Audio Watermarking: A Way to Copyright Protection

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Abstract

The audio watermarking is generally used as a multimedia copyright protection tool. In this paper, we propose an efficient digital audio watermarking algorithm based on the alteration of DC component of the frame of an audio signal. The algorithm performance is validated in the presence of the standard watermarking attacks. Natural variability of these audio features allows watermarking alterations to be imperceptible to the human observer. On the other hand, significance of these features makes the system robust to common signal processing operations.

1. Introduction

The recent growth in computer networks & internet has enabled user to modify & access digital contents very easily. The issue of information security has gained extensive attention. Digital watermarking [1][2] has been proved as an appropriate solution for copyright protection and to enforce the intellectual property rights(IPR). The digital document may be text, audio, image or video. When the digital document is in the form of an audio signal, the embedding technique is called audio watermarking [3]. It is also defined as the robust & imperceptible communication of digital audio data .

A watermarking scheme is said to employ informed detection if it requires the original host (audio) signal to be present at the watermark detector. Conversely, a watermarking scheme is said to employ Blind Detection if it does not require the original host signal to be present at the watermark detector.

Watermarking techniques should possess certain properties based on the type of watermark & the intention for which it is used. According to the International Federation of Phonographic Industry (IFPI)[4], audio watermarking should meet the various requirements listed as follows.

a) Imperceptibility: The most important requirement of audio watermarking is that the quality of the original signal has to be retained after the embedding of watermark. 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 using common audio signal processing operations and attacks. The detection rate of watermark should be perfect.

c) Capacity: It refers to the number of bits that can be embedded into the audio signal within a unit of time. A user should be able to alter the amount of information embedded depending upon the applications.

d) Security: It implies that the watermark can only be detected by the authorized person.

e) Speed: The watermark embedding and extracting processes have to be fast enough depending upon the application.

The main challenge in digital audio watermarking is to achieve the good trade off between the robustness and high watermark data rate. The most important requirements are perceptibility, robustness, data rate are shown by a magic triangle in Fig. 1.

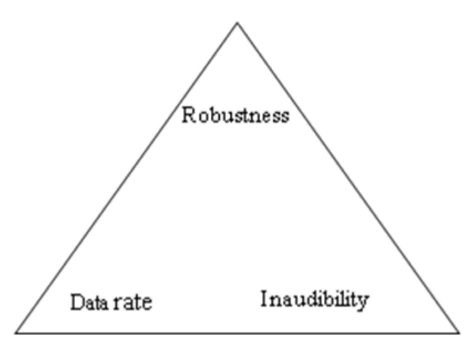

Fig. 1. Magic Triangle

1.1 Applications

In the last decade, digital watermarking has attracted considerable research interest. Numerous applications in various domains (e.g. audio, video) have been proposed and related watermarking techniques have been studied rigorously. It may be used for a wide range of applications [2][5], such as:

- Copyright protection
- Source tracking
- Broadcast monitoring
- Covert communication
- Fingerprinting.
- Copy control

The main focus of this paper is to hide watermark in digital audio signal by altering DC value of audio frame.[7] The digital media that carries the watermark is called a cover signal or host audio signal. The watermark is embedded into the host signal by a watermark embedded and is detected by a watermark detector. A watermark key prevents unauthorized watermark embedding and watermark detection [5].

The rest of the paper is organized as follows. In Section 2, theoretical background of digital audio watermarking is briefly described. Section 3 gives the idea about the proposed approach. Evaluation of proposed technique is depicted in the Section 4 followed by the conclusion in the last section.

2. Theoretical background

Based on their embedding domain, digital audio watermarking is grouped into two categories as time domain and transform domain. Among the large number of proposed techniques, few techniques are reviewed in the literature. In time domain watermarking system, watermark is directly embedded into audio signal. Wide range of time domain embedding techniques for digital audio signal such as Least Significant Bit (LSB) alteration, Echo Addition, phase coding and Spread Spectrum methods have been developed.

LSB coding is the earliest method developed in the audio watermarking area..

Nedeljko Cvejic et al. [6] have presented LSB coding approach with increase in depth of the embedding layer from 4th to 6th LSB layer & high bit rate. It has been proved to be more robust for noise addition than the standard LSB technique. This method is useful for the applications which require low robustness & high data rate.

In phase coding method is one of effective watermarking approach because the listener can not detect any difference occurred due to the small phase shift. This approach is useful for the application which requires less distortion in original audio signal. The basic phase coding method proposed by Cvejic Needljko [5] embeds the whole watermark signal into the phase spectrum of the first block. In this scheme, as the watermark is not embedded over the entire audio data available, cropping attack can easily remove the watermark signal.

