



Performance Improvement of Hybrid Image Watermarking Algorithm Using Discrete Wavelet Transform and Human Visual Model

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Abstract

With the growth of multimedia technology huge amount of digital data are exchanged in internet but digital data can be duplicated by unauthorized users. To avoid this problem the watermarking algorithm is being involved in this paper which proposed, hybrid image watermarking algorithm based on Discrete Wavelet Transform (DWT) and Human Visual Model (HVM) for copyright protection and securing the digital data. In this image watermarking robustly and imperceptibly, DWT and HVM is used to obtainable weight factor according to the image features such as brightness, texture and frequency band. At each level of DWT sub band, watermark is inserted into the selected coefficients of the sub band in a manner of HVM that the watermark embedding visual artifact occurs in the brightness, frequency band and textured areas of the image. The perceptual process of HVM is used to modify four levels wavelet coefficients and to determine the optimal strength at which the threshold to embedding reaches the perceptual invisibility of watermarked image to various attacks. Performance is evaluated such as Peak Signal to Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM) and Quality Index (QI) of watermarked image. The experimental results shows that hybrid image watermarking has better robustness as compared with some other related methods and displays the effectiveness of presented image watermarking algorithm is the best.

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Key Words: Hybrid Watermarking, Watermark embedding, DWT, Human Visual Model.

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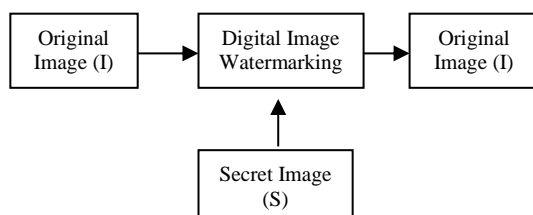
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1.Introduction

The Technology is developing in a rapid manner for multimedia technology. It can be transmitted by digital media. It will be distributed in a digital format and copied without ownership [1]. That's why copyright protection has become very essential in internet and multimedia content [2]. Digital image watermarking cannot be related to stenography [7] and cryptography [8].

Fig. 1. Digital Image Watermarking.

Stenography is not considering any changes of embedding and detected in the image. Similarly, cryptography does not provide any authenticate identity to the user. To overcome these drawbacks a new technique has been introduced as digital image watermarking. It is effectively providing both copyright protection [5] and ownership identification [6] of the owners. Fig.1 represents the method of digital image watermarking. The secret image is hidden into an original image using hybrid image watermarking so that the copyright policies can be met.



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Digital image watermarking is classified into two types according to processing domain [1] namely the spatial domain and frequency domain. The spatial domain watermarking is used to analyze the pixel value of an original image in a direct manner. Spatial domain watermarking robustness is very low compare with another watermarking algorithm [2]. Frequency domain [3] watermarking is used to modify the pixel values using Transform technique. Frequency domain watermarking is effective when compared with other methods against noise attacking, filtering, compression, cropping and rotation. In digital image watermarking [1], the embedding process can be represented as

$$W = (I + \alpha * S) \quad (1)$$

Where W denotes watermarked image, I denote original image, S denotes secret image and α denotes watermark embedding strength.

2.Literature Review

Hybrid image watermarking algorithm has been used to improve the different security concern that arises due to advancement of multimedia technology and their associated services. The Digital watermarking technique is investigated and a bit-based watermarking in frequency domain is done using the wavelet transform method and firefly algorithm [1-2]. Fuzzy based watermarking algorithm, security can be increased through different sub band are exchanged [3].Wavelet domain watermarking is accomplished through human visual perceptions and block based watermarking technique it proposed HVS characteristics for security reasons to selection of significant block to hide the watermark image.SVD presented the watermarking method, an image is considered as a low-low U matrix elements by applying transform technique [4]. It is embedded with the Discrete Fourier Transform (DFT) and the spectrum magnitude is analyzed and accordingly the watermark strength is adjusted [5].Pixel based Watermarking methodology based on the zig-zag order coefficients are improved by DCT block coefficient. First DCT transform can be computed by grouping image pixels of specified size. This Result is considered with 3 frequency sub band coefficients [6-8].

