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Embedding Binary Watermark Image using DWT Coefficients

Kwang-Chae Park[1], Ceol-Soo Bae[2*]
[1]Electronic Engineering, Chosun University
[2]Information and Communication Engineering, Catholic Kwandong University

이산 웨이블릿 변환계수를 이용한 이진 워터마크 영상

박광채[1], 배철수[2*]
[1]조선대학교 전자공학과, [2]가톨릭관동대학교 정보통신공학과

Abstract Multimedia documents can be transferred quickly and easily across the Internet, and has attracted considerable interest in multimedia security and multimedia copyright protection. This paper proposes an animage watermarking scheme embedding a binary watermark image using Discrete Wavelet Transform (DWT) coefficients. The original image is transformed to the wavelet domain and decomposed in subbands. The binary watermark image, as a sequence of bits, is embedded into the middle frequency subbands. The original image is not needed to detect the watermark image. The proposed method detected fewer watermark bits but produced an approximately 10dB higher PSNR than the max/min method.

요 약 멀티미디어 자료들은 인터넷을 통해 빠르고 쉽게 전송된다. 이것은 멀티미디어 보안 및 저작권 보호에 있어 넓은 관심을 불러일으킬 수 있다. 이에 본 논문에서는 저작권 보호를 위해 이산 웨이블릿 변환 계수를 사용하여 이진 워터마크 이미지를 포함하는 이미지 워터마킹 기법을 제안한다. 원본 이미지를 웨이블릿 영역으로 변환하고 서브 대역으로 나눠진다. 변환된 영상은 이진워터마크 영상은 비트 시퀀스로 중간 주파수 서브 밴드에 삽입된다. 원본 이미지는 워터마크 영상의 검출에 필요로 하지 않는다. 제안된 방법에서 워터마크 비트수는 적게 검출되지만 최대/최소값 보다 10dB의 PSNR이 더 생산되었다.

Key Words : binary watermark image, image watermarking, Discrete Wavelet Transform(DWT), Digital watermarking

1. Introduction

With the explosive growth of the Internet and multimedia systems, multimedia contents have been increased. However, there are some problems that it is easy to transfer and copy multimedia documents but impossible to identify the original one. Therefore, there is an increase in concern over copyright protection of digital contents. Traditionally, encryption and control access techniques were employed to protect against unauthorized copying after the media have been successfully transmitted and decrypted. Recently, watermark techniques are utilized to maintain the copyright[1].

Digital watermarking means all of the technical methods that embed and detect the watermark without changing quality and size of data, which is special format of data to protect digital contents. Therefore,

This study was supported by research fund from Chosun University, 2013.
*Corresponding Author : Ceol-Soo Bae(Catholic Kwandong Univ.)
Tel: +82-11-369-08797 email: baecs@kd.ac.kr
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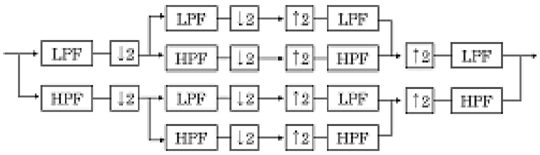
watermarking is necessary technique to protect digital multimedia intellectual copyright. It is important to make watermark that can not be damaged by any manipulation to insist the ownership of digital data.

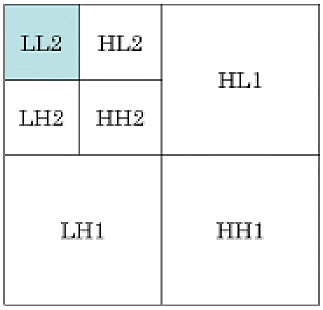
In this paper, we embed the binary watermark image into the coefficients according to the DWT domain. A sequence of watermark bits is embedded into the LH2 or HL2 subband based on 2-level DWT. We enhance the performance embedding watermark bits into the DWT coefficients except DC value and the neighbors. The performance when averaging the result detected from both LH2 and HL2 subbands is better than when using one of them. The PSNR between original image and watermarked image is more than 40dB, so the watermark is invisible.

