A Novel Secured Approach of Digital Image Watermarking Using Wavelet Decomposition

[1]Vivek Soni, [2]Rashika Gupta, [3]Ravimohan
1Research Scholar, 2Assistant Professor, 3Professor & H.O.D.
Dept. of ECE, SRIT, Jabalpur

Abstract: **There is a need of an effective watermarking technique for copyright protection and authentication of intellectual property. In this work we proposes a digital watermarking technique which makes use of simultaneous frequency masking to hide the watermark information into host. The algorithm is based on wavelet based decomposition of both the images. It generates a watermark signal using DWT in sub-bands, and at the same time the host is also decomposed into sub-bands, then sub-band mapping or coding is done in frequency domain. Since the watermark is shaped to lie below the masking threshold, the difference between the original and the watermarked copy is imperceptible. Recovery of the watermark is performed without the knowledge of the original signal. The software system is implemented using MATLAB and the characteristics studied.**

Keywords: **Watermarking, DWT, Security, Sub-band Coding.**

Introduction

In modern world each and every form of information, like text, images, audio or video, has been digitized. [14] Widespread networks and internet has made it easier and far more convenient to store and access this data over large distances. Although advantageous, this property threatens the copyright protection purpose [14].

Media and information in digital form is easier to copy and modify, and distribute with the aid of widespread internet. Every year thousands of sound tracks are released and within a few days are readily available on the internet for download. Without any information on the track itself, it's easy for someone to make profit out of them by modifying the original and selling under a different name. As a measure against such practices and other intellectual property rights, digital watermarking techniques can be used as a proof of the authenticity of the data.

Digital Watermarking is the process of embedding or inserting a digital signal or pattern in the original data, which can be later used to identify the author's work, to authenticate the content and to trace illegal copies of the work [12].

Requirements

Some of the requirements of the digital watermarking are:

***** The original media should not be severely degraded and the embedded data should be minimally perceptible. *****The words hidden, inaudible, imperceptible, and invisible mean that nobody notice the presence of the hidden data.

***** The hidden data should be directly embedded into the carrier, rather than into the header of it.

***** The watermark should be robust, also it should immune to all types of modifications including channel noise, filtering, re-sampling, cropping, encoding, lossy compressing, digital-to-analog (D/A) conversion, and analog-to-digital (A/D) conversion, etc.

***** It should be easy for the owner or a proper authority to embed and detect the watermark.

***** It should not be necessary to refer to the original signal when extracting a watermark.

Important Parameters for Audio Watermarking

As discussed earlier the main requirements of an efficient watermarking technique are the robustness and inaudibility. Some of the pre-requites parameters are:

- *Dynamics*
- *Filtering*
- *Ambience*
- *Conversion and lossy compression*
- *Noise*

Overview of Digital Audio Watermarking Techniques

Watermarking techniques can be classified into two groups based on the domain of operation. One is time domain technique and the other is transformation based method. The time domain techniques include methods where the embedding is performed without any transformation. Time domain watermarking technique is the example of least significant bit (LSB) method. As against these techniques, the transformation based watermarking methods perform watermarking in the transformation domain. Few transformation techniques that can be used are discrete cosine transform and discrete wavelet transform. In transformation based approaches the embedding is done on the samples of the host signal after they are transformed. Using of transformation based techniques provides additional information about the signal [11].

In all-purpose, the time domain techniques provide least robustness as a simple low pass filtering can remove the watermark [1]. Hence time domain techniques are not advisable for the applications such as copyright protection and airline traffic monitoring; however, it can be used in applications like proving ownership and medical applications. Watermarking techniques can be distinguished as visible or we can say it as non-blind watermarking and blind watermarking. In the following, we present typical watermarking strategies such as LSB coding, spread spectrum technique, patchwork technique, and quantization index modulation (QIM).

LSB Coding

LSB coding is based on the replacement of the LSB of the carrier signal with the bit pattern from the watermark noise [16]. The robustness relies upon number of bits that are being replaced in the host signal. This type of technique is usually used in image watermarking because each pixel is represented as an integer hence it will be easy to replace the bits. The audio signal has real values as samples, if transformed to an integer will degrade the quality of the signal to a great extent (see Fig 1).

