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Audio Watermarking Using DWT-SVD-Firefly Algorithm

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Abstract: **In terms of a solution to the financial losses incurred from unauthorised copying, content owners predominantly turn to cryptography, which is one of the most commonly used methods of protecting digital content. In the cryptography process, the content is encrypted prior to the delivery to the consumer, and then a decryption key is provided only to those who have purchased legitimate copies of the content. However, cryptography does not offer a robust solution to content piracy. For example, a pirate could purchase the encrypted content legitimately and then use the decryption key to produce and distribute copies of the content illegally. In other words, once decrypted, the content has no further protection. Thus, there is a strong need for an alternative or complement to cryptography. In terms of the solution to the problems encountered with cryptography, watermarking has been proposed as it has potential to offer more robustness. It can protect the digital content during its normal usage because the copyright information is placed within the digital content in such a way that it cannot be removed. This unique feature of watermarking makes it one of the most promising techniques for digital content protection, which has been the motivating factor behind much of the research in the last two decade.**

Keywords: **Prison Reforms.**

I. INTRODUCTION

Technological advances in computing, communications, consumer electronics and their convergence have resulted in phenomenal increases in the amount of digital content that is being generated, stored, distributed, and consumed. The term "content" broadly refers to any digital information, such as digital audio, video, graphics, animation, images, text, or any combinations of these types. This digital content can be easily accessed, perfectly copied, rapidly disseminated and massively shared without it losing quality, as opposed to the situation with earlier analogue media, such as audio cassettes and Video Home System (VHS) tapes. However, these advantages of digital media formats over analogue transform into disadvantages with respect to copyright management, because the possibility of unlimited copying without a loss of fidelity has led to a considerable financial loss for copyright holders. In terms of a solution to the financial losses incurred from unauthorized copying, content owners predominantly turn to cryptography, which is one of the most commonly used methods of protecting digital content. In the cryptography process, the content is encrypted prior to the delivery to the consumer, and then a decryption key is provided only to those who have purchased legitimate copies of the content. However, cryptography does not offer a robust solution to content piracy. For example, a pirate could purchase the encrypted content legitimately and then use the decryption key to produce and distribute copies of the content illegally. In other words, once decrypted, the content has no further protection. Thus, there is a strong need for an alternative or complement to cryptography.

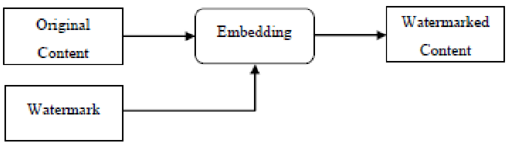


Figure 1. The flowchart of the embedding process

In terms of the solution to the problems encountered with cryptography, watermarking has been proposed as it has potential to offer more robustness. It can protect the digital content during its normal usage because the copyright information is placed within the digital content in such a way that it cannot be removed. This unique feature of watermarking makes it one of the most promising techniques for digital content protection, which has been the motivating factor behind much of the research in the last two decades. This chapter is organized as follows: First, a brief history of watermarking is given followed by an overall illustration of how watermarking algorithms work. Then, typical applications of watermarking are introduced. The motivation and contributions of this thesis are explained subsequently. Finally, an overview of this thesis is provided.

II. DISCRETE WAVELET TRANSFORM

In numerical analysis and functional analysis, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution: it captures both frequency *and* location information (location in time). The discrete wavelet transform has a huge number of applications in science, engineering, and mathematics and computer science. It is shown that discrete wavelet transform (discrete in scale and shift, and continuous in time) is successfully implemented as analog filter bank in biomedical signal processing for design of low-power pacemakers and also in ultra-wideband (UWB) wireless communications.

