Digital Image Watermarking Scheme using Adaptive Block Division

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Abstract: Digital image watermarking scheme using adaptive block division is proposed. To increase the perceptual invisibility, the image is divided into blocks by local properties and the human visual system (HVS), then the significant blocks are selected in the divided blocks. The significant coefficient is determined by Weber's law in these blocks. To increase the robustness, low frequency domains of the discrete cosine transform (DCT) and the discrete wavelet transform (DWT) are used. The watermark is embedded into the selected significant blocks of the DCT's and DWT's low frequency domains with adaptive watermark strengths. The watermark strength is determined by the variance and the local properties of the significant block. The experimental results prove that the proposed scheme has a good robustness against several image processing operations (e.g. median filtering, cropping, scaling, JPEG, JPEG2000, etc.) without significant degradation of the watermarked image.

1. Introduction

As the digital image technology and its applications are growing fast, digital images are now widely distributed on the Internet and other media. And the copyright-protection of digital image is more necessary against pirating. As the solution of this problem, a digital watermark technology is the general method for the copyright-protection of digital data.

In general, a digital watermarking technique has to satisfy two properties; perceptual invisibility and robustness. Though the original image is watermarked, the image should not be distorted visually, and should be perceptually invisible. And the watermark should be difficult to remove. The former is perceptual invisibility and the later is robustness of digital watermark technique. These properties have trade-off one.

Until now, there are many watermarking schemes have been proposed. To preserve the perceptual invisibility and the robustness of the watermark, these techniques embed the watermarks in spatial domain or frequency domain, such as DCT [1], [2] and DWT [3]-[5]. In recent years, almost techniques embed the watermark in the frequency domain, because the frequency domain methods have a better robustness than spatial domain. DCT is standardized in JPEG which is a widely used compression format. And JPEG2000, the new generation compression standard, is based on DWT.

In this paper, we propose the adaptive block division scheme for digital image watermarking using low frequency domains of DCT and DWT. For the perceptual invisibility, the image is divided into blocks according to its local properties and the HVS, then the significant blocks are selected in the divided blocks. To get more robustness against attacks (e.g. median filtering, cropping, scaling, JPEG, JPEG2000, etc.) without significant degradation of the watermarked image, we embed the watermark in the low frequency domains of DCT and DWT. The low frequency domain has the almost energy of the image. So a small change of this band induces the serious degradation of the watermarked image. Therefore, invisibility and robustness are considered simultaneously in the watermark embedding process. To accomplish these properties, the original image is divided into adaptive blocks using region split algorithm [6] and the significant blocks are selected among these blocks by each block properties. And the selected significant blocks are transformed using DCT or DWT. Binary pseudo random sequence is used for watermark signal and bi-directional coding [7] is used for watermark embedding. These watermarks are embedded in the low frequency domains of the wavelet decomposition and the dc component of the DCT according to its block properties. Therefore, this proposed scheme achieves good robustness of image watermarking without image degradation.

Following sections explain the proposed watermarking algorithm. Section 2 briefs the adaptive block dividing process. Section 3 explains the watermark embedding. Section 4 explains the watermark retrieval. Section 5 shows the experimental results. And the conclusion of the paper is in section 6.

2. Adaptive Block Division

The watermarking methods in recent years embed the watermark into the whole image or the sub-blocks of the transform domain according to the HVS without local properties of the image. But most images have different local properties, so these properties need to be considered for watermarking technique.

According to the human visual system, human eye is more sensitive to change in simple region of image than complex region. Using this property, we proposed enhanced watermarking method using adaptive block dividing.

As shown in Figure 1, the original image is divided into significant blocks. Firstly, the original image is divided into 64×64 sub-blocks. According to the local property, each sub-block is divided into more small blocks such as 32×32, 16×16, 8×8. In this processing, the significant block is determined by the block variance and mean. The block variance V_k is calculated by equation (1).