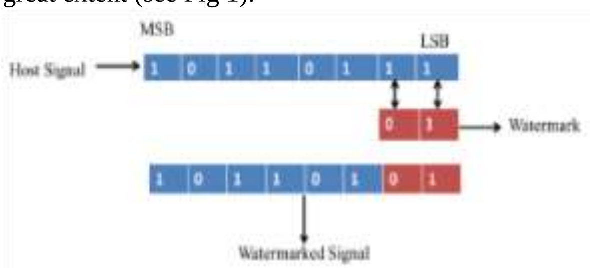

Fig 1: LSB Embedding

Spread Spectrum Technique

These techniques are derived from the concepts used in spread spectrum communication [15]. The basic approach is that a narrow band signal is transmitted over the large bandwidth signal which makes them undetectable as the energy of the signal is overlapped. In the similar way the watermark is spread over multiple frequency bins so that the energy in any one bin is very small and certainly undetectable [14]. In spread spectrum technique, the original signal is first transformed to another domain using domain transformation techniques [13]. The embedding technique can use any type of approach for example quantization. Zhou *et al.* proposed an algorithm embedding watermark in 0th DCT coefficient and 4th DCT coefficients which are obtained by applying DCT on the original signal [5]. Both embedding and extraction procedure can be interpreted using Figure 2. The original signal is transformed into frequency domain using DCT. Then watermark is embedded to the sample values in that domain. Reverse procedure is followed to obtain the watermarked signal (see Fig 2).
Embedded signal will go through some attacks, thus, noise is added to the signal. To extract the watermark the attacked signal is fed through extraction procedure. The procedure for extractions follows the same steps as that in embedding procedure as shown in Figure 2. The extraction process involves taking the attacked signal and applying DCT, framing the obtained components. And they obtained frames are used to obtain the watermark. Care is taken to replicate the procedure used for embedding process.

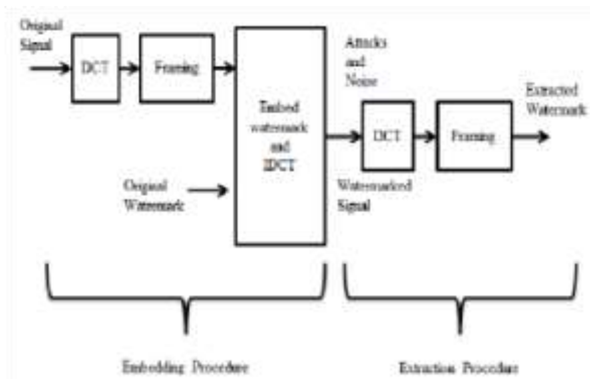

Fig 2: Example for spread spectrum technique

Patchwork Technique

In this method the data to be watermarked is divided into two distinct subsets. One part of the data is selected and customized in opposite directions in both subsets [13]. N*A* and N*B* indicate the size(s) of the individual *A* and *B* parts and *Δ* be the total of the change made to the host signal. Suppose that *a*[*i*] and *b*[*i*] represent the sample values at **i^th^** position in blocks *A* and *B*. The difference of the sample values can be written as [23]:

$$S = \frac{1}{N_A}\sum_{N_A} a[i] - \frac{1}{N_B}\sum_{N_B} b[i]$$
$$= \frac{1}{N}\sum_{N}(a[i]-b[i]); \quad N_A = N_B = N$$

The expectation of the difference is used to extract the watermark which is expressed as follows [4].

$$E\{S\} = \begin{cases} 2\Delta; \text{for watermarked data} \\ 0; \text{for unwatermarked data} \end{cases}$$

Watermarking in spectral domain

There are many transforms that can be used for conversion of a time domain image data into frequency domain. Among most popular transforms are:

- Discrete Cosines Transform (DCT)
- Fast Fourier Transform (FFT)

Discrete Cosine Transform

The discrete cosine transform is a technique for converting a signal into elementary frequency components [17]. The DCT can be applied on both one-dimensional and two dimensional signals like audio and image, but gives best results for audio signal mixing. The discrete cosine transform is a spectral domain transformation, which has the inherit properties of Discrete Fourier Transformation [17]. Basically DCT uses only cosine functions of various wave numbers as basic functions and operates on real-valued spectral coefficients & signals. DCT of a 1-dimensional (1-d) sequence and the reconstruction of original signal from its DCT coefficients termed as inverse discrete cosine transform (IDCT) [17]. In the following, fdct(x) is original sequence while Cdct(u) denotes the DCT coefficients of the sequence.

$$C_{dct}(u)=\alpha(u)\sum_{x=1}^{N_{1t}-1} f_{dct}(x)\cos\left[\frac{\pi(2x+1)u}{2N_{1t}}\right], \; for\, u=0,1,2,...,N_{1t}-1$$

$$f_{dct}(x,y)=\sum_{u=1}^{N_{1t}-1}\alpha(u)C_{dct}(u)\cos\left[\frac{\pi(2x+1)u}{2N_{1t}}\right], \; for\, x=0,1,2,...,N_{1t}-1$$

$$where\; \alpha(u)=\begin{cases}\sqrt{\frac{1}{N_{1t}}} & \text{for } u=0\\ \sqrt{\frac{2}{N_{1t}}} & \text{for } u\neq 0\end{cases}$$

From the equation for Cdct(u) it can be inferred that for u = 0, the component is the average of the signal also termed as dc coefficient in literature [38]. And all the other transformation coefficients are called as ac coefficients. Some of the important applications of DCT are image compression and signal compression.

