DWT- SVD Digital Watermarking Technique for the Protection of Audio Signal

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Abstract

Security of data is essential today because of cyber-crime, which has highly increased these days. The present study proposes a new algorithm using features of Human Auditory System and the signal processing theories. The aim of study is to develop a new audio watermarking algorithm, which computationally efficient, imperceptible robust and have higher capacity with this background. A blind imperceptible algorithm with robust audio watermarking is proposed cascading two well-known techniques, the discrete wavelet transform and the singular value decomposition. Discrete Wavelet Transform decompose the audio signal into the subbands. Singular value decomposition is a powerful technique for matrix computation and analysis. Experimental results of our algorithm has strong robustness for audio signals processing operations.

keywords—Audio watermarking, discrete wavelet transform (DWT), singular value decomposition (SVD)

1. Introduction

Information generation and transmission is essential of life. With the development of Internet technology and digital multimedia technology, large amounts of digital content that is being generated, stored, distributed, and consumed [1]. The digital multimedia technologies have brought two main problems, namely the digital multimedia security and intellectual property right [2]. There are various techniques are available for secure information like as cryptography, steganography and watermarking [3]. **Digital watermarking is the process that embeds copyright information as 'watermark' into the multimedia object, so that the watermark can be extracted later to make an assertion about the ownership [4**][5][6][7] .

The general watermarking scheme is shown the figure 1 and 2.

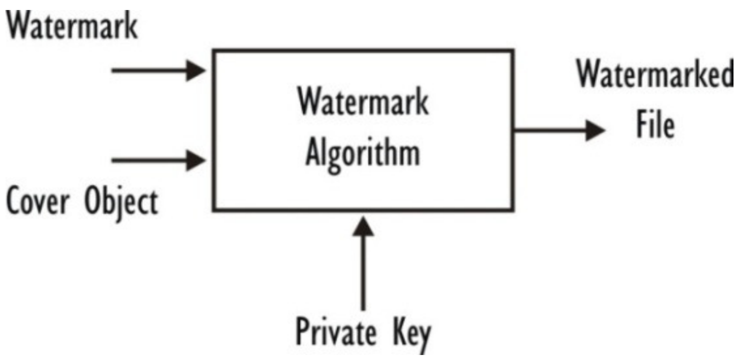
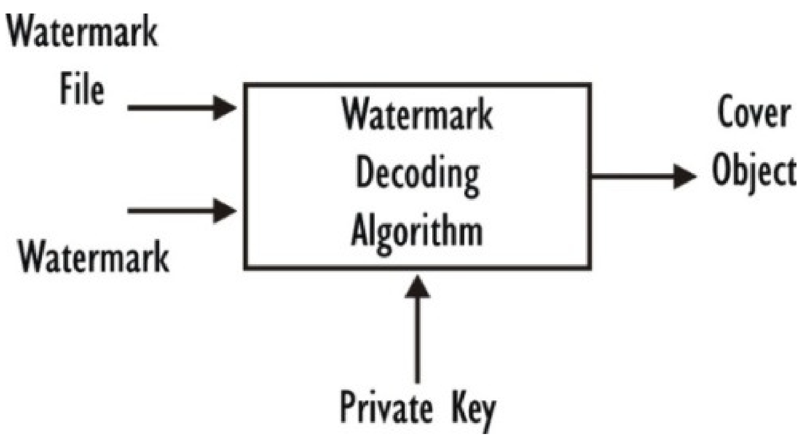


Figure 1: Watermark embedding process

Figure 2: Watermark extraction process



2. Classification of Digital Watermarking

In this section the digital watermark are classified according to the features, their techniques and application and segmented into various categories .

