An Efficient Discrete Wavelet Transform Based Hybrid Image Watermarking Algorithm Using Human Visual Model

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AN EFFICIENT DISCRETE WAVELET TRANSFORM BASED HYBRID IMAGE WATERMARKING ALGORITHM USING HUMAN VISUAL MODEL

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ABSTRACT

More than ever with growing of multimedia technology, the digital data are exchanged in the internet, which can be duplicated by unauthorized users. To avoid this problem the watermarking technology has brought this paper. Performance improvement with compare to existing algorithm is obtained by proposing a new watermarking algorithm based on Human Visual Model (HVM) and Discrete Wavelet Transform (DWT) for securing the digital data and copyright protection. DWT is applied to the input image and at each level of DWT sub bands to embed a watermark image in selected coefficients of the sub band. HVM integrate the weight factor effect of human visualization by considering into the eye's vision is less sensitivity area, depending on brightness, frequency band and texture areas of the image sub band. In the proposed approach robustly and imperceptibly, DWT and HVM are used for obtainable weight factor, according to human eye perceptual 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) is used to evaluate and achieve the

imperceptible watermarked image. Results of PSNR values of hybrid image watermarking are between 49.73db to 36.24db. Experimental results show that our hybrid image watermarking process has enhanced robustness and displays the effectiveness of presenting images watermarking system.

Keywords – Watermarking, DWT, Human Visual Model, DWT-HVM, PSNR.

1. INTRODUCTION

With the fastest development of communication technology in internet environment and can be transmitted by digital media content that has been distributed and duplicate in a digital data, Which can be easily used in an illegal way and copied without ownership[1]. In order to copyright protection has become very important in internet environment and multimedia data. Thus, digital image watermarking is a technique to introduce as embedding watermark content into multimedia content without any degradation [2]. An image watermarking algorithm does not relate to cryptography [3] and stenography [4]. In Cryptography, after retrieving data does not visible or understandable. Similarly, stenography technique is not considering any changes of embedding process, and retrieved in the image. To resolve these problems using a new technique has been introduced as digital image watermarking process [5]. Watermarking process can be effectively provided both copyright protection and ownership identification of authorized copyright. The digital image watermarking process is shown in Fig 1. Watermarking process is designed the secret image (S) is embedded into an original image (I) using digital image watermarking process for copyright protection and ownership identification [6].

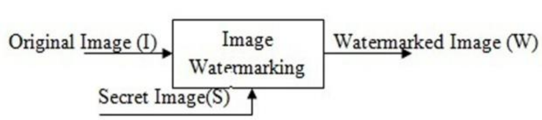


Fig 1. Image Watermarking

Generally, digital image watermarking can be implemented in two ways; according to processing domain are spatial domain and frequency domain. In spatial domain watermarking, directing changes in the pixel values of the original image. Which robustness is very low compared with a DFT watermarking algorithm [7] [8]. Frequency domain [9] watermarking is modifies the pixel values using, such as the Discrete Cosine Transform (DCT), the Discrete Fourier Transform (DFT), and Discrete Wavelet Transform (DWT). In Frequency domain is more robust than the other method [10] against noise attacks, filtering, compression, cropping and rotation. In digital image watermarking, the embedding process can be represented as

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

Where W is the watermarked image, I is the original image, S is the secret image and α is the watermark embedding strength.

2. RELATED WORK

The digital image watermarking process has been used to improve the different security concern that arises due to advancement of internet environment and their associated multimedia technology. Pixel based watermarking on spatial domain technique, here embedding can be accomplish pixel by pixel by taking into account of the texture and the luminance area of an image. Spatial domain can be easy for convincing unauthorized arbitrators by extracting secret image from watermarked image [1]. Least Significant Bit (LSB) technique is proposed with random right circular shifts for security reasons to change the order or arrangement of bit sequences [2]. In [3], the authors presented the watermarking method in which an image is considered as a low frequency magnitude coefficient by applying transform technique such as Discrete Fourier Transform (DFT) embedding by substitution of both the magnitude and phase. The magnitude is adjusting the watermark strength and the phase is holding the information. In [4], have proposed watermarking method is on the zig-zag order coefficients using DCT block coefficient. First DCT transform can be computed by grouping image pixels of specified size and also considers as three frequency sub bands are low, middle and high frequency sub band then middle frequency sub band coefficients are arranged into zig-zag order. DCT coefficients consider the as blocks is determined based on the watermark bit to adjust of the array basis function are Direct Current (DC) coefficient and Alternating Current (AC) coefficients. The DCT coefficient are modified depends on the DC coefficient and median of the AC coefficients ordered by a zig-zag sequence [5] [6]. In [7], presented that digital image watermarking algorithm based on one level DWT and embeds an invisible watermark into the original image by using alpha blending process. In [8], proposed method an efficient watermarking with the use of rough entropy as embedding strength and rough set based classification for reduction of statistical redundancies between wavelet sub band such as LL, LH, HL and HH. SVD-based on non-overlapping 4×4 image blocks, level shifting is used to control the embedding strength in accordance with the intensity of pixels in each block. While mixed modulation helps to improve robustness without compromising image quality [9].

