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Audio Watermarking Based on Empirical Mode Decomposition

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Abstract: an audio watermarking based on Empirical mode decomposition is proposed. The watermark is embedded in the final residual because of the intrinsic feature of the final residual. The audio signal is divided into set of frames and by using the empirical mode decomposition (EMD), frames are decomposed into set of intrinsic mode functions (IMF) and a final residual. The watermarked data is embedded in the final residual and the algorithm works by shifting each element of the final residual for make its sum greater or less than 0. This algorithm does not change the property of the final residual after embedding the watermark bit on to the final residual because of the watermark is robust against various types of attacks.
Keywords: Audio watermarking, Empirical mode decomposition (EMD), Final residual, intrinsic mode functions (IMF).

I. INTRODUCTION

Watermarking is an effective way to protect copyright of audio signal by beating the copyright information into the original audio signal in an imperceptible way. It is a mission to balance robustness, imperceptibility and capacity of audio watermarking simultaneously. For this different watermarking techniques have been proposed earlier. A robust watermarking scheme to different attacks is proposed. But it contain only limited transmission bit rate. So to solve this above problem proposed another method such as watermarked schemes performed in the wavelets domain. A disadvantage of wavelet approach is that the basic functions are fixed, so they do not necessarily match all real signals. To solve these above problems, newly, a new signal decomposition method raised to as Empirical Mode Decomposition (EMD) has been introduced for evaluating non-stationary signals.

If the watermark embedding in the extrema of the last IMF, it is found that whether the watermark bit to be embedded is 0 or 1, these existing algorithms change every sample of the final residual without considering the imperceptibility of the watermarking. There for proposed audio watermarking based on empirical mode decomposition for avoiding the above problem. It is found that the watermark embedding in the final residual is more robust than the watermark embedding in the extrema of the last IMF.

II. RELATED WORKS

Kais Khaldi [1] proposed an audio watermarking via EMD. The audio signal is divided into frames and by applying EMD such that each frame is decomposed adaptively into a set of intrinsic mode functions and a final residual. The watermark and synchronization code is combined and to form a binary sequence and which is embedded in the extrema of the last IMF. It is shown that a low frequency mode stable under different attacks and preserving audio perceptual quality of the host signal. The data embedding rate of the algorithm is 46.9–50.3 b/s.

Mehbooba P Shareef [2] proposed an secret audio watermarking using empirical mode decomposition and chaotic map which ensures imperceptibility, robustness and high payload capacity. To prevent unauthorized third parties removing watermark from the audio signal, use a tinkerbell chaotic map. It generates random secret keys and watermark is embedded into the following keys. Watermarking algorithms are publicly available so that using these algorithms watermark bits can easily remove. To achieve this watermark location is in an audio signal should be kept secret. This is achieved by generating random keys using a chaotic map.

Liang Wang [3] proposed an EMD and psychoacoustic model based watermarking for audio. The analysis filterbank decomposition, the psychoacoustic model and the empirical mode decomposition (EMD) are the three key techniques used in the novel audio watermarking method. The watermark bits are embedded directly in the signal either by time domain or transform domain processing. The watermark bits are embedded in the final residual of the subbands in the transform domain. The inaudibility, capacity and robustness of the audio watermarking system are evaluated, so as to optimize the system performance.

Marius Telespan [4] proposed an audio watermarking based on empirical mode decomposition and beat detection which is used to detect the location for embedding the watermark. So as to find the embedding location, use a simplified psychoacoustic model. It split the input into audible frequency bands and two phase comb filtering on those bands to find the beat metrical structure. Then, at each embedding location, take several frames and decompose them into Intrinsic Mode Functions.

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III. PROPOSED WATERMARKING ALGORITHM

The idea of the proposed watermarking is that divide the watermark signal into set of frames and each frame decomposed adaptively to form a set of intrinsic mode functions and a final residual. Suppose the given signal $x(t)$ can be decomposed as the summation of n IMFs $h_1(t), h_2(t), \ldots\ldots, h_n(t)$ and a final residual $r_e(t)$ as follows

$$x(t) = \sum_{i=1}^{N} h_i(t) + r_e(t) \qquad (1)$$

The watermark is embedded into the final residual. EMD^{-1} is applied to the modified extrema to recover the watermarked audio signal by superposition of the IMFs of each frame followed by the concatenation of the frames. Figure 1 shows the architecture diagram of watermark embedding and watermark extraction. For data extraction, the watermarked audio signal is split into frames and EMD applied to each frame. Watermarked bits are extracted from the final residual.

