*International Journal of Latest Engineering and Management Research (IJLEMR)*
*ISSN: 2455-4847*
*www.ijlemr.com || Volume 02 - Issue 07 || July 2017 || PP. 17-27*

# Implementation of Digital Watermarking Using DWT-SVD And Extracting Using IDWT

Girija Shanker Chandraker
*VITS Jabalpur*

Nitin Tiwari
*Assistant Professor*
*VITS Jabalpur*

**Abstract:** With the expansion of digital technology, computer science, communication and network, online services are extensively launched but it's unlawful copying, piracy, spiteful manipulations and counterfeit has turn on the need for multimedia security. Digital watermarking is an well-organized way to solve these tribulations as it offers copyright protection of data by embedding additional information (digital signature or watermark) such that it can be detected, extracted later to make an declaration about the multimedia data. In literature, the host file is called the asset and the bit stream is called the message. Steganography and cryptography are other well familiar methods. Digital watermarking has numerous applications such as broadcasting monitoring, owner identification, content authentication and file reconstruction. A good watermarking system should aspire at keeping the watermark robust hostile to malicious attacks in spatial, spectral and hybrid domain. It ought to or we can say it should find a good sense of balance between robustness and imperceptibility. Digital image watermarking techniques at all times works in two domains either spatial or transform domain. In spatial domain, the embedding as well as extraction of watermark is done by changing the intensity and the colour value of various selected pixels. A diversity of spatial domain algorithms are - Least Significant bit (LSB), patchwork method with streak block mapped coding, method based on district intersecting. Various transform domain algorithms are spread spectrum, Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). To make sure security of watermark, it is encrypted before embedding.

## I. Introduction

Encryption is the method of encoding messages or information in such a manner that only authoritative parties can merely read it. Keys can be public or private. Public keys are those which are made accessible to all by means of a public accessible directory while private keys are those which remain confidential to its respective owners. Public – Private Key is very effectual pair as no matter what is encrypted using public key is decrypted by a private key. Every digital watermarking technique comprise of two algorithms: one as the embedding algorithm and other as the detecting algorithm as depicted in the Figure 1 and Figure 2 respectively. This project put forward an algorithm of digital image watermarking using Discrete Wavelet Transform and Singular Value Decomposition. DWT-SVD technique is used to embed watermark. Random statistical property creates watermark random in attacker's eye, but is decrypted by authorized person. The host image is decomposed using one level DWT-SVD, Encrypted watermark's lower frequency singular value is embedded in host image lower frequency singular value. Inverse Discrete Wavelet transform (IDWT) of watermarked image is done to recreate it. Watermark is extracted and decrypted.

Figure 1Watermark Embedding.

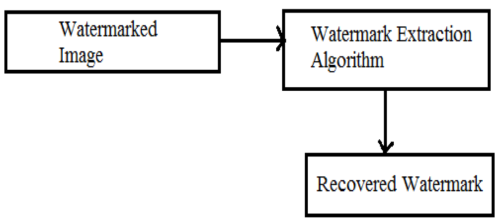
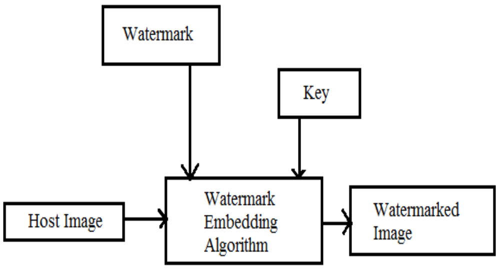


Figure 2. Watermark Extraction.




Digital watermarking is the process of conveying information by imperceptibility embedding it into the digital media. The purpose of embedding such information depends on the application and the needs of the owner/user of the digital media.

Digital watermarking is described as a possibility to interface and close the gap between copyright and digital distribution. It is based on steganography techniques and enables useful rights protection mechanisms. Digital watermarks are mostly inserted as a plain-bit sample or a transformed digital signal into the source data using a key-based embedding algorithm and a pseudo noise pattern. The embedded information is hidden in low-value bits or least significant bits of picture pixels, frequency, or other value domains, and inked inseparably with the source of the data structure.

