Volume 5, Issue 6, June 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Digital Audio-Watermarking using DWT-HAAR Transform

Sakriti Dutt
Department of Computer Science and Engineering,
Guru Nanak Dev University, Amritsar
Punjab, India

Abstract*— Many watermarking algorithms have been given in the past for digital images. But not many algorithms are present for audio-watermarking because of its complexity and due to the high sensitivity of Human ears in comparison to Human eyes. In this paper, DWT-HAAR transform has been used for the purpose of audio-watermarking. An introduction has been provided which gives a brief history and advantages of this technique. Algorithm for watermarking has been presented. Performance of algorithm has been evaluated using various parameters and also under different attacks. Comparison of this technique has been presented with DCT and DWT technique which have been given in the past.

***Keywords*— PSNR, NCC, DCT, DWT, HAAR**

I. Introduction

Every day, Music Industry looses a lot of money because of illegal copying of audio files. In the situation like this, audio watermarking can serve as a boon. Watermarking is **one type of stenographic techniques** whose primary goal is the protection of the object rather than the invisibility of the object. The watermarking technique has better robustness. A watermarking system would embed an amount of information that cannot be altered or removed without making the cover object entirely ineffectual. A watermarking system involves substitution between capacity and security.

The audio watermarking techniques can be frequency domain and time domain. As clear from the name, latter uses the time domain for embedding while the former uses a transform domain. Frequency domain techniques are way more effective than time-domain techniques because addition of watermark is done in the selected region in the transformed area of the original audio signal, this is done in such a way that both the imperceptibility and the robustness is maintained. DFT, DCT, DWT etc methods are used to transform and for finding the region for embedding the watermark into the original signal. [6]

These transformation techniques provide the user with the additional information about the signal therefore more data can be embedded into the audio signal [7]. Since low pass filter can easily remove the watermark from the original audio signal therefore the time domain method is less robust [8]. This paper discusses about an effective and robust audio-watermarking algorithm which is DWT-HAAR based. It satisfies all the requirements for audio-watermarking namely—inaudibility or imperceptibility, robustness and capacity. A comparison of this algorithm with a DWT[6] and DCT[10] based audio-watermarking algorithm also has been given.

A. History of audio watermarking

Stories of art of secret communication can be found in old greek literature like tales by Herodotus and in Iliad by Homer. The word Steganography means secret communication. Greeks used to tattoo the message on the head of a slave and the tattoo used to have a secret message hidden which used to disappear once the hair regrew. Message hiding was used by rebels during American Revolution. They used to use invisible ink. The text used to appear once the message was held close to flame. [2]

The art of steganography was used in both the world wars as well. In the World War I, Morse code was used and during World War II, microdots were used to hide the message. The messages were hidden in the periods used after the sentences and hence were not visible to the naked eye[2]. Watermark is the term which has originated from the paper industry. It is basically a design embedded on the paper which is used for identifying the maker of the paper and the paper itself. The watermarks first appeared in Fabriano, Italy ,known as the Birth Place of watermarks, in 1292. During the end of the 13th century, there were many paper mills which used to produce different papers of varying quality, format and raw material. In order to avoid confusion and because of the intense competition, watermarks were invented. These watermarks also helped in the identification of the manufacturer. This idea further gave birth to the idea of digital watermarks in the early 90s. [3]

B. Advantages of audio watermarking

1) Fingerprinting: Data embedded in the audio file can be used to track the history of usage of the audio file as well as owner of the audio data can get the idea about the popularity of the audio file. [4]

2) Copyright protection: In the case of the multiple ownership issue, the identity of the real owner can be known easily using the information embedded in the audio file. [4]

3) Broadcast monitoring: A company can know about the number of times an advertisement is played on a T.V. channel or any radio channel. [4]
4) Copy control: Now a days, some recording devices have been developed which can stop the recording or copying of an audio file as soon as it detects a watermark which indicates the recording of the music as illegal. [4]
5) Information carrier: The blind type of audio watermarking technique can be used for sending information from one place to another. But is less robust. [5].
6) Airline traffic monitoring: A particular frequency is used by the pilot to communicate with the ground station but sometimes miss communication can occur. In order to prevent such as event from happening, a unique identifier which can be flight number is embedded in the voice signal.

