Lossless Inter-frame Video Coding using Extended JPEG2000

Shoko IMAIZUMI, Ayuko TAKAGI, and Hitoshi KIYA
Department of Electrical Engineering, Tokyo Metropolitan University,
1-1 Minamiosawa, Hachioji-shi, Tokyo 192-0397, Japan
Tel.: +81-426-77-1111 ext. 4351, Fax.: +81-426-77-2756
E-mail: {[shoko,ayuko]@isys.,kiya@}eei.metro-u.ac.jp

Abstract: This paper describes an effective technique for lossless inter-frame video coding sequences based on a JPEG2000 CODEC. This technique has diminished the compression rate for lossless video coding. In this proposed method, firstly a predicted image for an input image is generated by motion estimation(ME), and then a difference image between the input image and the predicted image is calculated, and finally the difference image becomes an input image to a JPEG2000 encoder for lossless coding. Simulation results show the effectiveness of this method.

1. Introduction

MotionJPEG2000(MJ2)[2] is a new standard for either lossless or lossy video coding. In MJ2, intra-frame coding is used for each frame and the amount of data after coding is quite large. In video coding, however, the amount of data can be reduced by eliminating temporal redundancy using inter-frame coding. Inter-frame coding is based on motion estimation(ME)[1], and is used in MPEG[3] that is a lossy coding standard for video sequences. While, for lossless video coding, approaches using ME have been studied in [4], [5], [6].

This paper proposes a method of lossless video coding using ME with JPEG2000(JP2)[7]. The process is as follows,

(1) Generating a predicted image for a current image using ME
(2) Calculating a difference image between the current image and the predicted image
(3) Inputting the difference image to a JPEG2000 encoder

As MJ2, JP2 is a standard for either lossless or lossy image coding. JP2 adopts discrete wavelet transform(DWT), and it is well known that DWT gives better quality to image incomparision to that by discrete cosine transform(DCT) which is used in JPEG and MPEG. Several types of scalability have been defined in JP2, such as SNR, resolution, and position scalability. The proposed method does not modify the JP2 CODEC, and thus these scalabilities are retained.

This proposed method adds following two more technique to ME.

- Interpolating pixels to improve the accuracy of estimated motion vectors(MVs)
- Processing ME by 8 × 8 block to find the detailed motions

In this paper, we evaluate how ME contributes to compression rate for lossless video coding.

2. Review

In this section, we review three systems used in the proposed method. The systems are fundamental to the proposed method.

2.1 Bitstream hierarchy in MPEG[8]

MPEG is lossy inter-frame video coding system. A MPEG sequence is the top layer of the coding hierarchy and consists of a header and some numbers of groups-of-pictures(GOPs). A GOP is a random access point. It is the smallest coding unit that can be independently decoded within a sequence, and consists of a header and some number of pictures. There is temporal redundancy between frames. To eliminate the redundancy, MPEG takes four picture types : I-picture(intra coded pictures), which are coded without reference to any other pictures; P-pictures(predictive coded pictures), which are coded using ME from a previous I or P-pictures; B-pictures(bidirectionally), which are code using ME from a previous and a future I or P-picture, and D pictures, which are intended only for a fast forward search mode. A typical coding scheme contains a mix of I, P, and B-pictutres. Figure 1 illustrates a number of pictures in display order. The arrows show the dependency relationship of the predictive and bidirectionally predictive coded pictures.

2.2 Block-matching Motion Estimation

Let us divide a current frame into 16 × 16 blocks, called macro blocks. Figure2 shows the process of block matching. The process of block matching is to find the macro block in search window of previous frame which is most similar to the current frame. The accuracy of ME depends on the matching criteria. One of the most popular criteria is SAD, given by

$$\mathrm{SAD}(k,l) = \sum_{i=1}^{16}\sum_{j=1}^{16} |P_t(i,j) - P_{t-1}(i+k, j+l)| \quad (1)$$

