A Novel Audio Watermarking Scheme using cascading SVD and DWT

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Abstract-**In this paper, we propose an effective, reliable robust, and an inaudible audio watermarking algorithm. The proposed algorithm uses reduced singular value decomposition (SVD) in cascade with the 2 level discrete wavelet transform (DWT). These two transforms are used because they transform the energy of the signal to few coefficients which are robust to common signal processing. To make it robust against cropping or de-synchronization Barker code is embedded to the audio signal along with the watermark. Experimental results presented in this paper demonstrate the effectiveness of the proposed algorithm.**
Keywords- *Audio watermarking, Intellectual property, SVD (Singular value Decomposition), Barker code, Robustness, Discrete Cosine Transform (DCT), Discrete Wavlet Transform (DWT)*

I. INRODUCTION

The threat of copying the multimedia content and its illegal distribution is at its peak. The digital revolution through which the copying, storage & the transfer of the multimedia data become easy has now become a boon for the negative shade people who are involved in illegal copying and distribution. Similarly it has become a curse for the multimedia creators who want revenues from their creations. There is a great no in peoples mind now for providing their multimedia creation on a public platform. Encryption type of data protection techniques is not sufficient for protecting the intellectual rights of the genuine multimedia provider. Digital watermarking technology, on the other hand, is now attracting attention as a new method of protection against unauthorized copying of digital multimedia files that includes image, audio and video components. Digital watermarking basically is a process of embedding a watermark on to a media file without introducing perceptual degradation.

In the recent past much of the work is done for image and video watermarking. But now the watermarking an audio signal is gaining popularity among the researchers. As compared to the image and video watermarking, audio watermarking is proved to be tough due to complexity and higher sensitivity of the human auditory system (HAS) to the as compared to the human visual system (HVS) .In addition, the embedding of the watermarking bit is tough as the audio signal is represented through less number of bits per second as compared to the image and the videos. Watermark is the copyright information specific to the owner and should be unique. The watermarking of a multimedia can be done in time as well as transform domain. In our previous work a brief description of the watermarking requirements, the different applications , the subjective and the objective measures for evaluating the watermarking, the comparison of the different watermarking schemes under an umbrella of methodology being used, imperceptibility of the watermarked media, robustness against attacks specially the synchronization attacks which are very prominent in audio media, the payload of the technique, security of the watermarking system which essentially says that even after the algorithm is known to the intruder or the pirates he is not able to separate the watermarks, what if the watermark & algorithm is known to the intruder & he uses it on some other audio media to defame the owner, need for non blind watermarking in case the same watermarked audio media is re watermarked through another watermark & different keys and the future objectives are discussed in our previous papers [1]. The typical watermarking system consists of an embedding module & an extraction module. We in our previous work have also proposed a watermark generation module as an additional module which is used to generate unique watermark from the biometric features of an individual. This unique watermark can deal with ambiguous situation which can arise due to having a similar watermark with two persons [2].In this paper; we propose an audio watermarking algorithm that satisfies the requirements of effective audio watermarking inaudibility and watermark robustness to removal or degradation. The robustness requirement is met by the proposed algorithm by exploiting the attractive properties of two powerful mathematical transforms; the Discrete Wavelet Transform (DWT) and the Reduced Singular Value Decomposition (RSVD). SVD is used mostly for image watermarking and very few have applied it on audio watermarking. The SVD based watermarking techniques are categorized into two groups– One using the original signal for watermark extraction/ detection called as the non blind techniques**[3-5]** ,and the second category that is blind which doesn't require the original [6 -12]. In all the SVD based techniques the watermark is embedded by manipulating the singular values in accordance with the watermarking bit. Many of the watermarking methods also exists which embed the watermark in the different DWT coefficients [13-14]. Few methods also used the combination of DWT and SVD for watermark embedding and extraction [15-16].In the proposed algorithm, watermark bits are not embedded directly into DWT's coefficients, but rather on the elements of singular values and the unitary matrix column values of the DWT sub-bands of the audio frames. The rest of the paper is organized as follows. The two transforms, DWT and SVD, are outlined in section 2. Barker Code is described in section 3. The proposed audio SYN-DWT-SVD watermarking algorithm is described in section 4 and evaluated with respect to imperceptibly (inaudibility) and robustness, in section 5. Conclusions are given in section 6.

