SPEECH WATERMARKING USING DISCRETE WAVELET TRANSFORM, DISCRETE COSINE TRANSFORM AND SINGULAR VALUE DECOMPOSITION

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Abstract: The main goal of this paper is to embed a watermark in the speech signal, using the three techniques such as Discrete Cosine Transform (DCT) along with Singular Value Decomposition (SVD) and Discrete Wavelet Transform (DWT).In this paper, various combinations were tried for embedding the watermark image into the audio signal such as DWT and SVD, DCT with SVD and DCT, DWT with SVD. Their performance was evaluated based on Signal to Noise Ratio (SNR) and Bit Error Rate (BER). From the results it can be seen that the combination of DCT with DWT and SVD method provides better result.

Keywords: Speech Watermarking, Discrete Cosine Transform, Singular Value Decomposition, Discrete Wavelet Transform, Signal to Noise Ratio, Bit Error Rate

I. INTRODUCTION

Nowadays digital watermarking has received attention for protecting the multimedia data, and it is a process of embedding watermark data into the audio signal. Due to the development and growth in internet and digital multimedia technologies, illegal copying, modifying and altering the multimedia contents have become very important issues. Hence there, is a need for protecting the data, and so many authors have invented many techniques in both image and video to overcome these problems, where these techniques can also be applied to audio watermarking. The audio watermarking is not easy to develop because of the sensitivity of the human auditory system and it can be classified into two types namely time domain and frequency domain algorithms. The time domain algorithm is used to insert the watermark directly into the audio signal, and the frequency domain algorithms are used to insert the watermark based on modifying the frequency coefficients. When compared to frequency domain, time domain algorithms are easy to implement and require less computational cost, but it is less robust to some audio signal-processing attacks. The frequency domain watermarking are more complex and high robustness against various attacks. The commonly used and popular watermarking algorithms are DFT, DCT and DWT [2]. Transforming audio signal from time domain to frequency domain helps to embed the watermark into perceptually significant part of a signal with a high robustness.

Generally, the watermarking is divided into visible and invisible watermarking. The example of visible watermarking includes the different logo that can be placed over the still picture or a moving picture. In the invisible watermarking, the embedded image cannot be perceived with human eyes. Depending upon the requirement, the watermarking schemes can also be classified as blind, semi-blind and non-blind [1]. Blind scheme requires only the secret key(s), semi-blind scheme requires secret key(s) and the watermarking bits and non-blind scheme require both the original signal and the secret key(s) for watermark embedding[1].The applications of audio watermarking include the copyright and copy protection authentication, fingerprinting and broadcast monitoring, data augmentation and source tracking. An effective audio watermarking should have the basic requirements such as Imperceptibility, Security, Robustness and Payload.

The paper is organized as follows. In section 2 the related Work are analyzed. Section3 analyzes DWT, DCT and SVD techniques. Section 4 simplifies the experimental results and discussion. Finally, the conclusion is summarized in Section 5.

II. RELATED WORKS

Bhat et al. [3] proposed an adaptive audio watermarking algorithm, where the watermarking information is embedded in the DWT domain based on SVD. The results were imperceptible and robust to many attacks, but its capacity is not very high. Bai Ying [4] presented an audio watermarking algorithm based on SVD-DCT. It uses SVD to modify the transformed coefficients. The watermarking information is embedded by modifying the DCT coefficients of the blocks, which is composed of SVs, obtained by performing SVD transform on audio blocks. The result shows that this method has a good performance at imperceptibility and robustness.

The authors N.V.Lalitha et al. [5] has proposed an improved audio watermarking, using DWT and SVD. The authors have compared two different algorithms such as Discrete Cosine Transform (DCT)-Singular Value Decomposition (SVD) and Discrete Wavelet Transform (DWT)-SVD. They state that the DWT-SVD technique is robust for most of the attacks rather than the DCT-SVD. By combining the two transforms DWT-DCT along with SVD, inaudibility and different levels of robustness can also be achieved. Jyotirmayee Mishra et al. [1] proposed an efficient audio watermarking for copyright protection based on DWT and SVD techniques. The scheme was subjected to a series of imperceptibility (audio fidelity) and robustness tests. Satyanarayana

Murty. P et al. [6] proposed a semi-blind watermarking scheme using Discrete Wavelet Transform, Discrete Cosine Transform and Singular Value Decomposition for copyright protection. A DCT is applied to the HF band of DWT decomposition reference image. Then they hide the watermark into reference image by modifying the singular values of transformed DCT coefficients with the singular values of watermark. The proposed algorithm was robust against motion blur and sharpening attacks.

