Audio Watermarking Based on Hybrid Low and High Wavelet Frequencies

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Article Info

Article history:

Received Nov 09, 2015
Revised Mar 14, 2016
Accepted Mar 20, 2016

Keyword:

Audio watermarking
Copyright protection
Imperceptibility
Robustness
Wavelet domain

ABSTRACT

Transform-domain digital audio watermarking has a performance advantage over time-domain watermarking by virtue of the fact that frequency transforms offer better exploitation of the human auditory system (HAS). In this research paper an adaptive audio watermarking is proposed based on the low and high wavelet frequencies band (LF, HF). The embedded watermark can be of any types of signal (text, audio and image). The insertion of the watermark data is performing in a frequency domain after applying discrete wavelet transformation on the cover audio segments. The normalize correlation and the signal to noise ratio metrics are used to test the performance of the proposed method in terms of the robustness and imperceptibility. Test results show that an improvement of the robustness against some type of attacks when the watermark is adaptively embedded in a different wavelet bands.

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1. INTRODUCTION

Globalization and internet are the main reasons for the growth of research and sharing of information. They have become the greatest tool for malicious user to attack and pirate the digital media.

Digital Watermarking is the process that embeds data called a watermark into a multimedia object such that watermark can be detected or extracted later to make an assertion about the object. The watermarking technique during the evolution was used on images, and is termed as Image Watermarking. Image watermarking has become popular; however, the malicious user has started to extract the watermark creating challenges for the developers. Thus, developers have found another digital embedding source as audio and termed such watermarking as Audio Watermarking which involves the hiding of data within a digital audio file.

A general block diagram of any watermark system is shown in Figure (1), which usually consists of a binary data sequence, is inserted into the host signal (embedding process). Thus, a watermark embedding has two inputs, one is the watermark message (usually accompanied by a secret key) and the other is the host signal (e.g. image, video clip, audio sequence etc.). The output of the watermark embedding is the watermarked signal, which cannot be perceptually discriminated from the host signal.

In the literature the digital audio watermarking techniques can be grouped into two types; time and frequency domain techniques [1].The two domains have different characteristics, and thus performances of their techniques may vary with respect to the robustness and imperceptibility (inaudibility) requirements of audio watermarking. Inaudibility refers to the condition that the embedded watermark should not produce audible distortion to the sound quality of the original audio, in such a way that the watermarked marked version of the file is indistinguishable from the original one [2]. Robustness determines the resistance of the watermark against removal or degradation. The watermark should survive malicious attacks such as random cropping and noise adding, and its removal should be impossible without perceptible signal alterations [3].

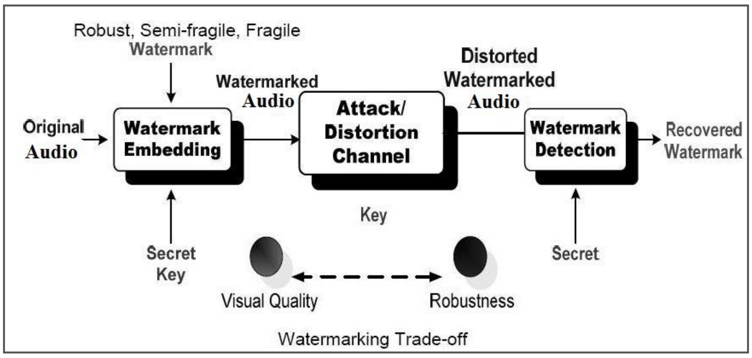


Figure 1. Block diagram of audio watermarking scheme

Li et al [4] proposed for robust audio watermarking in wavelet domain. It emphasizes on enhancing security by dynamically modifying embedding strategy. The modification is based on real-time changes of the watermark information and host audio. Bhaskari et al [5] presented a novel blind audio watermarking scheme to embed a meaningful data into digital audio by encoding the data using godelization technique and then the data is embedded into the digital samples based on a private key. The proposed watermarking algorithm can extract the hidden data which is embedded without the help of the original audio signals. Experimental results show that there is no distortion between the original and watermarked audio signals.

Abdul-Majeed and Mohammed [6] executed two methods (DC, DCT), the applied methods don't required the original signal to detect the watermarked signal , SNR after implementation of the DC and DCT method on symphony and speech signals (55.4229 dB, 29.2226 dB) and (21.2506 dB, 19.7124 dB) respectively. It is concluded that the DC method is better and has a good performance than the DCT method for embedding the watermark data of type (speech) in both types of signal (Symphony, Speech). Patil and Chitode [7] proposed an effective watermarking algorithm based on Discrete Wavelet Transform for audio. This approach embeds the image watermark data into approximate coefficients of the wavelet transform.

