Audio Watermarking by Hybridization of DWT-DCT

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Summary

With the growth of social media, authentication and patent protection of audio files contents protection becomes a challenging task.The old techniques proposed to overcome this problem have not sufficient ability to control the copyright protection of contents. This paper proposes a hybrid DWT-DCT algorithm for copyright protection of audio files. The audio signal is divided into frames according to the size of watermarking image. After that, watermark is added into audio file to protect the contents of audio file from unauthorized user.Finally the watermarked audio is tested against different attacks includingre-sampling, re-quantization, adding white Gaussian noise and filtering with 10 KHZ.The results are further compared with previously described technique. The experimental results demonstrate that this technique is robust enough against different attacks.

Keywords:

Audio watermarking, Discrete Wavelet Transform, Discrete Cosine Transform, Human Auditory System, Human Visual System, Adding White Gaussian Noise.

1. Introduction

Audio Watermarking is a technique in which extra Information is added in to the data for securing the audio data from unauthorized use. A digital watermark is an extra signal accumulated to the actual digital signal (acoustic data, videocassette type data, or captured data), which can afterward be extracted to prove the authorization of audio. The watermark is intentionally embedded into the digital form of data so that official users can readily access it. With the rapid growth in network technology and digital medium caustic method, illegal users can easily steal the original data and make copies of the original one without the permission of the owner. Nevertheless, the possession and copyright of multimedia documentation are not typically confined. A big problem faced by substance providers and stack holders is the safety of their material. That is why watermarking is becoming very important topic now a days. Water marking is being used in different areas of computer science. Water marking is used for securing the image data and video data as well as audio data. Different watermarking techniques are also used to secure databases. Audio water marking is a technique that is used to secure audio files from unauthorized user. An extra information like signature or any random logo of image type or extra information about the owner is added into the audio signal. The embedding is done in such a way that the listener could not able to distinguish the noise in watermarked audio file. But embedding watermark into an audio is much more complex than embedding into a video or captured data (image). Because the HAS (human acoustic system) is more complex than the HVS (Human vision system). Human eyes can be deceived but human ear cannot be deceived so easily due to its high sensitivity. That’s why we find less techniques of audio watermarking than video or image watermarking. The main benefit of this research area is that the music industry will not more suffer from piracy. It was very common problem in music industry. Before that the music files were pirated and Illegal copies of files were distributes among the public. Due to which the original owner of data was not able to get reward of his work.

The DWT transform split the host auditory signal into different multi-resolution sub-bands, enabling algorithm maker to place the most suitable sub-bands for embedding the watermark bits. The discrete cosine transform (DCT) is a method that has the aptitude to change an indicator signal into basic regularity mechanism.The main applications of DWT are feature extraction, feature highlight, and feature reduction.In this research the two main functions of DWT are used for audio signal processing. Wave decompose function is used to decompose the audio signal and wavereconstruct function is used to reconstruct the audio signal after embedding the watermark into audio. In this research different attacks are performed just tocheck the robustness of our proposed technique. AWGN, filtering with 10 KHZ,requantization and resampling attacks are performed in this research. The main objective of this technique is that it gives better results than all previously described techniques. It was robust enough against different attacks.

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2. Review of literature

Conventionally, cryptography or copyright protection has become the standard technique for securing information. Before the digital era, encrypted or enveloped information have been interchanged among populace. Picture watermarking became the mostly used sketch of growth because of its resemblance to the technique a painter would represent their formation of a picture by sketching his sign at the bottom corner of the painting.

With the growth of this industry audio watermarking has been started. A literature survey of different audio watermarking schemes is explained this year, in which advantages and flaws of different audio watermarking schemes are presented (Jaya Bajpai, 2016).Nikmehr introduce a novel technique of audio watermarking in which he work in frequency domain and mixed two techniques (DWT and DCT) for watermarking the audio signal(Hooman Nikmehr, 2010). A mixture of SVT and SVD was represented in 2010. It was a great success at that time because the algorithm shown good results. (Ali Al-Haj, 2011). The mixture of two techniques took a very positive change in the growth of this industry. In 2011 Lalitha, purposed an algorithm which was consisting of DWT and SVD transformation. This algorithm also shows the good results than previously describedDCT-SVD(G. S. N.V.Lalitha, Dr.V.Sailaja, 2011)et al.

