International Journal of Engineering &Technology, 7 (3.12) (2018) 1112 -1117

SPC

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Robust and Secured Digital Audio Watermarking using Improved DWT-SVD-DFT Approach

Krunalkumar N. Patel[1]*, Saurabh A. Shah[2], Dipti B. Shah[3]

[1]Department of Computer Science and Engineering.Madhuben & Bhanubhai Patel Women ICT College (MBICT), New V.VNagar,India
[2]Department of Computer Engineering, C. U. Shah University, Wadhwan, India
[3]Department of Computer Science & Technology, G H Patel P G, Vallabh Vidyanagar, India
**Corresponding author E-mail: [1]Knpatel@mbict.ac.in*

Abstract

Today, the use of digital data like image, audio and video is tremendously increasing due to the advancement in technology and internet revolution. With this advancement to attain the one's ownership and copyrights for this digital data is the biggest challenge. Digital watermarking is one of the technique to attain one's ownership and copyrights with securely. It is the technique in which the owner's copyright information can be embedded into the original media either in the form of an image, audio, text or video. There are two main factors we need to observe for this digital audio watermarking to maintain the robustness as well as imperceptibility against the piracy, malicious attacks, and various transformation operations. Though there are many challenges to achieve this results, in this paper, our proposed audio watermarking technique is used to improve the robustness, imperceptibility of the embedded information with security. For Security, in our proposed work we are using synchronized secret key concept with DSSS encryption algorithm and two important powerful transformation methods used that are DWT (Discreet Wavelet Transformation) up to 4-level to get lowest frequency sub-band and after that DFT is applied to get lowest frequency from sub-band found by DWT in which the modifications are done and then SVD (Singular value Decomposition)is applied to it, so that original audio file does not have any impact of watermark bits to get the better robustness and imperceptibility.

Keywords: *Audio watermarking, DWT, SVD, watermark embedding and extraction, robustness, imperceptibility, SNR, IDWT, D-matrix Formation.*

1. Introduction

In the modern era due to advancement in communication technology the use of internet is growing rapidly. Because of this the immense use of online resource sharing and accessing is increased which may include copying and downloading. Today, the sharing of audio recording and audio files over the internet is becoming more popular and easier. By considering these perspectives, protecting the intellectual belongings rights of such digital works against malicious user attacks and piracy has become a sweltering research topic that requires imperious solutions. Emerging technologies for digital audio security has three main objectives as follows: security of the content transmission, authentication of audio information delivered and copyrights to protect original audio data from unlawful distribution and theft [1]. Before the invention of various methods for digital watermarking it was very insecure to transmit the authentic digital information authentically and in a secure way, but after the emergence of that some traditional methods like cryptography and steganography are found to achieve this safe and secure surrounding [2]. Cryptography is the method used to transfer the important digital information over the unsecured channel by providing the encryption and decryption terminology, however, there is a major drawback of this method is once the recipient decrypted the data then it is hard to find where the modification of the information has been done [3]. To enhance the security of the digital data steganography methods are used but we are lacking the major key factor robustness against various attacks or modification of data that might occur during transmission [4]. Steganography is the method in which the secret message is going to embedded within the original message so that it cannot be identified by the others [5]. Today, with rapid growth of social media and other technologies sharing and accessing the digital data over the internet many applications like audio recording and sharing of audio files, they are not considering copyright protection issue frequently due to its complexity. But after considering this copyright violation issues digital watermarking approach becomes the most promising solution compared to cryptographic and steganography processes, against the mitigating and alteration of intellectual properties [6]- [7]. Digital Computerized Audio watermarking is all the more difficult at that point picture and video watermarking in light of the fact that Human Auditory System (HAS) is touchier then visual guide of human according to [8]. The effects of various attacks on audio watermarking cannot be easily inferred than the video and image watermarking [9]. Digital audio watermarking is the technique to protect intellectual belongings like sharing online music, recordings over the internet [10]. To implement the efficient audio watermarking technique, we should consider the following key factors like robustness, security and perceptibility with accurate information embed with less amount of data [11]- [12]. Here to achieve this factors we need to prove the better results. The robustness is referring to where original content is not being altered against the different attacks and tempering of original media. The watermark detecting rate should

