Adaptive Blind Watermarking Algorithm Using Biased-Shift of Quantization Coefficient

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Abstract: In this paper, we proposed a blind watermarking algorithm to use characteristics of a scalar quantizer which is similar with the recommended in the JPEG2000 and JPEG. This algorithm shifts a quantization index according to the value of each watermark bit to prevent losing the watermark information during the compression by quantization. Therefore, the watermark is embedded during the process of quantization, not an additional process for watermarking, and adaptively applied as an assigned quantizer according to application area. In the embedding process, a LFSR(Linear feedback shift register) is used to hide the watermarking positions. Therefore the embedded watermark can be extracted by only the owner who knows the initial value of LFSR without the original image. The experimental results showed that the proposed algorithm satisfies the robustness and imperceptibility corresponding to the major requirement of watermarking.

Keyword: Watermarking, Quantization, JPEG, JPEG2000, MPEG, Blind

1. INTRODUCTION

As watermarking technique has developed, application area about the watermarking has been transferred from the frequency domain to the spatial domain. The watermarking applied in the frequency domain has better robustness against attack, but there is a drawback that can not correctly choose the frequency element for watermarking, which is the position to be embedded by the watermark. The watermarking applied in the frequency domain embeds the watermark into the frequency coefficient by means of changing the value. Cox[1] and Barni[2] proposed a watermarking algorithm to embed the watermark into the frequency domain based on the DCT(Discrete cosine transform) after selecting the significant coefficient as the mark-space that is the position selected for embedding the watermark. Xia[3] and Hsieh[4] also proposed a method which uses the multi-resolution property of the DWT(Discrete wavelet transform). Since the spatial information as well as the frequency information can be used in the DWT domain, the research for the watermarking in the DWT domain has been increased. As the JPEG2000 standard also has been widely used, the relative researches have been increased[5].

This paper proposes a watermarking algorithm which uses characteristic of scalar quantization. The proposed algorithm is executed during the process of quantization which is generally used for the lossy compression in the JPEG or JPEG2000 standard. The proposed watermarking algorithm minimizes the quality degradation of a watermarked image by limiting the variance of a coefficient within a half of a quantization step size. Since the watermarking is executed without the special step for calculation during quantization, it is possible to minimize the delay time and embed/extract a watermark by real-time. From these properties, the proposed algorithm can be blindly extracted without an original image.

2. PROPOSED WATERMARKING ALGORITHM

Since the image and the video are generally used as a compressed form in almost application, one must consider the information loss of the image and video to be compressed during the compression process. The main reason is to quantize coefficients, which corresponds to an essential tool for lossy compression. Therefore our research deeply considers the relationship between quantization and watermarking and, proposes an adaptive blind watermarking algorithm from it.

The quantization in the JPEG and JPEG2000 which are international standards for the still image is a lossy compression process which is executed by dividing the coefficient with the quantization step size. The equation (1) and (2) show the quantization process for the JPEG and JPEG2000 respectively.

$$q_b(u,v) = round\left(\frac{a_b(u,v)}{\Delta_b(u,v)}\right) \quad (1)$$

$$q_b(u,v) = sign(a_b(u,v)) \cdot \left\lfloor \frac{|a_b(u,v)|}{\Delta_b} + 0.5 \right\rfloor \quad (2)$$

2.1. Watermark Embedding

The proposed watermarking algorithm uses the biased shift of a quantization coefficient(or index) with the watermark value and the mark-space. Before embedding the watermark, we scatter the watermark itself for the safety of it.

In this paper, we use the 32-bit LFSR which has the property of primitive polynomial in the equation (3), and represent the rearrange algorithm of the watermark using the LFSR in Fig. 1.

$$P(x) = x^{31} + x^{22} + x^2 + 1 \quad (3)$$

```
procedure{Watermark_Mix}
input: m×n original watermark
output: m×n mixed watermark
begin
initialize LFSR with a key(key_LFSR);
for i=1 to m×n {
  LFSR(i)=(z0..zj-1, zj..zk-1);
  w(xi, yi)=wi;
}
end(Watermark_Mix)
```

Fig. 1. Rearrangement algorithm for watermark data

The proposed embedding algorithm for watermarking does not always round the quantization coefficient divided by a step size of the quantizer, and the selected coefficient shifts into a lower or an upper integer by the proposed embedding condition as shown in Fig. 2. Thus the watermarking is simultaneously operated with the quantization step. If the LSB(Least significant bit) of a quantization coefficient is '0', the watermarking works by the equation (4) and (5) according to the corresponding a bit information(ω in the equation (4) and (5)) of the watermark.

$$a_b(u,v)' = sign(a_b(u,v)) \cdot \left\lfloor \frac{|a_b(u,v)|}{\Delta_b} \right\rfloor \times \Delta_b \quad (4)$$

$$a_b(u,v)' = sign(a_b(u,v)) \cdot \left\lceil \frac{|a_b(u,v)|}{\Delta_b} \right\rceil \times \Delta_b \quad (5)$$

In Fig. 2, The $a_b(u,v)$ is a quantized index of a quantization coefficient, the $a_b'(u,v)$ is a watermarked index, and the $_b$ is a step size of the scalar quantizer.

