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A Method of Inserting Binary Data into MPEG Video in the Compressed Domain

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SUMMARY In many applications of digital video database systems such as digital library, video data is often compressed with MPEG video algorithms. It will be an important technique to insert the additional information data like indexes and contents effectively into video database which is compressed with MPEG, because we can always deal with the additional information with video data itself easily. We propose a method for inserting optional binary data such as index information of digital library into MPEG-1 and -2 bitstreams. The binary data inserted MPEG video bitstreams using our proposed scheme are also according to the specification of the MPEG video frame structure. The proposed method allows us to extract the inserted binary data perfectly though MPEG-1 and -2 video are lossy algorithms. And the quality of decoded images after extracting added information is almost the same as that of ordinary MPEG bitstreams. Furthermore, traditional standard MPEG-1 and -2 video decoder which can not extract inserted binary data can also decode images from the binary data inserted MPEG video bitstreams without obvious image degradation. There are some different points between the proposed insertion technique of the binary data and the watermarking technique. The technique of watermarking prepares to deal with alter watermarking by others. And the technique of watermarking is required for the identification of the signature and the perfect extraction of the inserted image signature is not required in the lossy MPEG video environment. On the other hand, we have to extract all of the inserted binary information data correctly with the insertion technique of the binary information. Simulations using MPEG video sequences with inserted binary data are presented to quantify some performance factors concerned. We have not heard about inserting data method which purpose is such as index and content information insertion.
key words: *inserting binary data, MPEG, digital library, watermarking*

1. Introduction

In many multimedia applications such as digital TV, DVD, and image database system, video data is often compressed with MPEG. In case that video data is stored as digital library, it is compressed with MPEG most of time. In these applications, there will be many advantages when we search a certain video sequence, scene, or frame if we can insert optional binary data such as the index information and content information of the video or each frame. To realize the insertion of these kinds of information, we have to develop a method to insert binary information effectively into MPEG video bitstream without obvious degradation of image. And we have to realize to extract inserted index information perfectly although MPEG video is a lossy algorithm. Furthermore, the video data is usually stored for digital library under the MPEG compressed condition. Therefore we realize to keep the MPEG video format even after the binary data is inserted into MPEG video compressed data. According to keep the MPEG video format, we can decode images from binary data inserted MPEG bitstream using a traditional standard MPEG video decoder. Furthermore, the optional information insertion in the compressed domain is useful because the inserted information can be extracted without video data decoding. When the index information can be extracted from image data itself, we can easily handle the database of additional information such as index information. It is, moreover, possible to extract the inserted information anytime and we do not loose the information, even though image data goes out alone freely. Therefore it is so convenient to insert additional binary data information into image data and we can extract the inserted binary data information anytime even though the video format is changed.

In this paper, we propose a method for inserting binary data into MPEG-1 and -2 bitstreams. The proposed method allows us to extract the inserted binary data perfectly, although MPEG video is non-information preserving coding. And the quality of decoded images after inserted binary data extraction is almost the same as that of the original MPEG decoded image. Furthermore, the traditional standard MPEG-1 and -2 decoder can be also used for decoding the images when we do not need to extract the inserted binary data, and the quality of decoded images is also almost the same as the original decoded images.

The technique of watermarking which inserts image information into MPEG video has been studied [5], [6]. This technique is the method for inserting the signature information for copyright protection. There

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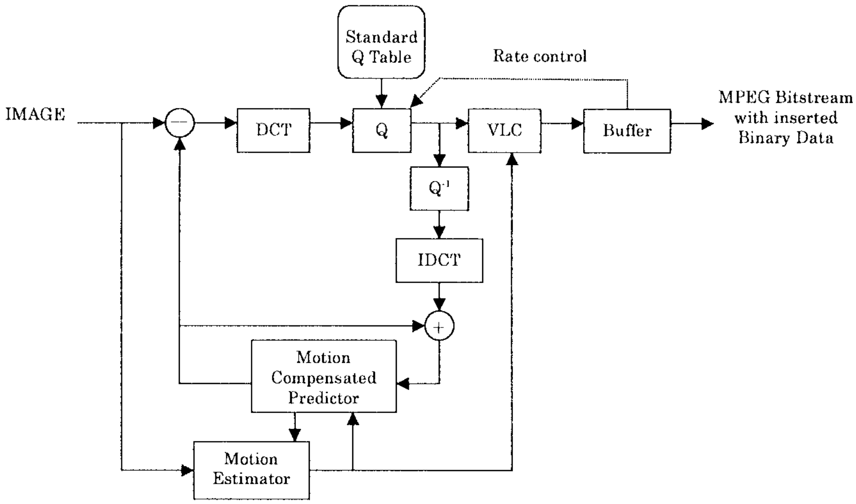