II. BASIC OF TRANSFORM USED

II.1 Discrete Wavelet Transform (DWT)

In this section, we briefly introduce the DWT and SVD transforms and outline their relevance to the problem of digital watermarking. Discrete wavelet transform (DWT) is a novel transform technique which is used for multi resolution analysis of the signals. The multi resolution analysis means that the signal can be analyzed and represented in time domain as well as frequency domain effectively .Starting from the original audio signal ***S***, DWT produces two sets of coefficients. The approximated low frequencies coefficients are produced by passing the signal through a low pass filter. The high frequencies detailed coefficients are produced by passing the signal through a low pass filter**.**

Depending on the application and the length of the signal, the low frequencies part might be further decomposed into two parts of high and low frequencies. Due to its excellent spatio-frequency localization properties, the DWT is very suitable to identify areas in an audio signal where a watermark can be embedded effectively.

III.2 Singular Value Decomposition

Singular value decomposition (SVD) is a numerical technique for diagonalizing matrices. The SVD of an ***N x N*** matrix ***A*** is defined by the operation
A = US V^T as shown in Figure 3

$$\begin{bmatrix} V_{1,1} & . & . & V_{1,n} \\ V_{2,1} & . & . & V_{2,n} \\ . & . & . & . \\ V_{n,1} & . & . & V_{n,n} \end{bmatrix}^T \begin{bmatrix} \sigma_{11} & 0 & 0. & 0 \\ 0 & \sigma_{22} & 0 & 0 \\ . & . & . & . \\ 0 & 0 & 0 & \sigma_{nn} \end{bmatrix} \begin{bmatrix} U_{1,1} & . & . & U_{1,n} \\ U_{2,1} & . & . & U_{2,n} \\ . & . & . & . \\ U_{n,1} & . & . & U_{n,n} \end{bmatrix}$$

Fig. 1: The SVD operation SVD (A) = U S V^T

The entries corresponding to the diagonal of the matrix S are called the singular values of ***A*** and are assumed to be arranged in decreasing order. The columns of the ***U*** matrix are called the left singular vectors while the columns of the ***V*** matrix are called the right singular vectors of ***A*.** Slight change in the singular values or the entries corresponding to the columns of the unitary matrices don't disturb the transparency and also these values are not prone to common signal processing operation if used for the processing of the signal. So SVD-based audio watermarking algorithms exploits this to add the watermark information to the singular values of the diagonal matrix ***S*** or the columns of the unitary matrices in such a way that imperceptibility /inaudibility is not disturbed and robustness requirements of effective digital audio watermarking algorithms is achieved.

III. 3. Synchronization Code

Synchronization is one of the key issues of audio watermarking. Time-scale or frequency-scale modification tries to misalign the signal when detection / extraction is to be done .So in all a loss of synchronization takes place and thus the watermark can't be detected or extracted. To make the signal robust to synchronization attacks a code is also embedded along with the watermark. Watermark detection starts by alignment of watermarked block with detector. Losing synchronization causes false detection. So we need synchronization algorithms based on robust synchronization code. The proposed scheme embeds Barker code in the front of the watermark to locate the position where watermark is embedded. Barker codes are subsets of PN sequences and are commonly used for frame synchronization in digital communication systems. The correlation side lobe C_k for a k symbol shift of an N-bit code sequence $\{x_j\}$ is given by

$$C_{k=} \sum_{i=1}^{N} x_i x_j$$

j=i+1

Where x_j is an individual code symbol taking values +1 or -1 for j=1, 2, 3 …N. We convert the -1 value to zero.