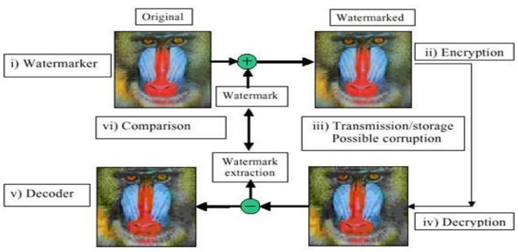
## II. Contributions of the Work

Recently, watermarking schemes based on hybrid combination of Singular Value decomposition (SVD) and Discrete wavelet transform (DWT) have gained popularity due to its simplicity in implementation and some attractive mathematical features of SVD and DWT. Here, a brief description of SVD and DWT and their role in the watermarking schemes have been presented.

**Basic on Watermarking**

The increasing amount of applications using digital multimedia technologies has accentuated the need to provide copyright protection to multimedia data. A digital watermark can be described as a visible or preferably invisible identification code that is permanently embedded in the data.
It means that it remains present within the data after any decryption process. A general definition canbe given: "Hiding of a secret message or information within an ordinary message and the extraction of it at its destination." Complementary to encryption, it allows some protection of the data after decryption. As we know, encryption procedure aims at protecting the image (or other kind of data) during its transmission. Once decrypted, the image is not protected anymore. By adding watermark, we add a certain degree of protection to the image (or to the information that it contains) even after the decryption process has taken place. The goal is to embed some information in the image without affecting its visual content. In the copyright protection context, watermarking is used to add a key in the multimedia data that authenticates the legal copyright holder and that cannot be manipulated or removed without impairing the data in a way that removes any commercial value. In Figure 1.4 a general Watermarking scheme in order to give an idea of the different operations involved in the process.

Figure 3General Watermarking Scheme




## III. Problem Analysis

Now a day, there are many watermark embedding/detection schemes proposed but only a few techniques are being used commercially. Many proposed methods have poor response from the industry because of the inability by strict criteria imposed by the today's industry. Generally, the watermarking techniques are classified into two main categories: first one spatial domain approach and second one frequency domain approach. Most of the early research on digital watermarking employs the spatial domain approach and concentrates on the imperceptibility. Recently many robust watermarking schemes using the frequency domain approach. Most of these approaches are based on discrete Fourier transform (DFT) cosine transforms (DCT) or wavelet transforms (DWT).

A serious problem with watermarking technology is the insufficient robustness of existing watermarking algorithms against geometrical distortions for example translation, rotation, scaling, cropping, change of aspect ratio and shearing. These geometrical distortions cause the loss of geometric synchronization that is necessary in watermark detection and decoding. Vulnerable to geometric distortion is a major weakness of many watermarking methods.

Therefore, in this paper, it can be proposed a watermark algorithm based on dividing image into blocks and apply DCT with sandwiching the watermark data in between pseudorandom sequences. The whole paper is organized in different sections, in first Section, an illustration of theoretical foundations of DCT algorithm; embedding algorithm and extraction algorithm are presented. The results and analysis are developed in subsequent sections.

**Brief of Problem to be solved, objective and constraints/ assumption**

The purpose is to know about how one can embed information in an image such that he/she can later claim the ownership of that image by extracting back the embedded information. Understanding how the robustness of the image watermarks can be improved.Implementing several of the watermarking algorithms and examine them in terms of how they meet the requirements of different applications and general requirements of watermarking.

## IV. Problem Formulation

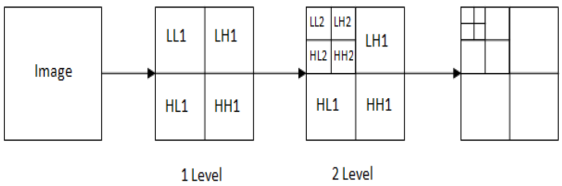
Different authors had presented different methodologies on watermarking schemes. In order to be effective, digital watermark must be robust, recoverable from a document, provide the original information embedded reliably, and be non-intrusive and also removable by authorized users. Robust watermarks are those which are difficult to remove from the object in which they are embedded despite a variety of possible attacks by pirates including compression such as JPEG, scaling and aspect ratio changes, rotation, translation, cropping, row and column removal, addition of noise, filtering, cryptographic and statistical attacks, as well as insertion of other watermarks.