2. PYRAMID VECTOR QUANTIZATION

Discrete Wavelet Transform(DWT) which makes it possible to represent the image in spatial-frequency domain is more advantageous than what utilize only frequency characteristics. We can effectively describe an image through the spatial characteristic, like the edges of image, and frequency characteristic which the energy distribution is concentrated in lower frequency region in DWT domain. Fig 1 is 2-channel filter bank that describe the analysis and synthesis bank of an image for 1-level DWT. An image is decimated after low-pass and high-pass filtering in horizontal and vertical direction. We can get several different size of decomposed subbands and can extract some information from these subbands. For the perfect reconstruction, decomposed subbands are interpolated and reconstructed through LPF and HPF.



[Fig. 1] 2-channel filter bank

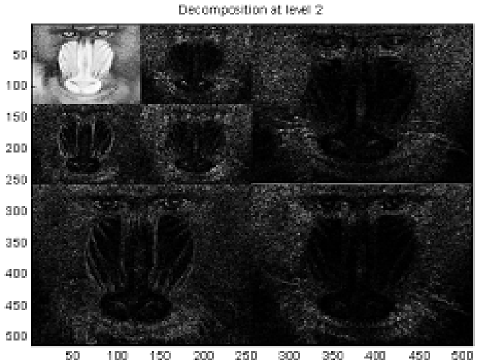


[Fig. 2] 2-level 2-D DWT with all subbands

The subbands after 2-level two-dimensional(2-D) DWT are represented in [Fig 2]. It produces a low-frequency subbands LH2, and three series of high-frequency subbands LHj, HLj, HHj. The mathematical expression of J-level DWT is showed in (1),

$$
\begin{aligned}
f_{LL}^{J}(u,v) &= \sum_{i_1=0}^{K-1}\sum_{i_2=0}^{K-1} g(i_1)g(i_2)f_{LL}^{J-1}(2u-i_1, 2v-i_2) \\
f_{LH}^{J}(u,v) &= \sum_{i_1=0}^{K-1}\sum_{i_2=0}^{K-1} g(i_1)h(i_2)f_{LL}^{J-1}(2u-i_1, 2v-i_2) \\
f_{HL}^{J}(u,v) &= \sum_{i_1=0}^{K-1}\sum_{i_2=0}^{K-1} h(i_1)g(i_2)f_{LL}^{J-1}(2u-i_1, 2v-i_2) \\
f_{HH}^{J}(u,v) &= \sum_{i_1=0}^{K-1}\sum_{i_2=0}^{K-1} g(i_1)g(i_2)f_{LL}^{J-1}(2u-i_1, 2v-i_2)
\end{aligned} \quad (1)
$$

where J is the level of DWT, K is the filter length, g(n) and h(n)are the impulse responses of the lowpass and high pass filters, respectively, and f0LL(u,v)=f(u,v) is the original image. An example of 2-level DWT is shown in [Fig 3].



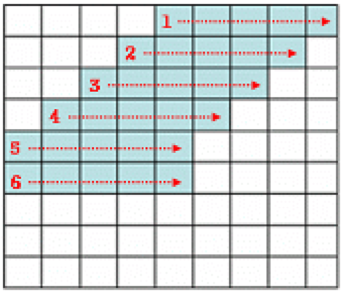
[Fig. 3] 2-level 2-D DWT of'Baboon' image

3. Proposed watermarking method

3.1 watermark Embedding

Our watermarking scheme is based on 2-level DWT. The original image is transformed to wavelet domain. In this paper, the middle frequency bands, LH2 and HL2 subbands, are considered to embed watermark. A binary watermark image is treated as a sequence of bits and we embed and detect the bits sequentially. Here are the steps for embedding watermark.

1. Make a binary watermark image a sequence of bits, Wi. I is the length of watermark bits.
2. Decompose the original image using 2-level DWT.
3. Extract the DWT coefficients of LH2 or HL2 subband except the DC and the neighbors as described in [Fig 4]. And divide the coefficients into I sets of coefficients, Ci. Each set contains 5 coefficients.