Fig. 1 Standard MPEG encoder.

are some different points between the proposed insertion technique of the binary data and the watermarking technique. The technique of watermarking prepares to deal with alteration by others. And the technique of watermarking is required for the identification of the signature and in that case we do not have to extract the inserted image of signature perfectly in the lossy MPEG video environment. On the other hand, we have to extract all of the inserted binary information data correctly with the insertion technique. Simulations using MPEG-1 and -2 video encoding with binary data insertion are presented to quantify some performance factors concerned. We have not heard about inserting data method which purpose is such as index and content information insertion.

2. MPEG Encoding Algorithms

To explain our proposed method, we will first review a traditional standard MPEG video encoder. Figure 1 shows the block diagram for the traditional MPEG video encoder. In the MPEG video, there are three types of picture; I-picture, P-picture, and B-picture. The input image is divided into 8×8 blocks, and each 8×8 blocks are performed DCT, then are quantized by using quantization matrix table. The power of image spectrum is usually concentrated on low frequency of DCT coefficients, and in many cases most of high frequency of DCT coefficients becomes to '0' after quantization. As shown in Fig. 2, all DCT coefficients besides of DC coefficient after quantization on each 8×8 block are encoded to variable length coding by zigzag scanning. And the last group of '0' coefficients is coded to the symbol of End of Block (EOB). These variable length codes and motion vectors form a MPEG bitstream. The bit rate control of the MPEG bitstream is performed by adjusting the quantization step size according to the output buffer level.

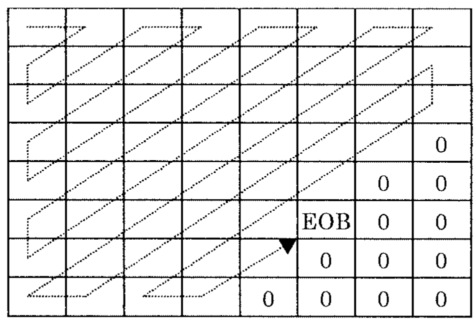

Fig. 2 Zigzag scanning of quantized DCT coefficients.

3. Inserting Additional Data Conditions

The following are the conditions of our proposed method for inserting the binary data information into MPEG-1 and -2 video bitstreams.

A. Maintenance of inserted information in non-information preserving coding

The inserted index or content information is usually not allowed us to be extracted with loss of bits. Therefore we have to extract the inserted binary information perfectly even though MPEG video algorithm is non-information preservingcoding.

B. Decoding on standard MPEG-1 and -2 decoder

We have to consider the decoding of MPEG bitstream which includes the inserted index or content information by traditional standard MPEG-1 and -2 video decoder. Thus the bitstream format of the binary data inserted MPEG video has to be still based on the standard MPEG video.

C. Prevention of the degradation of image quality by information insertion

There are two reasons of the degradation of image quality. One is the reason that an original image data is replaced to the inserted binary data for an additional information insertion. The other reason is that the change of compression ratio according to the increased entropy of the information inserted image data. When the amount of data increases, we have to encode image with high compression ratio to maintain the compressed image data size. As a result, the quality of image is degraded.

We have to try to prevent image degrading by those reasons when we insert the information.

4. Proposed Method

We propose the method of inserting binary data to meet with the inserting additional data conditions as mentioned above. Figure 3 shows the picture type sequence of GOP (Group of Picture) in MPEG-1 and -2 sequence. A GOP in MPEG-1 and -2 usually consists of 12 or 15 pictures and there is an I-picture in a GOP. In our proposed method, we insert the binary data into each 8×8 blocks. To show a simple case, we insert 1 bit binary data information into each 8×8 blocks on luminance plane of I-pictures in the MPEG-1 and -2 bitstreams.