The most useful applications of two-dimensional (2-d) DCT are the image compression and encryption [17]. The 1-d DCT equations, discussed above, can be used to find the 2-d DCT by considering every row as an individual 1 -d signal. Thus, DCT coefficients of an M×N two dimensional signals Cdct2(u, v) and their reconstruction *fdct2*(x, y)can be calculated by the equations below:

$$C_{dct2}(u,v)=\alpha(u)\alpha(v)\sum_{x=0}^{M_{2t-1}}\sum_{y=0}^{N_{2t-1}} f_{dct2}(x,y)\cos\left[\frac{\pi(2x+1)u}{2M_{2t}}\right]\cos\left[\frac{\pi(2y+1)v}{2N_{2t}}\right]$$

$$f_{dct2}(x,y)=\sum_{x=0}^{M_{2t-1}}\sum_{y=0}^{N_{2t-1}}\alpha(u)\alpha(v)C_{dct2}(u,v)\cos\left[\frac{\pi(2x+1)u}{2M_{2t}}\right]\cos\left[\frac{\pi(2y+1)v}{2N_{2t}}\right]$$

$$where\; u\,\&\,x=0,1,2,...,M_{2t-1} \quad and \quad where\; v\,\&\,y=0,1,2,...,N_{2t-1}$$

$$\alpha(u)=\begin{cases}\sqrt{\frac{1}{N_{2t}}} & \text{for } u=0\\ \sqrt{\frac{2}{N_{2t}}} & \text{for } u\neq 0\end{cases} \quad \& \quad \alpha(v)=\begin{cases}\sqrt{\frac{1}{N_{2t}}} & \text{for } v=0\\ \sqrt{\frac{2}{N_{2t}}} & \text{for } v\neq 0\end{cases}$$

In frequency domain, coefficients are slightly modified. This will make some unnoticeable changes in the whole image and makes it more robust to attack compared to what we have in spatial methods. One of the most popular approaches in this category is the discrete cosines transform (DCT) method.

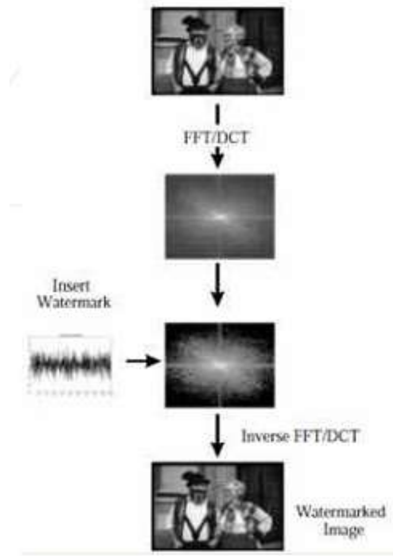

Fig 3: Watermarking in Spectral Domain

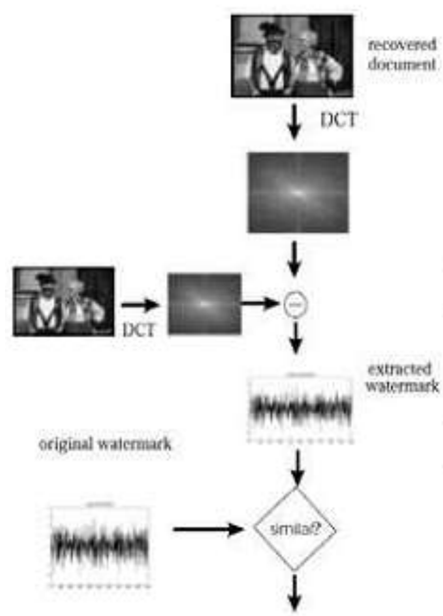

Fig 4: Watermark Extraction Process

Watermarking in hybrid domain

Watermarking in hybrid domain is modifying the image for both spatial and spectral parameters. One of the mostly used algorithms in this domain is performing the previous method in small blocks of the image. This could happen in 8×8 blocks which ideally match JPEG compression to provide lowest distortions to the message facing with JPEG compression attack. Figure 4 illustrates this method. Pixels in blue represent intensity of middle frequencies in the image and they are most suitable for carrying message data. The code has not been brought here because it is basically performing spread spectrum algorithm in separate smaller blocks.

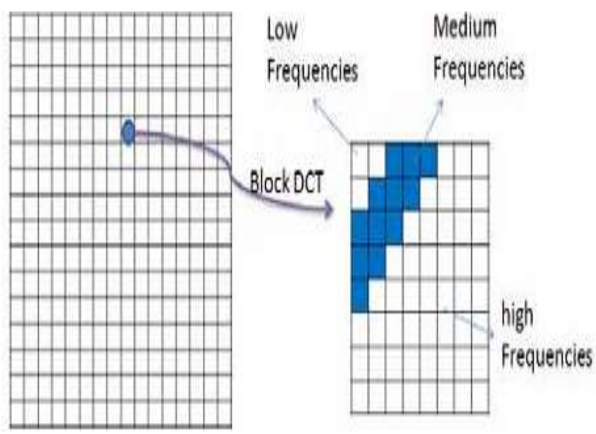

Fig 5: Block-based hybrid Watermarking method

Spread Spectrum Theory

Spread spectrum is a means of transmission in which the signal occupies a bandwidth in excess of the minimum necessary to send the information; the band spread is accomplished by means of a code which is independent of the data, and a synchronized reception with the code at the receiver is used for de-spreading and subsequent data recovery. The process of watermark embedding can be viewed as intention jamming of the watermark signal with the music or the audio signal. In this case the signal (watermark) has much less power than the jammer (music). It is one of the problems to be overcome at the receiver end. The following analysis expresses the process of watermark generation in spread spectrum terminology. The approach selected in this algorithm is the Direct Sequence Spreading. Figure 1 shows the basic spread spectrum communication system.

