Sensors & Transducers, Vol. 175, Issue 7, July 2014, pp. 144-149

Sensors & Transducers

H.264/AVC Video Watermarking Algorithm Against Recoding

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Received: 7 June 2014 /Accepted: 30 June 2014 /Published: 31 July 2014

Abstract: In this paper, an effective video watermarking method based on H.264/AVC was proposed. We select Intra_4×4 and Intra_16×16 as the embedding target, each macroblock would be embedded into 1 bit watermark. In Intra_4×4, we explorer the characteristic of the DCT coefficient and adjust them to embed watermark while in Intra_16×16 we modulate the LSB bit of the DC coefficient to realize watermark insertion, furthermore, we control the embedding strength to make the video quality and the bit-rate acceptable. Experiment results demonstrate that the watermark can resist the recoding effectively, while the real-time performance can also be obtained. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: H.264/AVC, Video watermark, Recoding.

1. Introduction

Digital multimedia has a tremendous growth during the last decade as a result of their notable benefits in efficient storage, ease of manipulation and transmission. However, unfortunately, the very nature of the digital media makes the work of pirates and hackers easier, since it enables perfect copies with no loss of value. Digital watermarking can be a promising solution in a digital-rights-management system. By embedding copyright information into a video, we can not only record the owner of the video but can also authenticate the integrity of the video stream [1-3]. Watermarking is an ideal solution for protection of intellectual property rights.

H.264/AVC is an efficient video coding standard jointly developed by the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) standards committees. The main goals of the standardization effort have been enhanced the compression performance and “network-friendly” [4]. H.264/AVC achieves a higher coding performance than the previous video coding standards, such as MPEG-2 and MPEG-4. In order to achieve this performance, H.264/AVC adopts various advanced techniques, such as variable block-size motion estimation, multiple reference frame motion estimation, spatial intra-prediction, and novel entropy coding.

Now, some digital video watermarking schemes suitable for the H.264/AVC video compression standard have been proposed. In [5], the authors employ a human visual model adapted for 4×4 DCT block to increase the payload and robustness while limiting visual distortion, and the watermark is embedded in the coded residuals to avoid decompressing, which can get a perfect video quality and imperceptibly of the watermark, but it cannot resist the recoding attacks very well. The authors in works [6-10] utilize the intra-prediction-mode to hide information, the transparency is desirable, but these schemes can’t resist any attacks, some common operation followed by recoding will make the information undetectable. This problem still exists in work [11]. Some robust video watermarking schemes were present in [12-15]. Noorkami [14] proposed a robust watermarking algorithm for H.264/AVC. The watermark information was embedded in a selected subset of the quantized DCT coefficients. The author used a key-dependent algorithm to select a subset of the coefficients for watermark embedding to obtain robustness to malicious attacks. In [15], the author indicates that in a compressed video, the P-frames were highly compressed by motion compensation, and the P-frames appear more frequently in the compressed video and their watermarking capacity should be exploited. So the watermark bits were embedded to nonzero-quantized ac residuals in P-frames. The experimental results show that the video watermark detection algorithm has controllable performance, and high robustness to several different attacks. In [16], the watermark is embed by altering the LSB of the low-frequency DCT coefficient of specific 4×4 blocks during the CABAC (Context-Based Adaptive Binary Arithmetic Coding) process, which can get a low computational complexity, however, the mode would change after recoding, which make the watermarked 4×4 blocks can't be located and lead to desynchronization during watermark extraction.

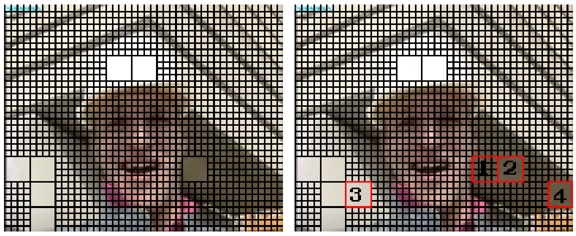
In this paper, we present a recoding resisted method for H.264/AVC, which can solve the desynchronization problem. We embedded the watermark into I4 and I16 in I-frames. In I4, we modulate the specific characteristic of the DCT coefficient to embed the watermark, while in I16 we modify the LSB bit of the DC coefficient to realize watermark insertion. This scheme has a low complexity and it can realize blind detection, which can meet the requirements of the modern detection of real-time perfectly.

