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Digital Audio Watermarking Algorithms

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Abstract— Many effective watermarking algorithms have been proposed and implemented for digital images and digital video.However, a few algorithms have been proposed for audio watermarking.This is due to the fact that, human auditory system(HAS) is far more complex and sensitive than human visual system(HVS). Robust watermarking algorithm is used to embed the watermark into an audio and perform different attacks. But which is having a limited transmission bit rate.In order to improve the bit rate audio watermarking in wavelet domain have been proposed. The limitation of this approach is the basis functions are fixed and it is not necessary for all the real signals. In this research work, a new method of embedding a binary image into the audio signal and additive audio watermarking algorithm based on EMD(empirical mode decomposition) is proposed.First, the original audio signal is segmented into frames. Each frame is decomposed into IMFs by using EMD. Watermarks are then embedded into each frame. Experimental results demonstrate that is inaudible and this algorithm is robust to common operations of digital audio signal processing, such as noise addi- tion, re-sampling, requantization and so on.To evaluate the performance of the proposed audio watermarking method, subjective and objective quality tests including Bit Error Rate (BER) and Signal to Noise ratio (SNR) are conducted.

Index Terms— — Digital audio watermarking, spread spectrum watermark, HHT (Hilbert Hung Transform), IMF (Intrinsic Mode Function), EMD (Empirical Mode Decomposition).

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1 INTRODUCTION

MAIN requirements of digital audio watermarking are imperceptibility, robustness and data capacity. More precisely, the watermark must be inaudible within the host audio data to maintain audio quality and robust to signal distortion applied to the host data. Finally, the watermark must be easy to extract to prove ownership[1][2][3][4]. To achieve these requirements, seeking new watermarking scheme is a very challenging problem. Recently, a new signal decomposition method referred to as Empirical Mode Decomposition(EMD) has been introduced. A major advantage of EMD relies on no priori choice of filters or basis function. Break down any signal into a reduced number of zero-mean with symmetric envelopes AM-FM components called Intrinsic Mode Functions(IMFs). We choose in our method a watermarking technique in the category of Quantization Index Modulation(QIM)[3] due to its good robustness and blind nature.

1.1 Literature review

The development of network and multimedia technol- ogy makes it convenient to access the multimedia in- formation. These technologies bring people many conveiences but they also bring us some large side effects.

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The problem of multimedia copyright protection becomes increasingly serious. Digital audio watermark technology is commonly achieved by certain modification to the host signal. [1] Generally, With the aid of audio watermarking technology it is possible to embed additional information in an audio track. To achieve this, the audio signal of a music recording, an audio book or a commercial is slightly modified in a defined manner. This modification is so slight that the human ear cannot perceive an acoustic difference. Audio watermarking technology thus affords an opportunity to generate copies of a recording which are perceived by listeners as identical to the original but which may differ from one another on the basis of the embedded information

Only software which embodies an understanding of the type of embedding and embedding parameters is capable of extracting such additional data that were embedded previously. Without such software or if incorrect embedding parameters were selected it is not possible to access these additional data. This pre- vents unauthorized extraction of embedded information and makes the technique very reliable. This characteristic is utilized by Music Trace in a targeted manner. Every Music Trace customer receives a unique set of embedding parameters. Consequently, each customer is only capable of extracting that information which he embedded himself. Accessing embedded information of other customers, by contrast, is not possible. In addition to the inaudibility of the watermark and process security, two other factors play an important role. The first of these is the data rate of the watermark, i.e., an indication of the volume of data which can be transmitted in a given period of time. The other is the robustness of the watermark. Robustness is an indication how reliably a watermark can be extracted after an intentional attack or after transmission and the inherent signal modifications. The watermarking process implemented by Music Trace was investigated by the Eu- ropean Broadcasting Union (EBU) in terms of robustness. Forms of attack investigated included analog conversion of the signal, digital audio coding or repeated filtering of the signal. This revealed that the watermark can no longer be extracted only

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when the quality of the audio signal has been substantially degraded as a result of the attack. The factors data rate and robustness are mutually dependent. If more inaudible information are to be transmitted in a certain time the robustness of the watermark declines as a consequence. For embedding additional data, Music Trace utilizes data containers that permit an acceptably high data rate and robustness. The two most commonly used data containers permit transmission of 48-bit additional data in 5 seconds with a very high robustness or 48- bit additional data in 2.7 seconds with slightly lower robustness[6].

