Audio Watermarking Based on BCH Coding using CT and DWT

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***Abstract*—A blind Cepstrum transform-Discrete wavelet transform (CT-DWT) composite audio watermarking based on BCH coding is proposed. It takes the advantages of error correcting coding and cepstrum transform to lower the bit error rate (BER) of the extracted watermark. Experimental results show that the watermark embedded with our proposed watermarking scheme is robust and invisible. Moreover the performance of the BCH-coding scheme is superior to non BCH-coding scheme.**

I. Introduction

Today multimedia data such as audio, video and images can be easily copied and changed, and the need for copyright protection of multimedia data is increasing. Digital watermarking is the technique of embedding information directly into the media data by making small modification to them. The fundamental and most important properties of watermark are imperceptibility and robustness [1]. Many audio watermarking algorithms have been proposed in the literature [2]. A non-blind audio watermarking algorithm based on the wavelet transform (WT) and the complex cepstrum transform (CCT) was proposed in [3]. Experimental results show that the algorithm compromises inaudibility and robustness of the watermark effectively. Huang *et al*. [4] gave a blind audio watermarking based on BCH coding. The watermark is embedded in discrete cosine transform (DCT) coefficients of the original audio using human auditory system (HAS) features. This scheme demonstrates good robustness to MP3 compression, additive noise and cropping. Wei Li *et al*. [5] proposed a wavelet based blind audio watermarking scheme. In this scheme, a watermark is embedded in the approximate sub-band of the fifth-level wavelet transform. Experimental results show that this scheme is robust to many attacks. In this paper, a BCH-coding-based audio watermarking scheme using cepstrum transform (CT) and discrete wavelet transform (DWT) based on [3], [5] is presented. In section II, we explain the proposed watermarking method. Experimental results are given in section III. Finally the conclusion is drawn in section IV.

II. Proposed Watermarking method

We apply the code BCH[n,36] to the watermark data, where n denotes the block length of the BCH codeword [4]. Cepstrum transform [6] consists of three consecutive steps: Fourier transform, taking logarithm and inverse Fourier transform. The cepstrum transform is given by: $X(n) = REAL(IFFT(log(FFT(x(n)))))$. The corresponding inverse cepstrum transform is given by: $x(n) = REAL(IFFT(exp(FFT(X(n)))))$. Discrete wavelet transform [5] splits the signal into two parts, the high-frequency detail sub-band and the low-frequency approximate sub-band. The low-frequency part is split again into two parts of high and low frequencies. This process is continued a finite number of times. The original signal can be reconstructed using inverse DWT (IDWT).

Watermark Embedding: The logo image P is a binary image of size $M \times M$ and is given by $P = \{p(m_1, m_2) : 1 \leq m_1 \leq M, 1 \leq m_2 \leq M, p(m_1, m_2) \in \{0, 1\}\}$. The binary watermark image is encrypted using a random permutation and is subsequently encoded using BCH[127,36]. The original audio is first segmented into frames, with a frame size of 1024 samples. The number of frames is equal to the size of the BCH-coded watermark. The time domain audio frame is transformed into cepstrum domain using cepstrum transform. The audio frame in cepstrum domain is decomposed into 2-level wavelet transform using 4-coefficient Daubechies wavelet (db4) filter. We calculate the mean $m_k(i)$ of the wavelet coefficients $C_k(i)$ at the approximate sub-band. The mean of the wavelet coefficients is modified to zero, and the modified coefficients are denoted as $C_k^{'}(i)$. A bit $w(i)$ of the watermark data is embedded into $C_k^{'}(i)$ as follows. If $w(i) = 1$, then $Y_k(i) = C_k^{'}(i) + \beta$ and if $w(i) = 0$, then $Y_k(i) = C_k^{'}(i) - \beta$, where β is the magnitude of $m_k(i)$. From inverse DWT and inverse CT we will get the original audio signal.

Watermark Extraction: The input watermarked audio signal is segmented with a frame size of 1024 samples. The frame is transformed into cepstrum domain and is decomposed into 2-level wavelet transform using the db4 filter. The mean value of wavelet coefficients at the approximate sub-band is calculated. If the mean value is larger than zero, a bit "1" is detected. If the mean is lower than zero, a bit "0" is detected. The extracted watermark is decoded using BCH decoding. The decoded watermark is finally decrypted using the random permutation used in the embedding process.