4.1 In Case of 1-Bit Binary Data Insertion on Each Block

A. Inserting 1-bit binary data in the DCT domain

For example, we can insert 2,640 bits binary data in an I-picture which the size of the image is 704×240. We define here QDCT(p) is the quantized DCT coefficient which is the p-th order of zigzag scanning on 8×8 block in I-picture, where the range of p is from 0 to 63. In our proposed method, we replace the p-th quantized DCT coefficient: QDCT(p) to 1 bit binary data (0 or 1) of the inserted information. If the MPEG decoder knows the position of QDCT(p) where we insert object information in 8×8 block, the inserted binary data can be extracted perfectly. Even though the MPEG algorithm is non-information preserving coding, the encoding process after quantization on MPEG is the information preserving coding. Therefore, we replace the inserting binary data from the quantized DCT coefficient. As a result, the information inserted MPEG bitstream is still suited to standard MPEG-1 and -2 video bitstream, so the standard MPEG-1 and -2 decoder can decode image from the data inserted MPEG bitstream.

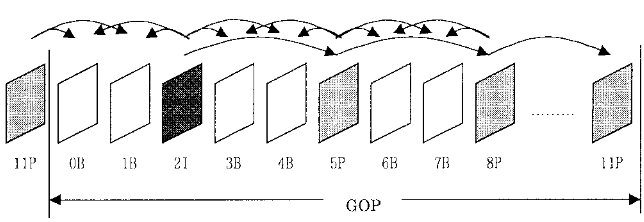

Fig. 3 A sequence of picture type in GOP. (the period of I/P picture: M=3 the number of picture in GOP: GOP=12 I: intra-picture, P: predictive-picture B: bidirectionally predictive-picture)

B. Inserting binary data position: p

The high frequency area of DCT coefficients is better than the low frequency area for the position of inserting information data in 8×8 block. There are two reasons. The first reason is that the high frequency DCT coefficients in 8×8 block are often become '0' after quantization. When we insert the data at the position where the original quantized coefficient is '0,' we can reset the coefficient value to '0' after extracting the inserted information data. As a result, we can inset the information data without changing value of coefficient after extracting. Therefore we can reduce the degradation of image quality by replacing coefficient values. The purpose of this is to prevent the degradation of image quality by replacing data. When the value of QDCT(p) does not equal to '0' before data insertion, the lack of inserted information data is occurred. On the other hand, if we can find the position of p where each value QDCT(p) of all 8×8 block equal to '0,' we can reproduce the perfect values of quantized DCT coefficients when we extract all inserted information data at decoder side and change the value of inserted data ('0' or '1') to '0.'

The second reason is that the high frequency noise is less visible than low frequency noise in the DCT domain. Then we can reduce the degradation of decoded image quality when we decode information data inserted MPEG bitstreams by traditional standard MPEG-1 and -2 decoders. When we do not extract and remove the inserted information data, this inserted data cause the degradation of image. It is better to choose a high frequency coefficient of quantized DCT coefficients for inserting data from the view point of image noise visibility.

If we insert the binary information into P-picture and B-picture, it is difficult to predict the effect of noise visibility because P-picture and B-picture are coded with inter-frame prediction. In our proposed method, we insert object information in I-picture which is coded with intra-frame prediction. We insert the binary information into luminance plane because chrominance plane is interpolated in many cases.

Furthermore, the position of inserted data affect the image compression ratio according to the increased entropy of image data. The last group of '0' coefficients of quantized DCT in zigzag scanning is coded to EOB (End of Block). When a data '1' is inserted into the last coefficient group of '0,' the code for inserted data '1' should be added. This means a increasing of compressed image data size. When we have to keep the size of compressed image file, we have to quantize with coarser step then the quality of image is more degraded.

Standard Q table

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	83

Modified Q table

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	①

Fig. 4 Modified quantization table in case of 1-bit binary data insertion. The value of standard quantization table which corresponds to inserted binary data position is changed to '1.'

C. Modified quantization table

In traditional standard MPEG decoding, we use a same quantization table which is used for encoding. However, in our proposed binary data inserting method, we prepare a different quantization table for decoding from for encoding, and send it to the decoder in the MPEG bitstream. The first purpose of preparing different quantization table is to reduce the noise of addition information data. As shown in Fig. 4, the values of a quantization table in high frequency area are so big. Therefore, even though the value which we replace for inserting information after quantization of DCT coefficients is so small, it change to big value with inverse quantization and such big value cause image degradation so much. For preventing this image degradation, we change the value of quantization table where we insert the information data to small. Then we send this modified quantization table, and the decoder use it for inverse quantization. Using this proposed method, we can make small value for quantization step where we insert the binary information data, and we prevent the image degradation by inserting information data. Figure 4 shows a sample of modified quantization tables which we send to MPEG decoder in case we insert the data into QDCT(63).