be high to prove the ownership [13] [14]. Perceptibility is measured by signal to noise ratio.
The quality must be maintained against various alteration means the signal to noise ratio must be maintained within the desirable range so human cannot capture the modification done in the host signal [15]- [16]. Lastly, security is the main concern of copyright content for the ownership of the original content that must be fulfill with accuracy. Digital Audio watermarking is the process of embedding the digital data like digital signature, a message or any image into the original signal that perceptually transparent in order to mark its ownership [17] [18].

2. Literature Review

Up until now, a few Digital Audio watermarking strategies have been talked about by thinking about various applications, distinctive calculations and improvements. For the most part, there are different advanced audio watermarking procedures have been proposed. From that notable strategies for Digital Audio watermarking in view of the confinements of perceptual properties of Human Auditory System (HAS) are including least significant bits (LSB), low bit encoding, spread spectrum, patchwork coding, echo coding, frequency masking and phase coding. In the field of digital audio watermarking the main key factors are robustness, imperceptibility and security of the intellectual properties. According to work slightly related with this concept, the journey begins so far for digital watermarking especially for the popular patchwork algorithm based on a pseudorandom, statistical model was proposed in [19]. The authors in [20] proposed a robust digital audio watermarking scheme based on, combination of three transformation methods DWT-DCT-SVD. In this approach exploration of DE optimization and DM quantization is mentioned. This proposed technique is gives the high robustness against various common signal processing attacks. In, [21] the author discussed the secure spread spectrum algorithm which gives the better robustness for signal processing and geometric transformations. In this method they created the watermark as uniquely distributed Gaussian random vector. Then it is embedded into a spread-spectrum by just modifying the largest 1000 coefficients. Another method discussed in [22] light of the spread range innovation is a various reverberate technique. In this strategy it replaces a huge resound into the first sound flag with various echoes utilizing distinctive counterbalances. In [23] the authors proposed an audio watermarking algorithm that is imperceptible to the human auditory system(HAS). In this approach they have used block structuring and then the watermark is embedded in the desired size smaller block segments of audio and then they added a pseudo-random sequence with it. However, in [24] the author improved the watermark embedding algorithm in which they have used the combination of frequency masking and frequency hopping spread spectrum techniques to increase the imperceptibility and robustness. This approach is specifically robust for MP3 compression with respect both. In [25], the authors used different approach in that they used 2-level DWT technique and embed watermark bits into DWT coefficients and proposed an improved watermark algorithm which is in [26]. The authors in [26] proposed a watermarking algorithm based on two transformation domain methods: Discrete Wavelet Transform(DWT) and Singular Value Decomposition(SVD) to achieve maximum robustness and imperceptibility. In this approach, they applied 4-Level DWT on original audio to find the low frequency sub-band. Then Detail D sub-band matrix are formed and then calculated the SVD for the same, after that they embedded watermark in new calculated S matrix bit component. Here alpha is used as watermark intensity factor. The author claims the desirable results by applying this algorithm to test it for various types of music and they produced a results with respect to both robustness and imperceptibility. In [27] authors enhanced the algorithm proposed by [26], they embedded thumbprint image as a watermark image for ownership. Moreover, they used cryptographic hash function to generate the summery of thumbprint from image and then they used it to embed as a watermark instead of the image by using this approach they reduced the bits of watermark and original audio signal is maximized by this method. In [28], the authors proposed an efficient digital audio watermarking algorithm for watermark embedding and watermark extracting techniques in which they used 2-level DWT and Singular Value Decomposition (SVD), they also proposed the new D matrix formation of details sub-bands to maximize the two major factors for efficiency, that are robustness and imperceptibility. In [29], the author discussed discrete cosine transform technique, based on a spectral transformation.

3. Proposed Method

In this proposed strategy two most capable strategies are utilized: Discrete Wavelet Transform (DWT) and Singular Vector Decomposition (SVD) to enhance the imperceptibility and robustness. Here, two algorithms are represented for watermark embedding and watermark extracting along with block diagrams of audio watermarking technique.

