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Robust Audio Watermarking using Improved DWT-SVD approach

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***Abstract*—** Digital watermarking is the technique with the use of that owner's copyright information can be embedded into the original media either it is in the form of an image, audio or video. It is an essential to maintain the ownership for digital media in sharing of the information. For this audio watermarking is one of the most likely medium to maintain the robustness as well as imperceptibility against the piracy, malicious attacks, and various transformation operations. Though there are some challenges to achieve this results, in this paper, our proposed audio watermarking technique is used to improve the robustness, imperceptibility and accuracy of the information with security. For robustness, in our proposed work we are using synchronized secret key concept and two important transformation methods used are DWT (Discreet Wavelet Transformation) up to 2-level in which the modifications are done in low frequency sub-band and SVD (Singular value Decomposition), so that original audio file does not have any impact of watermark bits to get the better performance. Also, there are more efficient results are presented as per robustness value calculated in this paper with compare to previous work done.

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

I. INTRODUCTION

In 21st century due to globalization and advancement in communication technology the use of internet is growing rapidly. Because of this the immense use of online resource sharing and accessing which may include copying and downloading. Today, the sharing of audio recording and audio files over the internet is becoming easier in day to day life. By considering these contexts, protecting the intellectual belongings rights of such digital works against malicious user attacks and piracy has become a sweltering research topic that requires imperative solutions. One of the most promising approach that has seriously attracted many of the researchers in recent years is digital watermarking [1]. In earlier days it was unsafe to transmit the authentic digital information securely, but after that some traditional methods like cryptography and steganography are found to accomplish this secure surrounding [2]. Steganography methods are not robust against various attacks or modification of data that might occur during transmission. Before this methods people were using invisible ink concept with writing information, merging two images to create a new one to hide the information, drawing a standard painting with some small modifications, shearing the header information of the messenger in the form of a message etc. [3]. Cryptography is used to protect the important information which are going to be transferred, however, there is a drawback of this method is once the data is decrypted it is hard to find where the modification of the information has been done [4]. Today, with rapid growth of sharing and accessing the information 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 tempering and alteration of intellectual belongings [5]- [6]. The effects of various attacks on audio watermarking cannot be easily implied than the video and image watermarking [7]. Audio watermarking is more challenging then image and video watermarking because hearing capacity is more sensitive then visual aid of human according to [8]. Because of that, audio watermarking technique becomes most popular technique than image and video watermarking to protect intellectual belongings like sharing online music, recordings over the internet [9]. In addition, we can embed less amount of data in audio watermarking [10]. Any efficient audio watermarking should meet the desired requirements like robustness, security and perceptibility with accurate information [11]- [12]. Here each term has their specific meaning to fulfill the objective of desired results. The first objective is robustness refers to where original content is not to be altered under different attacks and tempering of original

media. In addition, the watermark detecting rate should be high to prove the ownership [13] [14]. Second perceptibility refers to quality must be maintained against various distortion means the signal to noise ratio must be maintained within the desirable range and modified signal must not be captured by human [15]- [16]. Lastly, security is the main concern of copyright content that must be fulfill with accuracy [17]. Rest of the paper is organized as follows, Section I contains the introduction of the watermarking techniques, Section II contain the related work of various digital audio watermarking techniques, Section III contains the methodology proposed in this research work with flow diagrams, Section IV describes results and discussion with various comparisons, Section V concludes research work with future directions.