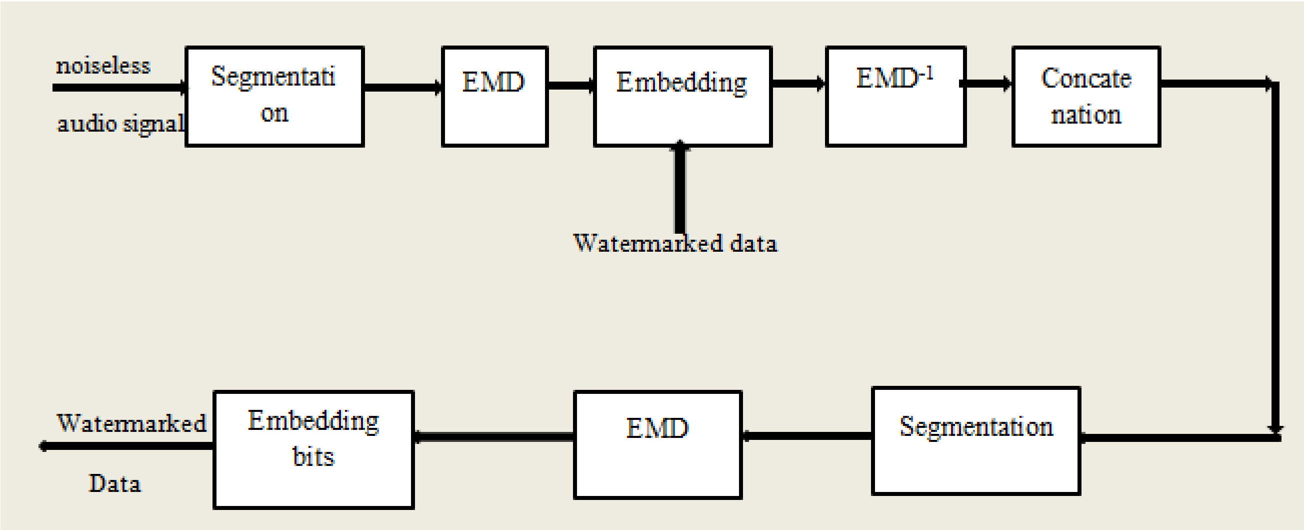

Fig.1.Architecture diagram of watermark embedding and watermark extraction

A. *Watermarking Embedding Algorithm*

Suppose the original audio signal is A = {a(t),1≤ t ≤ length} in which length denotes the length of the audio signal. First segment the audio signal A into length N frames F = {f(t),1 ≤ t ≤ N} and then apply empirical mode decomposition to each frame. The decomposition can be represented as follows

$$f(t) = \sum_{i=1}^{N} h_i(t) + r_e(t) \qquad (2)$$

In order to maintain the robustness the watermark bits are embedded into the final residual $r_e(t)$. Suppose the watermark sequence to be embedded is W ={w(i),1≤i ≤ length/N}, half of which consists of 0 bit and the other half is 1 bit. The idea is to embed watermark into the $r_e(t)$ using the intrinsic feature of final residual. The sum of all elements in $r_e(t)$ denoted as SR and use it as the feature to embed watermark. SR is define as follows

$$SR = \sum_{t=1}^{N} r_e(t) \qquad (3)$$

Adjust the elements of $r_e(t)$ according to the watermark bit to be embedded. When the watermark bit is 1, the value of SR is assured to be greater than 0 and when the watermark bit is 0, the value of SR less than 0. Watermark bits are embedded by the equation define as follows

$$r_e^w(t) = \begin{cases} r_e(t) + (|SR|/N + \alpha).S, & w(i) = 1 \\ r_e(t) - (|SR|/N + \alpha).S, & w(i) = 0 \end{cases} \qquad (4)$$

Eq. (4) embeds watermark by adjusting elements of $r_e(t)$. First divide the absolute value of SR equally into N parts and each part equals |SR|/N. For each element of $r_e(t)$, add or subtract |SR|/N to make $\sum_{t=1}^{N}(r_e(t) + |SR|/N)$ or $\sum_{t=1}^{N}(r_e(t) - |SR|/N)$ equals 0. The effect of α is to make $\sum_{t=1}^{N}(r_e(t) + (|SR|/N + \alpha))$ or $\sum_{t=1}^{N}(r_e(t) - (|SR|/N + \alpha))$ greater or less than 0. In Eq. (4), the embedding strength S is set to be a value equal to or greater than 1. It is clear that $r_e^w(t)$ remains to be a final residual

