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ENHANCING THE ROBUSTNESS OF AUDIO WATERMARKING TECHNIQUE USING HISTOGRAM BASED ALGORITHM

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ABSTRACT

Broadband communication networks and multimedia data available in a digital format is having many challenges and opportunities for innovation. Flexible software which is simple to use and decreasing prices of digital devices have made it possible for clients from all around the world to create and exchange multimedia data. To increase the robustness of digital audio watermarking against desynchronization attacks such as TSM (Time-Scale Modification) operations is still an important issue. In this paper, it is observed that the histogram shape and the audio mean are two robust features to the TSM attacks. Accordingly, a multi-bit robust audio watermarking algorithm is proposed by modifying the histogram. The audio histogram with equal sized bins is extracted from a selected amplitude range referred to the audio mean, and then the relative relations in the number of samples among groups of three neighbouring bins are designed to carry the watermark by reassigning the number of samples in the bins. The watermarked audio signal is obviously similar to the original one.

KEYWORDS: Audio Watermarking, Histogram, Synchronization, TSM

INTRODUCTION

Audio watermarking plays an important role in ownership protection. Audio watermarking should be robust to temporal scaling of ±10% and be able to resist most common signal processing manipulations and attacks, such as random cropping, MP3 compression, resampling etc. Among the various problems to be solved in audio watermarking, the robustness against desynchronization distortions such as TSM and random cropping is the most challenging one for previous watermarking schemes yet. Desynchronization attacks that cause displacement between encoder and decoder are difficult for a watermark to survive. In [6], the synchronization code was introduced aiming at conquering cropping attacks. However, the synchronization code is very weak to TSM. For example, a small amount of scaling will be able to cause the watermark extraction failed. TSM is a common audio processing strategy in a variety of software tools. Under TSM operations, even with the scaling amount of ±10%, the acoustic quality of audio is still quite perfect since HAS (Human Auditory System) is not sensitive to TSM. This makes TSM to be a serious attack operation in audio watermarking. Generally, there are mainly two modes of TSM operations, pitch-invariant scaling and resample scaling. The pitch-invariant mode preserves audio pitch, while the resample mode keeps pitch and tempo neither by modifying playback speed. Few algorithms can effectively resist the TSM. In the existing literature, several algorithms have been proposed aiming at solving this problem by using exhaustive synchronization pattern. Theoretically, it has been proven that the number of samples in the audio histogram bin is linear to temporal linear scaling, and the audio mean is invariant to such attack. In experimental testing, it is observed that the number of samples in the bins is almost linear to the TSM attacks, and the audio mean is rather robust to this kind of scaling attacks. As a conclusion, the audio mean and the relative relations in the number of samples among different bins are taken as two robust features to the TSM. As a robust feature to TSM, the audio mean is exploited to compute the histogram with equal-sized bins from a selected amplitude range so that the watermark is robust to amplitude scaling. The use of three successive bins as a group is designed to embed one bit of information by reassigning the number of samples in the three bins. In the extraction, the synchronization code is introduced for searching of the watermark. The original audio signal is not required. Additionally, we analyze the performance of the proposed watermarking algorithm.

PROPOSED WATERMARKING ALGORITHM

In this a Histogram Based Algorithm a multi-bit watermark aiming at solving the TSM manipulations is proposed. The watermark insertion and recovery are described by the histogram specification. The robustness of the audio mean and the relative relation in the number of samples among different bins to the TSM attacks are used in the design. The mean invariance property is used to select the amplitude range to embed bits so that the watermark can resist amplitude scaling attack and avoid exhaustive search. In the extraction, a synchronization code is exploited to eliminate the effect of TSM on the audio mean.

Watermark Embedding

The basic idea of the proposed embedding scheme is

- Select the amplitude range from the digital audio signal.
- Extract the histogram from a selected amplitude range.
- Divide the bins of histogram into many groups such as each group including three consecutive bins.
- For each group, embed one bit by reassigning the number of samples in the three successive bins.
- The watermarked audio is obtained by modifying the original audio according to the watermarking rule. The embedding model is as shown in following Figure 1.