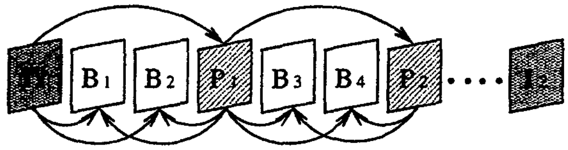


Figure 1. Dependency relationship between I, B, and P-pictures

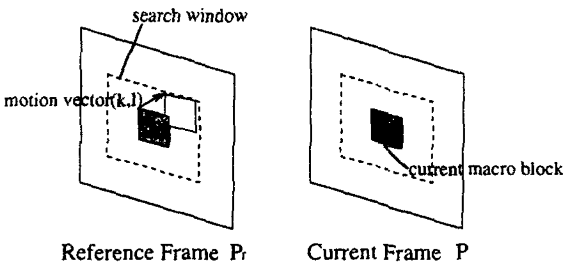


Figure 2. Block-matching motion estimation

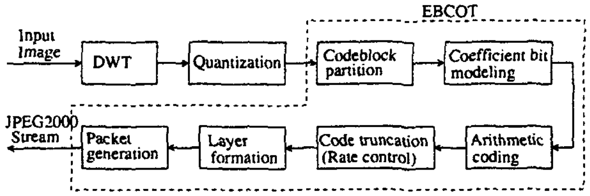


Figure 3. *JPEG2000 encoder*

where (k, l) is the location in search window. $P_t(i, j)$ is a pixel at (i, j) in the current frame and $P_{t-1}(i, j)$ is a pixel in the previous frame. When the value $SAD(k, l)$ is minimum, (k, l) stands for the MV of the macro block.

2.3 JPEG2000 coding procedure

Figure 3 is a block diagram of a JPEG2000 encoder. An input image is decomposed into sub-bands by a discrete wavelet transform and the wavelet coefficients of each sub-band are quantized. After quantization, each sub-band is divided into rectangular blocks, called code-blocks, which form the independent input to coefficient bit modeling and arithmetic coding. A separate arithmetic code is generated for each code-block. The arithmetic code for each code block has a lot of truncation points so that it can be truncated into a various lengths. One truncation point is allocated for each code blocks subject to a target bit rate. After that, the layer structure is formed for scalability of a bit stream.

3. Proposed Method

This section shows our proposed method of lossless coding for video sequences with less data. In this method, we apply ME to lossless coding for video sequences using JP2. Figure 4 shows the coding system of the proposed method.

ME is performed for an input current image(Figure 5(a)) with a reference image(Figure 5(b)) and then a predicted image(Figure 5(c)) and motion vectors are calculated. In this method, we calculate the difference(Figure 5(d)) between the predicted image and the original input image and then it is coded in lossless. Motion vectors are coded using VLC(Various Length Coding). These two information are sent to the decoder. They are decoded in the decoder to generate the complete restored images.

