INTERPOLATION BASED ROBUST AUDIO WATERMARKING USING DWT AND SVD TRANSFORMATION

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Abstract— **Digital Watermarking is a process to hide digital watermark (copyright information) in digital content with a purpose to enable copyright protection and illegal distribution. Digital audio watermarking deals with embedding digital data in an imperceptible manner in the host audio signal. Audio watermarking involves much more complex techniques to embed a watermark in view of the superiority of Human Auditory System (HAS) over Human Visual System (HVS). Transform domain watermarking embeds the watermark in the frequency domain, thereby providing a much more robust and invisible watermarking scheme as compared to temporal domain, which is comparatively fragile. It turns out that digital watermark embedding in audio signals in any domain results in audible disturbances in the original audio signal. Thus, frequency domain watermarking has to be augmented with suitable techniques so as to implement robust and imperceptible watermarking which is the requirement in most of the applications. The Proposed watermarking algorithm embeds a watermark in the Singular values of the S matrix obtained after the decomposition of the original audio signal using SVD Transformation. Also, the watermark is embedding in the real values of the S matrix using an agreed upon policy for interpolation of the values, and the interpolation key has to be known to both the parties for watermark detection and extraction. It is for this reason that the proposed algorithm is able to achieve a high PSNR metric as compared to the other algorithms that use DWT and SVD based watermarking approaches. Peak Signal to Noise Ratio (PSNR) is evaluated as a function of embedding capacity and robustness. The proposed method provides an optimized way to embed a watermark using interpolation based on SVD technique. MATLAB is used to simulate the technique and results are derived. MSE, PSNR are used as a quality metric for evaluation of the results.**

Index Terms- **Digital Audio Watermarking, Singular value decomposition, Discrete Wavelet Transform, Copyright protection.**

I INTRODUCTION

1.1 Introduction

Watermarking Digital content is the need of modern digital data processing and transmission. This is because it provides the basis of Intellectual Property Rights (IPR), without which millions of unauthorized copies of digital content can be created. Watermark refers to specific information that can be added in a content to later provide a proof of ownership of the document. In the case of digital watermarking, both the watermark and the host are digital data, generally termed as watermark signal and host signal in the watermarking terminology. Watermarking algorithms were primarily developed for digital images and video data and research in the field of audio watermarking started comparatively later. A simple illustration of the basic theory of watermarking is shown in figure 1.1.

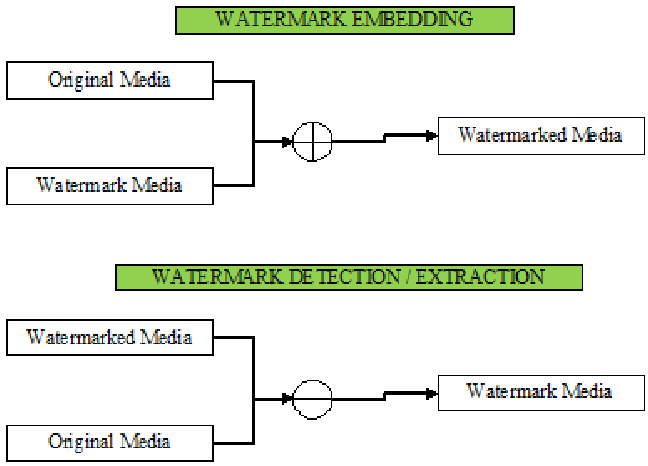

Fig 1.1 Basic Watermarking Illustration

The scenario depicted above is termed as Non-Blind watermarking technique. The case when the original media is not required at the detection time for extraction of the watermark data is termed as Blind watermark technique and it is implemented in this paper.

With the growth of the Internet, illegal distribution and unauthorized copying of digital media have been easier to the extent such that this can be done even with the cheapest commodity computer [1]. As a result, the music industry and audio related communication channels claim a multibillion dollar annual revenue loss due to piracy [2], which is likely to increase due to peer-to-peer file sharing Web communities. One source of hope for copyrighted content distribution and management of unauthorized copying on the Internet lies in technological advances that would provide ways of enforcing copyright in client-server scenarios. Traditional data protection methods such as encryption or scrambling cannot be used since the content must be played back in the original form, at which point, it can always be rerecorded and then freely distributed. A suitable solution to this problem is marking the media signal with a secret, robust, and imperceptible watermark (WM) [3]. The media player at the client side can detect the mark present in media and consequently implements a corresponding e-commerce policy.

Digital Watermark is defined as a digital pattern or signal which is put into a digital data that is referred to as copyright information. Watermarking is a prime method of the protection of copyright possession of electronic data, together with videos, image, audio, etc. The term watermarking arrives with the use of invisible ink to inscribe secret messages. A general requrement for the watermarking process is robustness. Besides that the presence of a watermark is identified, it should be preferably impossible for an attacker to destroy or remove the cover object impracticable. Usually, the watermark has three different properties embedded watermark without unnoticeable, undividable from the work, and experience the same alteration as the work.