In spread spectrum scheme presented by D. Kirvoski & Malvar [9], each watermark bit is spread over a number of MCLT frequency coefficients. This approach shows strong robustness against additive noise this method requires original audio signal to extract the watermark.

The watermarking scheme described by Hafiz Malik [10] use direct sequence spread spectrum & inserts the watermark into a randomly selected frequency band of the original audio signal. This method shows very low perceptual distortion & mean square error as compared to Cox's method [8]. It shows strong robustness to standard signal processing operations.

In time domain algorithms, watermark is embedded without any transformation & watermark can be easily destroyed. Implementation of these methods is very easy & requires less computation. The watermark signal is shaped before embedding. This enables the system to maintain the audibility of the original audio signal. The robustness of the time domain algorithm is poor. Hence most of the research work is focused on transform based watermarking techniques. Because the audio signal sampling frequency is low, and the human auditory system (HAS) is more sensitive than the human visual system(HVS), so the amount of information to be embedded in the audio signal is much less than in the visual media[4][5].

Transform domain audio watermarking technique take the advantage of frequency masking property of Human auditory system. Transforming audio signal into frequency domain enables watermarking system to hide the watermark into perceptually significant component of an audio signal. It gives high robustness against signal processing operations.

This technique includes the use of discrete cosine transform (DCT), Discrete Fourier Transform (DFT), and discrete wavelet transforms DWT. Each of these transforms has its own characteristics and represents the audio in different ways. Transforming audio signal from time domain to frequency domain enables watermarking system to embed the watermark into perceptually significant part of a signal. This will develop the technique with a high robustness

Pranab kumar Dhar [11] has proposed a Discrete Cosine Transformation (DCT) based audio watermarking technique. In this approach, watermarks are embedded into the selected peaks of highest energy component. It shows strong robustness against different types of attacks & gives SNR up to 24dB which is greater than Cox's method for different audio signals.

Pranab Kumar Dhar & Jong –Myon Kim [12] have proposed watermarking scheme based on discrete Fourier transform (DFT). In this watermarking method watermark bits are embedded into the most prominent peak of each frame of an audio signal. Though it shows high robustness against different types of attacks & achieves improved SNR up to 28dB as compared to DCT based technique discussed by Pranb & Kim [11] for different audio samples but it doesn't give good robustness against MP3 compression attack.

Akira Nishimura et al. [12] have presented a sub band coding amplitude modulation based audio watermarking approach. This scheme shows strong robustness against perceptual audio coding (i.e.MP3) & reverberation but this technique is very sensitive to pitch modification. Watermark embedding & extraction process enhances the security of the watermark data using a secret key.

Most of existing audio watermarking techniques have low embedding capacity, poor robustness against active attacks, high embedding distortion. The selection of the approach depends on several factors. The most important factors are the type of host audio, the computational complexity of the approach and the application for which it is being used that defines the degree of robustness required.

3. Proposed work

This section provides an overview of our proposed watermarking scheme, which consists of the watermark embedding process and watermark extraction process.

Watermark is embedded in lower frequency components of the audio signal, which are below the perceptual threshold of the human auditory system. This technique involves shifting the DC level for the input audio signal to negative and positive level according to the binary watermark sequence.

Level 0 = DC Bias Multiplier (Power of a Frame)
Level 1 = +DC Bias Multiplier (power of a Frame)

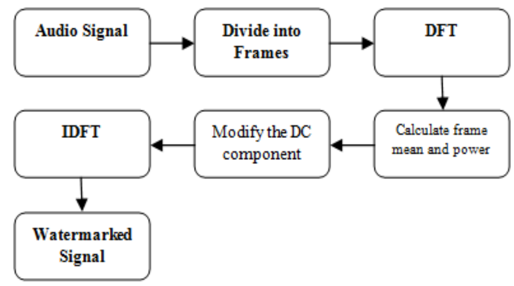

Fig. 2 Watermark Embedding process

Where,
Level 0 = value of the negative level
Level 1 = value of the positive level
DC Bias Multiplier = constant for DC bias multiplier.
Frame Power = frame power to the associated frames.

3.1. Watermark Embedding

Figure 2 illustrates the proposed watermark embedding process. The audio signal is divided into several fixed-sized frames.

In order to alter the DC component of a frame, the frame of a audio signal is processed using following steps;

1) The Discrete Fourier Transform (DFT) is computed for each frame, x[n].The first element of the vector thus computed represents the DC component of the frame.

2) The mean and power content of each frame is calculated as follows,

Frame mean = $(1/N)\,\Sigma\, x[n]$
Frame power = $(1/N)\,\Sigma\,(x[n])^2$

Where N=Number of samples in each frame.

