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강건한 워터마킹을 위한 최적 부대역 결정

Optimal Sub-bands Decision for Robust Watermarking

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요 약

본 논문에서는 퍼지추론을 이용하여 워터마크가 삽입될 최적의 부 대역을 결정하는 방법을 기술하였다. 제안한 방법은 퍼지추론 및 대조도 등과 같은 인간의 시각시스템도 고려하였다. 먼저 시각시스템과 통계적 특성을 활용하여 최적의 계수 대역을 설정하였고, 외부환경 변화에도 대응할 수 있는 퍼지 추론기를 설계 하였다. 비가시성과 워터마크의 정확도를 실험한 결과, 대조도는 스므드 영상에서 우수하였고, 러프한 영상에서는 통계적 특성이 우수함을 보였다.

Abstract

This paper is concerned with fuzzy inference-based optimal sub-bands decision scheme which is to be embedded the watermark. It concentrated not only on design of fuzzy inference algorithm but also on human visual parameters (HVP), such as contrast sensitivity, texture degree. In the first, such human visual parameters as contrast sensitivity, texture degree as well as statistical characteristics are involved to select the optimal coefficients region. Secondly, fuzzy if - then rule which can be able to adapt the wide variety of environments is developed. The performance of proposed approach is evaluated with respect to the imperceptibility and correctness of watermark. According to some experimental results, contrast sensitivity function is superior in smooth image. On the other hand, statistical characteristics provide good results in rough images.

Key words : Watermark, Coefficient region, HVP, DCT

I. Introduction

Rapidly expansion of internet, lots of digital multimedia contents are distributed on-line. These multimedia contents are easy to be stolen, copied rapidly, perfectly by way of transmitting on network. Therefore, the copyright protection and enforcement of intellectual property rights for digital media has become an important issue. One of the faithful solutions and the most popular method is a digital watermark technology which is the practice of hiding a message into the digital media such as audio, image and video. Since the late 1990s, there are lots of related papers available in the technical journals, conference proceedings [1]-[5]. Applications of digital watermarking include owner identification, authentication, proof of ownership and copy control. Watermarking strategies divided into two major categories: transform-domain and spatial-domain

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approach. Transform-domain watermarking methods, also called multiplicative watermarks, such as Fourier transform, discrete cosine transform (DCT), discrete wavelet transform (DWT). The watermark is hidden in the middle or lower frequency band is more liable to be suppressed by compression. Therefore, for watermarking, how to select the best frequency band of the image is more important than any other procedures.

This paper has double-aim, in first to incorporate human visual system (HVS) into transform domain watermarking, in second to reduce the complexity of the fuzzy inference rules.

Ⅱ. Relations between HVP and DCT Coefficients

There are many requirements for a good-designed watermark such as robustness, imperceptibility, unambiguousness etc. Among all types of watermarks, two most common requirements for effective watermarking are required. It should be perceptually invisible, which means the watermark is not visible under typical viewing conditions. It should also be robust to common signal processing and intentional attacks. Spatial domain watermarking which process directly to the location and luminance of the image pixel is one of the fundamental methods in the beginning of digital watermarking researches. This method has the disadvantage that they tend not to be robust congenitally in spite of having simple and easy for implementation. In general, transform domain based approached are superior to that of spatial domain in preserving contents fidelity and robustness under attacks. In this scheme, three main steps should be specified: image transformation, watermark embedding and watermark recovery [6].

The HVP has identified by several phenomena which is related with spatial resolution, intensity resolution, and intensity sensitivity and so on. Let us discuss in more detail the characteristics of these visual properties of HVP which can be described in many terms. Contrast sensitivity means variance or difference of the pixel's brightness. The more contrast property the coefficients region has, the stronger the embedded watermark could be. Contrast sensitivity Cs can be expressed as

$$Cs = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \quad (1)$$

Where $I_{\max}$ and $I_{\min}$ denotes the maximum and minimum brightness for selected region, respectively.