3.1. Digital Audio Watermark Embedding Process

- Change over the double picture watermark into a one-dimensional vector b of length m × n. A watermark bit Bi may take one of two qualities: 0 or 1.

$$B_i = \{[0,1], 1 \le i \le (m \times n)\} \quad (1)$$

- We have to Encrypt the message image or original image with pseudo random(PN) code/key generated at the time of embedding using DSSS system.

Msg_Image =EXOR (bi, PN)

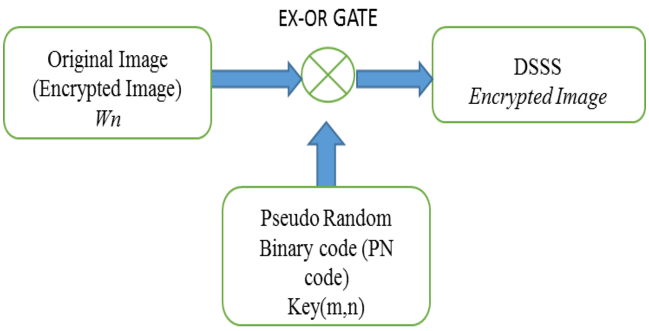

Fig. 1: DSSS Encryption Process

- Sample the first audio signal at a testing rate of 44,100 examples for every second and divide the inspected record into N frames. The ideal frame length will be prevent mined tentatively in such an approach to build information 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 shown in Figure 4. Find Lowest frequency component of D4 matrix using fast Fourier transformation(FFT).
- Obtain the 4-Level DWT to get the lowest frequency component in LL segment as shown in figure 2.

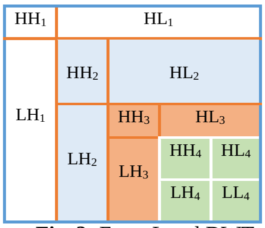

Fig. 2: Four- Level DWT

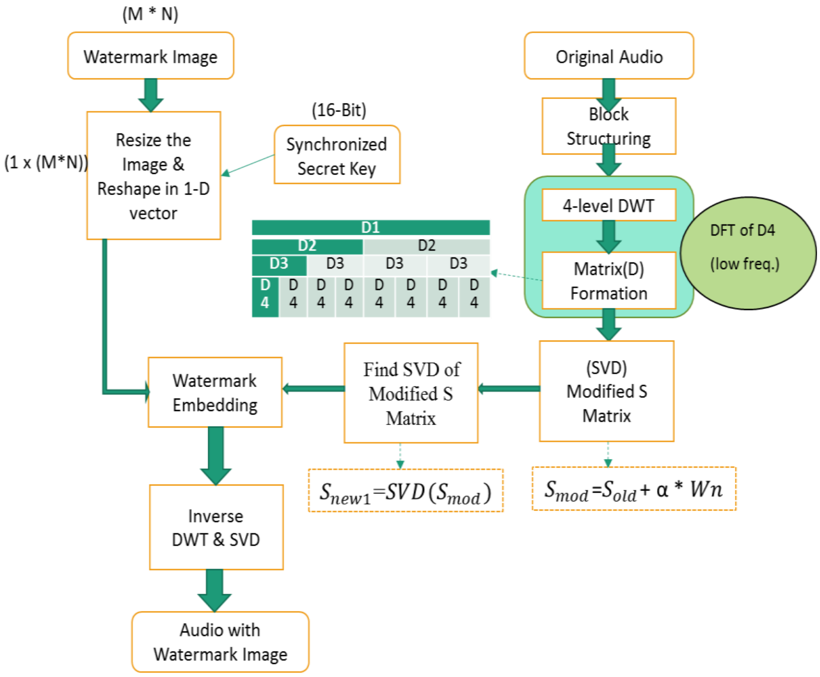

Fig. 3: Proposed Digital Audio Watermark Embedding Algorithm

- Arrange the four detail sub-groups D1, D2, D3, and D4 in a network D as appeared in Figure 4. The lattice development is done along these lines to appropriate the watermark bits all through the multi-determination sub-groups D1, D2, D3, and D4. Shaping the network with the Dn, instead of utilizing An alone, is done to take into account grid development and subsequent utilization of the lattice based SVD administrator. The extent of grid D is 4 × (L/2), where L alludes to the length of the casing.