2. Proposed Method

In H.264/AVC, each frame is encoded in intra or inter mode, in the encoder, the optimal encode mode would be selected to reduce the redundancy. However, after any attacks followed by recoding, part of the macroblocks in the video would be transferred, which make the decoder to lose synchronization.

2.1. Desynchronization Problem in Watermarking

For the luminance samples in intra-frames, Intra_4×4(I4) or Intra_16×16(I16) encode mode would be selected for each macroblock. Actually, I16 is selected for smooth regions while I4 is appropriate for the more textured area. Embed the watermark in I4 macroblock can get the transparency perfectly because of human eye is less sensitive to the textured area. As a matter of fact, after any simple processing followed by recoding, the encode mode of some macroblocks would change between I4 and I16, as depicted in Fig. 1.



(a): I-frame of foreman (b): the frame after recoding

Fig. 1. Mode changes after recoding.

From Fig. 1 we can find that the encode mode of the indexed macroblocks 1, 2, 3 and 4 had changed after recoding. Thus, if we select the specified I4 blocks of aggregate B, B={B1, B2, B3, …, Bi, …, Bn} to embed the watermark, however, after recoding, few macroblocks in B change to I16, then the detector would skip over the very few macroblcoks and desynchronization happens, which made the watermark unachievable.

Therefore, the mode changes would cause desynchronization during watermark extraction. We recode the standard video sequences of foreman, container, carphone, news and then statistics their first fifteen intra-frames, the distribution of I4 and I16 and their transfer probability are shown in Table 1.

Table 1. Distribution of I4 and I16 and their transfer probability.

	I4 (%)	I16 (%)	I4<–>I16 (%)	I4–>I16 (%)
Foreman	94	6	4	3
container	60	40	1	2
Carphone	84	16	4	4
news	86	14	2	2

From Table 1 we can find that mode changes exist in all the video sequences, therefore, we should make out an effective method to solve the desynchronization problem.

2.2. Watermark Embedding

Most of the relative works aim at selecting the more steady blocks to embed watermark to resist desynchronization, however, transfer problem still exists more or less, only one watermarked-macrolbock changes would cause desynchronization and make the detection fail. In this case, we propose a method that embed watermark in every macroblock in intra-frames, that means, each intra-macroblock is correspond to one bit, in the decoder, we can extract the watermark bit to bit from every macroblock in intra-frames. In this way we can solve the desynchronization problem.

In I4, firstly we categorized the NNZ into 2 groups, as shown in Fig. 2, here the scheme of categorization can be various and we make it as the private key to extract the watermark in the detector, this is one of the measures to enhance the security, furthermore, the target 4×4 block which has the biggest NNZ value in the current I4 is selected, which category the NNZ of the block belongs to indicates the watermark bit, therefore, we set the higher-frequency zero-DCT-coefficient to 1 to satisfy the condition. We embed the watermark by set the zero-coefficient to 1 but not clear the zero-coefficient to ensure that after watermark embedding the NNZ value of the 4×4 block is still the biggest one, we can locate the very block by this condition and detect the watermark implicitly in the receiver.

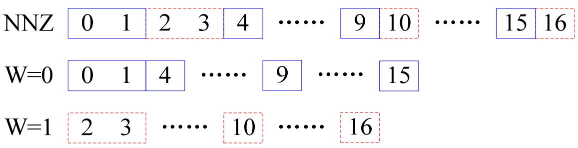


Fig. 2. The categorization scheme of NNZ and watermark embedding.

I16 contributes a smaller part in I-frames, we embed watermark in I16 to prevent desynchronization, and we modulate the DC coefficient of luma samples in the current I16 to embed watermark, as depicted in (1).

$$DC(LSB) += 1 \quad if\,(W_i \mathrel{!=} DC(LSB)), \qquad (1)$$

The watermark, which is embedded in every macroblock in I-frames, is robust enough to resist recoding, and we can utilize it to authenticate the integrity of the video stream.

2.3. Watermark Extraction

Detect the watermark from I4 and I16 macroblocks in I-frames orderly, as depicted in Fig. 3.