The DWT of a signal x is calculated by passing it through a series of filters. First the samples are passed through a low pass filter with impulse response g resulting in a convolution of the two:

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k].$$

The signal is also decomposed simultaneously using a high-pass filter h. The output is the detail coefficients (from the high-pass filter) and approximation coefficients (from the low-pass). It is important that the two filters are related to each other and they are known as a quadrature mirror filter. However, since half the frequencies of the signal have now been removed, half the samples can be discarded according to Nyquist's rule. The filter outputs are then sub sampled by 2 (Mallat's and the common notation is the opposite, g- high pass and h- low pass):

$$y_{\mathrm{low}}[n] = \sum_{k=-\infty}^{\infty} x[k]h[2n-k]$$

$$y_{\mathrm{high}}[n] = \sum_{k=-\infty}^{\infty} x[k]g[2n-k]$$

This decomposition has halved the time resolution since only half of each filter output characterizes the signal. However, each output has half the frequency band of the input so the frequency resolution has been doubled.

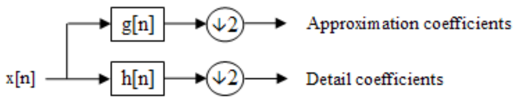


Figure 2: Block diagram of filter analysis

III. PROPOSED WORK

The audio watermarking is necessary to avoid the original sound form theft and tempering. To protect and watermark the audio signal the algorithm should be such that it audio signal shouldn't be changed in any aspect and it should be robust and message hidden in the audio signal should not be retrieved very easily by others. To fulfill these we proposed the combination of Discrete Wavelet transform (DWT) and Singular Value Decomposition (SVD) is used which is further modified by bacterial Foraging optimization (BFO). The embedding formula used in our case is

$$S_w = S + \alpha . W$$

Where S_w is the watermarked audio signal, S is the original audio signal, α is the gain factor which is the measure of robustness and imperceptibility of message and W is the watermark message bit.DWT is a frequency transform capable of giving a time-frequency representation of any given signal. Starting from an audio signal S, DWT produces two sets of coefficients: the approximation coefficients A1 produced by passing S through a low-pass filter and the detail coefficients D1 produced by passing S through a high-pass filter.

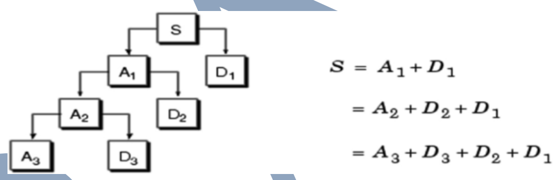


Figure:3 Three level decomposition of DWT

Four level DWT decomposition is used in this work for more robust and imperceptibility. For a four-level DWT decomposition, this is done by forming a matrix of the detail sub-bands (D1, D2, D3 and D4) as shown in Figure 4.3. The resultant DWT matrix is processed by the SVD transform to embed the watermark bits.

DWT1							
DWT2				DWT2			
DWT3		DWT3		DWT3		DWT3	
DW T4	DW T4	DW T4	DW T4	DW T4	DW T4	DW T4	DW T4

Figure 4: Decomposition of input signal into 4 levels DWT

Convert the binary image watermark into a one-dimensional vector b of length M×N. A watermark bit bi may take one of two values: 0 or 1.

$$b_i = \{0,1\} \qquad 1 \le i \le M \times N$$

Sample the original audio signal at a sampling rate of 44,100 samples per second and partition the sampled file into N frames. The optimal frame length will be determined experimentally in such a way to increase data payload. Perform a four-level DWT transformation on each frame. This operation produces five multi-resolution sub-bands: D1, D2, D3, D4, and A4. The D sub-bands are called 'detail sub-bands' and the A4 sub-band is called 'approximation sub-band'. The five sub-bands are arranged in the vector. Arrange the four detail sub-bands D1, D2, D3, and D4 in a matrix D as shown in Figure 4.2.. Forming the matrix with the Ds, rather than using A alone, is done to allow for matrix formation and subsequent application of the matrix-based SVD operator. The size of matrix D is 4 × (L/2), where L refers to the length of the frame. Decompose matrix D using the SVD operator. This operation produces the three orthonormal matrices Σ, U, and V^T as follows:

$$D = U * \Sigma * V^T$$

Where the diagonal matrix Σ has the same size of the D matrix. The diagonal σii entries correspond to the singular values of the D matrix. However, for embedding purposes, only a 4 × 4 subset of matrix Σ, assigned the name S hereafter, is used as shown below. This is a trade-off between imperceptibility (inaudibility) and payload (embedding capacity). That is, using the whole Σ matrix for embedding will increase embedding capacity but will lead to severe distortion in imperceptibility (inaudibility) of the watermarked audio signal.