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if the intrinsic feature of $r_e(t)$ satisfy the requirement of embedding. Otherwise, the watermark is embedded according to (4) which is equivalent to shifting $r_e(t)$ upward or downward. Eq. (4) doesn't change the shape of $r_e(t)$ so that $r_e^w(t)$ remains to be a final residual. Half of the watermark sequence consists of 0 and the other half is 1.So use p_{az} and p_{bz} to denote the probability that SR of the un-watermarked final residual $r_e(t)$ greater than 0 and less than 0 respectively. The relationship of p_{az} and p_{bz} can be described as

$$p_{az} + p_{bz} = 1 \quad (5)$$

If SR is greater than zero, no change is needed to be made to $r_e(t)$ and the embedding bit is 1. When the embedding bit is 0, elements in $r_e(t)$ should be adjusted with probability $p_{az}\frac{1}{2}$. Similarly, it has the probability $p_{bz}\frac{1}{2}$ to change $r_e(t)$ when SR is less than zero and the embedding bit is 1. To sum up, the probability that the original final residual $r_e(t)$ has been changed can be represented as

$$p_{az}\frac{1}{2} + p_{bz}\frac{1}{2} = \frac{1}{2} \quad (6)$$

Based on this above study, the variation of the amplitude of one frame can be denoted as Δ and there are two possible values of Δ:

$$\Delta = \begin{cases} (|SR|/N + \alpha) \cdot S \cdot N \\ 0 \end{cases} \quad (7)$$

In Eq.(7), each value of Δ has the probability 0.5. Thus the mathematical representation of Δ can be represented as

$$E(\Delta) = 0.5 \cdot (|SR|/N + \alpha) \cdot S \cdot N \quad (8)$$

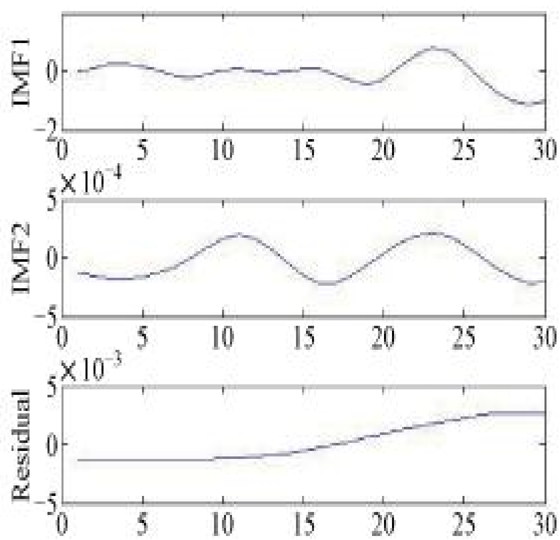

Figure 2.Un-watermarked audio frame

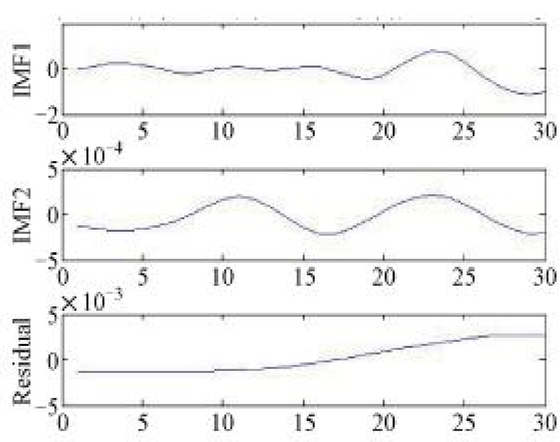

Fig.3.Watermarked audio frame with watermark bit 1

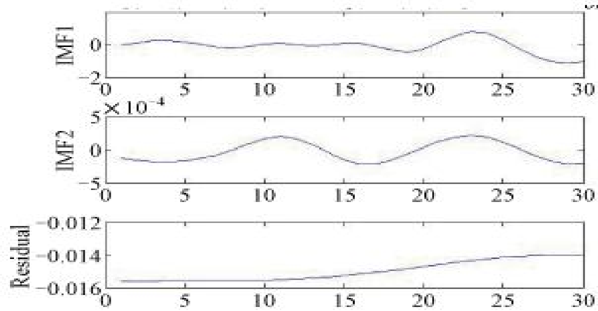

Fig.4.Watermarked audio frame with watermark bit 0

From Fig.2, Fig.3, Fig.4 can find that both un-watermarked frame and watermarked one are decomposed into two IMFs and one final residual no matter whether the watermark bit embedded is 0 or 1. It is obvious from the figure that the watermarked IMFs are visually in distinguishable from the original ones. Fig.2 shows that SR is greater than 0. Thus no modification is needed when the watermark bit to be embedded is 1 so that Fig.3 is as same as Fig.2. When the watermark bit embedded is 0, $r_e(t)$ shifts downward to make SR less than zero as shown in Fig.4.

