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# Implementation of Audio Watermarking Using Wavelet Families

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**Abstract**

The implementation of audio watermarking in images using wavelet families is proposed in this paper. The secret data used is audio and the input image is color image. The algorithm is based on decomposition of images using Haar wavelet basis, Daubechies wavelet, Biorthogonal wavelet, Reverse biorthogonal wavelet and Discrete approximation of Meyer wavelet. The later part of the paper compares the watermarking results of different wavelet families for quality metrics such as PSNR, MSE, RMSE and Entropy. The retrieval of secret data is satisfactory under certain attacks such as cropping, compression, noise effect, geometrical attacks and contrast enhancement.

**Keywords**

**Audio watermarking, Wavelet families, DWT, Copyright protection**

## I. INTRODUCTION

During the past decade, the growth of internet industry is tremendous and the use of digital multimedia has increased manifolds. The easy reproduction, coping or transmission digital data has urged the demand for watermarking for the content authentication, copyright protection and protection of Intellectual Property Rights (IPR). Digital watermarking exploits the properties of Human Vision System (HVS) and provides better masking properties.

Watermarking is a process of embedding information into the audio, video or digital image to comply the information regarding the ownership or to track copyright tampering[8]. Watermarking is done to ensure that the watermark is imperceptible and robust to image processing attacks.

Watermarking is used to embed the secret data on an image or any type of multimedia data. Its prime area of application is telebroadcasting and web applications. The audio watermarking system hides the secret audio in the cover image. It hides information in the data in such a way that the basic appearance of the data is not destroyed [2].

Watermarking an audio file within an image is still a very amateur area [7]. The cover image is used to hide the information or secret audio sample owing to the fact that HVS is less sensitive than Human Auditory System(HAS) and provides better masking properties[9].

Watermarking a binary sequence in an audio [3-4] or an image [5-6] is relatively easy as the watermark consists of just two binary values and the deviation of the coefficients of the transformed host from a predefined threshold are monitored to find out either a '1' or '0' value of watermark. But an audio signal swings between a limited range and embedding it in a cover image results in severe tampering of its amplitudes. We are emphasizing on devising an algorithm that allows minimum audible distortion to the audio by embedding watermark in the wavelet coefficients (decomposition of image using wavelet basis) that belong to approximation band.. When watermarked image is subjected to certain attacks such as cropping, compression, noise effect etc., the recovery of hidden data is not much affected. The performance parameters for watermarking scheme are robustness, perceptual quality, capacity and security.

## II. PROPOSED WATERMARKING SCHEME

The proposed technique uses the wavelet transformation domain to embed the data so as to exploit the advantages of wavelet transformation being resistant to frequency attacks [1].Hide the audio in one of the frequency band of wavelet transform of image. The algorithm uses simple substitution method in wavelet coefficients of the cover image for embedding as the encoding and decoding is faster. The cover image used is color image (24bit) of size 1024x1024. The proposed watermark embedding and extraction process is described as follows:

### A. Watermark Embedding

1. Select the color image (24bit).

2. Separate the three planes of color image and choose B plane of color image for embedding purpose.

3. Compute 2D-DWT to convert B plane of color image into four sub bands. The four sub bands obtained are approximate band(LL), Vertical band(LH), Horizontal band(HL) and Diagonal band(HH) shown in fig. 1.

| | |
|---|---|
| LL | HL |
| LH | HH |

Fig.1 2D DWT Coefficients

The approximation band consists of low frequency wavelet coefficients which contain significant part. The other bands also called as details bands consists of high frequency coefficients. DWT has been employed in order to preserve the high frequency components of the image.

4. Select the LL sub band of decomposed image for hiding audio.

5. Convert the approximation band from 2D to 1D.

6. Check the length of LL band, if the LL band length is less than secret audio length, you can't hide the data in cover image.