In the MPEG-1 and -2 bit format, the area for a user-defined quantization table is prepared in a sequence header field. Then the standard MPEG-1 and -2 video decoder can decode image using our proposed modified quantization table. And second purpose is to find the position of p where we insert the information data. At the decoder side, we can know the position (p) of data insertion to find the position which the value of received quantization table is '1.'

We consider the best position p of inserting information to be depend on images. However, we decide that the position p is always fixed to 63 in all 8×8 blocks in our following discussion. We have simulated the data inserting algorithms with different inserting positions and compared the image quality. The quality of inserted image do not show clear difference between the best position and fixed position 63. Thus, using fixed position p scheme, the procedure to decide the inserting position at encoder and to search the inserting position at decoder can be reduced.

4.2 In Case of 2-Bit or More Binary Data Insertion on Each Block

When we need to insert more than 2,640 bits binary data in one I-picture which the size of image is 704×240, we can insert 2-bit or more binary data on each block. For example, when we insert 2-bit binary data on each block in our proposed method, we replace both the p-th quantized DCT coefficient: QDCT(p) and (p-1)th quantized DCT coefficient: QDCT(p-1) to 1 bit binary datas (0 or 1) of information which we insert. Figure 5 shows a sample of quantization table which we send to MPEG decoder in case we insert the data into QDCT(63) and QDCT(62).

4.3 Encoding and Decoding Procedure

Overall, we show our proposed encoding and decoding procedures.

A. Encoding procedure

Figure 6 shows the block diagram of the proposed inserting binary information MPEG encoder. In MPEG video encoding, input image data is processed until quantization by standard MPEG encoding procedure. After quantization, we replace an original quantized DCT coefficient on same position of each 8×8 block through the whole video sequence into inserted binary data bit, then we do VLC encoding. We prepare a modified qantization table which is shown in Fig. 4, and we put it into the area of MPEG video sequence header. After all the procedures are described as following.

· 1) We replace the binary information data into the position on quantized DCT coefficients; QDCT(63).

· 2) We change the value of quantization table where we replace data in 8×8 block to '1,' and insert this modified quantization table into sequence header, then we make a MPEG bitstream.

B. Decoding procedure in case of extracting object information

Figure 7 shows the block diagram of the proposed extracting binary information MPEG decoder. In MPEG

Standard Q table

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	83

Modified Q table

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	①	①

Fig. 5 Modified quantization table in case of 2-bit binary dat insertion. The values of standard quantization table which corresponds to inserted binary data positions are changed to '1's.

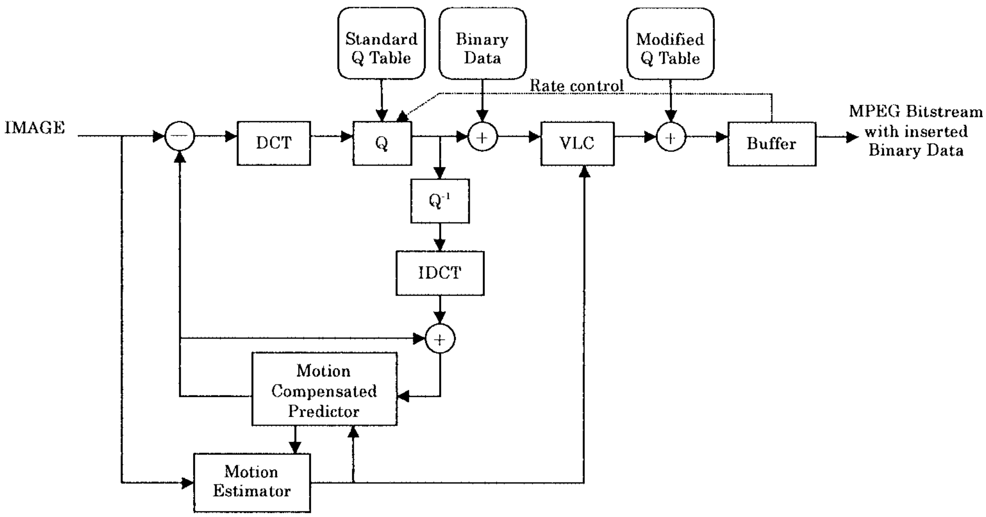

Fig. 6 Data inserting MPEG encoder. Modified quantization table is inserted into MPEG bitstream, then sent to MPEG decoder.