DWT based watermarking methods to recover an image using statistical detector. The enhancement of digital image watermarking can be used as human visual system (HVS). The Image can embed in another image by alternating its pixel value [9-10]. Perceptual image watermarking method based on 1-

level DWT [10-12].

The Invisible watermark was embedded into an original image by alpha blending method [13-15]. Anefficient watermarking with rough entropy is utilized by which the embedded strength is improved [16-20]. The statistical redundancy between wavelet sub bands was studied [20-25].

All the methods discussed above refer to DFT, DCT, SVD and DWT watermarking embedding and extracting only. But, DFT, SVD and DCT method is less computation compared to DWT, high computation and accurate in Human Visual perception because of multi resolution property of DWT. In this proposed method, a new hybrid image watermarking algorithm based on DWT and Human Visual model is analyzed. Among the transform-based techniques, DWT performs better because of superior Human Visual Model. HV model with weight factor is used for effective coefficient selection. Then watermark image is added to the chosen sub band.

In this paper, Section 2 explains the Literature review of watermarking algorithm, Section 3 discrete wavelet transform and HV model, Section 4 explains the DWT-HVM and proposed hybrid image watermarking, Section 5 explains the experimental results. At last, Section 6 is concluded with remarks. 901

3. Background

3.1. Discrete Wavelet Transform (DWT)

In DWT, it analyzes a signal at different frequencies and at different resolutions. DWT is processed as a filter bank, as shown in Fig. 2, Which are used to analyze and reconstruct the signal. Based on the frequency bands the filter bank categorizes the signal. The X(Z) signal is separated as LPF i.e., H0(Z) and HPF i.e., H1(Z). At each level the H1(Z) produce detail co-efficient and H0(Z) associated with scaling function to produce an approximation co-efficient. The X(Z) is passed across a set of LPF down sampled by 2 and HPF up sampled by 2.

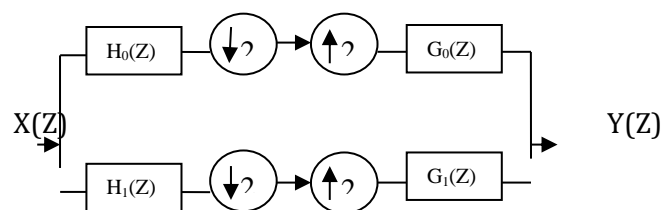


Fig. 2. Filter bank.

In DWT, X(Z) is decomposed and transform into four sub bans of level-1. The Row matrix on left end



contains down sampled low pass coefficients of every row. Right end has up sampled high pass coefficient of each column, shown in Fig. 3. Next, Approximation coefficient performs one step to all columns. This Operation decomposes the 512x512 gray scale image into LL, LH, HL and HH sub bands.

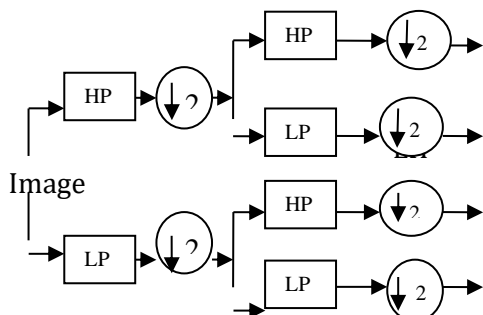


Fig. 3. Wavelet decomposition by filter bank.

The DWT splits an input image into high and low frequency band. The Low frequency band has larger scale and least resolution. The High frequency band obtains the image information on various resolution and scales. Fig. 4(a) is the input image and Fig. 4(c) shows the 1-level of decomposition and representation of 4 sub bands. The Input will be selected from previous LL sub band. In 2-level decomposition, LL1 was selected for DWT. In 3-level of decomposition, LL2 was selected. Finally, the DWT is applied on LL3 and getting 4 sub bands shown in Fig. 4(d).