7. If the LL band length is greater than secret audio, you can hide the data in cover image.

8. Insert the watermark into selected wavelet coefficients using additive multiplicative equation [10]:

$$V_i' = V_i + \alpha X_i$$

Where $X_i$ = the i[th] watermark value

$V_i$ = the original wavelet coefficient

$\alpha$ = the strength of watermark

$V_i'$ = modified wavelet coefficient

As the strength of watermark is increased the robustness of watermark increases and its recovery is good but the image suffers visible degradation. So the value of the watermark strength is chosen as a trade-off between perceptibility and robustness.

9. Compute the inverse DWT for B plane of color image and add R and G planes to it generate watermarked image.

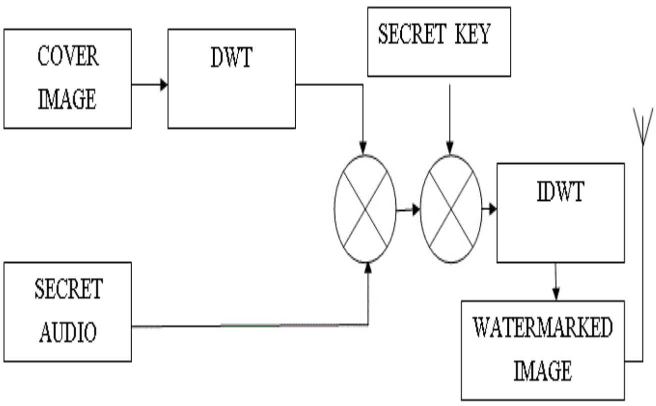



Fig.2 Watermark Embedding

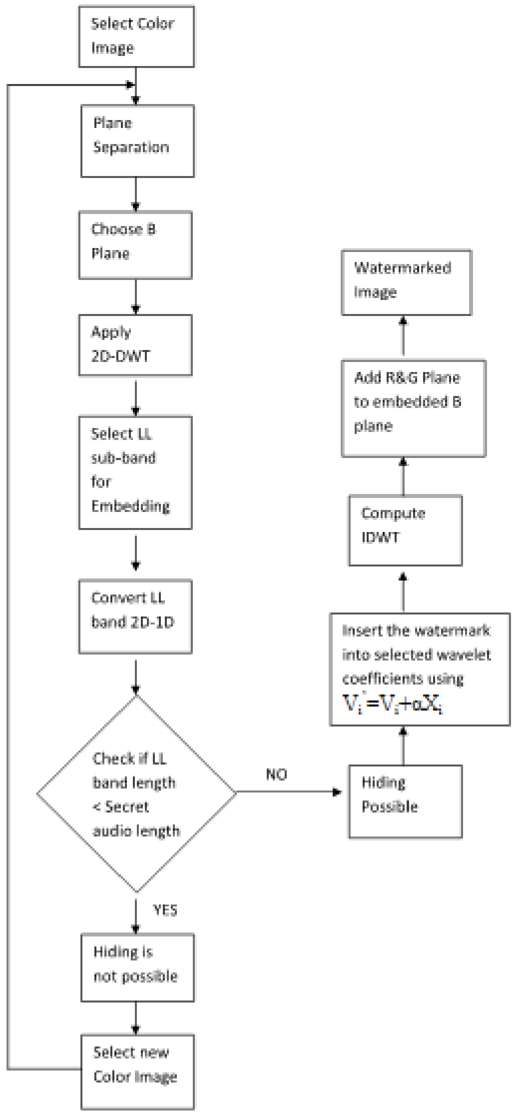



Fig 3. Flow chart of Embedding Process

**B. Watermark Extraction**

1. Apply DWT on original image and watermarked image to get four bands

2. Extract the watermark by using the inverse of the insertion equation [10]. The watermark is extracted by using equation