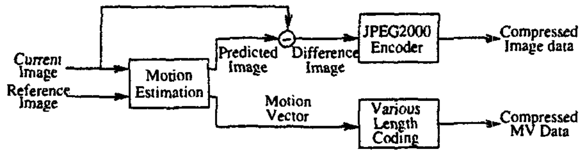


Figure 4. Coding system of the proposed method

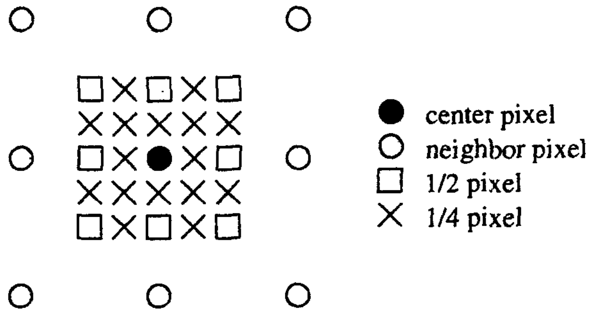


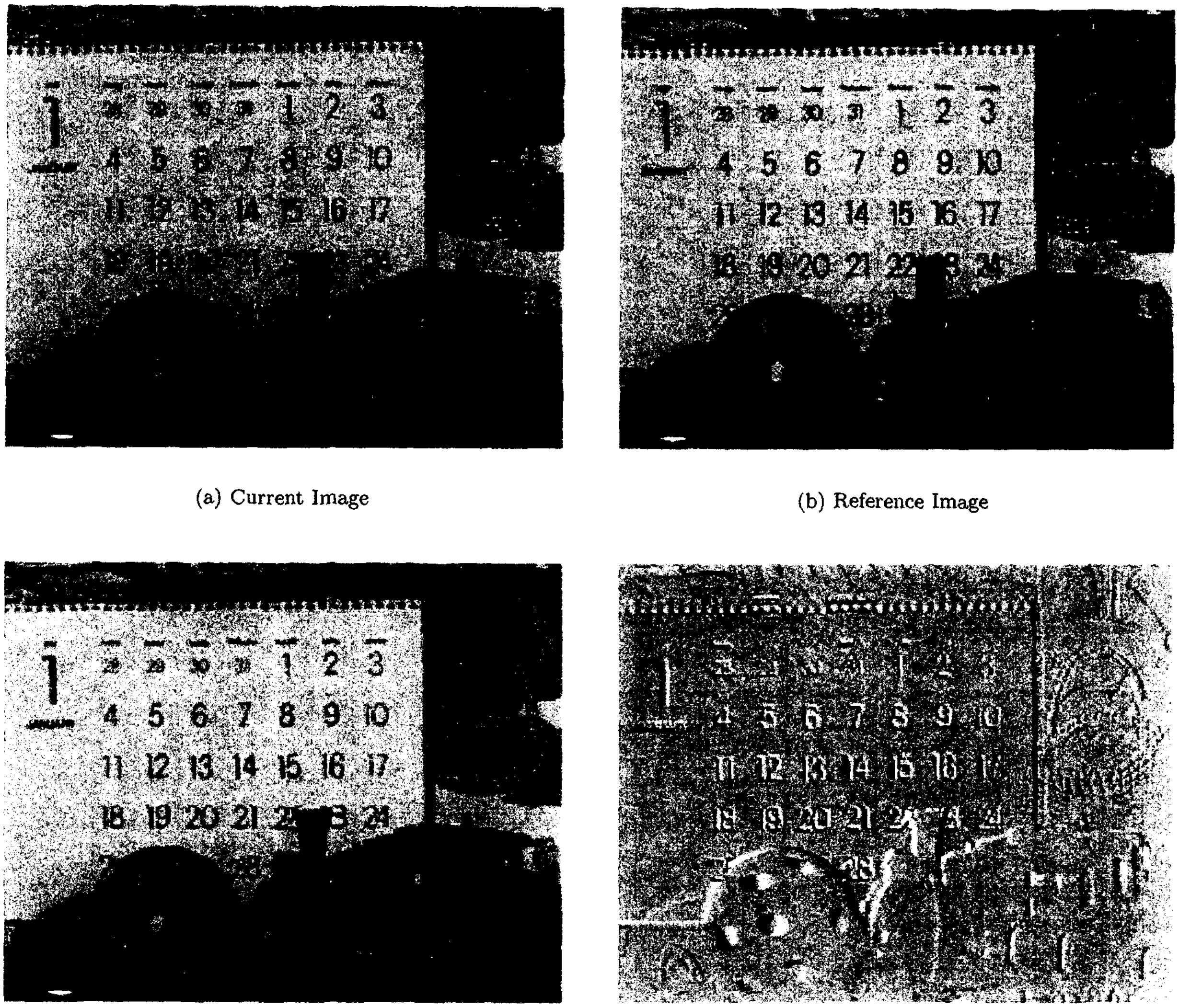
Figure 6. Generation of half and quarter pixels by linear interpolation

There are some conditions to meet on selecting the lossless CODEC. The codec must deal with both positive and negative numbers for lossless coding of inter-frame differences. Also the bit width will exceed over 8 bits. Moreover each pixel data must be integer for lossless coding even in using half or quarter pixel value. To solve the problems and encode video sequences in lossless, we use the JP2 codec. It can deal with both positive and negative numbers and bitwidths upto 32 bits.

By increacing the accuracy of ME, the data of inter-frame difference can be reduced with higher compression. To make ME more accurate, we use the following two methods.

(a) **ME using quarter pixels** Half pixels have been already used for ME in MPEG codec. To improve the accuracy of estimated motion vector, quarter pixels are introduced. The concept of a half pixel and quarter pixel is shown in Figure 6. A half pixel is generated by interpolating the center pixel and the neighbor pixels. Then a quarter pixel is generated by interpolating the center pixel and the half pixels. For lossless coding, the value of an interpolated pixel is rounded to be an integer. Consequently, motion vectors are obtained more accurately, and the SAD becomes small. As a result, the inter-frame difference is high compressed.

(b) **ME with 8×8 block size** ME is generally performed by macro blocks. To find the detailed motions, ME is performed with 8×8 block size. By using 8×8 block size, it enable to search minuter motion with 4times as many motion vectors. Thus the SAD of each block becomes small and the inter-frame differnce image is coded with higher compression.