IV. THE PROPOSED ALGORITHM

In this section we describe the major steps of proposed algorithm i.e. watermark embedding procedure and watermark extracting procedure. The proposed algorithm employs a cascade of two additional steps Barker code generation and embedding and watermark generation and embedding.

IV.1 Preprocessing

Transform the speech signal into binary bits using [3].

Let Wi be the binary watermark thus produced

$W_i = \{[0, 1],\}$

IV.2 Watermark embedding procedure

The steps involved in embedding of the watermark on to a cover audio signal are as follows:

Step 2. Audio signal is sampled at a rate of 44.1 kHz. Then partition the entire samples into segments of equal length say L consisting one frame. Each frame is composed of 25 ms samples. The summation of *N* frames makes up the overall sampled audio signal as illustrated in the following equation:

$$\mathbf{A} = \sum_{i=1}^{N} A_i$$

Let A^k denotes kth segment, A^k is cut into two sections A^{k1} and A^{k2} with length as L_1 and L_2 samples respectively. Synchronization code and watermark are embedded into A^{k1} and A^{k2} respectively

Step 3 constructing the matrix

Arrange each frame through the column of a matrix creating a matrix having no. of columns equal to the no. of frames and no. of rows equal to the no. of samples within a frame.

Step 4 Perform 2 level DWT on each column this will restrict the energy content corresponding to each frame to few DWT Coefficients.

Step 5. Perform SVD on the matrix thus formed. Decompose the DWT matrix using the SVD operator. This operation produces the three orthonormal matrices *S*, *U* and V^T

as follows:

$DC = U*S*V^T$

Step 6. Embed the watermark Bit

(i). Using the S matrix.

Embed the binary watermark bits into the DWT-SVD-transformed audio signal as follows:

hiddenBit = {0, 1}

Diff = S (i, i) – S (i+1, i+1)

Diff = { > boundary (1.0) we left both singular values unchanged

hiddenBit = 0 & diff < limit
S(i, i) = S(i, i);
hiddenBit = 0 & diff >= limit
S(i, i) = S(i, i) – diff + lvalue(0.4);
hiddenBit = 1 & diff >= limit
S(i, i) = S(i, i);
hiddenBit = 1 & diff < limit
S(i, i)={S(i, i) – diff + uvalue
if (S(i, i) – diff + uvalue < S(i-1,i-1))
S(i+1,i+1) +diff – uvalue
if (S(i+1, i+1) + diff - uvalue > S(i+2, i+2))}

Otherwise check the difference between S(i-1, i-1) & S(i+2, i+2)

(ii) Using column 2 of the V matrix.

Diff = V (i, 2) – V (i+1,2)

Diff = { > boundary (1.0) we left both singular values unchanged

hiddenBit = 0 & diff < limit
V(i,2) = V(i, 2);
hiddenBit = 0 & diff >= limit
V(i,2) = V(i, 2) – diff + lvalue(0.4);
hiddenBit = 1 & diff >= limit
V(i, 2) = V(i,2);
hiddenBit = 1 & diff < limit
V(i, 2)={V(i, 2) – diff + uvalue
if (V(i, 2) – diff + uvalue < V(i-1,2))

V(i+1,2) +diff – uvalue
if (V(i+1,2) + diff - uvalue > V(i+1, 2))}

So this way simultaneously two bits are inserted which increases the payload by twice.

Step 7. Perform Inverse SVD and DWT

Apply inverse SVD using U and V^T matrices which are unchanged and S matrix which is modified in step 6 as follows:

$CD_w = U*S*V^T$

Apply the inverse DWT operation on the CD_w matrix to obtain watermarked audio frame.

Step 8. Multiple watermark addition

Repeat step 3-7 on each segment to obtain a multiple watermarked audio signal.

IV.3 Watermark Extraction Procedure

Step 1. Synchronized Code Detection

Locate the beginning position of the watermarked segment based on the frame synchronization technology of digital communication.