Direct Sequence Spreading

Basically coherent direct-sequence systems use a pseudorandom sequence and a modulator signal to modulate and transmit the data bit stream. The major difference between the un-coded and coded types is that basically coded version uses redundancy and "scrambles" the data bit stream before the modulation is done and reverses the process at the reception. The watermarking algorithm uses the coded scheme.

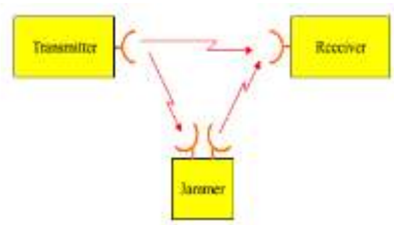

Fig 6: Basic Spread Spectrum Theory

DISCRETE WAVELET TRANSFORM (DWT)

The wavelet transform decompose the image in four channels (LL, HL, LH and HH) with the same bandwidth thus creating a multi-resolution perspective. The advantage of wavelet transforms is to allow for dual analyses taking into account both frequency and spatial domains.

Wavelets are being widely studied due to their application in image compression, owing to which compression resistant watermarks may be achieved through their use. Another interesting feature of the DWT is the possibility to select among different types of filter banks, tuning for the desired bandwidth. The most commonly used filters are: Haar, Daubechies, Coiflets, Biorthogonal, Gaussian.

When the DWT is applied to an image, the resolution is reduced by a 2^K, where K is the number of times the transform was applied.

These algorithms are called the "Wavelet based Watermarking" [8]. The watermark is inserted by substituting the coefficients of the cover image for the watermark's data. This process improves mark robustness, but depends on the frequency. The low frequency (LL) channel houses image contents in which a coefficients change, however small, will damage the cover image, which in turn challenges the fidelity propriety. However when this region of the spectrum is watermarked, a robust mark against compressions like JPEG and JPEG2000 is attained. Furthermore, when the middle and high frequency channels are marked, some benefits against noise interference and several types of filtering show up. Therefore these algorithms tend to be adapted for human visual system (HSV) to avoid small modification in the cover image being perceptible.

Taskovski et al. [21] implemented two watermarks using binary marks in LL2 and HH2 respectively, resulting in a mark which is robust against manipulations like compression and weak against cropping and rescaling. Similarly, [22] created a watermark adapted to JPEG2000 using two algorithms to modify the wavelet coefficients of the LH2 band of the cover image, introducing only minimal differences between the watermarked image and the original. The decision, which algorithm to use, is based on which one produces the smallest change.

To create a watermark which is resistant against noise and some kinds of processing [23] proposed an algorithm that makes three watermarks: pseudo-random, luminance and texture. The first mark is embedded in LL1 band and the others are inserted by segmenting the cover image in blocks and ordering according to the sum of coefficients and standard deviation. This algorithm is robust against cropping, noise and several compression levels.

In order to increase its recovery capacity, error correcting codes can be applied to the watermark; however, its storage capacity will be reduced due to the additional redundancy. A performance comparison of the Hamming, BCD, and Reed Solomon codes is presented in [12]. For small error rates, the codes are effective in error elimination when compared to no coding; on the other hand for higher rates, no benefit has been observed.

Mixing spatial and transform analysis, we have a robust watermark with different features. An algorithm that applies the SVD in all bands of the first level of DWT is proposed [24], making this a watermarking process in all frequencies. Bao [25] made a watermark of the singular values (SV) of each band of the cover image, in order to achieve the least possible distortion according to the human visual system. This watermark is resistant against JPEG encoding, but is fragile against filter manipulation and random noises. An algorithm with greater robustness against cropping, Gaussian noise and compression is proposed in [24]. Initially, the DWT is applied to HL1 or HH1. In the selected band, HH2 or HL2 must be selected and divided into 4x4 blocks.

Performance Evaluation of Watermarking Methods

Several Functions are used for quality assessment of the digital watermarking algorithms, examining tests on the resulted watermarked image.

MSE: Mean Squared Error (MSE) function is defined as:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(X_i - X_i^*\right)^2$$

PSNR: Peek Signal to Noise Ratio (PSNR) is defined as for SNR of an image:

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

SSIM: The Structural Similarity (SSIM) is a function defined as equation given below:

$$SSIM = \frac{\left(2\mu_x\mu_y + c_1\right)\left(2\sigma_{xy} + c_2\right)}{\left(\mu_x^2 + \mu_y^2 + c_1\right)\left(\sigma_x^2 + \sigma_y^2 + c_2\right)}$$

Where: "μ", "σ", & "σxy" are mean, variance, and covariance of the images, and "c1, c2" are the stabilizing constants.

Robustness: Basically this term is related to the security and immunity to the attacks.