Watermark algorithm has to be secure in a way that an adversary should not be capable of detecting the existence of embedded data. A security requirement differs with the application and the most severe are in cover communication applications. In certain cases, data is encrypted before embedding it into the host audio. An unauthorized user must not be capable of extracting the data in a considerable amount of time even after knowing the fact that the host signal consists of the watermark and is well-known with the precise watermark embedding algorithm.

Digital audio watermarking is the need of time in the exponential growing era of internet and high speed data transfer. Robustness is a critical aspect of an audio watermarking for a vast class of application. It refers to the property of watermark, being resists against the attacks, which contain several image processing operations. However, watermarking robustness against cutting and cropping operations is difficult and not much improvement has been achieved till now. The majority of the work in watermarking techniques, for robustness against cutting and cropping, proposes a method in which watermark is embedded repetitively in several segments of the audio so as to provide resistance against cropping operations in which some area, might containing a useful part of the information is lost. In this paper work, a watermarking technique is proposed in which watermarking implemented using discrete wavelet transform and singular value decomposition with interpolation.

Digital watermarking is a concept closely related to steganography [4], in that they both hide a message inside a digital signal. However, what differs them is their goal. Watermarking process tries to hide a message related to the actual content of the digital signal, while in steganography the digital signal has no relation to the message, and it is simply used as a cover to hide its existence. Watermarking has been around for several centuries, in the form of watermarks initially found on plain paper and subsequently on currency and paper bills. However, the field of digital watermarking was only developed during the last 16 years and it is now being used for most of the different applications. The increasing pattern of research on watermarking over the past decade [5] has been largely driven by its important applications in digital copyrights management and protection.

Digital watermarking is required for multimedia security here in this work digital audio watermarking is used for security of audio signal with the watermark and robust result are obtained. This work deals a frequency domain watermarking uses a blind approach. The requirement of audio watermarking deals with The requirement of audio watermarking deals with Perceptual transparency, Watermark bit rate, Robustness, Blind or informed watermark detection, Security and Computational complexity properties. Audio watermarking has many applications in different sectors such as in musical industry data communications multimedia security which includes Ownership Protection, Proof of Ownership, Authentication and Tampering Detection, Finger Printing, Broadcast Monitoring, Copy Control and Access Control and Information Carrier. Various available techniques of audio watermarking are in Frequency Domain Audio Watermarking, Time Domain Audio Watermarking, Compressed Domain Audio Watermarking and Wavelet Domain Audio Watermarking.

1.2 Problem Statement

1. In this paper, an interpolation based DWT and SVD technique are used to embed Watermarks and techniques are developed to improve the effectiveness of their embedding and detection in audio. WM robustness is enabled using repetition coding into the frames i.e. short segments of the audio signals. Thus, cutting or cropping the audio file does not remove the watermark. Watermark algorithm has to be secure in a way that an adversary should not be capable of detecting the existence of embedded data. The security requirement differs with the application and the most severe are in covert communication applications. In certain cases, data is encrypted before embedding it into the host audio. An unauthorized

user must not be capable of extracting the data in a considerable amount of time even after knowing the fact that the host signal consists of the watermark and is well-known with the precise watermark embedding algorithm.

1.3 Motivation

Digital Data can be shared by multiple users, over a distributed network, and managed for long period of time without any damage. Consequently, the copyright protection problem arises as unauthorized distribution and copying of digital data are simple even with low cost commodity computers. As a result, the digital watermarking technique is introduced to protect the ownership of the contents. A technology of Digital Audio Watermarking is to hide the copyright information in an audio file without making the information being audible to the listener, and by minimally affecting the audio quality of the original file. Among all the techniques of audio watermarking which are developed to date, the interpolation using DWT, SVD audio watermarking technique is perfect in its class by being robust to any kind of intended or non-intended attack. Also, it provides a blind watermarking technique in which the original file is not required at the detector for watermark detection or extraction. This paper proposes a robust audio watermarking technique based on the interpolation technique using singular values based watermark algorithm which provides a blind watermark technique.

II RESEARCH APPROACH

The proposed work primarily deals with audio watermarking in the frequency domain using DWT and SVD based watermarking using interpolation Technique. The proposed technique is two-fold. For a given audio signal, the DWT transformation is done and higher order coefficients are chosen for watermark embedding. This is because these coefficients contain much of the information contained in the host signal, and thus provides a way to implement robust watermarking. The higher order coefficients are then transformed to the square matrix and SVD decomposition is performed.

In this paper, text data is used as a watermark. This data is first converted into decimal numbers by using ASCII codes which are then transformed into 7 bit binary numbers. Then, a binary string of zero and one is obtained. Corresponding to each one or zero in the watermark string, the binary values are embedded in the higher order coefficients of the S matrix. For the purpose of watermark embedding, the 63 bits between the first and the 65th value is considered, as these upper and lower limits are kept unchanged to be used for the computation of the step size for the purpose of watermark embedding. Thus, the watermark data in the form of interpolated values is embedded in the higher order coefficients of the S matrix. PSNR is evaluated as a function of the tradeoff between embedding capacity and robustness.

