Performance evaluation of DWT based image watermarking using error correcting codes

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Abstract

Due to excessive proliferation of digital multimedia, the need of protecting the ownership of digital media becomes a major issue. For content protection digital image watermarking plays an important role in Multimedia security fields. Methods developed under this are used to protect Intellectual property rights of digital data such as video, image, audio, etc. without affecting the fidelity of the original data. In this paper we show that if the logo is coded using error correcting codes before being embedded into the watermarked image the robustness of the watermark is increased. Different codes that are taken into consideration in this paper are Hamming and cyclic codes. Here the encoded and embedded watermarked image is considered to be encountering an AWG noise while transmission. We observe that the SNR and PSNR of the watermarked image even in AWGN channel are better when logo is coded before embedding. Also we observe that Hamming codes SNR and PSNR are much more superior to cyclic codes.

Keywords

Discrete Wavelet Transform, Error Correcting codes, SNR and PSNR.

1. Introduction

Image watermarking techniques have been given considerable amount of attention in the recent literature. Digital image watermarking is concerned with hiding information into a digital image. This information may be used for various applications such as authentication, copyright protection, proof of ownership etc. Some desirable properties of a watermarking techniques include the following: [1]

a) The inserted watermark should not introduce visible artifacts. The watermark should not be easily removable.
b) The watermark should be resilient to lossy data compression such as JPEG.
c) The watermark should be resilient to image processing technique such as median filtering.
d) The watermark can only be extracted by privileged individuals who are given the security key.

2. Discrete Wavelet Transform

The Wavelet Transform provides a time-frequency representation of the signal. It was developed to overcome the short coming of the Short Time Fourier Transform (STFT). While STFT gives a constant resolution at all frequencies, the Wavelet Transform uses multi-resolution technique by which different frequencies are analyzed with different resolutions. The Discrete Wavelet Transform (DWT), which is based on sub-band coding, is found to yield a fast computation of Wavelet Transform. It is easy to implement and reduce the computation time and resources required. [2][7]

The DWT is computed by successive low pass and high pass filtering of the discrete time-domain signal. This is called the Mallat algorithm or Mallat-tree decomposition. In fig(1), the signal is denoted by the sequence x[n], where n is an integer. The low pass filter is denoted by G_0 while the high pass filter is denoted by H_0. At each level, the high pass filter produces detail information; d[n], while the low pass filter associated with scaling function produces coarse approximations, a[n]. [8][9]

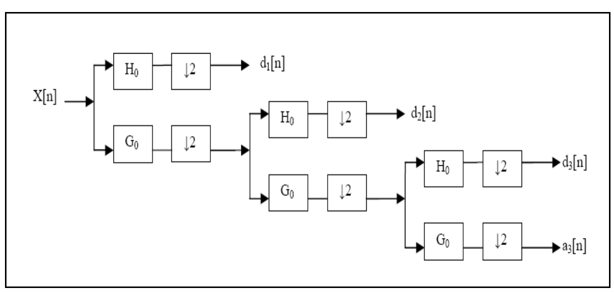

Fig.1: Three level Wavelet Decomposition tree

At each decomposition level, the half band filters produce signals spanning only half the frequency band. This doubles the frequency resolution as the uncertainty in frequency is reduced by half. In accordance with Nyquist's rule if the original signal has a highest frequency of ω, which requires a sampling frequency of 2ω radians, then it now has a highest frequency of ω/2 radians. It can now be sampled at a frequency of ω radians thus discarding half the samples with no loss of information. This decimation by 2 halves the time resolution as the entire signal is now represented by only half the number of samples. Thus, while the half band low pass filtering removes half of the frequencies and thus halves the resolution, the decimation by 2 doubles the scale. With this approach, the time resolution becomes arbitrarily good at high frequencies, while the frequency resolution becomes arbitrarily good at low frequencies. The filtering and decimation process is continued until the desired level is reached.

