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Review Article

Proposal Paper for improving SVD and Quantization Technique for Audio Watermarking

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Abstract

This paper discusses basics of audio watermarking and the concepts of Quantization Index Modulation (QIM), Singular Value Decomposition (SVD), µ-law and their benefits that are useful for watermarking of audio signals. Survey of some related papers discusses the usefulness of QIM technique when used with Discrete Wavelet Transform (DWT) or SVD technique and improvement in DWT based technique using Logarithmic Quantization Index Modulation (LQIM) using µ-law which provides motivation for a new methodology based on LQIM using µ-law to improve SVD technique.

Keywords: *Audio Watermarking, blind, QIM, SVD, µ-law*

1. Introduction

[1]Watermarking field is one of the interesting, important and popular research areas for ownership protection of the media (image, audio, video etc.) to prevent illegal distribution of the media and can also be used for media authentication, broadcast monitoring (audio or video through radio or TV broadcasting) and various other application areas. A lot of work has been done on image, audio and video watermarking, but on image and video more work has been done than audio watermarking as image and video use visual characteristics for watermark embedding, on the other hand, audio use human auditory system (HAS) properties for watermark embedding into signal, which is a complex task as HAS is very sensitive than Human Visual system (HVS) and thus small distortion in sound quality can be easily heard. Signal to noise ratio should be greater than 20 db, so that distortion is not perceivable to human ear.

Watermarking system generally consists of two important basic procedures i.e watermark embedding and watermark detection. But before watermark is embedded, watermark is generated using some generator(eg., pseudorandom number generator) or is converted into suitable format required for watermarking, for eg., preprocessing watermark using Arnold scrambling, using chaotic sequences or some other method to improve the security of the watermark. After preprocessing of the watermark, watermark embedding algorithm is employed to insert watermark into the original audio signal. Many of the techniques have been implemented in literature for watermarking which are generally categorized into two embedding domains which are time-domain based watermarking and transformation-domain based watermarking. Time–domain techniques are based on direct modification of the sample values, thus can easily create distortion in audio quality. Popular time-domain techniques are least bit modulation, echo hiding etc. Transformation domain techniques involve spread spectrum and frequency transformation techniques such as Direct Sequence Spread Spectrum (DSSS), Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT), and Discrete Cosine Transform (DCT) etc. Many approaches based on DWT & DCT, DWT & SVD or DCT &SVD etc. have been proposed in literature. Techniques based on transformation embedding domain are very complex and have low capacity in comparison to tome domain methods, but has proven to be robust and has good perceptual quality than time domain techniques.

Watermark detection process is based on two approaches- (a.) *Informed watermark detection*: This approach requires original signal for detection of the watermark from watermarked audio. (b.) *Blind watermark Detection*: This approach does not require original signal for detection of watermark from the watermarked signal. Recent researches are more focused on blind detection approach to avoid making use of original signal to detect watermark from watermarked audio. Watermark detection system is very important from owner's perspective, as the watermark from the watermarked audio should be only detected by the owner's watermark detection system, so that it can be proved that watermarked audio belongs to the original owner in case of multiple ownership dispute. Also one of the most important properties is that

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watermark system should be able to extract watermark from the watermarked audio even after being attacked by many attacks when this signal passed through different communication channels. This property is referred to as robustness. Attacks can be of various categories such as low pass filtering, Additive White Gaussian Noise (AWGN), noise reduction, resampling, requantization, MP3 compression, echo addition etc. which are common signal processing manipulations against which watermarking system must be robust.

2. QIM

Quantization, from signal processing point of view, is the process of mapping sampled amplitude values into a set of discrete values. The most common type of quantization is known as *scalar quantization* (Hyoung Joong Kim, 2004), which can be as simple and intuitive as rounding high-precision numbers to the nearest integer, or to the nearest multiple of some other unit of precision. Scalar quantization watermarking scheme quantizes a sample value *x* and assign new value to the sample *x* based on the quantized sample value and watermark bit. For one of the schemes using binary watermark b taking only values 0 or 1, the watermarked sample value *y* is represented as follows:

$$y = \begin{cases} q(x,D) + D/4 \text{ if } b = 1 \\ q(x,D) - D/4 \text{ otherwise} \end{cases} \quad (1)$$

where q(.) is a quatization function and *D* is a quantization step.
Graphically it is represented as:

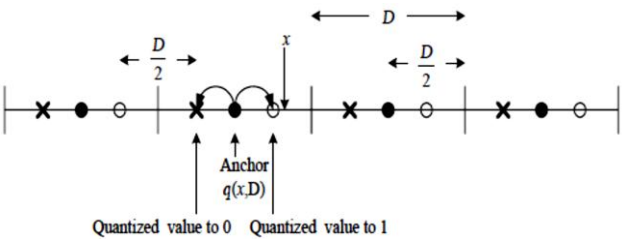

Figure1: A simple quantization scheme

From the graph it can be seen that, if the watermarking bit *b* is 1, the anchor is moved to the white circle (◦). Otherwise, the cross (×) stands for the watermarking bit 0.

