ROBUST AUDIO WATERMARKING USING DWT AND SVD BASED ON PARTICLE SWARM OPTIMIZATION

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Abstract : Digital Watermarking refers to hiding digital copyright information in digital content with a purpose to enable copyright protection and preventing 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 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 is non-blind and embeds watermark in the SVD Transformation of the High Frequency band obtained after the DWT transformation of the Audio Samples. The original audio samples are subjected to the DWT transformation and subsequent SVD Transformation of highest order coefficients. Also, the watermark is embedded in the singular values of S matrix using Particle Swarm Optimization Technique for watermark detection and extraction. The watermark embedding is done in conjunction with PSO to achieve PAFM and correspondingly, low imperceptibility. 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 over audio samples. The proposed method provides an optimized way to embed a watermark using PSO based DWT and 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.

***IndexTerms* - Digital Audio Watermarking, Singular Value Decomposition, Discrete Wavelet Transform, PAFM, PSO, Copyright protection, Robustness**

I. INTRODUCTION

1.1 Introduction to Digital Watermarking

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) [1], 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 scheme of watermarking is shown in figure 1.1.

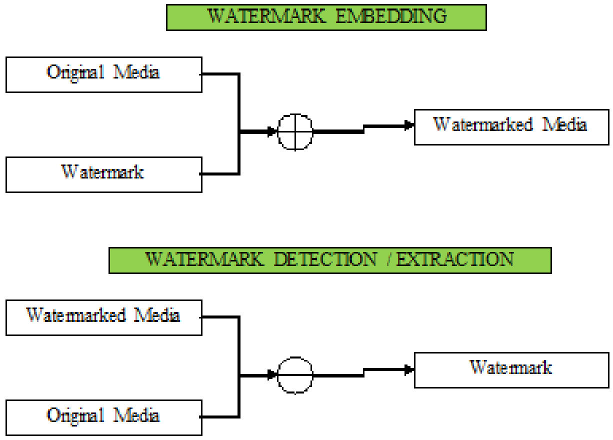


Fig 1.1 Basic Watermarking Schemes

The scenario depicted above is termed as Non-Blind watermarking [2] technique. The case when the original media is not required at the detection time for extraction of the watermark data is termed as blind watermarking technique. In this paper, a non-blind watermarking technique is proposed in which the original unmarked audio is required at the receiver for the purpose of watermark extraction.

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. As a result, the music industry and audio related communication channels claim a multi-billion dollar annual revenue loss due to piracy [3], which is likely to increase due to peer-to-peer file sharing Web communities. 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. An appropriate solution to this problem is marking the media signal with a secret, robust, and imperceptible watermark (WM) [4]. The media player at the client side can detect the mark present in media and can implement a corresponding copyright policy.

Digital Watermark is defined as a digital pattern or signal which is embedded inside digital data in the form of copyright information. Watermarking is a widely accepted 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 requirement for the watermarking process is robustness. Besides that the presence of a watermark can be identified, it should be preferably impossible for an attacker to destroy or remove the watermark from the cover media. The desirable properties of the watermark are as follows:

1. Robustness: Property to maintain the presence against large class of attacks.
2. Imperceptibility: Property to change the cover media, as low as possible, so as to make the human user, unable to distinguish between original and watermarked data.
3. Embedding Capacity: Refers to the size of the watermark data that can be embedded in the cover data.

Usually, these three requirements presents a tradeoff, meaning that increasing any one of these reduces the other two desirable properties. This is illustrated in figure 1.2 which holds for any type of watermarking and steganography technique.

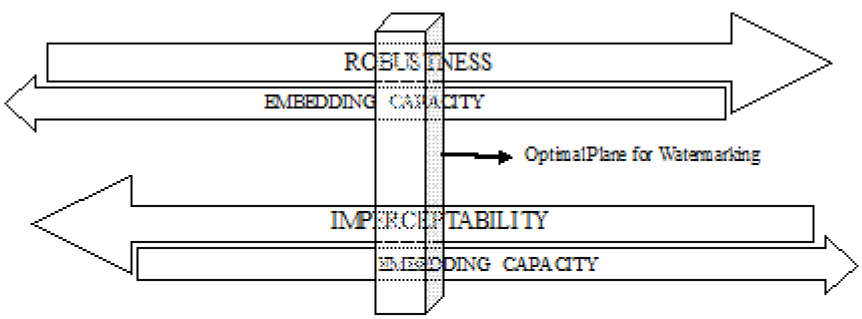


Fig 1.2 Optimal Watermark Embedding Scheme

Watermark algorithm need 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 these are most critical 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 watermark embedding algorithm.

1.2 Digital Audio Watermarking

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 resistant 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, a watermarking technique is proposed in which watermarking is implemented using discrete wavelet transform and singular value decomposition with POS techniques to achieve imperceptibility.

Digital watermarking is a concept closely related to steganography [5], in that they both hide a message inside a digital signal. However, their goal is different. Watermarking process tries to hide a message so as to enforce the copyright protection for the digital data, while in steganography the digital data 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 research on watermarking over the past decade [6] has been largely driven by its important applications in digital copyrights management and protection.

Digital watermarking is critical for multimedia security. In this paper, digital audio watermarking is investigated for the security of audio signal. This work proposes a blind frequency domain watermarking. The requirement of audio watermarking is characterized by perceptual transparency, watermark bit rate, robustness, blind or informed watermark detection, security and computational complexity properties. Audio watermarking has many applications in different sectors, the most important among which is the music industry. Also, the watermarking application largely involves ownership protection, authentication and tampering detection, finger printing, copy control, access control, etc.. Various available techniques of audio watermarking are in Frequency Domain Audio Watermarking [7], Time Domain Audio Watermarking, Compressed Domain Audio Watermarking and Wavelet Domain Audio Watermarking.