1.1 Empirical Mode Decomposition

EMD is the fundamental part of the HHT (Hilbert Hung Transform). The decomposition is starts from finer scale to coarser ones. Any signal x(t) is expanded by EMD as follows:

$$x(t)=\sum_{j=1}^{C} IMF_j(t)+r_c(t)$$

Where C is the number of IMFs and $r_C(t)$ denote the final residual. The IMFs are nearly orthogonal to each other, and all have nearly zero means. The number of extrema is decreased when going from one mode to the next, and the whole decomposition is guaranteed to be completed with a finite number of modes. Breakdown any signal into a reduced number of zero-mean with symmetric envelopes AM-FM components called Intrinsic Mode Functions(IMFs).The idea of the proposed watermarking method is to hide into the original audio signal a water- mark together with a Synchronized Code (SC) in the time domain. The input signal is first segmented into frames and EMD is conducted on every frame to extract the associated IMFs (Fig 1).

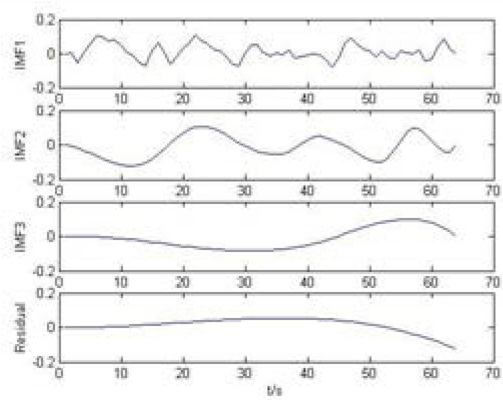

Fig. 1 Decomposition of the watermarked audio frame by EMD

Then a binary data sequence consisted of SCs and informative watermark bits (Fig 2) is embedded in the extrema of a set of consecutive last-IMFs. Since the number of IMFs and then their number of extrema depend on the amount of data of each frame, the number of bits to be embedded varies from last-IMF of one frame to the following.

Sync-code	Watermark bits	Sync-code

Fig. 2. Data structure m_i

If we design by N_1 and N_2 the numbers of bits of SC and watermark respectively, the length of binary sequence to be embedded is equal to $2N_1+N_2$. Thus, these bits are spread out on several last-IMFs (extrema) of the consecu- tive frames. Further, this sequence of $2N_1+N_2$ bits is em- bedded p times. Finally, inverse transformation(EMD_1) is applied to the modified extrema to recover the wa- termarked audio signal by superposition of the IMFs of each frame followed by the concatenation of the frames.For data extraction, the watermarked audio signal is split into frames and EMD applied to each frame . Binary data sequences are extracted from each last IMF by searching for SCs.The SCs are used to identify the location of the watermark.

1.2 synchronization code

Synchronization code is used to identify the location of the watermark or where the watermark is embedded. Which is embed both in frequency domain and time do- main. The advantage of embedding in time domain is low cost while searching the SCs. Consider U be the unknown sequence and V be the SC. Both have same length. If there is different bits between U and V then only the U is considered as SC. They compare with a given threshold.

2 Watermark Embedding

Before embedding, SCs are combined with watermark bits to form a binary sequence denoted by m_i. m_i consist of zeros and ones. Watermark embedding is shown in Fig 3

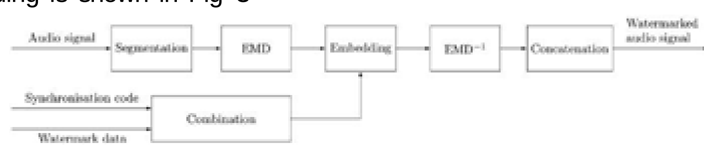

Fig. 3. Watermark embedding

First the audio signal is divided into number of frames and each frame is decomposed by EMD. EMD decomposes each frame into intrinsic mode functions. The number of IMFs is depends on the length of the data and the synchro- nization code. The binary data sequence is embedded into the extrema of the last IMF. The binary sequence consist of the watermarked bits and the synchronization bits. The synchronization bits is used to identify the location of the watermark. After embedding the watermark into the ex- trema of the last IMF we concatenate the IMFs and getting a watermarked audio signal. The watermarked audio and the original audio is indistinguishable.Embedding a binary logo image which is shown in figure 4.