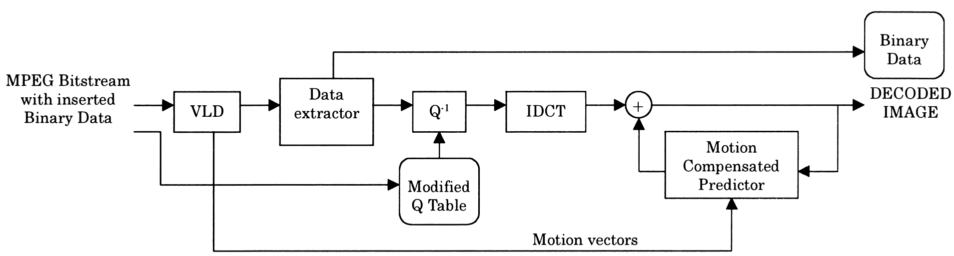

Fig. 7 Standard MPEG video encoder.

video decoding, input MPEG data is processed until VLD by standard MPEG decoding procedure. After VLD, we extract the inserted bit on same position of each 8×8 block through the whole video sequence, then we continue MPEG video decoding. After all the procedures are described as following.

· 1) We extract the value of object information on each block. When the value is not '0' or '1,' that block is not inserted the object information.

· 2) We set '0' into QDCT(63) at inserted data position after extracting the object information data.

C. In case of non-extracting object information

Figure 8 shows the block diagram of the proposed non-extracting object information MEPG decoder. In our proposed data inserting method, final data inserted bitstream is perfectly based on MPEG standard video, then we can decode MPEG image using standard traditional MPEG decoder.

· 1) We decode image with normal standard MPEG video decoder.

· 2) The additional information on each 8×8 block cause noise of decoded image. But we change the value

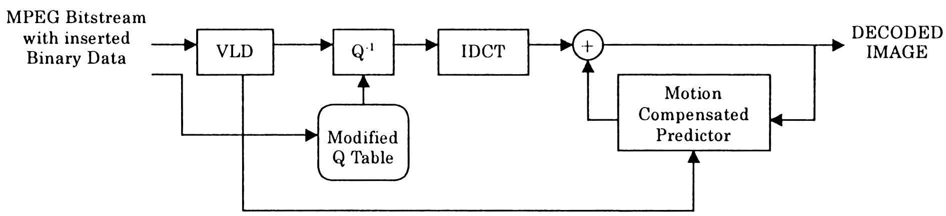

Fig. 8 Standard MPEG video encoder.

Table 1 PSNR comparison of decoded I-picture between the non-inserted original MPEG and inserted binary data MPEG decode.

Video sequence	Encoding target bit rate (bps)	Original MPEG image (PSNR)	Inserted binary data MPEG image	
			Extracting	Non-extracting
Flower garden	5 M	37.041678	37.045448	37.045957
	1 M	26.957671	26.772836	26.772835
	64 K	25.195681	25.193520	25.192984
Mobile calendar	5 M	31.627535	31.517664	31.517531
	1 M	23.788723	23.650839	23.650757
	64 K	22.655844	22.654881	22.654684
Football	5 M	41.074782	40.971517	40.971398
	1 M	32.955331	32.668385	32.668341
	64 K	28.843833	28.920211	28.918615

of quantization table where we insert the data to '1,' then noise of decoded image is small.

5. Simulation of Binary Data Insertion

We have simulated the proposed inserting binary information into MPEG-2 method. We prepared tree kinds of grayscale video sequences which are mobile and calendar, football, and flowergarden. The number of all these three sequences frames is 13 frames (0–12), and each frame size is 704×240. We insert binary data on each 8×8 block of luminance plane in I-picture.