1.2 Audio Watermarking Applications

In this section, numerous application areas for digital watermarking are represented and benefits of digital watermarking against standard technologies are examined. The most common motivation behind watermarking scheme is ownership or copyright protection. In other contexts, fragile watermarking scheme can also be used for tempering detection of original audio. The watermark, which is known only to the copyright holder, is anticipated to be robust and secure such that they should survive common signal processing modifications and deliberate attacks, enabling the owner to reveal the existence of this watermark if there is a disagreement of ownership. In ownership protection applications, a watermark holding ownership information is entrenched to the multimedia host signal. Watermark detection must be having a little false alarm possibility [8]. Alternatively, ownership protection applications need a minute embedding ability of the system, since the number of bits that can be extracted and embedded with a small possibility of error does not need to be large. As elaborated in, anyone that is able to identify a watermark can possibly remove it as well. So, because adversaries can easily obtain a detector, they can remove owner's watermark and replace it with their own. To attain the level of the security essential for the proof of ownership, it is crucial to restrict the accessibility of the detector. It is still more challenging to use watermarks not just in the recognition of the copyright ownership, but also as an actual evidence of ownership. The trouble arises when an adversary uses editing software's to substitute the original copyright notice with the one owned by an adversary and then claim to possess the copyright. In earlier watermarking systems, the trouble was that the watermark detector was easily available to adversaries. When an adversary is not having the detector, the elimination of a watermark is able to make very difficult. Though, even if an owner's watermark cannot be detached, an adversary may try to weaken the owner. An opponent, using a personal watermarking system, might be capable of making it come into view as if the watermark data was there in the owner's original host signal. This trouble can be solved using a small modification of the problem statement. As a substitute for a direct evidence of possession by embedding, for instance, "Dave owns this image" watermarked signature in the host algorithm will in its place try to establish that the adversary's image is derivative from the unique watermarked image. This algorithm provides indirect proof that it is more likely that the real owner possesses the disputed image, since the real owner is the one who has the account from which the further two were formed.

Forging a suitable authentication watermark in a tampered host signal must be prohibited. The robustness beside removing the watermark or making it untraceable is not a worry as there is no such incentive from an attacker's viewpoint. In common, the watermark embedding ability has to be high to assure the need for extra data as compared to ownership defense applications. The detection should be carried out without the original host signal since either the original is occupied or its integrity has yet to be recognized. This kind of watermark detection is generally called as blind detection.

In practical applications, it is also advantageous to locate in spatial dimension and to distinguish the unintentional modifications e.g., distortions acquired due to reasonable MPEG compression from content tampering itself. A set of data is put in the host signal and is afterward used to decide whether the host signal tampered in the content authentication applications. Broadcast Monitoring [9] is another typical application of audio watermarking. Watermarking is a modern technology that has verified to be extremely important to content owners, copyright holders, producers, and broadcasters all through the world. By embedding a digital watermark in video or audio content at the point of production or broadcast, it permits content owners, for instance, to recognize with a coarse precision as to where and when content is broadcast, who is broadcasting the content and for how much time. Watermarking is a clear optional method of coding recognition information for an active broadcast monitoring [17]. Various applications for audio watermarking are there in the field of broadcasting. It has the benefit of being embedded inside the multimedia signal relatively than making use of an exacting segment of the broadcast signal. Therefore, it is compatible with the previously installed base of broadcast equipment, together with digital and analog communication channels. Numerous applications of watermark broadcasting are already available on a profitable basis. These include advertising research, program type identification, and broadcast coverage research. The main disadvantage is that embedding procedure is more compound than simply inserting data into file headers. It is also a matter of concern, mainly for content creators, as the watermarking would bring in distortions and corrupt the audio quality of multimedia.

Copy Control and Access Control [10] forms another major class of audio watermarking applications. A watermark detector is generally integrated into a recording or playback system, such as in the proposed DVD copy control algorithm or while developing of Secure Digital Music Initiative (SDMI) [11]. Once a watermark has been detected and the content is decoded, the copy control or access control policy is enforced by directing particular hardware or software operations such as enabling or disabling the record module In the application of copy control, the embedded watermark represent a certain copy control or access control policy.. These applications require watermarking algorithms to be defiant against deliberate attacks and signal processing alteration, capable of performing a blind watermark detection, and to be able to embed a nontrivial number of bits in the original signal.

II. PROBLEM DEFINITION AND RESEARCH APPROACH

2.1 Problem Statement

In this paper, PAFM [12] based DWT and SVD techniques are used to embed watermark data. The PAFM is achieved with Particle Swarm Optimization (PSO) [13] Algorithm and techniques are presented to improve the effectiveness of their embedding and detection in audio. Watermark algorithm need to be robust in such a way that an adversary should not be capable of removing or tempering embedded data. Watermark 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. The security requirement differs with the application and these are most severe 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. The proposed technique is non-blind which means that the original unmarked audio file is required at the receiver.

2.2 Motivation

Digital Data can be shared by multiple users, over a distributed network and several copies are stored locally on client machines. Consequently, the copyright protection problem arises in the form of unauthorized distribution and copying of digital data. Digital watermarking techniques are used to protect the ownership of the contents. Digital audio watermarking aims to hide the copyright information in an audio file without making the information being audible to the listener, thereby minimally affecting the audio quality of the original music 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 non-blind watermarking technique. This paper proposes a robust audio watermarking technique based on the interpolation technique using singular values based watermark algorithm which implements a blind watermark technique, with an improved value of Peak Signal to noise ratio.

2.3 Research Approach

The proposed work primarily deals with audio watermarking in the frequency domain based on DWT and SVD based watermarking using PSO 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, a sample image is used as a watermark. The image is partitioned into non overlapping segments, obtained after transformation through SVD. Corresponding to each segment, the singular values of the original audio file are modified, implementing watermarking embedding process. It turns out that the direct embedding of watermark data into the SVD transformation creates audible disturbances in the cover audio. Thus watermark embedding is used in conjunction with Firefly algorithm so as to ensure imperceptibility in the cover audio. PSNR is evaluated as a function of the tradeoff between embedding capacity and robustness.

This paper is organized as follows. Section 1 presents a brief overview of the subject matter of this paper. It discusses the scope, problem statement, motivation, research approach and the whole layout of the paper in a comprehensive way. Section 2 focuses on the various tools and techniques developed for embedding digital data in multimedia contents. It further discusses diverse categories of embedding techniques including robust and fragile watermarking, blind and non-blind watermarking and their application areas. It also covers the fundamental concepts of audio watermarking implemented through DWT and SVD techniques. This section provides the detailed overview of various research papers that contributed to the subject. It also creates a background for the concepts and techniques presented in subsequent sections of the work. Section 3 illustrates the proposed technique of interpolation based watermarking algorithm using DWT, SVD and PSO. Section 4 presents the analysis of the proposed work, simulation results and the plots for various measurements based on quality metrics. Section 5 presents the conclusion and the future scope of the paper.