The variance of the pixels in sub-image influence the texture, and texture sensitivity means the perceptibility of sine wave. The more complex the background is, the larger the watermark could be. Therefore, texture sensitivity Ts is calculated by DCT coefficients of an image. Namely, quantization results of the DCT coefficients are the same as integer and finally, Ts can be expressed by

$$Ts = \sum \{ rnd[X_k(x, y) / Q(x, y)] \} \quad (2)$$

Where $X_k(x, y)$ means the k^{th} DCT coefficients block and (x, y) refers to the location.

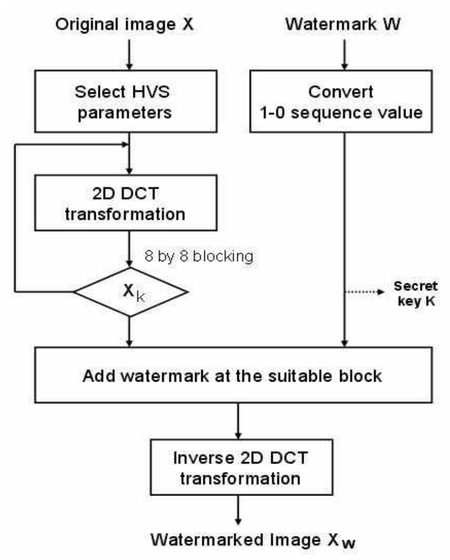
Entropy means the mathematical expectation of the information with respect to the occurrence of the events. When it comes to increase the entropy, watermarking region can be extended. Entropy sensitivity E_s can be defined as

$$E_s = \sum_{x,y=0}^{7} p_k(x, y) \log \frac{1}{p_k(x, y)}$$
$$p(x, y) = \frac{X_k(x, y)}{\sum_{x,y=0}^{7} X_k(x, y)} \quad (3)$$

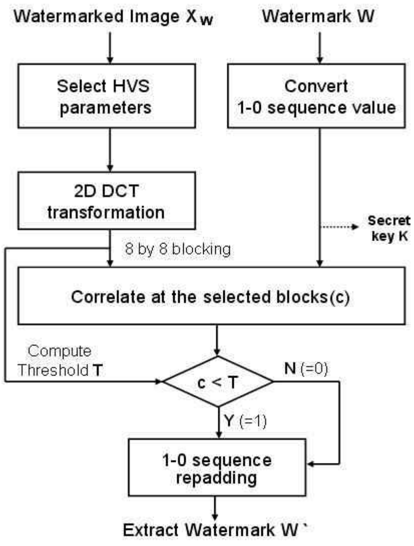
Not only these HVP but also statistical parameters such as average, standard deviation are also utilized to generate an effective watermarking. These functions are given by

$$Av_k = \left\{ \sum_{x,y=0}^{7} X_k(x,y) \right\} / size(X_k)$$
$$Std_k = \sqrt{\left\{ \sum_{x,y=0}^{7} (a(x,y) - Av_k)^2 \right\} / size(X_k)} \quad (4)$$

One of the main goals, in our approach, is to incorporate the HVP into the transform domain watermarking algorithm so as to select the optimal parameters due to the characteristics of original image. Proposed watermarking embedding and extraction process are shown in Fig. 1.



(a)



(b)

Fig. 1. Proposed watermark scheme: (a) watermark embedding, (b) watermark extraction

Ⅲ. Determining Optimal Sub-bands Using FI

The main issues of watermarking schemes focus on how to reserve imperceptibility as well as robustness by utilizing HVP. We have already reported some results related with watermark based on human visual parameters as well as statistical values [9].

One important feature of our algorithm is it's capability to adaptively calculate the watermark strength and the number of region to be watermarked. To solve these problems, in this approach, the fuzzy inference rules and membership functions were devised based on both characteristics of HVP and statistical parameters. These characteristic variables can be represented by a number of fuzzy-set values [8]. In order to design the adaptive fuzzy rule, we calculated the maximum tolerance range of each HVP due to environmental condition such as variation of background, unpredicted noise. Consequently, these tolerance ranges of each sub-band which are crisp set of coefficients data are converted into the fuzzified value, which can directly be used in membership function. Interpolative technique is also utilized so that we reduce the number of inference rules that is standard if-then inference based on the generalized modus pones inference paradigm.