In this paper, considering the co-operation with a real-time codec which compresses or reconstructs the video or image, we propose the relatively simple algorithm with the minimal delay time for deciding the watermarking position. We additionally use the algorithm depicted in Fig. 1 for the security together with the selection algorithm of the mark-space. According to the following rules, the mark-space is chosen.

1) After selecting a value, k among the parallel output of the LFSR, the watermark is embedded into the $(k+1)_{th}$ position from the current quantization index.

2) A sequence is selected from the serial output of the LFSR, and the watermarking works in the corresponding position which has the value of '1'.

After combining the watermark rearranging algorithm with the watermark positioning algorithm, we show the proposed algorithm for the watermarking embedding in Fig. 3. In this figure, the $LFSR_p(j)$ represents the j_{th} position by the serial output from the current position P, and the w_i represents the i_{th} position of the watermark bit.

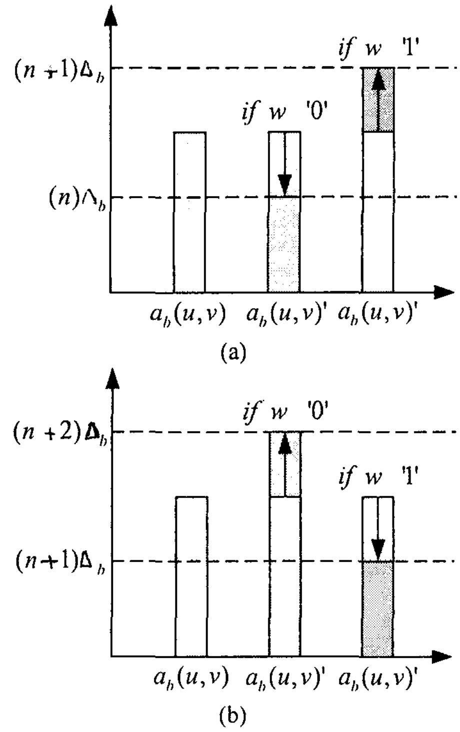

Fig. 2. Watermark embedding; (a) the case of LSB([$a_b(u,v)/b$])='0', (b) the case of LSB([$a_b(u,v)/b$])='1'.

```
procedure{Watermark_Embedding}
begin
  initialize LFSR with a key(key_embed);
  j=0;
  for (i=1 to m×n){
    if LFSR_p(j)= '1' then
      if(LSB([a_b,i(u, v)/b])='0') then
        if(wi=0) then
          embed wi by eq.(4);
        else
          embed wi by eq.(5);
      if(LSB([a_b(u, v)/b])='1') then
        if(w=0) then
          embed wi by eq.(5);
        else
          embed wi by eq.(4);
        j=j+1;
    else
      j=j+1;}
end {Watermark_Embedding}
```

Fig. 3. Watermark embedding algorithm

2.2. Watermark Extracting

The decision method for the extracted watermark is in Fig. 4. If the extracted watermark bit belongs to the even step of quantization, the corresponding watermark bit has '0', otherwise it has '1'. In this process, the extracted watermark bit w_i' is rounded and is analyzed by the equation (6). Finally we obtain the extracted watermark bit w_i''. The proposed algorithm for watermark extracting is represented in Fig. 5.

$$w_i'' = \begin{Bmatrix} 0, if (2n-1/2)\Delta_b \le w_i' < (2n+1/2)\Delta_b \\ 1, if (2n+1/2)\Delta_b \le w_i' < (2n+3/2)\Delta_b \end{Bmatrix} \quad (6)$$

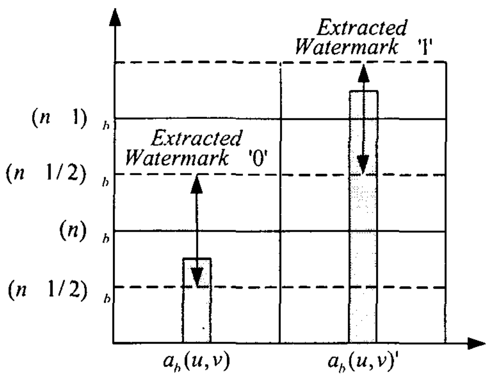

Fig. 4. Watermark extraction method

The watermark extracting algorithm is inversely the same process as the embedding algorithm.

```
procedure {Watermark_Extraction}
begin
 initialize LFSR with key_embed;
 j=0;
 for (i=1 to m×n){
   if (LFSR_p(j)='1') then
     if ([(a_b(u,v)'+b/2)/b)]=even) then
       w_i''= 0 by eq. (6);
     else
       w_i'' =1 by eq. (6);
     j=j+1;
   else
     j=j+1; }
 initialize LFSR with key_LFSR;
 for (i=1 to m×n){
   LFSR(i)=(z_0...z_{j-1}, z_j...z_{k-1});
   w_i=w_i''(x_i, y_i); }
 form to n×m 2-dimensional image
End {Watermark_Extraction}
```

Fig. 5. Watermark extraction algorithm

3. APPLICATION OF WATERMARKING

Since the proposed algorithm uses the properties of the coefficient in the frequency domain of the DCT or DWT and accomplishes the watermarking during scalar quantization, it can be applied into the JPEG and JPEG2000 standard without any modification. The proposed algorithm also has automatically the adaptive property for each image or application because it uses a previously defined quantizer which has the large or small step size as the application.

