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Comparison of Digital Audio Watermarking Using DCT And DWT

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Abstract

This paper introduces an algorithm of digital watermarking based on Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). According to the Characters of human vision, the absolute values of DCT Coefficients are divided into an arbitrary number of segments and the energy of each segment is calculated. Watermarks are then embedded into the selected peaks of the highest energy segment. Watermarks is extracted by performing the inverse operation of watermark embedding process. Our proposed method achieves SNR (signal-to-noise ratio) values ranging from 13 dB to 24 dB. The simulation results show that this algorithm is invisible and has good robustness for some common audio processing operations.

Keywords: Watermarking, DCT, DWT

Introduction

As digital multimedia works (video, audio and images) become available for retransmission, reproduction, and publishing over the Internet, a real need for protection against unauthorized copy and distribution has increased. These concerns motivate researchers to find ways to forbid copyright violation. The most promising solution for this challenging problem seems to lie in information hiding techniques. Information hiding is the process of embedding a message into digital media. The embedded message should be imperceptible; in addition to that, the fidelity of digital media must be maintained the watermarks are embedded into the selected prominent peaks of the highest segment of absolute DCT coefficients. Experimental results indicate that the proposed watermarking method provides strong robustness against several kinds of attacks such as noise addition, cropping, re-sampling, re-quantization, MP3 compression. Our proposed method achieves SNR (signal-to-noise ratio) values ranging from 13 dB to 24 dB. Audio watermarking should meet the following requirements :(a) Imperceptibility: the digital watermark should not affect the quality of original audio signal after it is watermarked; (b) Robustness: the embedded watermark data should not be removed or eliminated by unauthorized distributors using common signal processing operations and attacks; (c) Capacity: capacity refers to the numbers of bits that can be embedded into the audio signal within a unit of time; (d) Security: security implies that the watermark can only be detectable by the authorized person. All these requirements are often contradictory with each other. However, it should satisfy the important properties such as imperceptibility and robustness.

In this paper, we propose an effective audio watermarking algorithm that is based on the DWT. The DWT transform decomposes the host audio signal into several multi-resolution sub-bands, enabling algorithm to locate the most appropriate sub-bands for embedding the watermark bits. In the proposed algorithm, the watermark bits are embedded in the high-resolution sub-bands of the audio signal, so that satisfactory robustness and imperceptibility inaudibility) performances are obtained.

Related Work

In this proposed dissertation work, watermarking system aims at implementing watermarking in frequency domain using methods viz.DCT [1] and DWT [2]. Both the methods of digital audio watermarking consists of three modules viz. signal generation module, watermark embedding module and watermark detection module. Signal generation module: Watermark signal is generated using a non-invertible function which takes a watermarked key as an input. Input speech or audio with appropriate sampling frequency is considered for our proposed method. In watermark embedding module: watermark embedding is performed in time domain or in transform domain. Our proposed method will be using transform Domain to embed the data. In Watermark detection module: Watermark detection is performed by some sort of correlation detector or statistical hypothesis testing, with or without resorting to the original signal. De-embedding also inverse fashion carried out.

Proposed Work

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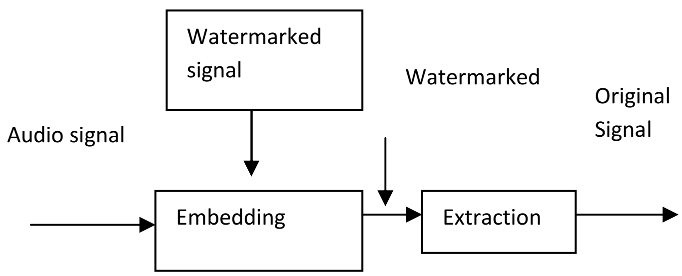

Figure.2. Block diagram of Digital Audio Watermarking

Both the methods of digital audio watermarking consists of three modules viz. signal generation module, watermark embedding module and watermark detection module.

Signal generation module: Watermark signal is generated by using a non-invertible function which takes a watermarked key as an input. Input speech or audio with appropriate sampling frequency is considered for our proposed method.

Watermark embedding module: Watermark embedding is performed in time domain or in Transform domain. Our proposed method will be using Transform Domain to embed the data.

Watermark detection module: Watermark detection is performed by some sort of correlation detector or statistical hypothesis testing, with or without resorting to the original signal. De-embedding also inverse fashion carried out.

Basic watermarking system consists of watermark embedding process and watermark detection process. A watermark consists of a sequence of real numbers. $X = \{X_1, X_{2,} ----X_n\}$ we create a watermark where each value of X_i is chosen independently according to N(0,1) where $N(\mu,\sigma^2)$ denotes a normal distribution with mean µ and variance σ2.For watermarking, Cox's method [6] is used to embed watermarks into the highest 'm' DCT coefficients of the whole sound excluding the DC component by the following equation.

$$vi' = vi\,(1+\alpha\, xi) \qquad (1)$$

where, m is the length of the watermark sequence, *vi* is a magnitude coefficient into which a watermark is embedded, *xi* is a watermark to be inserted into *vi*, _ is a scaling factor, and *vi'* is an adjusted magnitude coefficient. The watermark sequence is extracted by performing the inverse operation.

