Digital Audio Watermarking Using DWT-SVD and Secret Sharing

Krishna Rao Kakkirala and Srinivasa Rao Chalamala
TCS Innovation Labs, TATA Consultancy Services, Hyderabad, India
Krishna.kakkirala@tcs.com and srini.chalamala@atc.tcs.com

***Abstract*—This paper describes an audio watermarking method where a copyright information is imperceptibly added into the audio signal. The copyright information or watermark could be a binary logo or some unique binary pattern. In this paper we borrowed a cryptographic technique method known as secret sharing method. The secret sharing method along with discrete wavelet transform (DWT) and singular value decomposition (SVD) is used to embed and retrieve the watermark from the audio signal. The advantage using secret sharing in audio watermarking is that it will make the watermark robust to both cryptographic and compression attacks. The simulation results show that the new technique is robust against different attacks such as compression, noise, sampling rate conversion etc.**

***Index Terms*— audio, attack, dwt, svd, secret sharing, watermark, wavelets, singular**

I. Introduction

Now a day's internet is the main sources to transfer digital data form one place to another as a result of this threat such as illegal copying and tampering increasing to counter these threats a copyright protection mechanism is required. One such technique is the digital watermarking. Watermarking is a technique to insert a unique data or random sequence belonging to the owner into the host signal which is audio signal in this case, without degrading the quality of such host signal and not be lost due to watermark removal attacks such are compression, noise, sampling rate conversion etc. and as well as embedded watermark should be in audible. Watermarking techniques mainly comprises of embedding and extraction or detection blocks. Embedding block adds the watermark into the host data while extraction block extracts the watermark from watermarked data.

In this paper we present an effective new non blind audio watermarking algorithm based on combination of three techniques including discrete wavelet transform (DWT), singular value decomposition (SVD) [1] and secret sharing. DWT [2] decomposes the given host audio signal into approximate coefficients and detail coefficients. Further decompositions are done on the approximation coefficients of the previous level. This way discrete wavelet transform is performed repetitively to obtain four level decomposition. Detail coefficients of all the level are used to form the matrix in the specific order and then Singular value decomposition (SVD) is performed on this matrix to obtain eigenvalues also called singular values. These singular values are used along with watermark bit to produce secret shared bits. These secret shared bits are added into four eigenvalues which are obtained using SVD. Finally inverse SVD followed by four level inverses DWT will be performed to produce watermarked audio signal [1]. While extracting we need the original host audio signal as well as watermarked or attacked audio signal. The extraction process is similar to embedding.

This paper is organized into different sections. In II we explain about basics of wavelet transform, singular value decomposition and secret sharing, in the Section III we give detail description about watermark embedding and extraction process, Section IV shows the simulation results proving the strength of our algorithm in terms of robustness against different attacks and followed by conclusion in Section V.

II. Background

In this section we briefly describe about the DWT, SVD and secret sharing techniques in this section.

A. Discrete Wavelet Transform

Wavelet gives the time-frequency representation of the given signal. Wavelets are a set of non-linear bases. These bases are selected based on the function being approximated. Wavelets employ the dynamic set of bases functions in order to represent the given signal in most efficient way unlike static bases families [3]. DWT is very much suitable to identify the frequency regions of the audio signal where watermark can be embedded effectively [3]. DWT on a given signal produces two signals whose length is half the length of the input signal, one of these two signals is called as approximate coefficients and other is called as detail coefficients. The Fig. 1 represents the simple one level wavelet decomposition and reconstruction.

Manuscript received March 15, 2013; revised June 29, 2013

doi: 10.12720/ijsps.1.1.59-62

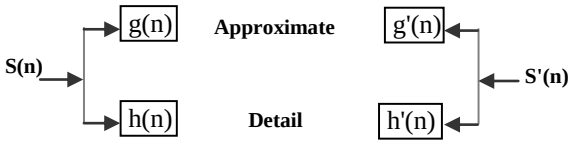

Figure 1. DWT decomposition and reconstruction.