We use different methods to extract watermark from I4 and I16. In I4, firstly we locate the 4×4 block which has the biggest NNZ, which category the NNZ belongs to indicate the watermark, as depicted in Fig. 2, In I16, the watermark can be detected just by reading the LSB bit of the DC coefficient, as shown in (2).

$$W_i = DC_{LSB}, \qquad (2)$$

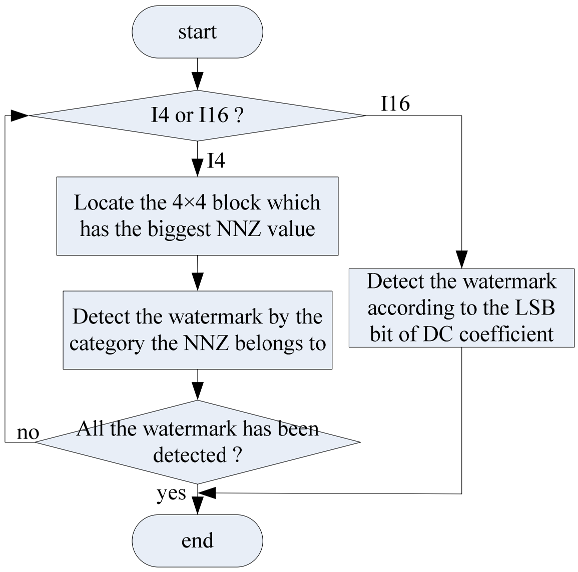


Fig. 3. Watermark detection.

3. Experiment Performance and Analysis

In order to verify the performance and effectiveness of our proposed watermark algorithm, we implemented our method using the H.264 reference software version JM8.6 [18] using the following 8 QCIF format standard video sequences: foreman, carphone, container, news, bridge-close, highway, mother-daughter, silent. All videos are coded at 15 frames/s with "IBPBP…" GOP structure, main profile are adopted, 75 frames are coded in total. The watermark is a 34×43 binary image, as shown in Fig. 4.

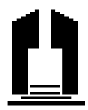


Fig. 4. Watermark image.

3.1. Effect on Video Quality

Fig. 5 illustrates the PSNR comparison of the first 5 GOP between the original and the watermarked video of foreman, carphone, container and silent. Since the PSNR do not take the temporal into account, we introduce the SSIM[19] (Structural Similarity) to evaluate video quality in addition, and compared the results with [10], as shown in Fig. 6.

From Fig. 5 and Fig. 6 we can find that the data hiding introduces little influence to the video. The main reason is that we modulate the higher-frequency DCT coefficient to embed the watermark, in addition, we adjust the embed strength to achieve the controllable video quality. We compared the watermarked video with the original to evaluate the imperceptible performance subjectively, Fig. 7

displays the frames of foreman before and after data insertion, there are little difference between the watermarked image and the original, so the algorithm meet the human perceptual requirement.

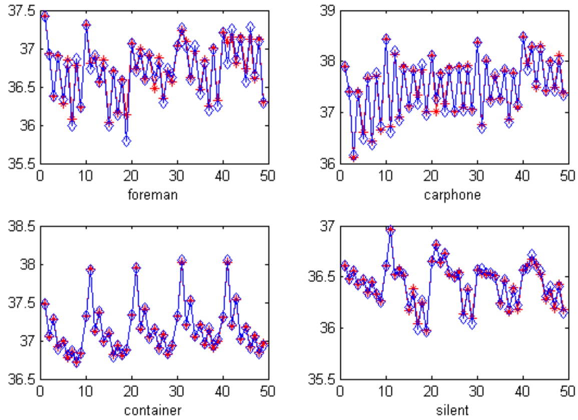


Fig. 5. PSNR comparison.

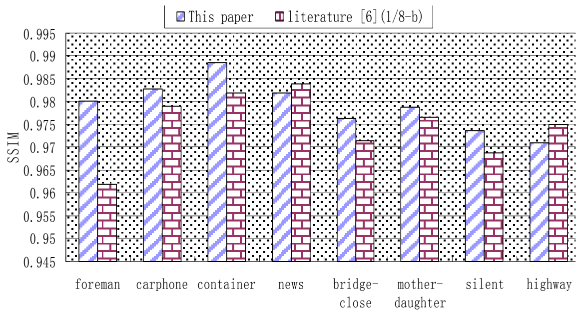


Fig. 6. SSIM comparison.

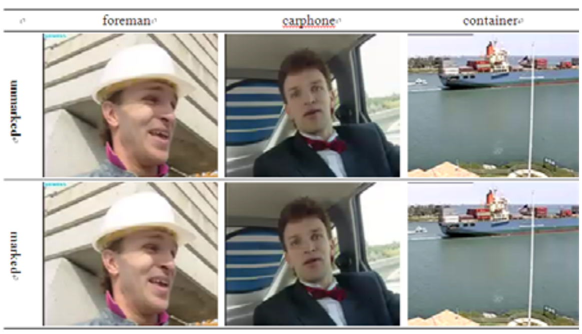


Fig. 7 Frames before and after watermark embedding.