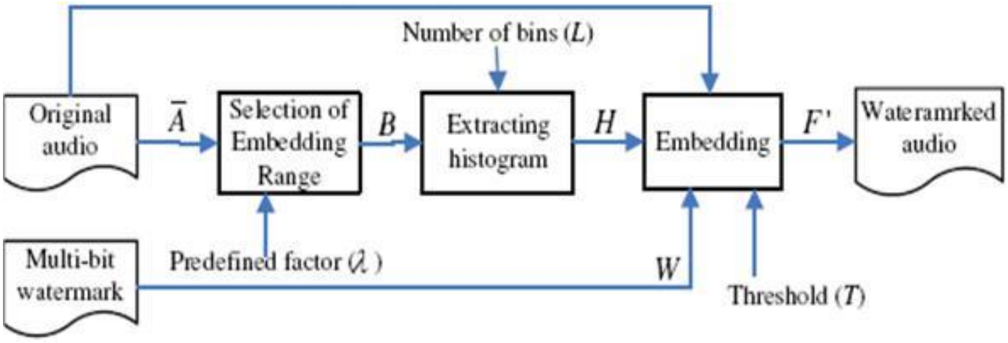

Figure 1: Watermark Embedding Model

The detailed embedding process is described as follows.

Suppose that there is a binary sequence, W = { w_i ∣i=1,…,L_w} to be hidden into a digital audio F = {f_i ∣i=1,…N }. The modified mean value of the $\bar{A}$ can be calculated as,

$$\bar{A} = \frac{1}{N}\sum_{i=1}^{N} |f(i)|$$

Now to embed all the watermark bits, select the amplitude range $B = [-\lambda\bar{A}, \lambda\bar{A}]$ from F to extract the histogram H = {h_i ∣i=1,…, L}, where $L \geq 3Lw$. λ is a selected positive number for satisfying $h(i) >> L$ and λ ∈ [2.0, 2.5] is a suggested range so that the histogram bins extracted can hold enough samples. This observation is achieved based on the extensive testing on different kinds of audio signals.

Suppose that three consecutive bins are represented as BIN 1, BIN 2 and BIN 3, their samples in the numbers are *a*, *b* and *c*, respectively. Now apply the following watermarking rules to embed one bit of information, described as,

$2b/(a + c) \geq T$ if $w(i) = 1$

& $(a + c)/2b \geq T$ if $w(i) = 0$

Where T is a selected threshold used to control the watermark robustness performance and the embedding distortion. The value of T should not be less than 1.1 in order to effectively resist the TSM. If the embedded bit $w(i)$ is '1' and $2b/(a + c) \geq T$, no operation is needed. Otherwise, the number of samples in three neighbouring bins, *a*, *b* and *c*, will be adjusted until satisfying $2b'/(a' + c') \geq T$. In case of embedding the bit '0', the procedure is similar. The rules applied to modify *a*, *b* and *c* as *a'*, *b'* and *c'* are referred to Equations (1), (2), (3) and (4) as shown below. If the embedded bit $w(i)$ is '1' and $2b/(a + c) < T$, some selected samples from BIN 1 and BIN 3 in the number denoted by $I1$ and $I3$, will be modified to BIN 2, achieving $2b'/(a' + c') \geq T$. The modification rule is described as Equation (1).

$$f1'(i) = f1(i)+M \qquad 1 \leq i \leq I_1$$

$$f3'(i) = f3(i)-M \qquad 1 \leq i \leq I_3 \tag{1}$$

where f1(i) and $f3(i)$ denote the i^{th} modified sample in BIN 1 and BIN 3, $I1$ and $I3$ are computed by using the following equation,

$$I_1 = I \,.\, a/(a + c); \;\; I_3 = I \,.\, c/(a + c);$$

$$I \geq [T\,(a + c) - 2b]/(2 + T) \tag{2}$$

If the embedded bit $w(i)$ is '0' and $(a + c)/2b < T$, some selected samples from BIN 2 will be modified to BIN 1 and BIN 3, respectively, achieving $(a' + c')/2b' \geq T$. The modification rule is described as Equation (3).