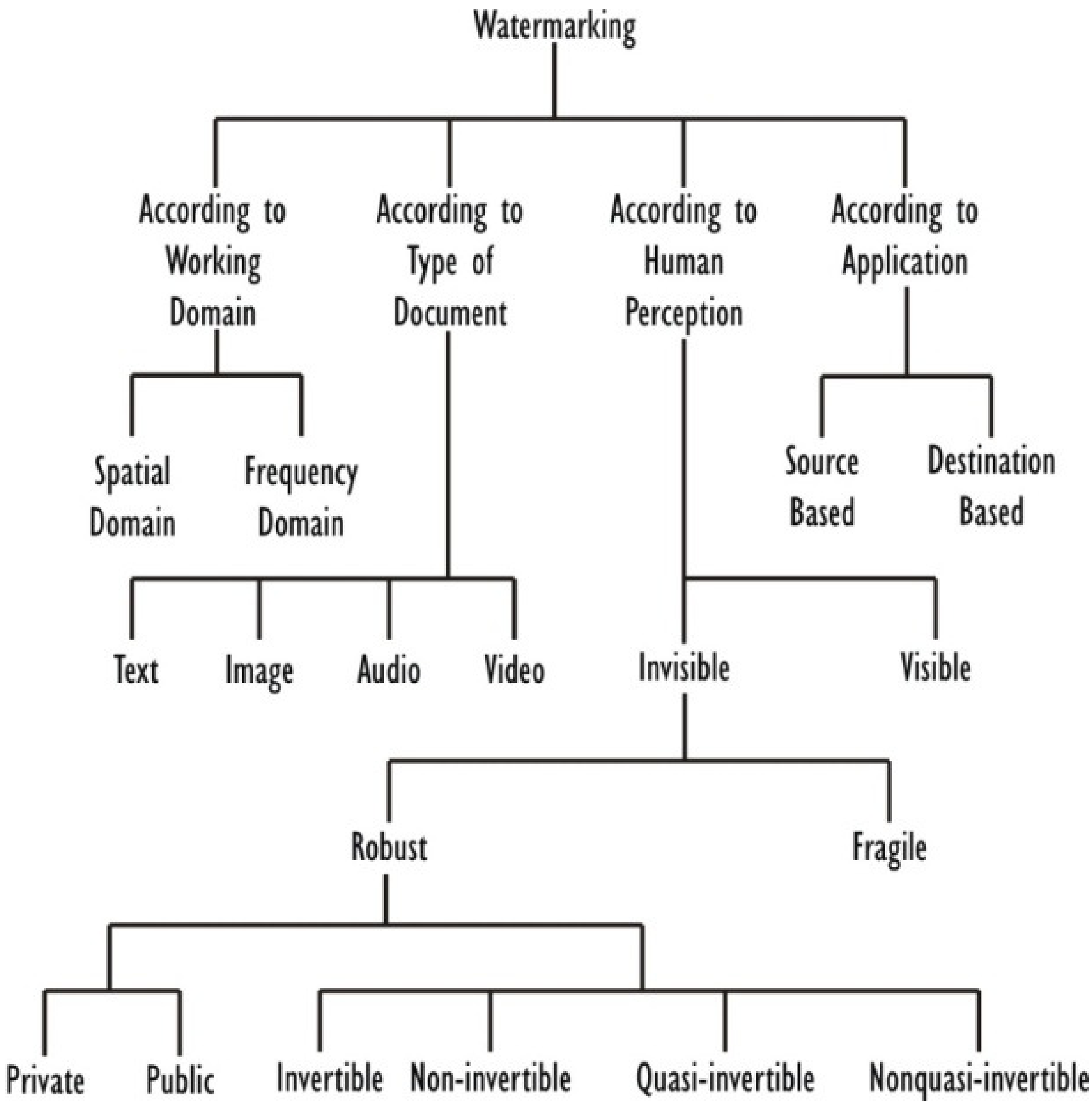


Figure 3: Types of digital Watermarking.

3. Digital Audio Watermarking Applications

Copyright protection : In the copyright protection applications, a watermark containing copyright information is embedded to the multimedia original signal.

Proof of ownership : It is even more demanding to use watermarks not only in the identification of the copyright ownership, but as an actual **proof of ownership**.