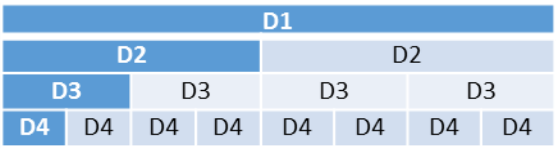

Fig. 4: Formulation of P matrix

Using SVD decompose the Di matrix. That produces the three orthonormal grids Σ, U, and VT as follows:

$$Di = Ui * \sum * Vi^{T} \tag{2}$$

where the corner to corner lattice Σ has a similar size of the Di network. The corner to corner sections compare to the particular estimations of the Di network. Be that as it may, for implanting purposes, just a (4 × 4) subset of framework Σ, appointed the name S from there on, is utilized as demonstrated as follows. This is an exchange off between imperceptibility (unintelligibility) and payload (embedding limit). That is, utilizing the entire Σ framework for implanting will increment installing limit however will prompt serious bending in imperceptibility (unintelligibility) of the watermarked audio signal.

$$K_{matrix}(\mathrm{K_{tr}}) = \begin{vmatrix} K_{11} & 0 & 0 & 0 \\ 0 & K_{22} & 0 & 0 \\ 0 & 0 & K_{33} & 0 \\ 0 & 0 & 0 & K_{44} \end{vmatrix} \tag{3}$$

Arrange 12 bits of the first watermark bit vector b into a scaled 4 × 4 watermark lattice W. The watermark bits must be situated in the non-corner to corner positions inside the lattice, as demonstrated as follows.

$$Wn = \begin{vmatrix} 0 & b0 & b1 & b2 \\ b3 & & b4 & b5 \\ b6 & b7 & & b8 \\ b9 & b10 & b11 & \end{vmatrix} \tag{4}$$

- For instance, the watermark 12-bit watermark design 1010 0011 0101 must be changed over to the accompanying matrix frame before the real embedding is done.
- Embed watermark grid W bits into framework K as per the accompanying 'added substance implanting' equation:

$$Kw = Ktr + \alpha * Wn \tag{5}$$

- where Kw is the watermarked K grid, and α is the watermark intensity which ought to be tuned the exchange off amongst robustness and imperceptibility. With this sort of implanting, the particular estimations of Di stay unaltered, and therefore, capable of being heard mutilation caused by modifying the solitary qualities is dodged.

- Decompose the new watermarked network Kw utilizing the SVD administrator. This task produces three new or-thonormal matrices as takes after:

$$Kw = U_d * K_{new1} * V_{d'} \tag{6}$$

- Make U1 and V1 vector for inverse SVD using

$$U1(:,:,i) = U_d \text{ and } V1(:,:,i) = V_d \tag{7}$$

Where i= block size

- Generate K_new vector using Snew1

$$K_{\_new}(1:4,1:4) = K_{new1} \tag{8}$$

- Apply the converse SVD activity utilizing the U, K_new and VT frameworks, which were unaltered, and the K_new matrix, which has been adjusted by Equation (6). The Dwt lattice given underneath is the watermarked:

$$D_{wt} = U_w * K_{\_new} * V_w{}' \tag{9}$$

- In last, find the inverse DWT to get the original audio with watermarked embedded image.
- Repeat every single past advance on each casing. The general watermarked audio signal is acquired by linking the watermarked outlines got in the past advances.