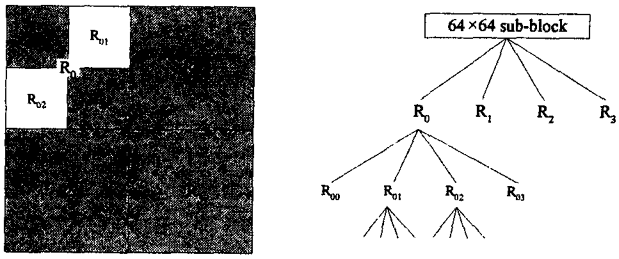


Figure 1. Block division structure and quadtree representation.

The proposed algorithm uses region split algorithm for image dividing. Adaptive block dividing process is performed as:

Step 1. Entire image is divided into 64×64 sub-blocks.

Step 2. For each 64×64 sub-block do Step 3~Step 4.

Step 3. Calculate the block variance and mean.

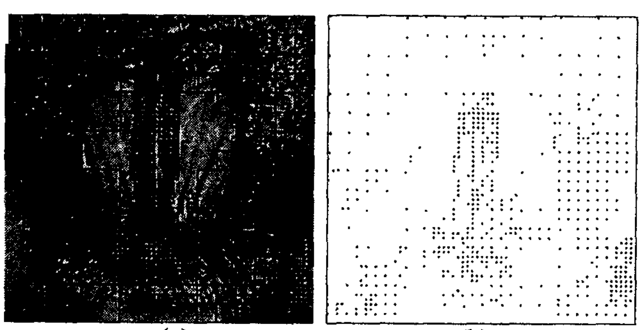
Step 4. If the calculated variance V_k and mean μ_k are higher than certain threshold V_{th} and μ_{th} or the divided block size is the minimum 8×8 block size, then the split process is stop. Otherwise the blocks are divided continuously.

Step 5. Repeat Step 3~Step 4 for each sub-block.

$$V_k = \frac{\sum_{i=1}^{n} (\mu_k - x_k(i))^2}{n-1} \qquad (1)$$

where

- k is the number of the block.
- μ_k is the mean of the block.
- n is the number of pixels in the block.
- x_k is the i-th pixel in the block.



(a) (b)

Figure 2. Divided Significant Blocks and Coefficients (a) Significant Blocks (b) Significant coefficients.

After this process, the image is divided into significant blocks such as 64×64, 32×32, 16×16 and 8×8, as shown in Figure 2 (a).

3. Watermark embedding

After block dividing, watermark is embedded into each significant block. Embedding process consists of several operations as in Figure 3. Firstly, each significant block is transformed using DCT or DWT. If the block size is 64×64 and 32×32, the block is transformed using DWT with 4-level and 3-level. And 16×16 and 8×8 blocks are transformed using DCT. In the 16×16 and 8×8 blocks, 3-level DWT or more level is not efficient. Therefore, these blocks are transformed using DCT. In the 64×64 and 32×32 blocks, DCT is not efficient transform because DCT has some problems like the blocking effect. But in small size block, this problem is solved using HVS.

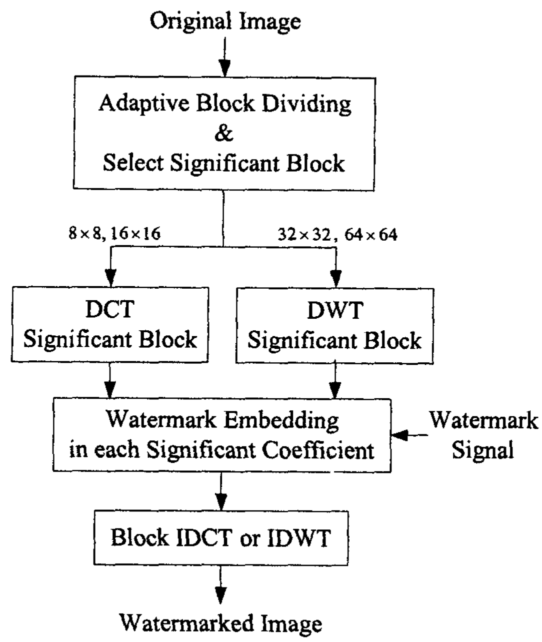


Figure 3. Watermark Embedding Process.

