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A Robust Algorithm for Audio Watermarking

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ABSTRACT:

Watermarking is concept of embedding a picture into another multimedia file such as digital images and digital videos. Various effective watermarking algorithms have been proposed and executed for such cases. However, very few algorithms have been proposed for audio watermarking because of its difficulty in analysing or interpreting the human audio system than the human visual system. In this paper, describing a robust audio watermarking algorithm based on Discrete Wavelet Transform (DWT). Embedding an invisible watermark into an audio sample is important to generate a copy right protection or to send a confidential information like signature of a person to avoid forgery.

Keywords: Watermarking, audio system, Discrete Wavelet Transform (DWT), copy right, forgery.

INTRODUCTION

Now-a-days, there is a lot of advancements in the computer technology and tele-communication networks. Multimedia files are generated, stored and distributed in very simple manner across the wold. However, the protection of multimedia files is becoming difficult. So, to overcome such limitations introduced the concept of watermarking for providing copyright protection. With this idea, we can maintain ownership of particular multimedia files and providing our own copyright protection. Digital watermarking is a technology which also allows a secret message to be hidden in a computer file, without the detected by any other user. The watermark will not disturb the usage of original file and does not affect in any way. The information of watermark is helpful predominantly to identify the owner of a particular digital file i.e., a painting, a music or a text.

Digital watermarking has been proposed in recent years as a means of protecting multimedia contents from intellectual piracy. This is achieved by modifying the original content, by inserting a signature which can be extracted, when necessary, as a proof of ownership. Indeed, many effective digital image and video watermarking algorithms have been proposed and implemented at a commercial scale [9]. However, and due to the fact that the human audio system is far more complex and sensitive than the human visual system, few algorithms have been proposed for audio watermarking [4].

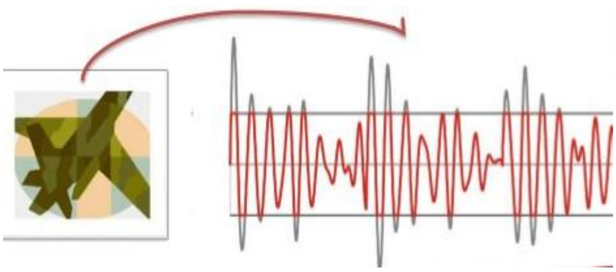

Figure 1: Watermarking an image into audio signal

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LITERATURE WORK

Audio watermarking techniques reported in literature can be grouped into two types; time-domain techniques and frequency-transform domain techniques [1, 3]. 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. 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.

Time-domain techniques include the Least Significant Bit substitution (LSB) and echo hiding techniques, among many others [5, 7]. LSB embeds the watermark information in the least significant bits of the audio sample values by overwriting the original bits [7, 10]. 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 [12, 15]. 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 [14]. 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 previous inventions, the Fourier transform magnitude coefficients over the frequency range from 2.4 KHz to 6.4 KHz are replaced with the watermark sequence since human sensitivity declines compared to its peak around 1 KHz. Moreover, human ears are relatively insensitive to phase distortion, and especially lack the ability to perceive the absolute phase value, therefore, the watermark is represented by the relative phase between selected coefficients and their neighbours. The problem with these watermarking schemes that they are less robust to signal processing and malicious attacks, such as audio compression.

Other than time-domain and frequency domain techniques, spread-spectrum watermarking methods are becoming popular. These methods, embed a narrow-band signal (the watermark) into a wide-band channel (the audio file) to spread the watermark data across the large frequency band, namely the audible spectrum [8, 16]. Watermark detection is done by calculating the correlation between the watermarked audio signal and the watermark signal. Finally, Patchwork methods use pseudorandom processes to embed a certain statistic into a data set which is detected in the reading process with the help of numerical indexes, like the mean, describing the specific distribution. Computational complexity of these methods is very high, and synchronization is difficult to implement.

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AUDIO WATERMARKING

The aim of digital audio watermarking is to provide the artistic and creative work owner the capability to verify that the work has belonged to them. Besides copyright protection purposes, an audio watermark has other useful effectiveness's such as consisting a metadata which is additional description about the artist or the content or even you can add a URL address in the audio file to tell the purchaser where to get more information about the song or download the full album. "Digital Watermarking" is the technique of embedding some information into multimedia content by modifying the media content slightly.