3.2. Digital Audio Watermark Extracting Process

Given the watermarked audio signal and the relating U1 and V1 networks that were registered in Equation 7 and put away for each casing, the installed watermark can be extricated by the strategy laid out in Figure 5 and depicted in detail in the take after following steps:

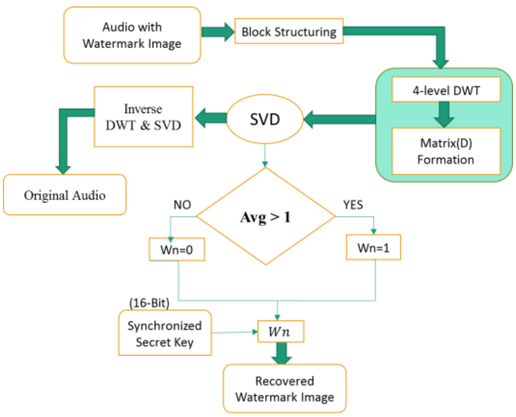

Fig. 5 Proposed Digital Audio Watermark Extracting Algorithm

- 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 shown in Figure 4.
- Obtain the 4-Level DWT to get the lowest frequency component in LL segment as shown in figure 2.
- Arrange the four detail sub-groups D1, D2, D3, and D4 in a network D as appeared in Figure 4. The lattice development is done along these lines to appropriate the watermark bits all through the multi-determination sub-groups D1, D2, D3, and D4. Shaping the network with the Dn, instead of utilizing An alone, is done to take into account grid development and subsequent utilization of the lattice based SVD administrator. The extent of grid D is 4 × (L/2), where L alludes to the length of the casing.

- Using SVD decompose the Di matrix. That produces the three orthonormal grids Σ, U, and VT as follows:

$$Di = Ui * \sum * Vi^T \tag{10}$$

- where the corner to corner lattice Σ has a similar size of the Di net-work. The corner to corner sections compare to the particular estimations of the Di network. Be that as it may, for embedding purposes, just a (4 × 4) subset of framework Σ, appointed the name S from there on, is utilized as demonstrated as follows. This is an exchange off between imperceptibility (unintelligibility) and payload (embedding limit). That is, utilizing the entire Σ framework for embedding will increment installing limit however will prompt serious bending in imperceptibility (unintelligibility) of the watermarked audio signal.
- Obtain the matrix S_tr from S matrix derived from SVD decomposition of D Matrix Using given equation:

$K_{\_tr} = K(1:4,1:4)$ and U1p, V1p (U1, V1 matrix from watermark embedding procedure using equation.

$$U1p = U1(:,:,i) \text{ and } V1p = V1(:,:,i) \tag{11}$$

Where i = block size

- Find new Kmatrix from given equation:

$$K_{wp} = U_{1p} * K_{\_tr} * V_{1p'} \tag{12}$$

Extract the 12 watermark bits from each edge by looking at the non-askew estimations of lattice Kwp. It has been tentatively seen that there are two gatherings of non-corner to corner esteems that are ex-tremely unmistakable. The qualities at the positions where a 0 bit has been inserted have a tendency to be significantly littler than those qualities at the positions where a 1 bit has been implanted. Therefore, to decide the watermark bit W(n), the normal of non-inclining esteems is first registered, name it avg, at that point for each non-corner to corner esteem Kwpij, W(n) is separated by the accompanying recipe:

$$Wn = \begin{cases} 0 & K_{wij'} \le avg \\ 1 & else \end{cases} \tag{13}$$

$$avg = 0.1 * \max(K_w) \tag{14}$$

- Lastly we have to decrypt the recovered Image with pseudo random(PN) code/key generated at the time of embedding using DSSS system as Figure 1.

$$Msg\_Image = EXOR(W_n, PN) \tag{15}$$

3.3. Results

As shown in the below figure 5 and figure 6. It depicts the original audio signal and original watermark image to be embedded

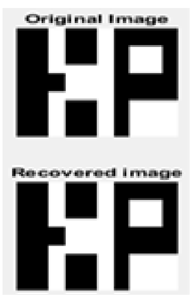

Fig. 6: Original watermark image

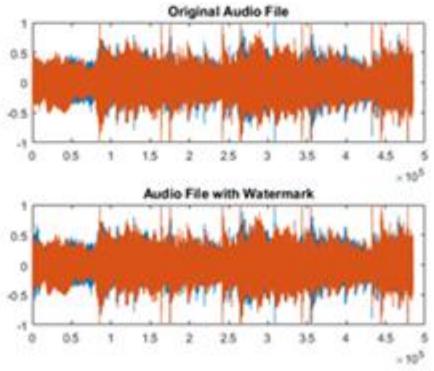

Fig. 7: Original Audio Signal

According to our main objective to achieve the maximum robustness we tested our algorithm against various attacks and after that we found that we achieved it as per table 3 given below. For robustness calculation we have used the following formula: here X is the correlation factor, range for the robustness factor is between 0 to 1.