3) The first element of the frame vector obtained through DFT is modified to represent watermark bit as described above with DC Bias Multiplier = 100.

4) The Inverse Discrete Fourier Transform (IDFT) of the frame vector gives the modified frame.

These steps are performed until all the watermark bits are encoded.

3.2. Watermark Detection

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For the decoding process, the watermarked audio signal is divided into equal sized frames with the frame size being equal to that used during encoding. For a given frame, the frame mean is calculated and the binary watermark sequence is decoded according to the sign of the frame means as shown in Fig.3

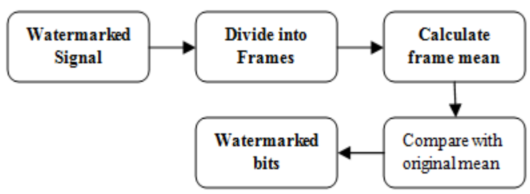

Fig. 3 Watermark extraction Process

4. Performance Evaluation

The performance of the proposed approach is evaluated in terms of Signal to noise ratio imperceptibility & robustness [15]. Two types of measures are applied on the Watermarked audio signal as follows

4.1. Objective Measures

The most commonly used objective measure is SNR which define the overall error between the original audio & watermarked audio signal.

4.2. **Subjective Measure:**

The subjective measures need qualitative evaluation to assess audio quality. This evaluation includes listening to the original audio & watermarked audio & finding the difference between them by the use of five point scale as shown in Table 1.

Imperceptibility ensures that quality of the signal is not perceivable distorted. Watermark should be imperceptible to a listener. The quality of the watermarked signal is evaluated in terms of Signal to noise ratio (SNR) using the following equation

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

Where w(n) & $w^*(n)$ are original audio signal & watermarked audio signal respectively as shown in fig. 4 & fig.5.

TABLE 1
SUBJECTIVE GRADES

Grade	Description	Quality
5	Imperceptible	Excellent
4	Perceptible	Good
3	Slightly annoying	Fair
2	Annoying	Poor
1	Very annoying	Bad

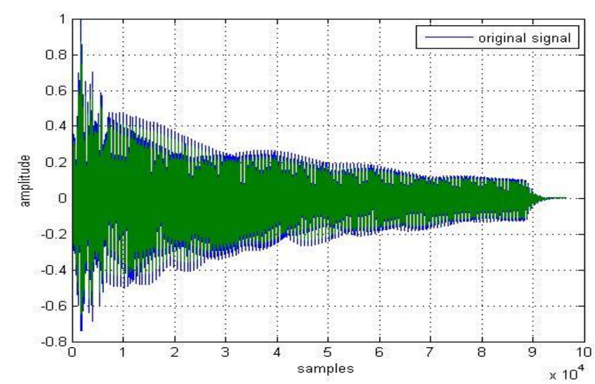

Fig.4 Original Audio signal

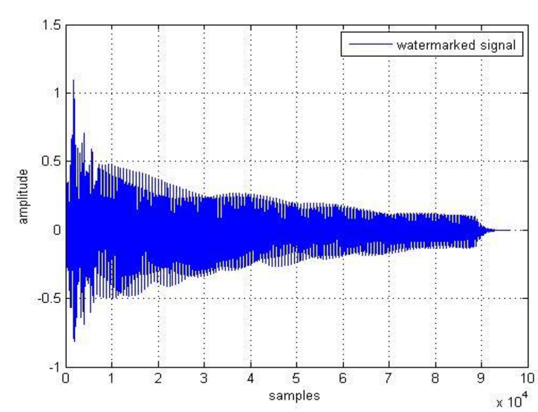

Fig. 5 Watermarked audio signal

Table 2. Shows the performance of our proposed method in terms of Signal to noise ratio. It gives improved SNR as compared to traditional watermarking methods.

TABLE 2
SNR (dB) values for various attacks

Audio File	Volume Scaling	Additive Noise	LPF	Re-sampling	Re-quantization
Speech	20	43.06	30.77	45.86	35.72
Music	20	41.72	32.81	49.71	35.11
Instrumental	20	49.11	29.78	54.21	42.39

5. Conclusion

The proposed approach is implemented by altering the dc component of the frame using MATLAB software. The algorithm was also subjected to a series of imperceptibility (audio fidelity) and robustness tests. Proposed scheme shows strong robustness against Low pass filtering, Volume scaling, Additive random noise, Re-sampling and Re-quantization. The robustness of the scheme can be increased up to certain level by selecting longer audio files or by inserting the watermark signal multiple times. It has been observed that SNR values depend on type of music, songs with loud pitch.

6. Future Scope

Future research scope is to enhance the capacity of the system to carry hidden data & making the system more robust to attacks

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