QIM methods, which are a class of digital watermarking and information embedding methods, were introduced by (B. Chen and G. W. Wornell 2000 & 2001) that achieve provably good rate-distortion-robustness performance. Quantization index modulation is a non-linear technique and refers to embedding information by first modulating an index or sequences of indices with the embedded information and then quantizing the host signal with the associated quantizer or sequence of quantizers. When QIM technique is used for embedding watermark, the first step is usually to find maximum value of audio signal and difference between 0 and maximum value is divided into intervals. Normally the interval size is referred as stepsize which should be chosen such that capacity, robustness and distortion tradeoff can be balanced. Signal index values are modified based on the watermark symbol (0 or 1 for a binay watermark) referred to as quantizer and thus for a binary watermark there are two quantizers. In other words, signal values are shifted based on the watermark bit value and the interval in which these values lie.

QIM is very useful technique in the field of watermarking, as it can not only achieve good performance against capacity, robustness and distortion tradeoff, also it is a very simple technique to implement, thus have low- complexity realizations and most importantly it is used for blind approach for watermark detection.

3. SVD

SVD is a numerical tool in linear algebra that can be used to diagonalize matrices in numerical analysis .
Let A be any matrix of size m by n and its SVD representation can be expressed as

$$\mathbf{A} = \mathbf{U}\,\mathbf{S}\,\mathbf{V}^T \quad (2)$$

Where U is orthogonal m by k matrix and the columns of **U** are eigenvectors of $\mathbf{AA}^T$. Likewise, **V** is orthogonal k by n matrix and the columns of the V are eigenvectors of $\mathbf{A}^T\mathbf{A}$. Matrix **S** is a diagonal matrix which is of same size as matrix **A**. Diagonal entries of matrix **S** of size k by k are the square roots of non-zero Eigen values of $\mathbf{AA}^T$ and $\mathbf{A}^T\mathbf{A}$**.** Non –zero Diagonal entries represent the singular values of **A** and they fill the first r places on the main diagonal of **S**, where r is rank of **A** ((Gregor Gregorcic, 2001) & (Vivekananda Bhat K. et. al., 2011)).

To apply this technique to audio signal for watermarking, it is reshaped from 1-D vector to 2-D and viewed as a non-negative real matrix. SVD has been found useful in watermarking field because of the properties this method possesses such as stability, proportionality, transpose, flipping, rotation, scaling as discussed by (B. Lei et. al., 2012). These properties are useful for developing robust watermarking approaches in that watermarked signal will not be corrupted by attacks such as rotation, noise addition and scaling. SVD technique has a very attractive property that slight modification of SV values does not affect the transparency of cover object which can be widely used to develop more effective audio watermarking techniques. SVs are invariant under common signal processing operations. SVD is a very simple technique and have low complexity, watermarking scheme designed based on SVD proves to be good technique.

4. μ-LAW

μ-law (pronounced as mu-law) is a compression/ decompression algorithm and this method makes it possible to keep the level of SNR high with less data bits

(Xinkai Wang et. al., October 2012). This is represented in mathematical terms as follows:

$$y = \ln(1+\mu x) / \ln(1+\mu), \quad \mu>0, 0\leq x\leq 1 \qquad (3)$$

where x is input value and y is output normalized value, μ is a compression parameter representing the degree of compression, μ=0 representing no compression and μ=255 set according to international standards and ln represents the natural logarithm.

As a companding method, μ-law algorithm can reduce the quantization error (hence increasing signal to quantization noise ratio) and increase the SNR without requiring the addition of more data bits. So this method is able to achieve good perceptual quality of signal.

5. Related work

In literature, many audio watermarking algorithms have been developed. Watermarking schemes based on transformation methods have been found most successful rather than time-domain based techniques as transformation methods have less perceptual quality distortion and were found to be more robust but Of course these methods have higher complexity than time domain based methods. But recently newly proposed techniques are also focusing on easy calculations and implementations along with high robustness, high imperceptibility and blind nature of watermark extraction.

