Dual Image Efficient Watermarking Technique Based on LWT-CZT-SVD and Arnold Transform with Grey Wolf Optimization

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Research Article

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Dual Image Efficient Watermarking Technique Based on LWT-CZT-SVD and Arnold Transform with Grey Wolf Optimization

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Abstract

In this paper, a new algorithm of multi-image watermarking is proposed for the security of multimedia data by using the features of Lifting wavelet transform (LWT), Singular value decomposition (SVD), Chirp Z-transform (CZT), and Arnold transform (AT). In the embedding procedure, split the input image into sub-bands using lifting wavelet transform and select HL and LH sub-bands for image watermarking, then apply the chirp Z-transform in the selected sub-bands and then decompose these two sub-bands by using SVD. Two watermark images are selected for embedding them into the input image, and the security of the second watermark is increased by using Arnold transform. Apply the lifting wavelet transform on both the watermark images and then transform them by SVD. Singular values (SVs) of watermarks are used to embed into SVs of the input image. The grey wolf optimization (GWO) technique is preferred here to calculate the scaling factor. Scaling factor plays very important role in the performance of watermarking. The effectiveness of the proposed algorithm is checked by applying different types of attacks. The superiority of the proposed work is mentioned in the results. Peak signal to noise ratio (PSNR), Normalized correlation coefficient (NCC) & Mean square error (MSE) is used for performance evaluation.

Keywords: Lifting wavelet transform (LWT), Chirp Z-Transform (CZT), Singular value decomposition, Arnold transform (AT), Grey wolf optimization (GWO).

1 Introduction

With the drastic growth in computer science and image processing, it is challenging to secure our multimedia data. Digital image watermarking is not only a technique of ownership, but image retrieval is also a crucial aspect of watermarking. Cryptography is one of the techniques to secure online data. Arnold transform is also preferred for scrambling of an image to provide security. Image watermarking must follow the criterion of integrity with improved performance. The performance of the proposed algorithm can be measured by calculating peak signal-to-noise ratio (PSNR), mean square error (MSE), normalized correlation coefficient (NCC), and structural similarity index measurement (SSIM).

Andalibi et al. [1], performed watermarking by isolating the host image into sections that are properly textured and those that are not properly textured. For textured portions, they apply an Arnold transform and one lossless rotation to convert the image into a visually similar texture, whereas for poorly textured regions, they merely employ a lossless rotation. Finally, use a typical wavelet based embedding technique to embed altered logos into each region. They use a multi-step extraction process that starts with an affine parameter estimation to account for any geometrical modifications. Kaur et al. [2], proposed a new image watermarking technology based on visual cryptography, which creates two shares with DWT-SVD. The method is highly secure and crucial in the attack on image processing. The model also depicts the future potential and provides a step-bystep implementation of the embedded algorithm. Loan et. al. [3], proposed a blind watermarking technology that uses chaotic encryption and may be used on both colour and grayscale photographs. Before embedding the watermark in the host image, the Discrete Cosine Transform (DCT) is used. The host picture will be segmented into 8×8 non-overlapping blocks, and a watermark bit will be implanted by altering the difference between neighbouring blocks' DCT coefficients. To give double layer security to the watermark, Arnold Transform is used in conjunction with chaotic encryption. The results of the simulations reveal that the suggested technique is resistant to most image processing procedures such as median filtering, JPEG compression, cropping, sharpening, and so on.

DYu Y et. al. [4], proposed a novel audio zero-watermarking algorithm, based on wavelet transform (DWT) and cosine transform (DCT). After DWT and DCT, the watermark is registered by equating mean absolute values of consecutive frame coefficients. The suggested system is highly resistant to typical attacks such as low-pass filtering, AWGN, down sampling, and MP3 compression, as demonstrated by experimental results. Lutovac B et. al. [7], proposed a method based on Zernike moments and DCT. Kalra G.S. et. al. [9], appended Hamming codes to the intensity component of the colour image row by row and column by column before inserting the watermark. For the security of the ECC inserted watermark, two encryption approaches were used. The starting row and column number for that 8×8 block was used to compute the pixel position for placing the watermark. The strength of pixel embedding is evaluated using the criterion that low frequency is more resistant to general signal processing attacks, resulting in less value being embedded and vice versa.

