WATERMARKING OF COMPRESSED VIDEO BASED ON DCT COEFFICIENTS AND WATERMARK PREPROCESSING

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Abstract: Considering the importance of watermarking of compressed video, several watermarking methods have been proposed for authentication, copyrights protection or simply for a secure data carrying through the Internet. Applied to the H.264/AVC video standard, in most of cases, these methods are based on the use of the quantized DCT coefficients often experimentally or randomly selected. In this paper, we introduce a watermarking method based on the DCT coefficients using two steps: the first one consists in a watermark pre-processing based on similarity measurement which can allow to adapt the best the watermark to the carrying coefficients of low frequencies. A second step takes advantage from the coefficients of high frequencies in order to maintain the video quality and reduce the bitrate. Results show that it is possible to achieve a very good compromise between video quality, embedding capacity and bitrate.

1 INTRODUCTION

Today, with the progress in network services and multimedia applications, the interest of watermarking compressed documents is becoming more and more important due to the easy transmission of data and all the issues that follow.

With the availability of video sharing and dissemination services through Internet, it becomes important to develop appropriate tools for authentication or copyright protection or just to offer a secure data transmission service without using additional channels.

Indeed, dealing with compressed video, several watermarking methods have been proposed for the H.264/AVC, the newest video coding standard which is known for its coding efficiency (Richardson, 2003), (ITU-T, 2005). These methods generally use the motion vectors or the quantized discrete cosine transform (DCT) coefficients in order to propose fragile or robust video watermarking solutions.

Most of methods that use the DCT coefficients exploit the human visual properties to reduce the degradation caused by the watermark embedding. This degradation is propagated by the inverse quantization and the inverse DCT operations at the decoding step, and also by the Intra and Inter predictions. Thus, the video quality can be improved by selecting the appropriate areas that respond to some constraints such as embedding the watermark according to the choice of the coding mode or other DCT blocks' properties.

In this context, we have worked on designing a watermarking method for the video codec H.264/AVC, useful for video authentication in order to ensure the protection of data against unauthorized modification, to check credibility and the origin source of the video and respond this way to the need for reliable information.

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However, video watermarking methods cannot be designed without thinking of three important constraints: embedding capacity, video quality, and video bitrate. Our main motivation, though, is to arrive at a compromise between these constraints and if possible reduce the bitrate for a better use within the network applications.

The idea of decreasing the bitrate was suggested in (Wang and Hsu, 2008) where the authors proposed a fragile watermarking algorithm for JPEG image, based on modifying the last nonzero coefficient in each DCT quantized block. The proposed algorithm provides an authentication capability, and decreases the size of JPEG compressed-domain images with no visual impact.

Our proposal is based on the quantized significant DCT coefficients where both of the coefficients of low and high frequencies are used in order to obtain a sufficient embedding capacity and maintain or reduce the bitrate. A watermark preprocessing is performed by applying a rotation several times in order to find the best position of the watermark in the video and maintain the video quality.

In the next section we describe the different stages of our method. Results are presented in section 3. Finally, we give the conclusion in section 4.

2 RELATED WORK

Several watermarking methods based on the DCT coefficients and watermark preprocessing were proposed for the H.264/AVC video codec (figure 1). However, they are different in the choice of the block and the DCT coefficients for the watermark embedding and in the appropriate watermark processing. The aim is to respond to the application needs in terms of robustness or fragility, video quality and bitrate. Among these works, Quan and Hong (2008) proposed a real time video watermarking method based on the low frequencies DCT coefficients features in I frame on H.264 to generate the watermark information. Middle frequencies of 4x4 DCT blocks are used to embed the watermark, and the blocks with a DC coefficient equal to zero are avoided; the aim is to maintain the compromise between robustness and invisibility. Chen, Lai and Chang (2009) proposed a video watermarking method based on two algorithms for low and high energy blocks of Intra frame in order to consider the high frequency noise attack and the low-pass filter attack. The watermark is preprocessed by an encryption using a Torus Automorphisms algorithm and the Secret Image Sharing technology to increase robustness.

Another robust video watermarking scheme is based on the choice of one middle frequency in the 4x4 DCT blocks for the embedding process. In order to accommodate the computational complexity of the video codec, the 2 D 8 bits watermark undergo a preprocessing based on five steps (DCT decomposition and zigzag scanning, normalization, frequency masking, transformation, reduction of the level) transforming it to a simple 1D sequence (Zhang, Ho, Qiu and Marziliano, 2007).