II. BASICS ABOUT TRANSFORM

In this section of the paper, a few details about DCT and DWT have been given.

A. DCT

Representing a signal, DCT is a kind of transform in which coefficients are obtained as a result of sum of all cosine functions which have been oscillating at varying frequencies[11]. DCT for a one dimensional signal with length K can be represented as follows:

$$DCT(n) = b(n)\sum_{k=0}^{K-1} g(k)\cos\left[\frac{\pi(2k+1)}{2K}\right] \qquad (1)$$

Here $n =$ 0, 1,2,….., K-1. Inverse DCT function for 1-d signal is given below:

$$g(k) = \sum_{k=0}^{K-1} b(n)DCT(n)\cos\left[\frac{\pi(2n+1)k}{2K}\right] \qquad (2)$$

In the case of (1) and (2), for $n =$0, 1,2,…..K-1, $b(n)$ will be :

$$b(n) = \begin{cases} \sqrt{\frac{1}{K}} & if\ n = 0 \\ \sqrt{\frac{2}{K}} & if\ n \neq 0 \end{cases} \qquad (3)$$

DCT quantizes the data, hence the original data is lost. Therefore, quality of the signal is adversely affected.

B. DWT

Discrete Wavelet Transform has a capability of providing both the time and frequency representation of the signal. It provides two coefficients—Approximation and Detailed[6]. A 1- dimensional DWT can be given as below:

$$B_\varphi(j,k) = \frac{1}{\sqrt{M}}\sum_n g(n)\varphi_{j,k}(n) \qquad (4)$$

$$B_\psi(j,k) = \frac{1}{\sqrt{M}}\sum_n g(n)\psi_{j,k}(n) \qquad (5)$$

Inverse DWT can be obtained as below:

$$g(n) = \frac{1}{\sqrt{M}}\sum_k A_\varphi(j,k)\varphi_{j,k}(n) + \sum_k A_\psi(j,k)\psi_{j,k}(n) \qquad (6)$$

Here equations (1) and (2) represent the approximation and detail coefficients for the wavelet respectively and here $\psi(n)$ represents the wavelet function and the $\varphi(n)$ is the scaling function respectively.
Orthogonal DWT Filters **:** Haar is the most basic orthogonal wavelet filter. The low pass and high pass filters for decomposition and reconstruction are orthogonal. The most significant quality of Haar Wavelet is that approximation of any real function can be done. Along with this, the implementation is considerably easier because of the two components of the filter design and moreover it requires less precision. For Haar wavelet, the vanishing moments is 1 and it is considered as the most basic wavelet. Haar wavelet is highly used in the applications such as image compression because of the fact that it is the simplest wavelet and because of its easy to manage scaling functions.

III. PROPOSED AUDIO-WATERMARKING ALGORITHM

The proposed DWT-HAAR based audio watermarking algorithm has been performed in two parts—embedding process and Extraction process

A. Watermark embedding process

Step1: The original audio signal(A) was sampled at a sampling rate and partitioning of the sampled file into frames ,each having certain samples, is performed.
Step 2: Apply DWT-HAAR on the original audio signal to produce LL, LH, HL and HH sub-bands. In other words, Approximation and detail sub-bands are obtained. Let LL be denoted by letter ℓ.

$$A_{\varphi}(j,k) = \frac{1}{\sqrt{M}} \sum_{n} f(n)\,\varphi_{j,k}(n) \quad (7)$$

$$A_{\psi}(j,k) = \frac{1}{\sqrt{M}} \sum_{n} f(n)\,\psi_{j,k}(n) \quad (8)$$

Here equations (1) and (2) represent the approximation and detail coefficients for the wavelet respectively and here $\psi(n)$ represents the wavelet function and the $\varphi(n)$ is the scaling function respectively. Here approximation coefficient represents the low-low(LL) sub-band while detail coefficient represents the details of the signal which is given by High-low(HL), Low-high(HL) and High-high(HH) sub-band.