Preet et. al. [10], took a colour image as host and uses multi-image for watermarking. They use lifting wavelet transform, DCT and Arnold transform (AT). RGB-coloured host image is converted to YCbCr colour space. Lifting wavelet transform (LWT) is used to decompose the 'Y' component up to the second level, and DCT is used to transform the LL2 and LH2 sub-bands. DCT is also applied to both watermarks, with the first one being encrypted via AT. Finally, the watermarks are incorporated in the host image after being DCT converted. A.K. Ray et. al. [11], introduced the Rivest – Shamir – Adleman (RSA) algorithm as a watermarking tool. Using first level DWT, multiple frequency subbands of the host picture are retrieved, whereas SVs of the watermark are generated, which are then encrypted using the RSA technique. The watermark image's encrypted SVs are incorporated in the SVs of the altered host picture. Though it appears that the created method achieves minimal imperceptibility, the fact that it employs the RSA algorithm strengthens the security of the scheme. In [12], chaotic encryption-based watermarking is used. Chaotic encryption is used to provide the security. To provide security Arnold transform is used in [13]. A robust and distortion less multi-image watermarking by using LWT, DCT and error correction code is performed in [14]. Different type of watermark schemes is defined in [15]. They also provide a proper description of cryptography, steganography and fingerprinting. RDWT, NSCT, AT, and SVD transforms are all employed efficiently in [16]. This methodology includes dual image watermarks, and the set partitioning in hierarchical tree (SPIHT) algorithm is successfully used to compress the watermarked image. Redundant discrete wavelet transform is another method to produce robust watermarking [17].

The paper is structured in the following manner- Section 2 describes the theoretical background of the proposed work whereas Section 3 proposed watermarking technique. Section 4 deals with simulation results and comparison of results with other schemes whereas concluding remarks are mentioned in Section 5.

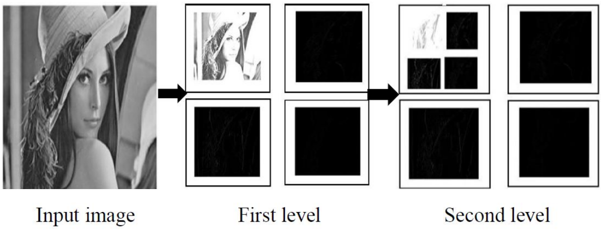

Fig. 1 Lifting Wavelet Transform of input image

2 Theoretical Background

2.1 Lifting Wavelet Transform

LWT is a faster, more efficient, and second-generation transform. LWT is a faster substitution of discrete wavelet transform (DWT). DWT traditionally uses up and down sampling, but LWT is based on the split and merge technique. Retrieval of the image is better in LWT than other wavelet transforms because LWT smoothens the image by reducing the aliasing effect. LWT depends on three processes - splitting, lifting and normalization. Two level decomposition of host image is shown in Fig. 1.

2.2 Chirp Z-transform

The Discrete Fourier Transform (DFT) is a variant of the CZT (CZT). Unlike DFT, which samples the Z plane at uniformly spaced locations along the unit circle, CZT samples the Z plane along spiral arcs, which correspond to straight lines in the S plane. CZT used to enhance the quality of image. CZT is more effectively used in medical imaging. A revolutionary algorithm for inverse CZT is proposed by Sukhoy et. al. [27]. The chirp z-transform has three critical applications [28], poles are being enhanced, Frequency analysis with high resolution and narrowband, Interpolation in time, or a change in sampling rate.

2.3 Singular value decomposition

A real matrix 'A' is decomposed into three matrices 'L', $'\Sigma'$ and 'R' using SVD where 'L', 'R' are left and right orthogonal matrices and $'\Sigma'$ is a diagonal matrix which consists of SVs [18]. Mathematically SVD can be defined as:

$$A = L_1 \Sigma_1 R_1^T + L_2 \Sigma_2 R_2^T + \dots\dots\dots + L_r \Sigma_r R_r^T \tag{1}$$

In Eq. (1) 'r' denotes rank of matrix 'A'. In watermarking techniques SVD is very frequently used because SVD provides better stability when attacked by different types of attacks.