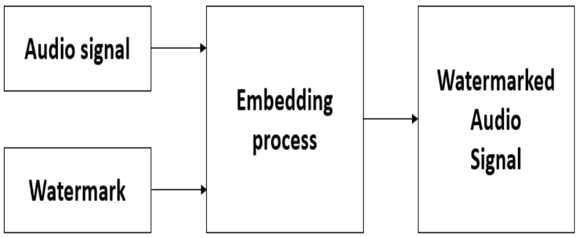

Figure: Flow diagram for Audio watermarking

Digital audio watermarking involves the concealment of data within a discrete audio file. There are numerous applications for this type of technologies. Intellectual property protection is currently the main driving force behind research in this area. To combat the online music piracy, a digital watermark could be added to all recording prior to release, signifying not only the author of the work, but the user who has purchased a legitimate copy. Latest operating systems equipped with digital copyright management software will extract the watermark from audio files prior to playing them on the system. This type of particular software will ensure that the user has paid for the song or not by comparing the watermark to the existing purchased licences on the system.

On other side, non-rights-based concept of watermarking technology includes embedding auxiliary information which is related to a particular song, like lyrics, album information, or a small website page, etc. Watermarking could be used in voice conferencing systems to indicate to others which party is currently speaking. A video application of this technology would consist of embedding subtitles or closed captioning information as a watermark.

DWT BASED ALGORITHM

The algorithm we propose here is based on applying the Discrete Wavelet Transform (DWT) on the digital audio signal in which a watermark is to be embedded. The algorithm consists of two procedures; watermarking embedding procedure and watermarking extraction procedure.

Watermark Embedding Procedure

The embedding procedure performs four major operations; Audio signal reading and processing, watermark pre-processing, DWT-based frequency decomposition of the audio signal, and watermark embedding in the DWT-transformed audio signal. The operations are described in the following steps.

1. Read the audio signal and process the signal such that the 1-Dimensional audio is represented with 2-Dimensional image format.

$$\boldsymbol{I = reshape(audio, 512, 512)}$$

2. Express the watermark image as a 2-Dimensional matrix whose size is MXN.

$$\boldsymbol{W = \{W(i,j), 0 \le i \le M-1, 0 \le j \le N-1\}}$$

3. Decomposing the audio signal into four bands using DWT based frequency decomposition method.

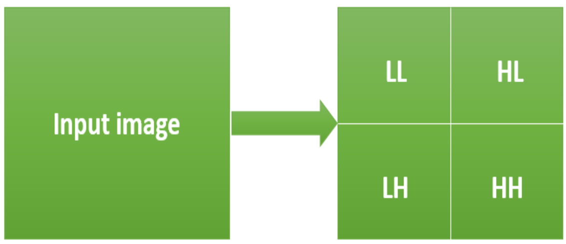

Figure: Decomposing an image using DWT

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4. Finally the watermark image is embedded into any one band out of {LH, HL or HH}. The embedding process is based on the following algorithm-1.

Watermark Extraction Procedure

The watermark extraction procedure enables the owner of the audio clip to extract the embedded watermark. The procedure requires knowledge of the original audio file, the watermark intensity, and the size of the watermark, in order to extract the watermark. The watermark extraction steps are a direct reversal of steps carried out in the embedding procedure.

Algorithm-1:

```
for i = 1:M
   for j = 1:N
      [ll hl lh hh] = dwt2(a, 'wavelet basis');
      if (abs(hl(x,y) < T))
         if (wm(i,j) ==1)
            hl(x,y) = t + (abs(hl(x,y))/T);
        else
            hl(x,y) = -t - (abs(hl(x,y))/T);
        end
   end
mbed = idwt2(ll,hl,lh,hh,'wavelet basis');
end
```

Extraction steps are described as follows:

1. Apply the two-level Discrete Wavelet Transform on watermarked host audio signal which produces one approximate (LL) and three detailed (HL, LH and HH) sub-bands.

2. Compute the watermarked vector from the signal.

3. Divide the result with amplification factor α to get the normalized watermark vector.

4. Finally multiply the image by 255 to reconstruct the original grey-scale watermark image.

The algorithm for extracting the watermark from the watermarked audio signal is given in Algorithm-2

IMPERCEPTIBILITY (INAUDIBILITY)

Imperceptibility or Inaudibility 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. Humans cannot sense the minute changes in the music file after watermarked. To measure imperceptibility, we can use Signal-to-Noise Ratio (SNR) as an objective measure, and a listening test as a subjective measure.