Recently a technique based on quantization index modulation and discrete wavelet transform was implemented by (X. Wang et. al., July 2012) which is based on blind detection approach for watermark extraction and is adaptive in nature as for watermark extraction fixed quantization step is not used. Watermark is embedded in the vector norm of the segmented approximation components after 2-level DWT with 4-coefficient Daubechies Wavelet (Db4) of the original audio signal using approach of QIM. Vector norm helps in improving robustness and adaptive quantization steps used for watermark extraction helps in better extraction scheme. In order to improve the robustness, imperceptibility and security, a binary image encrypted by Arnold transform as watermark was embedded into vector norm, the count of which depends on the size of the watermark image. Moreover, a detailed method has been designed to search the suitable quantization step parameters. Experimental results indicate that with this scheme capacity achievable is high, up to 102.4 bps, and still algorithm is able to maintain good quality of the audio signal and tolerate a wide class of common attacks such as additive white Gaussian noise (AWGN), Gaussian Low-pass filter, Kaiser Low- pass filter, resampling, requantizing, cutting, MP3 compression and echo, but does not perform well in case of amplitude scaling attack, so this algorithm needs to be improved to tolerate this attack.

To improve this method, team of same authors proposed improved technique (Xinkai Wang et. al., October 2012) to achieve better results, which adopts DWT and Logarithmic Quantization Index Modulation (LQIM) instead of QIM. LQIM is QIM technique based on μ-law companding, which was utilized to transform vector norm of the segmented wavelet approximation components of the original audio signal, and the binary watermark image scrambled by chaotic sequence was embedded in the transformed domain with a uniform quantization scheme. Although this technique was not adaptive, still it was able to achieve better results than previously proposed technique. Algorithm show superior behavior against AWGN, MP3 compression, echo and Amplitude Scaling. Moreover, with almost the same imperceptibility and capacity results provided, the algorithm is able to achieve good robustness against common attacks, especially amplitude scaling attack and also reduce computational complexity, which is useful for real-time applications.

SVD based techniques have also less complexity but techniques only based on SVD does not achieve better imperceptibility results. Recently SVD and dither modulation based technique was proposed by (V. Bhat K et. al., 2010) which achieved better results than earlier time domain based techniques. This motivated a new more improved approach based on SVD and QIM by the team of same authors (V. Bhat K et. al., 2011). Original audio signal was segmented according to size of watermark into blocks of 2D matrix whose rows and columns were chosen to achieve good rate-distortion-robustness tradeoffs. SVD was applied to each block, and Euclidean norms were computed for blocks and watermark bits were embedded by quantizing the norms of the blocks using predefined quantization coefficient. This method achieved good BER and NC results against AWGN, resampling, requantization and MP3 compression, achieved higher data payload and superior performance than related watermarking schemes. This technique is also easy to implement than various transformation domain based techniques.

In the next section, a new technique based on SVD is proposed which also admits easy calculation and will provide better results.

6.proposed methodology

As it was discussed earlier in this paper, μ-law companding was applied to improve DWT and QIM based technique (Xinkai Wan et. al., July 2012) by applying LQIM which was able to achieve very good results due to benefits provided by μ-law compression. As μ-law achieves better SNR so this can also benefit to improve SVD and QIM based technique as discussed earlier (V. Bhat K et. al., 2011). Keeping this in view a new technique can be implemented based on SVD and μ-law which will roughly carry following steps-

Steps to be carried out in embedding of watermark bits in the original signal-

1. Segment the original audio signal into M*M 2D blocks of each of size r*r. where M*M is the total number of watermarking bits. Rows and columns are choosen according to good rate-distortion-robustness tradeoff.

2. Apply SVD to each 2D block and obtain the Euclidean norm for each block of SV values.
3. Apply µ-law algorithm to the Euclidean norm values to obtain normalized output.
4. Output values thus obtained are modified according to watermarking bits and quantization parameters specific to LQIM (based on µ-law).
5. After obtaining the modified values, modified norm values are computed.
6. Based on modified norm values, modify the SV values.
7. From modified SV values, inverse SVD is applied.
8. Finally modified 2D blocks are converted into 1D vector representing the watermarked signal.

In the process of watermark extraction, 1-3 steps are performed for audio signal (watermarked and perhaps may be attacked during transmission), then watermarking bits are identified based on quantization parameters i.e on quantization interval or stepsize conditions based on LQIM. These watermarking will be then arranged into M*M watermark and will be compared to original watermark for performance analysis.

For performance analysis, metrics like SNR, NC, BER, payload in bps test will be used in objective evaluation and SDG will be calculated based on listening test as subjective evaluation measure.

Conclusion

This paper presents the new technique based on SVD and LQIM using µ-law companding that is to be implemented to improve SVD and QIM based technique. This paper initially introduces some basic concepts and benefits of QIM, SVD and µ-law companding algorithms. Review of some recent papers discusses the usefulness of QIM technique when applied to vector norm of DWT and Euclidean norm of SVD. A different class of QIM based on µ-law when combined with DWT resulted in better performance. Keeping this in view, a new blind watermarking approach based on SVD and LQIM was proposed which will improve performance of SVD and QIM based technique by improving the SNR and reducing of quantization error.

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