



A novel Hybrid Inaudible Audio Watermarking with Binary Image as Watermark using DWT

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Abstract

Digital audio watermarking has become an important technique for copyright protection and secured data communication. There are numerous algorithms evolving in audio watermarking. We propose a novel hybrid inaudible algorithm for watermarking audio signals using Discrete Wavelet Transform (DWT). In our proposed algorithm we are using audio signal as host information and binary image as watermark. The multi resolution properties of DWT properties like transpose, flip, rotation, scaling and translation invariance are making the watermarking process robust and more capacitive (to hold large amounts of information). Our spread spectrum based embedding algorithm is verified for various watermarking coefficients (α) and proposed to have to variable α according to quantization levels of host information instead of single value.

Our proposed algorithm is tested for various types of music signals with varying bit rates as host information and binary image as watermark. The proposed algorithm is tested and found very robust to filtering, extra noise, resampling, quantization and MP3 compression attacks. In this paper we also compare the performance of our algorithm with existing DWT based, techniques in information capacity (PSNR) and robustness (Normalized Correlation Coefficient).

Keywords

Digital Audio Watermarking, Discrete Wavelet Transform (DWT), watermarking coefficients, PSNR and Normalized Correlation Coefficient

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1. INTRODUCTION

The proliferation of digitized media (audio, image and video) is creating a pressing need for copyright enforcement schemes that protect copyright ownership. Existing conventional cryptographic systems permit only valid key holders access to encrypted data, but once such data is decrypted there is no way to track its reproduction or retransmission. Therefore, conventional cryptography provides little protection against data piracy, in which a publisher is confronted with unauthorized reproduction of information. A digital watermark is intended to complement cryptographic processes. It is a perceptible, or preferably imperceptible, identification code-information that is permanently embedded in the data and remains present within the data after any decryption process [1].

In general, an effective watermarking scheme should satisfy the following basic requirements:

1. *Imperceptibility*: the perceptual difference between the watermarked and the original documents should be unnoticeable to the human observer, i.e., watermarks should not interfere with the media being protected.
2. *Trustworthiness*: a satisfactory watermarking scheme should also guarantee that it is impossible to generate counterfeit watermarks, and should provide trustworthy evidence to protect the rightful ownership.
3. *Robustness*: given a watermarked document, an unauthorized party should not be able to destroy the watermark without also making the document useless, i.e., watermarks should be robust to common signal processing and intentional attacks. In particular, they should still be detectable or extractable even after common signal processing operations have been applied to the watermarked image

The Audio Watermarking techniques may be classified in different ways. The classification may be based on the type of watermark being used, i.e., the watermark may be an audible or not. In the sense the host and watermarked audio signals not differentiable (Inaudible) or differentiable (Audible). This is non differentiability or non audibility property is made possible by exploiting characteristics of the Human Auditory System (HAS). Audio watermarking is especially challenging as compared to image watermarking because the HAS is far more sensitive than the visual system. Perturbations in a sound file can be detected as low as one part in ten million [2]. Nonetheless, various "tricks" can be employed to cause inaudible distortion. The auditory system acts like a band pass filter bank with strongly overlapping filters. The MPEG psycho acoustical model represents these filters as "critical bands," each with a particular sensitivity. If a signal is maintained below the threshold of sensitivity, then the watermark will be inaudible. Above 2 kHz, the HAS focuses more on the temporal envelope of an audio signal than the actual structure [3][4]. Thus, small changes in the spectrum above 2 kHz are less likely to be noticed by a human listener. This holds good for audio signals inserting into audio host, but fails in case of embedding image information into audio signal. Another way we have is, temporal masking involves two sounds that occur over a very short period of time (on the order of milliseconds). The ear essentially ignores the weaker sound even if it occurs before the stronger masking sound.

A second classification is based on whether the watermark is applied in the time domain or the transform domain. Time-domain techniques include the Least Significant Bit substitution (LSB) and echo hiding techniques, among many others [5, 6]. LSB embeds the watermark information in the least significant bits of the audio sample values by overwriting the original bits [6, 7]. It takes advantage of the quantization error that usually derives from the task of digitizing the audio signal. On the other hand, echo watermarking attempts to embed information into the original discrete audio signal by introducing a repeated version of a component of the audio signal with small offset, initial amplitude and decay rate to make it imperceptible [9]. In general, time-domain audio watermarking is relatively easy to implement, and requires few computing resources, however, it is weak against signal processing attacks such as compression and filtering.