In 2012 Voice base watermarking was introduced byTakmare. It was different from audio watermarking because in this technique voice signal was used as watermark in any relational database (Sachin Balawant Takmare, 2012). In 2012 Komal gave an overview on different new techniques of watermarking and briefly describe the qualities of a good watermark (Ms. Komal V. Goenka1, 2012) et al. In 2013 Kaur presented a blined audio watermarking algorithm which was also robust enough against external attacks. (Kaur, 2013) In 2014 Zhao and Wang proposed an algorithm which was again the mixture of two techniques. A combination of DWT and SVD was presented in this algorithm. And different types of attacks were made against this technique and good results were achieved (Huan Zhao, 2014) et al. In 2014 Can work in time domain and use the spread spectrum technique and embed watermark information on host signal directly. After this a number of robustness attacks were hit on the host signal. This technique also shown good results against robustness (Yekta Said Can, 2014). Duttworks on DWT HAAR wavelet transformation for watermarking an audio. This was also a new concept in this field. This work was also done in frequency domain. It was a success full turn and the algorithm shown good results against different attacks of robustness (Dutt, 2015).The work on data hiding in Audio was done by Singh using was a good step in the domain of audio watermarking. It becomes a milestone for future work on audio watermarking. (Singh; Sujit M. Deokar, 2015). A performance analysis of DCT and DWT AW based on SVD is also presented by three Indian researchers(S. U. R. N.V.Lalitha, 2016). A novel audio watermarking method is also proposed to satisfy the IHC evaluation criteria by using different wavelet filters(Toshiki Ito, 2016). An aware extraction technique of audio watermarking using spread spectrum methodology has also been presented. This technique is different from previous spread spectrum AWT because here extraction process is blind and unique then other techniques.(Rangkun Li, 2016). A mixture of DWT SVD and quantized indexed modulation is also a marvelous enhancement in the field of audio watermarking. This is alsoa blind technique and shown good results as compared to the previous techniques(A.R. Elshazly, 2016). A DWT-DCT Arnold scrambling and cyclic codes based AW technique is also presented by subir which is robust enough against external attacks and blind also (Subir, 2016).

3. Proposed Method

3.1 DWT

Discrete Wavelet Transform is a helpful tool for handling digital signal. It has been broadly used in computer science and engineering (Huan Zhao, 2014). The DWT of signal x can be explained as follows

$$y1low[m] = \sum_{k=\infty}^{\infty} x1[l]g1[2m-1] \qquad (1)$$

$$y1high[m] = \sum_{k=\infty}^{\infty} x1[l]h1[2m-1] \qquad (2)$$

Where g1, and h1, refer low-pass fitter and high-pass fitter respectively. A signal is decomposed in to two parts. First is called the approximate part and the second one is called detailed part (see equation 1 and equation 2). The detailed part is further decomposed into two parts called high frequency part and the low frequency part.

3.2 DCT

DCT represents a signal into series of different coefficients that are summation of cosine functions of different amplitude and frequencies. Usually it is use to determine the correlation of different parts of signal. The DT of signal with length Y can be explained as equation 3 4 n 5a and 5b.

$$c(x) = w(x)\sum_{z=0}^{Y-1} f(z)\cos\left[\frac{\pi(2z+1)x}{2Y}\right] \quad (3)$$

Where x=0,1,2,….,Y-1 for 1-D signal

Reverse DCT is stated as:

$$f(z)=\sum_{x=0}^{Y-1} w(x)c(x)\cos\left[\frac{\pi(2x+1)z}{2Y}\right] \quad (4)$$

In eq 3 & 4 for x=0, 1,2,……,y-1,w(x) is

W(x) = $\sqrt{\frac{1}{y}}$ if x=0(5a)

W(x)= $\sqrt{\frac{2}{y}}$ if x≠0(5b)

In this portion the embedding and extraction methodology is explained further in detail:

3.3 Embedding Procedure

The watermark embedding procedure is going to be explained here. First of all an audio file of wave format is taken and then this file is converted into vector format using DCT-DWT. Then a random watermark image is taken and embedded into wavefile after that inversion scheme of DWT and DCT is applied just to convert back into wave format from vector format. After applying all the above mentioned procedure a watermarked audio is get.

Hybrid DWT-DCT algorithm for embedding the watermark

Step1: First of all we find the number of samples in audio file and then find the number of samples in each frame.

Step2: Then the audio file is decomposed by using multi level 1-D wavelet decomposition.

Step3: Audio signal is decomposed in to sub bands by using low pass filters and high pass filters.

Step4: Similarly second and thirds level dwt is applied one by one and we get further mid bands.

Step5: Now these mid bands are transformed again by using DCT.

Step6: Watermarked image is converted into binary so that the watermark signal is synchronized with audio signal later.

Step7: Watermark image is further resized into 64*64 matrixes and convert into column vector.

Step8: Find the number of pixels in image.

Step9: Add coefficient of image into each frame at its first location.

Step10: Take inverse of that coefficient using DCT.

Step11: And then audio wave file is reconstructed by using multilevel 1-D wavelet reconstruction.