In the most proposed methods using DCT or DWT, the watermark embedded in the high frequency domain. When the watermarked image is attacked, the individual pixel's value or coefficient maybe changes a lot and the watermark cannot be successfully retrieved. The low frequency domain has a good robustness against attacks. In our method, the watermark is embedded in the low frequency domain. But low frequency domain has a weak invisibility for change. The watermark is embedded only into the significant coefficient, which is selected by HVS.

The significant coefficient (SC) is the DC component in DCT applied block. As shown in Figure 4, in DWT applied block, the significant coefficient is selected using Weber's law in base-band.

Weber's law, simply stated, says that the size of the just noticeable difference is a constant proportion of the original stimulus value as in equation (2). According to Weber's law, k is constantly 0.016 under the ordinary light intensity I.

$$\frac{\Delta I}{I} = k = 0.016 \tag{2}$$

The coefficient, which has minimum SC_{th}, is selected as significant coefficient as equation (3).

$$SC_{th} = \left| \frac{|C'(i,j) - C(i,j)|}{C(i,j)_{mean}} - k \right| \tag{3}$$

where $C'(i,j)$ and $C(i,j)$ have same meaning with equation (4) and $C(i,j)_{mean}$ is the mean value of the $C(i,j)$ in the base-band.

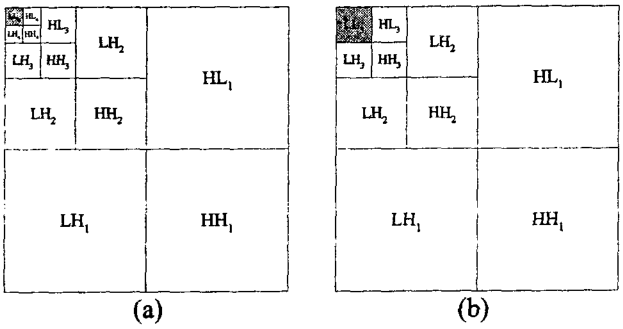


Figure 4. Watermark Embedding Region in (a) 64×64 significant block (b) 32×32 significant block.

Binary pseudo random sequence is used for watermark signal w_k and bi-directional coding is used for watermark embedding. The watermark embedding process is performed as follows [7].

If $w_k = 0$,

$$C'(i,j) = C(i,j) + \alpha \times C(i,j) \times \log V_k \tag{4}$$

If $w_k = 1$,

$$C'(i,j) = C(i,j) - \alpha \times C(i,j) \times \log V_k \tag{5}$$

In equation (4) and (5), $C(i,j)$ and $C'(i,j)$ mean significant coefficient of transformed block and those are corresponding watermarked coefficient respectively. The α means the watermark embedding strength and the V_k means the block variance in equation (1). Using this equation the watermarking is adaptively achieved by the block properties.

4. Watermark Retrieval

Watermark retrieval method is performed in the following manner. Original image is used for watermark retrieval. As in the embedding process, original image and watermarked image are divided by adaptive block division method in Section 2. And these divided blocks are transformed using DCT or DWT. In this step, original watermark is not necessary. But in the calculating matching ratio (MR), original watermark is necessary. Watermark retrieval is done as following equation (6).

Retrieved watermark w'_k is

$$\begin{cases} 1 & \text{if} \quad |C'(i,j)| > |C(i,j)| + \beta \times |C(i,j)| \times \log A_k \\ 0 & \text{if} \quad |C'(i,j)| < |C(i,j)| - \beta \times |C(i,j)| \times \log A_k \end{cases} \tag{6}$$

where β is smaller than α.