A detailed survey on image watermarking process can be found in the literature toward wavelet transform based image watermarking. DWT watermarking which makes the method robustness to JPEG compression and quantized the wavelet coefficients depending on the perception weight factor before hide secret image [10]. DWT based watermarking algorithms are security can be improved embedding process by selecting various sub band levels [11]. In [12], the digital image watermarking can be used as human visual system (HVS) is not sensitive to small modification in the image pixel values. The secret image can be embedded into an original image by alteration the pixel values to a limited extent that humans eye's cannot predict [13]-[16].

All the methods discussed above refer to frequency domain watermarking methods, such as DFT, DCT and DWT is more robustness than the pixel watermarking method. But, DFT and DCT method is less computationally compared to DWT. In DWT based hybrid image watermarking, which is considered an efficient, high computation and accurate in human visual perception because of multi resolution property of DWT. In this proposed method, a new enhancement of the hybrid image watermarking method based on DWT and Human Visual model is analyzed. Among the transform-based techniques, DWT performs better because of the superior Human Visual Model. Here, a sub band is selected to embed the secret image more robustly and imperceptibly. HV model is used to determine the weight factor and selecting the significant coefficients to embedding the watermark image into the selected sub band of an image. The experimental results of watermarked images are tested for different type of image processing attacks and the results are compared with the existing methods.

The rest of the paper is organized as follows, discrete wavelet transform and HV model is explained in Section 2, proposed hybrid image watermarking is explained in Section 3, the experimental results are presented in Section 4. Finally, the concluding remarks are given in Section 5.

2.1. DISCRETE WAVELET TRANSFORM (DWT)

DWT is used to analysis of a signal at different frequencies and resolution. DWT is processed as a filter bank shown in Fig 2. Filter bank is used to analyze and reconstruct the signal. Filter bank can be separated a signal into different frequency bands in the input signal. Here, input as X(Z) signal is separated as LPF i.e., $H_0(Z)$ and HPF i.e., $H_1(Z)$. At each level the $H_1(Z)$ produce detail co-efficient and $H_0(Z)$ associated with the 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.

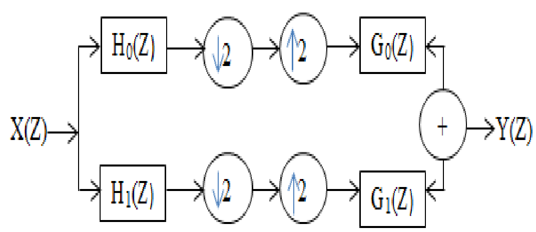


Fig.2. Filter bank

Here, image as X(Z) is breaking the signal and perform first DWT is one step of the transform on all rows. DWT is computed by High Pass Filtering (HPF) and Low Pass Filtering (LPF) as shown in fig 3. The left side of the row matrix contains down sampled low pass co-efficient of each row, the right side contains up sampled high pass co-efficient of each column shown in Fig 3. Next, Approximation coefficient performs one step to all columns. This operation can consider approximation coefficient is broken into four sub band, namely LL, LH, HL and HH [3].

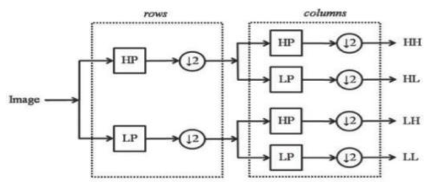


Fig.3. Wavelet decomposition by filter bank.