Device control: Device control is a technique in which device can be control by identifying the watermark from the host signal.

Authentication and tampering detection : In content authentication applications, a set of secondary data is embedded in the host multimedia signal and is later used to determine whether the host signal was tampered.

Copy control and access control: Copyright protection is the most important application of watermarking. The objective is to embed information identifies the copyright owner of the digital media, in order to prevent other parties from claiming the copyright.

Fingerprinting: The objective of this application is to convey information about the legal recipient rather than the source of digital media, in order to identify single distributed copies of digital work.

Broadcast monitoring: Producers of advertisements or audio and video works want to make sure that their works are broadcasted on the time they purchase from broadcasters.

Information carrier: The embedded watermark in this application is expected to have a high capacity and to be detected and decoded using a blind detection algorithm.

4. Audio Watermarking Techniques

Digital watermarking techniques for audio, based on their embedding domain can be classified as Time Domain Audio Technique and Transform Domain Audio Technique.

Time domain audio watermarking: In time domain technique, watermark is embedded without any transformation & watermark can be easily destroyed. It is very easy to implement & requires less computation as compared to frequency domain techniques. Various time domain embedding techniques for digital audio signal such as Least Significant Bit (LSB) replacement, Echo hiding, phase coding and Spread Spectrum methods have been proposed. These techniques show poor robustness against common signal processing operations like resampling, Low pass filtering, re-quantization, compression, etc.

Transform (frequency) domain audio watermarking: Majority of the signals in practice are represented in time domain. However, the time domain analysis of the signal cannot give complete information of the signal since it cannot provide the different frequencies available in the signal. Watermark is embedded in frequency domain of a signal using Discrete Cosine Transform, Discrete Fourier Transform, and Discrete Wavelet Transform. Watermarking system enables to embed the watermark into significant part of a signal which gives high robustness against general signal processing operations when algorithm transfer audio signal from time domain to frequency domain In this study we are using DWT and SVD domain.

Discrete wavelet transform: The basic idea of discrete wavelet transform (DWT) in audio process is to multi-differentiated decompose the audio into sub- audio of different spatial domain and independent frequency district [8]–[18]. Then transform the coefficient of sub- audio. After the original audio has been DWT transformed, signal is decomposed into 4 frequency districts which is one low-frequency district(LL) and three high-frequency districts (LH,HL,HH). An original audio can be decomposed of frequency districts of HL1, LH1, HH1. The low-frequency district information also can be decomposed into sub-level frequency district information of LL2, HL2, LH2 and HH2. By doing this the original audio can be decomposed for n level wavelet transformation.

Singular value decomposition: The singular value decomposition, or SVD, [16][19] is very powerful and useful matrix decomposition, particularly in the context of data analysis, dimension reducing transformations of images and satellite data etc, It is the method of choice for solving most linear least–squares problems.

5. Watermarking algorithms based on DWT-SVD domain

Our proposed algorithm adopts combination of two powerful transforms, namely, DWT, which is a novel discipline capable of giving a time frequency representation of any given signal, and SVD, which is a numerical technique applied after DWT. We providing two techniques that belong to watermark embedding and extraction respectively, as follows:

Watermark embedding technique

- Input the original audio signal using a track of sampling frequency samples per second.

[data,Fs,nbits]=wavread(audio_input);

Fs : returns the sample rate (FS) in Hertz

nbits : the number of bits per sample (NBITS) used to encode the data in the file.

- Input the watermark image which to be embedded in the input signal.

If the image is colored then convert it into the grey scale image.

wm1 = double(im2bw(rgb2gray(imread(wm1))));

- Perform the DWT transformation on each frame using **Haar wavelet** and decompose original audio signal into four sub-bands.

[ca1 ch1 cv1 cd1] = dwt(audio_input, 'haar');

Four multi-resolution sub-bands ca1, ch1, cv1, cd1 are produced. Where ca1 are lower frequency band (approximation sub band) and ch1, cv1 and cd1 are higher frequency band (detail sub-band).