III. PROPOSED DWT AND SVD BASED WATERMARKING SCHEME

3.2 DWT of Audio Signal

Most of the compressed mp3 files available now are encoded in the form of dual channel audio. Generally one of the channels consists of music and the other one consists of the audio. Any of the channels of a combination of two can be used for watermark embedding. In this paper, the music channel is used for watermarking data embedding as the human ear has high perceptibility for disturbances in vocals as compared to those in music. One dimension DWT is performed on the music channel data and the output of the DWT is tabulated in the form of lower and higher order DWT coefficients. Discrete Wavelet Transform of a signal, with a given wavelet specification, converts it into LL, LH, HL and HH bands.

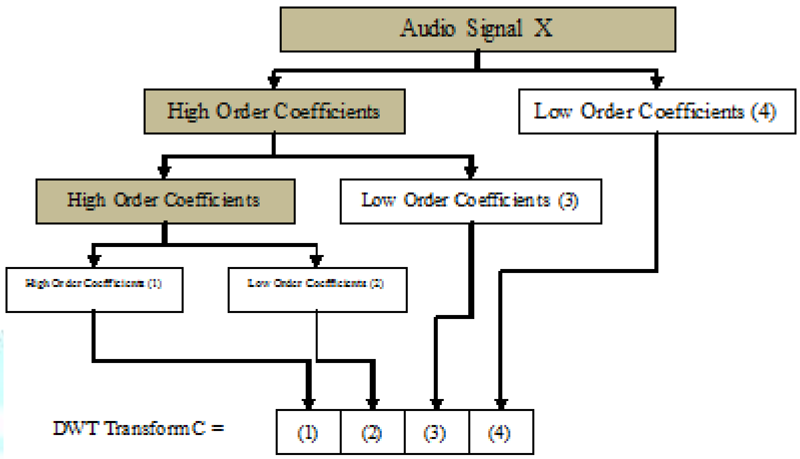


Fig 3.1 A Three Level DWT Transform of the Stereo (Mono) Audio Signal

The given audio signal is subject to DWT transformation. The DWT decomposition of the original audio signal takes the form as illustrated in figure 3.1. The proposed watermarking algorithm embeds the watermark in the level 2 coefficients of the highest frequency so as to provide 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. The reconstruction of the audio signal is done by combining the matrices in conjunction with the chosen filter.

3.3 Proposed Watermarking Technique

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 uses 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 **Sayed** Afzal Mortaza**,** et. al. [27] is based on the modification of the PSO Firefly Algorithm. Firstly, the proposed technique extend the base algorithm by embedding the watermarking bits in the S matrix coefficients of SVD transform through non overlapping and repetition embedding, whereas the former implements the watermarking by embedding the watermarking bits in a non-repetitive manner. Thus, cutting or cropping the audio file does not remove the watermark. Secondly, the proposed algorithm modifies the thresholing value based using Firefly algorithm on the basis of PAFM. It is proved through the simulation results given in Section 4 that the proposed method gives better PSNR characteristics as compared to the quantization for the watermarking bits to be embedded in the SVD matrix coefficients.

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.

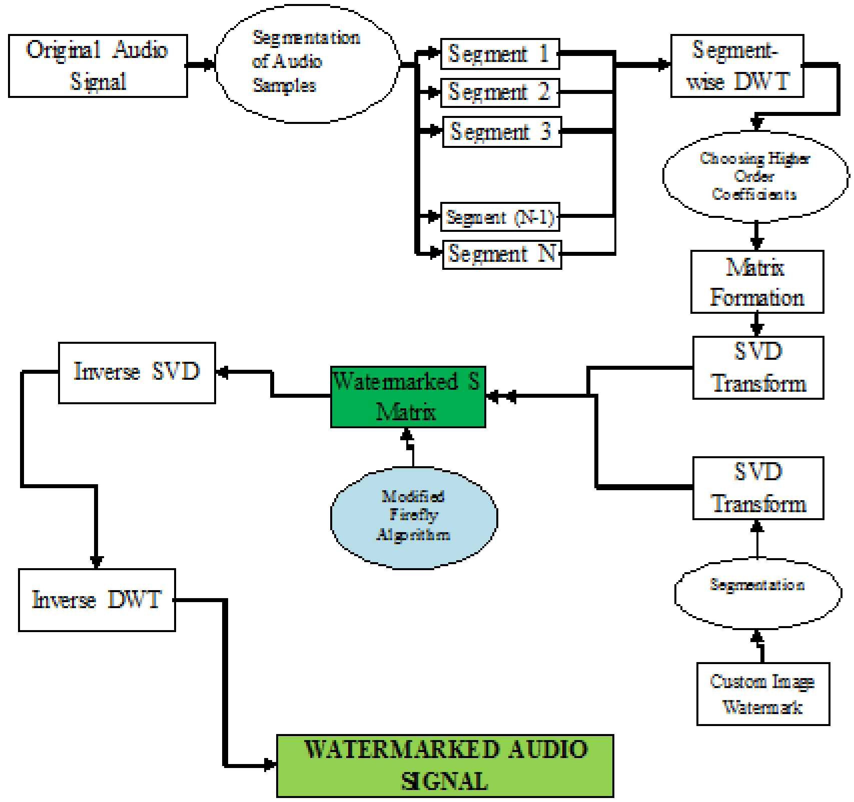


Fig. 3.2 Watermark Embedding Scheme

The stepwise implementation of the proposed scheme is depicted in the following algorithm:

Algorithm for Proposed Audio Watermarking

1. Read the samples of the given audio file (.mp3) separately for channel 1 and 2.
2. Choose appropriate channel for watermark embedding. This can be deduced by separating visualizing the plot of the samples and choosing the one with higher magnitude values. This is because lower magnitudes correspond to silent intervals, which can make the watermark perceptible.
3. Consider the number of samples, starting from the first samples, which are exact multiple of B, where B is the number of Blocks, for the purpose of watermark embedding. Let the number of samples in each block be N.
4. Obtain the single level DWT transform of the audio samples.
5. The L and H bands so obtained in step 4, consists of half of the samples considered in step 3. The count of the samples in L and H is identical and equal to N/2.
6. The H band is considered to implement a robust watermarking scheme. The H samples are grouped into segments of 4 samples each. Each such partition is used to embed four bits. Thus N/2 bits can be embedded in an audio consisting of N samples. For a standard sampling rate of 44100 samples per second, there are 44100*3*60 samples in a 3 minute audio. Thus 3969000 bits can be embedded in a 3 minute audio file. This corresponds to a binary image of size ~2000X2000 pixels or a gray-scale image of dimension ~700X700 pixels, or a color image of dimension ~400X400.
7. Each segment of 4 samples is subjected to SVD transformation to obtain U, S and V matrices. The image to be embedded is also partitioned into non-overlapping segments of 2X2 and SVD is performed for each segment. The Singular values of SVD decomposition of the watermark image are embedded into the Singular values of the audio samples. The watermark is embedded in S matrix is accordance with PSO techniques to achieve imperceptibility. This step is elaborated in subsequent section.
8. Inverse SVD is computed to get the part values of the higher order coefficients of DWT decomposition.
9. Inverse DWT of all the higher order coefficients together with the lower order coefficients is computed to obtain the watermarked audio samples.