B. *Watermarking Extracting Algorithm*

The sum of all elements in $r_e^w(t)$ is denoted as

$$SR^w = \sum_{t=1}^{N} r_e^w(t) \qquad (9)$$

SR^w of the ith audio frame is denoted as $SR^w(i)$. In the extracting process, determine the watermark bit embedded in the ith frame based on the positive and negative properties of $SR^w(i)$ and watermark extracting algorithm can be denoted as

$$w'(i) = \begin{cases} 1, & \text{if } SR^w(i) > 0 \\ 0, & \text{if } SR^w(i) \le 0 \end{cases} \qquad (10)$$

Based on Eq.(10), the watermark bit extracted is deemed as 1 when $SR^w(i) > 0$ and reckoned as 0 when $SR^w(i) \le 0$

IV. CONCLUSIONS

An audio watermarking based on empirical mode decomposition is proposed for avoiding MP3 compression, re-quantization, filtering, cropping and resampling. The audio signal is divided into set of frames. Then apply EMD into the frames and the frames are decomposed into set of intrinsic mode functions and a final residual. The watermark is embedded into the final residual, because of the watermark embedded in the final residual is more robust than compared with the watermark embedded in the extrema of the last IMF.

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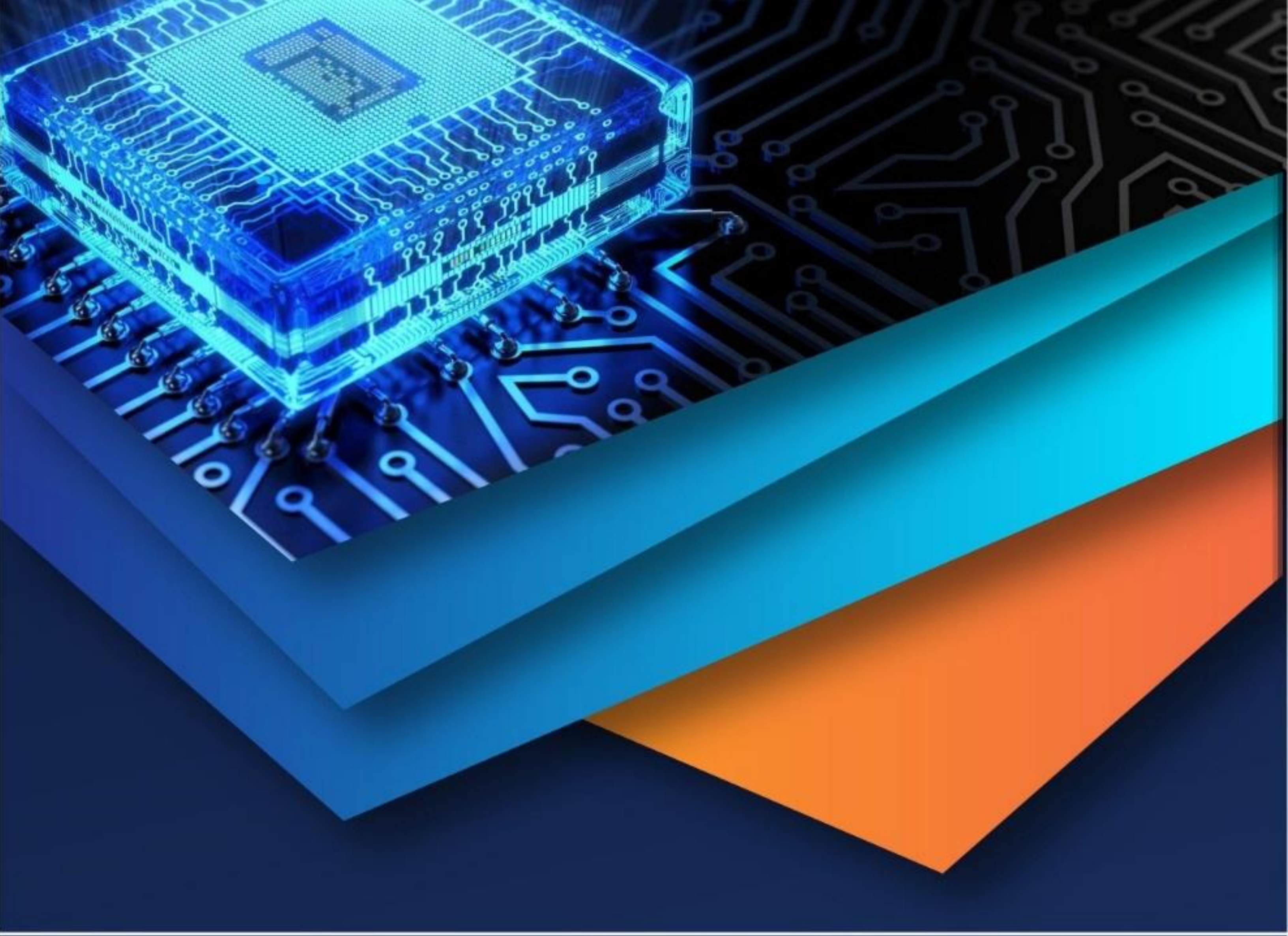

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