The general equation for a 1-D DCT for N data items is defined by the following equation

$$X_c[k] = \sum_{n=0}^{N-1} \alpha(n) x(n) \cos\left[\frac{2\pi k n}{N-1}\right] \qquad 0 \le 1 \le N-1$$

(2)

And the corresponding inverse1-D DCT transform is i.e. IDCT is given below:

$$x[n] = \frac{1}{N-1}\sum_{k=0}^{N-1} \alpha[K] X_C[K]\left[\frac{\pi k n}{N-1}\right] \qquad 0 \le n \le N-1$$

(3)

Where, K=0, 1, 2 …N-1, $x[n]$ -DCT results, N= Length of DCT.

In order to evaluate the performance of the proposed watermarking method in terms of watermark detection, the correlation coefficient between the original watermark X and the extracted watermark X* is calculated by the following similarity SIM(X,

$$SIM(X, X^*) = \frac{X \cdot X^*}{\sqrt{X^* \cdot X^*}}$$

X*) equation:

It is highly unlikely that X* will be identical to X. To decide whether X and X* match, we determine whether the SIM(X, X*) > T, where T is a detection threshold. In order to evaluate the quality of watermarked signal, the following signal-to-noise ratio (SNR):

$$SNR = 10\log_{10}\frac{\sum_{n=1}^{N} S^2(n)}{\sum_{n=1}^{N}\left[S(n)-S^*(n)\right]^2}$$

where S(n) and S*(n) are original audio signal and watermarked audio signal respectively

Watermark embedding using DWT

In the similar way the embedding watermark for DWT is given by following equations.

$$W_L(n,j) = \sum_m W_L(m,j-1)\,h_0(m-2n)$$

(4)

$$W_H(n,j) = \sum_m W_L(m,j-1)\,h_1(m-2n)$$

(5)

Where, m is the length of the watermark sequence. W_L (n, j) is the nth scaling coefficient at the j^{th} stage, W_H (n ,j) is the n^{th} wavelet coefficient at the j^{th} stage, and $h_0(n)$ and $h_1(n)$ are the dilation coefficients.

Corresponding to the scaling and wavelet functions. The effectiveness of these algorithm is verified by comparing for their performance features such as, PSNR . We intend to evaluate the robustness of the watermark to common signal manipulations including data compression, adding noise and re-sampling. In order to reconstruct the original data, the discrete wavelet transform coefficients are up-sampled and passed through another set of low pass and high pass filters, which is expressed as:

$$W(n,j)=\sum_k W(k,j+1)g_0(n-2k)+\sum_l WH(l,j+1)g_1(n-2l)$$

where *g0(n)* and *g1(n)* are respectively the low-pass and high-pass synthesis filters corresponding to the mother wavelet, The *jth* level coefficients can be obtained from the *(j+1)th* level coefficients. Due to its excellent spatio-frequency localization properties, the DWT is very suitable to identify areas in an audio signal where a watermark can be embedded effectively. The quality of DWT watermarked signal, the following signal-to-noise ratio (SNR)::

$$SNRL(dB) = 10\log_{10}\frac{\sum_n A_n^2}{\sum_n (A_n - A'_n)^2}$$

where An and A'n are original audio signal and watermarked audio signal respectively
Signal to noise ratio will be calculated by this formula for both method.

$$PSNR = 10 \times \log_{10} \frac{255^2}{MSB} \quad (6)$$

Experimental Result

Performance of DCT watermarking method for different types of Wav audio signals sampled at 44.1 KHz.

Imperceptibility Test

Informal listening using head set reveals that the watermark embedded into the original audio signal using the proposed watermarking method does not affect the quality of the sound, which ensures the imperceptibility of the embedded watermark. Table 1 shows the SNR results of the proposed watermarking method for different values of α. Our proposed method achieves SNR values ranging from 13 dB to 24 dB for different watermarked sounds.

Table 1. SNR results of the proposed watermarking method

	SNR		
Types of Signal	=0.1	=0.2	=0.3
Symphony	21.5905	17.5699	14.0481
Gayageum	22.7490	16.7284	13.2066
HumanVoice	23.8578	17.8373	14.3153
Classical	24.9609	18.9403	15.4185

Robustness Test

The robustness of a watermarking method is defined as the ability of watermark detector to extract the embedded watermark after common signal processing operations and attacks. Robustness is measured in terms of the similarity function. Table 2 shows the performance of our proposed method in terms of similarity when no attack is applied to four different types of watermarked audio signals.