Noise: Gaussian, Poisson, Salt & Pepper, and Speckle etc. Also in extraction process the image from host has loss of some components which appears as noise.

Proposed Methodology

"IMAGE TO IMAGE FREQUENCY MASKING USING DWT (SUB-BAND CODING)"

In this proposed work input image (original signal) is embedded into host image signal. In this proposed blind frequency masking algorithm entire unwatermarked host signal is not needed at the detector. Instead, a password is required (Co) usually a data reducing function, is used by the watermark detector to nullify "noise" effects represented by the addition the host signal in the embedder. In a blind watermark detector, the un-watermarked host signal is unknown, and cannot be removed before a watermark extraction. Under these conditions, the analogy with Figure 6 can be made, where the added watermark is corrupted by the combination of impacts of the cover work and the noise signal. The received watermarked signal cwn, is now viewed as a corrupted version of the added pattern wa and the entire watermarked detector is viewed as the channel decoder.

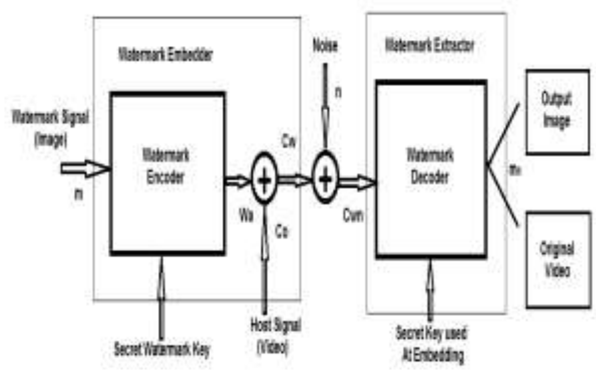

Figure 2: Proposed Frequency Masking Watermarking system with blind detection

The Discrete Wavelet Transform (DWT) is used in a wide variety of signal processing applications. 2-D discrete wavelet transform (DWT) decomposes an image or a video frame into sub-images, 3 details and 1 approximation. The 2-D DWT is an application of the 1-D DWT in both the horizontal and the vertical directions. DWT separates the frequency band of an image into a lower resolution approximation sub-band (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components.

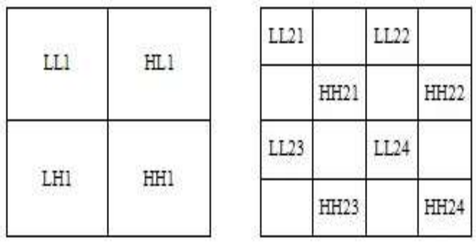

Figure 1: DWT sub-bands in (a) level 1, (b) level 2.
Proposed Embedding Process

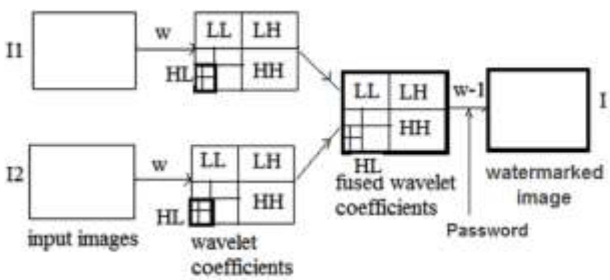

Figure 4.10 Watermark Embedding Block Diagram

4.2.1 Proposed Watermark Embedding Algorithm

(1) First take image i.e. information signal.
(2) Convert it in to frequency domain by taking its wavelet transform (DWT).
(3) Result in transformed/decomposed image.
(4) Similarly find transformed of host image i.e. carrier signal with any one of the wavelet filters.
(5) Each of these filters decomposes the image into LL, LH, HL and HH sub-bands.
(6) Form embedded signal by adding transformed information and carrier signal i.e. selected watermarked sub –band(s).
(7) The take inverse wavelet transform (IDWT) i.e. convert it into time domain.
(8) Obtain watermarked image.