Embedded watermark can be faithfully recovered under different attacks such as volume scaling, resampling, low pass filtering & re-quantization, etc. Experimental results show that the embedded watermark is perceptually transparent. The proposed method gives improved Signal to Noise ratio (more than 20 dB) for common attacks which satisfies IFPI requirement & improved peak signal to noise ratio.

2. DWT – BASED AUDIO WATERMARKING ALGORITHM

Discrete Wavelet Transform is used in a wide range of digital signal processing applications including multimedia (image\audio\video) compression, communication and security. This transform can effectively represent signals especially those have localized variations [8].

Figure (2) shows an implementation of a one-level forward DWT based on a two quadrature mirror filter bank, where ho (n) and h1 (n) are low-pass and high-pass analysis filters, respectively, and the block ↓2 represents the down-sampling operator by a factor 2. Thus, for 1D-DWT, the signal is convolved with these two filters and down-sampled by a factor of two to separate it into an approximation and a representation of the details. A perfect reconstruction of the signal is possible by up-sampling (↑2) the approximation and the details and convolving with reversed filters (go (n) and g1 (n)).

Based on this algorithm, the one-dimensional discrete wavelet coefficients of any stage can be computed from the coefficients of the previous stage using the following iterative equations:

$$WL(n, j)=\sum_{m} WL(m, j-1)\, h_0(m-2n) \quad (1)$$

$$WH(n, j)=\sum_{m} WL(m, j-1)\, h_1(m-2n) \quad (2)$$

Where $WL(n, j)$ is the nth scaling coefficient at the jth stage, $WH(n, j)$ is the nth wavelet coefficient at the jth stage, and h0(n), h1(n) are he dilation coefficients corresponding to the scaling and wavelet functions, respectively. The inverse transform is as follow:

$$WL(n, j) = \sum_{k} WL(k, j+1)\, g_0(n-2k) + \sum_{l} WH(l, j+1)\, g_1(n-2l) \qquad (3)$$

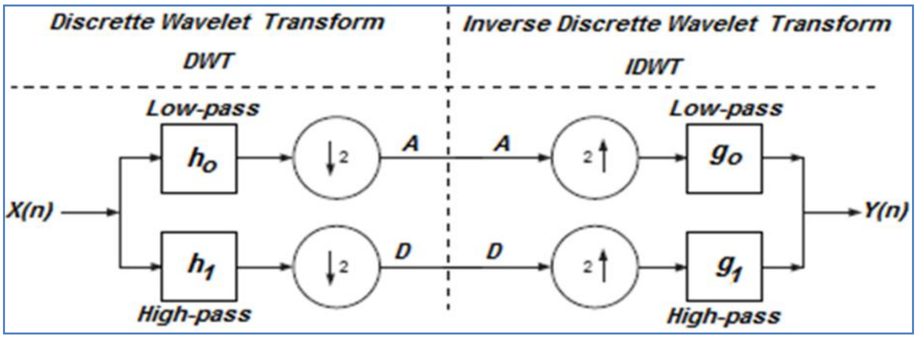


Figure 2. One - level forward DWT and its inverse IDWT

2.1. Watermarking Embedding Process

In this stage the cover audio and a watermark (text, image, and audio) files are loaded, then the audio sequence is partitioned to segments. The segmented audio signal is presented in frequency domain by the low and high frequency coefficients according to the wavelet bands. In Figure (3) the flowchart of the embedding process of the proposed method is shown.