Algorithm-2:

```
for i = 1:M
   for j = 1:N
      [ll hl lh hh] = dwt2(mbed, 'wavelet basis');
        if ((hl(x,y) < T) & (hl(x,y)>0))
           w(i,j) = 1;
        else ((hl(x,y) > -T) & (hl(x,y)<0))
           w(i,j) = 0;
      end
   end
end
```

Signal to Noise Ratio (SNR) is a statistical difference metric which is used to measure the similitude between the undistorted original audio signal and the distorted watermarked audio signal. The SNR computation is done according to following equation, where A corresponds to the original audio signal, and A' corresponds to the watermarked audio signal.

$$SNR\ in\ dB = 10\ log_{10} \frac{\sum_n A_n^2}{\sum_n (A_n - A_n')^2}$$

Although SNR is a simple way to measure the noise introduced by the embedded watermark and can give a general idea of imperceptibility, it does not take into account the specific characteristics of the human auditory system.

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Therefore, a parameter called Perceptual Audio Quality Measure (PAQM) is preferred.

SIMULATION RESULTS

The concept of embedding an image into an Audio signal is performed with the MATLAB simulation software. The signature of the owner can be watermarked inside a music or audio file. For verifying the result, a .wav file is taken as input. The plot for the input audio signal and the chosen watermark image is as shown in the following figures.

The audio may be any file, like a person's voice or music composed by music director or any sound which is audible to the human beings.

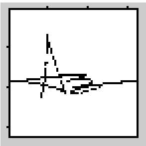

Figure: Watermark image

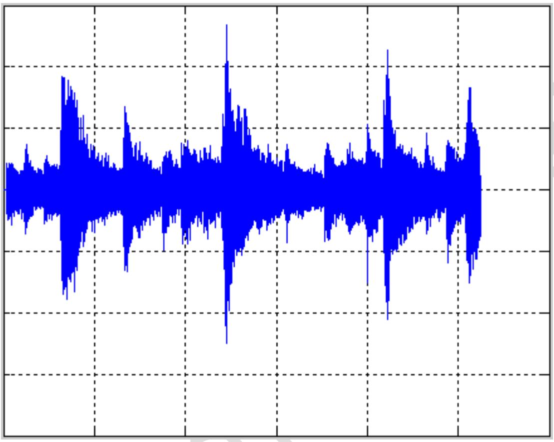

Figure: Input audio signal

The input host audio signal is first reshaped to form a 2-Dimensional image format. The audio input is undergone through two-level Discrete Wavelet Transform and decomposing the image into four different sub bands. And the watermark image is embedded in any one of the detailed bands like LH, HL or HH bands. The below figure shown the audio signal after embedding the watermark and there are no sensible changes in the audio and the watermark is not affecting the audible clarity of the music file.

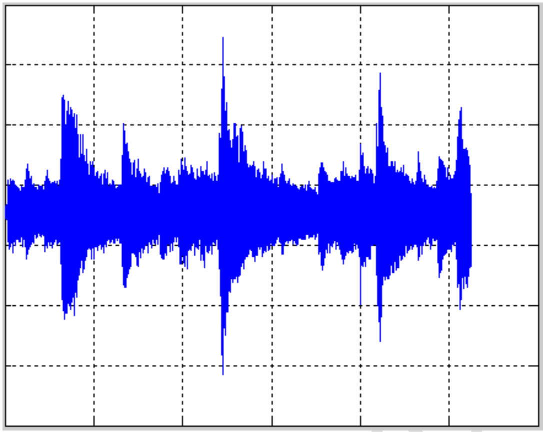

Figure: Watermarked host audio signal

In the process of extraction, the watermarked audio signal is given as input and undergone through some inverse recovery algorithm to extract the watermark. The below figure gives the output of extraction algorithm and the error between the original watermark and extracted watermark image. The error image is complete Black, which represents the binary value '0' i.e., the error is zero and the watermark is extracted successfully.

(a) (b)

Figure: (a) Extracted watermark (b) Error Image

CONCLUSION

Audio watermarking is an active research area that has been driven by the need to solve the copyright protection problem of digital audio products and also any secret information can also be hidden inside an audio signal to avoid the unauthorized access of information. Such a technology is helpful to overcome the problem of forgery of signature. Many promising audio watermarking techniques have been proposed and proved to be effective, however, and due to the challenging nature of audio signal processing, there remains much to do. In this paper, we proposed an effective audio signal watermarking Algorithm based on the discrete wavelets transform. The spectrum of the host

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audio signal was decomposed to locate the most appropriate regions to embed the watermark bits, imperceptibly and robustly. Indeed, our simulation results demonstrated the audibility and robustness of the proposed audio watermarking algorithm.

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