Frequency domain audio watermarking techniques employ human perceptual properties and frequency masking characteristics of the human auditory system for effective watermarking [8]. In these techniques, the phase and amplitude of the transform domain coefficients are modified in a certain way to carry the desired watermark information. Popular transforms include the Discrete Fourier Transform (DFT), the Discrete Cosine Transform (DCT), and the Discrete Wavelets Transform (DWT).

In transform domain methods during watermarking phase watermark added samples of transformed signal will be inverse transformed making watermark to get distributed irregularly over the watermarked signal, making the attacker difficult to get the knowledge of presence of watermark. The localization is the most essential criterion to adapt a technique in watermarking. Wavelet is one of the transform domain techniques that feature localization.

2. DWT

Discrete Wavelet Transform: The DWT is similar to DCT and DFT and gives multi resolution analysis with good time localization. DWT can be realized by iteration of filters with rescaling. The resolution of the signal, which is a measure of the amount of detail information in the signal, is determined by the filtering operations, and the scale is determined by up-sampling and down-sampling (sub-sampling) operations [10].

The DWT is computed by successive low pass and highpass filtering of the discrete time-domain signal as shown in figure 2.2 & 2.3 this is called the Mallat algorithm or Mallat-tree decomposition. Its significance is in the manner it connects the continuous-time multiresolution to discrete-time filters. In the figure, 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, $a[n]$.

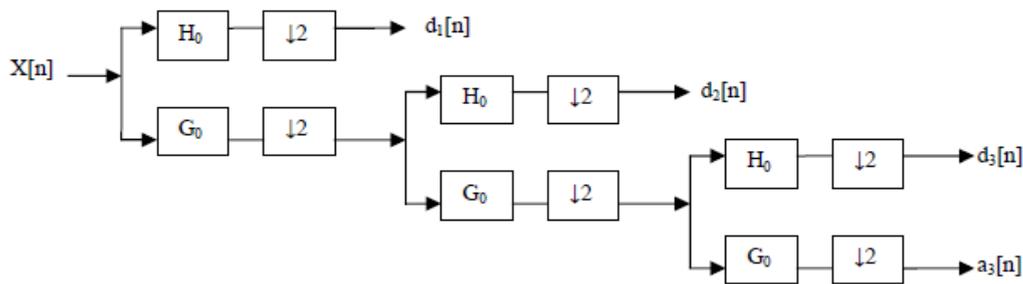


Figure 2.2 Three-level wavelet decomposition tree.

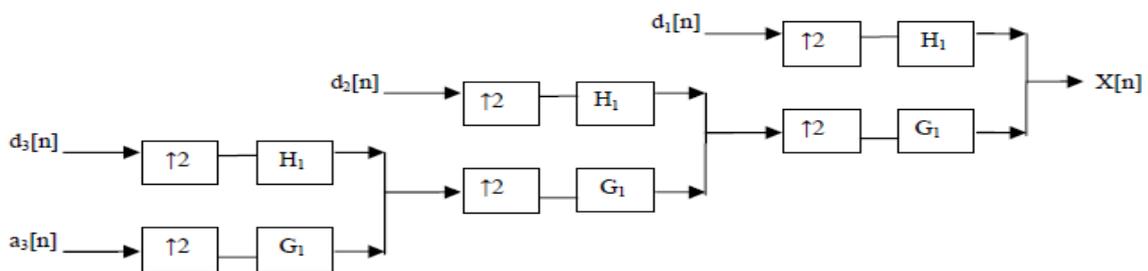


Figure 2.3 Three-level wavelet reconstruction tree.

Let $G_0(z)$ and $G_1(z)$ be the low pass analysis and synthesis filters, respectively and $H_0(z)$ and $H_1(z)$ the high pass analysis and synthesis filters respectively. Then the filters have to satisfy the following two conditions as given in [11]:

$$G_0(-z)G_1(z) + H_0(-z)H_1(z) = 0$$

$$G_0(z)G_1(z) + H_0(z)H_1(z) = 2z^{-d}$$

The first condition implies that the reconstruction is aliasing-free and the second condition implies that the amplitude distortion has amplitude of one.

3. PROPOSED ALGORITHM

In this paper, DWT based hybrid technique is proposed for watermarking of binary watermark image on audio signal. The robustness and perceptibility of watermarked audio signal is tested with two quantifiers such as PSNR and NCC.

1. Embedding Procedure

The audio signal is processed through DWT with db4 as wavelet filter. The low pass band of third level is selected for embedding the binary watermark image. In pure DWT based approach, the portion of binary watermark is embedded into third level Low pass band coefficients.