Step12: All the low pass and high pass filters are reconstructed to get the audio file format again.

Step13: At the end inverse DWT is applied to have the watermarked audio signal.

3.4 Extraction Procedure

After embedding the watermark a big challenge is to extract the watermark just to see the originality of audio file. For this purpose a watermarked audio file is used. And then this file is converted by using DWT. After formatting the image is extracted and the transpose of that image is taken. This algorithm is basically used to extract image from the watermarked audio file. The main operation is done by using pixels of the image and the number of samples in each audio frame. Then DWT of original audio is taken. Then extraction of image is done. After that un-normalized the image and take transpose of image and then reshape it to display.

3.5 Hybrid DWT-DCT algorithm for Watermark extraction

Step1: Take particular frame of watermark embedded audio.

Step2: Also take particular frame of original audio by using Repeat j=1 to f (where j is a simple counter variable and f is the number of sample in each frame)
end

Step3: Take DWT and DCT of each frame of watermark embedded audio and original audio by using multi level 1-D wavelet decomposition.

Step5: Take particular frame of audio

Step4: Now subtract the coefficient of image and audio.

Step5: Subtracted image coefficient is then multiplied by maximum size of original image and then divided by image factor 0.01 to un-normalized the image, so that image is converted into binary.

Step5: Take inverse of un-normalized image.

Step6: After that the image is converted from column vector to binary and then into 64*64 blocks.

Step5converts the elements of the array of image into unsigned 8-bit integers

Step7: Show image to ensure the presence of watermarked audio.

4. Experimentation

In this section the results of proposed algorithm is shown. Five wave files of different genre are used as a host signal and two different random logos are used as a watermark. After embedding, different attacks are applied on all the watermarked audio signal just to check the robustness of the audio. In this research 5 different genre of music (Jazz, POP, Rock, Hip-Hop,RnB)are used in wave format . The experimental results of extraction of watermark are shown below. The results of PSNR, NC, MOS and BER have also shown in table 2 and 3.

For checking the efficiency of watermark image, the peak signal to noise ratio rule of the dissimilarity between an original watermark W and the corresponding extracted watermark W. This PSNR is formulated as follows

For checking the efficiency of watermark image, the peak signal to noise ratio rule of image, the peak signal to noise ratio rule of the dissimilarity between an original watermarks and the corresponding extracted watermark. If the value of PSNR is greater than 35 so thevalue is in an acceptable range. (Sujit M. Deokar, 2015)

Conclusion

In this section the robustness of proposed algorithm is also being checked. Different attacks like AWGN (adding white Gaussian noise), filtering 10 KHZ, requantization and resampling is applied to the watermarked audio and result is compared with the previously described techniques. The PSNR and NC(normalized correlation) is checked after these all attacks. For checking the imperceptibility the MOS grading is being used.

TABLE 1: MOS Grading Scale

MOS Scale	Meaning
5	Imperceptible to Human Ear
4	Slightly Perceptible
3	Slightly Annoying
2	Annoying
1	Very Annoying

A listening test was performed for checking the imperceptibility rate of proposed algorithm after above mentioned attacks. Five wave files are checked and tested against two different random watermark logos. The experimental results with watermark one of all files are shown in table 2 and the experimental results with second watermark are shown in table 3.

In This table all the five wave files (Jazz, Rock, Pop, HipHop, and RnB) are tested with and without attacks. The PSNR, NC, MOS and BER values are shown in different columns of table respectively. All the files are one by one tested thrice. First DWT is applied then DCT is applied and after all the combination of these both is applied and the results are displayed in table.All the experiments of table 2 are applied using a random logo of flowers. The extraction results of all the experiments with flower watermark are shown bellow in figure 1.1, 1.2, 1.3,2.1,2.2,2.3 and so on. Results show that the combination of DWT and DCT gives good results then the plain DCT and DWT. And this technique is also robust enough against different attacks.

TABLE 2: Results before and after attacks with Watermark one (A random logo of flowers)