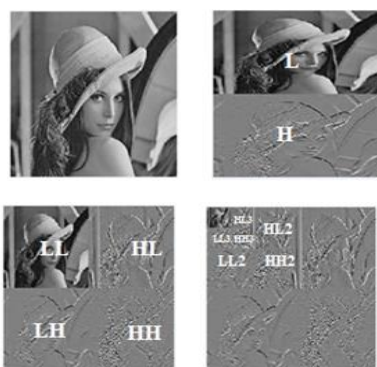


Fig.4.Input Image (a), Low and High band (b), Level-1 of DWT (c) and 3rd Levels of DWT (d).

This Feature reveals the wavelet transform on having effective space directions. Hence it is suitable for Human Visual model (HV) analyses. The Watermarking algorithm has design has to consider multi-resolution decompositions.

3.2. Human Visual Model

The image formation in human eye is based on the weight factor brightness, frequency band and texture. Based on these weight factors Human Visual Model is designed. The Digital image watermarking, is aiming to place the secret image into an original image. The Original image quality is also considered. Human Visual Model is used in proposed method for the reason of this model capable observing abrupt changes in image. After reviewing [2], a new method is introduced which considers three weight parameter in the image features. Then, combining these three weight factors together as per equation (2) a complete final weight factor $w_l(i, j)$ is obtained for the watermarking in wavelet domain.

$$w_l(i, j) = B_l(i, j)f(l, s)T_l(i, j) \quad (2)$$

Where l - level of sub band, $B_l(i, j)$ is brightness weight factor, $f(l, s)$ is frequency weight factor and $T_l(i, j)$ is texture weight factor in this equation (2) is explained below.

1. Human eye vision is less sensitive to the areas of the image where brightness is high or low. In DWT, the LL sub bands can be used to estimate the brightness values of each wavelet coefficient. So, the calculation of brightness weight factor as follows:

$$B_l(i, j) = \frac{1}{256} I_3^3 \left(1 + \left\lfloor \frac{i}{2^{3-l}} \right\rfloor, 1 + \left\lfloor \frac{j}{2^{3-l}} \right\rfloor \right) \quad (3)$$

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2. Human eye vision has low sensitivity on noise present at high frequency sub band. This weight factor states that data embedded is much less perceivable on high frequency sub band. So, the calculation of frequency weight factor as follows:

$$f(l, s) = \begin{cases} \sqrt{2}, & \text{if } s = 1 \\ 1, & \text{otherwise} \end{cases} \cdot \begin{cases} 1.00 & \text{if } s = 0 \\ 0.32 & \text{if } s = 1 \\ 0.16 & \text{if } s = 2 \\ 0.10 & \text{if } s = 3 \end{cases} \quad (4)$$

Where, l - Level of DWT, s - Sub band values.

3. Human eye vision has low sensitive towards noise at textured areas. It is more near to edges. The DWT level of sub band will be $M \times N$ matrix. The Textured weight factor calculation as follows:

$$T_l(i, j) = \sum_{k=0}^{3-l} \frac{1}{16^k} \sum_{s=0}^2 \sum_{x=0}^1 \sum_{y=0}^1 [I_{k+l}^s \left(y + \frac{i}{2^k}, x + \frac{j}{2^k} \right)]^2 \cdot Var(I_3^3) \quad (5)$$

Where, $Var(I_3^3)$ variance of sub band of LL3. K is level of sub band. Form the equations (3), (4) and (5) to get final weight factor $w_l(i, j)$ according to equation (2).

4. Proposed Hybrid Image Watermarking

Proposed hybrid image watermarking is discussed in this section. It consists of two subsections. Sub-section 4.1 deals with DWT- HVM procedure, hybrid



image watermarking is explained in Sub-section 4.2.