2.4 Arnold transform

Copyright protection is a difficult operation that must be accomplished in order to safeguard information against hostile attacks. As a result, the Arnold transform is used to scramble the image. Scrambling is carried out for a predetermined number of iterations [20]. Mathematically AT can be formulated as:

$$\begin{Bmatrix} AT_1^{'} \\ AT_2^{'} \end{Bmatrix} = \begin{Bmatrix} 1 & 1 \\ 1 & 2 \end{Bmatrix} \cdot \begin{Bmatrix} AT_1 \\ AT_2 \end{Bmatrix} \tag{2}$$

In Eq. (2) $\begin{Bmatrix} AT_1^{'} \\ AT_2^{'} \end{Bmatrix}$and $\begin{Bmatrix} AT_1 \\ AT_2 \end{Bmatrix}$ represents pixel values of image after and before AT whereas 'N' is the size of image. Arnold transform is periodic in nature.

2.5 Grey Wolf Optimization

The hunting action of wolves and social hierarchy are mimicked by the GWO. Grey wolves' pack hunting is another engaging societal activity, in addition to their social hierarchy. Enclosing, hunting, and attacking the target are the three primary components of GWO [19]. The fitness function Eq. (3)used during GWO is given by-

$$\frac{\frac{\sum_{n=1}^{i} NCC_1^i + MSE_1^i}{n} \frac{\sum_{n=1}^{i} NCC_2^i + MSE_2^i}{n}}{P} \tag{3}$$

Where n represents the number of attacks, NCC used for normalised correlation coefficient (NCC_1 for first watermark logo and NCC_2 for second watermark logo), MSE for mean square error (MSE_1 for first watermark logo and MSE_2 for second watermark logo) and P shows the number of parameters used i.e., 4 (NCC_1, $NCC2_2$, MSE_1, MSE_2). The steps involved in GWO are as follows:

- Initialize the population size and number of cycles (iterations) and to start the process we have to generate the starting values of wolves by using Eq. (4)-

$$W = lowerbound + rand * (upperbound - lowerbound) \tag{4}$$

  Where W shows the initial values of wolves, rand is the random function in between 0 and 1 and lower and upper bound shows the range of the parameters used in the equation which we have to optimize.
- After calculating the initial values of wolves calculate the function value by using Eq. (3). Then from these function values get the first best position (X_α), second best position (X_β) and third best position (X_γ). enditemize
  - We have to proceed further by using equations Eq. (5) to Eq. (9)-

$$X_1 = X_\alpha - A_1 * D \tag{5}$$

$$A_1 = 2 * a * rand - a \tag{6}$$

$$a = 2 * (1 - \frac{iteration}{maxiteration}) \tag{7}$$

$$C_1 = 2 * rand \tag{8}$$

$$D = |C_1 * X_\alpha - X(t)| \tag{9}$$

Where X(t) shows the current iteration, rand represents random number between 0 and 1, X_1 is the value for first best, A_1 and C_1 are coefficient vectors and * represents multiplication.

- Similarly, we have to calculate values for second (X_2) and third best (X_3) positions.
- Calculate new position value of wolves by using Eq. (10)-

$$X_{new} = \frac{X_1 + X_2 + X_3}{3} \tag{10}$$

Where X_{new} shows the new value of wolves.

- Then calculate the value of function by using Eq. (3). After that we need to find the greedy solution to compare our new value with previous value and if new value is more optimized then replace it with old value and this way complete rest iterations.

3 Procedure of Watermarking

Watermark embedding and watermark extraction procedure is shown in Fig. 2 and Fig. 3.