5. Experimental Results

In the experiment, several 512×512 still images were used. After the embedding process, the peak signal to noise ratio (PSNR) of watermarked image without any attack is about 48 dB and the watermark can be retrieved above 99% perfectly. As shown in Figure 5(b), there is no visible degradation in the watermarked image. Figure 5 shows the retrieval response MR to 1000 random watermark sequence. In this figure, the MR is the highest value (1.000) only for embedded watermark and about 0.500 for other binary random sequence. Because the embedded watermark is binary random sequence, it is natural that other sequences have about 0.500 for retrieval response.

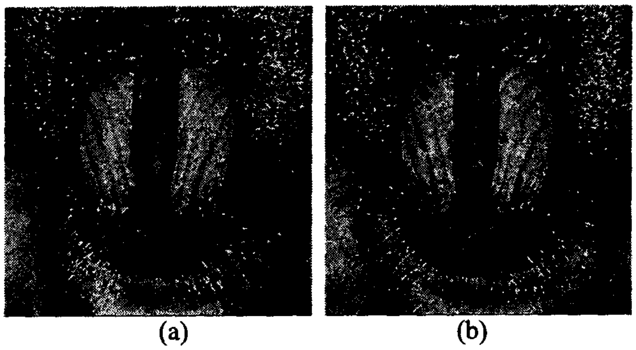


Figure 5. Comparison of original image and watermarked image (a) Original image and (b) Watermarked image.

In the following figures and tables, the retrieval responses MR is shown the robustness of our proposed scheme after several attack such as low pass filtering, median filtering, cropping, scaling, JPEG and JPEG2000 compression. These attacks are widely used for robustness of watermarked image. Especially, JPEG is a widely used compression format.

Scaling is very easily performed in the editing of digital image. We test our algorithm in the case of scaling the watermarked image by 0.25×0.25, 0.25×0.5, 0.5×0.5, 0.5×0.6, 2×2 and 2×3 respectively. The experiment results shown the watermark can still be retrieved as shown in Table 1. A lot of digital images are used in the Internet by JPEG compression and the default quality factor is 75%. In the case of JPEG compression with quality factor 50%, the watermark can survive successfully as shown in Table 2 and the MR is above 0.900. JPEG2000 is the new generation compression standard, which is based on DWT. In our experiments, we tested the watermarked image with JPEG2000 compression using Power Compressor [8].

When the compression ratio is 5:1, 10:1 and 20:1, the retrieval response is shown in Table 2.

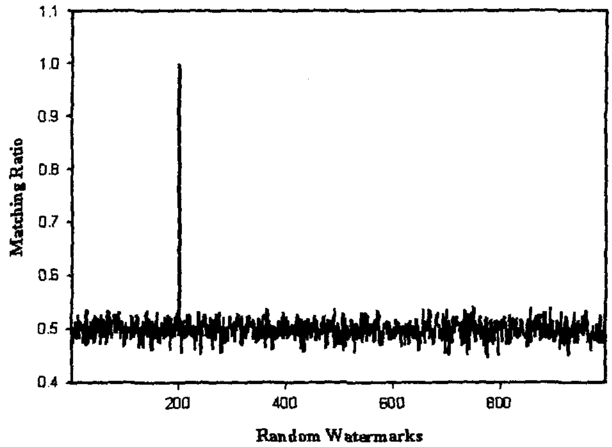


Figure 5. Retrieval response (Matching Ratio) to 1000 randomly generated watermarks (1.000).

