

Digital Watermark Based Error Detection for MPEG-4 Bitstream Error

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Abstract: In this paper, a new approach is proposed for the error detection dedicated to MPEG-4 video coding by using the digital watermarking. In the process of encoding, the proposed scheme abstracts the macroblock features of headers, motion vectors, and Discrete Cosine Transform (DCT) coefficients, which are embedded in the quantized DCT coefficients as the digital watermarks. The decoder performs the accurate error detection through the watermark extraction. Simulation results demonstrate that the error detection ability of the proposed approach can be significantly enhanced, and that digital watermark embedding incurs little degradation to the picture quality.

1. Introduction

The spread of video coding, such as MPEG-4 and H.263, has heightened applications for video communications at low bit rates over Wireless and on the Internet. However, an error occurs in wireless environments in the probabilities of 10^{-3} through 10^{-5} . It is also noticed that the congestion of IP packets causes a packet loss of 10^{-3} on the Internet when the bandwidth is not guaranteed. Thus, taking steps against errors as well as improving the compression efficiency is of practical importance under these circumstances [1].

Although for the MPEG-4 video coding there are a number of error resilience tools to reduce the effect of such errors, they are not effective for detecting all errors. For solving the problem, a new approach of digital watermarking is devised to improve the error detection ability by embedding the features of a macroblock (MB) in an encoder. We also show that digital watermark embedding incurs little degradation to the picture quality.

2. Conventional Error Detection Overview

The following methods are conventionally proposed to detect errors in a decoder.

- 1) Detection of the discontinuity in the neighboring patterns of an error block [2], [3].
- 2) Detection based on the parity bits added to the bitstream in an encoder [4].
- 3) Detection of syntax and semantic violations in the decoding process [1], [5].
- 4) Detection based on digital watermark embedding in

the quantized DCT coefficients [6].

Methods 1) through 3) have had a number of technical issues problems in practical use, such as the accuracy for judgment of error patterns, the compatibility with the conventional coding scheme, and the error detection ability. On the other hand, as for the method 4), a check marking method is introduced on the basis of the digital watermark embedding in the quantized DCT coefficients, where an error can be efficiently detected by checking the contradiction between the syntax of check markers and the information of decoded DCT coefficients. This error detection is more effective than methods of 1) through 3), since not only the error detection ability is enhanced, but also the check markers incur little degradation to the picture quality. However, the problem inherent in this method is that it only detects errors in the DCT coefficients.

3. Proposed Approach

This section describes a new approach which uses for the MB headers, the motion vectors (MV), and the DCT coefficients (Figure 1).

3.1 Embedding Check Marker in Encoder

Fundamentally, a check marker is embedded in the coefficients subsequent to the last quantized non-zero DCT coefficient in each DCT block (Figure 2(a)). However, a

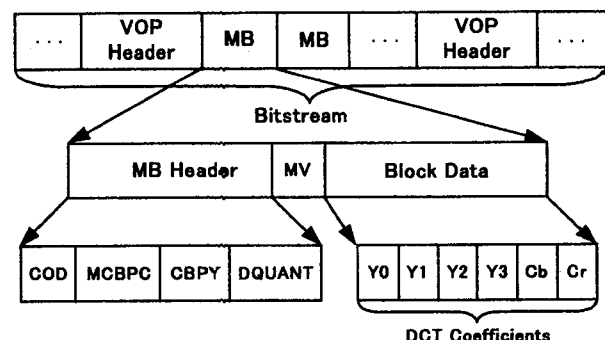


Figure 1 Example of structure for MB header, motion vector, and block data.

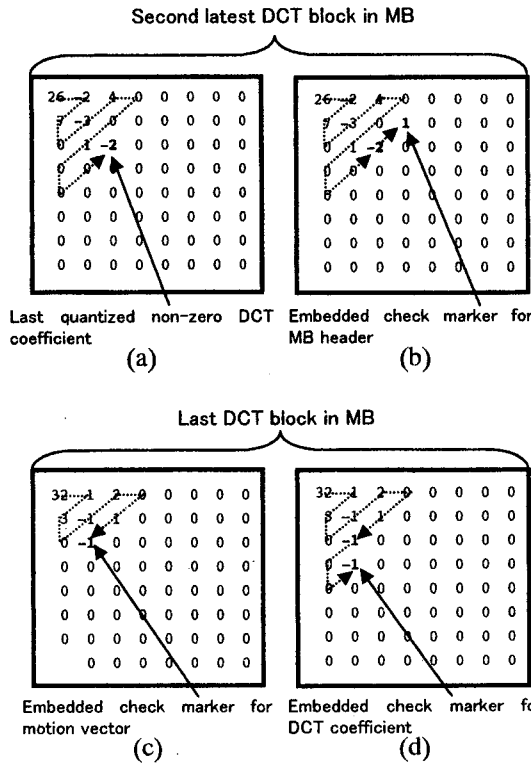


Figure 2 Check marker embedding procedure in 8 x 8 DCT block.

condition should be added to control embedding, when the number of non-zero DCT coefficients is not so enough in one block, since embedded check markers may greatly degrade the picture quality. Considering that our approach needs two DCT blocks in a MB for the check marker embedding, we can see that if the MB is under the following conditions, no check marker is embedded.