[Fig. 4] Extraction of coefficients in DWT subband

4. Sort the 5 coefficients of i-th set, C^i, in the increasing order,
   $C_1^i < C_2^i < C_3^i < C_4^i < C_5^i$. And let
   $M_i = (C_1^i + C_2^i + C_4^i + C_5^i)/4$.
5. If $W_i = 1$ then
   $C_3^i = M_i + \alpha * \mathrm{abs}(M_i)$, and if $W_i = 0$ then
   $C_3^i = M_i - \alpha * \mathrm{abs}(M_i)$ (0< α <1,constant).
6. Combine the watermarked subband and the rests, and then reconstruct the image using inverse DWT. The watermarked image, WI is constructed.

3.2 Watermark Detection

The watermark detection is reverse of watermark embedding step. It can be described following :

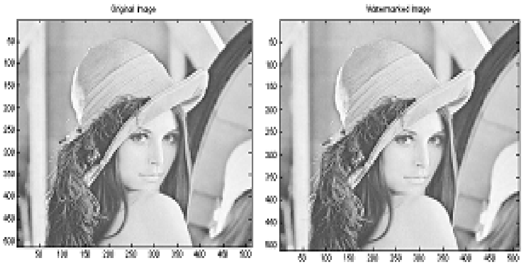
1. Decompose the watermarked image WI using 2-level DWT.
2. Extract the DWT coefficients of LH2 or HL2 subband except the DC and the neighbors and divide the watermarked coefficients into I sets, WCi, containing 5 coefficients.
3. Sort the 5 coefficients of i-th set, WCi, in the increasing order,
   $WC_1^i < WC_2^i < WC_3^i < WC_4^i < WC_5^i$. Let
   $M_i = (WC_1^i + WC_2^i + WC_4^i + WC_5^i)/4$.
4. If $WC_3^i > M_i$ then detected watermark bit, $EW_i = 1$, and if $WC_3^i < M_i$ then $EW_i = 0$.
5. Make a binary image using the detected watermark bits EW_i.

4. Experimental Results

In this paper, we used 512*512 gray images, 'Lena' and 'Baboon', as the original image and a 50*20 binary image as the watermark. We embedded the watermark into LH2 and HL2 subbands. We compared the result of detecting each subband and averaging the results of detecting both subbands. We choose the weighting factor αproperly which makes the performance best, by calculating the PSNR(Peak Signal to Noise Ratio) between original and watermarked images. Finally, we compared with the results of previous algorithm using max, min values of DWT coefficients.

[Table 1] Embedding watermark LH2 subband

α	Lena		Baboon	
	Detected bits	PSNR (dB)	Detected bits	PSNR (dB)
0.01	895	46.83	922	45.26
0.05	893	46.83	920	45.26
0.1	891	46.80	919	45.22
0.2	887	46.77	917	45.18
0.3	884	46.68	916	45.10
0.4	878	46.58	914	44.96
0.5	874	46.47	910	44.82

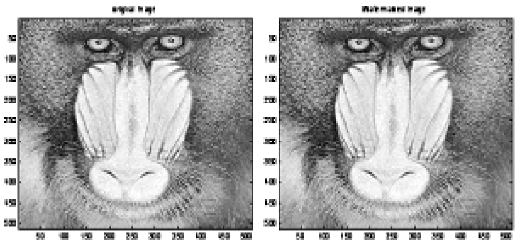


[Fig. 5] Original image(left) and watermarked image (right)in LH2 subband at α =0.1

Table 1 contains detected watermark bits and PSNR between original image and watermarked one in LH2 subband according to various α. PSNR and detected bits increased as α decreased from 0.5 to 0.1 but they are almost same when α is below 0.1. Fig 5 shows the original image and watermarked image in LH2 subband at α is 0.1. Table 2 contains the results using HL2 subband. As α decreased detected bits and PSNR increased but they almost same when α is smaller than 0.1. The detected bits in Table 2 is larger than that in Table 1 and PSNR is also larger when using 'Lena'image. Fig 6 shows the original image and watermarked image in HL2 subband at α is 0.1.