III .PROPOSED WORK

3.1 Audio Watermarking Through DWT and SVD

Watermarking an audio signal refers to embedding some digital data in the audio signal so that it can later be extracted or detected for the proof of copyright. The proposed watermarking algorithm used both the DWT and SVD techniques so as to provide a robust and imperceptible watermarking for the audio signal. The contribution of the proposed watermarking technique over Al. Haj [27] is two-fold. Firstly, the proposed technique extends the base algorithm by embedding the watermarking bits in the S matrix of SVD transform through interpolation whereas the former implements the watermarking by embedding the watermarking bits in the off-diagonal elements of the S matrix, through quantization. It is proved through in the simulation results given in Section 4 that the interpolation method gives better Psycho Acoustic Frequency Masking characteristics as compared to the quantization for the watermarking bits to be embedded in the S matrix coefficients.

It is also shown that by embedding the watermarking bits into the diagonal elements of the S matrix, a blind watermarking scheme can be implemented, which has a number of advantages as compared to non-blind or semi-blind technique. The technique proposed by [27] gives a blind watermarking in the case of watermark detection. However, to extract the watermark, the original unmarked copy of the audio file is needed and thus, provides a semi-blind watermarking technique.

Secondly, the proposed algorithm also embeds the watermarking bits redundantly into the frames, i.e., short segments of the audio signals. Thus, cutting or cropping the audio file does not remove the watermark.

Thus the proposed algorithm provides a robust and imperceptible watermarking scheme which is the two major requirements in audio watermarking. The schematic of the embedding and the detection scheme is shown in the subsequent figures.

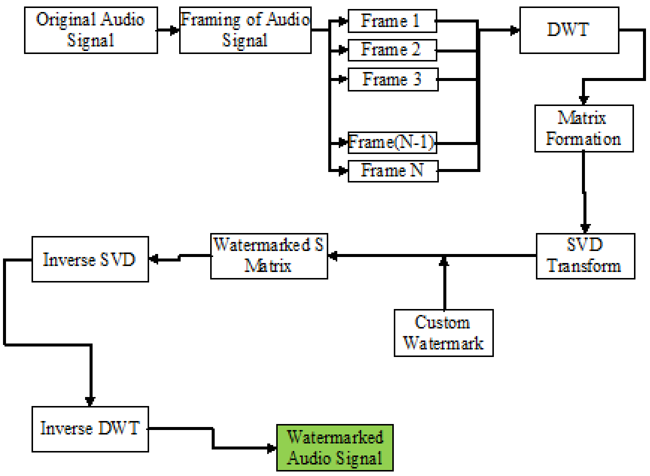

Fig. 3.1 Watermark Embedding Scheme

3.2 DWT Decomposition

The DWT decomposition of the original audio signal takes the form as illustrated in figure 3.2. The proposed watermarking algorithm embeds the watermark in the level 3 coefficients of the highest frequency so as to provide the robust watermarking. The reason for the same can be justified by virtue of the property of the DWT transform. The lower order terms are replaced by zero in the process of thresholding as applicable in MPEG layer III compressions. The same is also used in JPEG compression. However, the higher order terms remain unchanged in the compression, thus providing a robust watermarking.

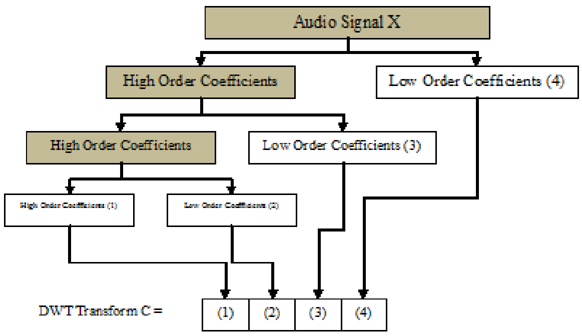

Fig 3.2 A Three Level DWT Transform of the Stereo (Mono) Audio Signal

The reconstruction of the audio signal is done by combining the matrices in conjunction with the chosen filter.

3.3 SVD of the highest order Coefficients

The most commonly used DWT transformation that is applicable in a wide range of application goes up-to level three. This is because of the simple implementation of a wide variety of watermarking and steganographic algorithms. Given a data frame consisting of N samples, the lower and higher order terms in first order DWT transformation consists of N/2 elements each. A second level, each part of the higher order terms consists of N/4 elements. At third level, the higher order coefficients consist of N/8 elements. This is illustrated in figure 3.2 shown above and also in the simulation results in Section 4.