Step1: Read host audio signal and apply the third level DWT with db4 filter, cA3 be the low pass band coefficients.

Step2: Read binary image as watermark and reshape it into a single column vector into 'wmk'

Step3: Alter the cA3 coefficients with respect to wmk as,

$$cA3_new = cA3 + \alpha * wmk \text{ where } \alpha \text{ is watermarking coefficient.}$$

Step4: Apply inverse DWT on cA3_new and the other sub bands obtained in step1 to produce Watermarked Audio.

Step5: Evaluate PSNR between hosts audio and watermarked audio as a measure of imperceptibility.

$$PSNR = 10 * \log \frac{Max(A, A')}{\sum \sum [Mean[Mean[(A - A')^2]]]}$$

2. Extracting Procedure:

Extraction procedure involves extraction of watermark information (binary image) form watermarked audio using host audio. The extracted binary image is compared with original watermark binary image for robustness by measuring normalized correlation coefficient. The detailed description as fallows,

Step1: Read host audio signal, watermarked audio signals and apply the third level DWT with db4 filter, cA3 ,eA3 be the low pass band coefficients of host and watermarked respectively.

Step2: Obtain the watermark from the cA3 ,eA3 coefficients with respect as,
 $wmk=(eA3-cA3)/\alpha$ where α is watermarking coefficient.

Step3: Evaluate NCC between original watermark and extracted watermark as a measure of Robustness.

$$NCC = \frac{\sum(A - mean(A)) \sum(B - mean(B))}{\sqrt{\sum(A - mean(A))^2} \sqrt{\sum(B - mean(B))^2}}$$

4. EXPERIMENTAL RESULTS

The experiments are performed on audio signal (WAV File) of single channel, sampling frequency 44.1KHz samples each sample is represented by 16 bits and no of samples being 192437. A binary image 'Grains.bmp' of dimension 256X256 is used as Binary watermark image. The result shows that there is *no perceptibility* in watermarked audios in DWT from PSNR measurements 72. The unities in NCC values are observed in extraction process proving *Trustworthiness*. The details are tabulated in table 1. All these experiments are performed using Matlab(R2013a) installed on Intel corei3 CPU @3030GHz processor and 4GB RAM.

Table1: Performance of DWT, based watermarking in Imperceptibility and Trustworthiness

<p>Input Host Audio with 16 bits representing each sample and with length of 192437</p>	<p>Input Binary Watermark of dimension 256X256</p>
<p>DWT based Watermarked Audio PSNR=72.03DB</p>	<p>Extracted image from DWT based watermarked Audio, Ncc=1.000</p>

The robustness of the algorithm is tested with various signal processing attacks are listed in the Table 3. He watermarked audio signals are made to go through the various signal attacks like filtering, Gaussian Noise, Mp3 Compression, Sub sampling and Re-Quantization.

Experiments are performed on various instrument music signals[11] with different bit rates as host audio signals and the grains.bmp as watermark with db4 wavelet filter and $\alpha=0.0005$.the results are tabulated in table 2. The PSNR values in tables are promising increased PSNR with increased bit rate.

Table 2: Bit rates (Bytes per minutes) vs PSNR.

S.No	Instrument	80Bpm	90Bpm	110Bpm	120Bpm
1	Guitar	73.830	75.3192	75.8081	76.2081
2	Electric Piano	72.6754	73.0410	73.9512	74.5946
3	Bass	74.4761	74.9414	75.1526	75.2808

Table3: Robustness with respect to various attacks

S.NO	Attack	Extracted Images
1.	Butterworth Low pass filtering (2 nd Order & Cutoff Frequency=0.9)	
	Normalized Correlation Coefficient	0.7286
2.	White Gaussian Noise (SNR=80)	
	Normalized Correlation Coefficient	0.9716
3.	MP3 Compression	
	Normalized Correlation Coefficient	0.8453
4.	Sub-Sampling (Half the sample rate of Input Audio)	
	Normalized Correlation Coefficient	0.81738
5.	Re-Quantization (10 bits representation)	
	Normalized Correlation Coefficient	0.64035

The performance of our algorithm is compared with [12] Ali Al-Haj's DWT approach where the DWT is used during embedding is claiming PSNR of range 20dB to 30dB, which is quite a double of Ali Al-Haj.

5. CONCLUSION



Audio watermarking is performed by considering a WAV audio file as host and a binary image as watermark using DWT. The results are quite promising good in the requirements of watermarking algorithm i.e imperceptibility, trustworthiness and robustness. A three level db4 wavelet is used in DWT.

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