Depending on the application and length of the signal, either low (approximate) frequency or high (detail) frequency coefficients can be further decomposed into multiple levels [6]. In our application we used four levels DWT and approximate frequency are used as input for further levels.

B. Singular Value Decomposition (SVD)

Singular value decomposition is a numerical technique which decomposes the input data into three sub matrices.

$$I = USV^T$$

where I is input signal, *U* is left singular vector matrix, *V* is right singular vector matrix, and *S* is the diagonal matrix whose diagonal elements are singular values of given signal and these are also called as eigenvalues of the given signal. These singular values represents the energy of the signal.

Because of translation, scaling properties of SVD it can be used as a tool to develop watermarking schemes.

C. Secret Sharing

Secret sharing is a cryptography technique, which modifies the binary data from one form to another form.

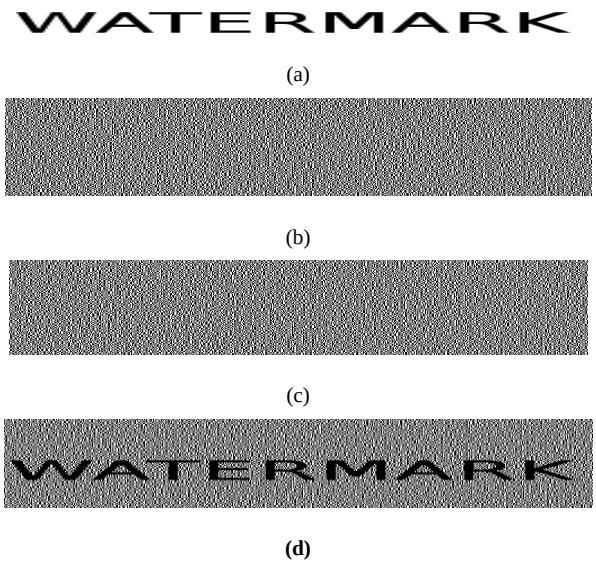

Figure 2. An example of (2,2) share image; (a) input image; (b), (c) share images; (d) retrieved image

In this paper the watermark is changed in to different from which can be embedded into host signal and which shares each bit of watermark information to four bits.

These four bits are embedded into four SVD singular values. Watermark will be extracted by performing exclusive-or operation between share image and complementary share image and then dilation and erosion will be performed.

This paper uses the (2, 2) secret sharing scheme [4], [5] to protect the copyright. This scheme splits the watermark into two different shares. One is called as principle share image and second one is complimentary share image. These two shares must be used while retrieving the original watermark. Below Fig. 2 shows (2, 2) secret scheme. In Fig. 2.d is the retrieved image, which contains information which can be recognized by visually.

III. Watermark Embedding and Extraction

The proposed scheme contains two blocks. One is watermark embedding and another one is watermark extraction.

A. Watermark Embedding

The block diagram of watermark embedding phase is shown in the Fig. 3. During watermark embedding the host audio is fragmented into frames of fixed size, and DWT is performed on each frame up to four levels. Each frame is the input to first level DWT and approximate coefficients of previous level are used to decompose the signal in to next levels. This way the signal is decomposed into four levels. Detail coefficients of each level are collected and a matrix is formed from these[7]. The example matrix is show in Fig. 4.

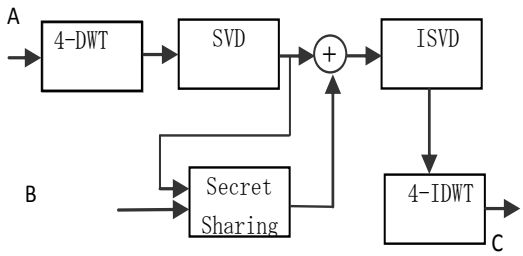

Figure 3. Watermark embedding scheme

A: I/p Audio
B: Watermark Logo
C: Watermarked Audio
Where *CDn* are the detail coefficients of *level n*. The *CDn* are repeated to fit the matrix dimension.