3.1 Embedding procedure

To apply the watermark in the input host image we take one host image LENA and two watermark images. First watermark image is EC logo and second watermark is MNNIT logo. In the embedding process, firstly we have to apply second level decompose on LENA image by using LWT to get second level LH and HH sub-bands. Then after that apply CZT on LH and HH sub-bands. Then apply LWT on EC logo and select HL sub-band and apply Arnold transform on MNNIT logo along with LWT to select LH sub-band. Then apply SVD on HL and LH sub-bands of LENA image and also perform SVD on HL sub-band of EC logo and LH sub-band of MNNIT logo. Then combine all the singular values by using suitable scaling factor with the help of grey wolf optimization. Then get the watermarked image by using inverse operation.

- Apply the second level lifting wavelet transform on input host image and select second level HL and LH sub-bands.
- Apply chirp Z-transform on LH and HL sub-bands to get LH_Z and HL_Z.
- Apply singular value decomposition on LH_Z and HL_Z to get dominant singular values SV_{LHZ} and SV_{HLZ}.

- Apply one level LWT on first watermark image (EC logo) to get HL_w sub-band. Then apply SVD on HL_w to get SV_{HLW}.
- Apply Arnold transform along with one level LWT on second watermark image (MNNIT logo) to get LH_w sub-band. Then apply SVD on LH_w to get SV_{LHW}.
- EC and MNNIT logo are embedded into the singular value of input host image.

$$SV_{W1} = SV_{HLZ} + \delta * SV_{HLW} \tag{11}$$

$$SV_{W2} = SV_{LHZ} + \delta * SV_{LHW} \tag{12}$$

Here δ is the optimized scaling factor obtained from GWO.

- Now apply inverse SVD along with inverse CZT and LWT to get watermarked image.

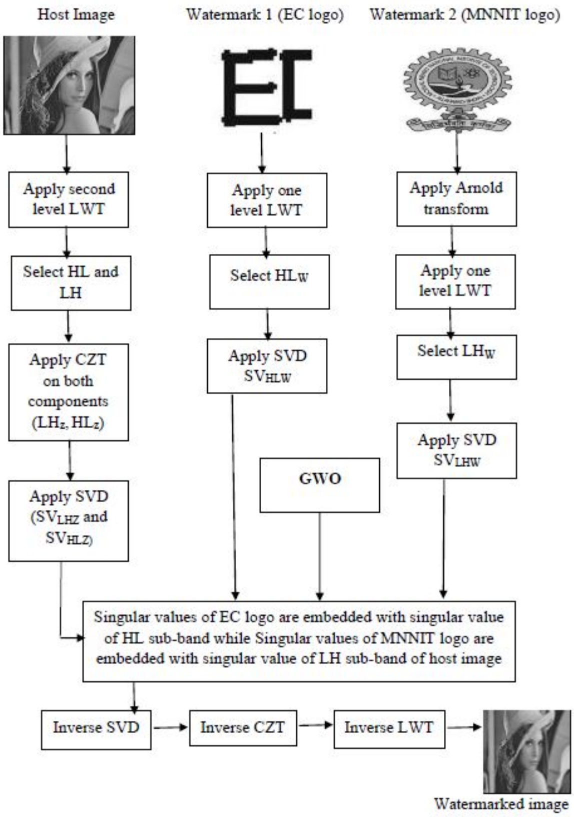

Fig. 2 Embedding Algorithm

3.2 Extraction procedure

Watermarked image is needed for extraction procedure. For the extraction of two watermark images, we need to follow the just reverse procedure of embedding process.

- Apply the two level LWT on watermarked image to get second level low-high and high-low sub-bands. Then apply CZT on above obtained sub-bands to get LH_{ZR} and HL_{ZR}. Then apply SVD on LH_{ZR} and HL_{ZR} to get SV_{LHZR} and SV_{HLZR}.
- To get the EC and MNNIT logo back we have to apply inverse embedding-

$$SV_{recw1} = \frac{SV_{HLZR} - SV_{HLZ}}{\delta} \tag{13}$$

$$SV_{recw2} = \frac{SV_{LHZR} - SV_{LHZ}}{\delta} \tag{14}$$

- Apply the inverse SVD on SV_{recw1} and inverse LWT to get EC logo.
- Apply inverse SVD on SV_{recw2}, then apply inverse LWT and inverse Arnold transform to get MNNIT logo back.