3.4 PSO-Firefly Algorithm

Nature Inspired and Heuristic Algorithms are widely used now-a-days in the solution of the problems that cannot be solved using classical approaches. The Firefly algorithm is a meta-heuristic algorithm and widely used to solve a large class of problems. The picture of firefly and its flashing is shown in figure 3.3.

Fig 3.3. Typical Firefly Flashing action.

Firefly flashes are a part of the complex system of insect seduction. Male fireflies in the air, make distinctive patterns of flashing and flying to signal females of their species on the ground. Females, then responds with a flash, after a set of intervals, that signals they are of the same species.

The flashing part of the firefly consists of a reflector, light cells and a transparent endoskeleton. The light cells are the place where the chemical reactions take places. The endoskeleton forms the transparent cover over the entire light emitting part. In a firefly, nearly 100 percent of the entire energy is converted to the light whereas in a classical bulb, about 10 percent of the energy is converted into light and the rest appeared in the form of heat.

The distinctive patter of some of the North American Fireflies is shown in the figure 3.4

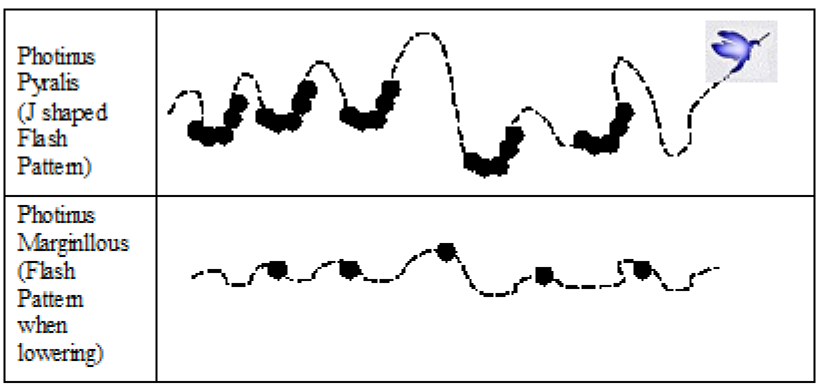


Fig 3.3. The Flashing behavior of two of the most common Fireflies of North America.

Firefly algorithm was proposed by Xin-She Yang and inspired by the flashing behavior of fireflies. Each Firefly exhibit flashing behavior so as to attract other fireflies or to attract a prey.

FA uses the following three idealized rules:

1. Fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex.
2. The attractiveness is proportional to the brightness, and they both decrease as their distance increases. Thus for any two flashing fireflies, the less bright one will move towards the brighter one. If there is no brighter one than a particular firefly, it will move randomly.
3. The brightness of a firefly is determined by the landscape of the objective function.

As a firefly's attractiveness is proportional to the light intensity seen by adjacent fireflies, Following relationship can be used to account for the intensity of flashing action as seen by the other fireflies at a distance r.

$$\beta = \beta_0 . e^{-\gamma r^2}$$

Where β_0 is the attractiveness (=intensity) at r=0.

The movement of a firefly i is attracted to another more attractive (brighter) firefly j is determined by

$$x_i^{t+1} = x_i^t + \beta_0 . e^{-\gamma r^2}\left(x_i^t - x_j^t\right) + \alpha_t \in_i^t$$

In the above equation, the second term is due to attraction and the third term is due to randomness. In the third term, the parameter α is the randomization parameter and $\in_i^t$ is a vector of random numbers drawn from a Gaussian Distribution or uniform distribution at time t. If $\beta_0 = 0$, it becomes a simple random walk. On the other hand, if $\gamma = 0$, it reduces to a variant of particle swarm optimization.

A simple way to apply FF technique to audio watermarking is to modify the randomness parameter, in iterations, in accordance with the following equation:

$$\alpha_t = \alpha_0 \delta^t, \qquad 0 < \delta < 1$$

where, α_0 is the initial randomness scaling factor and δ is a cooling factor. For most of the applications, the value of δ is from 0.95 to 0.97.

3.5 Parameter Specification for watermark embedding

Table 3.1 gives the parameter values of Watermarking Scheme for MP3 Audio.

TABLE 3.1

Parameter values of Watermarking Scheme for MP3 Audio

S. No.	Parameter	Values
1	Audio Length (in seconds)	S
2	Audio Sampling Rate	R
3	Total Samples (in each channel)	S*R
4	Samples in each bock where number of blocks is B	S*R/B
5	Higher order Coefficients in Single Level DWT transform	S*R/(2*B)
6	Each Higher level DWT coefficient corresponds to one bit watermarking data. The size of watermarking image is L*L where	L*L = S*R/(2*B) → L = $[S*R/(2*B)]^{1/2}$

Let the size of the image watermark to be embedded in the audio be 100X100. Thus, 10,000 pixels are required to be embedded in the audio. Consider that the image is binary and each pixel is represented by either 0 or 1, corresponding to black or white color respectively. Thus, 10,000 samples are required as higher order coefficients in the DWT. The block size required is thus 20,000 samples. Thus 20,000 audio samples are required for embedding of 100X100 binary image watermarks. Section 4 illustrates the proposed scheme using simulation model in MATLAB. PSNR is used as quality metric and the results are compared with that of the benchmark techniques.

IV. ANALYSIS OF PROPOSED WORK

4.1 Analysis of the MP3 file

The mp3 audio file bahubali.mp3 (copied in CD ROM), is used for simulation in the proposed model. The file information can be obtain through the MATLAB info command. The file information is as shown below:

CompressionMethod: 'MP3'
NumChannels: 2
SampleRate: 44100
TotalSamples: 1139324
Duration: 25.8350

It is easy to verify the duration of the audio by dividing the total number of samples by the sampling rate, giving 1139324/44100 = 25.835.

As shown in the info, the mp3 audio considered here consists of dual channels. The plot of channel 1 and channel 2 are shown in figure 4.1 to 4.4 respectively.