The DWT Transformation is applied upto 4^{th} level of decomposition on the lower frequency subband of each level.

- Apply SVD to HH (high frequency) band cd4

[Uh Sh Vh] = svd(cd4,'econ');

Consequently, three orthonomal matrices Uh Sh Vh are generated as follows:

$U*S*V^T$

Here S will be a 4x4 diagonal matrix as follows:

$$S = \begin{bmatrix} S11 & 0 & 0 & 0 \\ 0 & S22 & 0 & 0 \\ 0 & 0 & S33 & 0 \\ 0 & 0 & 0 & S44 \end{bmatrix}$$

- Apply the SVD on the Watermark image

[Uw Sw Vw] = svd(watermark_image, 'econ')

- Replace singular values of the HH (high frequency) band of the audio signal with the singular values of the watermark image.
- A binary image is used as watermark. It contain more meaningful information about the copyright owner, in addition to the fact that an image could still identified if some of its bits goes missing during extraction.
- The watermark image used is binary image represented by matrix of size (Z1 *Z2)
- By Generating the signature of the watermark the Binary-image is converted into one dimensional vector V where its length is Z1 × Z2@ (image size) such that:

Vi = [0 1] 1<= i <= (Z1 * Z2)

- Embed the bits of converted binary-image into the DWT-SVD-transformed audio signal using the following function :

$S_{11\ w} = S_{11} + alpha * V(x)$

where S_{11w} is the watermarked signal S_{11} is a input signal , alpha is the watermark intensity, and V (x) is the watermark bit which accepts only the values of 0 and 1.

- Apply the inverse SVD and DWT to obtain the watermarked audio signal.

The watermark embedding process is shown in the figure 4 block diagram.

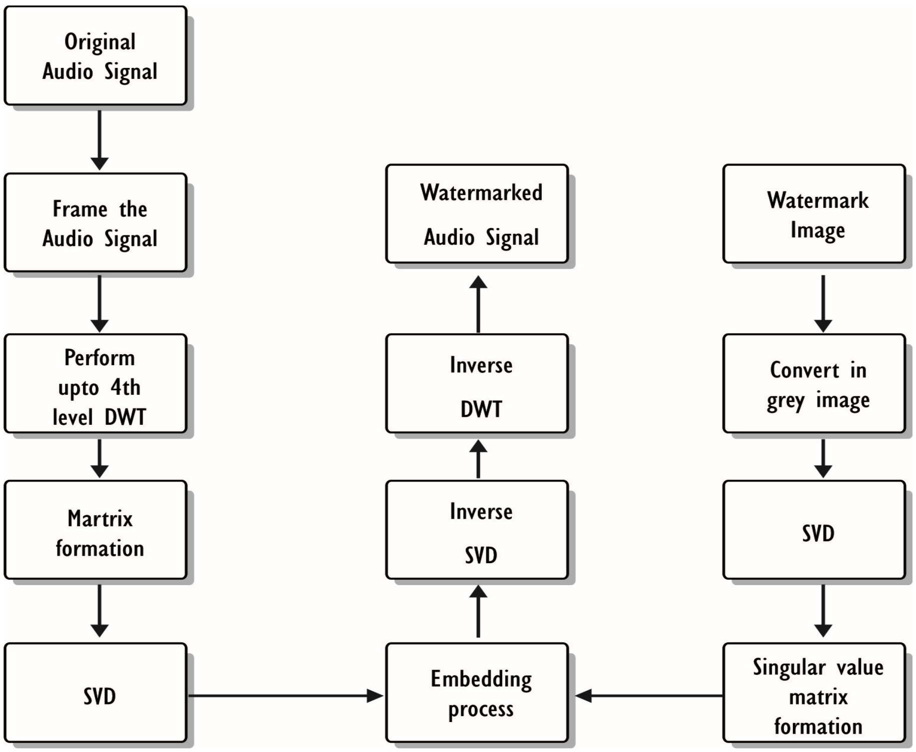


Figure 4: Watermark embedding process

Watermark extraction technique

In watermark extraction technique and in order to obtain our binary-image, we need to have the watermarked audio signal and singular values for each frame of the original audio signal.