## V. Methodology

**Singular Value Decomposition (SVD)**

SVD is an effective numerical analysis tool used to analyze matrices. In SVD transformation, a matrix can be decomposed into three matrices that are of the same size as the original matrix. From the view point of linear algebra, an image is an array of non-negative scalar entries that can be regarded as a matrix.

Figure 4Workflow of DWT




Without loss of generality, if *A* is a square image, denoted as $A \in R^{n\times n}$, where *R* represents the real number domain, then SVD of *A* is defined as

$$A = USV^T$$

Where, $U \in Rn\times n$and $V \in Rn\times n$are orthogonal matrices, and $S \in Rn\times n$is a diagonal matrix, as

$$S = \begin{bmatrix} \sigma_1 & & & \\ & \sigma_2 & & \\ & & \ddots & \\ & & & \sigma_n \end{bmatrix}$$

Here diagonal elements i.e. σ's are singular values and satisfy

$\sigma_1 \geq \sigma_2 \geq \ldots \sigma_r \geq \sigma_{r+1} \geq = \ldots\ldots = \sigma_n = 0$

It is noticeable that the unique property of the SVD transform is that the potential $N^2$ degrees of freedom or samples in the original image now get mapped into

S ⇒ N Degrees of freedom

U ⇒ N (N -1) / 2 Degrees of freedom

V ⇒ N (N -1) / 2 Degrees of freedom

totaling $N^2$ degrees of freedom.

SVD is an optimal matrix decomposition technique in a least square sense that it packs the maximum signal energy into as few coefficients as possible. It has the ability to adapt to the variations in local statistics of an image.

**Discrete Wavelet Transform (DWT)**

The DWT is nothing but a system of filters. There are two filters involved, one is the "wavelet filter", and the other is the "scaling filter". The wavelet filter is a high pass filter, while the scaling filter is a low pass filter. DWT includes many kinds of transforms, such as Haar wavelet, Daubechies wavelet, and others. Figure 2.1 shows the workflow of DWT. After applying a 1- level DWT on an image, we get the approximation subband*LL*, the horizontal subband*LH*, the vertical subband*HL*, and the diagonal subband*HH*. Moreover, if we want to apply a 2- level DWT on the image, we just simply apply another 1-level DWT on the approximation subband*LL*. After applying a 2- level DWT, we also get the approximation subband$LL_2$, the horizontal subband$LH_2$, the vertical subband$HL_2$, and the diagonal subband$HH_2$of the approximation subband*LL* other than subbands*LH*, *HL*, *HH*.

An advantage of DWT over other transforms is it allows good localization both in time and spatial frequency domain. Because of their inherent multi-resolution nature, wavelet coding schemes are especially suitable for applications where scalability and tolerable degradation are important**.** Applying IDWT to *LL, HL, LH, and HH*, we can get four different frequency's images that are low frequency image, middle-low frequency image, middle-high frequency image, high frequency image separately.

The aim of digital watermarking is to embed a piece of information into digital documents, like pictures or movies This is for a large panel of reasons, such as copyright protection, control utilization, data description, checking, or content authentication. Digital watermarking must have essential characteristics including imperceptibility and robustness against attacks In digital watermarking an imperceptible signal ''mark'' is embedded into the host image, which uniquely identifies the ownership. After embedding the watermark, there should be no perceptual degradation. These watermarks should not be removable by unauthorized person and should be robust against intentional and unintentional attacks.

Many watermarking schemes have been proposed in recent years, which can be classified into two categories: spatial domain and frequency domain watermarking In spatial domain watermarking, a great number of bits can be embedded without inducing too clearly visible artifacts, while frequency domain watermarking has been shown to be quite robust against JPEG compression, filtering, noise pollution, and so on. More recently, chaotic methods have been proposed to encrypt the watermark, or embed it into the carrier image for security reasons. In this paper, a new robust watermarking technique is proposed. Firstly Adaptive Median filter function is used on host image before applying wavelet function. The image obtained gone through 3-level wavelet transform. Embedding is done using singular value of medium frequency band. An extraction algorithm is developed for the extraction of watermark. Proposed technique developed shows robust against various attacks.