- There do not exist two or more DCT coefficients in a block in an Intra MB.
- There is only one DCT block in a MB.

3.1.1 Embedding The Feature of MB Header Information

The feature of the MB header information is embedded in the DCT coefficient as the check marker, where the MB header information is COD, MCBPC, CBPY, DQUANT, etc. Calculate $HeaderSum$, the sum of these decimal-converted values, and then seek the header feature $Header_{cm}$ by

$$Header_{cm} = MOD_n(HeaderSum), \quad (1)$$

where $MOD_n(x)$ denotes the remainder when x is divided by n . According to the prescribed syntax of the MB header check markers in Table 1, the feature of the MB header information is embedded in the second latest DCT block in a MB (Figure 2(b)).

Table 1 Check marker syntax for MB header.

$Header_{cm}$	0	1	2	3
Zero-run	0	0	1	1
Level	-1	1	-1	1

Table 2 Check marker syntax for motion vector.

MV_{cm}	0	1	2	3
Zero-run	0	0	1	1
Level	-1	1	-1	1

Table 3 Check marker syntax for DCT.

DCT_{cm}	0	1	2	3	4	5
Zero-run	0	0	1	1	2	2
Level	-1	1	-1	1	-1	1

3.1.2 Embedding The Feature of Motion Vector

Calculate $MVSum$, the sum of the values of the motion vectors in the vertical and horizontal directions, and seek MV_{cm} , the feature of the motion vector information, as follows

$$MV_{cm} = MOD_n(MVSum + HeaderSum). \quad (2)$$

According to the prescribed syntax of the motion vector check markers in Table 2, the feature of the motion vector information is embedded in the last DCT block in a MB (Figure 2(c)).

3.1.3 Embedding The Feature of DCT Coefficients

Calculate first the non-zero coefficient level and the zero-run number in each block, and then their total sums in a MB, denoted by $LevelSum$ and $RunSum$, respectively. Seek DCT_{cm} , the feature of the DCT coefficient, by the following equation

$$DCT_{cm} = MOD_n(|LevelSum + RunSum + MVSum + HeaderSum|). \quad (3)$$

According to the prescribed syntax of the DCT check markers in Table 3, this feature is embedded as the DCT coefficient subsequent to the check marker of the motion vector information (Figure 2(d)), and the quantized DCT coefficients are encoded by the variable length coding to generate the bitstream.

3.2 Error Detection in Decoder

Compare the embedded check markers with the decoded features of MB header, the motion vector information, and the DCT coefficients, and judge whether there occurs an error or not in a MB. The decoding procedure of the error detection is summarized as follows. As a countermeasure

Table 4 Error detection rate.

Video sequence	Num. of error MBs	Conventional method 1 (Syntax method)		Conventional method 2 (DCT check marker method)		Proposed method	
		Detected error MBs	Error detection rate	Detected error MBs	Error detection rate	Detected error MBs	Error detection rate
Akiyo	432	71	16.44%	294	68.06%	358	92.59%
Silent	387	66	17.05%	251	64.86%	335	91.21%
Foreman	372	80	21.51%	198	53.23%	302	87.10%

Table 5 PSNR degradation by check marker.

Video sequence	Postfilter	Average PSNR (dB)			
		Without CM (Syntax method)	With DCT CM (DCT CM method)	With proposed CM (Proposed method)	Degradation by proposed method
Akiyo	Without	40.93	40.83	40.17	0.76
	With	40.58	40.54	40.49	0.09
Silent	Without	33.86	33.59	33.16	0.70
	With	33.99	33.73	33.51	0.48
Foreman	Without	31.34	30.94	30.74	0.60
	With	31.38	31.13	31.07	0.31

CM: Check Marker

for the picture quality degradation by the check marker, the nonlinear noise removal postfilter is applied to the decoded pictures [7].

1) The conventional decoding process:

The variable length decoding is performed on the bitstream to get the quantized DCT coefficient.

2) Error detection by the conventional method [1], [5]:

If any of the following syntax violations is detected in the decoding process by the conventional method, then an error-occurrence is found.