The main operations of this approach can be summarized as follows:

- The watermarked audio signal is used with the same sampling frequency used in the embedding.
- Perform upto four level DWT transformation.
- Apply singular value decomposition (SVD).

$A= U * S* V^T$

- Extracting singular values from each sub-band.

$V(x)= (S_{11w} - s_{11})/alpha$

- Construct the original binary-image by re-forming the extracted bits.

The watermark extraction process is shown in the following block diagram figure 5.

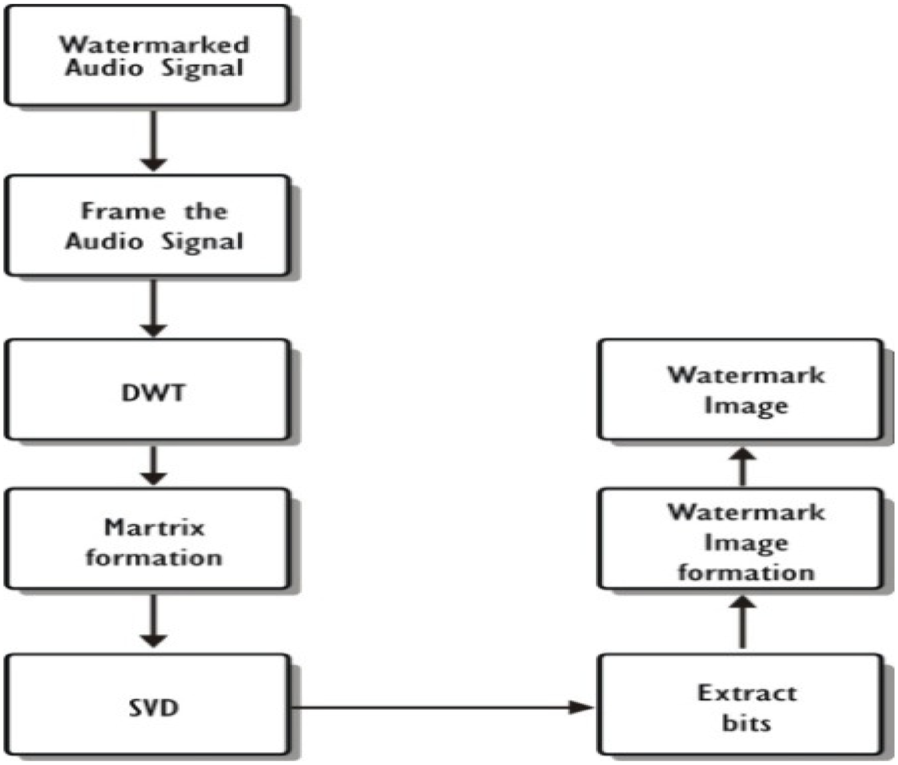


Figure 5: Watermark extraction process

6. Experimental result

In this experiment, we have the audio file Audio Clip1.WAV as s input signal and Copyright.BMP as watermark image. The WAV file has a frequency of 44.1 KHz , the 16 bit per second sample. The total duration of audio file is 20 sec. The total smaple in the audio file is 2205000.

