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A Multiple Audio Watermarking Algorithm Using 2D Code and Hadamard Transform

Jihah Nah[1,+], Jizhe Cui[2] and Jongweon Kim[3]

[1] Dept. of Electrical and Electronics Eng., Yonsei University, Seoul, Korea

[2] Dept. of Information Mgmt. & Information System, Yanbian University, China

[3] Dept. of Copyright Protection, Sangmyung University, Seoul, Korea

Abstract. In this paper, a multiple audio watermarking algorithm was proposed for embedding information of multiple users into audio content to trace illegal distribution. The information is generated by Dot Code A which can express multiple user's information with error correction. The Hadamard transform was used for spreading the Dot Code A. This also ensures the algorithm has robustness. The embedding range has chosen in [-0.5, -0.3] and [0.3, 0.5] of AC coefficients in the DCT domain. When the strength was 0.7, the SNR of the test audios were over 53dB and we could extract the Dot Code exactly.

Keywords: Audio watermarking, 2D Dot Code, Hadamard transform, Multiple information

1. Introduction

Recently, the digital watermarking algorithms have been actively developing for the purose of copyright protection. However, the studies on the multiple watermarking algorithm are still lacking. The multiple watermarking algorithm is the technology required for conformation of the copyright [1]. In general, the traditional multiple watermarking algorithm has at least two different ways. The content is divided into a number of blocks, then a different watermark for each block is embedded[2]-[5]. Another one of the multiple watermarking is that the watermark integrated the multiple information is embedded into the content using single watermarking algorithm[6].

The former algorithm has several problems which is exposed to various attacks and does not have good efficiency of viewpoint for information hiding because the algorithm tried to embed too much information and the information is spread in the blocks. The latter algorithm requires a large amount of raw data, such ase mapping tables because it processed the embedding information by pre-processing[1].

In this paper, the audio watermark algorithm is developed by 2D coding method using 2D barcode, Dot Code A and code division multiplexing for the watermark generation in order to solve these problems. The algorithm fully utilized the error correction capability of the 2D barcode and strengthened the robustness by introducing the orthogonal code feature of the code division multiplexing and the principle of the chip sequence.

Section 2 described the 2D coding and the principle of the spread spectrum were introduced, and the embedding and extracting processes have been described in section 3. Section 4 evaluate the performance of the algorithm for analysis of the experimental results and conclusion was described in section 5.

2. 2D Coding and Spread Spectrum

The Dot Code A has two advantages comparing to the QR code and Data Matrix code which are the standard 2D barcodes. It has four black dots which represent the boundary of the barcode at the corners and

+ Corresponding author.
E-mail address: jihah.nah@gmail.com.

looks like the QR code which has three triple layered squares at the corners. And, the duplicated pattern of the Data matrix can be implemented by repeated use of the Dot Code A.

Fig. 1 shows the example of the Dot Code A which can express 20bits information[7].

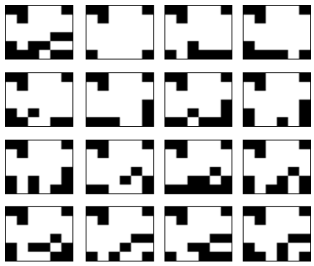

Fig 1 Dot Code A expressed 0~15

The Dot Code A has following features;

Feature 1: A square array of dots represents the data and the size is available from 6x6 to 12x12.

Feature 2: The black dot means 1, and the white means 0. The four dots are printed at the each corner for expressing the boundary of the code.

Feature 3: The direction of the code is decided by left upper corner symbol. This symbol also distingush the symmetrical pattern.

These features expressed by 10 dots and these make the finder pattern[5]. The features are proper to application of the multiple audio watermarking algorithm by modifying the Dot Code.