$$S = \begin{bmatrix} S_{11} & 0 & 0 \\ 0 & S_{22} & 0 \\ . & . & . \\ . & . & S_{nn} \end{bmatrix}$$

Arrange 12 bits of the original watermark bit vector b into a scaled 4 × 4 watermark matrix W. The watermark bits must be located in the non-diagonal positions within the matrix, as shown below.

$$W = \begin{bmatrix} 0 & bit1 & bit2 & bit3 \\ bit4 & 0 & bit5 & bit6 \\ bit7 & bit8 & 0 & bit9 \\ bit10 & bit11 & bit12 & 0 \end{bmatrix}$$

BFO algorithm starts from this step. The searching space dimension of bacteria is equal to the number of chunks as it will be final tuned gain value. The table 4.1 correlates the bio term in BFO algorithm with our technical counterpart.

Table 4.1: Technical counterpart of bio inspired variables

	Variable in Bio Inspired Algorithm	Terms in our technical concept
1	Position of bacteria/swarms	Gain factor values
2	Number of dimension of searching space	Number of gain factors to be tuned for embedding
3	Update in positions	Change in the gain factor's value

The fitness function used for our proposed scheme in BFO takes PSNR, MSE and NCC in consideration which is:

$$fitness\ value = \left(\frac{1}{PSNR + NCC}\right) + MSE$$

Since fitness value should be minimized so inverse of PSNR and NCC is considered here. For each collection of gain values (number of gain values is equal to number of audio signal chunks) the embedding algorithm is executed and fitness value is calculated by above equation. Once all iterations are finished, the gain factor values for minimum fitness function is picked as the final gain values, which are used further for embedding of watermark message. The steps for BFO algorithms are discussed below and put in a table to segregate from rest.

IV. RESULTS & DISCUSSION

Discussed in previous chapter this thesis work is to suggest a new method for audio watermarking and analysis is done in MATLAB. We have used MATLAB 2013a's signal processing toolbox to test our proposed algorithm and a comparison is done with the already existing DWT-SVD algorithm. Results of reference paper are not quoted here, as test conditions are different along with sample watermark images and input audio samples. MATLAB's signal processing toolbox provided may functions ready to use which reduces our hassle to write script for those and we were able to concentrate on our proposed work's implementation. The results has been tested for a recorded signal at 44100 Hz frequency as well as at live recording of audio signal at the same frequency. Different types of watermark messages with varying sizes are used for analysis purpose.The searching space dimension of bacteria in BFO depends upon the number of tuning variables in the application used. In our case the input audio signal is divided into 50 chunks and for each chunk a different gain factor is used which gives optimal results for embedding.

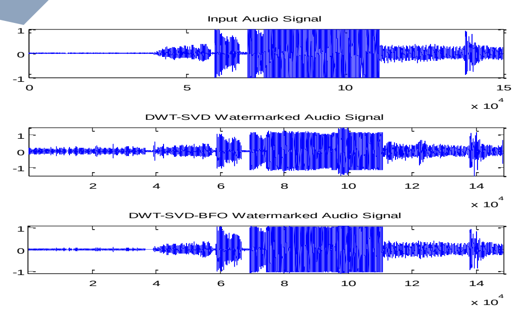


Figure: - (a) Recorded input signal (b) DWT-SVD watermarked signal (c) DWT-SVD-BFO watermark signal