Step 3: A binary image of M $\times$ N dimensions is chosen. Binary image is encrypted before the embedding procedure begins. Conversion of the watermark image into black and white has been performed. Let W denote a watermark image which is being used. Here b(m_1, n_1) denote the pixel coordinate of the image being used.

$$W = [b(m_1, n_1): 1 \le m_1 \le M, 1 \le n_1 \le N, b(m_1, n_1) \in \{0,1\} \quad (9)$$

Step 4: Inject the watermark into LL sub-band of the transformed audio-signal.

$$\ell_w = \ell + \gamma W \quad (10)$$

Where ℓ is the Low –level sub-band, ℓ_w is the low-band of watermarked audio file, γ be the scaling factor for the image and W be the image used as the watermark.

$$A' = l_w + hh + hl + lh \quad (11)$$

Here l_w is the low sub-band containing the watermark image, hh is the high sub-band, lh is the low-high sub-band and hl is the high-low sub-band. A' is the watermarked audio signal

Step 5: The modified LL sub-band will be combined with the other sub-bands.

Step 6: Inverse DWT-HAAR operation will be applied to get the watermarked audio signal. The following represents the inverse DWT-HAAR function.

$$A''(n) = \frac{1}{\sqrt{M}} \sum_{k} A_{\varphi}(j,k)\,\varphi_{j,k}(n) + \sum_{k} A_{\psi}(j,k)\,\psi_{j,k}(n) \quad (12)$$

A new audio file is then created and saved which is watermarked in nature.

Step7: Various attacks like Digital delay, Filter and Noisy attack are then applied on the watermarked audio file in order to evaluate the performance of the algorithm.

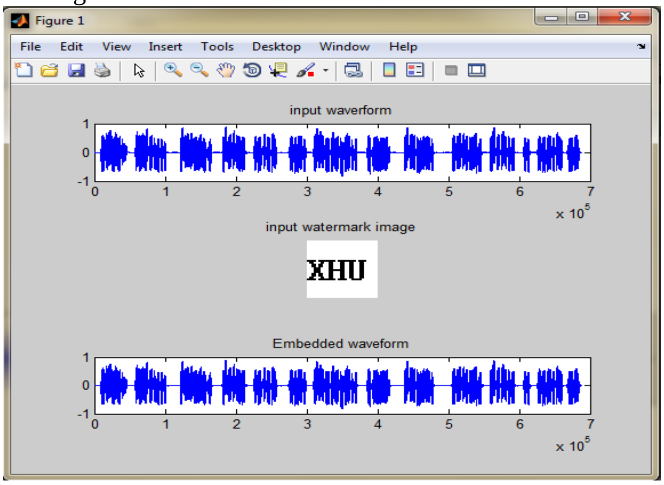

Fig 1 Embedding of watermark image into audio file

B. Audio watermarking extraction block

Step 1: Sampling of the watermarked audio signal at a sampling rate (fs) is done followed by partitioning of the sampled file into frames each one of them having a number of certain samples. Input the watermarked audio. Since it is a blind audio watermarking method, therefore it does not need the original audio file.

Step 2: Apply the DWT-HAAR transform on the watermarked audio signal. Same equations (7) and (8) as used above in the extraction algorithm will be used here.

Step 3: The signal will be decomposed to produce LL, LH, HL, HH sub-bands.

Step 4: The watermark image will be extracted.

$$W' = \frac{A_w - A}{\gamma} \quad (13)$$

Here W' is the image obtained as a result of extraction procedure. A_w be the watermarked audio file created. And γ is the scaling factor which was used in the case of the embedding methodology.

Step 5: inverse DWT-HAAR will be applied using the same method as in the case of equation (12)

Step 6: The extracted image W'will be compared with the original image to evaluate the Normalised Cross-correlation and to check if any attacks have been made on the audio signal. Bit Error rate for the audio file will also be evaluated. BER is also calculated.

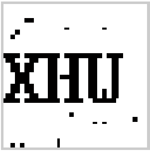

Fig 2 Extracted watermark image

IV. Experimental Results And Discussion

We have used a watermark image of size 32$\times$32. This algorithm has been implemented in Windows PC having Intel 2.27 GHz processor and 2048 MB RAM, and run using MATLAB R2013a. We have presented comparison between DCT , DWT and DWT-HAAR audio watermarking technique as well.

