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A Survey on Digital Audio Watermarking

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Abstract
Piracy and counterfeiting of the Intellectual Property such as patents, copyrights etc. is known to be a serious problem over the world. However,it is more enormous in some regions owing to the usage. Currently, a millions of digital audio data is being copied over networks causes the loss of revenue in music industries on big scale. The genuine owners and creators are looking forward to find out ways to discourage this process that ultimately prompted the research in Digital Watermarking to enable copyright protection in order to prevent illegal acts of forgery and illegally distribution of data. In this paper, we have surveyed the various existing methodologies of Digital Audio Watermarking for preserving the copyright laws and highlighting the related issues.
Keywords: *Digital Audio Watermarking, Signal to Noise Ratio, Robustness.*

1 Introduction

During the last decade, with the advancement in internet technologies in the form of multimedia, extensive availability of broadband communication networks, reliable and low cost storage devices, it is quite possible to replicate, transmit and store the audio files anywhere unethically.These conveniences have significantly increased the risks of copyright violation and have challenged the preservation of Intellectual Property Rights(IPR) [14][15].

Initially, conventional encryption algorithms were adopted for this purpose but theserestricts the permit of access to only authorized users and once decrypted, there is no way to prohibit further illegal distribution of the data. Thus, *Digital Watermarking* emerged out to be a promising solution to this problem. It has wide applications in copyright protection,fingerprinting,tamper proofing, broadcast monitoring etc. [23][24].Until now, significant research has been done with the image but not much growth has been observed in the fields of video and audio watermarking owing to the complex and sensitive Human Auditory System(HAS).

The remainder of this paper contains the content as follows, Section 2 describes the classification of digital watermarking, introduction to audio watermarking is given in Section 3.Section 4 contains the techniques of audio watermarking pertaining to various domain. Section 5 gives the detailed survey on the existing methodologies followed by conclusion in Section 6.

2Classification of Digital Watermarking

The process of Digital Watermarking can be categorized into different domains on various basis [23] -.

2.1 Based on working domain

I. **Spatial Domain:** Watermark is embedded in actual pixel value of host signal.
II. **Transform Domain:** Here, the initial step is to transform the original signal from time domain into other domains using DCT,DWT etc.

2.2 Based on extraction

I. **Blind Detection**:It is also known as public watermarking. The host signal as well as the watermark is not required for the purpose of extraction.
II. **Non Blind Detection**: The original (host) signal on which the embedding is performed is needed at the time of extraction. It is not in use practically since it requires twice storage capacities and bandwidth required for communication thereby increasing the intervening overheads.

2.3 Based on human perception

I. **Robust Watermarking**: Embedded watermark can sustain various attacks like cropping, compression, D/A conversion etc. It is applicable in copyright protection.
II. **Fragile Watermarking**: The fragile watermark gets tampered quite easily if encountered to slight modifications. It is applicable in tamper proofing, authentication etc.

2.4 Based on data

I. **Image**: Watermark is to be embedded in image, known as image watermarking.
II. **Text**: Watermark information is to be embedded in text data like organization's confidential documents.
III. **Audio**: Watermark is embedded into audio files like mp3,.wav,.au files etc.
IV. **Video**: Watermarking is applied on video files for preserving their integrity.

2.5 Based on key

I. **Symmetric Key:** As the name indicates, similar key is used at either sites; sender's and receiver's site. It is also known as public key.
II. **Asymmetric Key:**In asymmetric key method, different key is used at both the ends.