(a) Current Image (b) Reference Image

(c) Predicted mage (d) Difference Image

Figure 5. Example of images used in Figure 4

4. Simulation Results

In the simulation, we used *two kinds of video* sequences having different sizes, "Mobile and calender"(size 720×576) and "Tempete"(size 720×576). The video data is 8bit/pixel with no signs. We used ME to calculate the motion vectors and generate the interframe difference images. Motion vectors are coded using VLC and the difference image is coded with JP2 VM8.6[?] losslessly. In ME, reference frame is the frame just before the current frame. For each implementation, ME is performed by macro blocks(the size of search window $\omega = 8$) and 8×8 pixels blocks($\omega = 4$) with whole, half and quarter pixels. We compare the result with the conventional method using intra frame coding with JP2 or JPEG-LS[10](dealing with only positive numbers).

Table 1, 2 show the comparisons of filesize and bitrate of encoded images. As the results show, the data can be reduced by applying ME to lossless video coding. It makes motion vectors more accurate to use half and quarter pixels for ME and blocks having less SAD are selected. Though the data of motion vectors is more, the data of predicted images is less enough and the total filesize is reduced compared with the result using whole pixel for ME. When ME is performed with 8 × 8 pixels block size, the image data is about 2K bytes less. However the data size for motion vectors is 4 times as much as it obtained by ME with macro blocks, and the total filesize is increased. The simulations show the same result for both "Mobile and calender" and "Tempete".

5. Conclusion

We have described the method of lossless video coding using ME with JPEG2000. It is possible to make ME apply to lossless video coding with the combination of the exsiting algorithms. The simulation have shown that the proposed method is effective to reduce the com-

Table 1. Filesize and Bitrate after encoding : Mobile and calender

	pixel	blocksize used in ME	filesize [$kBytes$] difference	MV	total	bitrate [bpp] total
proposed method	whole	16 × 16	233.998	0.955	234.953	4.532
		8 × 8	231.783	3.947	235.730	4.547
	half	16 × 16	221.812	1.574	223.386	4.309
		8 × 8	218.977	6.580	225.557	4.351
	quarter	16 × 16	220.841	1.671	222.512	4.292
		8 × 8	217.556	6.999	224.555	4.332
conventional method	JP2	-	-	-	254.522	4.910
	JPEG-LS	-	-	-	243.620	4.699

Table 2. Filesize and Bitrate after encoding : Tempete

	pixel	blocksize used in ME	filesize [$kBytes$] difference	MV	total	bitrate [bpp] total
proposed method	whole	16 × 16	66.240	0.132	66.372	5.238
		8 × 8	66.027	0.607	66.634	5.258
	half	16 × 16	64.469	0.275	64.744	5.109
		8 × 8	63.974	1.174	65.148	5.141
	quarter	16 × 16	64.019	0.272	64.291	5.073
		8 × 8	63.438	1.194	64.632	5.100
conventional method	JP2	-	-	-	71.328	5.629
	JPEG-LS	-	-	-	65.020	5.131

pression rate for lossless video coding. The method is effective independently to image size.

References

[1] B.Furht, J.grttnberg and R.Westwater, "Motion Estimation Algorithms for Video Compression", Kluwer Academic Publishers, 1997.

[2] MotionJPEG2000 Committee Draft 1.0, ISO/IEC JTC1/SC29/WG1 N1987, Dec.2000.

[3] Information Technology-Generic Coding of Audio Visual Objects-Part2:Visual, ISO/IEC 14496-2:1999/And.1:2000.

[4] N.Ono and Y.Yashima, "An Efficiency Evaluation of Lossless Video Coding Using Motion Compensation," Technical Report IE95-18, IEICE, pp.21–27, May 1995.(in Japanese)

[5] G.C.K.Abhayaratne and D.M.Monro, "Embedded to lossless codimg of motion compensated prediction residuals in lossless video coding," Visual Communications and Image Processing 2001, Proc. SPIE vol.4310, pp.175–185, San Jose, CA, 21-26 January 2001.

[6] T.Nakachi, T.Sawabe, T.Fujii and T.Fujii, "A Study on Multi-resolution Lossless Video Coding," The 13th Digital Signal Processing Symposium of IEICE, B5-5, pp.439-444, Nov.2001.(in Japanese)

[7] ISO/IEC 15444-3, JPEG2000 Part1 final draft international standard, Aug.2000.

[8] ISO/IEC 15444-3, Information technology-Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s, 1993.

[9] ISO/IEC JTC 1/SC29/WG1 FCD 14495:Lossless and near-lossless coding of continuous tone still images(JPEG-LS), Jul.1997.

[10] ISO/IEC JTC 1/SC 29/WG 1 WG1 N1894: JPEG2000 Verification Model 8.6, 2000.