$$X'i = \frac{Vi' - Vi}{\alpha}$$

Where $X'i$ = the ith recovered watermark value

Vi = the original wavelet coefficient

α= the strength of watermark

3. Extracted watermark are the wavelet coefficients of audio sample which are passed to decoder to generate the speech.

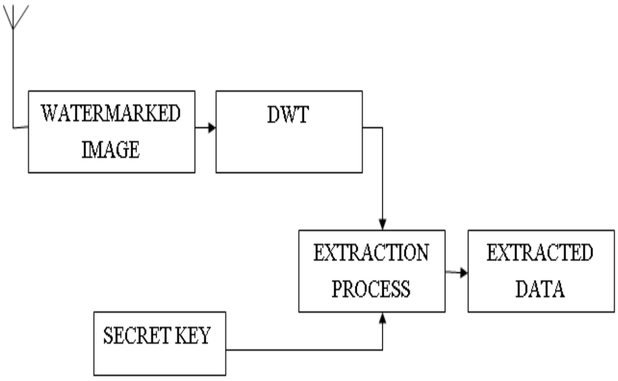



Fig.4 Watermark Extraction

## III. EXPERIMENTATION

The proposed algorithm has been experimented on a number of color images and a single audio clip that was WAV file. The result are discussed for three images namely 'Penguin', 'Lena' and '22bmp' while as one audio sample of duration namely 'sample1'(4.8135s) are taken into consideration.

The Peak Signal to Noise Ratio (PSNR) and entropy of the host image and the watermarked image is used to estimate the visual imperceptibility of the audio watermark. The correlation between the original audio clip and the extracted audio clip is monitored by the respective Root mean Square (RMS) values of each. Further the subplots of original and extracted audio samples are shown for different combinations of cover images and audio watermarks. The robustness of the scheme is to be tested by considering the different types of image processing attacks like cropping, rotation, contrast enhancement, Gaussian noise speckle noise, Poisson noise and salt and pepper noise effect. The experimental result should show that the embedding watermark into sub band coefficients is robust against different types of attacks.

## IV. QUALITY METRICS

### A. Mean Square Error and Peak Signal to Noise Ratio

The mean square error between original and watermarked image is calculated as follows [11]:

$$\text{MSE}=\frac{1}{Nt}\sum_{i,j}[X(i,j)-X'(i,j)]^2$$

Where X(i,,j) = original image

X'(i,,j) = watermarked image

& Nt = size of image

Peak Signal to Noise Ratio (PSNR) between original and watermarked image is calculated as follows [11]:

$$\textbf{PSNR (db)} = 10\log_{10}\frac{255x255}{MSE}$$

For acceptable perceptual quality, the PSNR value should be greater than 30dB. Higher the PSNR more similar is watermarked image to the original image.

### B. Entropy

Entropy is a statistical measure of randomness that can be used to characterize the texture of the input image.

R = -sum (x.*log(x))

Where x signifies the histogram counts for a grey-scale image.

Entropy of an image is one of the parameters of an image and it doesn't change when the image is not changed. In this paper Entropy is used as a quality metrics to measure the degree of perceptibility of watermark in the cover image by comparing the original and watermarked images. Thus the effect of embedding algorithm on cover image in terms of perceptual similarity between the original image and watermarked image using is measured through Entropy.

### C. Correlation Coefficient

The correlation coefficient between the original audio clip and the extracted audio clip is calculated to predict the quality of extracted audio. Its value lies between 0-1. 1 indicates exact reproduction of the original audio clip.