Here, SV_{recw1} shows the singular value for first recovered watermark (EC logo) and SV_{recw2} shows the singular value for second recovered watermark (MNNITlogo).

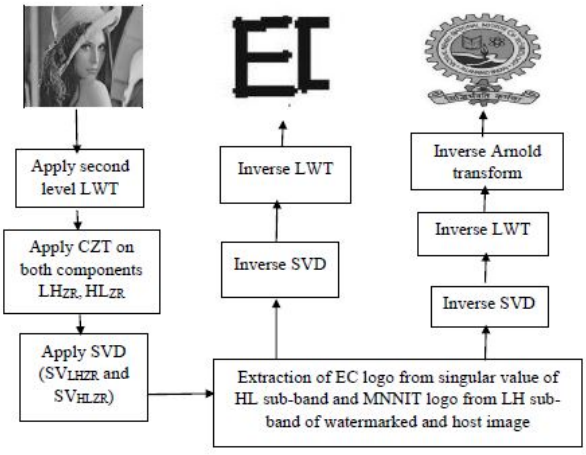

Fig. 3 Extraction Algorithm

4 Simulation Results

Experiments were performed on different input images of size 512×512 to check the effectiveness of proposed scheme. Eight standard images in the gray scale format namely Lena, Boat, Baboon, Pepper, Goldhill, Couple, Lungs Xray and

MRI are taken as the host image shown in Fig. 4. Two watermark images EC

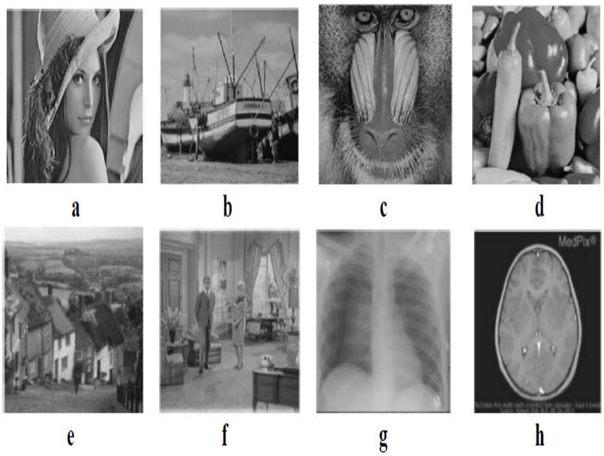

Fig. 4 Input images (a) Lena (b) Boat (c) Baboon (d) Pepper (e) Goldhill (f) Couple (g) Xray lungs (h) MRI

logo and MNNIT logo of size 256×256 are taken for watermarking shown in Fig. 5. Different watermarked images are shown in Fig. 6, and the extracted watermark images are shown in Fig. 7. All the results are calculated using MATLAB. Peak signal to noise ratio (PSNR), normalised correlation coefficient (NCC1 for first watermark i.e., EC logo and NCC2 for second Watermark i.e., MNNIT logo), and mean square error (MSE) is used for performance evaluation.

The PSNR (dB) values for different images are shown in Tab. 1. Lena input gives the maximum PSNR value (48.9481) without attack. The PSNR value for the rest of the images is also acceptable as the PSNR value of Boat is 48.3397, Baboon is 46.3174, Pepper is 47.0280, Goldhill is 48.0608, Couple is 48.8585, Xray is 48.5323, and MRI is 48.5617. Two medical images (Xray and MRI) also show outstanding quality of PSNR. The normalized correlation coefficient also gives better values without attack for both of the watermark images. Both the results show the effectiveness of the proposed technique. The attacked Lena host image and two extracted watermark images are shown in