4.2.2 Proposed Watermark Embedding Flow Chart

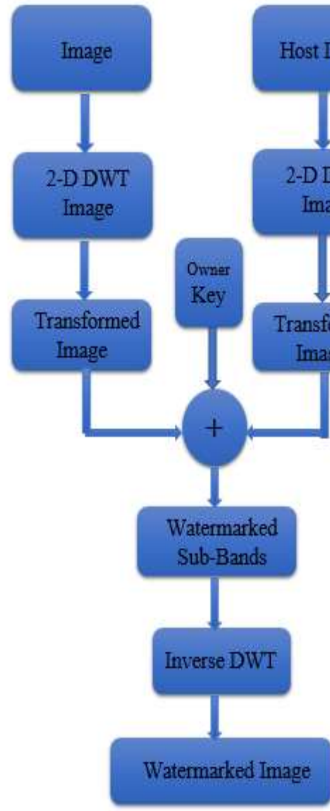

Figure 4.11 Proposed Embedding Algorithm Flow Chart

4.3 Proposed Detection Process

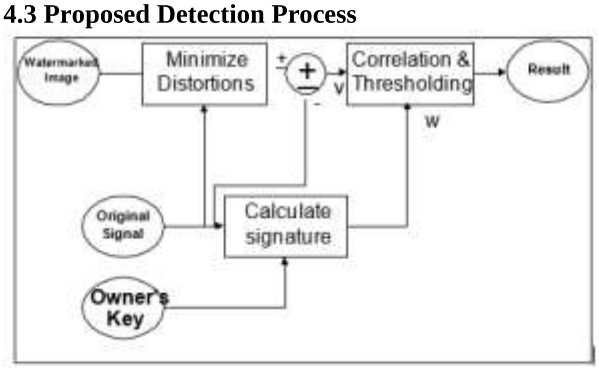

Figure 4.12 Watermark Detection Block Diagram

4.3.1 Proposed Watermark Extraction Algorithm

(1) First take watermarked image.
(2) Insert owner's key.
(3) Convert it in to frequency domain by taking its wavelet transform.
(4) Result in transformed/decomposed watermarked image.
(5) Take transformed carrier signal.

(6) Extract image from watermarked image using owner's key and reverse decomposition from selected sub-band(s).
(7) The take inverse wavelet transform (IDWT) i.e. convert it into time domain.
(8) Obtain original image i.e. information signal.

4.3.2 Proposed Watermark Extraction Flow Chart

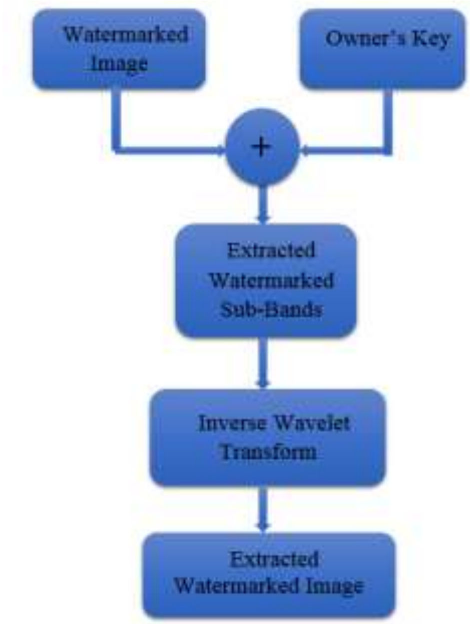

Figure 4.13 Proposed Extraction Algorithm Flow Chart

SIMULATION RESULTS & DISCUSSIONS

6.1 Host Image for Embedding

6.2 Watermark Image to be Hidden

6.3 Watermarked image

6.4 Extracted Image from Watermarked Image

6.5 Mean Squared Error (MSE)

Mean Squared Error (MSE) is one of the earliest tests that were performed to test if two pictures are similar. A function could be simply written according to equation given as:

$$M.S.E. = \frac{1}{n}\sum_{i=1}^{n}(X_i - X_i^*)^2$$

>> Simulation Result

Average MSE: 0.76

6.6 Peak Signal to Noise Ratio (PSNR)

Peak Signal to Noise Ratio (PSNR) is a better test since it takes the signal strength into consideration (not only the error). PSNR is used for measurement or the check of quality of the reconstruction of an image or frames of video. The inputs used for comparison here are the unprocessed data, and the reconstructed data after extraction process. PSNR is basically a general approximation to the human perception of reconstructed data quality. Generally higher PSNR means the reconstruction is of better in quality, but in few cases it may not be as. PSNR is generally defined in terms of the MSE. Given equation describes how this value is obtained:

$$PSNR = 10log_{10}\left(\frac{MAX_l^2}{MSE}\right)$$

Here, MAX_l is the maximum possible image pixel value. In case of when the pixels are represented using 8 bits / sample, MAX_l is taken equal to 255.

>> Simulation Result

Average PSNR: 50.8153218 dB

6.7 SSIM (Structural Similarity)

The main problem about the MSE & PSNR is that they are not similar to what similarity means to human visual system (HVS). The Structural Similarity (SSIM) Index quality assessment index is based on the computation of three terms, namely the luminance term, the contrast term and the structural term. The overall index is a multiplicative combination of the three terms.

$SSIM$ (x,y) = [$I(x,y)^{\alpha}$, $c(x,y)^{\beta}$, $s(x,y)^{\gamma}$]

Where;

$$I(x,y) = \frac{(2\mu_x\mu_y + c_1)}{(\mu_x^2 + \mu_y^2 + c_1)}$$

$$c(x,y) = \frac{(2\sigma_x\sigma_y + c_2)}{(\sigma_x^2 + \sigma_y^2 + c_2)}$$

$$s(x,y) = \frac{\sigma_{xy} + c_3}{\sigma_x\sigma_y + c_3}$$

Where; μ_x, μ_y, σ_x, σ_y, and σ_{xy} are the local means, standard deviations, and cross-covariance for images x, y. If α = β = γ = 1 (the default for Exponents), and C3 = C2/2 (default selection of C3) the Structural Similarity (SSIM) index simplifies to:

$$SSIM = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

>> Simulation Result

The SSIM value is 0.9400.