Step 2. Obtain SVD Matrix

Perform steps 1 through 5 of the embedding procedure until the *S* matrix is obtained for all frames of the watermarked audio signal.

Step 3. Extraction

extractedBit =

{ 0 if s(i, i) – s(i+1, i+1) < limit
 1 if limit < (s(i,i) – s(i+1,i+1)) < boundary }

Similarly extract the bit from the V matrix.

Step 4. Contruct the watermark sequence by appending the bits.

V. RESULTS

The performance analysis of the proposed method is done by finding the signal to noise ratio, the normalized correlation of the embedded and the extracted watermark and the bit error rate. For ready reference they are all defined below.

Signal to Noise Ratio (SNR): The signal to noise ratio is defined as the ratio of the signal power to the noise power and is given by

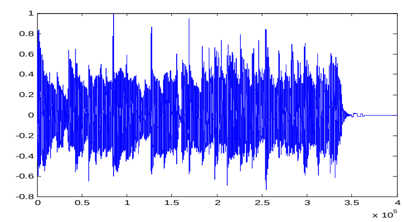
SNR = Power(Signal)/Power(Noise)

Normalized Correlation Coefficient(NC): It is defined as the similarity between the extracted watermark and the embedded watermark and is given by

$$NC(W,W^*) = \frac{\sum_{i=1}^{M} W(i) \quad W^*(i)}{\sqrt{\sum_{i=1}^{M} W(i)^2}\sqrt{\sum_{i=1}^{M} W^*(i)^2}}$$

BER : It is the ratio of the no. of watermarking bits which are having interpreted falsely to the total no watermarking bits

The following figures shows the spectra of original and watermarked guitar audio.



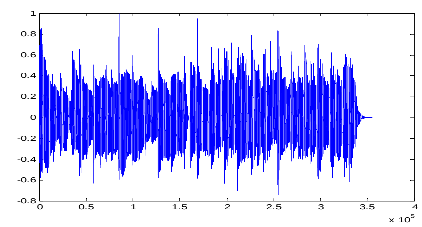


Fig.2 a) Watermarked audio   Fig2. b) Original audio

This sub-section introduces the test results of watermarking algorithm on different type of audio set. From the result we analyze that our algorithm is best for different content categories and attacks like the synchronization & the compression attacks.

Table 1: (%) BER & SNR value of proposed Algorithm

S.No	Audio Name	Type	SNR	BER
1	Bell01.wav	Mono	34.49	0
2	Noise.wav	Mono	28.057	0
3	Beat.wav	Stereo	31.382	0
4	Guitar.wav	Mono	31.420	0
5	Metal.wav	Stereo	33.706 6	0

6	Loop.wav	Stereo	35.592	0
7	Sports.wav	Stereo	32.63	0
8	Female.wav	Stereo	38.689	0.04604
9	Piano.wav	Mono	34.240	0
10	Bird1.wav	Mono	35.604	0.0852

We check the robustness of the watermark aginst some of the attacks

Table 2: %BER and SNR values of after introduced to different attacks

S.no	Attack	Audio 1	
		BER	SNR
1	Amplify	0.11111	33.0076
2	Add Sinus	0.11111	31.7423
3	Add Noise	0.62037	28.0579
4	Smooth	0.361111	31.2408

VI. Conclusion

In this paper, we propose a novel synchronization digital watermarking algorithm based on DWT-SVD. To improve the robustness of audio watermark, the proposed algorithm is constructed by selecting robust Barker code as synchronization code, embedding synchronization code to the mean value of several frames and embedding watermark on the singular value of DWT coefficients. The experimental results have illustrated the robust nature of our synchronization embedding scheme and inaudible nature of our watermarking scheme. In addition, the watermark can be extracted without the help from original audio signal and can be easily implemented. Despite the success of the proposed method, it also has drawbacks. Further research will focus on over-coming the drawbacks.

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