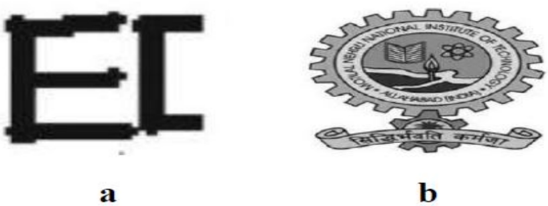

Fig. 5 Watermark images (a) EC logo (b) MNNIT logo

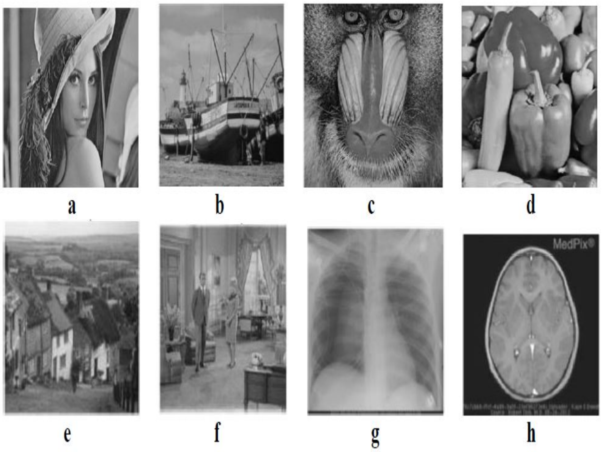

Fig. 6 Watermarked images (a) EC logo (b) MNNIT logo

Fig. 7 Extracted watermark images (a) EC logo (b) MNNIT logo

Table 1 PSNR (dB) and normalized correlation coefficient (NCC) for different input images using GWO.

Input images	PSNR (dB)	NCC1	NCC2
Lena	48.9481	1.0000	0.9999
Boat	48.3397	1.0000	0.9999
Baboon	46.3174	1.0000	0.9999
Pepper	47.0280	1.0000	0.9999
Goldhill	48.0608	1.0000	0.9999
Couple	48.8585	1.0000	0.9999
Xray	48.5323	1.0000	0.9999
MRI	48.5617	1.0000	0.9999

Fig. 8. Comparison of PSNR values shown in Fig. 9 and Fig. 10 using chart graph. NCC1 value is for EC logo and NCC2 value is for MNNIT logo shown in Fig. 8. The NCC1 values are generally higher than NCC2 values.

4.1 Performance analysis of results

The analysis of the proposed method can be done by discussing robustness, imperceptibility, security, and capacity.

Table 2 PSNR (dB), normalised correlation coefficient (NCC) and mean square error (MSE) of proposed technique under different attacks

Attacks	PSNR (dB)	MSE	NCC1	NCC2
Salt and pepper noise(0.001)	37.2907	2.0713e-04	0.9999	0.9998
Gaussian noise(0,0.001)	31.8504	8.5606e-04	0.9991	0.9990
Speckle noise (0.02)	24.4993	0.0032	0.9908	0.9906
Gaussian low pass filter (3*3)	43.7998	4.8300e-05	0.9996	0.9991
Average filter	26.9645	0.0037	0.9976	0.9968
Median filter	38.0919	3.1713e-04	0.9993	0.9990
Rotation (5 degrees)	14.1883	0.2337	0.9995	0.9991
Histogram equalization	21.8194	0.0210	0.9992	0.9990
Sharpening	28.6932	0.0022	0.9555	0.9432
Wiener filter (11*11)	31.4025	8.5406e-04	0.9993	0.9989
JPEG (90)	42.6227	8.3325e-05	1.0000	0.9998
JPEG 2000 (10)	46.2540	4.6150e-05	1.0000	0.9998
Dither	8.3776	0.4227	0.6238	0.6129
Motion blur	27.4055	0.0010	0.9977	0.9967
Shearing	12.3355	0.0236	0.9996	0.9991
Region of interest filtering (ROI)	33.0091	4.8475e-04	1.0000	0.9998

4.1.1 Analysis of invisibility

Imperceptibility of digital image watermark can be analysed by calculating PSNR (dB). Different input images are taken to check the transparency of algorithm. Two watermark images are embedded into the host image and the PSNR (dB) value without attack is shown in Table 1. The PSNR is a criterion for measuring picture distortion. The higher the PSNR between two frames, the more identical they are. The standard benchmark is 30 dB [22], and visual degradation is more noticeable with PSNR below 30 dB. In general, image quality is good when PSNR is larger than 30 dB, and the human eye cannot efficiently discern variations in the image. It is clear from Tab. 1 that in all the cases the value of PSNR (dB) is greater the 46, So we can conclude that the proposed method is meeting the criterion of invisibility.