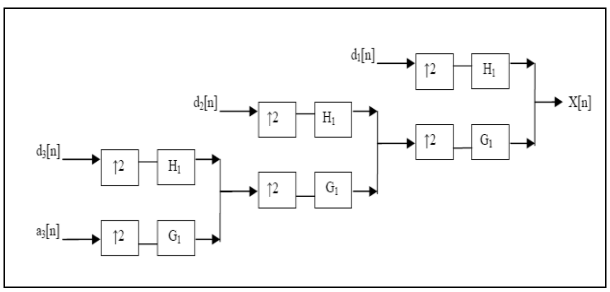

Fig. 2: Three – level Wavelet reconstruction tree

Fig (2) shows the reconstruction of the original signal from the wavelet coefficients. Basically, the reconstruction is the reverse process of decomposition. The approximation and detail coefficients at every level are up sampled by two, passed through the low pass and high pass synthesis filters and then added. This process is continued through the same number of levels as in the decomposition process to obtain and the original.

3. Error correcting codes

Many communication channels are subject to channel noise, and thus errors may be introduced during transmission from the source to a receiver. Error detection techniques allow detecting such errors, while error correction enables reconstruction of the original data. Even without malicious intervention, ensuring uncorrupted data is a difficult problem. Data is sent through noisy pathways and it is common for an occasional bit to flip. A Hamming and cyclic codes are used to add redundancy to the bits so that the errors can be detected or corrected to a certain extent. Hamming code is a linear block code. The main advantage of linear block codes is their simplicity in implementation and low computational complexity. Linear block code is usually composed of two parts. The 1st part contains the information bits, which are the original bits to be transmitted. The second part contains the parity checking bits. A linear block code with length n and k information bits is denoted as a (n; k) code.

Let C be a linear code over a finite field GF(q) of block length n. C is called a cyclic code, if for every codeword $c=(c_1,...,c_n)$ from C, the word $(c_n,c_1,...,c_{n-1})$ in $GF(q)^n$ obtained by a cyclic right shift of components is again a codeword. Same goes for left shifts. One right shift is equal to $n-1$ left shifts and vice versa. Therefore the linear code C is cyclic precisely when it is invariant under all cyclic shifts.

4. Watermark embedding and detection based on DWT using ECC

Watermarking in the DWT domain can be split into the two procedures: embedding of the watermark and extraction of the watermark. For embedding a bit stream is transformed into a sequence $w(1)...w(L)$, where L is the length of the bit stream and (k=1,...,L).The bit stream is then coded using digital error correcting codes like Hamming and Cyclic. This sequence is used as the watermark. The original image is first decomposed into several bands using the discrete wavelet transformation with the pyramidal structure. Decomposition is performed through two decomposition levels using the "Haar filter". The watermark is added to the largest coefficients in all bands of details which represent the high and middle frequencies of the image. Let $f(m,n)$ denote the DWT coefficients which are not located at the approximation band LL2 of the image.

The embedding procedure is performed according to the following formula and as shown in fig 3:

$$f'(m,n) = f(m,n)+\alpha\, f(m,n)\, w(k)\ldots\ldots\ldots\ldots..(1)$$

where α is the strength of the watermark controlling the level of the watermark $w(1)...w(L)$. By this, DWT coefficients at the lowest resolution which are located in the approximation band are not modified.

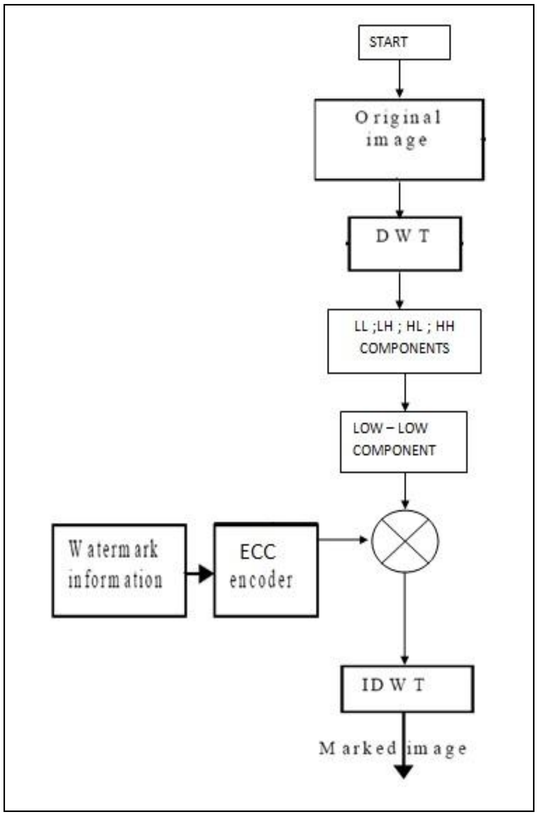

Fig.3: Flowchart for embedding Watermark using DWT with ECC

Fig. (4) shows the flowchart for watermark detection. The watermarked image is obtained by applying the inverse discrete wavelet transform (IDWT). In the watermark extraction procedure both the received image and the original image are decomposed into the two levels. It is assumed that the original image is known for extraction. The extraction procedure is described by the formula