3Audio Watermarking

Audio Watermarking is a practical methodology in which we embed the secret, robust and imperceptible information into the audio signal to preserve the *integrity* of the original audio data [14][15]. The embedded information may be an image, some other audio clip or a randomly generated pseudo sequence. The watermark should distinctively identify the owner; and embedded in such a way that is imperceptible to the third party. Embedding must tolerate the presence of common signal processing and compressiontechniques and various other deliberate attacks like cropping, re-quantization, sampling etc [5][19][24].A good Audio Watermarking algorithm possess the following special characteristics: Robustness, Imperceptibility, High Data Payload, Security, Verification and Reliability [10][14][15][24]**.**

Audio Watermarking algorithm can be divided into two main processes:

- Watermark Embedding
- Watermark Extraction

The *Embedding* procedure consists of original data and the watermark as inputs to the embedding block under which the embedding is performed [15].
The *Extraction* procedure consists of watermarked data and secret key as inputs and sometimes the original data for extracting the original signal.*Blind Detection* is often preferred for copyright verification owing to its practical feasibility [10][15][23].

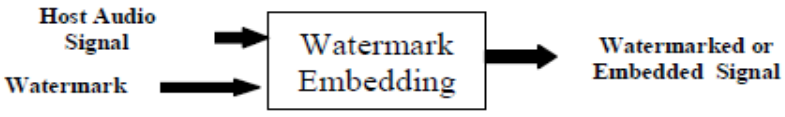

Fig. 1: Watermark Embedding Procedure

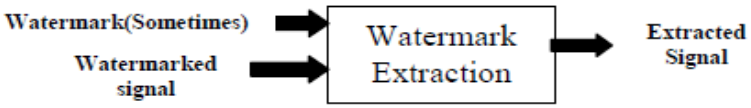

Fig.2: Watermark Extraction Procedure

4Techniques of Audio Watermarking

The broad classification of audio watermarking techniques can be made as discussed below –

4.1 Time Domain Methods

Time Domain Watermarking or *Spatial Domain* Watermarking is the oldest known watermarking techniques in which we add a watermark data or a pseudo-random sequence directly into the host signal;the processing overhead is much less than other methods. It takes much less time in the extraction process [8].As compared to transform domain methods, it lacks in terms of robustness against various attacks.

Least Significant Bit (LSB) Modification: In [13], LSB technique for audio watermarking is suggested, where LSB is used to modify the original audio sample's amplitude producing an unnoticed perceptual difference. The watermarked signal y(i) is produced as follows:-

$y(i) = x(i) + f((x(i) , w(i))$ ---------- **(1)**

Where*x(i)* is the host signal and *w(i)* is the watermark signal in the range $[-\alpha,+\alpha]$ where α being a constant.

Spread Spectrum (SS) Method: SS is a type of correlation method where detection of watermark is done by calculating correlation between the embedded pseudo-random sequence and watermarked audio signal [3].It, includes overheads like watermark shaping, sinusoidal modulation etc. [3][4][6][11].

Perceptual Masking: In this technique, perceptually shaped pseudo-random sequence is embedded into the different frames of the host audio signal [11].The time and frequency distribution of watermark is controlled due to which the amplitude of the watermark signal varies in accordance with the host audio signal.

Echo Hiding Method: This method embeds data into the host audio signal by introducing an *echo* which is not perceived by human ear such that

$x(n) = s(n) + \alpha\, s(n-d)$ ----------**(2)**

where 'd' is the *echo delay*[17] and is detected by Cepstrum or Auto-Cepstrum Correlation methods at the time of extraction.

4.2 Transform Domain Methods

Transform domain methods are practically more adopted, as they are robust against the popular attacks like filtering operations, compression, and noise attacks. These methods derive benefit of HAS to embed a watermark into those components that are perceptually significant and results into high robustness and imperceptibility of noise in the signal [8]. The techniques are as follows:

Phase Modulation (PM) Method: PM is an improvement over the phase coding techniques as it allows higher data payload and individually alters each coefficient after modulation [17],[20].

Replica Modulation:Frequency shifts, phase shift and amplitude shift schemes come under Replica Modulation. The frequency shift method does transformation of signal into frequency domain and modulates the signal of a few ranges before inverse transformation into the time domain [22]. Other transform domain methods includeDiscrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Discrete Fourier Transform (DFT) and Modified Patchwork Algorithm (MPA) etc. [2],[7],[10],[21].