4.1.2 Analysis of robustness

To comment on the robustness of the proposed algorithm we must need to calculate the normalised correlation coefficient (NCC) between the original watermark image and the extracted watermark. In the proposed method two watermarks are used for image watermarking. For better robustness the value of NCC must be close to 1.000. The NCC values are shown in Table 2. NCC1 is used for EC logo and NCC2 is used for MNNIT logo. By applying different types of attacks, we can see that the NCC values are greater than 0.9 in every case. The graphical representation of NCC value is shown in Fig. 11. We can conclude that the proposed work shows greater level of robustness.

4.1.3 Analysis of security

Arnold transform (AT) is used for increasing the security of proposed work. MNNIT logo is scrambled when passed through the AT. There is trade-off between security and robustness. The NCC2 values are less than the NCC1 value because we applied AT on second watermark.

Fig. 8 Attacked Lena watermarked image and the recovered watermark

4.1.4 Analysis of capacity

The size of the input image is 512×512 and second level LWT is performed on the host image. The size of the watermarks is taken as 256×256 and one level LWT is applied on these images. To calculate the capacity, we need number of pixels of watermark image (W_{pixel}) and number of pixels of host image (H_{pixel}). Therefore, the capacity can be defined- W_{pixel} / H_{pixel}. So, the

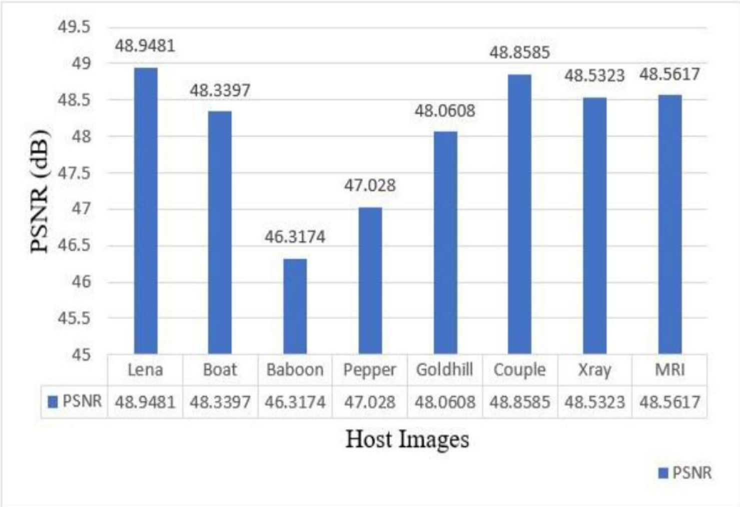

Fig. 9 PSNR values for different input images

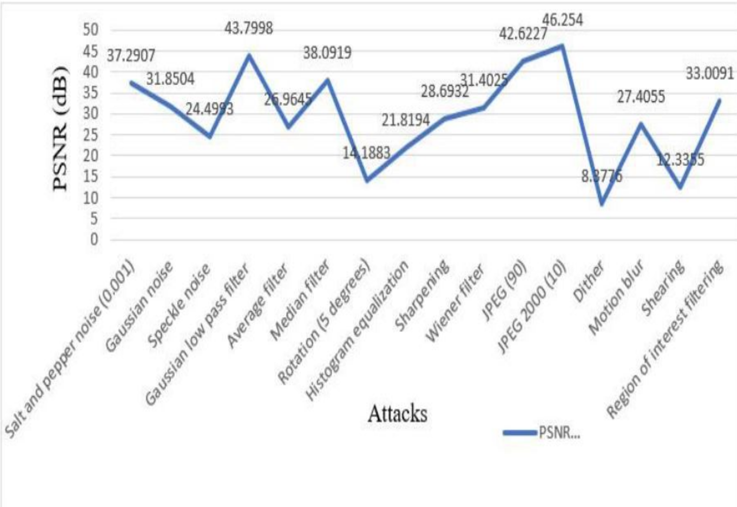

Fig. 10 PSNR values of Lena image for different attacks

capacity of proposed method is (256×256) / (512×512) =0.25. This suggests that the method is well capitalized.