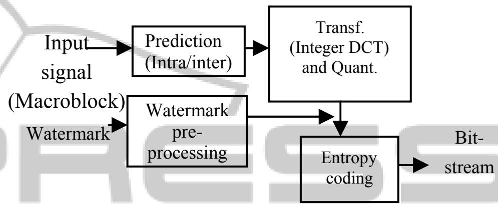

Figure 1: General scheme of embedding watermark in DCT coefficients of the H.264 video codec.

Our method is also based on the quantized significant DCT coefficients where two coefficients are used per block: the coefficients of low frequencies would ensure the necessary embedding capacity for the application, and the coefficients of high frequencies would reduce the bitrate and maintain the video quality. Embedding the watermark is performed after an initial step which consists in preprocessing the Watermark by applying a rotation several times and calculating each time the intercorrelation coefficient between the watermark signal and the carrying coefficients transformed to a binary signal. The aim is to find the best position of the watermark in the video so that the introduced distortion is reduced.

3 DESCRIPTION OF THE METHOD

3.1 Embedding Position and Formula

In a first step, we choose among the significant quantized DCT coefficients, the position of the coefficients which would carry the watermark. Choosing the low frequencies would allow to satisfy the embedding capacity required for the application, thus, to embed the watermark, the significant coefficients in position k= 4 according to the zigzag scan, are selected as illustrated in figure 2.

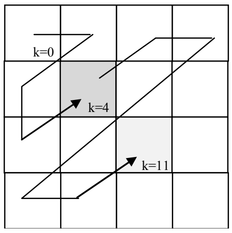

Figure 2: A zigzag scan in a block of DCT coefficients.

Coefficients equal to ±1 are not used because of the serious increase in bitrate they may cause. This is because ±1 have a special processing in the entropy coding stage of the video codec (Richardson, 2003). The DC coefficients are avoided because of the high degradation they may introduce, as well as the high frequencies coefficients because they are mainly composed from values equal to 0 or ±1.

In this case the majority of coefficients planned for embedding the watermark would be even coefficients. An example of a video histogram of significant DCT coefficients of the position k = 4 is given in figure 3.

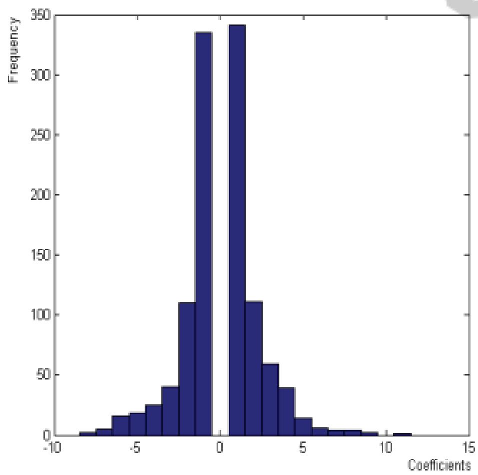

Figure 3: Histogram of the quantized significant DCT coefficients of position k=4 of Container sequence.

For the embedding process, simple methods are preferred such as the Least Significant Bit (LSB) method, in which the LSB of the coefficient is replaced by the watermark bit. That means that the bit 0 is preferebly embedded in an even value in order not to change the original value of the coefficient. However , the watermark may be composed of bits “1” more than “0”, and because we deal with more even coefficients than with odd ones as mentionned previousely; it may be better to change the embedding formula so that the LSB of the coefficient is replaced, not by the watermark bit, but by its complement. In this case we need to reserve one bit during the embedding process to know wich formula has been used.

3.2 Watermark Pre-processing

We suppose that our watermark has been encrypted to ensure its security. Our objective is to find the best transformation of the watermark in order to correspond - as much as possible- the bits “0” to even coefficients and the bits “1” to the odd ones.

To do so, we apply a rotation by one several times to the watermark. In each rotation, the last bit of the watermark becomes the first one and in each time we calculate the intercorrelation coefficient between the watermark signal (W) and the coefficients (transformed to binary signal C).

Considering W and C two binary sequences of the same length N:

W={W1=±1, W2, .. , WN}, C={C1=±1,C2,.. , CN}.

The intercorrelation function for positive delays is given by:

$$Cor_d(W,C) = \sum_{i=1}^{N-d} W_i\, C_{i+d}\,,\;\; d = 0,1,2,\dots,N-1 \quad (1)$$

In our case d=0.