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III. Experimental Results and Comparison

We have tested our scheme using several 16-bit mono audio signals in the WAVE format, sampled at 44100 Hz sampling rate. The embedded watermark is a binary image of size 36×36. The signal to noise ratio (SNR) is used for evaluating the quality of the watermarked signal and is given by $SNR = 10 \log_{10} \frac{\sum_{n=1}^{N} X^2(n)}{\sum_{n=1}^{N}[X(n)-Y(n)]^2}$, where X and Y are the original and watermarked audio signals respectively. The SNR of all selected audio signals are above 20 dB. In order to test the robustness of our scheme, the following attacks were performed: (A) *Additive white Gaussian noise* : White Gaussian noise is added so that the resulting signal has a SNR of 20 dB. (B) *Re-sampling*: The watermarked signal originally sampled at 44.1 kHz is re-sampled at 22.05 kHz, and then restored by sampling again at 44.1 kHz. (C) *Low-pass filtering*: The low-pass filter used here is a second-order Butterworth filter with cut-off frequency 11025 Hz. (D) *Re-quantization*: The 16-bit watermarked audio signals are re-quantized down to 8 bits/sample and back to 16 bits/sample. (E) *MP3 Compression*: The MPEG-1 layer 3 compression with 32 kbps is applied. (F) *Cropping*: Segments of 500 samples are randomly removed and replaced with segments of the signal attacked with filtering and additive noise.

TABLE I
NC and BER of extracted watermark from different attacks

Audio file	Attack type	With BCH (NC)	Without BCH (NC)	With BCH (BER (%))	Without BCH (BER(%))
Classical	Free	1	1	0	0
	A	1	0.9879	0	2
	B	1	1	0	0
	C	1	1	0	0
	D	1	0.9803	0	3
	E	0.9034	0.8792	18	21
	F	1	1	0	0
Country	Free	1	1	0	0
	A	1	0.9817	0	3
	B	1	0.9986	0	0
	C	1	0.9977	0	0
	D	1	0.9793	0	3
	E	0.8934	0.8584	19	24
	F	1	0.9986	0	0
Blues	Free	1	1	0	0
	A	0.9954	0.9514	1	8
	B	1	1	0	0
	C	1	0.9995	0	0
	D	1	0.9793	0	3
	E	0.9077	0.8705	18	23
	F	1	1	0	0
Pop	Free	1	1	0	0
	A	1	0.9795	0	3
	B	1	0.9986	0	0
	C	1	0.9986	0	0
	D	1	0.9864	0	2
	E	0.9039	0.8822	18	21
	F	1	0.9986	0	0

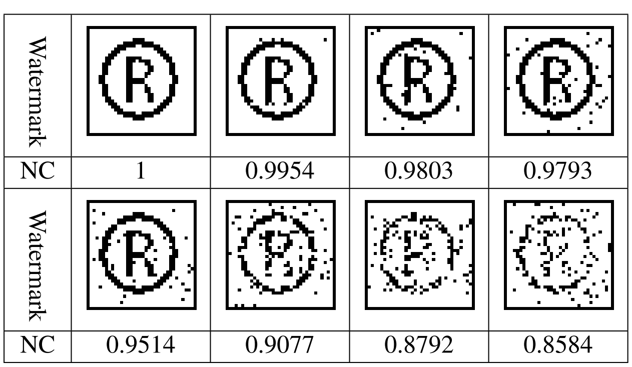

Fig. 1. Extracted watermark with various NC

The normalized correlation (NC) is used to evaluate the similarity measurement of the extracted watermark and is given by, $NC(Q, Q^*) = \frac{\sum_{i=1}^{M}\sum_{j=1}^{M} Q(i,j)Q^*(i,j)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{M} Q(i,j)^2}\ \sqrt{\sum_{i=1}^{M}\sum_{j=1}^{M} Q^*(i,j)^2}}$, where Q and Q^* are original and extracted watermarks respectively and i, j are indexes of the binary watermark image. The bit error rate (BER) is used to find the reliability of the extracted watermark and is defined as $BER = \frac{B}{M \times M} \times 100\%$, where B is the number of erroneously detected bits. The extracted watermark with different NC is shown in Fig. 1. In order to compare this method with the method without using BCH coding, the NC and BER for the above attacks are calculated. Comparison results are shown in Table I. From the table we can see that the proposed method gives higher NC and lower BER than the scheme without using BCH coding. This confirms the robustness and superiority of BCH scheme.

IV. Conclusions

An efficient and oblivious audio watermarking technique to hide binary data, based on BCH coding using CT and DWT, is proposed. BCH encoding lowers the extraction bit error rate. The proposed scheme achieves two important desirable watermarking characteristics: robustness and inaudibility. From the experimental results, we conclude that the our scheme achieves good robustness against common signal processing attacks. The performance of the proposed scheme is better than non BCH coding scheme.

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