Audio Watermarking using Arnold transformation with DWT-DCT

Navjot Kaur
M.Tech (CSE)
SGGSWU, Fatehgarh Sahib
Punjab, India
E-mail :- navjot.2088@gmail.com

Usvir Kaur
Assistant Prof. Department of CSE
SGGSWU, Fatehgarh Sahib
Punjab, India
E-mail :- usvirkaur@gmail.com

Abstract- In this research paper a new audio watermarking scheme is proposed using Arnold transformation with DCT-DWT. In audio watermarking embedding firstly, the audio convert signal was divided evenly, the audio segments were selected from the divided audio, then by doing the DWT and DCT embedded the watermark to the low frequency coefficients of those audio segments which were selected. Watermark is a binary image which was transformed using Arnold transformations. A random private key is used during watermark embedding for more security. Finally, all of the audio segments were regrouped. Experimental results demonstrate that the watermark is inaudible and this algorithm is robust to common operations of digital audio signal processing, such as white gaussian noise addition, compression and low pass filtering. To evaluate the performance of the proposed audio watermarking method, subjective and objective quality tests including Mean square Error (MSE), Bit Error Rate (BER), Signal to Noise ratio (SNR) and NCC are calculated.

Keywords: - *Audio Watermarking, Arnold Transformation, DWT, DCT*

I. INTRODUCTION

With the rapid development of the network (especially the Internet) and multimedia technique, the protection of intellectual property rights has been the key problem which we must solve. Under this background, digital watermarking has received a large deal of attention recently and has been a focus in network information security. Digital watermarking can be classified into image watermarking, video watermarking and audio watermarking according to the range of application. Audio watermarking is quite challenging than image watermarking due to the dynamic supremacy of human auditory system (HAS) over human visual system (HVS).

A significant number of watermarking techniques have been reported in recent years in order to create robust and imperceptible audio watermarks. Seok *et al.* in 2002 proposed watermarking scheme includes a psychoacoustic model of MPEG audio coding to ensure that the watermarking does not affect the quality of the original sound. The proposed watermark embedding scheme accomplishes perceptual transparency after watermark embedding by exploiting the masking effect of the human auditory system. *FU* in 2004 decomposed the audio signal using discrete wavelet transform into three levels making good use of multiresolution characteristics of wavelet transform. Ivo *et al.* in 2006 propose a maximum likelihood technique to combat amplitude scaling attacks within a quantization based watermarking context. Chen *et al.* in 2008 proposed a novel multipurpose audio watermarking scheme to make audio watermarking accomplish both copyright protection and content authentication with localization. The zero-watermarking idea is introduced into the design of robust watermarking algorithm to ensure the transparency and to avoid the interference between the robust watermark and the semi-fragile watermark. Lalitha et al. in 2012 propose that in order to provide authentication the watermark image is scrambled with Arnold transformation and then embedded into the Discrete Cosine Transformed (DCT) original audio signal. Yassine in 2012 propose an innovative watermarking scheme for audio signal based on double insertion of the watermark in DWT-DST domain of the host signal by using a gray scale logo image as watermark instead of randomly generated Gaussian noise type watermark.

II. APPLICATIONS OF AUDIO WATERMARKING

- *Copyright Protection:* Embedding the ownership of the information when information is being duplicated or abused.
- *Usage/ Copy tracking:* verify the usage and copy of the information by the embedded data.
- *Metadata or Additional information:* Embedding data to describe information, e.g Structure, indexing terms, etc.
- *Multiple data embedding:* Embedding smaller image in larger image or multiple audio data in a vedio.

- *Owner Identification:* Digital watermarking embed the watermark in the bit position of the content. When the device read the watermark identifies the owner of the content.
- *Broadcast monitoring:* A commercial advertisement may be watermarked by putting a unique watermark in each video or sound clip prior to broadcast. Automated monitoring systems can then receive broadcasts and check for these watermarks, identifying when and where each clip appears. This proves very helpful for the advertisers as they actually pay for only the number of times the advertisement was actually relayed.
- *Medical applications:* Names of the patients can be printed on the X-ray reports and MRI scans using techniques of visible watermarking. The medical reports play a very important role in the treatment offered to the patient. If there is a mix up in the reports of two patients this could lead to a disaster.