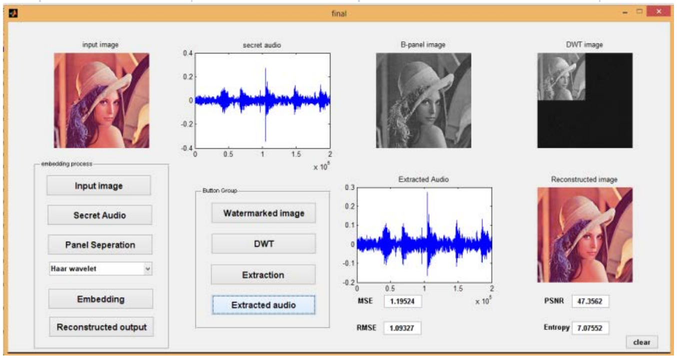
## V. RESULTS AND ANALYSIS

### A. Measuring Perceptual Quality of Watermarked Image

We use PSNR and Entropy to discuss the effect of embedding algorithm on cover image in terms of perceptual similarity between the original image and watermarked image. The results shows that there is only slight variation exist in entropy but PSNR remains almost constant for different cover images using same wavelet transform. This indicates that the embedding algorithm will modify the content of original image by negligible amount. The amount of noise added to color cover image is calculated by using MSE and PSNR. The data obtained for different wavelet families is tabulated in the table given below:

Table1: Simulation results of the proposed technique

| S.no | Cover image | Secret audio | Type of Wavelet | MSE | RMSE | PSNR | Entropy of orginal image | Entropy of Watermarked image | correlation coefficient |
|---|---|---|---|---|---|---|---|---|---|
| 1 | lena.bmp | sec.wav | Haar | 1.1952 | 1.0932 | 47.3562 | 7.442 | 7.0755 | 0.9984 |
| | | | db1 | 1.1952 | 1.0932 | 47.3562 | 7.442 | 7.0755 | 0.9984 |
| | | | bior 1.3 | 1.1929 | 1.0922 | 47.3646 | 7.442 | 7.0746 | 0.9987 |
| | | | rbior 1.3 | 1.2151 | 1.1023 | 47.2845 | 7.442 | 7.0755 | 0.9987 |
| | | | dmey | 1.0582 | 1.0287 | 47.8849 | 7.442 | 7.0445 | 0.9181 |
| 2 | 22.bmp | sec.wav | Haar | 1.1821 | 1.0872 | 47.404 | 6.8142 | 7.2648 | 0.9971 |
| | | | db1 | 1.1821 | 1.0872 | 47.404 | 6.8142 | 7.2648 | 0.9971 |
| | | | bior 1.3 | 1.1671 | 1.0803 | 47.4596 | 6.8142 | 7.2648 | 0.9946 |
| | | | rbior 1.3 | 1.1742 | 1.0836 | 47.4331 | 6.8142 | 7.3194 | 0.9946 |
| | | | dmey | 0.9809 | 0.9904 | 48.2145 | 6.8142 | 7.3067 | 0.9055 |
| 3 | Penguins.bmp | sec.wav | Haar | 1.0393 | 1.0195 | 47.963 | 7.709 | 7.4583 | 0.955 |
| | | | db1 | 1.0393 | 1.0195 | 47.963 | 7.709 | 7.4583 | 0.955 |
| | | | bior 1.3 | 1.0462 | 1.0228 | 47.9343 | 7.709 | 7.4616 | 0.9521 |
| | | | rbior 1.3 | 1.0577 | 1.0284 | 47.8871 | 7.709 | 7.4647 | 0.9566 |
| | | | dmey | 0.8996 | 0.9484 | 48.5902 | 7.709 | 7.4637 | 0.8699 |




**B PERFORMANCE OF THE EXTRACTION ALGORITHM**

The performance of extraction algorithm can be ascertained without considering any attacks on water marked image and with considering different types of image processing attacks on watermarked color image such as Poisson noise, salt and pepper noise, compression and rotation.