5. Literature Survey

This section represents the review of various audio watermarking techniques proposed by various authors emphasizing on the techniques involved and their merits and demerits.

Bassiaet. al.[13] proposed the robust audio watermarking technique in the time domain using blind watermark detection.

- It directly modifies the amplitude values such that it does not create any perceptual difference.
- The watermarking key used for embedding was known only to copyright owner.
- Robustness could be increased with higher amplitude values but introduced distortion in the signal.
- This method was statistically imperceptible and was able to resist attacks like MPEG compression, rescaling, filtering and quantization.

Kirovski&Malvar[3]proposed a SS technique in which each watermark bit is spread over a MCLT (Modulated Complex Lapped Transform) coefficients.SS techniques can be detected using correlation mechanisms.

- The MCLT coefficients within the range 2-7kHZ sub-band are considered for use in the detection process in order to minimize the carrier noise effects, sensitivity to down sampling and cropping.
- It suggests a nonlinear cepstrum pre-processing to reduce the carrier noise.
- Enables effective watermarking with prevention against detection de-synchronization, cepstrum filtering and chess watermarks.

Huang et. al.[9] proposed a blind, audio information bit-hiding algorithm with effective synchronization.

- The algorithm embeds synchronization signals in the time domain so that the computation for resynchronization can be kept lower.
- HAS features are exploited so that the watermark is placed in block-wise DCT coefficients of the original audio.
- Error-correcting codes are applied to lower the bit error rate.
- The hidden, imperceptible watermark is robust against attacks due to additive noise, MP3 coding, and cropping.

Wei Li, X.Xue, and PeizhongLu[18]proposed a novel localized and content-dependent audio watermarking algorithm.

- Emphasizes on determining the embedding regions with a steady state high-energy using different strategies.
- Such regions have the potential to maintain audio quality without introducing much distortion.
- The limitation that is observed that it works well for modern music but not on jazz, classicalmusic due to absence of obvious peaks on original waveforms.

Shijun Xiang and JiwuHuang[16]proposed a histogram based audio watermarking against time scale modification and cropping attacks.

- The paper proposed a multi bit robust audio watermarking solution against the most challenging attacks like TSM, cropping attacks.
- Studied the insensitivity on audio histogram shape and the modified mean to TSM and cropping operations.
- Embedding process is done such that the histogram is extracted from a selectedamplitude range where the watermark is resistant to amplitude scaling.
- It avoids exhaustive search in the extraction process.

Ali-Al Haj [1]proposed a technique of audio watermarking using DWT and Singular Value Decomposition (SVD) in the transform domain.

- When DWT is applied on host signal using Daubechies wavelet (dB1), approximatecoefficients (A) are obtained through low pass filtering while detailedcoefficients (D) are produced by high pass filtering.
- SVD is a numerical technique based on which the matrices are diagonalized allowing imperceptibility and robustness to audio watermarking algorithms.
- Different levels of decomposition can be used for DWT but the author suggested 3-level decomposition.

Zamani and A. Manaf[12] proposed a new optimization technique in audio watermarking using Genetic Algorithms.

- Fragile audio watermarking emphasizing on genetic concept to reduce the distortion taking place because of LSB substitution.
- The PSNR is significantly improved using Generic Substitution Based Audio Watermarking (GSBAW).

6. Conclusion

In this paper, we have done an extensive literature survey of different existing digital audio watermarking techniques involving different methodologies. Each technique has its own advantages and disadvantages but the key pillars on which these algorithmsstand are imperceptibility, robustness and data payload. that share a trade-off among them [19][23].If the payload is high, imperceptibility is affected and if payload is kept low then the robustness of the algorithm is affected. Thus, in future works there is a need to select such an algorithm which must be application specific and may be modulated according to the requirements beforehand. The summary of various audio watermarking techniques is given in Table 1.