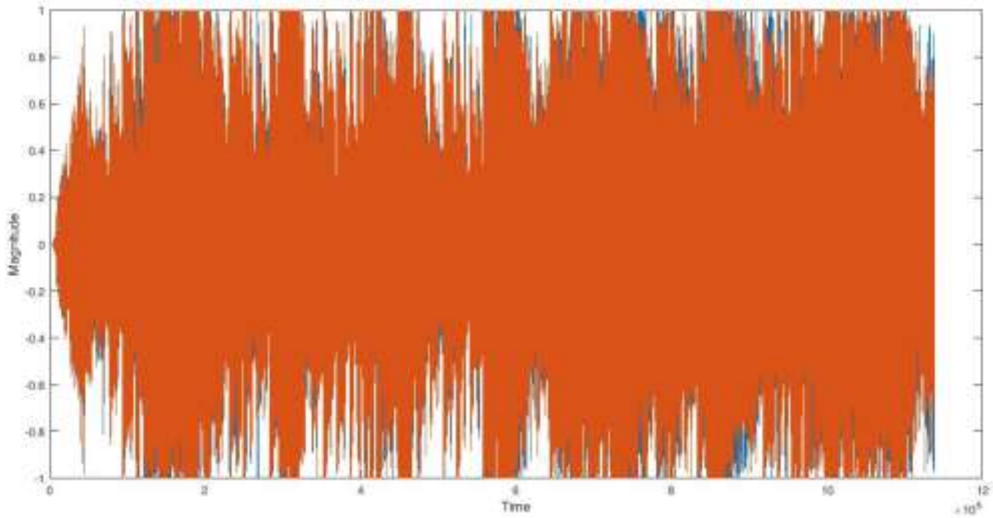


Fig. 4.1 Amplitude-Time Plot of combined Channel (y1+y2)

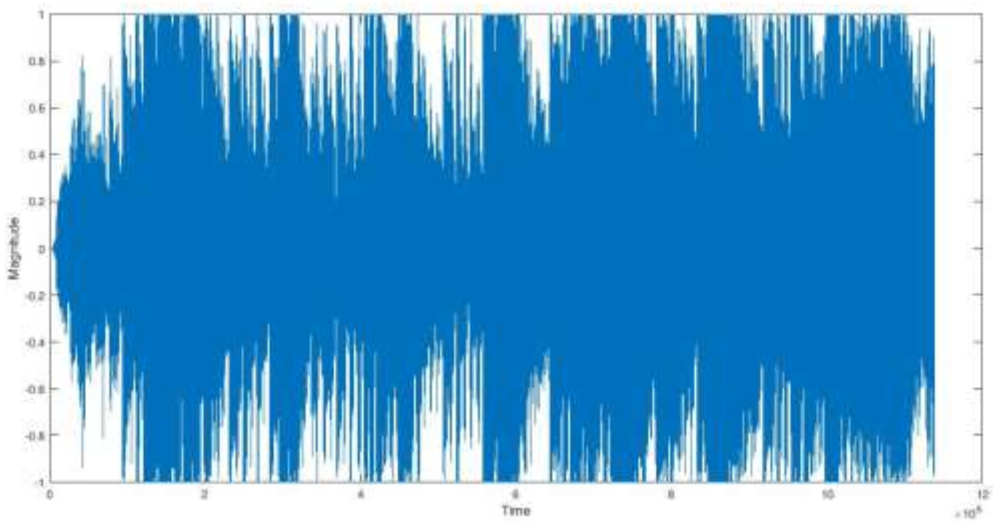


Fig. 4.2 Amplitude-Time Plot of first Channel (y1)

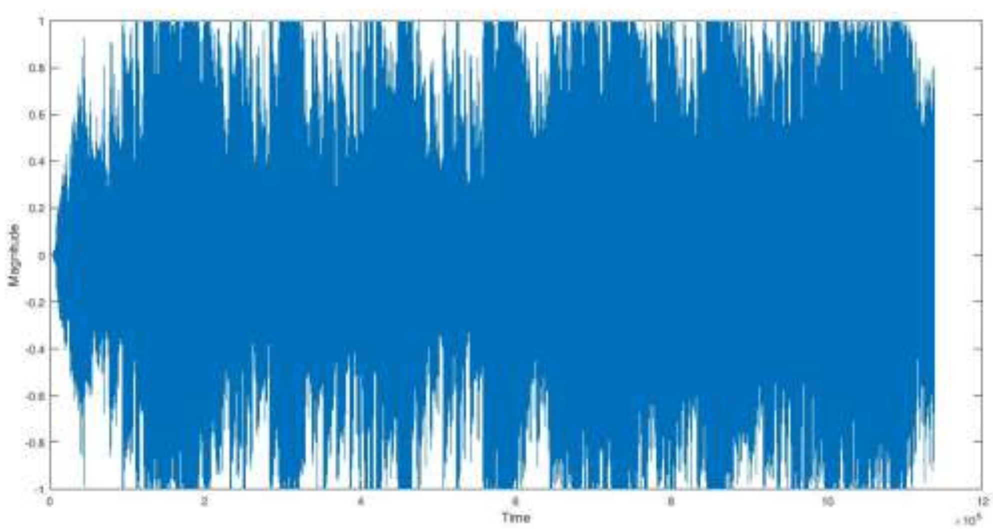


Fig. 4.3 Amplitude-Time Plot of second Channel (y2)

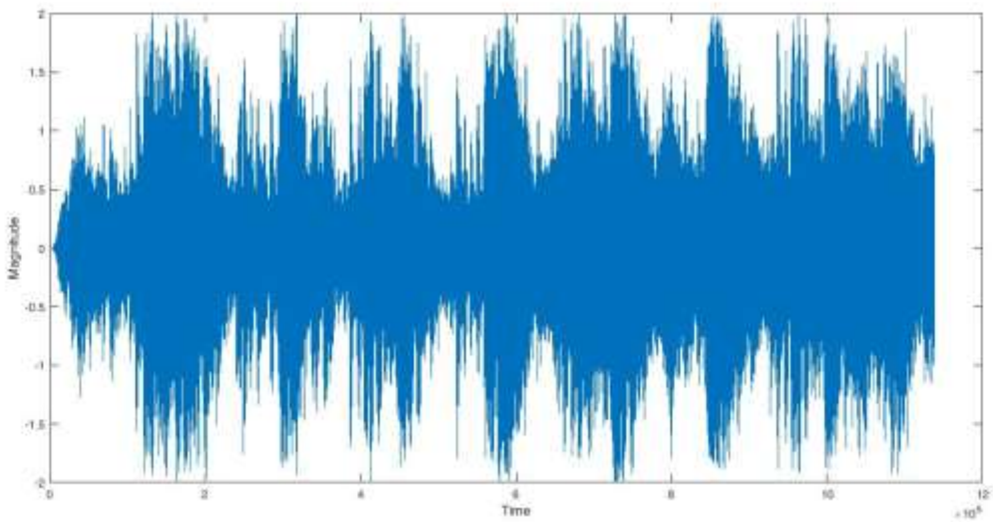


Fig. 4.4 Amplitude-Time Plot of difference of Channels (y1-y2)

4.2 Single Level DWT Transform of the MP3 file

A single level DWT transform can be performed over either channel 1 or 2. The plot of the higher and lower order coefficients after the Discrete Wavelet Transform using Haar filter is shown is figure 4.5 and 4.6 respectively.