[Table 2] Embedding watermark HL2 subband

α	Lena		Baboon	
	Detected bits	PSNR (dB)	Detected bits	PSNR (dB)
0.01	905	47.56	930	44.23
0.05	905	47.56	929	44.19
0.1	905	47.55	928	44.16
0.2	901	47.53	923	43.95
0.3	894	47.51	920	43.63
0.4	892	47.45	916	43.23
0.5	884	47.39	911	42.77



[Fig. 6] Original image(left) and watermarked image (right) in HL2 subband at α=0.1

[Table 3] Embedding watermark LH2 and HL2

α	Lena		Baboon	
	Detected bits	PSNR (dB)	Detected bits	PSNR (dB)
0.01	939	46.40	952	42.83
0.05	939	46.40	952	42.81
0.1	939	46.37	952	42.76
0.2	937	46.33	948	42.58
0.3	934	46.22	947	42.30
0.4	931	46.10	945	41.94
0.5	925	45.96	942	41.53

[Fig. 7] Original watermark(left) and detected watermark (right) in LH2 and HL2 subbands at α=0.1

Table 3 contains detected watermark bits and PSNR between original image and watermarked one using LH2 and HL2 subbands according to various α. PSNR and detected bits increased as αdecreased from 0.5 to 0.1 but they are almost same when α is below 0.1. Therefore, the performance is best when αis 0.1. PSNR is lower than Table 1 and Table 2 but it is still larger than 40dB and the detected bits also bigger. Fig 7 shows original watermark and detected watermark when α is 0.1.

[Table 4] Comparison with max/min algorithm

			LH2	HL2	Both
Max/Min	Lena	Detected bits	1000	1000	1000
		PSNR(dB)	38.97	41.70	37.53
	Baboon	Detected bits	1000	1000	1000
		PSNR(dB)	33.02	33.11	28.97
Mean	Lena	Detected bits	891	905	939
		PSNR(dB)	46.80	47.55	46.37
	Baboon	Detected bits	919	928	952
		PSNR(dB)	45.22	44.16	42.76

We experimented on the max/min algorithm and compared the result of that with proposed algorithm at α is 0.1 in [Table 4]. In max/min algorithm the detection of watermark bits is perfect but PSNR is lower than proposed algorithm.

5. Conclusions

This paper proposed an image watermarking method using mean value of DWT coefficients. Original image was transformed using 2-level 2-D DWT and binary watermark image was embedded into LH2 orHL2 subband using mean value of coefficients. Through the experimental results using both subband produced more detected bits and better PSNR than using one of the subbands. When αis 0.1 the performance was best. Our proposed method detected the watermark bits less but produced more PSNR about 10dB than max/min method. The advantage of the proposed method is visibility when we extracted watermark from the image. The corresponding experimental results show that the proposed method has performance of a robustness from the noise attack.

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Ceol-Soo Bae [Regular member]

- Feb. 1981 : Myongji Univ The Department of Electronic Engineering, MS
- Feb. 1988 : Myongji Univ The Department of Electronic Engineering, PhD
- Feb. 1999 ~ Dec. 2001 : Kwandong Univ, An Engineering College, Dean
- Feb. 1981 ~ current : Kwandong Univ, Information and Communication Engineering, Professor

<Research Interests>
Image processing, Signal process

Kwang-Chae Park [Regular member]

- Feb. 1980 : Chosun Univ Electrionic Engineering, MS
- Feb. 1994 : Kwangwoon Univ Electronics and Communications Engineering, PhD
- Nov. 2012 ~ current : Chosun Univ, Electrionic information technical college, Dean
- Mar. 1980 ~ current : Chosun Univ, Electronic Engineering, Professor

<Research Interests>
Data communication and Protocol, Signal process