4.1 DWT- HVM

With the reference of previous work related to DWT-HVM the proposed work is formulated. To improve the performance, robustness and hybridization is needed against different image processing attacks. In the proposed work, the original image faces the 3-level DWT. So that image will be decomposed. The Approximation looks similar as original. Then watermark image faces the 3-level DWT. In this work, a new hybrid method which takes those three features simultaneously into account. To find weight factor based on image features those are:

1. Brightness- $B_l(i, j)$
2. Frequency band - $f(l, s)$ and
3. Texture - $T_l(i, j)$

For embedding process, three-weight factor are merged to obtain final weight factor. Fig 5 represents the proposed hybrid image watermarking method with human visual perception. In this method original image is decomposed into 4 sub bands. The Previous level (LL) will be the input for every decomposition level. Finally, three-weight factor are calculated. Afterwards these weight factors are used internally for the embedding of host image.

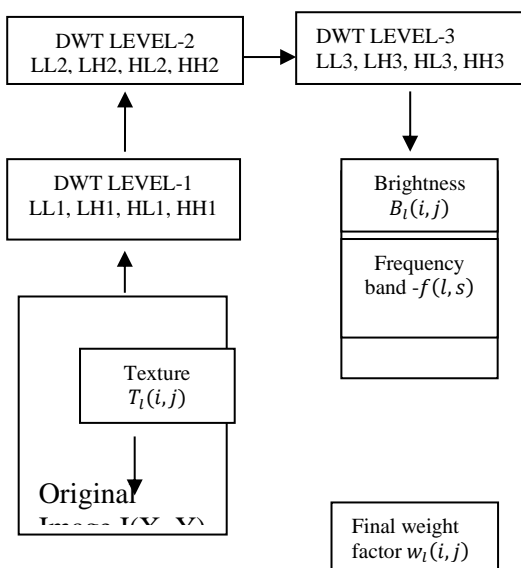


Fig. 5. Weight factor

4.2. Hybrid Image Watermarking

The Proposed image watermarking methodology embeds watermark image. The Host image is decomposed with DWT. A set of complete weight factor or mask based on Human Visual model

calculates the original image weight factors for 4-level sub bands. An original image is considered by gray scale image and size of input image is 512 X512. An input image is decomposed such as one approximation (LL1) sub band and detailed (LH1, HL1 and HH1)sub band using DWT. Again, apply DWT in LL1 band to get second level DWT sub band such as LL2, LH2, HL2 and HH2, DWT has been applied to 3 levels DWT sub band like as LL3, LH3, HL3 and HH3. The Secret image bits are repeatedly added to embed the watermark for chosen sub bands with respect to their based on weight factor threshold value. Threshold value obtained by mean value of weight factor if value less than threshold value then bits added, otherwise bits is not added. The Weight factor raises modification level. It has to be applied to a wavelet coefficient without any alterations. The Watermark embedded the gray scale logo image such as binary image. The Binary image size will be smaller than host image size. The Watermarked image can be obtained by applying inverse DWT.

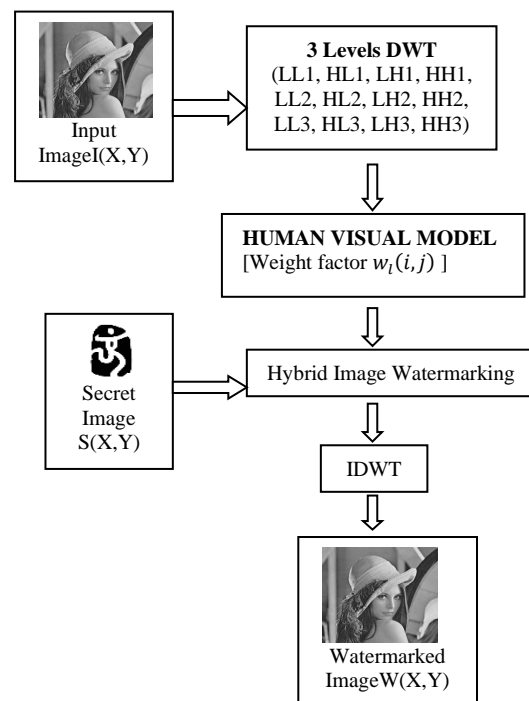


Fig.6. Hybrid Image Watermarking

Equation (1), Represents watermark embedding equation. Equation (6) Represents weight factor.