Singular value decomposition will be applied on the matrix formed from detail coefficients. SVD gives the three matrices U*S*V'. We need S matrix which contains four eigenvalues along diagonal direction.

Watermark is a binary pattern uniquely identifying the user will be secret shared into another image called share image. This share image is formed using input watermark, four eigenvalues obtained from input audio frame and Table I [5]. Four bits from share image will be added into four eigenvalues with some scaling factor. After adding the shared bits inverse operations (Inverse SVD, IDWT) will be performed to form watermarked audio frame. Finally all the frames are concatenated to from watermarked audio. The process is repeated till all the watermark bits will be added.

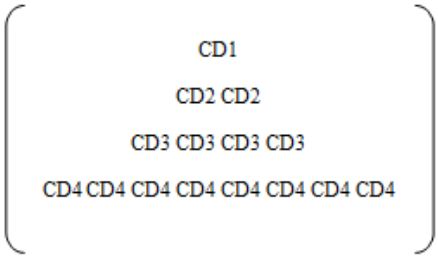

Figure 4. Matrix formed from detail coefficient

To extract the watermark we need original audio and watermarked audio. First synchronize the two audios and then perform the framing of audios. Repeat the same process as embedding on both original audio and watermarked audio till SVD and then subtract the original and watermarked eigenvalues which results in a four extracted share bits. Four eigenvalues of watermarked audio frame and its mean value and table-1 are used to extract the complementary share block. We perform exclusive-or between complementary share block and extracted share block to result in a four bit block. The watermark bit is extracted by majority voting among these four bits. The block diagram of extraction process is given in Fig. 5.

The explanation for the symbols on block diagram of Fig. 5 is given below.

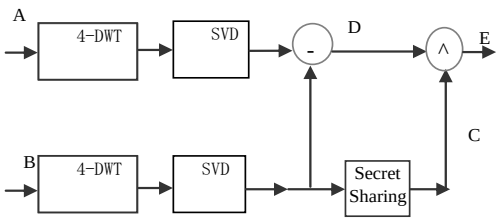

Figure 5. Watermark extraction

A: Input audio
B: Watermarked or attacked audio
C: Complementary Share Image
D: Extracted share block
E: Extracted watermark.
^ : Exclusive-OR
The detail algorithm is given below.

1) Share block generation

Input audio frame is transformed into 4-Level DWT domain and then SVD applied on formed matrix from detail coefficients of four level DWT. This SVD results in four singular values (eigenvalues).

- Call the four singular values as a, b, c and d.
- Find the average (M) of four singular values.
- Convert the binary watermark into 1D array, if it is logo (2D).
- Share block will be generated using watermark bit and four singular values and average and table 1.

2) Embedding

- Embed the share block of four bits to four singular values.

$$a' = a + \beta * ss(1);$$
$$b' = b + \beta * ss(2)$$
$$c' = c + \beta * ss(3)$$
$$d' = d + \beta * ss(4);$$

where β scaling factor.

- Find the inverse SVD on modified singular values and then 4 level DWT to get watermarked audio.

where *ss*(1), *ss*(2), *ss*(3), and *ss*(4) are share bits generated using *a*, *b*, *c*, and *d*, watermark bit and table 1.

3) Extraction

- Perform the 4-Level DWT and SVD on both original audio and watermarked/attacked audio and a, b, c, d and a1, b1, c1, and d1 are singular values of original and watermarked audio respectively.
- Subtract watermarked eigenvalues from original audio to get extracted share block.
- Get the complementary share block using watermarked eigenvalues and its mean and table 1.
- Finally perform exclusive-or as shown in table 2 between extracted share block and complementary share block to get resultant block.
- Extract the watermarked bit either 0 or 1 depending on majority bits of resultant block.

Rearrange the extracted bits into 2D array to get watermark.