This set of higher order coefficients is chosen for watermark embedding. However, this one-dimensional array is to be converted into a (possibly square) matrix so as to transform it through Singular Value Decomposition. The transformation of the linear vector into the matrix is done in such a way so as to keep the number of rows equal to or least greater than the number of columns, subject to the product of the rows and columns is equal to the total number of higher order coefficients of the DWT. The number of rows and columns in the matrix can be obtained by using the algorithm given below:

Algorithm : Converting the One dimension array (size, n) into (possibly square) matrix

1. Given a number "n", rows (r) and columns (c) of the (possibly square) matrix are to be computed. Compute $k = \sqrt{n}$.
2. If k is an integer, Set r = k, c= k, stop.
3. Else, continue in loop with increment value i:
   (a) tmp = $\lceil k \rceil$
   (b) r = tmp, c = n/tmp
   (c) If type(c) = integer, exit, else r = $\lceil k \rceil + 1$
4. Exit

After computation of r and c, the matrix is formed from the one dimensional array as per the dimensions of the rows and columns. The SVD based watermarking is one of the most widely accepted technique digital content watermarking. It takes the following form:

A = USV^T

This transform can be illustrated by taking the example of a 4 X 4 matrix as shown:

$$A = \begin{bmatrix} A_1 & A_2 & A_3 & A_4 \\ A_5 & A_6 & A_7 & A_8 \\ A_9 & A_{10} & A_{11} & A_{12} \\ A_{13} & A_{14} & A_{15} & A_{16} \end{bmatrix}$$

$$= \begin{bmatrix} a_1 & a_2 & a_3 & a_4 \\ a_5 & a_6 & a_7 & a_8 \\ a_9 & a_{10} & a_{11} & a_{12} \\ a_{13} & a_{14} & a_{15} & a_{16} \end{bmatrix} \begin{bmatrix} b_1 & 0 & 0 & 0 \\ 0 & b_2 & 0 & 0 \\ 0 & 0 & b_3 & 0 \\ 0 & 0 & 0 & b_4 \end{bmatrix} \begin{bmatrix} c_1 & c_5 & c_9 & c_{13} \\ c_2 & c_6 & c_{10} & c_{14} \\ c_3 & c_7 & c_{11} & c_{15} \\ c_4 & c_8 & c_{12} & c_{16} \end{bmatrix}$$

Here, both U and V are square matrices and S is a diagonal matrix. Moreover, both U and V are orthogonal matrices. Modifying any of the value of the either U or V matrix destroys the orthogonal property of the matrices and the process cannot be made reversible through SVD decomposition at a later stage at the time of detection. Also, the S matrix consists of coefficients which drop exponentially row-wise. This matrix consists of most of the information contained in the matrix A. The lower order elements of S matrix are considered for watermark embedding.

Expressed in terms of dimensions, one can rewrite:

$$A_{NXM} = U_{NXN} * S_{NXM} * V^T{}_{MXM}$$

3.4 Watermarking the S matrix in SVD transform

It is evident that most of the information in the digital data is encoded in the higher order terms of the DWT transform. Similar is the case with SVD transform in which most of the information in the digital signal is encoded in the higher order coefficients of the S matrix. The proposed technique first computes the DWT and then transforms through SVD, both of which complements the robustness of the proposed algorithm. In this scheme, a textual watermark is considered. The algorithm for watermark embedding and detection are given in subsequent sections.

3.4.1 Watermark Embedding

The watermark embedding is done as per the following scheme:

1. Given an audio signal S, compute the total number of samples, the sampling rate and a number of channels in the audio file.
2. Identify the first 2097152 (=2^{21}) samples for watermark embedding. For a normal sampling rate of 44100, this requires 47.55 seconds duration of the mp3 audio file. This is for the simple reason that the number of higher order coefficients after DWT of the given set is 2^{18}.
3. These higher order coefficients are then used for the construction of a matrix of the dimension 2^9*2^9.
4. The SVD transform after conversion to this matrix gives the S matrix of the same dimension as the original matrix. The 2^9 (=512) S values are then used for the watermarking purpose.
5. The last 8 values of the S matrix are used for embedding of 8 bits of the digital watermark into the matrix. This digital data may be the ASCII code of the message or the pixel color value of a grayscale image. The watermark embedding is done as per the scheme is given below:
    a. Obtain the last and the 449th last value of the S matrix of the SVD Transform.
    b. The values below this are least significant to affect the quality of audio and hence can be modified suitable to embed the watermark. This can be shown by replacing all the values from 450 to 512 to 0 and reconstructing the audio vector. Watermark embedding is done through the interpolation of numbers in positions from 450 to 512.
    c. Inverse SVD transform is taken to create the original matrix of higher order coefficients.
    d. Inverse DWT transform is taken to create the watermarked signal.

3.4.2 Watermark Detection

Watermarking Detection is straightforward in accordance with the watermarking embedding algorithm. The detection algorithm is given below:

1. Obtain the audio sample and consider the first 2^{20} samples of the audio file.
2. Obtain the DWT of the samples and consider the higher order coefficients which are 2^{18} in number.
3. Transform the Higher order coefficients to the matrix of dimension 2^9*2^9.
4. Convert the matrix to SVD and obtain the S matrix of dimension 512*512.
5. Obtain the last 10 values of the diagonal S matrix and detect the presence of watermark data by calculating the interpolated values (step size).
6. If the valid textual character is obtained, repeat the procedure, else shift the sample one next and repeat the procedure.