$$W(x, y) = I(x, y) + \alpha \cdot w_l(i, j) \cdot S(x, y) \quad (6)$$

Where $W(x, y)$ denotes watermarked image, $I(x, y)$ denotes host image, $w_l(i, j)$ denotes weight factor value, $S(x, y)$ denotes secret image and α denotes embedding strength parameter ($\alpha = 0.1$). The



Watermark should be little for spatially localization against geometric attacks. In watermark recovery, watermark repetitions are extracted. The proposed image watermarking obtains better results when compared with others.

4.3. Algorithm

Step 1: Take any gray scale image. Resize the gray scale image into 512x512.

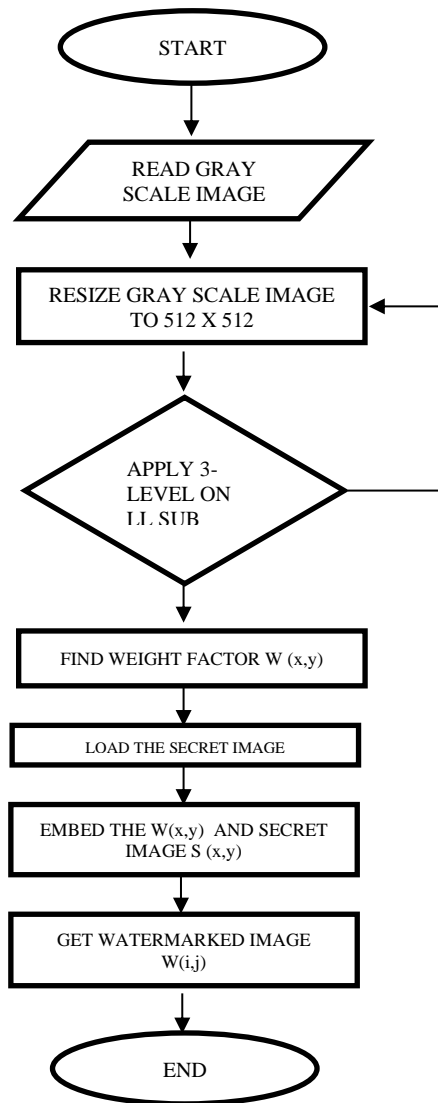
Step 2: Apply Discrete Wavelet Transform on gray scale image to get 4 sub bands such as LL1, HL1, LH1 and HH1.

Step3: Apply 2-level on LL1 sub band and repeat the steps up to certain level.

Step4: Find Weight factor $w_l(i, j)$ for sub band wavelet coefficient using human visual model.

Step5: Load the Secret Image and embed the $w_l(i, j)$ and Secret image to get watermarked image $W(x, y)$.

4.4. Flow Graph



5. Experimental Results





















The performance proposed hybrid image watermarking algorithm is evaluated on five original images. They are Anna University, Barbara, Lena, Cameraman and Girl images. The Table 1

shows the evaluated results of gray scale 8-bit images of size 512 X 512. In this 8-bit binary image of size 32 X 32 is the secret image and it is utilized as watermarking image shown in Table 1. The watermarked images and extracted images are



showed in Table1.

Table 1. Original image, secret image, watermarked image and extracted image.