The DWT apply an input image split into high and low frequency bands. The low frequency sub bands contain the largest scale and least resolution [4]. The high frequency bands contain details of an image at different scales and resolutions. Fig.4 (a) is an original Lena image, split into two bands as L and H shown in fig4 (b). Figure.4 (c) shows the first level of decomposition, there are 4 sub-bands: LL, LH, HL, and HH. For each successive level of decomposition, the LL sub band of the previous level LL is used as the input. In second level decomposition, the DWT is applying on LL to provide as LL2, LH2, HH2, and HL2 has shown in fig4 (d). For third level decomposition the DWT applied on LL2 and get 4 sub bands. Finally, the DWT apply on LL3 and then get 4 sub bands.

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

2.2. HUMAN VISUAL MODEL

In hybrid image watermarking, the aim is to insert the secret image into an original cover image without affecting image quality and perceptions [9]. After applying DWT on the original image to find an average of 4- level sub band is calculated. Watermark image is embedded into the 4-level sub band HH, HL and LH of original images using HVM. In order to satisfy the transforming condition, it is necessary to know Human Visual Model. HVM estimates the perceptions of changes in three weight factors such as Brightness$B_l(i,j)$, Frequency band $f(l,s)$ and Texture $T_l(i,j)$ of an image DWT sub band. Watermark image is embedded into original image as imperceptible, 4-level sub band and final weight factor $w_l(i,j)$ to consider how to human eye disturbs [10]. Some changes are introduced in [10], in order to better consideration in the account of human eye less sensitive areas are Brightness$B_l(i,j)$, Frequency band $f(l,s)$ and Texture$T_l(i,j)$. Then, combining these three weight factors together as per equation (2) a complete final weight factor $w_l(i,j)$ is obtained for the hybrid image watermarking in wavelet domain [11].

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

Where l represented the level of sub band, the (i,j)represented the wavelet coefficient position, $B_l(i,j)$ is brightness weight factor, , $f(l,s)$is frequency weight factor, $T_l(i,j)$is texture weight factor and the three weight factor were given as follows:

1. The human visual model has less sensitivity 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 [11]. So, the brightness weight factor is calculated as follows:

$$B_l(i,j) = \frac{1}{256} I_3^3(1 + \left[\frac{i}{2^{3-l}}\right], 1 + \left[\frac{j}{2^{3-l}}\right] \qquad (3)$$

Where I_3^3 are 4-level sub band of approximation coefficients.

2. The human visual model is less sensitive to noise in high frequency subbands of DWT. It is much less perceivable on high frequency sub band [11]. So, the frequency weight factor is calculated as follows:

$$f(l,s) = \begin{Bmatrix} \sqrt{2}, & if s = 1 \\ 1, otherwise \end{Bmatrix} . \begin{Bmatrix} 1.00\ if\ l = 0 \\ 0.32\ if\ l = 1 \\ 0.16\ if\ l = 2 \\ 0.10\ if\ l = 3 \end{Bmatrix} \qquad (4)$$

3. The human visual model is less sensitive to noise in textured area and it is more near the edges [11]. The level of the DWT sub band is represented as a matrix of values with size M x N. So, the calculating of textured weight factor as follows:

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

Form the equations (3), (4) and (5) to get final weight factor $w_l(i,j)$according to equation (2).

3. PROPOSED WATERMARKING PROCESS

In this section, the proposed new hybrid image watermarking process is explained in two subsections. Subsection 3.1 deals with DWT- HVM procedure, hybrid image watermarking is explained in Subsection 3.2.

3.1 DWT- HVM

After analyzing and literature survey the problem related to digital image watermarking process, there are various watermarking process [12] [13] available based on DWT. To improve the robustness, hybridization is needed against different image processing attacks.

In the proposed 4 levels DWT is applied on the original image to decompose it into four subbands; LL, LH, HL and HH. The three details subband; LH, HL and HH. An approximation subband; LL. DWT-HVM is shown in Fig 5; it estimates the perceptions of changes in three weight factors of an image DWT sub band. In this proposed method which takes account of subband level to find the weight factor [11] based on image features are given as:

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

and combine above three weight factors together to form a complete final weight factor for the embedding and detection process. In this method[11], 4 levels of DWT decomposition are performed in the original image.