		DWT				DCT				DWT+DCT			
		PSNR	NC	MOS	BER	PSNR	NC	MOS	BER	PSNR	NC	MOS	BER
JAZZ	NO ATTACK	46.12	1	5	0.99	42.61	1	5	0.98	49.63	1	5	1
	AWGN	46.11	1	5	o.98	42.02	1	5	0,94	46.32	1	5	1
	Requantization	40.32	0.98	4	0.93	38.26	0.92	4	2.67	42.63	1	5	0.99
	Resembling	30.28	0.97	3	0.86	25.63	0.88	3	0.99	39.34	0.96	4	0.96
	Filtering	29.2	0.96	2	0.89	20.1	0.86	2	0.98	38.44	0.89	4	0.81
ROCK	NO ATTACK	47.38	1	5	1	45.35	1	4	0.99	48.36	1	5	1
	AWGN	47.37	1	5	0.98	44.39	1	4	0,94	47.88	1	5	0.99
	Requantization	40.31	0.97	4	0.96	39.38	0.91	3	0.67	42.62	0.97	5	0.97
	Resampling	26.52	0.88	2	0.94	23.28	0.88	2	0.99	32.32	0.89	4	0.95
	Filtering	21.03	0.84	2	0.89	21.08	0.82	2	0.98	29.38	0.92	3	0.88
POP	NO ATTACK	44.47	1	5	1	40.61	1	4	0.99	48.34	1	5	0.99
	AWGN	44.46	1	5	1	39.28	1	3	0.67	46.33	1	5	0.97
	Requantization	39.5	0.98	4	0.89	32.62	0.93	3	0.99	42.62	0.98	5	0.89
	Resampling	35.26	0.97	4	0.86	31.33	0.92	2	0.98	40.11	0.99	4	0.85
	Filtering	30.51	0.97	3	0.81	28.68	0.91	2	0.99	36.32	0.86	3	0.88
HIPHOP	NO ATTACK	47.81	1	5	1	43.66	1	4	0.95	49.38	1	5	0.99
	AWGN	47.8	1	5	1	42.32	1	4	0.88	49.23	1	5	0.99
	Requantization	39.69	0.79	4	0.97	33.62	0.66	3	0.99	42.62	1	4	0.98
	Resampling	30.6	0.78	2	0.95	29.62	0.69	2	0.97	39.63	0.93	3	0.96
	Filtering	29.6	0.77	2	0.88	27.63	0.6	2	0.89	36.32	0.83	3	0.94
RnB	NO ATTACK	45.85	1	5	0.99	40.29	1	4	0.85	49.63	1	5	1
	AWGN	44.86	0.99	5	0.97	40.11	0.99	4	0.88	48.33	1	5	1
	Requantization	40.87	0.88	4	0.89	36.28	0.62	3	0.99	42.62	1	5	0.99
	Resampling	30.5	0.45	3	0.85	28.23	0.43	2	0.99	32.5	0.99	4	0.98
	Filtering	24.2	0.68	2	0.88	21.68	0.32	2	0.99	25.63	0.98	3	0.98

TABLE 3: Results before and after attacks with Watermark two (A random logo of vegetables)

		DWT				DCT				DWT+DCT			
		PSNR	NC	MOS	BER	PSNR	NC	MOS	BER	PSNR	NC	MOS	BER
JAZZ	NO ATTACK	42.99	1	5.00	0.99	40.09	0.62	5.00	0.98	48.08	1.00	5.00	1
	AWGN	42.97	1	5.00	o.98	38.08	0.39	4.00	0,94	48.07	1.00	5.00	1
	Requantization	39.25	1	4.00	0.93	27.95	0.02	4.00	2.67	35.95	1.00	5.00	0.89
	Resembling	30.17	1	3.00	0.86	25.31	0.02	3.00	0.99	31.30	1.00	4.00	0.86
	Filtering	29.11	1	3.00	0.89	29.56	0.02	3.00	0.98	39.55	1.00	3.00	0.81

ROCK	NO ATTACK	44.25	1	5.00	1	42.41	0.89	4.00	0.99	49.08	1.00	5.00	1
	AWGN	44.24	1	5.00	0.98	42.01	0.78	4.00	0,94	49.01	1.00	5.00	1
	Requantization	23.48	0.98	4.00	0.96	23.02	0.28	2.00	0.67	28.20	1.00	5.00	0.97
	Resampling	20.52	0.45	1.00	0.94	10.21	0.01	1.00	0.99	29.28	0.88	3.00	0.95
	Filtering	25.03	0.45	1.00	0.89	28.61	0.01	1.00	0.98	31.28	0.72	3.00	0.88
POP	NO ATTACK	41.34	1	5.00	1	39.09	0.02	4.00	0.99	47.73	1.00	5.00	0.99
	AWGN	41.33	1	5.00	1	38.08	0.02	4.00	0.67	47.72	1.00	5.00	0.97
	Requantization	26.23	0.99	4.00	0.89	24.95	0.02	3.00	0.99	32.70	0.98	4.00	0.89
	Resampling	24.13	0.98	3.00	0.86	27.31	0.02	3.00	0.98	30.31	0.98	3.00	0.85
	Filtering	28.40	0.98	3.00	0.81	35.56	0.01	2.00	0.99	38.23	0.98	3.00	0.88
HIPHOP	NO ATTACK	44.69	1	5.00	1	39.68	0.86	4.00	0.95	49.68	1.00	5.00	0.99
	AWGN	44.68	1	5.00	1	38.27	0.82	4.00	0.88	49.28	1.00	5.00	0.99
	Requantization	40.31	0.96	4.00	0.97	29.62	0.77	3.00	0.99	34.57	1.00	4.00	0.98
	Resampling	25.66	0.88	2.00	0.95	21.68	0.69	2.00	0.97	30.68	0.99	3.00	0.96
	Filtering	29.50	0.86	2.00	0.88	29.62	0.69	2.00	0.89	42.62	0.98	3.00	0.94
RnB	NO ATTACK	42.73	1	5.00	0.99	40.92	1.00	5.00	0.85	48.62	1.00	5.00	1
	AWGN	42.73	0.99	5.00	0.97	39.28	0.99	4.00	0.88	48.28	1.00	5.00	1
	Requantization	30.60	0.93	3.00	0.89	30.48	0.96	3.00	0.99	41.27	1.00	4.00	0.99
	Resampling	29.49	0.59	2.00	0.85	27.28	0.82	2.00	0.99	39.28	0.98	3.00	0.98
	Filtering	33.17	0.84	2.00	0.88	32.72	0.86	2.00	0.99	41.68	0.98	3.00	0.98