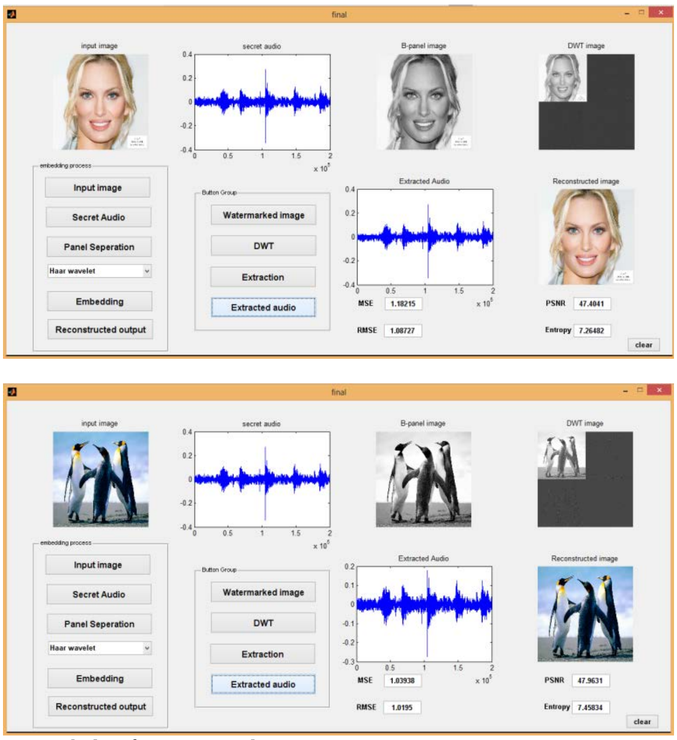


Fig.5 Subplots for Haar wavelet

The subplot of fig.6 shows original and extracted audio without considering attack on reconstructed output. It shows minimum audible distortion in extracted audio.

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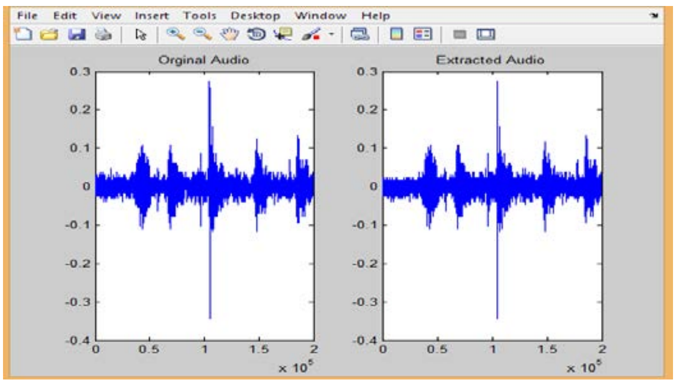


Fig.6 Subplots of original and extracted audio

The fig.7 shows the comparative charts for MSE, RMSE, PSNR and Entropy of watermarked images.

