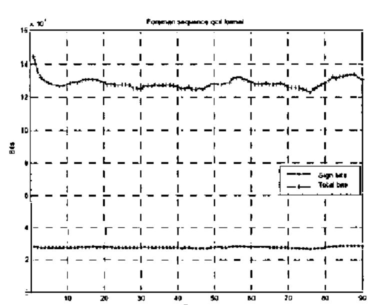

Fig.3 Foreman enhancement layer bits and the signs bits

experiment results of several typical sequence consider only the foregoing 90 frames, Fig.2 and Fig.3 illustrate the enhancement layer total bits and sign bits for Carphone and Foreman. In the two figures, *Sign bits* is the number of signs of residues value used for coding, *Total bits* is the total number of enhancement layer bits. Studying Fig.2 and Fig.3, we find that the sign bits occupy about one-fifth of the enhancement layer total bits in Carphone and Forema. It is obvious that sign bits occupy a big proportion in the enhancement layer total bits. If we could adopt effective technique coding the signs of DCT coefficients residue so as to decrease sign bits, coding efficiency would be well improved.

IV. NOVEL BIT-PLANE CODING SCHEME

A novel bit-plane coding scheme is proposed in this paper. The following example illustrates the procedure of the coding scheme: An original 8×8 block of the DCT coefficients residues is divided into a positive coefficients block and a negative coefficients block as is shown in Fig.4. The values of the original negative coefficients positioned are set to zeros in positive block. Similarly, the values of original positive coefficients positioned are set to zeros in negative block. Then the positive and negative coefficients blocks are zigzag scanned respectively, obtaining a positive coefficients sequence and a negative coefficients sequence as follows:

11,0,6,0,0,3,0,2,0,1,0,2,1,0,......,0,0 (positive)
0,5,0,2,4,0,1,0,2,0,1,0,0,0,......,0,0 (negative)

Writing every value in the binary format, the 4 bit-planes are formed as follows:

(+)1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,......,0,0
(-)0,0,0,0,0,0,0,0,0,0,0,0,0,0, ...,0,0 (MSB)
(+)0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,......,0,0
(-)0,1,0,0,1,0,0,0,0,0,0,0,0,0, ...,0,0 (MSB-1)
(+)1,0,1,0,0,1,0,1,0,0,0,1,0,0,0,0,......,0,0
(-)0,0,0,1,0,0,0,0,1,0,0,0,0, ...,0,0 (MSB-2)
(+)1,0,0,0,0,1,0,0,0,1,0,0,1,0,0,0,......,0,0
(-)0,1,0,0,0,0,1,0,0,0,0,0,1, ...,0,0 (LSB)

Converting the four bit-planes into (RUN, EOP) symbols and VLC, we have

VLC(0,0),flag0,Allzero (MSB)
VLC(1,0),flag1,VLC(1,0),VLC(2,1) (MSB-1)
VLC(0,0),VLC(1,0),VLC(2,0),VLC(1,0),VLC(3,0), flag1,VLC(3,1),VLC(4,1) (MSB-2)
VLC(0,0),VLC(4,0),VLC(3,0),VLC(2,0),flag1,VLC(1,0),VLC(4,0),VLC(5,1) (LSB)

Only one flag bit must be inserted between a positive coefficients bitstream and a negative one in a bit-plane. So the four bit-planes need 4 flag bits. The flag 0 denotes that there is no negative coefficients bitstream after a positive one in a bit-plane in a block. The flag 1 denotes a positive coefficients bitstream following a negative one. The flags are differentiating flags between a positive and a negative coefficients bitstream as well as judgment flags deciding if there is a negative coefficients bitstream after a positive one.