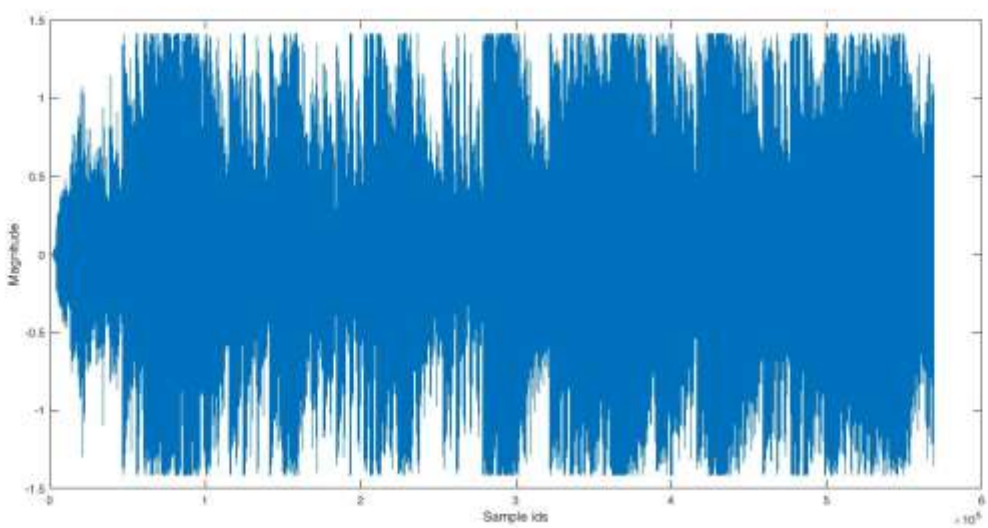


Fig 4.5 Plot of Higher Order Coefficients after DWT Transformation (Haar Filter)

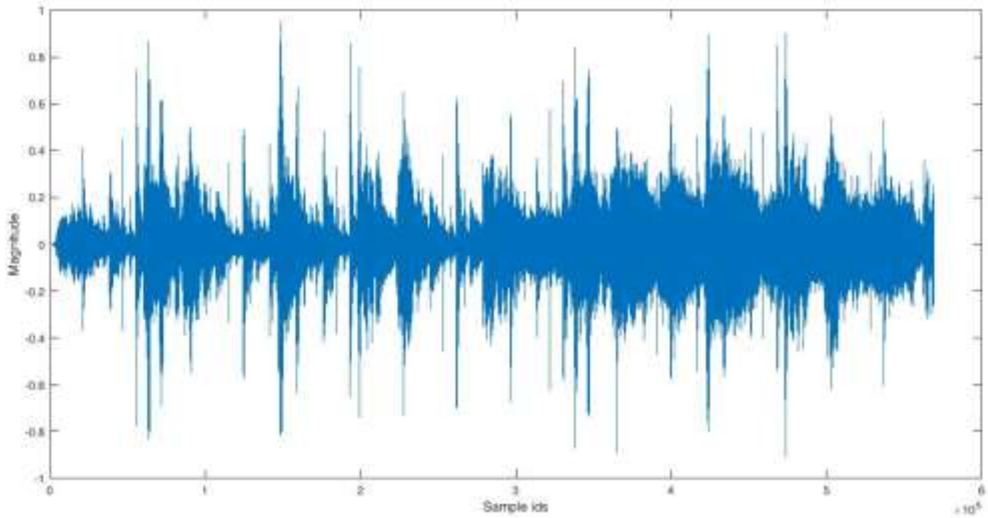


Fig 4.6 Plot of Lower Order Coefficients after DWT Transformation (Haar Filter)

Figure 4.5 and 4.6 clearly indicates that the magnitude of higher order coefficients is much larger than that of lower order coefficients. In fact, some of the most popular audio compression schemes round off the lower order terms to zero in view of compression. In almost all the watermarking techniques, the watermark data is embedded in the higher order coefficients to implement a robust watermarking. In other case, the watermark bits are embedded in the lower order coefficients to implement a fragile watermarking scheme. The choice of robust or fragile watermarking depends upon the application of watermarking under consideration.

4.3 Watermarking of Audio File

The following image watermark is chosen to be embedded into the audio file. The dimensions of the image are 120X120 pixels where each pixel is a binary 0 or 1, corresponding to color black or white, respectively.

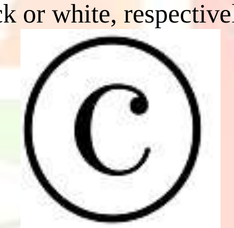


Fig. 4.7 Copyright / Watermark Image (Binary: 120X120)

The dimensions of the image are chosen to be a multiple of 4 for the simple reason that 4 coefficients are pairwise taken to form a matrix of 2X2 to compute the SVD and implement the watermark embedding process.

The image shown in figure 4.7 consists of total 14,400 bits which are required to be embedded in the audio channel 1.

For embedding 14400 bits, the proposed technique requires 14400 Higher order DWT coefficients which can be obtained after Single level DWT Transform of 14400X2 = 28800 audio samples.

For each group of 4 higher order DWT coefficients starting from the beginning, four bits of the image are embedded. This is illustrated in the following figure.