$$f_2'(i) = f2(i) - M \qquad 1 \leq i \leq I1$$

$$f_2'(j) = f2(j) + M \qquad 1 \leq j \leq I3 \tag{3}$$

where $f_2(i)$ denotes the i^{th} modified sample in BIN 2, $f_2'(i)$ and $f_2'(j)$ are the corresponding modified version of $f2(i)$ and $f2(j)$. $I1$ and $I3$ are computed by

$$I1 = I \,.\, a/(a + c); \; I3 = I.\, c/(a + c);$$

$$I \geq [2Tb - (a + c)]/(1 + 2T) \tag{4}$$

This process is repeated to embed all watermark bits. In our proposed embedding strategy, the watermark is embedded by directly modifying the values of some selected samples from the original audio. Hence the embedding process includes the reconstruction of watermarked audio, which is denoted by

$$F' = \{f'(i) \mid i = 1,\ldots,N\}$$

Watermark Extraction

Consider the effects of the TSM on the audio mean may cause the watermark detection failed, a predefined searching space denoted by $[\bar{A}''(1-\Delta1), \bar{A}''(1+\Delta2)]$ is designed for resynchronization. Here, $\bar{A}''$ denotes the mean of the watermarked audio $F'' = \{f''(i) \mid i = 1,\ldots,N''\}$ which has undergone some desynchronization attacks, such as TSM operations with different stretching modes. Based on our previous experimental analysis in, $\Delta1$ and $\Delta2$, the down and up searching error ratios of mean, are suggested not less than 5%. We use a PN (Pseudo-random Noise) sequence as a synchronization code, followed by the hidden multi-bit watermark. Only the watermark also provides the synchronization capability. The merit of part of payload as synchronization code can keep the watermark unknown for the detector. Our goal is to get an estimate of hidden bits, $W'' = \{w_i \mid_{i = 1,\ldots,Lw}\}$ by selecting an amplitude range from *F”* at a low error rate. *W’’* is composed of *Syn*(*i*)’’ and *Wmk*(*i*)’’. The histogram of *F”* is extracted with *L* bins as in the process of watermark embedding. Then the number of samples in three consecutive bins are computed and denoted by a*’’*, *b’’* and *c’’*. By comparing them, we can extract one bit of hidden information as follows,

$$w''(i) = \begin{cases} 1 & \text{if } 2b''/(a''+c'') \geq 1 \\ 0 & \text{otherwise} \end{cases} \qquad (5)$$

The process is repeated until all hidden bits are extracted. Once the synchronization code *Syn* (*i*)’’ is matched with the extracted synchronization bits *Syn*1(*i*)’’ or the searching process is finished, according to the best matching, we can extract the hidden watermark following the synchronization bits, denoted by *Wmk*1(*i*)’’. In the extraction, the parameters, *Lw*, and *Syn*(*i*)’’, are beforehand known, so the detection process is blind.

RESULTS OF HISTOGRAM BASED APPROACH

The Histogram based algorithm is applied to an audio signal in wav format Danube.wav (20s). The parameter λ=2.4 is selected to extract the histogram. The watermark is binary conversion of text information with the embedding threshold T=1.5.Robustness of algorithm is verified according to BER. This method shows the strong robustness for the TSM modifications. The Graphs of different wave files after applying different attacks are as shown below.