III. REQUIREMENTS OF AUDIO WATERMARKING

- *Imperceptibility:* The digital watermark should not affect the quality of original audio signal after it is watermarked.
- *Robustness:* The embedded watermark data should not be removed or eliminated by unauthorized distributors using common signal processing operations and attacks.
- *Capacity:* Capacity refers to the numbers of bits that can be embedded into the audio signal within a unit of time.
- *Security:* Security implies that the watermark can only be detectable by the authorized person.

IV. TRANSFORMATION USED

A.The DCT transform: The Discrete Cosine Transform is a technique for converting a signal into elementary frequency components[2]. The most common DCT definition of a 1-D sequence of length N is

$$C(u)=\alpha(u)\sum_{x=0}^{N-1} f(x)\cos\left[\frac{\pi(2x+1)u}{2N}\right],$$

For u=0,1,2,….,N-1. Similarly, the inverse transform is defined as,

$$f(x)=\sum_{u=0}^{N-1} \alpha(u)C(u)\cos\left[\frac{\pi(2x+1)u}{2N}\right],$$

For x=0, 1, 2,….N-1. In both equations (1) and (2) α(u) is defined as,

$$\alpha(u)=\begin{cases}\sqrt{\frac{1}{N}} & for\ u=0\\ \sqrt{\frac{2}{N}} & for\ u\neq 0\end{cases}$$

It is clear from eq.(1) that for u=0,

$$C(0)=\sqrt{\frac{1}{N}}\sum_{x=0}^{N-1} f(x).$$

The first transform coefficient is, referred to as DC Coefficient, the average value of the sample sequence. The other transform coefficients are called the AC Coefficients .

B. Arnold Scrambling: The K×K binary watermark image *W* is transformed into *W'* by Arnold transformation to lower the autocorrelation coefficient of image and then the confidentiality of watermark is strengthened . Arnold transformation is periodic and when it is iterated some times the original signal will be obtained[2]. The Arnold transformation is given by

$$\begin{bmatrix} a' \\ b' \end{bmatrix}=\begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix}\begin{bmatrix} a \\ b \end{bmatrix}(\text{mod } N_l)$$

Inverse Arnold transform is obtained by using the equation below. Here $(a_1, b_1)^T$ is the coordinate of the Arnold transformed image pixel coordinates and $(a_1', b_1')^T$ is the original pixel coordinates (Lalitha, Suresh and Telagarupa,2012). Mathematically,

$$\begin{bmatrix} a_1' \\ b_1' \end{bmatrix}=\begin{bmatrix} 2 & -1 \\ -1 & 1 \end{bmatrix}\begin{bmatrix} a_1 \\ b_1 \end{bmatrix}(\text{mod } N_l)$$

Here $\begin{pmatrix} 2 & -1 \\ -1 & 1 \end{pmatrix}$ is the inverse of $\begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix}$, where $\begin{vmatrix} 1 & 1 \\ 1 & 2 \end{vmatrix} = 1$.

C. The DWT Transform: The principle objective of the wavelet transform is to hierarchically decompose an input signal into a series of successively lower frequency approximation sub band and their associated detail sub bands. For the dyadic wavelet decomposition, at each level, the low frequency approximation sub band and detail sub band (or sub bands for multidimensional case) contain the information needed to reconstruct the low frequency approximation signal at the next higher resolution level. Wavelet techniques provide excellent space and frequency energy compaction, in which energy tends to a cluster spatially in each subband[7]. For DWT, the link between the spatial/temporal domain signals, f (t), and the DWT of f (t), d (k,l),is

$$f(t) = \sum_{k=-\infty}^{\infty} \sum_{l=-\infty}^{\infty} d(k,l) 2^{-k/2} \psi(2^{-k} t - l).$$

Where ψ (•) denotes the mother wavelet.

V. WATERMARK EMBEDDING

1. Read the original audio I of length LEN.
2. Read the Watermark Image W.
3. Binary Watermark Image is taken.
4. Calculate Arnold period.
5. Enter the Private Key of any length.
6. Calculate the Arnold Period for the size of Watermark Image.
7. Calculate the Number of iterations with the help of Private Key and Arnold Period.
8. Arnold Transformation will be applied on original watermark by number of iterations.
9. Convert the transformed Watermark to a vector.
10. Divide the Original Audio into segments of length Q (Q = LEN/ piece) evenly and numbered each segment, where "piece" is the length of every segment.