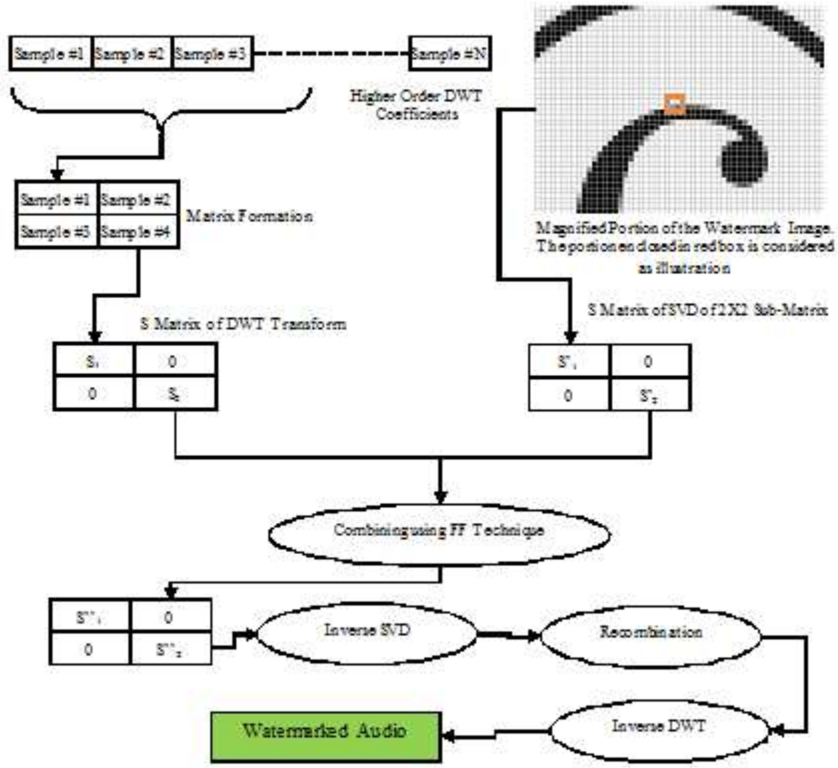


Fig 4.8 Watermark Embedding Scheme

The last 4 sample values of the audio file are tabulated here from the MATLAB command prompt.

S =

0.1477	0
0	0.0347

S =

0.5864	0
0	0.0813

S =

0.3006	0
0	0.0782

S =

0.2480	0
0	0.1303

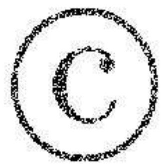
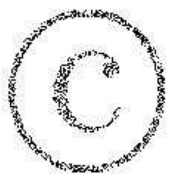
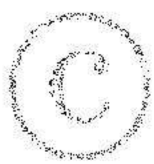
It is evident from the values that S is a diagonal matrix which consists of singular values. The modified SVD values are obtained after the embedding in the S matrix through FF Technique.

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

4.4 Watermark Extraction

The watermark can be extracted analogous to the method indicated in the figure 4.8 The extracted watermark after loudness fidelity increment is shown in following Table 4.1.

TABLE 4.1
EXTRACTED WATERMARK AND ATTACK DESCRIPTION

Extracted Watermark	Attack Description
	Increment of 10 percent in the loudness level.
	Increment of 20 percent in the loudness level.
	Increment of 40 percent in the loudness level.

4.5 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

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

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 [27]	PSNR [27]
Pop	0.0412	23.26508	0.0443	22.63495
Classical	0.0602	19.9711	0.059933	20.00969
Jazz	0.0432	22.85335	0.0491	21.7414

