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An Adaptive Digital Watermarking Using DWT and FIS

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ABSTRACT

In this paper, a Fuzzy Inference System(FIS) based watermarking algorithm in Discrete Wavelet Transform(DWT) domain is proposed. A 2D fuzzy inference values, in which the inputs are parameters of the coefficients of the DWT block of the original image and the output is strength of watermark embedded, is devised. The fuzzy inference algorithm guarantees that the watermark to be embedded into the original image adaptively. The experimental results shows that proposed approach is robust to the digital image processing schemes.

Key word : DWT, FIS, Coefficients, Inference rule.

Ⅰ. INTRODUCTION

Now days, in the advance of digital networks, it is suitable and economical to transmit multimedia contents using computer network rather than to send hard copies. But a major weak point to the use of electronic-based distribution and storage is the ease of intercepting. Namely, digital data has a lot of advantages over analog data, service providers are unwilling to offer services in digital form. Two complementary schemes: encryption and watermarking are being developed to provide copy protection or copyright protection for digital multimedia information [1]-[3]. Encryption schemes can be applied to the protection of digital data during the transmission from the source to the destination. But, in this case, after received and decrypted data is no longer protected. On the other hand, watermarking scheme can complement encryption by embedding a secret imperceptible data, so called watermark, directly into the source data in such a way result in always remains present. Such watermark techniques have following common characteristics: (1) Robust: The watermark is designed to resist against heterogeneous manipulations. (2) Fragile: The watermark is embedded with very low robustness. Therefore, this type of watermark can be destroyed even by the slightest manipulation. (3) Imperceptible: The watermark should not cause visual degradation of images [4][5]. Three types of watermarking system can be identified. Their difference is in the nature and combination of inputs and outputs: (1) Private watermarking system (or nonblind watermarking system): This kind of scheme require at least the original data and will be more robust than the others. (2) Public watermarking system(or blind or oblivious watermarking system): It requires neither the secret original nor the embedded watermark. (3) Semiprivate watermarking system(or semiblind watermarking system): It need not the original data for detection. Main applications of private and semiprivate watermarking are for evidence in court to prove ownership [6].

In this paper, A digital watermarking algorithm using discrete wavelet transform (DWT) and fuzzy inference system(FIS) is proposed. Transform-domain based techniques is presented in sec. Ⅱ. The proposed scheme based on DWT and FIS is described in Sec. Ⅲ. Finally section Ⅳ presents experimental results.

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II. Spatial-domain based Watermarking using DWT

The research of digital watermarking techniques have consequently become an interesting topic and its applications are various field of digital rights management(DRM) such as copyright protection, image authentication. Some kinds of water-marking methods can be classified with respect to the application. Digital watermark technologies fall into two main categories: spatial-domain, also called additive watermarking, and transform-domain methods. The basic requirement in watermarking is to make the embedded watermark imperceptible or difficult to notice for multimedia contents. In general, frequency-domain based approaches are superior to that of spatial-domain in preserving contents fidelity and robustness under attacks. Many techniques have been proposed in the spatial-domain technique, which process the location and luminance of the image pixel directly. It is one of the fundamental schemes and it has both the advantages of low complexity and easy implementation. But it's algorithms are generally not robust to intentional or unintentional attacks.

On the other hand, transform-domain methods, such as FFT, DCT, DWT are based on spatial transformation, and then process the coefficients in the frequency domain hiding data [7][8]. The main issue, in these applications, is to select the optimal range of frequency coefficients to hide a watermark.