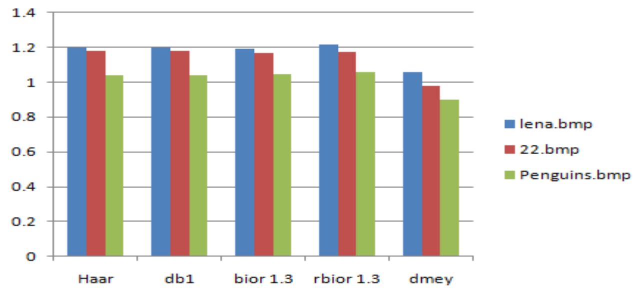

Fig. 7a MSE of watermarked images

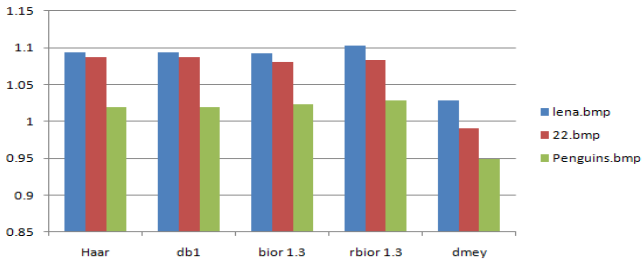


Fig. 7b RMSE of watermarked images

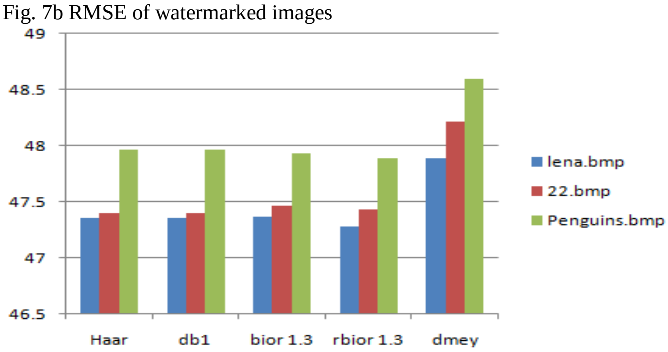

Fig. 7c PSNR of watermarked images

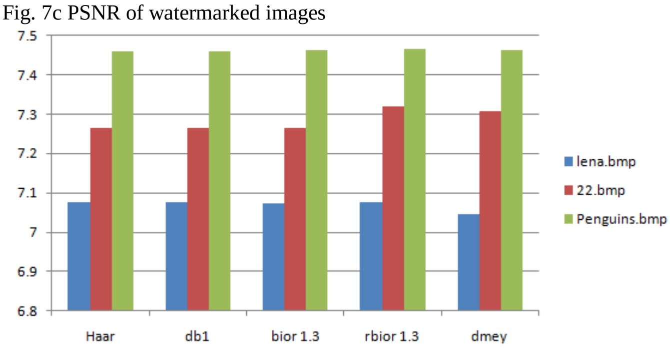


Fig. 7d Entropy of watermarked image

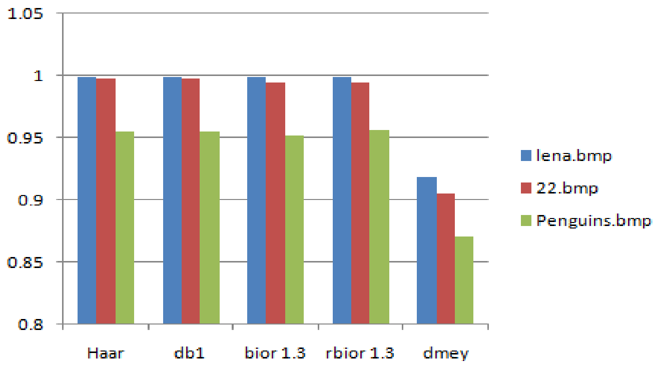


Fig. 7e Correlation coefficient of watermarked images

From simulation results of the proposed technique listed in Table 1, the following implications can be made on the case without considering any attacks:

1). Larger PSNR indicates better perceptual quality. As far as same transform is used, PSNR gives the same value for different images but provides different values of PSNR for different wavelet families. Dmey provides best result.

2). Entropy is same for the same image in different transforms. The value of the entropy is different for different images. The values of original entropy and watermarked entropy are to be considered for calculating the degree of perceptibility of watermark.

3). A perfect reproduction of original image will have an MSE equal to zero but watermarked image greatly differs from the original image when MSE will have large value. It is best in Dmey.

4). MSE, RMSE and PSNR is better in Dmey. But the CC value is poor in Dmey. On the average Haar , db1,bior 1.3 and rbio 1.3 provides better values for CC indicating that extracted audio quality will be better in these families.

5). Entropy for original and watermarked images are almost same indicating better perceptibility.

The expected result should show that the proposed algorithm works well and is resistant to different types of attacks. Also we are supposed to compare the results for different wavelet families and try to find the better one in particular respect. The work is under progress.

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## VI. FUTURE WORK

The future efforts should be focussed to:

(i). increase embedding capacity.

(ii). increase security of algorithm by using cryptography techniques along with watermarking.

(iii). extend the work to video watermarking.

(iv). Use multilevel transform to increase security.

(v). Analyse the proposed work by using contour-let transform and curve-let transform.

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