$$wr(k) = (fr'(m,n) - f(m,n))/ \alpha f(m,n) \ldots\ldots\ldots(2)$$

where $fr'(m,n)$ are the DWT coefficients of the received image. Due to noise added to the image by attacks or transmission over the communication channel the extracted sequence $wr(1)...wr(L)$ consists of positive and negative values. The detected and coded received noisy logo is then decoded to get a noise free logo. [14][17]

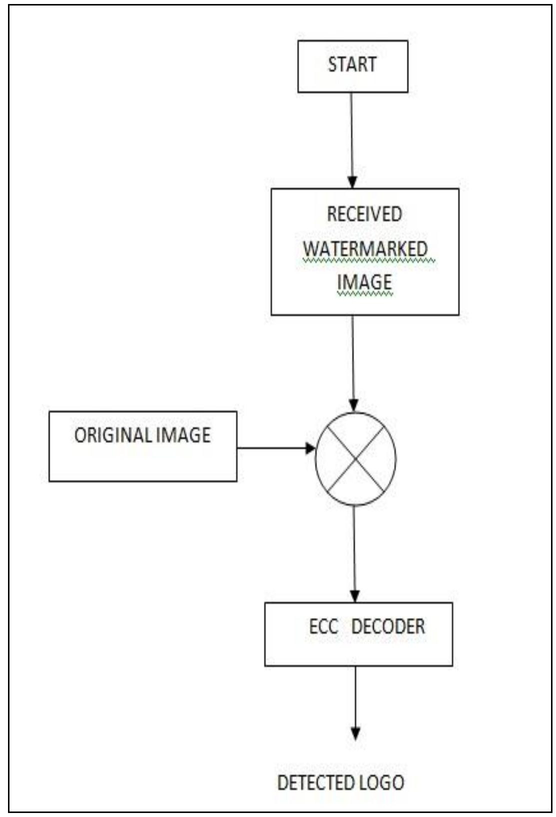

Fig. 4: Flowchart for extraction of Logo using DWT with ECC

5. Observations and Results

The "db1 or Haar wavelet' was chosen from the family of DWT for image watermarking. Fig 5.shows the 'Lena' image which was taken as the main image to be watermarked.

Fig. 5: Main Image

Four different test logos were taken for calculating SNR and PSNR. Fig 6. shows the test logos for experiment.Fig7. shows the decomposition done on the main image using DWT.

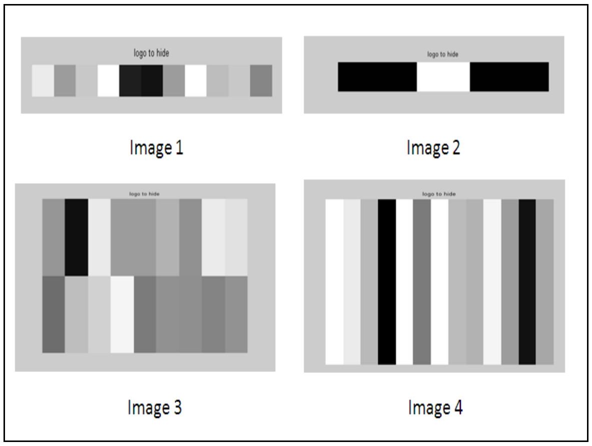

Fig. 6: Test logo images

Fig 8.shows output of addition of LL plane of DWT decomposed main image with the coded logo image.Fig.9 & 10 shows the final outputs obtained after detection and decoding of the watermarked image.