TABLE I. EXCLUSIVE-OR Rule

S.NO	Bit 1	Bit 2	Result
1	□	□	■
2	□	■	□
3	■	□	□
4	■	■	■

IV. RESULTS

In this section, we presented some experimental results for the proposed algorithm. We used ffmpeg tool [8] to simulate different attacks and measured the accuracy of the proposed algorithm using accuracy rate.

$$AR = (CP)/ (NP)$$

where CP is the correct bits that are extracted from attacked audio and NP is the total number of bits in the watermark. In this paper we used an audio with sampling rate of 48000 and frame length of 12000 samples and used the watermark with 300 bits and watermark binary logo is shown in the Fig. 6.

Figure 6. Input watermark

The following Table II depicts the accuracy rates and extracted watermark against different attacks. We tested this algorithm on different audios with different sampling rates. We have chosen the scaling factor value is 0.04. We can increase the scaling factor further to improve accuracy at the cost of audibility of watermark.

TABLE II. ACCURACY RATES

S. No	Attack	Accuracy Rate(%)	Extracted Watermark
1	No attack	100	TS
2	Decreasing sampling rate (44100)	100	TS
3	Increasing sampling rate (96000)	100	TS
4	AAC (84kbps)	76	
5	OGG (164kbps)	99.33	TS
6	Random noise with sigma (5 variance)	100	TS

V. CONCLUSION

The proposed algorithm uses DWT and SVD along with secret sharing method to watermark a given audio signal. We proved by simulation results that this algorithm is robust against different compression and sampling rate conversions. We can increase the robustness by increasing scaling factor at the cost of audibility of watermark. We can also improve the accuracy rates by using scrambling techniques and error correcting codes.

REFERENCES

[1] "Skiathos," Reprinted in *Mathematics and Simulation with Biological, Economical and Musicoacoustical Applications*, Greece: WSES Press, 2001, pp. 318-323.

[2] G. Tzanetakis, G. Essl, and P. R. Cook, "Audio analysis using the discrete wavelet transform," In *Proc. WSES Int. Conf. Acoustics and Music: Theory and Applications*.

[3] M. Ali. An introduction to wavelets and haar transform. Available: http://www.cs.ucf.edu/~mali/haar/

[4] S. H. Wu and H. F. Lin, "A non-embedded watermarking scheme for non-distortion digital product copyright verification," Master Thesis, Feng Chia University, Aug. 2004.

[5] S. L. Hsieh, J. J. Jian, I. J. Tsai, and B. Y. Huang, "A color image watermarking scheme based on secret sharing and wavelet transform," *SMC*, 2143-2148, 2007.

[6] J. S. Cho, S. W. Shin, W. H. Lee, J. W. Kim, and J. U. Choi, "Enhancement of robustness of image watermarks image watermark into colored image, based on Wt and Dct," in *Proc. International Conference on Information Technology Coding and Computing*, March 2000, pp. 483 – 488.

[7] A. H. Ali, C. Twal, and A. A. Mohammad, "Hybrid DWT-SVD audio watermarking," *ICDIM* 2010, pp. 525-529.

[8] http://ffmpeg.org/

Krishna Rao Kakkirala finished his B.Tech in Electronics and Communication Engineering from JNTU and perceived his Master Degree in Communication Systems from PSG Tech, Coimbatore. He joined in TCS,2008. Currently he is working as a Reseacher -R&D at TCS Innovation Labs, Hyderabad and working on digital video watermarking. His research interests include signal processing, image processing and pattern recognition.

Srinivasa Rao Chalamala finished his B.E. and M.Tech from Andhra university and IIT Kharagpur respectively both in Electronics and Communication Engg. He published few international conference papers during his tenure at IIT Kharagpur. He joined TCS CoE embedded systems Kolkata in 2004. Currently he is working as a Scientist R&D at TCS Innovation Labs Hyderabad. His research interests include signal processing, pattern recognition and machine learning. Currently he is working towards his Ph.D from IIIT Hyderabad.