3.2. Effect on the Bit-rate

The increasing percentage for bit-rate μ is introduced to estimate the performance of the algorithm in addition.

$$\mu = \frac{m-u}{u} \times 100\%, \tag{3}$$

where m and u denotes the bit-rate of the watermarked video and the original respectively. We compare the parameters of μ with [10] and [16], as shown in Table 2.

Table 2. Performance comparison.

	This paper	Ref.[10] (1/8-b)	Ref. [16] (n=2)
foreman	+0.2	+0.9	+0.16
carphone	+0.1	+1.0	+0.19
container	+0.4	+0.3	+0.17
news	+0.3	+0.25	+0.14
Bridge-close	+0.7	+0.51	+0.10
Mother-daugther	+0.8	+0.5	+0.27
silent	+0.4	+0.07	+0.11
highway	+0.3	+0.5	+0.48

From Table 2 we can find that the parameters of this paper is comparable with [10] and [16], in Intra_4×4, we set few zero higher-frequency coefficients to adjust the NNZ, in Intra_16×16, we modify the LSB bit of the DC coefficient to embed the watermark, we control the embedding strength to make the bit-rate increase acceptable.

3.3. Synchronization in Watermark Extraction

In this paper, we insert our watermark into macroblocks of I4 and I16, as they often change to each other after recoding, here, both of them are selected as the embedding target, in the decoder, we detect 1 bit watermark from the macroblocks of I4 and I16, therefore, we can synchronize the watermark extraction in spite of the encode mode changes still exist. The extraction of the watermark can be avoid from un-recognizable,

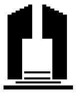
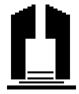
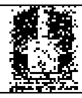
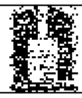
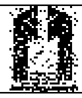
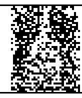
We attack our video under recoding to test whether the watermark can prevent recoding or not, and introduce a recovery rate η to evaluate the performance, as shown in (4).

$$\eta = \frac{recovered \quad pixels}{total \quad pixels} = \frac{\sum_{j=1}^{N}\sum_{i=1}^{M} W(i,j)W'(i,j)}{M \times \mathrm{N}} \times 100\% \tag{4}$$

where M and N denotes the width and height of the watermark image respectively, W denotes the original watermark while W' denotes the extracted one.

Table 3 depicted the extraction, from which we can find that the watermark can be detected fully with no attacks, meanwhile, the detected watermark can be recognized and can resist the recoding effectively.

Table 3. Watermark detection after recoding.

<table>
<tr><td></td><td>Without attacks</td><td>Recoding</td><td></td><td>Without attacks</td><td>Recoding</td></tr>
<tr><td rowspan="2">foreman</td><td>η =100</td><td>η =85.6</td><td rowspan="2">Bridge-close</td><td>η =100</td><td>η =75</td></tr>
<tr><td rowspan="7"></td><td></td><td rowspan="7"></td><td></td></tr>
<tr><td rowspan="2">carphone</td><td>η =81.9</td><td rowspan="2">Mother-daugther</td><td>η =76.7</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="2">container</td><td>η =80.2</td><td rowspan="2">silent</td><td>η =84.8</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="2">news</td><td>η =86.7</td><td rowspan="2">highway</td><td>η =68.6</td></tr>
<tr><td></td><td></td></tr>
</table>

4. Conclusions

In this paper, we embed each macroblock one bit watermark in I-frames orderly to prevent desynchronization. We modify few higher-frequency coefficients in I4 and modulate the LSB bit of DC coefficient in I16 to embed watermark, we control the embedding strength to make the video quality and bit-rate increase acceptable. The hiding and extraction processes can perform quickly, simply, which satisfy the need of real-time signal processing.

Acknowledgements

This work is supported by the National Natural Science Foundation of China (61170137, 61301247, and 61300055), The Outstanding (Postgraduate) Dissertation Growth Foundation of Ningbo University (Grant py2013005), Zhejiang Provincial Natural Science Foundation of China (Y13F020071), and Ningbo Natural Science Foundation (2013A610059, 2013A610057).

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