To clarify this point an example is given:

Let’s consider the sequences of dimension N= 8. C_4 is composed from coefficients of position k=4 in the block and W is the Watermark.

C_4={2, -3, 6, 4, 5, 2,-2,3}, W={0,0,1,0,1,1,0,1}.

The preprocessing consists in the following steps:

- C_4 is replaced by the binary sequence :
  C’$_4$= {1,-1,1,1,-1,1,1,-1}, 1 for even coefficients and -1 for odd coefficients.
- If we consider that the bit 0 is preferably embedded in an even coefficient, we transform the watermark W to W1={1,1,-1,1,-1,-1, 1,-1} , where the bit 1 replaces 0 and -1 replaces 1, then we apply a rotation (N-1) times to obtain:

W2={-1,1,1,-1,1,-1,-1, 1 },
W3={1,-1,1, 1,-1,1, -1, -1},
…,
W8= {1,-1,1,-1,-1, 1,-1,1}.

The highest value of the correlation coefficient is given for W3 or W6 (Cor = 6). The watermark corresponding to W3 is: W’={0,1,0,0,1,0,1,1}. After the embedding process (using the LSB method) the watermarked DCT coefficients become Cw_4={2, -3, 6,4,5,2,-3,3} where only one coefficient is modified. Besides, we can check that if we had embedded the signature without preprocessing we would have about four coefficients modified in the sequence C_4 .

During the embedding process we need to reserve coefficients to save the rotation dimension (three, in the example) so that we can deduce W from W' at the detection stage. Of course, the reserved coefficients won't be involved in the intercorrelation calculation. In our case, their number is experimentally estimated to 11 coefficients.

3.3 Video Quality Improvement and Bitrate Reduction

After the watermark preprocessing and the embedding process as described in the previous section, the coefficients of C_4 for which the watermark bits are causing a modification, are restored to their initial value after modifying the coefficients of position k=11 (C_{11}) instead of C_4.

The modification consists of transforming all the coefficients of the position k=11 to even values for those corresponding to the unchanged coefficients C_4 , and C_{11} become odd for those corresponding to the coefficients of C_4 supposed to be modified by the bit embedding. The idea is to exploit C_{11} to make the difference between the unchanged coefficients and the restored ones, and because of the position of C_{11} comparing to C_4 in the block (figure 2), we expect that the modification of C_{11} would introduce a smaller degradation.

The only coefficients of C_4 that won't be restored are those corresponding to the coefficients C_{11}=0. The embedding and extracting processes are presented in the next section.

3.4 Watermark Embedding/ Extracting

Embedding and extracting the watermark may be summarized as follows:

- Extract the sequence of M significant DCT quantized coefficients used for the watermarking, and transform it to a binary signal composed of ±1.
- Reserve about 12 bits for the additional information.
- Apply the watermark preprocessing:

• Transform the watermark signal W (composed of 0 and 1) to binary signal composed of ±1.

• Apply a rotation (N-1) times, with N= M-12, and calculate the correlation coefficient between the watermark and the binary signal representing the coefficients, using the formula (1).

• Deduce the new watermark W' to embed from the rotation dimension giving the highest intercorrelation coefficient.

The embedding and extracting algorithms are given bellow:

Cw_4 (i) is the i^th watermarked coefficient and 0≤i<N. The variables: Restore1, Restore2, Restore3, Restore4, NoRestore, initialized to 0, are introduced to identify the cases where the coefficients of C_4 are changed or not. "abs" is the absolute value and "mod" is the modulo operation.

```
     if  (k=4 and abs(C4(i))≠ 1) then
{
if (C4(i) > 0  )  then { if (C4(i) mod  2=1)
then  {if  (W'(i)=0)    then  {  Cw4  (i)=  C4(i)  –  1,
Restore1=1}
                         else        {Cw4(i)    =    C4(i)    ,
NoRestore=1}}
else    {if  (W'(i)=1)    then    {C  w4(i)=  C4  (i)  +  1,
Restore2=1}
                        else  {Cw4 (i)= C4(i) , NoRestore=1
}}
                        }
if  (C4(i) < 0  )  then { If  (abs(C(i)) mod  2=1)
then  {if  (W'(i)=0)    then    {Cw4(i)  =  C  (i)  +  1,
Restore3=1}
                        else {Cw4 (i)= C4(i) , NoRestore=1
}}
else  {if    (W'(i)=1)    then  {  Cw4(i)  =  C(i)  –  1,
Restore4=1}
                        else {Cw4(i) = C4(i) , NoRestore=1
}}
                             }
}
```