Images	Original image	Secret Image	Watermarked image	Extracted image
Anna University				
Barbara				
Lena				
Cameraman				
Girl				

The embedding capacity of hybrid image watermarking algorithm and watermarked images quality are calculated among original and watermarked images. The Peak-Signal-to-Noise Ratio (PSNR) is given by

$$PSNR = 20 * \log_{10}(Max_i) - 10 * \log_{10}(MSE)$$
















Where, Mean Square Error (MSE) is computed by the given below equation:

$$MSE = \frac{1}{m * n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} (I(i, j) - W(i, j))^2$$

Here, the signal is in original data, Noise occurs in watermarked image. Where 'I' and 'W' denotes the pixels of original image and watermarked images respectively. Max_i denotes the possibility of image maximum pixel values. The Results shows better image quality by the measurement of PSNR. It is better than the other existing methods. The robustness and imperceptibly of the hybrid image watermarking technique is compared with the existing methods DFT, DCT and SVD.



Table 2. PSNR value.

Original image	Watermarked image	Secret Image	PSNR			
			DFT	DCT	SVD	Proposed
			41.2	43.2	44.5	49.73
			42.12	42.64	43.2	45.24
			36.78	37.23	38.7	39.24
			32.14	32.56	33.2	35.12
			33.26	34.8	35.3	36.24

In DFT, the coefficients of all image blocks are altered. Then it is embedding into an individual watermark pixel. Hence there exists quality issues and error occurs during the extraction process. In DCT, the watermark image is embedded to the lowest frequency coefficients. So, there are lot of changes in the coefficients of middle frequencies blocks in the watermarked image. In SVD, it allows to retain and release of singular values, that may not consider the quality of the image.

The PSNR value of proposed method by evaluating the images of Anna University, Barbra, Lena, Camera man and Girl is compared with the PSNR value owned in DFT, SVD and DCT. The Proposed method has maximum perceptual quality images than hybrid image watermarking as shown in Table1.

Structural Similarity Index Measurement (SSIM) is applied to improve PSNR and MSE. These are not consistent with the perception human eye. The SSIM is calculated by using given equation

$$SSIM = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

Where μ_x and μ_y are average of x and y. σ_x and σ_y are variance of x and y. σ_{xy} is the covariance value between x and y. C_1 and C_2 stabilizes the values.

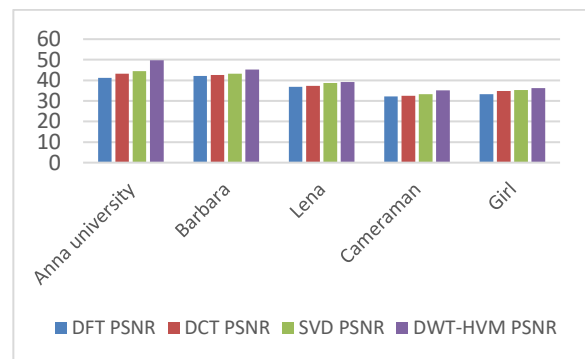


Fig. 8. PSNR Value comparisons

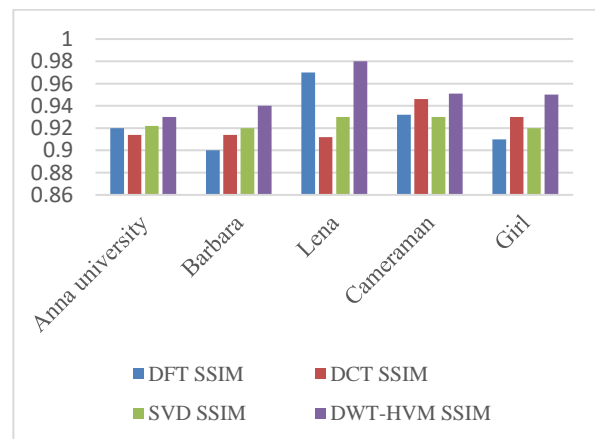


Fig. 9. SSIM Value comparisons



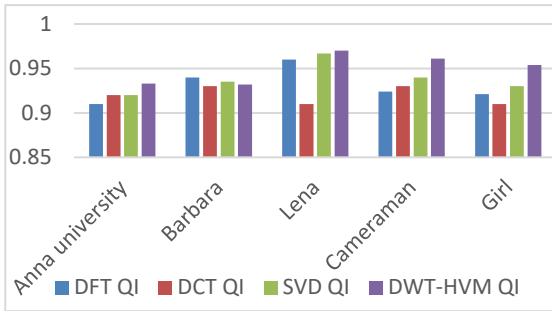


Fig. 10. QI Value comparisons

SSIM values ranges between -1 and 1, where value 1 is acquired when 2 images are identical. The results

shown give better image quality measurement as the SSIM than the other existing methods.