    A^0 denotes each segments, A^0 is cut into A^0_1 and A^0_2 with L_1 and L_2 samples.
11. Do the H-level DWT. H is selected such that length of low frequency coefficients should be MN.
12. Do the DCT on low frequency coefficients.

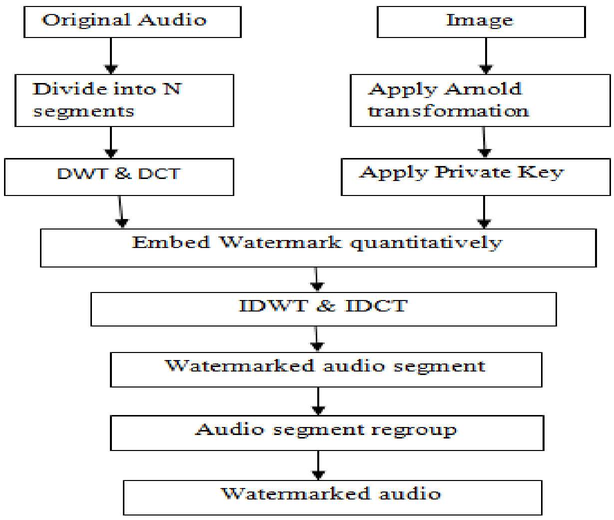
    a. $$A_2^{0^{HC}} = DCT(A_2^{0^{H}}) = \left\{ a_2^{0(t)^{HC}}, 0 \le t < \frac{L_2}{2^H} \right\}.$$
13. Embed the Watermark bits as per the Quantization Function given below

$$a_2^{0'}(t)^{HC} = \begin{cases} IQ(a_2^0(t)^{HC}) \times S_2 + \frac{S_2}{2} & \text{if } Q(a_2^0(t)^{HC}) = w_1(i,j) \\ IQ(a_2^0(t)^{HC}) \times S_2 - \frac{S_2}{2} & \text{if } Q(a_2^0(t)^{HC}) \neq w_1(i,j) \end{cases}$$
$$t = (i-1) \times N + j$$

where $0 \le i < M$, $0 \le j < N$, and S_2 is the quantization step, and

$$IQ(a_2^0(t)^{HC}) = \left\lfloor \frac{(a_2^0(t)^{HC})}{S_2} \right\rfloor,$$
$$Q(a_2^0(t)^{HC}) = \bmod\left(IQ(a_2^0(t)^{HC}), 2\right).$$

14. Do the Inverse DCT on quantized low frequency coefficients.
15. Do the Inverse DWT.
16. Re-arrange the segments of Audio into a single Audio, save it as a Watermarked Audio



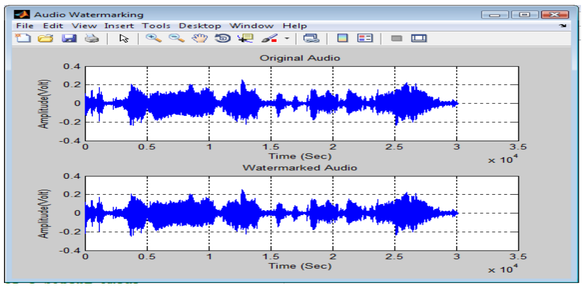


Fig1.1 Original and Watermarked Audios of wav 1

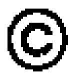


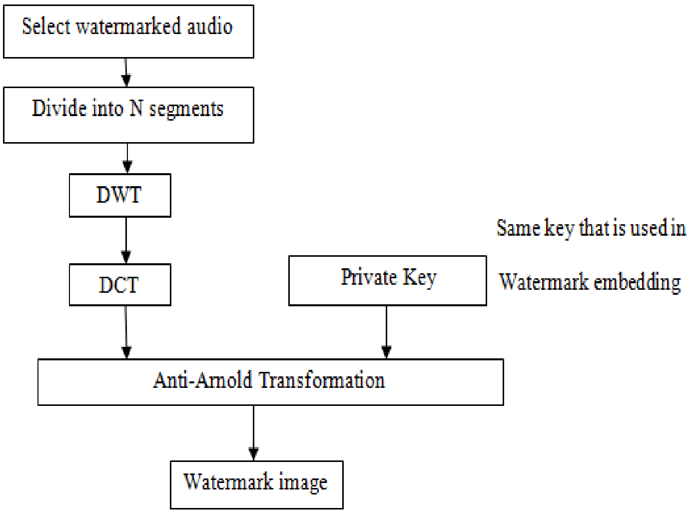
Fig1.2 Watermark Used

VI. WATERMARK EXTRACTION

1. Read the Watermarked audio I of length LEN.
2. Divide the Original Audio into segments of length Q (Q = LEN/ piece) evenly and numbered each segment, where "piece" is the length of every segment.
3. Do the H-level DWT.
4. Do the DCT on low frequency coefficients.
5. Extraction of Watermark bit is done as per following equation