In this table all the five wave files (Jazz, Rock, Pop, HipHop, and RnB) are tested with and without attacks. The PSNR, NC, MOS and BER values are shown in different columns of table respectively just like table 1.

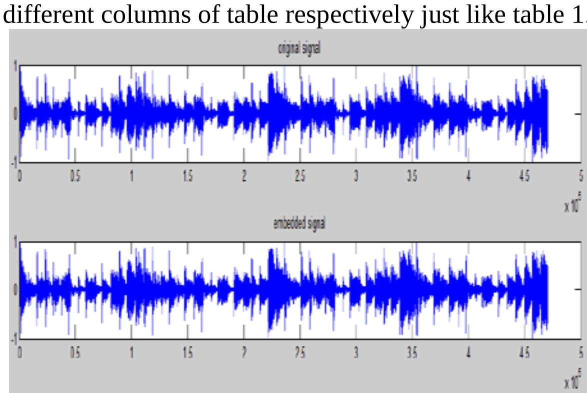


Figure 1: Original and Watermarked jazz signal

All the files are one by one tested thrice. First DWT is applied then DCT is applied and after all the combination of these both is applied and the results are displayed in table. All the experiments of table 2 are applied using a random logo of flowers. The extraction results of all the experiments with flower watermark are shown bellow in figure 2, 3, 4, 5, 6 and 7. Results show that the combination of DWT and DCT gives good results then the plain DCT and DWT. This technique is also robust enough against different attacks.