Suppose that the following two rules with two-input and single-output variable are in the model regarding HVP and statistical values:

$Rule$ = {If Cs is ZE then HVP is NM
If Cs is NB then HVP is NM
If Ts is PZ then HVP is NS
If Ts is PS then HVP is NS}

These can be written in the more compressed linguistic form

$Rule$ = { If Cs is ZE or NB then HVP is NM
If Ts is PZ or PS then HVP is NS}.

Where, Cs and Ts are the input variables with respect to the contrast and texture sensitivity; HVP is the out variable; and ZE, NB, and NM are the triangular type membership functions in the fuzzy set. Consequently, we can expand or compress a fuzzy rule into a new model both in considering input and output variables [10].

In the preprocessing, test images are transformed into the coefficients matrix by using DCT. Thus, some feature parameters related with the characteristics, such as frequency distribution, angle distribution and that of translation are selected. In fuzzy inference module, the two of them organize an information interface (the fuzzification and defuzzification) linking the fuzzy inference module.

During the inference process, the inference system evaluates the contribution of each rule to the output computation by calculating an if-then rule. In this stage, the Mamdani operator is utilized to calculate the fuzzy composition operation, which is defined by

$$\Phi[\mu_A(j), \mu_B(k)] = \mu_A(j) \wedge \mu_B(k) \quad (5)$$

Finally, defuzzification phase translates the fuzzy output into a crisp value, which means the optimal sub-band to be used for watermark embedding. We used the center of gravity method that based on finding a balance point of a property that can be the total geometric figure of output. This function is calculated by

$$x = \frac{\sum_{i=1}^{N} x_i \mu_0(x)}{\sum_{i=1}^{N} \mu_0(x)} \quad (6)$$

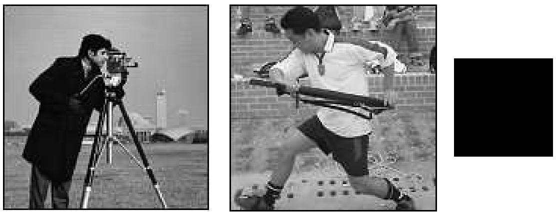
In our approach, two main stages including DCT pre-processing and fuzzy inference can be stated as follows:

Step 1. Definition:
DCTc: DCT coefficients, GDCTc: Group of DCTc,
MVoDCTc: Maximum variance of DCTc,
FIS: Fuzzy inference system
Sf: Similarity factor for FIS, Sw: Strong watermark, Ww: Weak watermark
/* stage for obtaining DCTc */
Step 2. Preprocessing
100 : Perform the 2D DCT
Step 3. while image block is not empty repeat
Step 4. Grouping DCTc into 3-level
Calculating MVoDCTc
Step 5. if MVoDCTc is larger than TH
goto 100
/* stage for fuzzy inference */
Step 6. Repeat step 7 - step 10.
Step 7. for each value of GDCTc applying FIS
given fuzzy association map
/* stage for embedding watermark */
Step 8. Find the defuzzification value.
Step 9. Find the Sf
Step 10. if Sf >then embedding a Sw
else Ww
Step 11.End of algorithm.

Ⅳ. Experimental Considerations

Experimental images are shown in Fig. 2. Each has a size of 256*256 and the gray level is 256, respectively. The watermark image is a binary image of size 32*32.

Several common numerical processing and geometric distortion were applied with respect the gray scale standard images.