One popular scheme of encoding secret information in the frequency domain is modulating the relative size of two or more DWT coefficients within one image. DWT is becoming a main scheme in the ongoing source compression standard JPEG-2000. This technique, in recent reports, has been applied to image watermarking. A wavelet decomposition of a function is a decomposition in a special basis of functions, so called wavelets. An important property of wavelet transform is that they preserve the spatial localization of image features. The wavelet coefficients are organized into wavelet subtree. For *symmetrical wavelets*, horizontal/vertical block reflections correspond to a horizontal/vertical reflection of the set of wavelet coefficients within each scale of a subtree. Consequently, it is closely related to and in some cases identical to subband codes, and quadrature mirror filters. discrete wavelet transform can be expressed as Eq.(1) and Eq.(2)

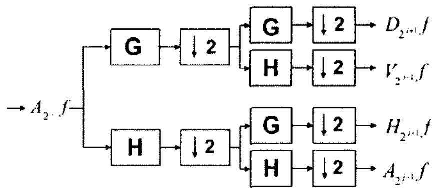
$$DWT_{m,n(f)} = a_0^{-m/2} \int dt\, f(t)\, \psi\, (a_0^{-m} t - n b_0) \qquad (1)$$

$$\int dt\, \psi(t) = 0 \qquad (2)$$

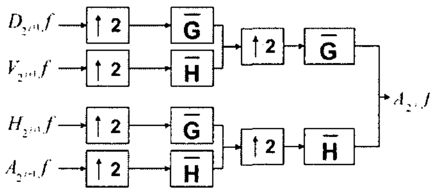
Consider a two-channel orthogonal filter bank, the usual wavelet decomposition for 2-D images can be expressed as

$$A_{2^{j+1}} f = \sum_k \sum_l h(2m-k)\, h(2n-l) A_{2^j} f$$
$$H_{2^{j+1}} f = \sum_k \sum_l h(2m-k)\, g(2n-l) A_{2^j} f$$
$$V_{2^{j+1}} f = \sum_k \sum_l g(2m-k)\, h(2n-l) A_{2^j} f$$
$$D_{2^{j+1}} f = \sum_k \sum_l g(2m-k)\, g(2n-l) A_{2^j} f$$

One way to construct these different levels of resolution is to cascade two-channel filter banks and a down-sampling procedure as illustrated in Fig. 1.



(a) Decomposition stage



(b) Reconstruction stage

Fig. 1 Wavelet transform

Namely, A level resolution wavelet decomposition will result a pyramid structure as shown in Fig. 2. LLn, LHn, HLn, and HHn represent the low-low, low-high, high-low, and high-high subband in resolution level n. The subband labeled LH2, HL2, and HH2 of multiresolution representation represent the high frequency information, such as textures and edge of an image. and these subbands are not sensitive to discover changes in human visual system.

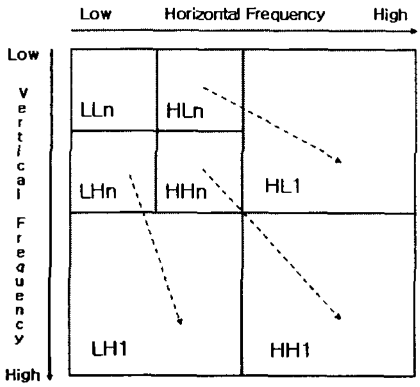


Fig. 2. 2-D time-frequency subband.

In here, using the DWT, we decompose an original image until level 3 and obtain the multiresolution representation(MRR) LHn, HLn, HHn(n= 1,2,3)

III. Proposed Algorithem Using DWT and FIS

As we described above section, how to select the best frequency portions of the image in which to hide the watermark is an important and difficult topics. A fuzzy inference system, a crisp data must be translate into if-then language of fuzzy inference. Transformed coefficients of DWT are crisp set, which have flexibility in modeling watermarking process. These value can be utilized and worked as another key parameter during the watermarking process. Taking the 3 group of coefficients which reflect the image complexity as the input values of the fuzzy inference. In order to generate a optimal inference rule, interpolative technique is utilized for the reduction of typical rules that is standard if-then inference based on the generalized modus ponens inference paradigm [9]. Proposed algorithm can be described informally as follows:

Step 1. *Definition:*
DWTc: DWT coefficients
GDWTc: Group of DWTc
MVoDWTc: Max. variation of DWTc
FIS: Fuzzy inference system
Wm: Watermark
SF: Similarity factor for FIS
SW: Strong watermark
WW: Weak watermark
/* stage for obtaining DWTc */
Step 2. preprocessing
100: Perform 1-level DWT
200: Perform 2-level DWT
Step 3. while image block is not empty repeat
step 4 ~ step 10.
Step 4. Grouping DCTc into 3-level
Calculating MVoDWTc
Step 5. if MVoDWTc is larger than TH
goto 200
else goto 100
/* stage for fuzzy inference */
Step 6. Repeat step 7 ~ step 10.
Step 7. for each value of GDWTc 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 $> \alpha - cut$ then embedding a SW
else WW
Step 11. End of algorithm.

Fuzzy inference rule is shown as in Table 1. this FIS means that the bigger the Fv and Fg, the less sensitive the human visual system, so the stronger the strength of watermark embedded possibly.

Table 1 . Fuzzy Association Map for FIS

Fv \ Fg	NB	NS	ZR	PS	PB
PB	PB	PB	PM	PB	PB
PS	PS	ZR	ZR	PM	PB
ZR	NS	ZR	ZR	ZR	PS
NS	NB	NM	ZR	ZR	NS
NB	NB	NB	NM	NB	NB

Fg=frequency group, Fv=frequency variation, PB=positive big, PM=positive medium, PS=positive small, ZR=zero, NS=negative small, NM=negative medium, NB=negative big.

By using the fuzzy rules in Table 1, we can insert the watermark W into the DWT coefficients to obtain the watermarked image X'. DWT is performed for each non-overlapped blocks of 16*16 in the original image and obtained watermarked image of $X_k(x,y)$. The watermark can be extracted by performing the inverse of embedding watermark.

Ⅳ. Experimental Consideration

We have performed some numerical experiments with the 128*128 standard image "Door" as shown in Fig. 3. The watermark image is a binary image of size 32*32.

To analyse the extracted result quantitatively, the correlation between W and W' is computed:

$$\text{sim}(W \cdot W') = \frac{W' \cdot W}{\sqrt{W \cdot W}} \quad (3)$$

where '·' denotes an inner product operator.

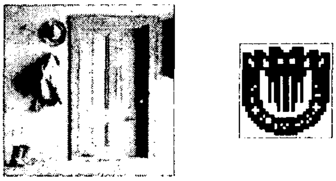


Fig. 3. Original Image & Watermark

Assuming that the original image W and the watermarked image W' both have image sizes N*M. The mean square error between W and W' can be represented by

$$A = 255^2$$
$$B = \frac{1}{N \times M} \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} [a(x,y) - b(x,y)]^2 \quad (4)$$

Consequently, PSNR can be calculated by Eq. (5)

$$\text{PSNR}(a,b) = 10 \log_{10}(A/B)[\text{dB}] \quad (5)$$

By employing the proposed methods, some experimental images are reproduced as shown in Fig. 4. Table 2 and Fig. 5 present results measuring the PSNR for each image respectively.

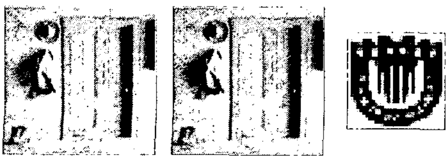


Fig. 4. Experimental results

Table 2. Measuring the PSNR

	Image	Watermark
Extracted	32.19 dB	16.15 dB

Deletion Rate	Embeded Crop Image	Extracted watermark	PSNR dB
6.25%			10.57
25%			6.64
50%			6.28
edge line			6.37

Fig. 5. PSNR for each partial deletion

Ⅴ. Conclusion

In this paper, DWT and FIS based watermarking algorithm have been presented. From the DWT coefficients, the input values of FIS is selected and calculated optimal output value for watermark. The *experimental results show that the watermarks are* invisible and relatively robust against noise. There are still some works to be done: Does the method perform better with various DWT coefficients?

If so, what is the most appropriate FIS? Moreover, the watermarked image need to be tested such attacks as rotation, noise addition and other image processing schemes.

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