5.1 In Case of 1-Bit Binary Data Insertion on Each Block

There is possibility of the many inserting data positions on quantized DCT plane in 8×8 block. And in this case, we chose a last position of zigzag scanned DCT coefficient; QDCT(63) to show a simple case. We do not say this position is the best, but we have been sure we can get sufficient results by simulation with this position. In this simulation, we use 1,664 blocks for inserting 208 bytes, eq. 1,664 bits data can be inserted in the whole 2,640 blocks in one I-picture. In the MPEG video encoding procedure, the bitrate control technique is usually used. The bitrate control we use is based on deviancy from estimated buffer fullness and normalized spatial activity [7].

Table 1 shows the PSNR comparison of decoded I-picture between the original MPEG decode images and inserted binary data MPEG decode images.

We can say that the degradation of inserted binary data MPEG decode image is almost nothing in both case of binary data extracting and non-extracting. And to compare with each MPEG encoding target bitrate, the quality of decoded image which target bitrate is 64 kbps is the best of these three. The reason is that the number of quantized '0' DCT coefficients is the most because quantization step size is increased according to decreasing the MPEG encoding target bitrate. Therefore, the possibility of changing coefficient value becomes small. And if the quantized DCT coefficients are '0,' the modification of quantization table makes nothing.

Table 2 PSNR comparison of decoded I-picture between using default MPEG Q table and modified Q table.

Video sequence	Encoding target bit rate (bps)	Using modified Q table (PSNR)	Using MPEG default Q table (PSNR)
Football	5 M	40.971517	39.031178
	1 M	32.668385	30.419968
	64 K	28.920211	23.501325

We have also simulated the effect of quantization table modification. Table 2 shows the comparison between using modified quantization table and using MPEG default quantized table.

We have succeeded to reduce the degradation of decoded image quality gratefully by using the our proposed modified quantization table.

5.2 In Case of 2-Bit Binary Data Insertion on Each Block

Table 3 shows the simulation results of 2-bit data insertion in one block. The total number of inserted bits is 418 bytes. We have tried two methods of 2 bits bi-

Table 3 PSNR comparison of decoded I-picture between the 1 bit/block insertion and 2 bits/block insertion.

Video sequence	Encoding target bit rate (bps)	Inserting 1 bit/block (PSNR)	Inserting 2 bit/block	
			QDCT(63)only (PSNR)	QDCT(63) and QDCT(62) (PSNR)
Football	5 M	40.971517	40.949606	40.952623
	1 M	32.668385	32.746674	32.752795
	64 K	28.920211	28.726297	28.911222

nary data insertion on one block. One is the method of 2-bit binary data insertion on QDCT(63) only. And the other is that of 2-bit binary data insertion on QDCT(63) and QDCT(62) respectively.

There is no obvious difference of PSNR of decoded image using between 1 bit/block insertion method and 2 bits/block insertion method. Therefore, when the total bit number we have to insert is smaller than the number of block in one I-picture, we can use both method of 1 bit/block insertion and 2 bits/block insertion. And when the total bit number is more than the number of block in I-picture, we can insert 2-bit or more binary data in one block. Overall, we have simulated the method of binary data inserting on I-picuture only this time, but it is also possible to insert binary data on P-picture and B-picture. In those case, the quality of decoded image using binary data insertion method in P-picture and B-picture is worse than in I-picture. Therefore, it is better to insert binary data in I-picture when the total bit number is smaller than the number of blocks in a picture. In case that the total bit number we have to insert is more than the number of blocks in a picture, we have two choices. One is the method to insert 2-bit or more binary data in one block on I-picture. And the other is method to insert 1-bit binary data in one block on I-picture, P-picture, and B-picture. We consider the simplicity of data handling in this tame, we then chose the method of binary data inserting on only I-picture.

6. Conclusions

We have studied the method for inserting the optional binary data into MPEG-1 and -2 bitstreams. Using this proposed method, we insert the binary data into a certain position of quantized DCT coefficients, and we can extract the inserted binary data from bitstreams perfectly. We choose a high frequency coefficient in the quantized DCT plane for inserting data, and we can prevent the degradation of decoded image quality. Furthermore, we modify the value of quantization table small, then we success to keep image quality when we decode data inserted MPEG bitstreams by traditional standard MPEG-1 and -2 video decoder. We have simulated our proposed method using binary data insertion, and we presented the effect of our proposed method.

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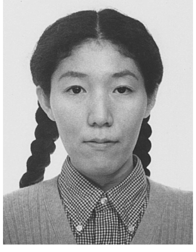

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