Concerning the values of C_{11}, they are transformed to even or odd values depending on the modifications that the coefficients of C_4 have undergone. The coefficient C_4 (i) is then restored if it has been changed unless C_{11} (i) was initially equal to 0. The corresponding algorithm is the following:

```
if  (k=11) then
{
if (NoRestore = 1 and C11(i)> 0) then
{ if (C11(i) mod 2 =0 ) then  Cw11(i) = C11(i),
                              else  Cw11(i) = C11(i) - 1 }
if (NoRestore = 1 and C11(i)< 0) then
{if (abs(C11(i)) mod 2 =0) then Cw11(i) = C11(i) ,
                                 else Cw11(i) = C11(i) + 1}
if (Restore1 = 1 or  Restore2 = 1 or Restore3 = 1
 or Restore4 = 1)  then
{
if ((C11(i)) > 0)  then
 { if (C11(i)  mod 2 =1 ) then Cw11(i) = C11(i),
                              else  Cw11(i)= C11 (i)- 1 }
if ((C11(i))  < 0)  then
```

{ if (abs(C_{11}(i)) mod 2 =1) then Cw_{11}(i) = C_{11}(i) ,
else Cw_{11}(i)= C_{11} (i)+ 1}
}

if (Restore1=1 or Restore4=1) then Cw_4(i) = Cw_4(i) +1
if (Restore2=1 or Restore3=1) then Cw_4 (i)= Cw_4 (i)-1
}

For the detection stage, the coefficients C_4(i) and C_{11}(i) are first extracted. The even values of C_{11} correspond to the cases where the watermark bits didn't introduce a modification in C_4 or they may be a modification in case C_{11}(i)=0, in this case the watermark bit corresponds to the LSB of the coefficient C_4(i). For odd values of C_{11}, the watermark bit corresponds to the complement of the LSB of the coefficient C_4(i). The corresponding algorithm is:

for i=0 to N do
{
if (abs(Cw_{11} (i)) mod 2 = 0)) then
{if (abs(Cw_4 (i)) mod 2 = 0) then W'(i)=0 else W'(i)=1 }
if ((abs(Cw_{11} (i)) mod 2 = 1)) then
{if (abs(Cw_4 (i)) mod 2 = 1) then W'(i)=0 else W'(i)=1 }
}

W is then deduced from W'. The 12 bits containing the additional information used for reconstructing the watermark (see section 3.1 and 3.2) are embedded in 12 blocks reserved for that aim, in low frequencies using the LSB method, and extracted using the expression:
if (abs(C_4(i)) mod 2 = 0) then W(i)=0 **else** W(i)=1.

4 RESULTS AND ANALYSIS

In this section we present the experimental results obtained by applying our watermarking proposal to various CIF video sequences including Walk, Bridge, Flower, Coast guard, Foreman (with Siemens logo) and Container. Using the base-line profile, the first 50 frames of the video clips are coded at the quantizer parameter (Qp=28), at a frame rate of 30 pictures/s. The proposed watermarking algorithm has been integrated into the H.264 JM reference software.

The watermark used for tests is a pseudo random binary sequence which is embedded only in the first frame (Intra coded frame) of the video clip. The objective is to assess the impact of the watermark embedding on the video quality and the bitrate. Results corresponding to the embedding capacity, the average of PSNR of 50 frames and the bitrate are tabulated in table 1.

The embedding capacity depends on the picture content and the choice of the coefficients used for embedding the watermark (C_4 in our case). It varies between 174 and 1484 bits/ I frame corresponding to sequences of Foreman and Flower respectively. We recall that in this embedding capacity there are about 12 bits reserved to carry information about the watermark (such as the rotation dimension, the embedding formula) and are necessary for its recovery; this is why it is important to ensure that the remaining embedding capacity is enough for the application.

In table 1 is also reported the average of PSNR of the 50 coded frame of the test sequences. The reduction in PSNR varies between 0.73 and 3.38 dB corresponding to Flower and foreman respectively.

However, for all the test sequences, the subjective quality is preserved and maintained throughout the frames as presented in an example of the PSNR graph of Bridge sequence in figure 4. Figure 5 shows three examples of unwatermarked I frames and the corresponding watermarked frames.