$$W' = w'(i,j) = \left\lfloor \frac{a^*(t)^{HC}}{S_2} \right\rfloor \bmod 2, (0 \le i < M, 0 \le j < N).$$

   Where w' is extracted watermark bit, S2 is Quantization step, a*(t) are low frequency coefficients.
6. Re-arrange the bits to MxN size to get the Scrambled watermark.
7. Enter the Private Key of any length.
8. Calculate the Arnold Period for the size of Watermark Image.
9. Calculate the Number of iterations with the help of Private Key and Arnold Period.
10. Arnold Transformation will be applied by number of iterations, calculated in previous step. Finally get the extracted watermark.



VII. EXPERIMENTAL RESULTS

In this paper, we chose meaningful binary image as watermark information. Watermark image w is a binary image of size M × N. In order to enhance the confidentiality of the watermark image and reduce its relevance, we used Arnold transform to scramble watermark image firstly, which can disrupt an image regularly and making the image looks like random noise.

Robustness and imperceptibility are very important for the copyright protection system of watermarking.

We can verify the performance of proposed watermarking algorithm. In the experiment we chose 10 audio signals

Signal to Noise Ratio: Signal to noise ratio is a parameter used to know the amount by which the signal is corrupted by the noise. It is defined as the ratio of the signal power to the noise power.

Signal to noise ratio can also be calculated by equation below. Z is the un-watermarked audio signal and *Z'* is the watermarked audio signal. Both *Z* and *Z'* has *Mt* samples

$$SNR = 10\log\left(\frac{\sum_{a=1}^{M_t} Z^2(a)}{\sum_{a=1}^{M_t}(Z(a)-Z'(a))}\right)$$

Mean Square Error: the **mean squared error (MSE)** of an estimator is one of many ways to quantify the difference between values implied by an estimator and the true values of the quantity being estimated. MSE is a risk function, corresponding to the expected value of the squared error loss or quadratic loss. MSE measures the average of the squares of the "errors." The error is the amount by which the value implied by the estimator differs from the quantity to be estimated. The difference occurs because of randomness or because the estimator doesn't account for information that could produce a more accurate estimate.

$$MSE(x,y) = \frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)^2$$

Where x_i is watermarked audio and y_i is original audio. N is no. of samples.

Table 1.1 Calculated values of SNR and MSE during watermark embedding.

Audio	MSE	SNR
WAV1	0.6849	21.2496
WAV2	0.7126	25.4476
WAV3	0.7043	34.7885
WAV4	0.7401	28.9161
WAV5	0.7376	43.6317
WAV6	0.7154	35.4825
WAV7	0.6947	42.9439
WAV8	0.6931	34.3708
WAV9	0.8477	34.0048
WAV10	0.6557	29.8657

In order to eliminate the subjective factors and reflect the fairness of copyright protection, we employed the normalized correlation coefficient (NC) to estimate the similarity between the original watermark and the extracted watermark. The normalized correlation coefficient (NC) is defined as equation.

$$NC(w,w') = \frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} w(i,j)\cdot w'(i,j)}{\sqrt{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} w^2(i,j)}\sqrt{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} w'^2(i,j)}}$$

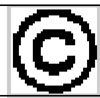
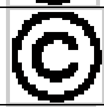
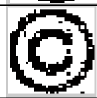
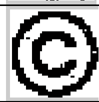
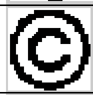
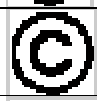
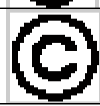
Bit Error Rate