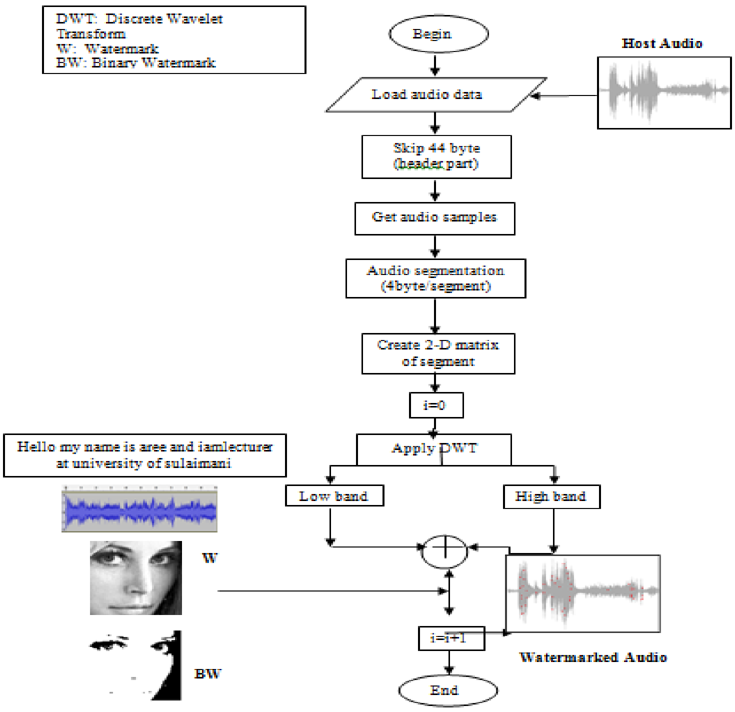


Figure 3. DWT audio watermarking embedding process

2.2. Watermarking Extraction Process

Figure 4 presents the flowchart of the extraction process of the proposed method.

3. SIMULATION RESULTS

In this research, different types of audio signal (classic and pop) are used as a cover media to investigate and evaluate the performance of the proposed audio watermarking algorithm. A wav file of 10 seconds in length is used for each type. The sample rate for both is 44.1 KHz and quantized to 16 bits per sample. A 75*78 gray scale image of Lena is used as a watermark for embedding in the low and high frequencies of a wavelet bands. The proposed method is tested for a text and audio file for the purpose of comparison.

To assess the robustness, the NC of the original and extracted watermark data is used according to Eqs. 4, SNR (Signal to Noise Ratio) is selected to evaluate the imperceptibility of the proposed schemes according to Eq. 5, the subjective evaluation is also considered to ensure the inaudibility using MOS (Mean Opinion Score) grading.

$$NC(w, w') = \frac{\sum_{i=1}^{N} W_i \; w_i'}{\sqrt{\sum_{i=1}^{N} w_i^2} \; \sqrt{\sum_{i=1}^{N} w_i'^2}} \quad (4)$$

Where N is the number of pixels in watermark, w and wˆ are the original and extracted watermarks respectively.

$$SNR\ (dB) = 10 \log 10 \; \frac{\sum_n A^2{}_n}{\sum_n (A_n \; - A'_n)^2} \quad (5)$$

Where A corresponds to the original signal, and A' corresponds to the watermarked signal.

3.1. Imperceptibility Test

Inaudibility is related to the perceptual quality of the embedded watermark data within the original (cover) audio signal. It makes sure that the quality of the audio is not perceivably distorted and the watermark is imperceptible to the listener. Equation (5) is used as an objective measure, and a listening test (MOS) as a subjective measure as shown in Table 1.

Table 1. MOS grading scale

MOS Grade	Description
5 – Excellent	Imperceptible
4 – Good	Perceptible, but not annoying
3 - Fair	Slightly annoying
2 – Poor	Annoying
1 - Bad	Very annoying

Table 2. presents the MOS and SNR values between the original and the watermarked audio files (classic and pop) when the capacity of the text file is (256 bytes), binary image watermark is (732 bits) and the audio file is (256 bytes).

Table 2. Imperceptibility values

Audio type	SNR (dB)			MOS		
	Text	image	audio	text	image	audio
Classic	25.2	31.2	23.1	3.1	4.7	2.9
Pop	24.7	33.7	21.9	4.01	5	4.3