II. RELATED WORK

So, much work has been done in the field of digital watermarking relevant to the concept of robustness, imperceptibility and security. According to work slightly related with this concept, the authors in [18] proposed a robust audio watermarking scheme based on, DWT-DCT-SVD with exploration of DE optimization and DM quantization. These technique is very robust to various common signal processing attacks. In, [19] the author proposed a secure spread spectrum digital watermarking algorithm which is robust for signal processing and geometric transformations. They constructed the watermark and embedded it in a spread-spectrum by modifying the largest 1000 coefficients. Watermark is constructed as uniquely distributed Gaussian random vector. In [20] the authors proposed an audio watermarking algorithm that is imperceptible to the human auditory system. They embedded the watermark by forming the desired size smaller block segments of audio and then with that they added a pseudo-random sequence. However, in [22] the authors introduced an improved watermark embedding algorithm which is the combination of frequency masking and frequency hopping spread spectrum techniques to increase the imperceptibility and robustness. By measuring the performance, they guarantee that this algorithm is specifically robust for MP3 compression with respect both [23]. In [24], the authors discovered various techniques for data hiding process like phase coding, echo data hiding, and least significant bit (LSB) coding by considering main objectives like tempering, detection against various attacks, copyright protection and amplification of data by embedding malicious information which fulfils the criteria to protect the intellectual belongings rights digital content. The authors in [25] proposed two efficient techniques: Discrete Wavelet Transform and Singular Value Decomposition to achieve maximum robustness and imperceptibility as follows: firstly, they found a 4-Level DWT of original audio and then calculated the SVD, after that they used new calculated S matrix bit component for embedding the bits of watermark image which is in a binary form. Then Detail D sub-band matrix are formed. Here Specifically alpha is used as watermark intensity. They have used this algorithm to test it for various types of music and they produced a results with respect to both robustness and imperceptibility. In [25], the authors used different approach in that they embed watermark bits into DWT coefficients which are generated by only 2-level DWT technique and proposed an improved watermark algorithm which is proposed in [26]. In [27] authors enhanced the algorithm proposed by [26], they embedded thumbprint image taken from its owner 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 efficient audio watermarking algorithm for watermark embedding and watermark extracting techniques, 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 proposed discrete cosine transform technique, it is a spectral transformation.

III. METHODOLOGY

A. *Watermark Embedding Process*

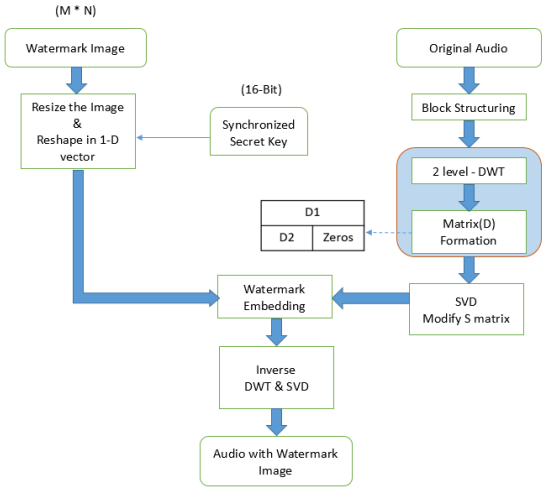

Fig. 1. Watermark Embedding Process

In this proposed method two most powerful transformation techniques are used: Discrete Wavelet Transform (DWT) and Singular Vector Decomposition (SVD) to improve the imperceptibility and robustness. Here, two algorithms are represented for watermark embedding and watermark extracting along with block diagrams of audio watermarking technique.

- According to the bock diagram shown in figure 1. Read the original audio file and do the block structuring to store the watermark image bits for embedding process. After that store the values of right and left side channels in particular variables say (m x n).
- After that check whether the watermark image size, here we say it ($W_{M \times N}$), is satisfying the following criteria for the embedding process: [As this is generalizing algorithm, here we can embed audio or text file as well instead of watermark image]

$$m \times n >= M \times N \quad (1)$$

Where m, n are the audio size and M, N are the watermark image size variables.

- Here to provide the security watermark image is encrypted by 16-bit shared synchronized secret key [Cn] in time domain.
- In next step reconstruction of watermark image is to be done into (1 x MN) size for embedding process, because we want to embed the bits into alternative fashion in left and right channels of the audio file which are in 1-D form.
- Obtain the 2-Level DWT to get the lowest frequency component in LL segment as shown in figure 2.

<table>
<tr><td>HH_1</td><td colspan="2">HL_1</td></tr>
<tr><td rowspan="2">LH_1</td><td>HH_2</td><td>HL_2</td></tr>
<tr><td>LH_2</td><td>LL_2</td></tr>
</table>

Fig. 2. Two- Level DWT

- Based on obtained DWT reconstruct the D matrix as shown in figure 3.