	SNR		
Types of Signal	=0.1	=0.2	=0.3
Symphony	31.5060	31.5060	31.5060
Gayageum	31.5060	31.5060	31.5060
Human Voice	31.5060	31.5060	31.5060
Classical	31.5060	31.5060	31.5060

Table 2. Watermark detection results of the proposed method without attacks

In order to test the robustness of our proposed method, four different types of attacks, summarized in Table 3, were performed to the watermarked audio signal.

Attacks	**Description**
Noise addition	Additive white Gaussian noise (AWGN) is added to the watermarked audio signal.
Cropping	We removed 10% samples from the beginning of the watermarked signal and then replaced these samples by the original signal.
Re-sampling	The watermarked signal originally sampled at 44.1 kHz is resembled at 22.050 kHz, and then restored by sampling again at 44.1 kHz.

Re-quantization	The 16 bit watermarked audio signal is quantized down to 8 bits/sample and again re-quantized back to 16 bits/sample.

Table 3. Attacks used in this study for the watermarked sound

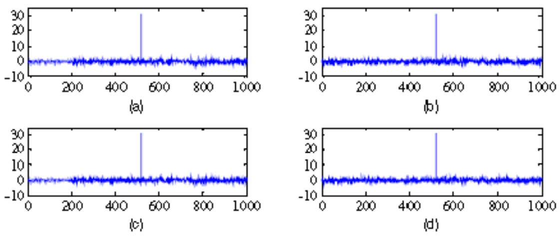

Figure.1 Watermark detector response of the proposed method for the audio file 'Symphony'for different types of attack: (a) Noise addition (b) Cropping (c) Re-quantization (d) Resampling

Table 4. Similarity results of the proposed method against noise attack

Types of Audio Signal	SIM		
	$\alpha = 0.3$	$\alpha = 0.2$	$\alpha = 0.1$
Symphony	31.2963	31.0412	29.7736
Gayageum	31.1618	30.7437	28.7173
Human Voice	31.4734	31.4328	31.2153
Classical	31.4902	31.4706	31.3647

Table 5. Similarity results of the proposed method against cropping

Types of Audio Signal	SIM		
	$\alpha = 0.3$	$\alpha = 0.2$	$\alpha = 0.1$
Symphony	30.9362	30.9362	30.9361
Gayageum	31.0210	31.0209	31.0210
Human Voice	31.0930	31.0930	31.0931
Classical	31.0234	31.0234	31.0234

Table 6. Similarity results of the proposed method against re-quantization

Types of Audio Signal	SIM		
	$\alpha = 0.3$	$\alpha = 0.2$	$\alpha = 0.1$
Symphony	31.4914	31.4699	31.3497
Gayageum	31.4827	31.4471	31.2568
Human Voice	31.5038	31.5008	31.4815
Classical	31.5051	31.5043	31.4988

Table 7. Similarity results of the proposed method against re-sampling

Types of Audio Signal	SIM		
	$\alpha = 0.3$	$\alpha = 0.2$	$\alpha = 0.1$
Symphony	31.5060	31.5060	31.5060
Gayageum	31.5060	31.5060	31.5060

Table 4: Similarities result of the proposed method against noise attack

Imperceptibility (Inaudibility) test for DWT:-

Imperceptibility is related to the perceptual quality of the embedded watermark data within the original audio signal. It ensures that the quality of the signal is not perceivably distorted and the watermark is imperceptible to a listener. To measure imperceptibility, we use Signal-to-Noise Ration (SNR) is a simple way to measure the noise introduced by the embedded watermark and can give a general idea of imperceptibility, in DWT method. Robustness test to evaluate robustness of the propose algorithm, we implemented a set of attacks that commonly affect audio signals. It is measured the similarity between the original watermark and the watermark extracted from the attacked watermarked images using the correlation factor ρ, which is computed as shown in equation below.

$$\rho(w,\hat{w}) = \frac{\sum_{i=1}^{N} w_i \hat{w}_i}{\sqrt{\sum_{i=1}^{N} w_i^2}\sqrt{\sum_{i=1}^{N} \hat{w}_i^2}}$$

where N is the number of pixels in watermark, w and $\hat{w}$ are the original and extracted watermarks respectively. The correlation factor $\boldsymbol{\rho}$ may take values between 0 (random relationship) to 1 (perfect linear relationship).

Conclusion

We evaluate the performance of our watermarking method for different types of Wav audio signals sampled at 44.1 KHz .The DCT and DWT based watermarking will be done using above equations on audio signal. The effectiveness of these algorithms is verified by conducting experimentation by comparing for their performance features. It shows strong robustness against several kinds attack. We will evaluate the robustness of the

Watermark to common signal manipulations including adding noise and re-sampling etc. our proposed method achieves SNR values ranging from 13 dB to 24 dB for different watermarked sounds.

References

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