The message is embedded into audio signal and depth of embedding is based on the gain factor used. The gain factor should be optimal so that there is a tradeoff between PSNR and MSE as discussed in previous chapter. For this purpose a bio optimized algorithm named bacterial foraging optimization (BFO) is used which gives the tuned gain factor value which results in high PSNR and low MSE. . the step size for the movement of bacteria and searching space dimension are important for a fine tuning and it can be observed by plotting the objective function value plot for whole iterations

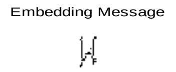


Figure 5: Embedding message with dimension 27*22

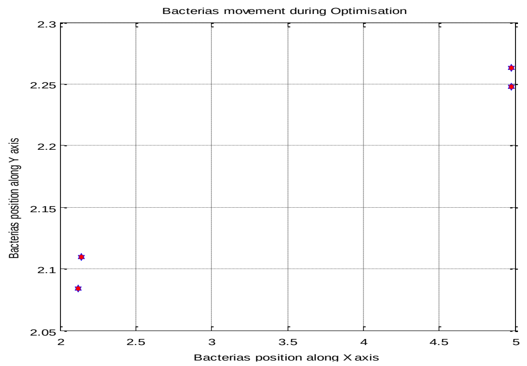


Figure 6: Final settled position of bacteria

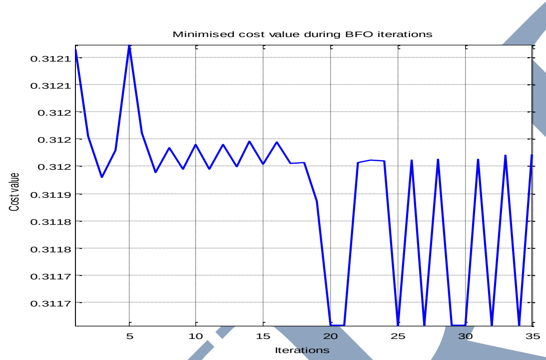
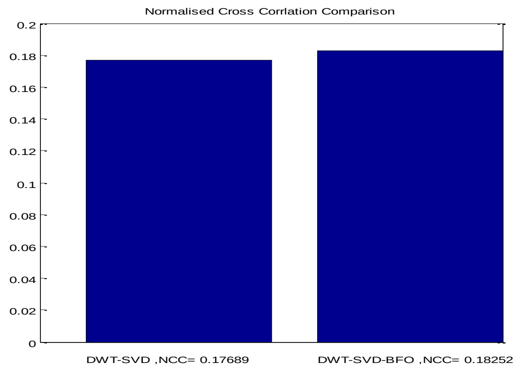
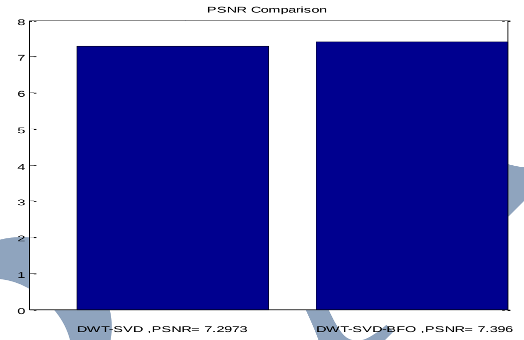


Figure 7: Objective function values plot

Table 5.1: BFO initialization parameters

No of bacteria	4
No of chemo tactic steps	2
Searching space dimension	50
Length of swim	2
Probability of elimination-dispersal	0.25





The size of watermark message used for iteration isn't chosen so large as BFO is an iterative process and large message size will increase the execution time of algorithm.