**The Basic Operation Of Digital Image Processing**

To understand what adaptive median filtering is all about, one first needs to understand what a median filter is and what it does. In many different kinds of digital image processing, the basic operation is as follows: at each pixel in a digital image we place a neighborhood around that point, analyze the values of all the pixels in the neighborhood according to some algorithm, and then replace the original pixel's value with one based on the analysis performed on the pixels in the neighborhood. The neighborhood then moves successively over every pixel in the image, repeating the process.

**A. Singular Value Decomposition**

SVD is a mathematical tool which used to decompose a matrix. Matrix is decomposed into two orthogonal matrices and one diagonal matrix consisting of the singular values of the matrix (Li Xin, 2011). From the point of image processing an image can be considered as a 2D matrix. Let A be an image matrix of size M× N. Using the SVD the matrix A can be decomposed as:

$$\mathbf{A= U_a S_a V_a^T}$$

$U_a$ and $V_a$ are orthogonal matrices of size M×N, and SA is a diagonal matrix of singular values. The columns of V called right singular vectors and the columns of U are left singular vectors of the image A. In SVD based watermarking, SVD of the original image is taken and then singular values of the matrix are modified by introducing the singular value of watermark. SVD approach is used in watermarking field because of the fact that singular values obtained after decomposition of the image matrix has good stability and do not change on introduction of small disruption such as watermarking, image compression and other signal processing DWT Image itself is considered as two dimensional signals. When image is passed through series of low and high pass filters, DWT decomposes the image into several sub-bands having different resolutions. Decompositions can be done at different DWT levels. By applying 2-level DWT on an image, the image is decomposed into four sub-bands LL, LH, HL and HH sub-bands, corresponding to approximate, vertical, horizontal, and diagonal features respectively. The sub-band denoted by LL is approximately half of the original image. While LH and HL sub-bands contain the changes of edges or images along horizontal and vertical direction, respectively. The sub-band HH contains the details in the high frequency of the image. Moreover, it can further decompose by applying 2-level DWT on the sub-image. After applying a 2-level DWT, sub-image get decomposes into the approximation sub-band (LL2), the horizontal sub-band (LH2), the vertical sub-band (HL2), and the diagonal sub-band (HH2). Again decomposition of image results into LL3, LH3, HL3 and HH3 sub-band respectively. DWT has good linear time complexity and adaptability. Applying inverse DWT to LL, LH, HL, and HH, results into four different frequency images, low frequency image (LL), middle-low frequency image(LH), middle-high frequency image(HL), high frequency image(HH).

**Method**

Assume the dimensions of the original image *A* is M×N and dimensions of the visual watermark *W* is N×N.

1) Using discrete wavelet transform (DWT), original image *A* is decomposed into four sub-bands *LLa*, *LHa*,*HLaandHHa*as shown in Figure 5.2.

2) Apply IDWT to high frequency sub-band *a HH* .

3) Apply SVD to high frequency sub-band :

$$HH_a = U_a^h S^h{}_a V_a^h$$

4) Using discrete wavelet transform decompose watermark image *W* , into four sub-bands: $LL_w$,$LH_w$,$HL_w$ *and* $HH_w$.

5) Apply IDWT to *HHw*sub-band of watermark image.

6) Apply SVD to high frequency sub-band:

$$HHw=U_W^H S_W^H V_W^H$$

7) Modify the singular value :

$$S_A{}^{*h}= \text{tand}\ ((\text{alpha}*S_w{}^h)\ /S_w{}^h)$$

Where *alpha* is a scaling factor.

8) Apply SVD on obtained singular value

$$S_a^{*h} = U_a^{hh} S^{hh}{}_a V_a^{hh}$$

9) Using DWT to $S_a^{hh}$, obtain $HHa^*$

$$HH_{aa}= DWT\ (S^{hh})$$

10) Apply IDWT to obtain watermarked cover image *A** using, L*L a, LH a HL a and* $HH_a^*$

| | |
|---|---|
| LL1 | HL1 |
| LH1 | HH1 |

<table>
<tr><td>LL2</td><td>HL2</td><td rowspan="2">HL1</td></tr>
<tr><td>LH2</td><td>HH2</td></tr>
<tr><td colspan="2">LH1</td><td>HH1</td></tr>
</table>

<table>
<tr><td>LL3</td><td>HL3</td><td rowspan="2">HL2</td><td rowspan="3">HL1</td></tr>
<tr><td>LH3</td><td>HH3</td></tr>
<tr><td colspan="2">LH2</td><td>HH2</td></tr>
<tr><td colspan="3">LH1</td><td>HH1</td></tr>
</table>

**B. Watermarking Extraction Process:**

1) Decompose the watermarked image *A** into four subbands using DWT:

$$LLa, LHa, HLa \text{ and } HHa^{*}$$

2) Apply IDWT to high frequency sub-band

$$HH\ a^{*}$$

3) Apply SVD to high frequency sub-band $HHa^{*}$

$$HHa = Uwa^{h} Swa^{h} V_{wa}^{h}$$

4) Decompose the original image *A* into four sub-bands.