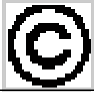
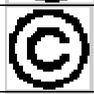
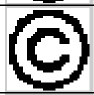
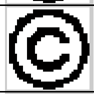
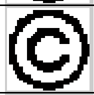
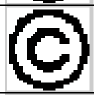
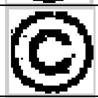
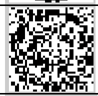
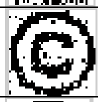
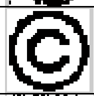
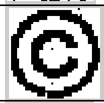
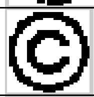
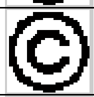
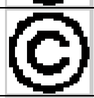
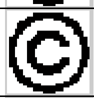
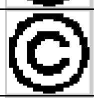
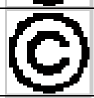
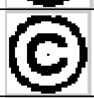
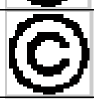
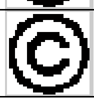
Bit error rate can be defined as the percentage of bits corrupted in the transmission of digital information due to the effects of noise, interference and distortion.

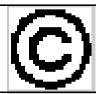
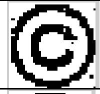
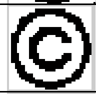
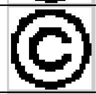
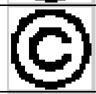
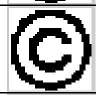
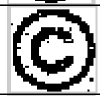
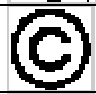
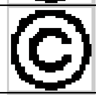
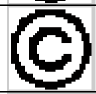
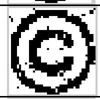
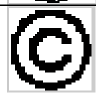
$$BER = \frac{Brr}{M \times N} \times 100\%$$

Where, *Brr* is the number of error bits and refers to the size of the image (totaling the number of bits in the image).

To evaluate the performance of watermark objectively, we did some common attacks to the watermarked audio; the experimental results were shown in tables:

Audio	**Attack**	**NCC**	**BER**	**Watermark**
WAV 1	No Attack	1	0	
	White Gaussian Noise	1	0	
	Compression	0.9771	2.8320	
	Low Pass Filtering	0.9945	0.6836	
WAV2	No Attack	1	0	
	White Gaussian Noise	1	0	
	Compression	1	0	

	Low Pass Filtering	1	0	
WAV 3	No Attack	1	0	
	White Gaussian Noise	1	0	
	Compression	1	0	
	Low Pass Filtering	1	0	
WAV 4	No Attack	1	0	
	White Gaussian Noise	0.9921	0.9766	
	Compression	0.7246	32.2266	
	Low Pass Filtering	0.9515	5.9570	
WAV 5	No Attack	1	0	
	White Gaussian Noise	0.8289	20.2148	
	Compression	0.9944	0.6836	
	Low Pass Filtering	1	0	
WAV6	No Attack	1	0	
	White Gaussian Noise	1	0	
	Compression	1	0	
	Low Pass Filtering	1	0	
WAV7	No Attack	1	0	
	White Gaussian Noise	0.9984	0.1953	
	Compression	1	0	
	Low Pass Filtering	1	0	

WAV8	No Attack	1	0	
	White Gaussian Noise	0.9905	1.1719	
	Compression	1	0	
	Low Pass Filtering	1	0	
WAV9	No Attack	1	0	
	White Gaussian Noise	1	0	
	Compression	0.9849	1.8555	
	Low Pass Filtering	1	0	
WAV10	No Attack	1	0	
	White Gaussian Noise	1	0	
	Compression	0.9680	3.9063	
	Low Pass Filtering	1	0	

VIII. CONCLUSION AND FUTURE SCOPE

The watermarking of audio data is an appropriate mechanism to protect the intellectual property rights. In this scheme we scramble the watermark with Arnold transformation and embed quantitavely it into the audio signal. Before embedding the watermark first apply DCT and DWT on audio file. The experimental results have illustrated the robust nature our watermarking scheme. In addition, the watermark can be extracted without the help from the original digital audio signal and can be easily implemented. To check the robustness SNR, MSE, NCC and BER is calculated. After embedding watermark, the SNR of all selected audio signals using the proposed method are above 20 dB which ensures the imperceptibility of the proposed system. This satisfies the IFPI requirement (20 dB).The value of MSE is always less than 1 for each audio file. The value of NCC of most of the audio files was 1 and BER was almost 0. It can be seen that using the proposed algorithm to embed watermark is inaudible and is robust to some common attacks like compression, noise and low-pass filter. We can extract watermark and it has good legibility.

In future work we will further improve the processing efficiency and simultaneously improve the watermark embedding capacity of the algorithm. This approach may also be extended to video watermarking.

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