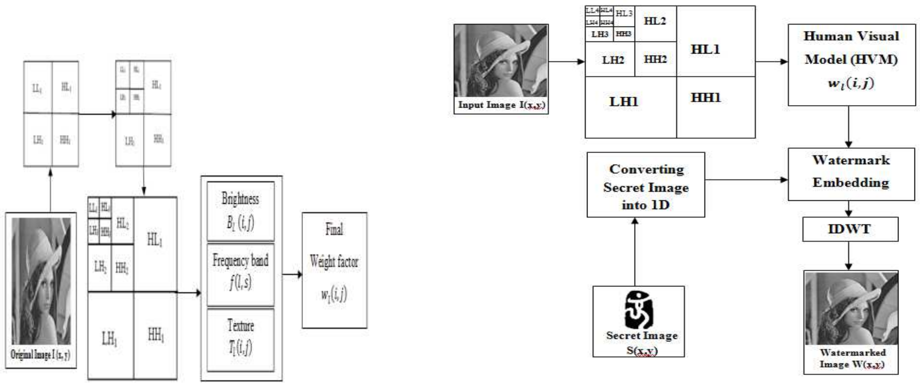


Fig 5. Weight factor

The LL sub band of the previous level (LL) is used as the input for each level of decomposition and finally calculating the three-weight factor and these weight factors are used internally for the embedding of host image.

3.2. Hybrid Image Watermarking

The hybrid image watermarking process is shown in Fig.6. In hybrid image watermarking process essentially includes the following steps: DWT decomposition, HVM and watermark embedding.

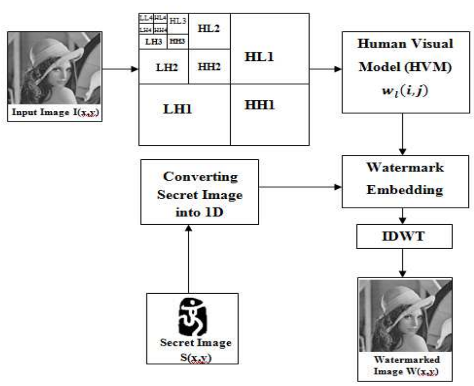


Fig 6. Hybrid image watermarking

An original cover image is considered as 512X512 gray scale images. The cover image is decomposed through DWT in 4 levels to determine significant coefficients. Let approximation (LL1) sub band and detailed such as LH1, HL1 and HH1 sub band in first level decomposition. In second level, apply DWT on LL1 band to get a DWT sub band such as LL2, LH2, HL2 and HH2, then DWT has been applied upto 4 levels DWT sub band. Finally, to get 4-level sub bands are significant coefficients as HH3, HL3, and LH3. DWT sub band can be modified using final weight factor $w_l(i,j)$ for wavelet co-efficient according to equation (2). Let $S(x,y)$ be this secret image, whose entry $S(x,y)$ is determined whether corresponding coefficient, $W(x,y)$ is chosen to hold the watermark $S(x,y) = 0$ or 1. Then the secret image is embedded by selection of significant coefficients HH3, HL3, and LH3 using HVM. Human Visual Model is proceeds for selection of significant coefficients by weight factor for 4-level sub band of cover image to embedding the secret image. The secret image and selected sub band HH3, HL3, and LH3 are converted into one dimensional, after converting the sub band coefficient to get the threshold value from final weight factor using the median value [11]. Let median value is considered as threshold value. Given that threshold value by final weight factors the secret image is added into all selected sub bands. The weight factor $w_l(i,j)$ is chosen to imply that disturb having values less than i.e.$W(x,y) <$ threshold value are not to be perceivable [11]. Given that secret image is binary, this algorithm allows to embed to each sub band the maximum unperceivable [12]. After applying inverse wavelet transform to get watermarked image. The watermark embedding process equation is already presented in equation (1). Now, complete weight factor included in the equation (6), the equation will be:

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

Where, $W(x,y)$ is the Watermarked Image, $I(x,y)$ is the Original cover image, $w_l(i,j)$ is the weight factor value of 4-level decomposition, $S(x,y)$ is the secret image and α is the embedding strength parameter.

In hybrid image watermarking algorithm is selected as gray scale images. Color images also used in this algorithm. To reduce the computation process color images are converted into gray scale images as

512x512. The secret images are selected as binary images as 32x32. The watermark requirements to be very small in order to make it spatially localized and to make robustness against geometric attacks like rotation, cropping and filtering. Experimental results of test images demonstrate that the proposed image watermarking perform are much better comparing to others methods.