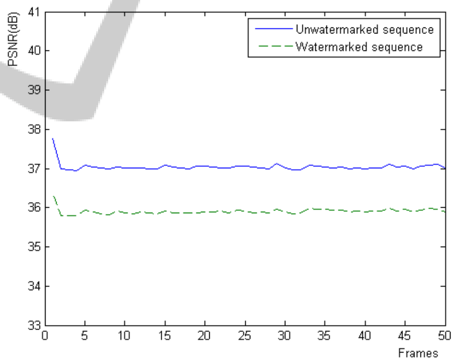

Figure 4: PSNR of unwatermarked and watermarked Bridge sequence.

Regarding the bitrate, it is maintained or reduced in most of cases and the most important reduction in bitrate is 0.91 kbit/s observed for Flower sequence.

This was expected because of the formula used to transform the odd values of C_{11} to even values. Indeed, the reduction of the coefficients "$C_{11}(i)= \pm 1$" to the value "0" is responsible of this reduction of the bitrate. Fortunately, it was possible to maintain the video quality because the number of the significant coefficients of C_{11} remains limited and both of the coefficients of low and high frequencies were involved in the embedding process.

The proposed scheme may be considered as a semi fragile one because the watermark is being embedded during compression it is not easy to erase it from the video stream and preserve the file content. Indeed any attack of the stream would cause an error in the decoding stage. However, if the watermarked video stream is decoded and re-encoded the watermark is lost which wouldconstitute a proof of the file manipulation while checking the authenticity.

Table 1 : The PSNR, the bitrate and the embedding capacity of the test sequences.

Sequences / Embedding Capacity (Bits /I frame) a. Unwatermarked seq. b. watermarked seq.		Average PSNR (dB) of 50 frames	Bitrate (kbits/s)
Walk / 295	a	39.05	1111.15
	b	36.41	1111.15
Bridge / 301	a	37.04	515.65
	b	35.90	515.44
Flower / 1484	a	36.63	1457.63
	b	34.78	1456.67
Coast guard / 315	a	38.33	1339.66
	b	37.54	1339.65
Foreman / 174	a	39.65	365.02
	b	36.27	364.84
Container / 457	a	39.02	186.43
	b	36.91	186.30

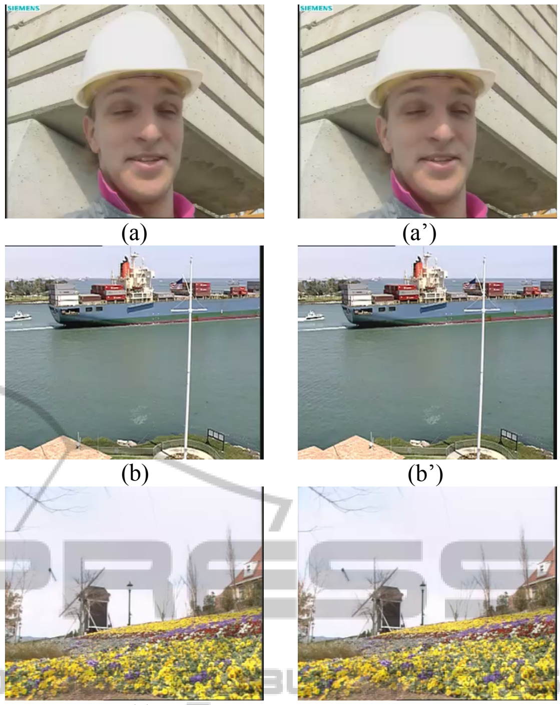

Figure 5: (a), (b) and (c) are the I frames of the unwatermarked sequences of Foreman, Container and Flower respectively and (a'), (b') and (c') are the corresponding watermarked frames respectively.

5 CONCLUSIONS

This paper describes a video watermarking method applied to the video codec H.264/AVC. The objective was to embed data in the video with the necessary amount of information for the video authentication. The watermarking process should preserve the video quality and reduce the bitrate which would constitute a boon for network applications.

The proposed method combines between the use of low and high frequencies to achieve a good compromise between the embedding capacity, the video quality and the bitrate. A watermark preprocessing helps considerably in improving the video quality.

Promising results have been obtained, however, while preserving this bitrate and quality, it would be interesting to increase the embedding capacity exploiting additional DCT coefficients and involving the P and B frames in the watermarking process. It is in this sense that our future work will focus.

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