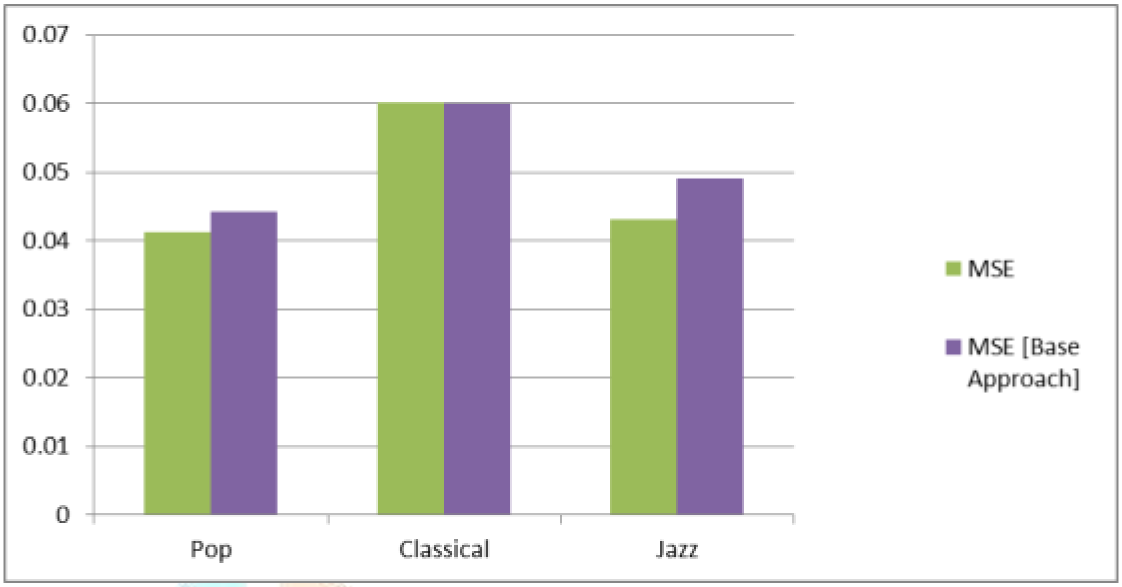


Fig. 4.9 Comparison plot of MSE

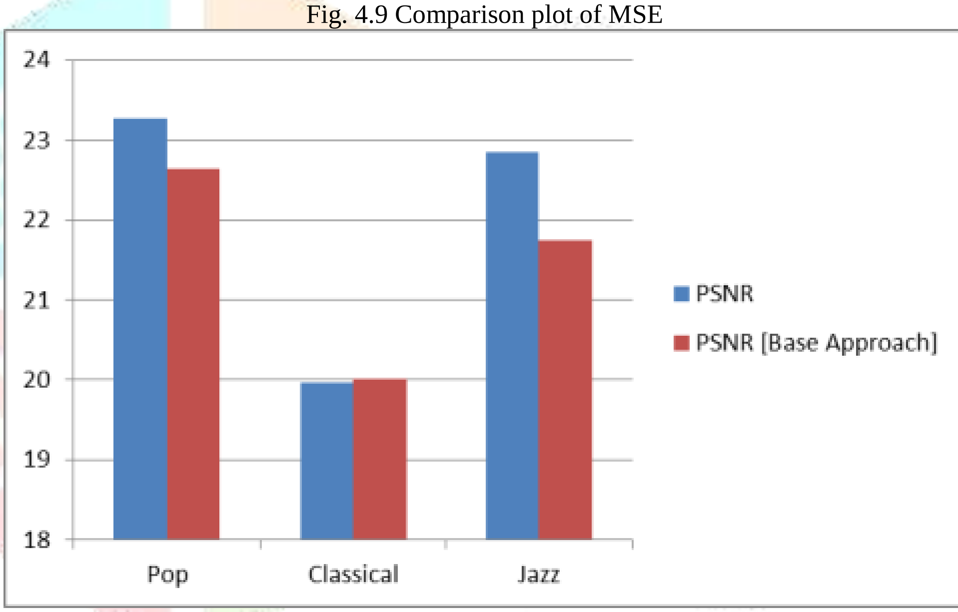


Fig. 4.10 Comparison plot of PSNR

It turns out that the proposed technique gives considerable improvements over the technique proposed by [27]. The small increment in the value of MSE over the base approach is due to the advantage of robustness. This is due to the reason that the SVD transformation is used for embedding in the S matrix domain to obtain imperceptible watermarking.

V. CONCLUSION AND FUTURE SCOPE

In this paper, the watermarking is done using DWT and SVD Transformation. Nevertheless, the watermarking of audio can be done either 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 watermarking algorithm is mostly applied in the transform domain. The embedded content should be statically undetectable, inaudible, robust again manipulation and secure. In this paper, discrete wavelet transform and Singular value decomposition based watermark embedding is presented in which the watermark values are embedded in the Singular values of the SVD Transformation. The proposed watermarking technique is blind which means that the original unmarked audio is required at the receiver for the purpose of watermark extraction.

In the table shown in the Section 4, the MSE values obtained for the proposed techniques are higher than those of the benchmark technique. This is because of the reason that watermark has been repeatedly added to the blocks of samples of the original audio so as to implement a robust watermarking technique. Nevertheless, it depends upon the choice in the application to embed watermark repeatedly or to embed it into a certain block in the entire audio. If only a single block is used for watermark embedding, then the proposed algorithm will be 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.

The major problems which is not often considered is 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. Moreover, imperceptivity is a critical issue in audio watermarking and can be increased to a larger extent with the used of more sophisticated Meta-Heuristic Approaches. As future scope of this work, both PSO and Meta-heuristic approaches will be applied to improve the imperceptibility.

REFERENCES

[1] Spinello, Richard A. "Intellectual property rights." *Library hi tech* 25.1 (2007): 12-22.

[2] Lei, Bai Ying, Yann Soon, and Zhen Li. "Blind and robust audio watermarking scheme based on SVD–DCT." *Signal Processing* 91.8 (2011): 1973-1984.

[3] Cooper, Jon, and Daniel M. Harrison. "The social organization of audio piracy on the Internet." *Media, Culture & Society* 23.1 (2001): 71-89.

[4] Oh, Hyen O., et al. "New echo embedding technique for robust and imperceptible audio watermarking." *Acoustics, Speech, and Signal Processing, 2001. Proceedings.(ICASSP'01). 2001 IEEE International Conference on*. Vol. 3. IEEE, 2001.

[5] Cvejic, Nedeljko, and Tapio Seppanen. "Increasing the capacity of LSB-based audio steganography." *Multimedia Signal Processing, 2002 IEEE Workshop on*. IEEE, 2002.

[6] Kim, Hyoung Joong, et al. "Audio watermarking techniques." *Intelligent Watermarking Techniques: (With CD-ROM)*. 2004. 185-217.

[7] Lie, Wen-Nung, and Li-Chun Chang. "Robust and high-quality time-domain audio watermarking based on low-frequency amplitude modification." *IEEE transactions on multimedia* 8.1 (2006): 46-59.

[8] Li, Wei, Xiangyang Xue, and Peizhong Lu. "Localized audio watermarking technique robust against time-scale modification." *IEEE transactions on multimedia* 8.1 (2006): 60-69.

[9] Haitsma, Jaap, et al. "Audio watermarking for monitoring and copy protection." *Proceedings of the 2000 ACM workshops on Multimedia*. ACM, 2000.

[10] Haitsma, Jaap, et al. "Audio watermarking for monitoring and copy protection." *Proceedings of the 2000 ACM workshops on Multimedia*. ACM, 2000.

[11] Craver, Scott, et al. "Reading Between the Lines: Lessons from the SDMI Challenge." *USENIX security symposium*. 2001.

[12] Mirza, Hanane H., et al. "Audio Watermarking Based on the Psychoacoustic Model and Modulated Complex Lapped Transform." *International Conference on Knowledge-Based and Intelligent Information and Engineering Systems*. Springer, Berlin, Heidelberg, 2007.

[13] Kennedy, James. "Particle swarm optimization." *Encyclopedia of machine learning*. Springer US, 2011. 760-766.

[14] Virag, Nathalie. "Single channel speech enhancement based on masking properties of the human auditory system." *IEEE Transactions on speech and audio processing* 7.2 (1999): 126-137.

[15] Cvejic, Nedeljko, ed. *Digital Audio Watermarking Techniques and Technologies: Applications and Benchmarks: Applications and Benchmarks*. IGI Global, 2007.

[16] Honsinger, Chris. "Digital watermarking." *Journal of Electronic Imaging* 11.3 (2002): 414.

[17] Yeo, In-Kwon, and Hyoung Joong Kim. "Modified patchwork algorithm: A novel audio watermarking scheme." *Information Technology: Coding and Computing, 2001. Proceedings. International Conference on*. IEEE, 2001.

[18] Cvejic, Nedeljko, and Tapio Seppänen. "Spread spectrum audio watermarking using frequency hopping and attack characterization." *Signal processing* 84.1 (2004): 207-213.

[19] Kirovski, Darko, and Henrique Malvar. "Robust spread-spectrum audio watermarking." *Acoustics, Speech, and Signal Processing, 2001. Proceedings.(ICASSP'01). 2001 IEEE International Conference on*. Vol. 3. IEEE, 2001.

[20] Gupta, Anindya. (2012). Improving the Performance of Spread Spectrum Audio Watermarking by Minimising the Cost Function. 10.13140/RG.2.1.4707.9767.

[21] Al-Haj, Ali. "An imperceptible and robust audio watermarking algorithm." *EURASIP Journal on Audio, Speech, and Music Processing* 2014.1 (2014): 37.