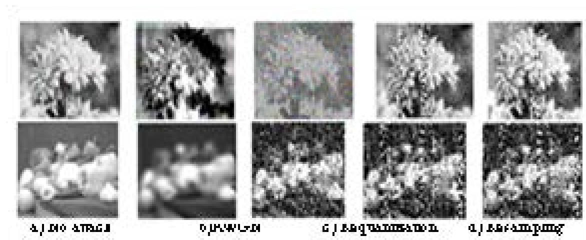


Figure 2: Discrete wavelet transform with jazz

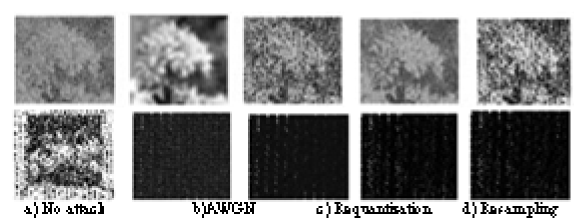


Figure 3: Discrete cosine transform with jazz

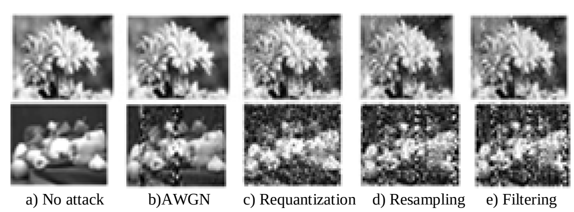


Figure 4: DWT + DCT with jazz

The experimental results of jazz signal with watermark one (random flower logo) and watermark two (random logo of vegetables) has shown in figure 2 with DWT. We can see that figure 2(a) is so clear because no attack applied on it. Figure 2(b) is also very clear and it shows that our technique is robust enough against AWGN attack and this is not affecting the value of vector combination of watermark. But when we talk about figure 2(c) and 2(d) we can see that this attack changes the vector combination of embedded watermark. Due to this, the value of PSNR and NC is also disturbed as shown in table 1 and table 2. Figure 2(e) is again a bit clear then 2(c) and 2(d) and the value of PSNR and NC also gives better results of this attack then requantization and resampling .Similarly in fig 3(a) to 3(e) the results of DCT has shown with random logo of flowers and random logo of vegetables. The figure 4(a) to 4(e) presents the combination of DWT, DCT which shows that these results are visually very bright and good because combination of DWT and DCT gives good values of PSNR, NC, and BER. Figure 3(a) to 3(e) displays the result of DCT with watermark two and it can be seen from figure 3(a) to 3(e) that DCT do not give good results with and without attacks. Similarly figure 4(a) to 4(e) the combine results of DWT, DCT with watermark two has shown that after the requantization, resampling and filtering the results are blur due to disturbance in vector combination of watermark.

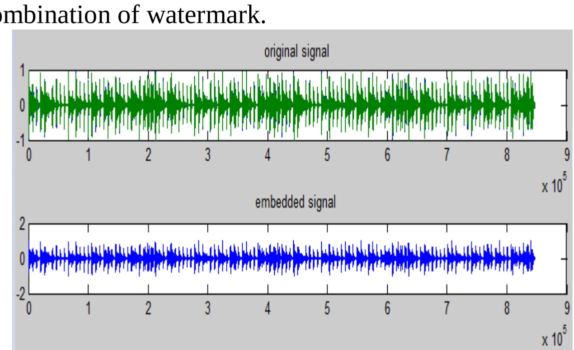
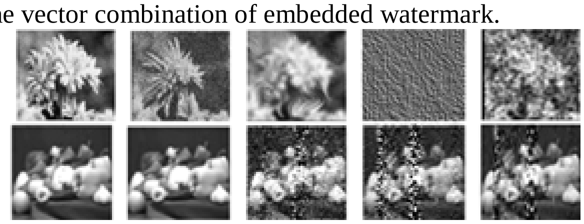


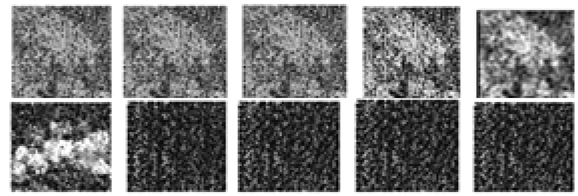
Figure 5: Original and watermarked Rock signal

The experimental results of Rock signal with watermark one and two has shown in figurr 6(a) to 6(e) with DWT. We can see that 6(a) is so clear because no attack applied on it. Figure 6(b) is also clear and it shows that our technique is robust enough against AWGN attack and this is not affecting the value of vector combination of watermark. Figure 6(c) is again a bit clear and PSNR and NC also gives better results of this attack. But when we talk about 6(d) and 6(e) we can see that this attack changes the vector combination of embedded watermark.



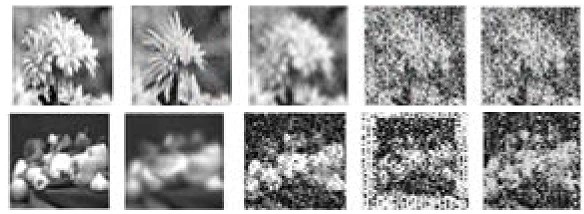
a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Fgure 6: Discrete wavelet transform with Rock



a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 7: Discrete cosine transform with Rock



a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 8: DWT + DCT with Rock

Due to this the value of PSNR and NC is also disturbed as shown in table 2 and table 3. Figure 6(e) is again a bit clear with watermark two than 6(c) and 6(d) and the value of PSNR and NC also gives better results of this attack then requantization and resampling. Similarly in figure 7(a) to 7(e) the results of DCT has shown with both watermarks. In figure 8(a) to 8(e) the results of combine DWT, DCT has shown and these results with watermark one are visually very bright and good because combination of DWT and DCT gives good values of PSNR, NC, and BER. Similarly the combine results of DWT, DCT with watermark two also very clear. Here also after the requantization, resampling and filtering the results are blur due to disturbance in vector combination of watermark two.