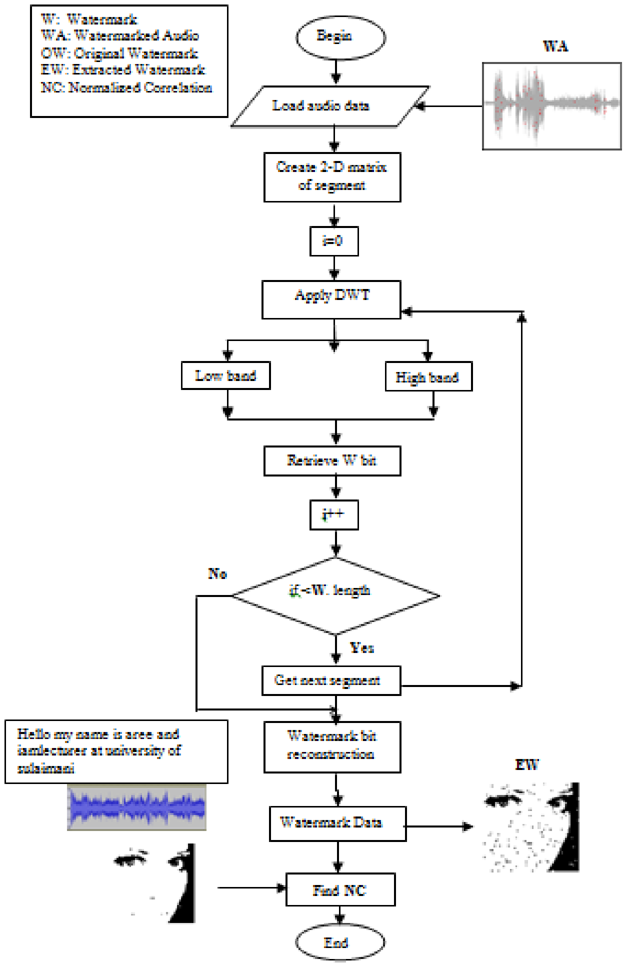


Figure 4. DWT audio watermarking Extraction process

Figures (5) and (6) represent the waveform of the classic and pop audio files before and after embedding the watermark image.

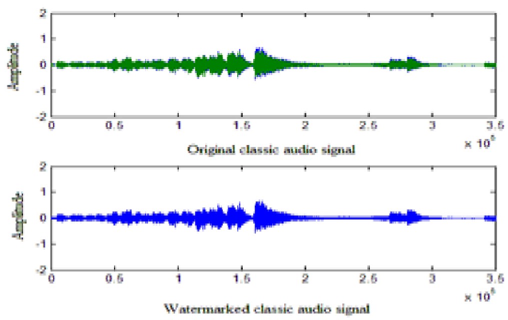


Figure 5. Classic music

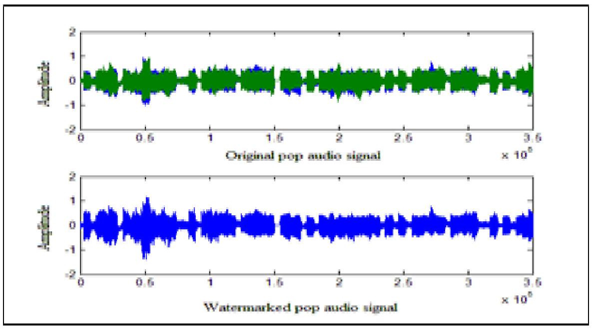


Figure 6. Pop music

3.2. Robustness Test

The performance of the proposed scheme against signal processing such as echo, amplification, smoothing filter and cropping among many others is tested. Although these types of attack may not change the quality of the cover audio signals, they may distort the watermark image added in the host signal. Attacks have been applied by some audio software tools such as (Audacity and GoldWave).

Figures (7, 8) show the extracted watermark after applying the attacks for both classic and pop musical signals respectively. The effect of the attacks is significantly varied from one type to another. The similarity between the original and the extracted watermark is also calculated using equation (4).

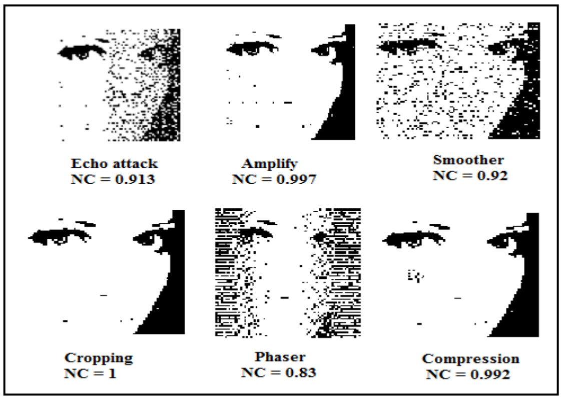


Figure 7. NC values for extracted watermark after attacks (classic audio signal)