The author Huan Zhaoet al [7] proposed a novel blind audio watermarking algorithm, which combined Singular Value Decomposition (SVD) with Discrete Wavelet Transform (DWT). It performs DWT on maximum singular values obtained from SVD of host audio. The proposed method has good imperceptibility and is robust to common audio attacks including add-noise, low-pass filtering, re-sampling, requantization, cropping and Mp3 compression. Emir Ganic and Ahmet M. Eskicioglu have proposed a hybrid scheme based on DWT and Singular Value Decomposition (SVD). They decompose the cover image into four bands; the SVD is applied to each band and embed the same watermark data by modifying the singular values. Modification in all frequencies allows the development of a watermarking scheme that is robust to a wide range of attacks.

III. DCT, DWT and SVD TECHNIQUES

Robustness, capacity and imperceptibility are the three important requirements of an efficient watermarking scheme. The DCT and DWT techniques have been widely used in many digital signal processing applications. The SVD is explored for image watermarking applications and it is a useful tool of linear algebra. The brief introduction of these three techniques is presented in this section.

A. Singular Value Decomposition

The watermarked audio signal based on Singular Value Decomposition is robust for

transposed, rotation, scaling and general geometric distortion. If A is a $m\times n$ real matrix with $m > n$, then A can be written as [10]:

$$U^T AV = S \quad (1)$$

$$USV^T = A \quad (2)$$

where U is a $m\times m$ matrix, A is a $m\times n$ matrix, and V is a $n\times n$ matrix. U and V are orthogonal matrices , which are the field of real numbers. The SVD of the N×N matrix I [9] can be depicted as follows:

$$I = USV^T = [u_1, u_2, \ldots., u_N]\begin{bmatrix} \lambda_1 & & \\ & \ddots & \\ & & \lambda_N \end{bmatrix}\begin{bmatrix} v_1 \\ \cdot \\ \cdot \\ \cdot \\ v_N \end{bmatrix} \quad (3)$$

where I denotes the input signal, U stands for left singular vector matrix, V is for right singular vector matrix, and S denotes the diagonal matrix. Here the elements are the singular values of given signal called as Eigen values which represent the energy of the signal. Where $U \in R^{N\times N}$ and $V \in R^{N\times N}$ are unitary matrixes, $S \in R^{N\times N}$ is a diagonal matrix and the superscript T denotes matrix transposition [9]. The diagonal elements of S are called the SV_s of I and assumed to be arranged in decreasing order, that is $\lambda_1 > \lambda_N$. The columns of the U and V matrix are called the left singular vectors and the right singular vectors of I [9].

B. Discrete Cosine Transform

DCT is used to convert time domain signal into frequency domain signal which is similar to Discrete Fourier Transform (DFT) which is used mainly in signal processing. DCTs are equivalent to DFTs of roughly twice the length, operating on real data with even symmetry. It can be used in many fields such as data compression, pattern recognition and image processing. Here, the 1-D sequence of length N for the DCT definition can be given by [5]

$$c(u) = \alpha(u) \sum_{x=0}^{N-1} f(x) \cos\left[\frac{\pi(2x+1)u}{2N}\right] \quad (4)$$

for u=0, 1, 2, .N-1. The inverse transform can be given as [5].

C. Discrete Wavelet Transform

DWT was developed mainly to overcome the shortcoming of the Short Time Fourier Transform, and can also be used to analyze non-stationary signals. It is a useful tool for processing digital signal processing and can be used widely in computer science and engineering. The DWT of signal can be defined as follows:

$$W(J,K) = \sum_{J} \sum_{K} X(k)\, 2^{-J/2}\, \varphi(2^{-J} N \; - K) \quad (5)$$

where Ψ (t) is the basic analyzing function called as mother wavelet. The successive high pass and low pass filtering of the signal is characterized using the equation given below:

$$Y_{high}[k] = \sum_{n} x[n]g[2k-n] \quad (6)$$

$$Y_{low}[k] = \sum_{n} x[n]h[2k-n] \quad (7)$$

The audio signals can be divided into low frequency and high frequency. The low frequency component concentrates most of the energy of audio signal, which is the main part of the original audio signal, and it changes slowly. The high-frequency signals change rapidly but reduce the computation time and resources required.