(a) Cameraman (b) Youngman (c) Watermark

Fig. 2. Experimental images: (a) Cameraman, (b) Youngman, (c) Watermark

To evaluate the imperceptibility of the watermarked image, the peak signal-to-noise ratio (PSNR) is used. Assuming that the original image W and the watermarked image W\` both have image size N*M. The mean square error between W and W\` is defined as follow:

$$A = 255^2$$
$$B = \frac{1}{N \times M} \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} [W(x,y) - W'(x,y)]^2 \quad (7)$$

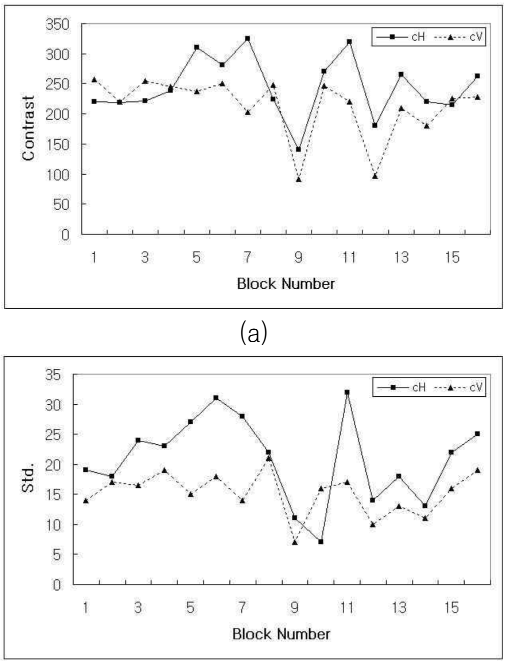
Consequently, PSNR can be calculated by Eq. (8)

$$PSNR = 10 \log_{10}(A/B)\,[dB] \quad (8)$$

For detection or verification, it needs to verify if a specific watermarking pattern exists or not. In this case, a correlation is often used for full extraction of the watermark. The correlation r between the embedded image and the original image, can be calculated by

$$r = \frac{\sum_m \sum_n (A_{mn} - \overline{A})(B_{mn} - \overline{B})}{\sqrt{\sum_m \sum_n (A_{mn} - \overline{A})^2 \sum_m \sum_n (B_{mn} - \overline{B})^2}} \quad (9)$$

Where A and B stand for the original image and embedded image, respectively, and $\overline{A}$ and $\overline{B}$ are the mean of the element of the each matrix (A) and matrix (B). We use Eqs. (1) and (4) to calculate the HVS parameter as well as statistic characteristics. Figures 3(a), 3(b) showing these HVS distribution corresponding to the each blocks in each sub-band named cH and cV.



(a)

(b)

Fig. 3. HVS distributions for each sub-bands: (a) contrast, (b) standard deviation.

To evaluate the imperceptibility of the watermarked image, the peak signal-to-noise ratio (PSNR) is used and, a correlation function is also utilized to compare the similarity between test watermark and extracted watermark. Experimental results showed that the proposed approach is robust to several signal processing schemes, including JPEG compression, Gaussian noise and geometric cropping. In Table 1, meaningful results are illustrated with respect to some attacks in each HVS parameters. It is also used destruction attack of JPEG compression and noise to measure the robustness of watermark. In Tables 2 and 3, we demonstrate the PSNR and correlation results after performing different factors of JPEG compression. Regarding noise attack, it is added in 20, 40, 60 and 80% to the watermarked image.

Ⅴ. Conclusions

This paper has presented results for hybrid-based watermarking scheme, which incorporate DCT-based watermarking with FI. Our approach has double-aim: in first to enhance the robustness of the watermarking and in second to reduce the number of the fuzzy inference rules. To do so, fuzzy inference algorithm is designed to select the optimal sub-bands. The effectiveness of our scheme is demonstrated on some experiments of signal processing function, such as JPEG compression, Gaussian noise and geometric cropping. Experimental results showed that proposed scheme has a better PSNR and has stronger response than previous results of Cox et. al. [7]. Finally, regarding the future research, it will be devoted to investigate the trade-off point which is the best case of relations between HVP and various attacks.