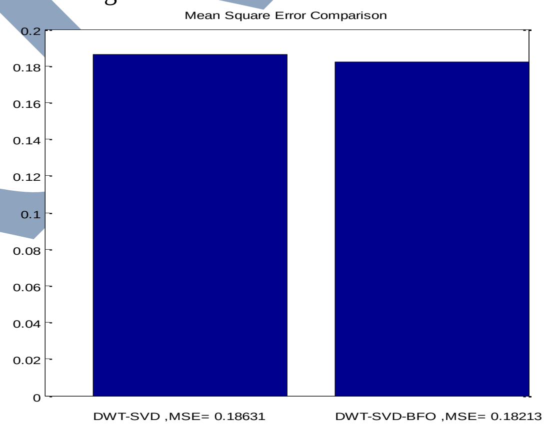


Figure (a): NCC comparison of DWT-SVD and DWT-SVD-BFO (b) PSNR Comparison (c) MSE Comparison

Figure: Bar plot comparison of table 5.2 value

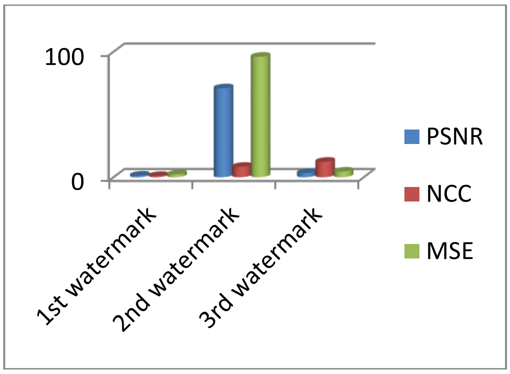


Table: % improvement in proposed work for recorded signal

	PSNR	NCC	MSE
1st watermark	1.3	1.02	2.24
2nd watermark	70.85	8.3	96
3rd watermark	3.3	12.29	4.5

Table: % improvement in proposed work for Live recorded signal

	PSNR	NCC	MSE
1st watermark	9.5	42.71	27.81
2nd watermark	50.59	64.54	86.74
3rd watermark	33.49	84.99	69.11

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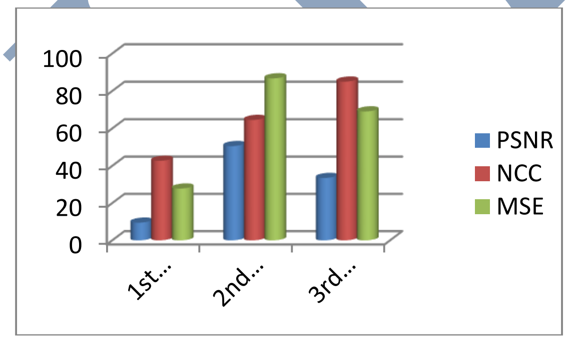

Figure 5.8: % improvement plot by proposed scheme for live recorded audio signal

V. CONCLUSION & FUTURE SCOPE

This thesis proposes a new algorithm considering the tuning of gain factor for embedding of watermark message in the audio signal. Proposed algorithm is based on quantization in DWT domains with SVD while considering the more active components of the signal. The performance of the algorithm is provided by evaluating the performance parameters such as peak signal to noise ratio, normalized correlation, and mean square error. From the results it is inferred that proposed algorithm is more robust than the DWT-SVD. The performance of the algorithm is improved by using the tuning of gain factor depending upon the number of chunks of audio signal in the embedding process. Choosing proper gain value and wavelet filters have considerable effect on the performance of the algorithm. Wavelet filters' decomposition level are considered to evaluate the algorithm performance completely. From studies level 4 produces better results bringing a tradeoff between PSNR and MSE. The audio watermarking is relatively new and has wide scope for research. This thesis is limited to binary image embedding and can be continued to gray scale images. The technique can be implemented on live signals rather than a fixed signal as considered in this thesis. Some of the real time audio signals include speech and conversation of pilot with ground controllers. Further research can be carried on embedding watermark in video sequences i.e. movies or surveillance. Applying watermarking technique the surveillance system will decrease the security issues by keeping track of the voice communication. One other application that can be targeted is the watermarking of the live objects such as a person taking his tone and image. The research can be extended by developing watermarking technique using neural networks.

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