5) Apply SVD to *HH* after applying IDWT on high frequency sub-band of original image, as in embedding process.

$$HH_{a} = U_{a}^{h} S_{a}^{h} V_{a}^{h}$$

6) Using DWT decompose watermark image *W* , into four sub-bands and apply IDWT to high frequency band then apply SVD to high frequency sub-band as in embedding
process:

$$HH_{w} = U_{h}^{w} S_{h}^{w} V_{h}^{w}$$

7) Extract the singular value of high frequency sub-band watermark image:

$$S_{w}^{*h} = a \tan d((S_{wa}^{h} * S_{a}^{h})/alpha)$$

8) Using $S_{w}^{*h}$ recover the high frequency sub-band ofwatermark image:

$$HHw = U_{w}^{h} S_{w}^{*h} V_{w}^{h}$$

9) Using $LL_{w}$, $LH_{w}$, $HL_{w}$ *and* $HH_{w}$ apply IDWT to recover the watermark image *W*

## VI. Extraction of Watermark From Noise

**Adaptive Median Filtering**

Therefore the adaptive median filtering has been applied widely as an advanced method compared with standard median filtering. The Adaptive Median Filter performs spatial processing to determine which pixels in an image have been affected by impulse noise. The Adaptive Median Filter classifies pixels as noise by comparing each pixel in the image to its surrounding neighbor pixels. The size of the neighborhood is adjustable, as well as the threshold for the comparison. A pixel that is different from a majority of its neighbors, as well as being not structurally aligned with those pixels to which it is similar, is labeled as impulse noise. These noise pixels are then replaced by the median pixel value of the pixels in the neighborhood that have passed the noise labeling test.

**Purpose**

1). Remove impulse noise
2). Smoothing of other noise
3). Reduce distortion, like excessive thinning or thickening of object boundaries

A new algorithm (Adaptive Decision Based Median Filtering Algorithm) is implemented to see if the performance of the image is increased with respect to the decision based median filtering.This algorithm seems to be similar to adaptive median filtering technique. A small change is made to this with respect to the decision based median filter and adaptive median filter. The change is made in Step B (c) with respect to decision based median filtering and at the end with respect to adaptive median filtering technique. If the median is also an impulse noise, the window size is increased by 2 in both horizontal and vertical direction (change made with respect to decision based median filter) and the same algorithm is repeated to see if the new median obtained after increasing the window size is an impulse noise. If it is an impulse noise again, the
same algorithm is repeated until the maximum size of the window is reached; otherwise thefiltered image pixel is replaced by the left neighbourhood pixel value as in the decision based median filtering (change made with respect to adaptive median filter). This new algorithm is applied to see if any better filtering of the corrupted image could be achieved as it is known that adaptive based algorithm provides better filtering than that applied without adaptive median filtering technique.

**Step A:**
A window is selected and the minimum, maximum and the median value of the window are detected as the first step. Let ij I be the pixel value, max I , min I and med I be the maximum pixel value, minimum pixel value and median pixel value respectively in the window.

**Step B:**
a) If min **I <ij I <**max I , then the pixel value is not an impulse noise and hence the same pixel value is retained in the filtered image else the pixel value is an impulse noise.
b) If ij I is an impulse noise, then it is checked to see if the median value is an impulse noise or not. If min **I <med I <**Imax or 0 <Imed< 255, the median is not an impulse noise and the filtered image pixel is replaced by the median value of the window.
c) If the median is also an impulse noise, and in this case the filtered image pixel is replaced by the value of the left neighborhood pixel value (which has already been filtered).