Table 1. Experimental results with respect to HVP for each attacks

HVS \ attack	Cameraman			Youngman		
	Cropping of 1/4	JPEG Q = 50	Gaussian noise mean = 0 Var.=0.01	Cropping of 1/4	JPEG Q = 50	Gaussian noise mean = 0 Var.=0.01
Contrast	0.972	0.890	0.975	0.732	0.894	0.962
Texture	0.963	0.876	0.968	0.966	0.872	0.948
Entropy	0.957	0.869	0.917	0.970	0.861	0.908
Std.	0.968	0.884	0.924	0.982	0.911	0.975

Table 2. Detection results of the JPEG compression attack

JPEG Ratio \ Method	Cox et al's method				Proposed method			
	Cameraman		Youngman		Cameraman		Youngman	
	PSNT [dB]	Corr (%)	PSNR [dB]	Corr (%)	PSNT [dB]	Corr (%)	PSNR [dB]	Corr (%)
10 %	12.47	83	10.89	83	16.84	92	16.79	93
30 %	11.20	78	11.11	81	15.51	90	15.79	91
50 %	11.41	77	11.16	78	13.39	84	13.15	87
70 %	9.57	75	10.33	75	10.73	72	10.29	71
90 %	9.13	73	9.66	71	7.30	45	7.40	48

Table 3. Detection results of the noise attack

Noise \ Method	Cox et al's method				Proposed method			
	Cameraman		Youngman		Cameraman		Youngman	
	PSNT [dB]	Corr (%)	PSNR [dB]	Corr (%)	PSNT [dB]	Corr (%)	PSNR [dB]	Corr (%)
80 : 1	11.02	80	10.89	79	14.66	92	14.19	91
60 : 1	10.56	78	10.42	78	12.47	86	11.47	83
40 : 1	8.70	66	8.96	67	9.69	74	8.83	68
20 : 1	6.56	44	7.03	51	7.29	53	7.01	50

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References

[1] C .Busch, W. Funk and S. Wolthusen,: Digital Watermarking: From Concepts to Real time Video Applications. *IEEE Computer Graphics and Applications,* Vol. 19 (1999), pp. 25-35.

[2] M. Barni, F. Bartolini, V. Cappellini, N, Checcacci,: Object Watermarking for MPEG4 Video Streams Copyright Protection. *Proceedings of the SPIE in Security and Watermarking of Multimedia Contents,* Vol. 3971 (2000), pp. 465-476.

[3] K. Tanaka, Y. Nakamura and K. Matsui,: Embedding Secret Information into a Dithered Multi-level Image. Proceedings of the 1990, *IEEE Military Communications Conference.* (1990), pp. 216~220.

[4] R. B. Wolfgang and E. J. Delp,: A Watermark for Digital Images, *Proc. of IEEE Int. Conf. on Image Processing,* Vol. 3, (1999,) pp. 219-222

[5] C. Hsu and J. Wu,: Digital Watermarking for Video, *Proc IEEE International Conference on Digital Signal Processing,* Vol. 1. (1997).

[6] A. Piva, R. Caldelli, A. Rosa,: A DWT-based Object Watermarking System for MPEG4 Video Streams, *Proc. of IEEE International Conference Image Processing. (2000),* pp. 5-8.

[7] I. J. Cox and M. L. Miller,: A review of watermarking and the importance of perceptual modeling, *Proc. SPIE Conf. on Human Vision and Electronic Imaging II* Vol. 3016. (1997), pp. 92-99.

[8] D. C. Lou, T. L. Yin, : Adaptive digital watermarking using fuzzy logic techniques, *the journal of the Society of Photo-optical Instrumentation Engineers,* Vol. 41, (2002) pp. 2675-2687.

[9] Y. H. Kim and H. H. Song,: An Adaptive Digital Watermarking using DWT and FIS, *Journal of Digital Contents Society,* Vol. 5. (2004), pp. 128-131.

[10] Y. H. Kim et al.: Adaptive Selection of Coefficient's Portions in the Transform Domain Watermarking, 9th international conference, *KES 2005,* proceedings, part II, (2005).

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