3.5 Maximum Watermark Embedding Capacity

For 2^{21} samples of audio which in .wav format at sampling rate of 44100 gives 47.54 seconds of audio, a maximum of 2^9 (=512) bits can be embedded in the audio, giving an embedding capacity of

$$\frac{2^9}{2^{21}*2^4} = \frac{1}{2^{16}} = \frac{1}{65536}$$

Thus, one bit is embedded in every 65536 bits of the host data. The denominator in the above equation consists a factor 2^4 for the reason that the audio file in the uncompressed mode has 16 bits per sample. In a file of 5 minutes of audio, having 5*60*44100*16 = 211680000 bits of data, a watermark of size 3230 bits can be embedded.

However, it provides a way of robust watermarking that is robust against file modification to significant extents. If the watermark is embedded redundantly for each set of 2^{21} samples, then a robust watermarking against cutting and cropping can also be obtained.

Section 4 discusses the simulation of the model and discusses the results. MATLAB is used as simulation tool and results are investigated and conclusions are drawn. This section also discusses the Quality metric, i.e. PSNR and the MSE of the watermarked samples. It compares the PSNR and MSE of representative music including POP, Classical and Jazz..

IV ANALYSIS OF PROPOSED WORK

4.1 DWT Transformation

The music file named old_school in wav format is operated for the simulation using the proposed algorithm. The file information is as shown below:

CompressionMethod: 'uncompressed'
NumChannels: 2
SampleRate: 44100
TotalSamples: 6759929

Duration: 153.2864
Bits Per Sample: 16

It is easy to verify the duration of the audio by dividing the total number of samples by the sampling rate, giving 6759929/44100 = 153.2864. Also, the bit rate is 256 bits per second, yielding the size of the mp3 data = 256*time i.e. 256*153.2864= 39241.3184 bits or 4.9 kb. However, due to the frame format of MPEG layer III data, the file size of the audio on disk is 1.23 Mb. Out of the total samples 6759929, the first 2^{21} samples of the first channel are considered for the purpose of watermark embedding.

These first 2097152 samples of the first channel are first transformed through DWT to obtain the higher and lower order DWT coefficients. The wavelet decomposition of the audio sample is carried out to figure out higher order and lower order coefficients. The plot of the original audio and the lower and higher order terms of the DWT transform are shown in figure 4.1 and 4.2 respectively.

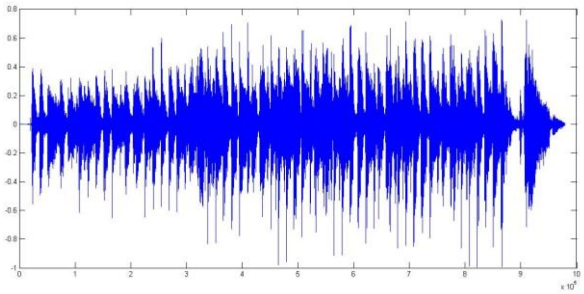

Fig 4.1 Amplitude graph of the Original Audio Signal. The Horizontal axis shows the sample number and the vertical axis shows the amplitude

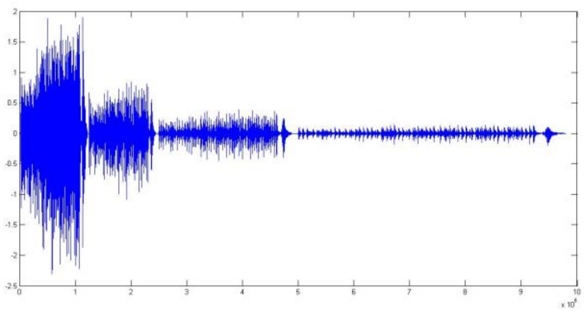

Fig 4.2 Amplitude graph of the DWT Audio Signal. The Horizontal axis shows the sample number and the vertical axis shows the DWT coefficient Magnitude.

As shown in figure 4.2, the leftmost part is the spectrum is the portion of the highest order magnitude of the terms of the audio channel and the rightmost is the lowest order terms. As stated previously, the leftmost coefficients are chosen for watermark embedding.

The count of the samples corresponding to the four segments as shown in figure 4.2 are as follows:

A1 = 262144 (=2^{18})
A2 = 262144 (=2^{18})
A3 = 524288 (=2^{19})
A4 = 1048576(=2^{20})

It is easy to verify that the sum of the count of all the four types of coefficients is 2097152, which is one more than the number of samples in the original audio. This one is added to make to a total number of samples even so as to carry out the process of differentiating the lower and the higher order coefficients of the original vector. The pictorial representation of the same is given in figure 4.3

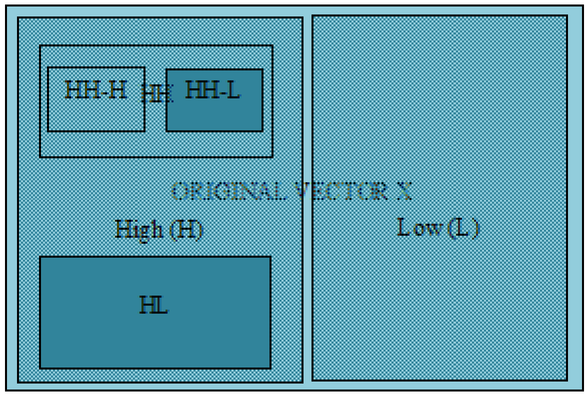

Fig 4.3 Pictorial representation of DWT

The C vector chosen for watermark embedding is given by the count of the vector elements from 1 to 262144.