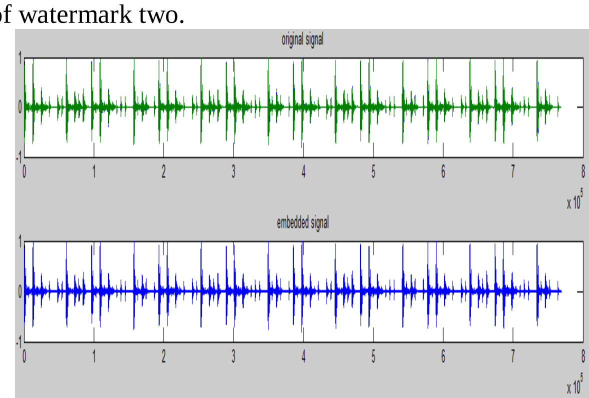
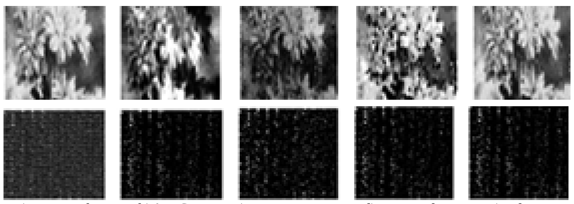


Figure 9: Original and Watermarked Pop signal

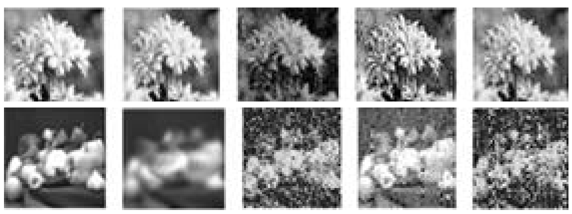
a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 10: Discrete wavelet transform with Pop



a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 11: Discrete cosine transform with Pop



a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 12: DWT + DCT with Pop

The experimental results of Pop signal with both the watermarks are shwon in figure 10, figure 11 and figure 12. We can see that 12(a) is so clear because no attack applied on it. Figure 12(b) is also clear and it shows that our technique is robust enough against AWGN attack and this is not affecting the value of vector combination of watermark. Figure 12(d) is again a bit clear and PSNR and NC also gives better results of this attack. But when we talk about 12(c) we can see that this attack changes the vector combination of embedded watermark. Due to this the value of PSNR and NC is also disturbed as shown in table 2 and table 3. Figure 12(e) is bit clear than 12(c) and the value of PSNR and NC also gives better results of this attack then requantization and resampling .Similarly in fig 11(a) to 11(e) the results of DCT has shown very poor results. The results of combine DWT, DCT has shown that the extracted watermarks are are visually very bright and good because combination of DWT and DCT gives good values of PSNR, NC, and BER. But the results with watermark two are little bit blurred after the requantization, resampling and filtering due to disturbance in vector combination of watermark.

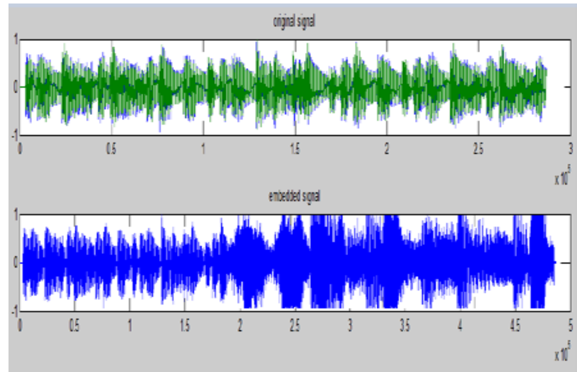
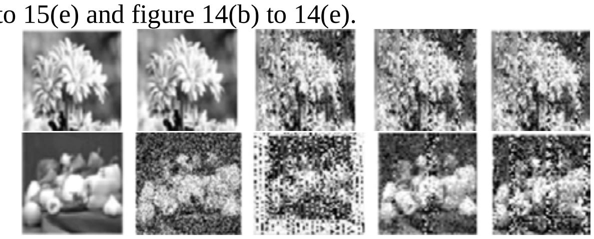


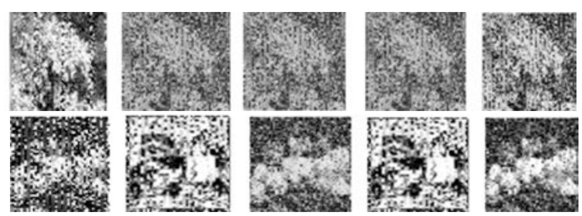
Figure 13: Original and Watermarked Hip-Hop Signal

The experimental results of Hip-Hop signal with watermark of random flower logo and random logo of vegetables has shown in figure 14, figure 15 and figure 16. We can see that figure 16(a) is so clear because no attack applied on it. Figure 16(b) is also very clear and it shows that our technique is robust enough against AWGN attack and this is not affecting the value of vector combination of watermark. Similarly fugure 16(c), 16(d) and 16(e) are litle bit blurred. But very clear as compare to figure 15(b) to 15(e) and figure 14(b) to 14(e).