4.2 Comparison of results

The proposed algorithm using grey wolf optimization provides good PSNR (dB) value in comparison with other schemes shown in Tab. 3. DWT-DCT based method proposed by [21] gives PSNR as 32.9505. Particle swarm optimization based method proposed in [22] gives PSNR as 44.5125. The algorithm proposed by Liu et. al. [23] provides PSNR as 42.4657 and the PSNR values in case of [24] and [25] are 40.12 and 44.8564 respectively.

Table 3 Comparison of PSNR (dB) values with other schemes

Scheme metrics	PSNR (dB)
Furqan et al.[21]	32.9505
Zhang et al. [22]	44.5125
Liu et al.[23]	42.4657
Hurrah et al.[24]	40.12
Nandi et al.[25]	44.8564
Proposed Method (Lena image)	48.9481

The comparison of NCC values with another scheme is shown in Table 5. In [26] two different methods of digital image watermarking are proposed, where two different watermarks are inserted in a medical host image at the same time. In this method, the host image is decomposed by using the third level Discrete wavelet transform (DWT), then Discrete cosine transform (DCT) and SVD are applied. The singular dominant values of first watermark are embedded in the LH2 sub-band of the host picture, while the second watermark's SVs are changed by the LL3 sub-band. Back propagation neural network (BPNN) is used to enhance the system's resilience. The capacity of the proposed method

Table 4 Comparison of NCC values with other schemes

Attacks	Zear et al. [26]				Proposed method	
	Without BPNN		With BPNN		NCC1	NCC2
	NCC1	NCC2	NCC1	NCC2		
Gaussian noise (0, 0.001)	0.9901	0.8939	0.9908	0.9515	0.9991	0.9990
Salt and Pepper noise (0.05)	0.6596	0.6287	0.6828	0.8405	0.9850	0.9799
Median filter (3*3)	0.9833	0.98457	0.9861	0.8657	0.9993	0.9990
Average filter (3*3)	0.9809	0.6709	0.9863	0.7348	0.9976	0.9968
Rotation (5 degrees)	0.7843	0.5798	0.9806	0.7912	0.9995	0.9991
Gamma correction	0.9200	0.9249	0.9668	0.9650	0.9845	0.9827

is equal to [21], [22], [23], [25] and [26] and greater than [24]. The capacity of [24] can be calculated as $(32\times32\times4)/512\times512{=}0.015625$.

Table 5 Comparison of watermark capacity with other schemes

Scheme metrics	Capacity
Furqan et al.[21]	0.25
Zhang et al. [22]	0.25
Liu et al.[23]	0.5
Hurrah et al.[24]	0.015625
Nandi et al.[25]	0.25
Zear et al. [26]	0.25
Proposed Method (Lena image)	0.25

5 Conclusion

This paper proposes a dual image efficient watermarking technique based on LWT-CZT-SVD and Arnold transform with grey wolf optimization. CZT is used to enhance the effectiveness of the proposed work. To get the optimized scaling factor GWO is used with proper fitness function. SVD is used to provide enhanced robustness against different types of attacks. Two watermark images embedded within a single host image reduce the danger of manipulation and reduce storage needs. The simulation results demonstrate the proposed scheme's outstanding robustness and imperceptibility against various attacks. The superiority of the proposed work is also demonstrated in the comparison of the results section. This proposed technique has greater scope in the medical field for future work. Machine learning (ML) and Artificial intelligence (AI) are also beneficial in digital image watermarking. We can also extend this proposed work for colour images in the future.

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