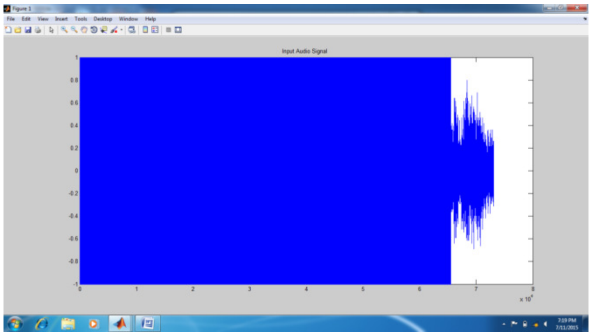


Figure 6: Input audio Clip

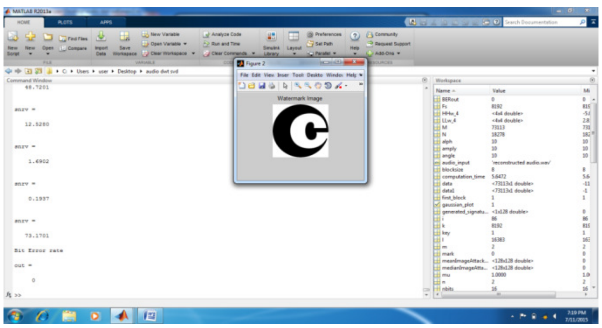


Figure 7: Watermark image

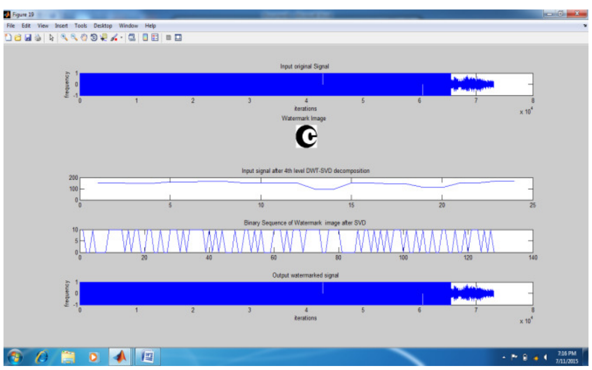


Figure 7 : Input signal (Audio Clip1.WAV), watermark image (Copyright.BMP), input signal after DWT-SVD decomposition, binary sequence of the image after SVD, watermarked signal

Table 1: Watermark intensity, execution time and SNR, PSNR for Audio clip

Watermark Intensity	Execution Time	PSNR (dB)	SNR (dB)
Alpha = 10	4.2932	72.5689	49.3468
Alpha = 5	4.2882	76.9865	52.3508
Alpha = 1	3.9843	82.4567	56.0706
Alpha =.05	3.9562	82.7896	56.2969
Alpha = 0.025	4.1256	83.0399	56.4671

7. Discussion

The perceptual transparency of the watermarked signal is calculated by signal-to-noirse ratio (SNR) and Peak signal to noise ratio (PSNR) . SNR is a statistical difference metric which is used to measure the perceptual similarity between the undistorted original and the distorted watermarked audio signal. The following signal-to-noise radio (SNR) equation is used:

$$SNR = 10.\log_{10}\left\{\frac{\Sigma_{n=0}^{N-1} x^2(n)}{\Sigma_{n=0}^{N-1}[x(n)-\tilde{x}(n)]^2}\right\}$$

where x(n) and x˜(n) are original audio signal and watermarked audio signal respectively. The Peak signal noise ratio is calculated by the following formula:

PSNR = 20log10 $((255)^2/\sqrt{MSE})$ where MSE is mean square error.

In our experiment we get SNR value 56.4671. Which shows the higher perceptual transparency.

7. Conclusion

The proposed algorithm possesses the advantages of both the DWT and SVD methods simultaneously. Discrete Wavelet Transform decompose the audio signal into the subbands. Singular value decomposition is a powerful technique for matrix computation and analysis. In our proposed method, SNR and PSNR value of watermark signal is reported to be higher as compared to other proposed method which are based on the different techniques like LSB, Echo addition, Phase coding, DCT, DWT, DFT etc. The results obtained in the present study are highly promising and assuredly outperform those obtained from appurtenant former works. The further simulation results obtained are also in total agreement with the requirements set by International Federation of the Phonographic Industry (IFPI) for audio watermarking.

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