The spread spectrum technique is used for generating the watermark from Dot Code. If the user code sequence is S, and the other user code is T, then the inner product of S and T is 0, and the inner product of S and S is 1. The relations are described eq.(1) and (2).

$$\boldsymbol{S} \cdot \boldsymbol{T} \equiv \frac{\mathbf{1}}{\boldsymbol{m}} \sum_{\boldsymbol{m}}^{\boldsymbol{i}=\mathbf{1}} S_i T_i = \mathbf{0} \quad (1)$$

$$\boldsymbol{S} \cdot \boldsymbol{S} \equiv \frac{\mathbf{1}}{\boldsymbol{m}} \sum_{\boldsymbol{m}}^{\boldsymbol{i}=\mathbf{1}} S_i S_i = \frac{\mathbf{1}}{\boldsymbol{m}} \sum_{\boldsymbol{m}}^{\boldsymbol{i}=\mathbf{1}} S_i^2 = \mathbf{1} \quad (2)$$

The sequence makes the Dot Code into random sequence.

3. Multiple Audio Watermark Generation

First of all, the Dot Code which includes the user information should be changed from uni-polar to bi-polar sequence. The Hadamard transform was equipped for this purpose. The Hadamard matrix is described $\boldsymbol{H(n, m)}$ where n is order. The definition that a Hadamard matrix $\boldsymbol{H}$ of order n satisfies

$$\boldsymbol{HH^T = nI_n} \quad (3)$$

where $\boldsymbol{I_n}$ is the $\boldsymbol{n} \times \boldsymbol{n}$ identity matrix and $\boldsymbol{H^T}$ is transpose of $\boldsymbol{H}$. Consequently the determinant of $\boldsymbol{H}$ equals $\pm \boldsymbol{n^{n/2}}$. Let $\boldsymbol{H}$ be a Hadamard matrix of order $\boldsymbol{n}$. Then the partitioned matrix

$$\begin{bmatrix} \boldsymbol{H} & \boldsymbol{H} \\ \boldsymbol{H} & -\boldsymbol{H} \end{bmatrix} \quad (4)$$

is a Hadamard matrix of order $2\boldsymbol{n}$.

For example, the 8×8 matrix can assign user code such as $\boldsymbol{H(8,1)}$, $\boldsymbol{H(8,2)}$, $\boldsymbol{H(8,3)}$, $\boldsymbol{H(8,4)}$, $\boldsymbol{H(8,5)}$, $\boldsymbol{H(8,6)}$, $\boldsymbol{H(8,7)}$, and $\boldsymbol{H(8,8)}$[6].

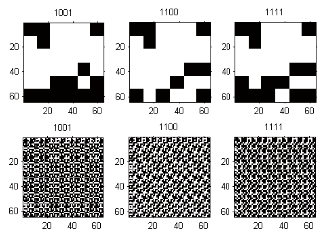

Fig. 2 Dot codes and Hadamard matrixes

Fig. 2 shows the Hadamard matrix of the Dot Code which is assigned according to the user respectively.

The Hadamard matrix was exclusive ORed by a random sequence for making a spread spectrum sequence. The random sequence is a PN(pseudo noise) code generated by computer. The PN sequence spreads the Hadamard matrix and the sequence is orthogonal.

4. Embedding and Extracting Process

The spread matrix which is watermark information is embedded into the audio signal using eq.(5).

$$\boldsymbol{Y}_i' = \boldsymbol{Y}_i(\boldsymbol{1} + \boldsymbol{\alpha x}_i) \quad (5)$$

where $\boldsymbol{Y}_i$ is a DCT coefficient, and $\boldsymbol{\alpha}$ is embedding strenth, $\boldsymbol{Y}_i'$ is wateamrked signal in the DCT domain. The embeddin g process is shown in Fig.3.

In the process, the original audio is transformed into the frequency domain by DCT and the watermark was embedded into some AC coefficients of the DCT[7]. In this paper, the watermark embedder chose the coefficients in the range of [-0.5, -0.3] and [0.3, 0.5] and embeds the watermark into the selected coefficients. After embedding the watermark, the IDCT was taken for producing the watermarked audio.

The watermark extracting process is reversed process of the watermark embedding as shown in fig. 4.