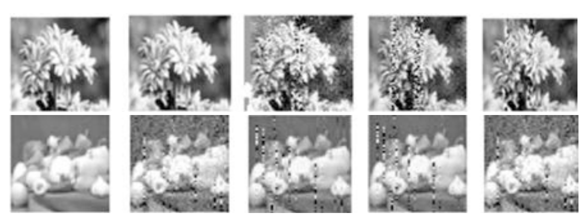
a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 14: Discrete wavelet transform with Hip-Hop



a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 15: Discrete cosine transform with Hip-Hop



a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 16: DWT + DCT with Hip-Hop

When we talk about figure 14 and figure 15 we can see that after applying the attacks the vector combination of embedded watermarkis changed. Due to this, the value of PSNR and NC is also disturbed as shown in table 2 and table 3. Figure 15(a) to 15(e) displays the result of DCT with watermark on and two, where it can be seen that DCT do not give good results with and without attacks.

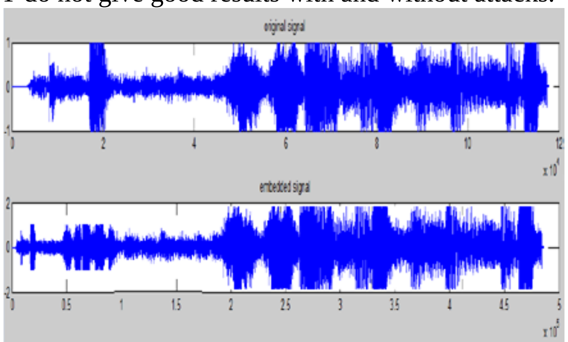
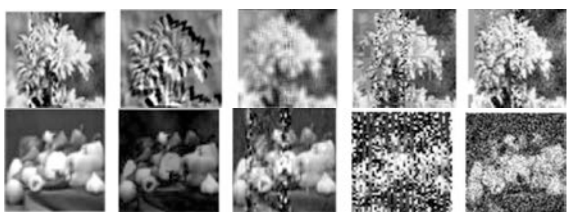
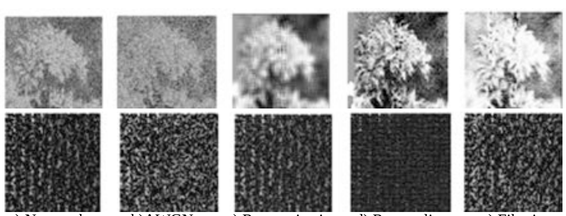


Figure 17: Original and Watermarked RnB signal



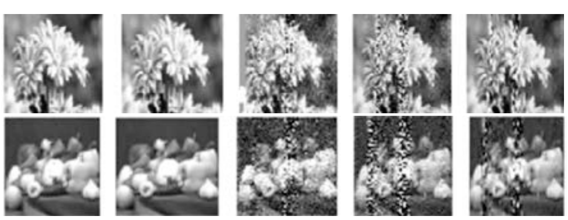
a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 18: Discrete wavelet transform with RnB



a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 19: Discrete cosine transform with RnB



a) No attack b)AWGN c) Requantization d) Resampling e) Filtering

Figure 20: DWT + DCT with RnB

Figure 18, figure 19 and figure 20 shows the experimental results of RnB signal with both watermarks. We can see that figure 20(a) is so clear because no attack applied on it. Figure 20(b) is also very clear and it shows that our technique is robust enough against AWGN attack and this is not affecting the value of vector combination of watermark. But when we talk about figure 20(c), 20(d) and 20(e) we can see that these attacks changes the vector combination of embedded watermark. Due to this, the value of PSNR and NC is also disturbed as shown in table 2 and table 3. Figure 19(a) to 19(e) shows the results of DCT with random logo of flowers and random logo of vegetables. Figure 20 shows the results of combine DWT, DCT, we can observe that these results are visually very bright and good because combination of DWT and DCT gives good values of PSNR, NC, and BER.

5. Conclusion

The experiments with five different signals and two different watermarks are described above, from these results it can be concluded that when no any attack, the results of extracted watermark (flowers/ vegetables) is visibly clear. The results after AWGN are also not bad. It demonstrate that this techniques is robust enough AWGN attack. But when requantization and resampling is applied the result of extracted watermark become slight blur. This shows that this technique do not show much robustness against these attack. But after applying filtering the extracted watermark is again clear so at the end, we can conclude that our technique is robust enough against different attacks like AWGN and filtering. The results of proposed approach are also caompare with simple DWT and DCT, we can also observe that the result of the hybridization of these both techniques has shown good results against different external attacks. The MOS and PSNR values are compared. That shows our proposed techanique is robust enough against different attacks.

As far as future directions of the work is concerned so the results can be further enhanced by using the mixture of any other transformation technique with the previous one like Discrete HAAR wavelet transform and DCT or DHT and DWT.

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