This paper clubs the properties of SVD, DCT and DWT by utilizing the wavelet coefficients of the cover signal to embed the watermark. The DCT coefficients of the wavelet coefficients are calculated, and singular values are decomposed. The singular values of the cover signal and watermark are added to form the modified singular values of the watermarked image. Then, the inverse transform is applied followed by the inverse DWT.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

All the experiments in this were performed using MATLAB 7.1 on different speech signals which are stored as 8 bit mono wave file. The S1, S2, S3 and S4 are the randomly selected signals and c1 and c2 are the watermark data which is shown in Figure 5. The Figures 3and 4 represent the performance of the techniques in a graphical form. In this paper the results were evaluated using Signal to Noise Ratio (SNR) and Bit Error Rate and their formulas are given in equation 9 and 10.

A. Signal to Noise Ratio (SNR)

$$S\,NR = 10\, Log_{10} \quad \frac{\sum_{n-1}^{L} x^2\,(n)}{\sum_{n-1}^{L} [x(n) - x^{*}\;\,(n)]} \quad (8)$$

where x (n) is the original signal and x*(n) is the watermarked audio signal.

B. Bit Error Rate (BER)

$$BER = \frac{E}{n_1 \times n_2} \times 100\%$$

(9)

The BER is used to measure the reliability of the extracted watermark, where E is the number of erroneously detected bits and n_1 x n_2 is the original watermark image size.

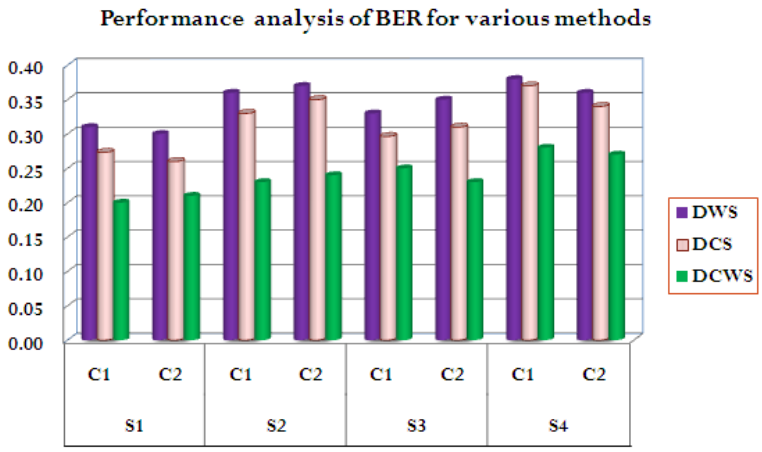

Fig 3: Performance analysis of BER

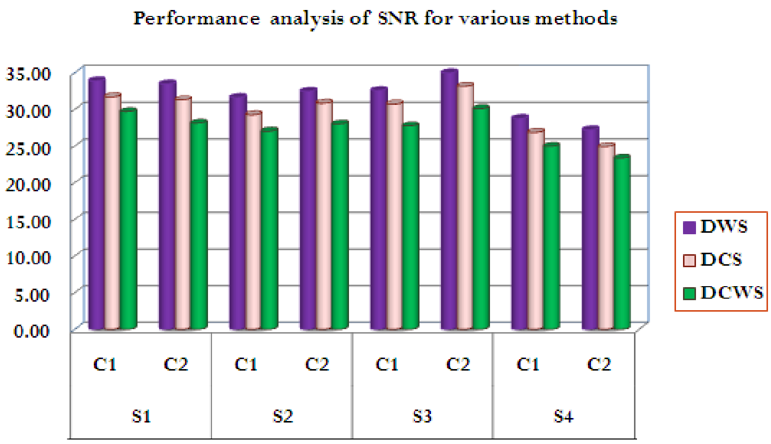

Fig 4: Performance analysis of SNR

DWT + SVD = DWS   DCT + SVD = DCS

DCT+ DWT+ SVD = DCWS

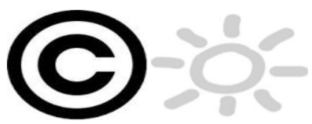

Fig 5: Watermark Data C1 and C2

Figures 3 and 4 show the result of the combined methods such as DWS, DCS and DCWS. The DWS is the combination of DWT and SVD, and the DCS is the combination of DCT with SVD. The DCWS is the combination of DCT, DWT with SVD. From the result it can be that the combination of all three methods named as DCWS provide better result.

V. CONCLUSION

In order to provide protection to the speech signal, the speech watermarking is made using the methods such as SVD, DCT and DWT. In this paper, various combinations were tried using the DWT and SVD, with DCT and SVD, and also with DCT, DWT and SVD which is named as DCWS. The experimental results show that the DCWS performs better than the other two combinations. In future, these methods can be enhanced, in order to provide a security to the speech signal without any degradation

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