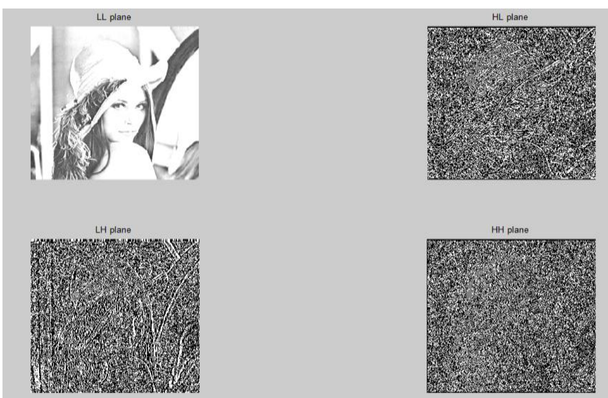

Fig. 7: DWT Decomposition

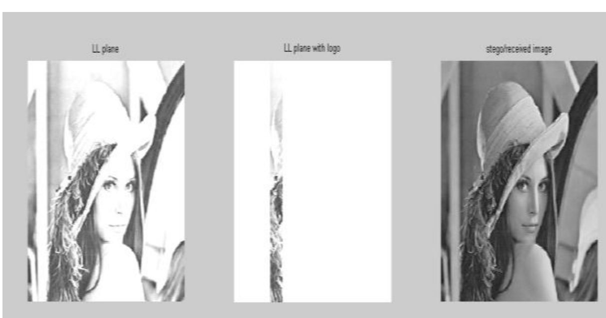

Fig 8. a): LL Plane of DWT decomposition,b) LL plane with added logo, c) Final Watermarked image.

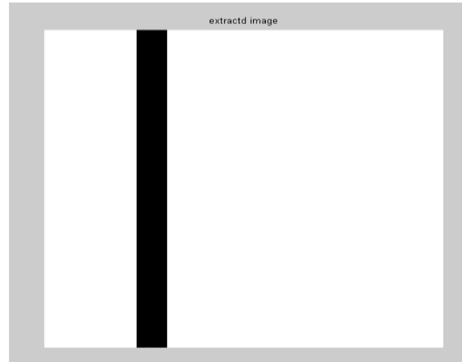

Fig. 9: Extracted coded logo

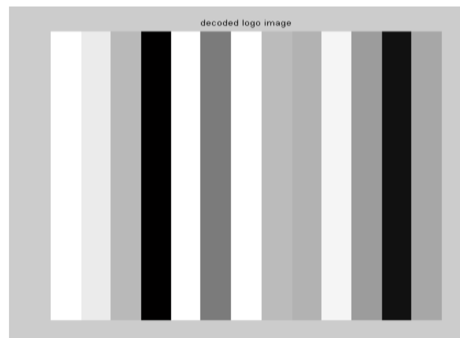

Fig. 10: Decoded logo

In the following observation tables it is observed that Hamming code incorporated with the Discrete Wavelet transform gives the highest value of signal to noise ratio and peak signal to noise ratio as compared to Cyclic codes. Result shown here is for various logo images.

Table 1: Difference between the SNR of the DWT watermarking using ECC with Effects of AWGN

Signal to Noise ratio			
TEST IMAGES	DWT without ECC	DWT with ECC	
		Hamming	Cyclic
Image 1	2.6342	16.7592	6.3159
Image 2	0.4919	12.5866	0.8624
Image 3	2.1049	8.2384	0.5842
Image 4	3.1156	12.9177	6.0674

Table 2: Difference between the PSNR of the DWT watermarking using ECC with Effects of AWGN

Peak Signal to Noise ratio			
TEST IMAGES	DWT without ECC	DWT with ECC	
		Hamming	Cyclic
Image 1	5.5287	19.6537	9.2104
Image 2	5.5285	18.607	6.8828
Image 3	5.1811	11.3147	3.6604
Image 4	5.9282	15.7303	8.88

6. Conclusion

From the results shown in the paper we see that the usage of error correcting code in watermarking drastically improves the SNR and PSNR values. Our results shows the improvement in SNR from 2.6342dB to 16.7592 and PSNR from5.5287dB to 19.6537dB obtained by using Hamming channel coding technique and improvement in SNR from 2.6342dB to 6.3159dB and PSNR from 5.5287dB to 9.2104dB by using Cyclic channel coding technique. This proves that the robustness of watermarked image is increased even when the watermark is transmitted through the AWGN channel. This makes the watermark more efficient and reliable to be used in highly noisy channels. In this paper we also prove that the Hamming code provides much better results than the cyclic codes. Where the SNR and PSNR value obtained from Hamming is 16.7592dB and 19.6537dB resp., cyclic gives only 6.3159dB and 9.2104dB resp.

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