When the watermark was embedded into the original audio, the embedder chose some coefficients, so, the extractor substracts the original coefficients from the DCT coefficients of the watermarked audio. The watermark is extracted from the spread pattern, and then Dot Code is extracted from the Hadamard matrix by taking the Hadamard Transform. The similarity of the original code and the extracted code is as below;

$$\sim(\boldsymbol{M},\quad \boldsymbol{M'}) = \frac{\boldsymbol{M \cdot M'}}{\sqrt{\boldsymbol{M \cdot M'}}} \quad (6)$$

where ~ is similarity.

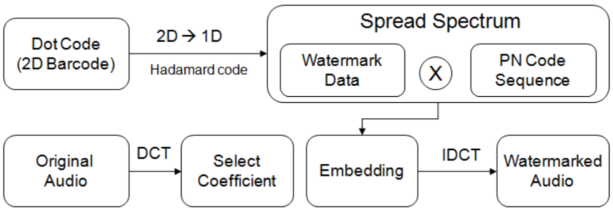

Fig 3 Embedding process of the proposed algorithm

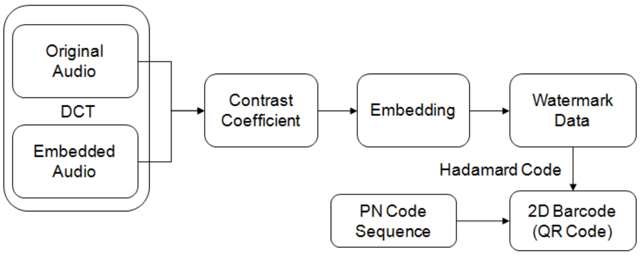

Fig 4 Extracting process of the proposed algorithm

The proposed watermarking algorithm can be implemented by two methods.

Method 1: In the case that there are two or more copyright holders, each holder was received an embedding information and Hadamard code. The information is spread by the Hdadmard code and the codes of several holders were integrated into a watermark. The integrated watermark is embedded by traditional single wateramrking algorithm.

Method 2: Assign the orthogonal code into each copyright holder, and confirm the information by the code. In this case, the embedding information is less than method 1.

5. Experiments and Results

For the algorithm evaluation, three musics were selected. The specification of the musics is shown in Tab.1.

After embedding the watermark, MP3 compression and echo attack, Sub Woofer Boost attack were tested. The echo attack was configured as initial volumn 70%, deday 75%, and delay 100ms. The test results were described in Tab.2.

Tab.1 Sample audio specification

Sample	File Format	Bit Resolution	Channel	Sampling rate	Length(s)
A	Wav/PC	16bits	2	44.1Khz	186.48
B	Wav/PC	16bits	2	44.1Khz	135.67
C	Wav/PC	16bits	2	44.1Khz	196.31

Tab. 2 Similarity test results

Sample	A			B			C		
α	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7
No attack	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
MP3	17.0	17.0	17.0	16.9	17.0	17.0	16.9	17.0	17.0
Sub WB	6.9	9.2	11.1	6.8	9.1	11.0	6.6	9.0	11.2
Echo	5.0	8.0	10.2	3.0	5.64	10.0	3.2	5.5	10.2
SNR(dB)	72.9	63.7	56.1	71.6	62.3	54.6	70.8	61.2	53.5

The test results described that the algorithm could confirm the watermark extraction when the alpha is greater than or equal to 0.3 exept echo attack. If the alpha is greater than or equal to 0.5, the algorithm could detect the watermark after the echo attack.

6. Summaries

A new multiple audio watermarking algorithm using Dot Code has been proposed. The algorithm is still non-blind watermarking, so the algorithm would be improved to the blind watermarking in the future. Although it is non-blind algorithm, it has robustness against to the MP3 compression, Sub Woofer, and echo attacks. Indeed the SNRs are over 50dB when alpha is 0.7. This means the algorithm is highly imperceptible.

7. Acknowledgements

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