**Step C:**
These steps are repeated until all the pixels have been tested.

## VII. DISCUSSIONS OF RESULTS

MSE is the mean square error and is given by:

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{i=0}^{N-1}\left[\{x(i,j)-y(i,j)\}^2\right]$$

The peak signal to noise ratio of an image is given by:

$$PSNR = 10\log10\left(\frac{255*255}{MSE}\right)$$

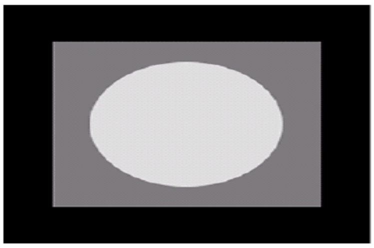


Figure 5Original Image

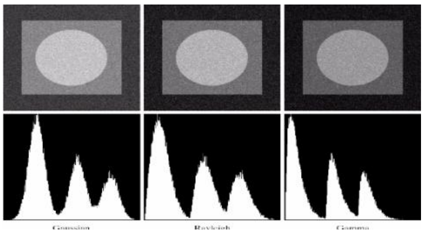


Figure 6Images and histograms resulting from adding Gaussian, Rayleigh and Gamma noise to the original image**.**

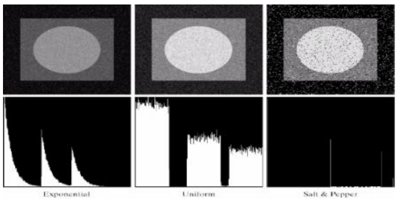
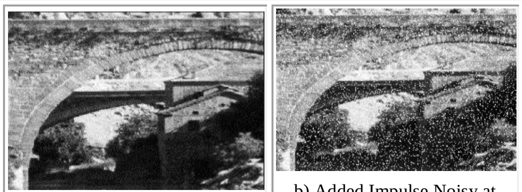


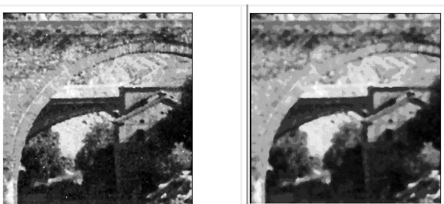
Figure7 (continued) Images and histograms resulting from adding Exponential, Uniform and Salt & Pepper noise to the original image.



a) Original image

b) Added Impulse Noisy at 10%

Figure 8Original image and Amalgamated noise image



a) 3x3 Adaptive Median Filtered;
b) b) 5x5 Adaptive Median Filtered

| | |
|---|---|
|  3x3 Adaptive Median Filtered applied 3 times |  5x5 Average Filter |

Figure 9Samples of the filtrated image.

Although Adaptive median filter is a useful non-linear image smoothing and enhancement technique. It also has some disadvantages. The median filter removes both the noise and the fine detail since it can't tell the difference between the two. Anything relatively small in size compared to the size of the neighborhood will have minimal effect on the value of the median, and will be filtered out. In other words, the median filter can't distinguish fine detail from noise.

| **Attack** | **Density** | **PSNR(db)** | **MSV** |
|---|---|---|---|
| Poisson noise | 5% | 44.85 | 0.0128 |
| | 20% | 36.26 | 0.0312 |
| | 35% | 30.20 | 0.0410 |
| | 50% | 29.99 | 0.0455 |
| Gaussian Blur | 5% | 43.97 | 0.0187 |
| | 20% | 35.84 | 0.1132 |
| | 35% | 32.33 | 0.0236 |
| | 50% | 28.65 | 0.0380 |
| Speckle Noise | 5% | 45.12 | 0.0340 |
| | 20% | 36.77 | 0.0623 |
| | 35% | 32.53 | 0.0800 |
| | 50% | 30.22 | 0.0952 |
| Gaussian Noise | 5% | 44.85 | 0.0100 |
| | 20% | 36.98 | 0.0210 |

| | | | |
|---|---|---|---|
| | 35% | 31.20 | 0.0310 |
| | 50% | 30.46 | 0.0445 |
| Salt and pepper noise | 5% | 43.12 | 0.0240 |
| | 20% | 35.91 | 0.0278 |
| | 35% | 31.88 | 0.0673 |
| | 50% | 30.30 | 0.0887 |

Table 6.1 Parametric outcome in each of the attacks

## VIII. Conclusion

Digital Image Watermarking can protect image, video, audio from unauthorized person, noise, copyright etc. During the analysis, we have found out each approach has its own merits and de merits.