- The detection of a code that does not exist in the prescribed table of variable length codes.
- The detection of a value exceeding the range of the motion vector.
- The detection of over 64 DCT coefficients in one block.
- The detection of a code exceeding the range of the escape code.

3) Error detection by the check marker extraction (the proposed approach):

If the comparison of each piece of decoded information with the check markers brings any of the following contradictions, then the detection of an error is identified.

- The contradiction with the syntax of the $Header_{cm}$.
- The contradiction with the syntax of the MV_{cm} .
- Based on the DCT_{cm} , each of the following cases indicates the detection of an error in the DCT coefficients;
 - Only one DCT coefficient in the block that the check marker has been embedded in.
 - A violation of the zero-run number preceding the check marker.

- The contradiction with the syntax of DCT_{cm} .

4. Simulation Results

To verify the effectiveness of the proposed approach, the error detection rate is calculated in the cases where errors are added to bitstream, and each of the error detection methods is applied. Three video sequences at QCIF, Akiyo, Silent, and Foreman, are encoded with 48 kbits/s, 10 frames/s using MPEG-4 Simple Profile @ Level 1. The experiment is then carried out as below.

1) Embedding the check marker:

Embed the check marker for each MB by the means describe in section 3.1.

2) Addition of errors:

Add random errors to the bitstream in the probability of 10^{-3} .

3) Error detection performance:

Count the MBs where the added errors have been correctly detected, and calculate the error detection rate. Also, calculate the error detection rate in the conventional method (syntax method) which detect syntax violations that are mentioned above in 2) of section 3.2. Furthermore, the error detection rate is calculated by the method (DCT check marker method) based on the checker marker for DCT coefficient [6].

4) Calculation of peak signal-to-noise ratio (PSNR):

Calculate PSNR of the decoded pictures in which some check markers have been embedded, to investigate the effect of the embedded check markers on the picture quality.

4.1 Error Detection Ability Evaluation

The error detection rate of the proposed approach is shown in Table 4, as compared with that of the conventional methods (syntax method and DCT check marker method). This result implies that the error detection rate of the syntax method and the DCT check marker method are 16.44% - 21.51% and 53.23% - 68.06%, respectively, and furthermore that the proposed approach can detect 87.10% - 92.59% of errors. Thus it can be confirmed that the proposed approach greatly enhances the error detection rate. As compared with the DCT check marker method, the check marker embedding in the MB header and the motion vector contributes to the improvements of about 30% for the detection rate. Reversible VLC and data partitioning are not used in this experiment. The combination of these error resilience tools and the proposed approach makes it possible to construct an error detection system that has a higher detection ability and is more accurate.

4.2 Effect of Check Marker Embedding on Picture Quality

To confirm the effect of the check marker embedding on the picture quality, the average of the Y component PSNR degradation in the decoded pictures is shown in Table 5, which indicates that the PSNR degradation by the proposed check markers is 0.60dB - 0.76dB, and that there is little degradation in the picture quality. However, the degradation is enhanced to 0.09% - 0.48% by the postfiltering. The order of the degradations without the postfilter is Akiyo, Silent, and Foreman, which agrees with the order of more embedded check markers. This shows that the picture which has the higher error detection ability degrades the more the PSNR.

Concerning the most degraded pictures in each picture sequence, a difference in the subjective picture quality can hardly be seen for Akiyo and Silent. On the other hand, Foreman has a little noise. Since the sequence has fast movements, the tendency for only the low frequency components to exist in the DCT blocks is strong. Therefore, the check markers are embedded more in the lower frequency components when compared to the other pictures. It seems that this caused the noticeable degradation in the worst case. Such degradation, however, is seen in just a part of the picture sequences. The proposed approach is more effective in improving error detection ability than the conventional method, and in controlling the degradation of the picture quality.

5. Conclusion

In this paper, we have proposed a new approach to enhance the error detection ability in the MB header information, the motion vector, and the DCT coefficients. Our approach achieves to detect errors accurately in MPEG-4 bitstream using the digital watermark embedding. It can be confirmed that the proposed approach greatly enhances in the error detection ability as compared with the conventional methods. And that the check markers have little effect on picture quality. Further, decoding is possible with only slight degradation, even in the case of a decoder that does

not correspond to this approach, because the approach has compatibility with MPEG-4 video coding. Moreover, the amount of processing for embedding check markers and detecting errors is not large because the approach is simple. This suggests that the approach has an advantage in its implementation. Based on the considerable knowledge obtained from this research, we intend to investigate the VLSI architecture of the algorithm.

Further studies are to consider a check marker embedding approach that causes less picture quality degradation, and to develop a more effective approach to detect errors combined with reversible VLC and data partitioning.

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