PSNR: To determine whether the imperceptibility requirement is satisfied, PSNR of the audio signal is evaluated. This is basically the ratio of the peak signal to that of the noise present. This is given by[1]:

$$\mathrm{PSNR}(Y, Y') = 20\log_{10}\frac{2^n - 1}{\mathrm{MSE}} \qquad (14)$$

Where Y and Y' are the original audio file and the watermarked audio file while n is the number of bits per sample. In an ideal case, maximum value for PSNR is infinity and the minimum value can be 0. PSNR is inversely proportional to MSE. Therefore, if MSE is 0 then value of PSNR will be infinite.

BER : Bit Error Rate (BER)[1] is used to evaluate the robustness of the algorithm. Higher the BER lower will be the robustness. It can be represented by using following equation:

$$\frac{B_{ERROR}}{M \times N} \times 100 \qquad (15)$$

Here B_{ERROR} gives us the number of error bits present. $M \times N$ are the dimensions of the image. Here M and N represent the dimensions of the watermark image. $W'$is the extracted image.

Error is the difference between calculated value and the actual value. To measure the error in the watermarked audio file, Mean squared Error (MSE) is used. It is the average of square of 'errors'. It is given by[1]:

$$MSE(Y, Y') = \frac{\|Y - Y'\|^2}{n} \qquad (16)$$

Here Y' is the calculated value and Y is the actual value. n is number of bits per sample. Lower the value of MSE better is the technique.

NCC : Certain similarity tests are also performed to evaluate the amount of similarity present between the watermark extracted and the actual watermark used. Normalised Cross-Correlation(NCC) is used to measure the same. NCC closer to 1 is considered as very good.

$$NCC(W, W') = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} W(i,j) * W'(i,j)}{\sqrt{\left(\sum_{i=1}^{M}\sum_{j=1}^{N} W(i,j) * W(i,j)\right)} * \sqrt{\left(\sum_{i=1}^{M}\sum_{j=1}^{N} W'(i,j) * W'(i,j)\right)}} \qquad (17)$$

To evaluate the performance of the proposed algorithm, various attacks like digital delay, filter and Additive white Gaussian Noise(AWGN) has been applied on the audio files. The comparative analysis of DWT[6] and DCT[10] method of audio-watermarking has also been given with proposed method.

Following table shows the performance of the proposed algorithm under normal circumstances.

TABLE I VARIOUS PARAMETERS FOR DWT-HAAR AUDIO WATERMARKING ALGORITHM UNDER NORMAL CIRCUMSTANCES

	NCC	**BER**	**PSNR**	**MSE**
Audio 1	0.9816	0.011384	108.8573	0.000920
Audio 2	0.9954	0.0101	138.8568	0.000029
Audio 3	0.4822	0	∞	0
Audio 4	0.5132	0	∞	0
Audio 5	0.5029	0	∞	0
Audio 6	0.5212	0	∞	0

The following table shows the performance of the algorithm under different circumstances. It also gives a comparison of the proposed technique with the DWT[9] and DCT technique[10] . PSNR and BER has been chosen for the comparison purposes.

TABLE III TABLE OF COMPARISON OF PROPOSED ALGORITHM WITH DWT AND DCT BASED ALGORITHM

		DWT-HAAR		**DWT**		**DCT**	
	Attack type	**PSNR**	**BER**	**PSNR**	**BER**	**PSNR**	**BER**
A u	**Delay**	107.3337	0.0115	56.6015	0.0162	3.9391	0.0253