3-1. JPEG

For obtaining much robustness for watermarking based on DCT domain, DC region which is less sensitive to the general change of frequency is the good candidate. So we apply the proposed watermarking into the DCT coefficient of the DC region during quantization. The quality degradation of an image rarely occurs by the watermarking worked in the DC region.

The proposed algorithm does not execute the watermarking by directly embedding a watermark into the DC coefficient, and it uses the property of the quantization coefficient. Therefore the quality degradation about the watermarked image is very small. Therefore we can obtain the robustness and good image quality after watermarking in the JPEG.

3-2. JPEG2000

For watermarking in the JPEG2000, the candidate subband for watermarking must be selected by estimating the error ratio according to the robustness about the subbands. Table 1 shows the result for the robustness of each subband. This experiment was executed with the 500 test images after the 4-level DWT.

As shown in Table 1, the subband HH4 has the most degradation, and the next is HL4. The subband LH4 is the most robust among all the subbands except LL4. Therefore we select LH4 as a mark-space and apply the proposed watermarking algorithm into the coefficient of LH4 during quantization in JPEG2000.

Table 1. Subband robustness in JPEG

JPEG Quality	Error Ratio (%)			
	LL4	LH4	HL4	HH4
12	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.5
8	0.0	0.3	0.3	20.9
6	0.0	3.6	3.3	34.3
4	2.9	23.8	24.7	55.5
2	1.6	43.0	48.8	69.2
0	36.7	58.2	65.4	76.1

4. EXPREMENTAL RESULTS

The proposed algorithm in this paper experimented with C++ language in Pentium IV 2.0GHz CPU. For the test of our watermarking algorithm, we used the 500 gray-scale images of 512×512 sizes. In this section, for example we explain the result about the Lena image which has evenly the low and high frequency component. The watermark was used a binary image of 32x32 size which has a special logo for visual confirmation after extracting the watermark. The PSNR(Peak signal to noise ratio) was used for invisibility estimation, and robustness against attack in image such as the JPEG compression, gaussian noise addition, sharpening, blurring, and cropping was measured by counting the number of the error bit and identifying the extracted watermark image after extracting process visually.

In Table 2, we show the error ratio of the extracted watermark after compressing the watermarked image by the JPEG and JPEG2000. Fig. 6 also shows the image results of the JPEG2000 watermarking. In this figure, one can rarely find the degradation in the watermarked Lena image.

We showed the excellent property of the proposed watermarking algorithm by comparing with the algorithm previously proposed by Mohamed[5] which is the most similar with our algorithm among previous researches. In Table 3, we attacked a watermarked image using the JPEG and JPEG2000 standard, and estimated the error ratio from the extracted watermark. The results showed the largest error rate to be 5.7% for attack, and the experimental result which compares the proposed algorithm with the Mohamed's algorithm showed that the proposed algorithm was better than it, exactly 4~5 times for the attacks of the JPEG and JPEG2000. From the results, it was identified for our algorithm to has more robustness then Mohamed[5].

Table 2. Error ratios resulting from various attacks for JPEG and JPEG2000 watermarking

Attack			Error Ratio(%)	
	JPEG	J2K	JPEG	JPEG2K
JPEG Quality(%)	40	60	0	0
	20	40	0	0
	0	20	0	0.8
JPEG2000 (bpp)	1		0.3	0
	0.5		0.3	0
	0.25		0.7	0
Gaussian Noise (%)	3		3.5	1.7
	5		5.5	4.3
Sharpening			2.2	0.7
Blurring			2.7	1.3
Cropping(%)	10		1.5	1.5
	15		3.2	3.8
	20		5.7	5.0

Table 3. Comparison to Mohamed's scheme

Attack		Error Ratio(%)	
		Mohamed's	Ours
JPEG Quality (%)	60	0	0
	40	1	0
	20	4	0.8
JPEG2000 (bpp)	0.5	0.5	0
	0.4	0.7	0
	0.2	14	3.5

5. CONCLUSION

In this paper, we proposed an adaptive blind watermarking algorithm based on linear and scalar quantization which is recommended in the JPEG and JPEG2000. The watermarking is executed by shifting a quantization coefficient or index during compression process by quantizer. The proposed algorithm has good invisibility for the watermarked image and shows the robustness against the various attacks such as sharpening, blurring, gaussian noise addition, and cropping.

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(a)

(b)

Fig. 6. JPEG2000 watermarking example for Lena image; (a) before, (b) after watermarking.