$$X(a,a') = \frac{\sum_{j=1}^{p} a_j a'_j}{\sqrt{\sum_{j=1}^{p} a'^2_j} \times \sqrt{\sum_{j=1}^{p} a'^2_j}} \quad (16)$$

Where j is the number of pixel in watermark, ai is the original watermark image bits and ai' is the recovered watermark image bits.
From the above results we can see that we have achieved maximum robustness for the recovered watermark image. Below are the resulting images which are generated from the proposed algorithm.

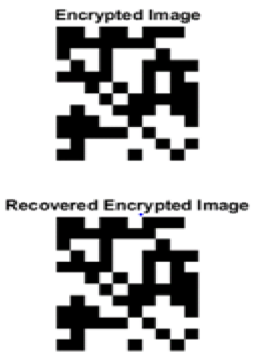

Fig. 8: Recovered and original watermark images and audio file signals

From figure 7 we can see that for various attacks like cropping, amplifying, and two noise attacks we got the maximum robustness but for the echo and bass boost not maximum but with notable values as compare with other work done. Here we are not getting 100% robustness in echo attack and for bass boost attack we are getting 100% robustness after we increase the watermark intensity factor value.

Table 1: Effects of Various attacks and Results obtained (Summery)

SR. No	Music Type	Attacks	SNR	Robustness
1	Instrumental	Cropping	30.1260	1
		Amplification	30.1260	1
		ECHO	30.1260	1
		Noise (AWGN)	30.1260	1
		HIGH BASS	30.1260	1
2	Jass	Cropping	29.5233	1
		Amplification	29.5233	1
		ECHO	29.5323	1
		Noise (AWGN)	29.5200	1
		HIGH BASS	29.5200	1
	Pop	Cropping	27.0543	1
		Amplification	26.5142	1
		ECHO	27.0543	1
		Noise (AWGN)	27.0543	1
		HIGH BASS	27.0543	1
4	Rock Music	Cropping	28.5751	1
		Amplification	26.0025	1
		ECHO	28.5751	1
		Noise (AWGN)	28.5751	1
		HIGH BASS	28.5751	1
5	Opera	Cropping	28.5751	1
		Amplification	26.0025	1
		ECHO	28.5751	1
		Noise (AWGN)	28.5751	1
		HIGH BASS	28.5751	1
6	Indian classical music	Cropping	30.1242	1
		Amplification	30.1242	1
		ECHO	30.1242	1
		Noise (AWGN)	30.1242	1
		HIGH BASS	30.1242	1

Comparative Analysis

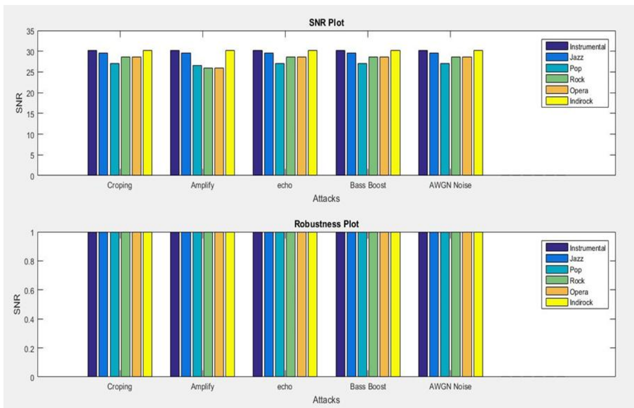

Fig. 9: Comparison for different intensity values to calculate Robustness and SNR