Algorithm:

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

Step 2: Four level of DWT decompositions is performed for the grayscale image. Apply Discrete Wavelet Transform on gray scale image to get 4 sub bands such as LL0, HL0, LH0 and HH0.

Step3: For each successive level of DWT decomposition, the LL sub band of previous level is used as input. Apply 2-level DWT on LL0 sub band and repeat the steps up to fourth level. Finally, fourth level of the 4-sub band, namely LL4, HL4, LH4 and HH4 each sub band size is 32x32.

Step4: Find Weight factor $w_l(i,j)$ for each sub band of wavelet coefficient using Human Visual Model and to get the threshold value from final weight factor. If selected the threshold value and compare to wavelet sub band coefficient value of embedding process.

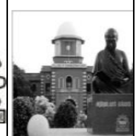
Step5: A binary image with dimension of 32 x 32 is used as a secret image. The secret image is converted from two dimensional to one dimensional.

Step6: However, the Secret image S(x,y) is embedded pixel by pixel based threshold value, rather than being converted into one dimensional, which facilitates the embedding process. Finally, apply IDWT and get a watermarked image $W(x,y)$.

5. EXPERIMENTAL RESULTS

To evaluate performance of the proposed hybrid image watermarking algorithm is tested and verified on a set of 512 X 512 real original images such as Anna University, Barbara, Lena, Cameraman and Girl respectively. Anna University image is captured as real time image for testing in this algorithm to get better robustness. Table:1 summarizes the results are tested using different gray scale images. The secret image resolution is 32x32 and also considered as binary image for watermarking embedding process. In this algorithm ratio of watermarking process is original image as 512 X 512 and secret image is 32 X 32. An original images, binary image, watermarked images and extracted images as shown in Table: 1.

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 performance of the hybrid image embedding capacity and quality of the watermarked image is evaluated by measuring Peak-Signal-to-Noise Ratio (PSNR) between cover images and watermarked images using the following equation:

$$PSNR = 20 * \log_{10}(Max_i) - 10 * \log_{10}(MSE) \quad (7)$$

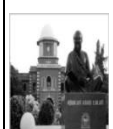
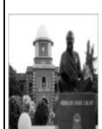
Where, Max_i is the maximum possible pixel value of the image and MSE is Mean Square Error.

Mean Square Error (MSE) is computed from below equation:

$$MSE = \frac{1}{m*n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}(I(i,j) - W(i,j))^2 \quad (8)$$

PSNR is used to measure the imperceptibility of the watermarked image. The signal in this case is the original image date, and the noise is the error introduced by watermarking process. Here, 'I(i,j)' and 'W(x,y)' represent the pixel values of cover image and the watermarked images respectively. The results show gives better image quality measurement as the PSNR is than the other method. The robustness and imperceptibility of the hybrid image watermarking technique is compared with that of existing methods DFT, DCT and SVD Table 2.

Table 2: Comparison of 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	43.21	**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 this watermarking method its validity, the PSNR value obtained for proposed watermarked method is compared with other method such as DFT, DCT and SVD. The hybrid image watermarking is under comparison offer low perceptual quality images than the proposed method as depicted by Table1.

This is because in DFT, all the coefficients of each block of image are modified in order to embed a single watermark bit. Which lead to loss of quality and error in extraction process. In DCT, the middle frequency of DCT coefficients of blocks of image are modified by large amount of changes in the pixels of image, secret image is embedding in the low frequency band. The main advantage of SVD is that the singular values are very stable, when small information (perturbations) is added into an image, their singular values do not change significantly fig 7.

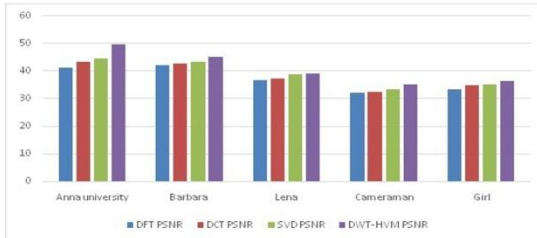


Fig .7. PSNR Value comparisons

SSIM is the Structural Similarity Index Measurement. SSIM is used to improve methods like PSNR and MSE which has been verified to be inconsistent with human eye perception. The SSIM is calculated by using given equation as

$$SSIM = \frac{(2\mu_x\mu_y+C_1)(2\sigma_{xy}+C_2)}{(\mu_x^2+\mu_y^2+C_1)(\sigma_x^2+\sigma_y^2+C_2)} \qquad (9)$$

Where, $\mu_x$and μ_y is the average of *x* and *y*. $\sigma_x$and $\sigma_y$are variance of *x* and *y*. $\sigma_{xy}$is the covariance value between *x* and *y*. $C_1$and $C_2$are two variables to stabilize the division with weak denominator.