For the purpose of conversion to the matrix, the prime factors of the length of highest order coefficients are obtained. The most nearly square matrix having elements equal to the number of elements in the highest coefficient matrix can be obtained by the greatest close two factors of the array.

An alternate way is to find two numbers closest to the square root of the number that on multiplication gives the corresponding vector count. In this case, the two numbers come out to be 512 and 512. A matrix is constructed from the array consisting of 512 rows and 512 columns, consisting of elements in a row-wise manner, having the elements of the highest order coefficients of the DWT transform. Nevertheless, there is no restriction on the number of samples to be considered for watermark embedding or the length of the audio file. For the case of simplicity in the simulation results, a square S matrix in the SVD transform is considered. However, the S matrix can be of any dimension. The maximum embedding capacity in S matrix is restricted to a minimum of the count of the row or columns. The algorithm for conversion of any row vector into the maximum possible square matrix is given in section 3.

4.2 SVD Transformation

The SVD transformation of the matrix is computed for the purpose of watermark embedding. As stated previously, both the U and V matrices are orthogonal matrices and changing in any of the element destroys the orthogonal property of the matrices. It is important to state here for ready reference that a matrix is orthogonal if the product of the matrix and its transpose matrix is equal to the identity matrix. In this work, the S matrix is used for watermark embedding.

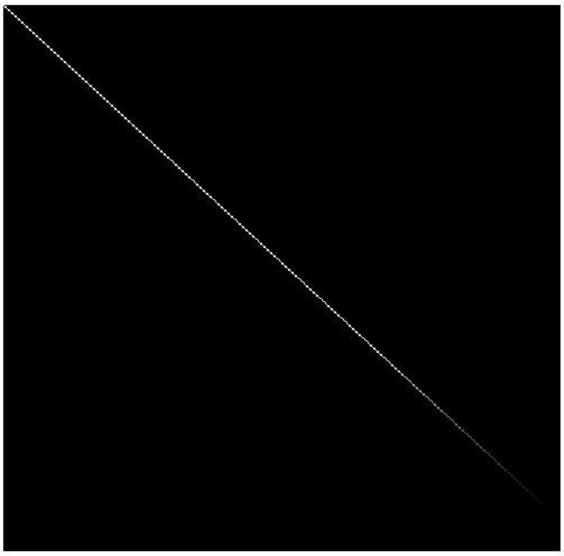

Fig. 4.4 Pictorial Representation of the Diagonal S matrix (Dimension 360X340)

The pictorial representation of the S matrix in image form is shown in figure 4.4.

4.3 Effect of rounding to zero in S matrix

To get an insight of the impact of S matrix on the host signal, it is important to investigate the effect of rounding to zero, the last 63 values of the S matrix. Rounding off to zero the last 63 values, the values of the square matrix does not show considerable change. Rather, the changes in the values of the square matrix are of the order of second places in the decimal values and hence imperceptible. Thus, it turns out that only the higher order bits of the S matrix carry most of the information contained in the host signal.

4.4 Watermark Embedding

Considering the digital watermark as the text watermark being the word "copyright". It consists of 9 letters each of which is encoded into 7 bit ASCII code for the purpose of watermark embedding. The numeric value corresponding to this textual watermark is;

99 111 112 121 114 105 103 104 116

Converting it to binary string gives a string of length 7*9 = 63 as shown;

110001111011111110000111100111100101101001110011111010001110100

These 63 values are embedded in the last 63 coefficients of the S matrix. The magnitudes of the last 63 elements of the S matrix are shown in figure 4.5.

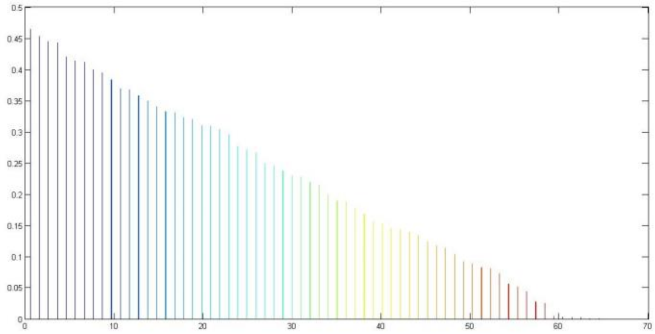

Fig 4.5. Magnitude of the last 63 elements of the diagonal matrix S

For the purpose of watermark embedding, the 63 bits between the first and the 65th value is considered, as these upper and lower limits are kept unchanged to be used for the computation of the step size for the purpose of watermark embedding.