Table 2: Comparison of proposed algorithm robustness with previous work

Reference	Algorithm	SNR
Uludag [31]	DC-level Shifting	21.24
Bender [30]	Echo	21.47
Bender [30]	Phase	12.20
Cox [21]	Spread Spectrum	28.59
Swanson [23]	Frequency Masking	12.87
Al-Haj [25]	DWT-SVD	28.55
(Proposed Method)	DWT-SVD-DFT	**30.12**

4. Conclusion

From the results tested against various attacks, it is observed that by using proposed algorithm we have achieved maximum robustness and imperceptibility with security. We have improved the results with compared to previous work done in this field. By this data hiding becomes more robust and original audio as well as watermark image can be easily recovered with minimal effort and it is also imperceptible against various attacks and distortion. It is also observed that for the attacks like echo and bass boost the results are more than good though this are the hard to achieve, but proposed algorithm gives better results for this. Future work will be focused as enhancing the proposed method against more attacks and alteration like compression.

References

[1] H. J. Kim, Y. H. Choi, J. W. Seok, and J. W. Hong, Audio watermarking techniques, ser. Innovative Intelligence. World Scientific Publishing Co., 2004, vol. 7 (Intelligent Watermarking Techniques), ch. 8, pp. 185–218.

[2] I.J. Cox, M.L. Miller, Jeffrey A. Bloom, J. Fridrich and T. Kalker, Digital Watermarking and Steganography, Second Edition, Elsevier, 2008, ISBN: 978-0-12-372585-1

[3] M. Navneet Kumar, "Watermarking Using Decimal Sequences," M.S. thesis, Louisiana State University, Baton Rouge, LA, USA, 2004.

[4] N.F. Johnson, S. Jajodia, and Z. Duric, Information hiding: Steganography and watermarking attacks and countermeasures, Kluwer academic Publishers, 2000

[5] Arnold, M., Schmucker, M. and Wolthusen, S.D. (2002) Techniques and Applications of Digital Watermarking and Content Protection. Artech House, Norwood.

[6] Yamamoto, K. and Iwakiri, M. (2010) Real-Time Audio Watermarking Based on Characteristics of PCM in Digital Instrument. Journal of Information Hiding and Multimedia Signal Processing, 1, 59-71.

[7] Natgunanathan, I., Xiang, Y., Rong, Y., Zhou, W. and Guo, S. (2012) Robust Patchwork-Based Embedding and Decoding Scheme for Digital Audio Watermarking. IEEE Transactions on Audio, Speech, and Language Processing, 20, 2232-2239.

[8] He, X. (2008) Watermarking in Audio: Key Techniques and Technologies. Cambria Press, Youngstown.

[9] Shahriar, M.R., Cho, S. and Chong, U.P. (2012) Time-Domain Audio Watermarking using Multiple Marking Spaces. Proceedings of the International Conference on Informatics, Electronics and Vision (ICIEV12), Dhaka, 974-979.

[10] Seitz, J. (2005) Digital Watermarking for Digital Media. Information Science, Hershey.

[11] Shore, S., Ismail, M., Zainal, N. and Shokri, A. (2013) Error Probability in Spread Spectrum (SS) Audio Watermarking. Proceedings of 2013 IEEE International Conference on Space Science and Communication (IconSpace), Melaka, 1-3 July 2013, 169-173.

[12] Pahlavani, F. and Pourmohammad, A. (2013) A Block Set Interpolation Technique Based Additive-White-Noise Robust Audio Watermarking Method. Proceedings of 2013 10th International ISC Conference on Information Security and Cryptology (ISCISC), Yazd, 29-30 August 2013, 1-5.

[13] Ai, H., Liu, Q. and Jiang, X. (2013) Synchronization Audio Watermarking Algorithm Based on DCT and DWT. Proceedings of IEEE Conference Anthology, Shanghai, 1-8 January 2013, 1-4.

[14] Can, Y.S. and Alagoz, F. (2013) Robust Frequency Hopping and Direct Sequence Spread Spectrum Audio Watermarking Technique on Wavelet Domain. Proceedings of 2013 International Conference on Electronics, Computer and Computation (ICECCO), Ankara, 7-9 November 2013, 382-385.