6.8 Correlation Analysis

6.8.1 Original and Watermarked Image

It is a graphical plot with pixel values (ranging from 0 to 255, for grey scale image) in X-axis and corresponding number of pixels in the image on Y-axis.

>> Simulation Result

Image histogram similarity = 0.932688

Image spatiogram similarity = 0.895747

6.8.2 Original and Extracted Image

>> Simulation Result

Image histogram similarity = 0.681429

Image spatiogram similarity = 0.580867

6.9 Simulation Results Summary

Table 6.1 shows various parameters obtained after simulation between Host and Watermarked (after embedding) image.

Parameters	Noise = 0 dB	Noise = 5 dB	Noise =10 dB	Noise =15 dB	Noise =20 dB
MSE	0.76	0.96	2.93	10.55	23.12
PSNR	50.82 dB	49.29 dB	43.62 dB	37.95 dB	34.53 dB
SSIM	0.9400	0.9221	0.8650	0.7865	0.7040

Table 6.1: Host vs Watermarked Image Results

Similarly, a comparison between original watermark and extracted watermark is shown in table 6.2 for various parameters.

Parameters	Noise = 0 dB	Noise = 5 dB	Noise =10 dB	Noise =15 dB	Noise =20 dB
MSE	103.89	108.89	111.83	116.17	119.54
PSNR	29.11 dB	28.278 dB	28.12 dB	27.91 dB	27.77 dB
SSIM	0.8606	0.8306	0.7489	0.5718	0.4186

Table 6.2: Watermark vs Extracted Watermark

6.10 Results Comparison

In the base paper SSIM values for JPEG/ JPEG2000, in the presence of gaussian noise between original and extracted watermark is given. Comparison of SSIM with our technique is shown in table 6.3.

SSIM / Gaussian Noise	Noise = 0 dB	Noise = 5 dB	Noise= 10 dB	Noise= 15 dB	Noise= 20 dB
This Work	0.86	0.83	0.74	0.57	0.41
Reference [5]	0.80	0.60	0.45	0.25	0.20

Table 6.3: Result Comparison for Watermark vs Extracted Watermark

In table 6.4 comparison of PSNR for different techniques [2] is given for gaussian noise of 5 dB, with our proposed technique. It can be clearly seen that the proposed method performs better in all the available techniques.

PSNR	LSB in 8th bit [2]	DCT [2]	DWT [2]	This Work
Gaussian Noise = 5 dB	46.3670 dB	46.2582 dB	44.0002 dB	49.29 dB

Table 6.4: Result Comparison for Host vs Watermarked Image Results

Conclusions

The level of watermarking increases robustness of the secret information. The watermarks are embedded into non overlapping DCT coefficients of the audio signal which are randomly selected and very hard to detect even with the blind detection. The audio watermarking is relatively new and has wide scope for research. For future, a new algorithm will proposed that taking features of Human Auditory System and the signal processing theories. Proposed algorithm is based on DCT domain while considering the more active components of the signal. Proposed algorithm is based on DCT domain while considering the more active components of the signal. Comparison shows the Noise PSNR is improved by 6% or 0.0606 dB.

References

[1] Aniket Roy et-al, "A perception based color image adaptive watermarking scheme in YCbCr space", 2nd IEEE International Conference on Signal Processing and Integrated Networks (SPIN), Pp- 537 – 543, Noida, 2015.

[2] Neha Bansal et-al, "Comparative Analysis of LSB, DCT and DWT for Digital Watermarking", 2nd IEEE International Conference on Computing for Sustainable Global Development (INDIACom), Pp. 40 – 45, New Delhi, 2015.

[3] Sudip Ghosh et-al, "A New Algorithm on Wavelet Based Robust Invisible Digital Image Watermarking for Multimedia Security", IEEE International Conference on Electronic Design, Computer Networks & Automated Verification (EDCAV), Pp- 72 – 77, Shillong, 2015.

[4] S. Abolfazl Hosseini et-al, "A New Method for Color Image Watermarking Based on Combination of DCT and PCA", IEEE International Conference on Communications, Signal Processing, and their Applications (ICCSPA), Pp. 1-5, Sharjah, 2015.

[5] Sha Wang et-al, "Adaptive Watermarking and Tree Structure Based Image Quality Estimation", IEEE Transactions on Multimedia, Volume 16, Number 2, February 2014.

[6] Dhananjay Yadav et-al, "Reversible Data Hiding Techniques", International Journal of Electronics and Computer Science Engineering (IJECSE), Volume 1, Number 2, 2013.

[7] Md. Iqbal Hasan Sarker et-al, "FFT-Based Audio Watermarking Method with a Gray Image for Copyright Protection", International Journal of Advanced Science and Technology, Volume 47, October, 2012.

[8] I.J. Cox, M. L. Miller, J. A. Bloom, J. Fridrich, and T. Kalker, Digital Watermarking and Steganography. Morgan Kaufmann, 2008.

[9] M. El-Gayyar and J. von zur Gathen, "Watermarking techniques spatial domain," University of Bonn Germany, Tech. Rep., 2006.

[10] J. Liu and X. He, "A review study on digital watermarking," First International Conference on Information and Communication Technologies, pp. 337–341, 2005.