In DCT method, image is compressed using of number of coefficient of pixels. If number of coefficient is increased, compressed of image also increased. So it is tough to capture real image.

In DWT method, image is wavelet using wavelet algorithm and high frequency sub band. So intruder do not get real image except descript of image.

In DFT method image has invariance to translation, rotation, scaling, the DFT-based DigitalWatermarking Algorithm has unique advantages in the resistance geometric transformations.DCT and DWT domain watermarking is comparatively much better than the spatial domain encoding since DCT domain watermarking can survive against the attacks such as noising, compression, sharpening, and filtering and also use JPEG compression method and DWT is used embedded zero-tree wavelet (EZW) image compression scheme and high frequency sub bands as LH,HL,HH etc.

The algorithm implemented here, satisfies our initial objective of copyright protection reasonably well. This algorithm managed to make the watermark robust enough without considerably degrading the image quality.

Apart from providing copyright protection we also attempted to make it difficult for an attacker to willfully destroy the watermark.

## IX. Scope for Future Work

Digital watermarking is an important topic because of the many illegal copies of images, music titles, and video films. This is strengthened by the digitalization of media assets, the rapid growth of the Internet, and the speed of file transfers. Therefore, it is necessary to have mechanisms to protect these digital assets and associated rights.The watermarking research is progressing very fast and numerous researchers from various fields are focusing to develop some workable scheme. Different companies are also working to get commercial products. We hope some commercial and effective schemes will be available in future. If an intelligent and secure watermarking application software system can be build and be implemented in a high-performance DSP processor, it has a huge potential market commercially.In this proposed algorithm, with fixed size of the image. In future, we may use an algorithm which provides the same formula for embedding different sizes of water mark image to different sizes of original image.

## References

[1] I. Cox, J. Kilian, F. Leighton, and T. Shamoon, "Secure Spread Spectrum Watermarking for Multimedia," *IEEE Transactions on Image Processing*, vol. 6, no. 12, pp. 1673-1687, Dec. 1997.

[2] M. Swanson, B. Zhu, and A. Tewfik, "Transparent Robust Image Watermarking," *Proc. IEEE Int. Conf. on Image Processing*, Sept. 1996, vol. III, pp. 211-214.

[3] I. Pitas, "A Method for Signature Casting on Digital Images," *Proc. IEEE Int. Conf. on Image Processing*, Sept. 1996, vol. III, pp. 215-218.

[4] R. Schyndel, A. Tirkel, and C. Osborne, "A Digital Watermark," *Proc. IEEE Int. Conf. on Image Processing*, Nov. 1994, vol. II, pp. 86-90.

[5] X. Xia, C. Boncelet, and G. Arce, "A Multiresolution Watermark for Digital Images," *Proc. IEEE Int. Conf.on Image Processing*, Oct. 1997, vol. I, pp. 548-551.
[6] F. Bartolini, M. Barni, V. Cappellini, and A. Piva, "Mask Building for Perceptually hiding Frequency Embedded Watermarks," *Proc. Int. Conf. on Image Processing*, Oct. 1998, vol. I, pp.-450-454.
[7] D. Kundur and D. Hatzinakos, "A Robust Digital Image Watermarking Method UsingWavelet-Based Fusion," *Proc. IEEE Int. Conf. on Image Processing*, Oct. 1997, vol. I, pp. 544-547.
[8] J. Delaigle, C. De Vleeschouwer, and B. Macq, "Psychovisual Approach to Digital Picture Watermarking*," Journal of Electronic Imaging*, vol. 7, no. 3, pp. 628-640, July 1998.
[9] S. Craver, N. Memon, B. Yeo, and M. Yeung, "Resolving Rightful Ownerships with Invisible Watermarking Techniques: Limitations, Attacks, and Implications," *IEEE Journal on Selected Areas in Communications*, vol. 16, no. 4, pp. 573-586,May 1998.
[10] P. Bas, J. Chassery, and F. Davoine, "Using the Fractal Code to Watermark Images," *Proc. IEEE Int.Conf. on Image Processing*, vol. I, Oct. 1998, pp. 469-473.