The similarities between the Watermark image and the extracted image can be calculated by universal image Quality Index (QI) and SSIM. The QI dynamic range is [-1, 1]. The SSIM best value is also 1. Table 3 shows various effects of parameter (SSIM, QI and PSNR) on watermarking performance. This Method has improved PSNR value, when comparing other existing methods such as DFT, DCT and SVD approach. In proposed method by using DWT-HVM technique obtained values of are more accurate than existing methods.

Table 3. Effects of parameter on watermarking performance

Images	DFT			DCT			SVD			DWT-HVM		
	SSIM	QI	PSNR	SSIM	QI	PSNR	SSIM	QI	PSNR	SSIM	QI	PSNR
Anna university	0.92	0.91	41.2	0.914	0.92	43.2	0.922	0.92	44.5	0.93	0.933	49.73
Barbara	0.90	0.94	42.12	0.914	0.93	42.64	0.92	0.935	43.21	0.94	0.932	45.24
Lena	0.97	0.96	36.78	0.912	0.91	37.23	0.93	0.967	38.7	0.98	0.97	39.24
Cameraman	0.932	0.924	32.14	0.946	0.93	32.56	0.93	0.94	33.2	0.951	0.961	35.12
Girl	0.91	0.921	33.26	0.93	0.91	34.8	0.92	0.93	35.3	0.95	0.954	36.24

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5.1 Results of image attacks

The Normalized Correlation (NC) is used to measure data similarities between watermarked image and

the various attacked images. The values of Bit Error Rate (BER) are tabulated for different input images and attacks, which is shown in Table 4.

Table 4. BER and NC after attacks

Attacks	BER	NC
Barbara	3.25	0.98
Cameraman	3.45	0.99
Lena	3.45	0.98
Girl	4.82	0.96
Anna University	3.91	0.99

Various attack applied on Barbara, Cameraman, Lena, Girl, Anna University images. The NC values are greater than 0.98 by extracted original image, it is better than existing methods.
















The effectiveness of proposed method is experimented on several types of image attacks such

as Salt and Pepper noise, Rotation, Filtering and Cropping which is shown in Table 5.

The evaluation is done for each and every attack on the watermarked image. The obtained SSIM values are better than DFT, DCT and SVD.



Table 5: Types of Attacks

Watermarked image	Noise image	Secret image	Types of Attacks	SSIM
			(NOISE) Salt & Pepper	0.99
			(NOISE) Salt & Pepper	0.989
			Rotation (10°)	0.98
			Filtering	0.989
			Cropping	0.978

6. Conclusion

In this paper, a hybrid method using DWT-HVM technique by hide the secret image into an original image using four levels of discrete wavelet transform and human visual model based weight factor is proposed. In this method, 3 Level sub band decomposition of image is performed in order to obtain a weight factor that implemented using DWT-HVM. To embed the proposed method, the original image of size 512*512 (LL3i.e., 64*64) is added to a secret image of size 32*32 for the evaluation of proposed method. Finally, IDWT is applied to get watermarked image. The recovered secret image from the Watermarked image shows the simulation results as high SSIM=0.98, when images being attacked. The simulation results of DWT-HVM proposed method shows the result comparison of SSIM=0.93, QI=0.93 and PSNR=49.73 values obtained from various images. The investigation and results show that the proposed method is dominant and removes the tradeoffs of all other existing methods. The proposed method outperforms the existing methods against most of the attacks. This hybrid watermark algorithm can be implement on the color images also in the future.

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