Table 1.TAXONOMY OF DIFFERENT AUDIO WATERMARKING TECHNIQUES

Authors	Technique of Watermark Embedding	Observations	Pros and Cons	Comparison with previous technologies
Bassia et al.	Amplitude Modification in Time Domain	Statistically Imperceptible Watermark	• Signal Distortions • Easy due to its presence in time domain	• Resist many attacks like MPEG2 compression, re-sampling, etc. • Not much robustifying against sophisticated attacks.
Kirovski and Malavar	Spread Spectrum(SS) and Correlation Mechanism	MCLT coefficients enabled to minimize the noise and cropping attacks.	• Nonlinearcepstrum pre-processing required to reduce noise • Prevention against detection de-synch.	• Overcomes the major weakness of SS technique. • Reliably detects watermark of audio clips with degradation beyond acceptable limits.
Huang et al.	Bit hiding algorithm with effective synchronization	Embedding is performed block wise in DCT coefficients	• ECC lowers bit error rate • Considerably robust against attacks like MP3 coding, cropping etc.	• It effectively exploits the well-known cryptographic method: ECC for lowering the computation for extraction.
Wei Li et al.	Content dependent algorithm	Few regions of interest are chosen with different strategies.	• Much less distortion in the signal. • Effective only for few kinds of audio type like jazz etc.	• Embedding is done in translation-invariant FFT domain to resist

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				small distortions. • Stands out as it is content dependent and based on selecting the embedding regions accurately.
Xiang and Huang	Histogram based audio watermarking	Analyses the insensitivity on audio histogram shape.	• Avoids exhaustive search during extraction as selected amplitude range is preferred. • Effective against popular attacks like TSM and cropping.	• Histogram shape and modified mean value provides improved results of resistance against significant attacks. • Future scope focus on securing the watermarking scheme.
Ali Al Haj	DWT-SVD based transform domain algorithm	3-level decomposition using dB1 wavelets performed.	• Data payload increases with clip length. • IFPI requirements met.	• Using mathematical tools, effectively improved the robustness of the algorithm. • Shortcomings include high data payload being a non-blind algorithm.
Zamani and Manaf	Genetic optimization and GSBAW	Aimed to Improvise the loopholes in other techniques	• Genetic optimization figures out the significant regions efficiently. • Requires skill in coding as genetic concept requires sampling to be done wisely.	• Payload permissible through GSBAW was much higher while maintaining the imperceptibility. • Listening tests successfully identified the noise imperceptibility threshold at 4bps.