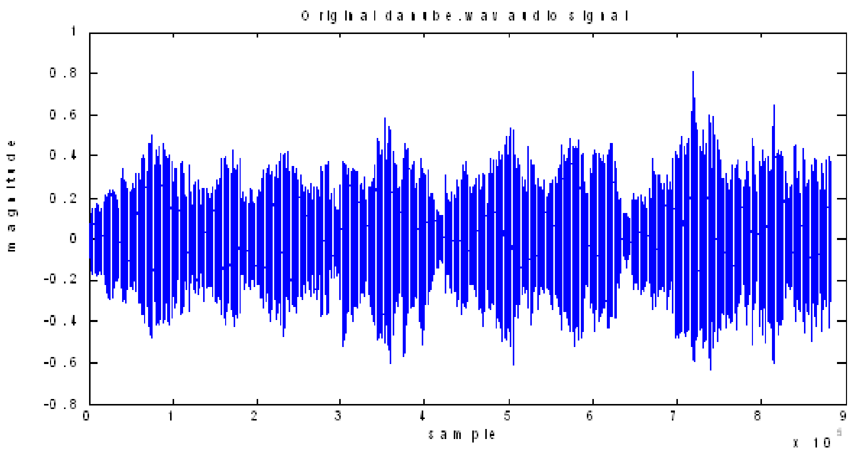

Figure 2: Original Audio Signal

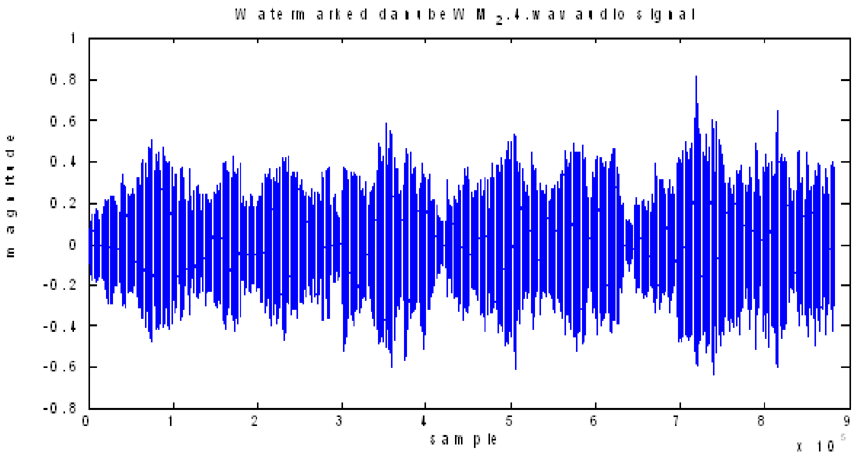

Figure 3: Watermarked Wave File

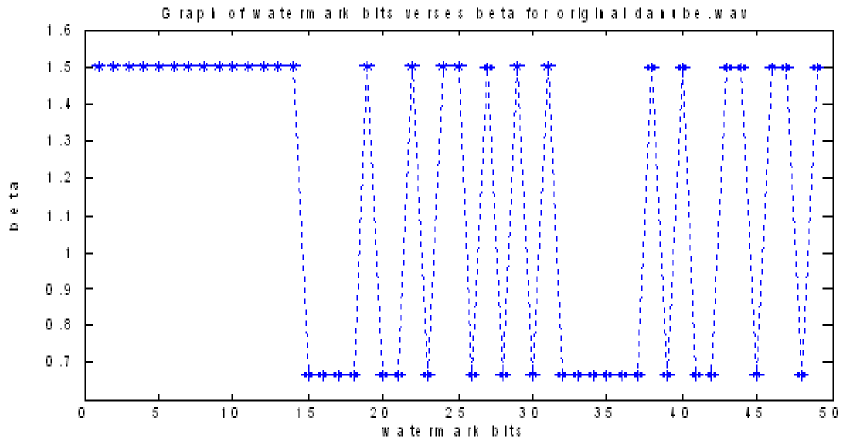

Figure 4: Watermark Bits Vs Beta

In figure 4 watermark bits verses beta is plotted. Beta represents relationship between different bins. From the Watermarked bin samples a”, b”, c”, beta is calculated as $2b''/(a''+c'')$. If beta is greater than or equal to one, watermark bit is one otherwise zero.

CONCLUSIONS

There are several types of algorithms for watermarking. Each type of algorithms has its own advantages and limitations. Each type of solution has robustness to some type of attacks but is less resilient to some other types of attacks. Main focus of the current work is to make the watermarking algorithms robust to time scale modifications. In case of practical application, choice of solution depends on the nature of application and requirements. Histogram based watermarking is robust to TSM attacks. In this technique a group of three successive bins is designed to embed one bit of information by reassigning the number of samples in the three bins. In the extraction, the synchronization code is introduced for searching of the watermark. The original audio signal is not required in the extraction process.

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