	Noise	44.6741	0.0902	44.6622	0.0903	44.6652	0.0903
	Filter	83.4513	0.0133	55.2883	0.0164	3.9391	0.0283
Audio 2	**Delay**	136.7159	0.0102	56.5686	0.0174	51.1501	0.0182
	Noise	45.9460	0.1482	45.0047	0.1489	45.0013	0.1488
	Filter	90.4829	0.0134	56.1889	0.0174	51.1501	0.0182
Audio 3	**Delay**	109.6470	0.0110	53.8045	0.0160	22.1334	0.0214
	Noise	47.9527	0.0853	47.9355	0.0854	47.9246	0.0853
	Filter	90.1553	0.0124	53.9487	0.0160	22.1334	0.0214
Audio 4	**Delay**	114.6956	0.0108	54.0082	0.0162	4.0228	0.0273
	Noise	46.5765	0.0865	46.5762	0.0866	44.0960	0.0873
	Filter	91.8510	0.0124	54.9787	0.0162	4.0228	0.0271
Audio 5	**Delay**	111.1537	0.0111	54.1381	0.0163	4.7725	0.0272
	Noise	45.4240	0.0861	45.4043	0.0862	45.4156	0.0862
	Filter	92.9021	0.0124	55.1792	0.0162	4.7725	0.0272
Audio 6	**Delay**	106.0053	0.0109	54.5429	0.0152	15.8396	0.0216
	Noise	53.6776	0.0866	53.6669	0.0867	53.6520	0.0868
	Filter	52.7442	0.01545	47.3040	0.0161	15.8396	0.0216

V. CONCLUSIONS AND FUTURE WORK

In this paper, a new and innovative technique of audio-watermarking has been presented. We have used DWT-HAAR transform in this respective technique. The requirements of imperceptibility, capacity and robustness are satisfied by this presented algorithm. It shows fair amount of robustness under noise, filter and digital delay attacks. The performance of this algorithm under adverse conditions is better in comparison to the DWT [6] and DCT[11] algorithm. Although, this algorithm can be applied only on audio files with wav format. Therefore, steps can be taken for further improvements.

REFERENCES

[1] Kaur, Navjot, and Usvir Kaur. "*Audio Watermarking using Arnold transformation with DWT-DCT*." International Journal of Computer Science Engineering. Vol.2 No. 6 pp:286-294.

[2] Cummins, Jonathan(2004), et al. "Steganography and digital watermarking." *School of Computer Science, The University of Birmingham.*

[3] Hartung, Frank, and Martin Kutter(1999): "Multimedia watermarking techniques." Proceedings of the IEEE Vol. 87 No.7 pp: 1079-1107.

[4] Mat Kiah, B. B. Zaidan, A. A. Zaidan, A. Mohammed Ahmed and Sameer Hasan Al-bakri(2011). "A review of audio based steganography and digital watermarking." International Journal of Physical Sciences Vol. 6 No.16. pp: 3837-3850

[5] M. Navneet Kumar, "Watermarking Using Decimal Sequences," M.S. thesis, Louisiana State University, Baton Rouge, LA, USA, 2004

[6] N.V.Lalitha, Ch.Srinivasa Rao, P.V.Y.JayaSree. "DWT-Arnold Transform Based Audio Watermarking." Asia Pacific Conference on Postgraduate Research in Microelectronics and Electronics (PrimeAsia). IEEE, 2013

[7] R. Polikar, "Home page - Dr. Robi Polikar," Jan 2001. [Online]. Available: http://users.rowan.edu/~polikar/WAVELETS/WTtutorial.html. Accessed: June 6, 2015.

[8] V. K. Bhat, I. Sengupta, and A. Das(2008), "*Audio Watermarking Based on Quantization in Wavelet Domain*," ICISS 2008, LNCS 5352, pp. 235 -242

[9] N.V.Lalitha, Ch.Srinivasa Rao, P.V.Y.JayaSree. "DWT-Arnold Transform Based Audio Watermarking." Asia Pacific Conference on Postgraduate Research in Microelectronics and Electronics (PrimeAsia). IEEE, 2013

[10] Yang, Yan, Rong Huang, and Mintao Xu. "*A Novel Audio Watermarking Algorithm for Copyright Protection Based on DCT Domain*." Electronic Commerce and Security, 2009.

[11] Ahmed, T. Natarajan, and K. Rao, "Discrete cosine transform," IEEE Transactions on Computers, vol. C-23, no. 1, pp. 90–93, Jan. 1974.