[11] M. Arnold, M. Schmucker, and S. D. Wolthusen, Techniques and Applications of Digital Watermark and Content Protection. Artech House, 2003.

[12] X. Wu, J. Hu, Z. Gu, and J. Huang, "A secure semi-fragile watermarking for image authentication based on integer wavelet transform with parameters," Australasian Information Security Workshop, vol. 44, 2005.

[13] M. Antonini, M. Barlaud, P. Mathieu, and I. Daubechies, "Image coding using wavelet transform," IEEE Transaction on Image Processing, vol. 1, pp. 205–220, 1992.

[14] Daubechies and W. Sweldens, "Factoring wavelet transforms into lifting steps," SIAM Journal on Mathematical Analysis, 1997.

[15] V. M. Potdar, S. Han, and E. Chang, "A survey of digital image watermarking techniques," 3rd IEEE International Conference on Industrial Informatics, pp. 709–716, 2005.

[16] Tefas, A. Nikolaidis, N. Nikolaidis, V. Solachidis, S. Tsekeridou, and I. Pitas, "Performance analysis of watermarking schemes based on skewtent chaotic sequences," NSIP'01, 2001.

[17] S.Teskeridou, V. Solochidis, N. Nikolaidis, A. Tefas, and I. Pitas, "Bernoulli shift generated chaoticwatermarks: Theoretic investigation," SCIA2001, 2001.

[18] W. Yan, Z. Shi-qiang, and W. Yan-chun, “Wavelet digital watermark based on chaotic sequence,” ICICIC’08, 2008.
[19] K. L. W. G. Natasa Terzija, Markus Repges, “Digital image watermarking using discrete wavelet transform: Performance comparison of error correction codes,” Visualization, Imaging and Image Processing, 2002.
[20] L. Haiyan, Z. Xuefeng, and W. Ying, “Analysis of the performance of error correcting coding in audio watermarking,” 3rd IEEE Conference on Industrial Electronics and Applications, pp. 843–848, 2008.
[21] P. Cika, “Watermarking scheme based on discrete wavelet transform and error-correction codes,” 16th International Conference on Systems, Signals and Image Processing, pp. 1–4, 2009.
[22] Bastug and B. Sankur, “Improving the payload of watermarking channels via ldpc coding,” Signal Processing Letters, vol. 11, pp. 90–92, 2004.
[23] Nafornita, A. Isar, and M. Kovaci, “Increasing watermarking robustness using turbo codes,” International Symposium on Intelligent Signal Processing, pp. 113–118, 2009.
[24] N. Pantuwong and N. Chotikakamthorn, “Line watermark embedding method for affine transformed images,” ISSPA 2007, pp. 1–4, 2007.
[25] S. Riaz, M. Y. Javed, and M. A. Anjum, “Invisible watermarking schemes in spatial and frequency domains,” International Conference on Emerging Technologies, 2008.
[26] R. Liu and T. Tan, “An svd-based watermarking scheme for protecting rightful ownership,” IEEE TRANSACTIONS ON MULTIMEDIA, vol. 4, pp. 121–128, 2002.
[27] R. A. Ghazy, N. A. El-Fishawy, M. M. Hadhoud, M. I. Dessouky, and F. E. A. E.-S. Samie, “An efficient block-by-block svd-based image watermarking scheme,” National Radio Science Conference, pp. 1–9, 2007.
[28] D. Taskovski, S. Bogdanova, and M. Bogdanov, “Digital watermarking in wavelet domain,” FIRST IEEE BALKAN CONFERENCE ON SIGNAL PROCESSING, COMMUNICATIONS, CIRCUITS, AND SYSTEMS, 2000.
[29] G. Hai-ying, L. Guo-qiang, L. Xu, and X. Yin, “A robust watermark algorithm for jpeg2000 images,” Fifth International Conference on Information Assurance and Security, 2009.
[30] D. R. Sans, “Identificao de propriedade em imagens com marcas d’gua no domnio da transformada wavelet,” Master’s thesis, Universidade Federal do Paran - UFPR, 2008, in portuguese.
[31] E. Ganic and A. M. Eskicioglu, “Robust dwt-svd domain image watermarking: Embedding data in all frequencies,” Proceedings of the 2004 workshop on Multimedia and security, pp. 166 – 174, 2004.
[32] P. Bao and X. Ma, “Image adaptive watermarking using wavelet domain singular value decomposition,” IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, vol. 15, pp. 96–102, 2005.
[33] K. Loukhaoukha and J. Y. Chouinard, “Hybrid watermarking algorithm based on svd and lifting wavelet transform for ownership verification,” 11th Canadian Workshop on Information Theory, pp. 177–182, 2009.
[34] F. B. C. Mendes, “Uma proposta de assinatura digital para imagens por meio de marca d’gua,” Master’s thesis, Universidade Federal de Uberlandia, 2008, in portuguese.
[35] F. Hartung, J. K. Su, , and B. Girod, “Spread spectrum watermarking: Malicious attacks and counterattacks,” pp. 147–158, 1999.