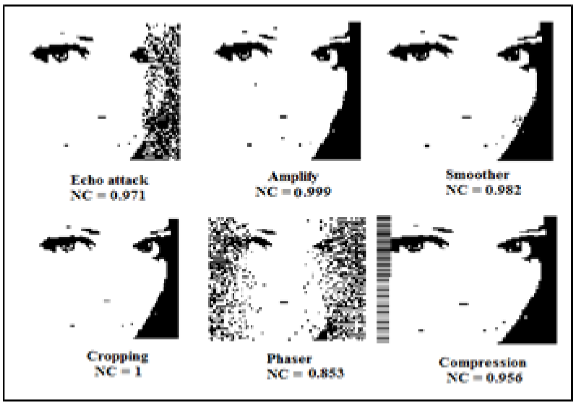
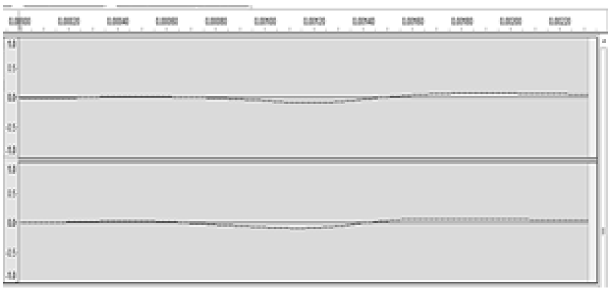
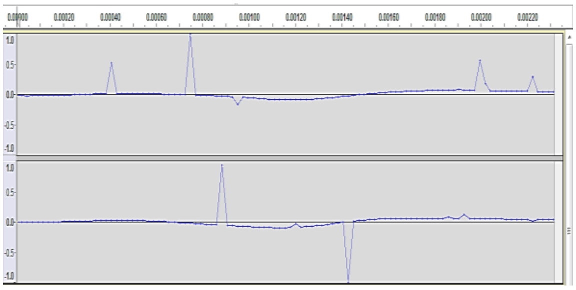


Figure 8. NC values for extracted watermark after attacks (pop audio signal)

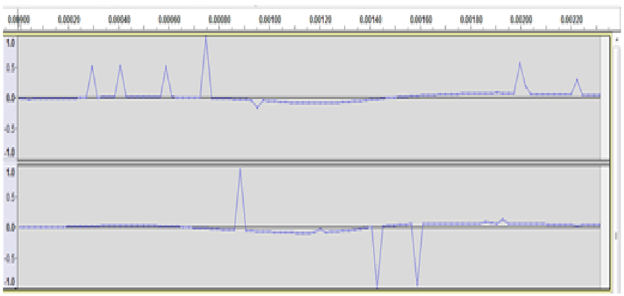
In Figure 9 a sample of audio file as a watermark of size (256 Bytes) and the extracted before and after an attack is represented.



Original watermark



Extracted watermark NC=0.9664



Extracted watermark after attack NC=0.9477

Figure 8. NC values for extracted watermark before and after attacks

3.3. Results Comparison

According to the proposed audio watermarking algorithms in the time and frequency domain, this work research gives better results when the watermark is embedded in high and low wavelet coefficients. Subjective and objective evaluation parameters for inaudibility and the robustness for both watermarked audio and the watermark itself outperform the obtained results in the recent related works. In table 3 the MOS and SNR results are presented compared with some related techniques.

Table 3. Performance comparison with other techniques

Reference	Algorithm	SNR(dB)	MOS
Uludage [9]	DCT	21.4	3.35
Deman [10]	Modified Phase	20.78	4.2
Ali Al-Haj [11]	DWT (low band)	25.031	5
Proposed scheme	DWT (low and high) bands	33.7	5

3. CONCLUSIONS

Few studies are available on digital audio watermarking comparing to the image and video watermarking. However, during the last decade audio watermarking studies have also increased considerably especially in frequency domain. The proposed technique is developed to solve the copyright protection problem of digital audio products. In this research, an effective audio watermarking scheme based on the low and high wavelet frequencies is proposed. Test results show that the watermark bits are embedded in an imperceptible and a robust way. The MOS value for a pop music has a grade 5 and the SNR value is 33.7 when the watermark type is a binary image of size (732 bits). For other types of watermark, the robustness and the imperceptibility are decreased as presented in Table 2.

ACKNOWLEDGEMENTS

We would like to thank the IEC2014 conference held in Erbil city to publish the maniuscript of this extended version of the research work. Author would thank also Miss Deman Mustafa who was one of my M.Sc. student to contribute this work in both time and transform domain.

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