This can be easily verified from the table 4.1 given below:

TABLE 4.1
ACTUAL AND INTERPOLATED VALUES OF THE LAST 64 DIAGONAL VALUES OF S MATRIX

S. No.	S Matrix Elements	Value	Differences Between Consecutive pairs
1	S(1,1)	29.81468	0.199009
2	S(2,2)	29.61567	2.307508
3	S(3,3)	27.30816	3.571861
4	S(4,4)	23.7363	0.64412
5	S(5,5)	23.09218	2.599979
6	S(6,6)	20.4922	1.998164
7	S(7,7)	18.49404	0.456435
8	S(8,8)	18.0376	0.551487
9	S(9,9)	17.48612	1.679001
10	S(10,10)	15.80711	0.622142
11	S(11,11)	15.18497	0.11127
12	S(12,12)	15.0737	0.21942
13	S(13,13)	14.85428	0.466518
14	S(14,14)	14.38776	0.197387
15	S(15,15)	14.19038	0.116191
16	S(16,16)	14.07419	0.367649
17	S(17,17)	13.70654	0.14669
18	S(18,18)	13.55985	0.431905
19	S(19,19)	13.12794	0.172056
20	S(20,20)	12.95589	0.131939
21	S(21,21)	12.82395	0.235561

22	S(22,22)	12.58839	0.189863
23	S(23,23)	12.39852	0.097388
24	S(24,24)	12.30113	0.139835
25	S(25,25)	12.1613	0.074908
26	S(26,26)	12.08639	0.223024
27	S(27,27)	11.86337	0.110707
28	S(28,28)	11.75266	0.097868
29	S(29,29)	11.65479	0.146889
30	S(30,30)	11.5079	0.201796
31	S(31,31)	11.30611	0.176737
32	S(32,32)	11.12937	0.0875
33	S(33,33)	11.04187	0.2636
34	S(34,34)	10.77827	0.079507
35	S(35,35)	10.69876	0.08118
36	S(36,36)	10.61758	0.146289
37	S(37,37)	10.47129	0.214908
38	S(38,38)	10.25639	0.197173
39	S(39,39)	10.05921	0.121039
40	S(40,40)	9.938173	0.093343
41	S(41,41)	9.844831	0.083066
42	S(42,42)	9.761765	0.102742
43	S(43,43)	9.659023	0.142113
44	S(44,44)	9.51691	0.087134
45	S(45,45)	9.429776	0.121754
46	S(46,46)	9.308022	0.125159
47	S(47,47)	9.182863	0.056618
48	S(48,48)	9.126245	0.112335
49	S(49,49)	9.01391	0.038903
50	S(50,50)	8.975007	0.041503
51	S(51,51)	8.933504	0.056663
52	S(52,52)	8.87684	0.143375
53	S(53,53)	8.733466	0.016375
54	S(54,54)	8.71709	0.256267
55	S(55,55)	8.460823	0.036924
56	S(56,56)	8.423899	0.162195
57	S(57,57)	8.261704	0.013768
58	S(58,58)	8.247936	0.072275
59	S(59,59)	8.175661	0.091419
60	S(60,60)	8.084243	0.083691
61	S(61,61)	8.000551	0.032508
62	S(62,62)	7.968043	0.065105
63	S(63,63)	7.902938	0.123138
64	S(64,64)	7.7798	0.199009

It is important to note that the differences in the values of the diagonal matrix do not follow a specific pattern. It is a higher percentage in some indexes and lowers in others. Out of the differences in the pair of values, the least difference is 0.013768, the greatest difference is 3.571861 and the average difference is 0.34976. Keeping this fact in mind, a policy can be set up for a real valued number for diagonal elements of the S matrix. The proposed interpolation policy uses an agreed upon interpolation variable. Rounding off the value of the average difference between the values of the S matrix to 2 decimal places, the value obtained is 0.35. This fraction is used for embedding 0 and 1 in the real number range. As shown in the table. To embed a 1, the real number is made exactly divisible by 0.35. Thus, the interpolated value corresponding to the first value S(1,1) (= 29.81468) is 29.75 which is exactly divisible by 0.35.

Places at which 0 needs to be embedded are kept unchanged while the places where 1 needs to be embedded, the actual value of the S matrix is replaced by the corresponding interpolated value. The modified S matrix elements after the embedding of the watermark are shown in figure 4.6.

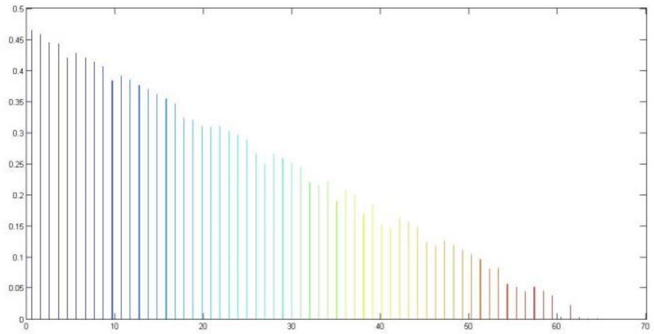

Fig. 4.6 Modified values of the S matrix (last 63 values)

The Inverse SVD transform, followed by inverse DWT transform is taken to get back the watermarked audio signal.