Fig. 4. Binary Watermark

Here the watermark is embedded by using the tech- nique called QIM which is given by the formula:

$e_i* = L(e_i/s)].s + sgn(3s/4)$............. if mi=1

$e_i* = L(e_i/s)].s + sgn(s/4)$ .... if mi=0

where ei and ei* are the extrema of the IMF of the host audio signal and the watermarked signal respectively.sgn function is equal to positive if ei is maxima and negative [] denots the floor function, and S denotes the embedding strength chosen to maintane the inaudiability constraint.

2 WATERMARK EXTRACTION

Here our input is the watermarked audio.again segment the watermarked audio into number of frames and conducting EMD in each frame. Then our next task is to recover the watermark which is embedded into the extrema of the last IMF without any error. For that the receiver is searching for the sc. Once he get the sc then we get the watermark which is embedded into an audio. Bz the sc is used to identify the location of the watermark. The watermark extraction is shown in fig 5.

Fig. 5. Watermark extraction

To extracting the watermark using the following rule:

$m_i* = 1$ if $e_i* - L(ei/s)].s >= sgn(s/2)$

$m_i* = 0$ if $e_i* - L(ei/s)].s < sgn(s/2)$

3 PERFORMANCE ANALYSIS

We evaluate the performance of our method in terms of BER(Bit Error rate) and NC(Normalized cross- Correlation). To evaluate the watermark detection accu- racy after attacks, we use BER and NC defined as follows:

$$BER(W,\tilde{W}) = {}^{M}{}_{Nj=1} W(i,j) \oplus W(\tilde{i},j)/M \times N$$

where $\oplus$ is the XOR operator and M*N are the binary watermark image sizes. W and $\tilde{W}$ are the original and recovered watermark respectively. BER is usd to evaluate the watermark detection accuracy after signal processing operations.

To evaluate the similarity between the original watermark and the extracted one use NC as follows:

3.1 Robustness Test

Robustness means how reliably a watermark can be extracted from the original one. To show the robustness of this method different attacks are performed. They are

- Noise: White Gaussian Noise(WGN) of 20db is added to the watermarked signal.
- Re sampling: The watermarked signal, originally sampled at 44.1khz, re-sampled at 22.05khz and restored back by sampling again at 44.1khz.
- Compression: Using MP3, the watermarked signal is compressed and then decompressed.
- Requantization: The watermarked signal is re-quantized down to 8 bits/sample and then back to 16bits/samples.

Figure 6 shows the original and watermarked audio.

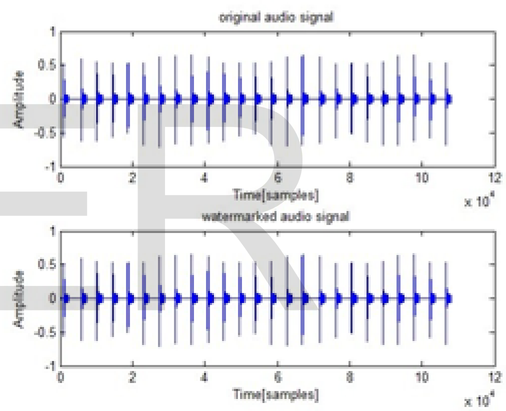

Fig. 6. audio signal and its watermarked version

4 CONCLUSION

To show the effectiveness of the scheme, simulations are performed on audio signals sampled at 44.1khz. The embedding watermark,W, is a binary logo image of size $M \times N = 17 \times 23$. Convert this 2D image into 1D image in order to embed it into the audio signal. The SC used is 16 bit sequence 1111100110101110. Each audio signal is divided into frames of size 64 samples and the threshold τ value set to 4. The S value is fixed to .25. Choosing these parameters are good compromise between imperceptibility of the watermarked signal, payload and robustness.

In this paper a new watermarking method based on EMD is introduced. The watermarking done by using a technique called QIM(quantized index modulation). The synchronization code together with the watermark bits is embed in the extrema of the last IMF. Synchronization code is used to identify the location of the watermark. And thus synchronized watermark has an ability to resist shifting and cropping attack. The S parameter is fixed for the audio. In-order to further improve this method by embedding different watermarks into different levels. If their is any distortion occurs in any levels will identify at the time of extraction. Thus this method is used for copy right protection in future.

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