References

1. Ali Al-Haj: A dual transform audio watermarking algorithm, Multimedia Tools and Applications: Volume 73, Issue 3, pp 1897-1912 (2014)
2. Ali Al-Haj, Ahmad Mohammad: Digital Audio Watermarking Based on the Discrete Wavelets Transform and Singular Value Decomposition: European Journal of Scientific Research ISSN 1450-216X.,vol. 39 ,no. 1, pp. 6-21 (2010)
3. D. Kirovski, & H. Malvar: Robust Spread Spectrum Audio Watermarking: Proceeding ICASSP '01 Proceedings of the Acoustics, Speech, and Signal Processing,on IEEE International Conference Volume 03, pp. 1345-1348 (2001)
4. D. Kirovski, & H. Malvar: Spread Spectrum watermarking of Audio Signals: IEEE Transactions on Signal Processing; vol. 51, no.4 ,pp. 1020-1033 (2003)
5. Fabien, A. P. Petitcolas, Ross J. Anderson and Markus G. Kuhn: Information Hiding:A Survey: Proceedings of the IEEE, special issue on protection of multimedia content, 87(7):1062{1078 (1999)
6. I.J. Cox, J. Kilian, F.T. Leighton, T. Shamoon : Secure spread spectrum watermarking for multimedia: IEEE Trans. Image Process. 6 (12) pp 1673–1687 (1997)
7. IK. Yeo, & HJ. Kim: Modified patchwork algorithm: A novel audio watermarking scheme: IEEE Transactions on Speech and Audio Processing; vol. 11, no. 4, pp. 381–6 (2003)
8. J. S.Pan, H. C.Huang, L. C.Jain, :Intelligent Watermarking Techniques: World Scientific Pub Co Inc. (2004)
9. Jiwu Huang, Yong Wang, Yun Q. Shi: A Blind Audio Watermarking Algorithm With Self-Synchronization: IEEE International Symposium on Circuits and Systems, ISCAS ,Vol. 3, pp. 627 – 630 (2002)
10. M. Arnold: Audio watermarking: Features, applications and algorithms: Proceeding of the IEEE International Conference on Multimedia and Expo,pp.1013–1016 (2000)
11. M.D. Swanson, Bin Zhu, A.H. Tewfik, Lawrence Boney: Robust Audio Watermarking using perceptual masking: Elsevier Signal Processing 66,pp. 337-355 (1998)
12. MazdakZamani, AzizahBt Abdul Manaf: Genetic Algorithm for fragile audio watermarking: Telecommunication Systems, vol. 59,Issue 3,pp. 291-304 (2015)
13. P. Bassia, I. Pitas, and N. Nikolaidis: Robust audio watermarking in the time domain: IEEE Trans. Multimedia, vol. 3, no. 2, pp. 232–241 (2001)
14. R. F.Olanrewaju, Othman Khalifa: Digital Audio Watermarking; Techniques and Applications: International Conference on Computer and Communication Engineering (ICCCE 2012), pp 3-5 J (2012).
15. Sanjay Pratap Singh Chauhan, S. A. M. Rizvi: A survey: Digital Audio Watermarking Techniques and Applications: 4th International Conference on Computer and Communication Technology (ICCCT) (2014)
16. Shijun Xiang and Jiwu Huang: Histogram-Based Audio Watermarking Against Time-Scale Modification and Cropping Attacks: IEEE TRANSACTIONS ON MULTIMEDIA, VOL. 9, NO. 7 (2007)
17. Vivekananda Bhat K, IndranilSengupta, Abhijit Das: An adaptive audio watermarking based on the singular value decomposition in the wavelet domain: Digital Signal Processing, Vol. 20, Issue 6, pp. 1547– 1558 (2010)
18. Wei Li, XiangyangXue, and Peizhong Lu: Localized Audio Watermarking Technique Robust Against Time-Scale Modification: IEEE TRANSACTIONS ON MULTIMEDIA, VOL. 8, NO. 1 (2006)
19. W. Bender, D. Gruhl, N. Morimoto, A. Lu: Techniques for data hiding: IBM Syst. J. 35 (3–4) pp.313–336 (1996).
20. X. Dong, M. F. Bocko, Z. Ignjatovic: Data hiding via phase manipulation of audio signals: IEEE Inter. Conf. on .Acoustics, Speech,and Signal Processing, Proceedings. (ICASSP '04). vol.5, no., pp. V-377-80 (2004)
21. X. Wang, & H. Zhao: A novel synchronization invariant audio watermarking scheme based on DWT and DCT: IEEE Transactions on Signal Processing; vol. 54,no.12, pp. 4835-40 (2006)
22. R. Petrovic, Audio Signal Watermarking Based on replica modulation, International Conference on Telecommunications in Modern Satellite,Cable and Broadcasting Service,Vol. 1,pp. 227-234(2001).
23.SiddharthGupta,VogeshPorwal: Recent Digital Watermarking Approaches,Protecting Multimedia Data Ownership: ACSIJ Advances in Computer Science: an International Journal, Vol. 4, Issue 2,No.14 ,ISSN : 2322-5157 (2015)
24. Digital Watermarking: https://en.wikipedia.org/wiki/Digital_watermarking