4.4 Performance Matrices

The Mean Square Error of the audio signal can be computed as follows:

[y1, Fs1] = audioread('original.wav');

[y2, Fs2] = audioread('watermarked.wav');

(Both the files are provided in the CD ROM attached)

As the total number of samples is 2097152, the MSE is

$$\mathrm{MSE} = \left\{ \sum_{k=1}^{2097152} [y1(k) - y2(k)]^2 \right\} / 2097152$$

It comes out to be 0.0123.

The mean square error and the PSNR for three classes of music come out as shown in the following table.

TABLE 4.2
QUALITY MATRIX FOR MSE, PSNR

Audio type	MSE	PSNR	MSE [26]	PSNR [26]
Pop	0.123	13.76492	0.224	8.558065
Classical	0.223	8.596928	0.423	3.036218
Jazz	0.21	9.118639	0.231	8.290785

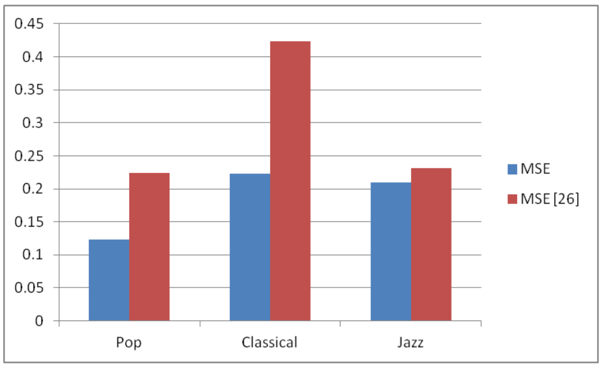

Fig. 4.7 Comparison plot of MSE

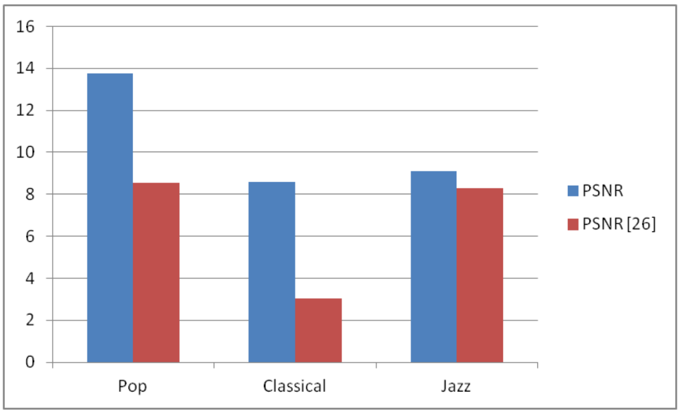

Fig. 4.8 Comparison plot of PSNR

It turns out that the proposed technique gives considerable improvements over the technique proposed by [26]. This is due to the reason that the SVD transformation is used for embedding in the S matrix domain and with the use of a small fraction of real number interpolation.

V CONCLUSION AND FUTURE SCOPE

An audio Watermarking Algorithm is a watermarking process applied on Audio signal. Watermarking of audio can be done in temporal and frequency domain. The temporal domain is very sensible to all the forms of echo, noise addition, down sampling, encoding. That is why the Audio Watermark algorithm is mostly applied in the frequency domain. The embedded content should be statically undetectable, inaudible, robust again manipulation and secure. Thus to be efficient for monitoring a file, fingerprinting, and to indicate if a content has been manipulated.

In this paper, discrete wavelet transform and Singular value decomposition based watermark embedding is improved using interpolation techniques in frequency domain. The Proposed watermarking algorithm embeds watermark in the Singular values of the S matrix obtained after the decomposition of original audio signal using SVD Transformation. Thus it provides a robust watermarking against several kinds of attacks. Also, the watermark is embedding in the real values of the S matrix using an agreed upon policy for interpolation of the values, and the interpolation key has to be known to both the parties for watermark detection and extraction. It is for this reason that the proposed algorithm is able to achieve a high PSNR metric as compared to the other algorithms that use DWT and SVD based watermarking approaches. Because of two levels of transformations, the resulting watermark embedding is robust against a large class of attacks.

Future Scope

An open problem which is not often considered is modern attacks, such as compression, channel fading, jitter and packet drop. These problems are severe for the case of watermark embedding algorithm presented. These issues can be resolved by embedding bits using repetition in the cover media. However, this reduces the embedding capacity. Moreover, the synchronization is still a challenge. Recently, with rapid production of digital media, these modern attacks are becoming more important. These attacks are particularly relevant in various networks such as GSM and the Internet. However, the major drawback associated with the proposed technique is the embedding capacity of watermark data. As stated in Section 3, an embedding capacity of $2^9/2^{21}$ is max achievable in this approach. Future work is focused to increase this capacity, and at the same time, increasing the robustness of the proposed technique.

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