<table>
<tr><td colspan="2">D1 (LL)</td></tr>
<tr><td>D2 (LH)</td><td>Zeros (LL)</td></tr>
</table>

Fig. 3. Formulation of D matrix

- Based on calculated D matrix find the singular vector decomposition and modify only S_{11} component using the following formula (do not modify the U and V matrix):

$$S_{11new} = S_{11old} + \alpha * Wn \quad (2)$$

Where α = watermark intensity and Wn= n^{th} bit of watermark image, S_{11new} is watermark first bit (1 row, 1 col)

- Now, find the inverse singular vector decomposition using new obtained value of S_{11new} by following:

$$D = U * S_{11new} * V^T \quad (3)$$

- In last, find the inverse DWT and SVD to get the original audio with watermarked embedded image.

The following are the watermark embedding algorithm steps:

1. Take the original Audio file (m x n)
2. Take the image (M x N) to be watermarked and reshape in (1 x MN)
3. Embed synchronized secret key with watermark image (time domain)
4. Formation of audio file in desired blocks for watermark embedding process
5. Obtain 2-level DWT and formation of D matrix.
6. Calculate the SVD components (U, Sold, V)
7. Change the S11 bit of S component using formula S11new=S11old + α * Wn
8. Find inverse SVD using formula: $U * S_{new} * V^T$ and find inverse DWT

B. Watermark Extracting Process

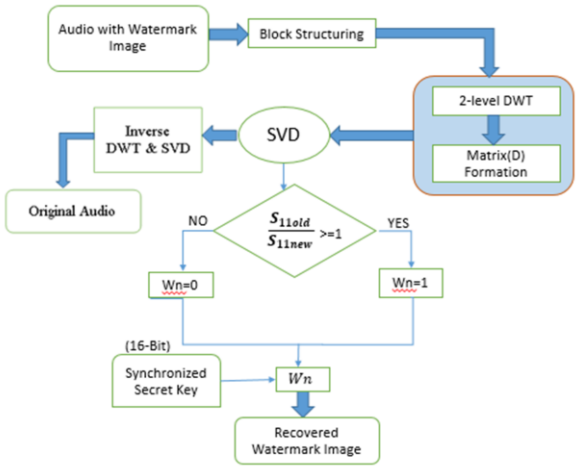

Fig. 4. Watermark Extracting Process

- According to the bock diagram shown in figure 4. Read the watermarked audio file and do the block structuring to store the watermark image bits for extraction process. After that store the values of

right and left side channels in particular variables say (m x n).

- In next step reconstruction of watermark image is to be done into (1 x MN) size for embedding process, because we want to embed the bits into alternative fashion in left and right channels of the audio file which are in 1-D form.
- Obtain the 2-Level DWT to get the lowest frequency component in LL segment as shown in figure 2.
- Based on obtained DWT reconstruct the D matrix as shown in figure 3.
- Based on calculated D matrix find the singular vector decomposition and modify only S_{11} component using equation 3. (do not modify the U and V matrix)
- Now, find watermarked image bit (Wn) based on calculated S11new using formula:

$$Wn=1 \ [S11old/S11new \geq 1]$$
$$Wn=0 \ [S11old/S11new \leq 0] \qquad (4)$$

- Finally, Extract watermark image using Shared synchronized secret key

The following table shows the watermark extraction algorithm steps:

1. Take the watermarked audio file (m x n)
2. Formation of audio file in desired blocks for watermark extraction process
3. Obtain 2-level DWT and formation of D matrix
4. Calculate the SVD components (U, Snew, V)
5. Find watermarked image bit (Wn) based on calculated S11new using formula

```
If (S11old/ S11new >=1)
        Wn=1
Else
        Wn=0
End
```