SSIM value are in range of between -1 and 1, where value 1 is acquired when two images is identical. The results show gives better image quality measurement as the SSIM is than the other method fig 8.

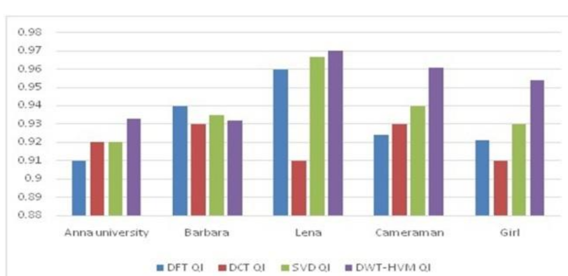


Fig 8: Results of SSIM.

In order to measure the similarity between the secret image and the extracted watermark image, the universal image Quality Index (QI) and SSIM are used besides to PSNR and NC. The dynamic range of QI is [−1, 1] while the best value 1 is achieved when two images are identical. Similarly, the best value of SSIM is also 1. Table 3 shows various effects of parameter (SSIM, QI and PSNR) on watermarking performance fig 9.

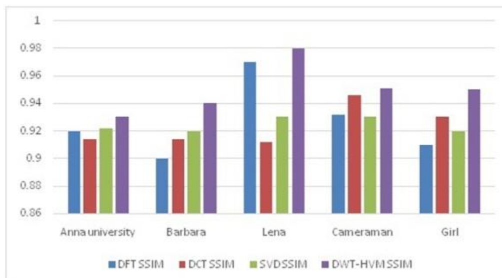


Fig 9: Results of QI.

This method considerably improves PSNR value than the method using DFT, SVD and DCT technique. Here, it improves robustness for each method is shown by below experimental result table 3.

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**	**0.93**	**49.73**
Barbara	0.90	0.94	42.12	0.914	0.93	42.64	0.92	0.935	43.21	**0.94**	**0.93**	**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	0.92	32.14	0.946	0.93	32.56	0.93	0.94	33.2	**0.95**	**0.96**	**35.12**
Girl	0.91	0.92	33.26	0.93	0.91	34.8	0.92	0.93	35.3	**0.95**	**0.95**	**36.24**

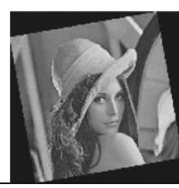
5.1 Results of image attacks

The Normalized Correlation (NC) is used to measure similarities of extracting watermarks and Bit Error Rate (BER) values against different image processing attacks of watermarked Anna university, Barbara, Lena, Cameraman and Girl images is reported in Table 4.

Table 4: BER and NC after attacks

Attacks	BER	NC
Barbara	3.25	0.98
Cameraman	4.56	0.99
Lena	3.45	0.98
Girl	4.82	0.96
Anna Univesity	3.9	0.99

Table 5: Types of Attacks

Input 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

Robustness of the proposed hybrid image watermarking is evaluated for various types of image attacks such as Salt and Pepper noise, Rotation, Filtering and Cropping summarizes in Table 5. The performance of proposed method under each attack is evaluated using watermarked image.

6. CONCLUSION

In this paper, a new hybrid image watermarking algorithm based on wavelet domain using HVM is proposed. HVM was employed to achieve high-level grades for the watermarking requirements and maintain the trade-off between fidelity and robustness against attacks. For this, proposed hybrid image watermark is embedded into the 4- Level of sub band by decomposed using weight factor and selected coefficients based on three weight factors using HVM. Finally, the performance of proposed hybrid image watermarking process is presented where the robustness against different type of geometric attacks such as salt and pepper noise, rotation, filtering and cropping. Experimental results on test images have shown that the proposed method outperforms the existing methods against the most of the attacks. Comparisons of quality measurement value in different techniques are PSNR, SSIM and QI using cover and watermarked image. Here, measure the PSNR, SSIM and QI value of proposed method is better compare to others. Analysis of this result, it carried out the requirements and security for the future research as video watermarking.

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