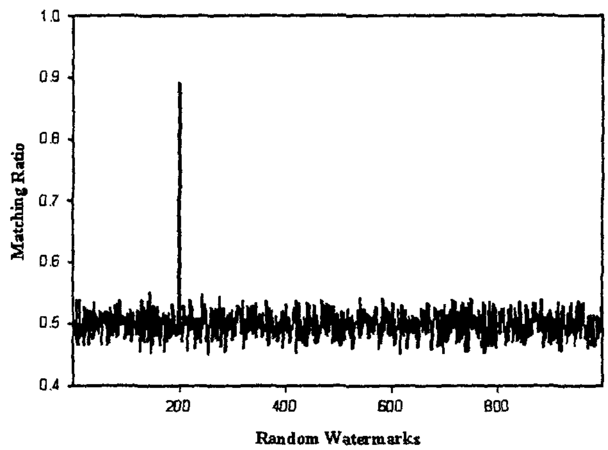


Figure 6. Retrieval response for watermarked image after 3×3 median filtering (0.892).

Table 1. Retrieval response under Image Processing.

Attack \ Image	Baboon	Lena	Man	Goldhill
PSNR(dB)	47.71	49.46	49.91	49.09
3×3 LPF	0.964	0.972	0.971	0.946
3×3 Median	0.892	0.981	0.979	0.946
50% Cropping	0.677	0.625	0.673	0.621
0.25×0.25 Scaling	0.891	0.908	0.897	0.866
0.25×0.5 Scaling	0.946	0.972	0.965	0.956
0.5×0.5 Scaling	0.998	0.997	0.991	0.992
0.5×0.6 Scaling	0.998	0.997	0.994	0.993
2×2 Scaling	1.000	0.994	0.994	0.995
2×3 Scaling	0.995	0.994	1.000	0.992

Table 2. Retrieval response under Image Compression.

Attack \ Image	Baboon	Lena	Man	Goldhill
JPEG 70%	1.000	1.000	0.997	0.995
JPEG 50%	0.998	0.992	0.994	0.988
JPEG 30%	0.905	0.919	0.920	0.903
JPEG 20%	0.851	0.797	0.864	0.834
JPEG 10%	0.705	0.686	0.717	0.728
JPEG2000 5:1	0.943	0.986	0.994	0.986
JPEG2000 10:1	0.828	0.983	0.950	0.949
JPEG2000 20:1	0.707	0.900	0.829	0.866

6. Conclusions

New algorithm for digital image watermarking using adaptive block division has been proposed. Original image is divided into significant blocks by the block property. The watermark is embedded into these significant blocks, which is transformed using DCT or DWT. To select the significant coefficient among these low frequency domain, we consider the block property and Weber's law. This achieved the good robustness though the watermarked image has greater invisibility. We have also shown that the proposed algorithm has more PSNR than recent methods.

References

[1] I. J. Cox, I. Kilian, T. Leighton, and T. Shamoon, "Secure spread spectrum watermarking for multimedia," *IEEE Trans. on Image Processing*, vol. 6, no. 12, pp. 1673~1687, Dec. 1997.

[2] A. Piva, M. Barni, F. Bartolini, and V. Cappellini, "DCT-based watermark recovering without resorting to the uncorrupted original Image," *IEEE Int. Conf. on Image Processing*, vol. 1, pp. 520~523, 1997.

[3] C. I. Podilchuk and W. Zeng, " Image adaptive watermarking using visual models," *IEEE Trans. on Selected Areas of Communications*, vol. 16, no. 4, pp. 525~539, May 1998.

[4] R. Dugad, K. Ratakonda, and N. Ahuja, "A new wavelet-based scheme for watermarking images," *IEEE Int. Conf. on Image Processing*, vol. 2, pp. 419~423, 1998.

[5] A. Lumini and D. Maio, "A wavelet-based image watermarking scheme," *Proc. of Int. Conf. on Information Technology: Coding and Computing*, pp. 122~127, 2000.

[6] I. Pitas, "*Digital Image Processing Algorithm.*" Prentice Hall International Ltd., 1993, pp. 254~297.

[7] C. H. Lee, H. W. Oh, Y. J. Beak and H. K. Lee, "Adaptive digital image watermarking using variable size of blocks in frequency domain," *Proc. of IEEE Region 10 Conf. on TENCON 99*, vol. 1, pp. 702~705, 1999.

[8] http://www.imagepower.com