[15] Dhar, P.K. and Shimamura, T. (2013) Entropy-Based Audio Watermarking Using Singular Value Decomposition and Log-Polar Transformation. Proceedings of 2013 IEEE 56th International Midwest Symposium on Circuits and Systems (MWSCAS), Columbus, 4-7 August 2013, 122-1227.

[16] Shahriar, M.R., Cho, S. and Chong, U. (2012) Time-Domain Audio Watermarking Using Multiple Marking Spaces. Proceedings of 2012 International Conference on Informatics, Electronics & Vision (ICIEV), Dhaka, 18-19 May 2012, 974-979.

[17] A.De," Multimedia watermarking in enhancing digital security, " ITU-T/ITU- Workshop, Banglore, India, August 2001.

[18] I. J. Cox, and M. I. Miller, "The first 50 years of electronic watermarking," Journal of Applied Signal Processing, vol. 2, pp. 126-132, April 2002.

[19] Arnold, M. 2000. Audio watermarking: features, applications, and algorithms. In IEEE International Conference on Multimedia and Expo (II). Citeseer.

[20] Lei, B.Y., Soon, I.Y. and Tan, E.-L. (2013) Robust SVD-Based Audio Watermarking Scheme with Differential Evolution Optimization. IEEE Transactions on Audio, Speech, and Language Processing, 21, 2368-2378.

[21] Cox, I.J., Kilian, J., Leighton, T. and Shamoon, T. (1997) Secure Spread Spectrum Watermarking for Multimedia. IEEE Transactions on Image Processing, 6, 1673-1687

[22] Xu, C., et al. 1999. Applications of digital watermarking technology in audio signals. Journal of the Audio Engineering Society 47(10): 805–812.

[23] Swanson, M.D., Zhu, B., Tewfik, A.H. and Boney, L. (1998) Robust Audio Watermarking Using Perceptual Masking. Signal Processing, 66, 337-355. http://dx.doi.org/10.1016/S0165-1684(98)00014-0

[24] Sehirli, M., Gurgen, F. and Ikizoglu, S. (2005) Performance Evaluation of Digital Audio Watermarking Techniques Designed in Time, Frequency and Cepstrum Domains. Proceedings of International Conference on Advances in Information Systems (ADVIS'04), Izmir, 20-22 October 2004, 430-440.

[25] Al-Haj, A., Mohammad, A. and Bata, L. (2011) DWT-Based Audio Watermarking. The International Arab Journal of Information Technology, 8, 326-333.

[26] Al-Haj, A. and Mohammad, A. (2010) Digital Audio Watermarking Based on the Discrete Wavelets Transform and Singular Value Decomposition. European Journal of Scientific Research, 39, 6-21.

[27] Al-Yaman, M.S., Al-Taee, M.A., Shahrour, A.T. and Al-Husseini, I.A. (2011) Biometric Based Audio Ownership Verification Using Discrete Wavelet Transform and SVD Techniques. Proceedings of the 8th International Multi- Conference on Systems, Signals and Devices (SSD'11), Sousse, 22-25 March 2011, 1-5. http://dx.doi.org/10.1109/SSD.2011.5993562

[28] Khalid A. Darabkh, Imperceptible and Robust DWT-SVD-Based Digital Audio Watermarking Algorithm, Journal of Software Engineering and Applications, 2014, 7, 859-871. http://dx.doi.org/10.4236/jsea.2014.710077

[29] A. B. Watson, "Image Compression Using the Discrete Cosine Transform," Mathematical Journal, vol. 4(1), pp. 81-88, 1994.

[30] Bender, W., Gruhl, D., Morimoto, N. and Lu, A. (1996) Techniques for Data Hiding. IBM Systems Journal, 35, 313- 336. http://dx.doi.org/10.1147/sj.353.0313

[31] Uludag, U. and Arslan, L. (2001) Audio Watermarking Using DC-Level Shifting. Project Report, Bogazici University, Istanbul. http://www.busim.ee.boun.edu.tr/speechweb/