- Extract watermark image using Shared synchronized secret key

IV. RESULTS AND DISCUSSION

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

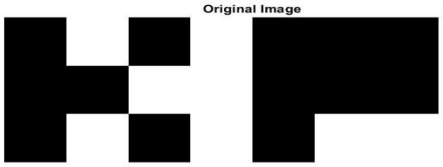

Fig. 5. Original watermark image

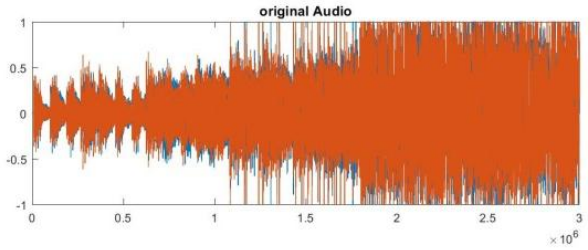

Fig. 6. Original Audio Signal

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.

$$X(a,a') = \frac{\sum_{j=1}^{p} a_j a'_j}{\sqrt{\sum_{j=1}^{p} a'^{2}_{j}} \times \sqrt{\sum_{j=1}^{p} a'^{2}_{j}}} \qquad (5)$$

Where j is the number of pixel in watermark, a_i is the original watermark image bits and a_i' 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.

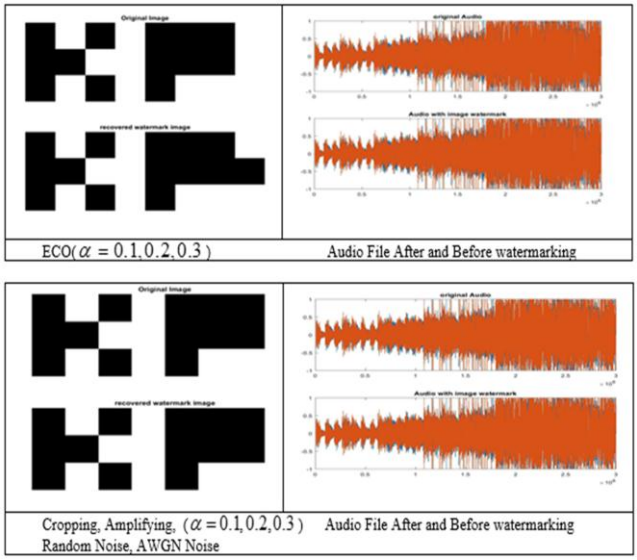

Fig. 7. Recovered and original watermark images and audio file signals

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 Calculated X for different values of α

Attacks	$\alpha = 0.1$	$\alpha = 0.2$	$\alpha = 0.3$
Cropping	1	1	1
Amplify	1	1	1
Echo	0.95346	0.95346	0.953462
Bass Boost	0.96110	0.96110	1
AWGN Noise	1	1	1
Random Noise	1	1	1

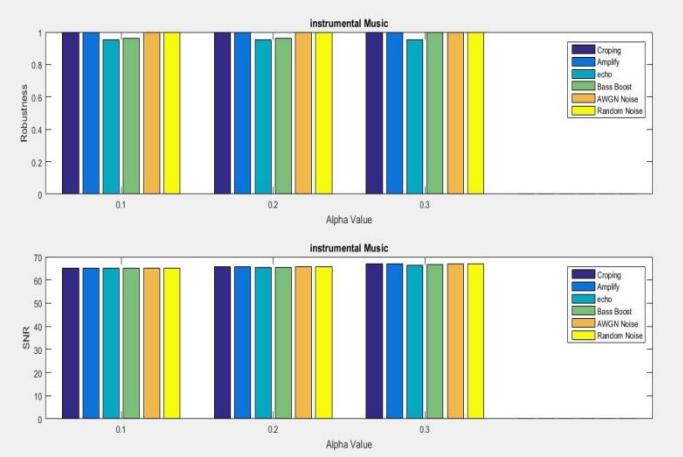

Fig. 8. Comparison for different intensity values to calculate Robustness and SNR

Below is the comparison with previous work presented by the various researchers

Table 2 Comparison of proposed algorithm robustness with previous work

Author	Method	SNR
Uludag	DC-level Shifting	21.24
Cox	Spread Spectrum	28.59
Bender	Echo	21.47
Swanson	Frequency Masking	12.87
Al-Haj	DWT-SVD	28.55
Proposed	DWT-SVD	66.95

V. CONCLUSION AND FUTURE SCOPE

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.

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