In the decoding end, the decoder receives the bitstream, decodes, and de-zigzag-scans the positive and negative DCT coefficients blocks are recovered, subsequently the reconstructed DCT coefficients block is achieved by the components value of the positive coefficients block subtracting the corresponding components value of the negative coefficients block in Fig.4.

$$\begin{vmatrix} 11 & -5 & 3 & -1 & 0 & 0 & 0 & 0 \\ 6 & -4 & 2 & 0 & 0 & 0 & 0 & 0 \\ -2 & -2 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{vmatrix} \underset{decoder}{\overset{encoder}{\rightleftharpoons}} \begin{bmatrix} 11 & 0 & 3 & 0 & 0 & 0 & 0 & 0 \\ 6 & 0 & 2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} - \begin{bmatrix} 0 & 5 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 & 0 & 0 & 0 \\ 2 & 2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Fig.4 A original 8×8 block of the DCT coefficients residues is divided into a positive coefficients block and a negative coefficients block

V. EXPERIMENT RESULTS OF NOVEL BIT-PLANE CODING SCHEME

In the experiments of section III, the tested average values of sign bits inserted in each 8×8 block are 47 bits and 45 bits in Foreman and Carphone respectively. MPEG-4 standard prescribes six bit-planes at most in FGS bit-plane coding. According to this proposed bit-plane coding scheme, at most six flag bits are used for each 8×8 block. Therefore 41 bits and 39 bits are subtracted in each block and 24948 bits and 23166 bits are cut down in each frame(qcif format, 596 blocks) in the Foreman and Carphone sequences respectively. If the direct binary-coding scheme mentioned in section II is used for coding (RUN,EOP) symbols, as the number of (RUN,EOP) symbols does not change in the proposed and original schemes, the above numbers are also the net numbers of bits decreased in the proposed new scheme.

In the proposed scheme, the probability distribution of (RUN,EOP) symbols will be changed because an original 8×8 block is divided into a positive coefficients block and a negative coefficients block. If the original VLC tables are adopted for coding (RUN,EOP) symbols, instead of decreasing, the bits of enhancement layer increase. Hence the original VLC tables must be modified in order to reduce the bits of enhancement layer. The original VLC tables are made up of four sub-tables: VLC-0 table, VLC-1table, VLC-2 table, and VLC-3 table. Different VLC tables are used for different layer bit-planes coding as shown in Table 2. After studing the rule of probability distribution of (RUN,EOP) symbols, We modified the VLC tables. The usage of the new VLC tables is shown in Table 3.

Table 2 VLC tables used for original bit-plane coding scheme

VLC Tables	Bit-planes
VLC-0	MSB
VLC-1	MSB-1
VLC-2	MSB-2 & MSB-3
VLC-3	other

Table 3 VLC tables used for proposed bit-plane coding scheme

VLC Tables	Bit-planes
VLC-0	MSB
VLC-1	MSB-1
VLC-2	MSB-2
VLC-3	MSB-3 & other

Fig.5 and Fig.6 compare the enhancement layer bits the proposed scheme and the original scheme. In the two the figuers, *Ori bits* is the bits of enhancement layer in the original coding scheme and *New bits* is the bits of enhancement layer in the proposed coding scheme.

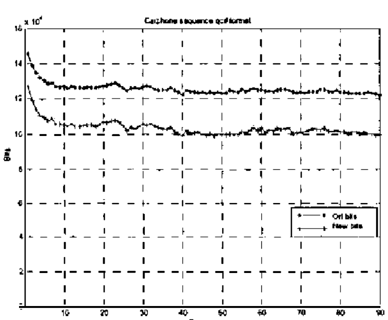

Fig.6 Carphone enhancement layer bits in proposed and original schemes

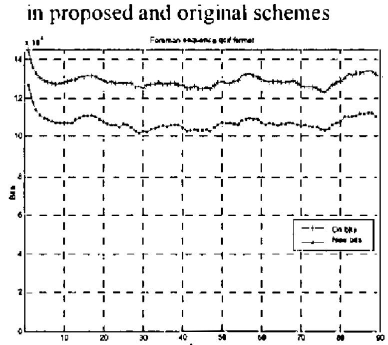

Fig.5 Foreman enhancement layer bits in proposed and original schemes

VI. CONCLUSION

From Fig.5 and Fig.6, we can see that, compared with that in original scheme, each frame's bits of enhancement layer in proposed scheme decrease one-sixth of original total bits. This novel bit-plane coding scheme improves coding efficiency. Because each bit-plane is divided into positive coefficients and negative coefficients in each block, however, if the bitstream is truncated in the center point between the positive coefficients bitstream and the negative coefficients bitstream, only the positive coefficients bitstream is decoded by the decoder. The part after the positive coefficients bitstream is set to zero.

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