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PSO based Lossless and Robust Image Watermarking using Integer Wavelet Transform

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Abstract

In recent days, the advances in the broadcasting of multimedia contents in digital format motivate to protect this digital multimedia content form illegal use, such as manipulation, duplication and redistribution. However, watermarking algorithms are designed to meet the requirements of different applications, because, various applications have various requirements. This paper intends to design a new watermarking algorithm with an aim of provision of a tradeoff between the robustness and imperceptibility and also to reduce the information loss. This approach applies Integer Wavelet Transform (IWT) instead of conventional floating point wavelet transforms which are having main drawback of round of error. Then the most popular artificial intelligence technique, particle swarm optimization (PSO) used for optimization of watermarking strength. The strength of watermarking technique is directly related to the watermarking constant alpha. The PSO optimizes alpha values such that, the proposed approach achieves better robustness over various attacks and an also efficient imperceptibility. Numerous experiments are conducted over the proposed approach to evaluate the performance. The obtained experimental results demonstrates that the proposed approach is superior compared to conventional approach and is able to provide efficient resistance over Gaussian noise, salt pepper noise, median filtering, cropping, rotation, contrast enhancement, scaling and Histogram Equalization attacks.

Index terms— image watermarking, IWT, PSO, SVD, PSNR, NC, SSIM.

1 I. Introduction

n recent years, the design of robust techniques has become an important field for providing a certain degree of security and content verification of multimedia documents. Users can readily offer their creative digital multimedia data on Internet, including audio, image, video or animation in several multimedia applications. Consequently, an emerging problem is to prohibit unauthorized duplication and dissemination of copyrighted multimedia materials. Nowadays, digital image watermarking has been developed to solve the problem for copyright protection and content verification of multimedia data [1][2][3]. It allows owners to hide their ownership rights and access controls into their original images. The ownership rights or access controls are called watermarks which can be various data formats such as logos, tags, sound or any other copyright information. Image watermarking can be roughly classified into several categories according to the domain they are developed, reference to host image, visibility, and robustness. For the case of watermark embedding, watermarking techniques can be developed in three domains, spatial, frequency and blend domains. Spatial domain methods embed a watermark via modifications to the pixel values of an original image. Frequency-domain schemes embed a watermark via modifications to the coefficients of the corresponding transformed-domain image of an original image. Blend-domain techniques have been developed in both spatial and frequency domains, which simultaneously take the advantages of the spatial domain and frequency-domain. Similarly, the watermark extraction techniques are also classified into blind, semiblind and non-blind types. Blind image watermarking techniques doesn't consider the original image during retrieval [4]. Semi-bling image watermarking just requires partial information such as watermark or extra information during retrieval. Finally, the non-blind image watermarking techniques require original images during extraction process.

However, non-bling image watermarking technique introduces an ambiguity problem, i.e., the original image was provided by authorized user or an unauthorized user. There is a possibility to attack by providing the original image to watermarking technique at extraction process. This is termed as ambiguity attack [1]. However, the semi-blind and blind watermarking techniques don't have this ambiguity problem. Thus, generally, blind and semiblind image watermarking techniques are preferred. Robustness and imperceptibility are the two properties generally considered during the design of any image watermarking technique. The imperceptible watermarking is the ability to not distinguish the watermarked image and original image. On the other hand, robust watermarking is the ability to detect the watermark image effectively from the watermarked image even under different transformations and also under different attacks.

This paper proposes a novel image watermarking technique based on Integer Wavelet Transform (IWT) and Particle Swarm Optimization (PSO). Compared to the conventional wavelet transforms, the IWT reduces the information loss in the extracted watermark. Since, there is problem of round of error in the conventional wavelet transforms; there is possibility of information loss. PSO is an optimization algorithm, used to optimize the watermarking constant, alpha. To show the efficiency of proposed approach, various images were processed for testing. Finally, the robustness of proposed approach was tested by applying various attacks on the watermarked image. Rest of the paper is organized as follows: section II illustrates the complete details about the related work. Section III illustrates the details about the indents of proposed watermarking technique such as particle swarm optimization, integer wavelet transform and the singular value decomposition. The complete detail of proposed watermarking methodology is illustrated in section IV. The performance evaluation of proposed approach is described in section V. a comparative analysis carried out between proposed and an earlier approach is also represented in this section. Finally, section VI concludes the paper.

2 II. Related Work

Generally, the image watermarking aims to achieve so many requirements such as robustness, imperceptibility, payload, security etc. Depends on the requirement, the watermarking technique can be developed. In the recent days, most of the work is focusing towards the improvisation of robustness and imperceptibility due to the enhanced multimedia applications. In the past decades, a lot of watermarking algorithms have been developed in transform domain, for example, discrete cosine transforms (DCT) [5] and discrete wavelet transforms (DWT) [6]. Comparing DWT for JPEG2000 with DCT for JPEG, DWT has merits such as no blockiness, fast processing time, and high compression ability; the robust watermarking scheme based on DWT has attracted great interest. Waveletbased watermarking scheme can be classified into two categories: wavelet tree-based watermarking methods and block-based DWT watermarking methods. The wavelet tree-based watermarking methods are generally using the energy difference among grouped wavelet coefficients for invisible watermark embedding and extraction [7][8][9][10][11]. Wang and Lin [7] grouped two wavelet trees into a so-called super tree, and each bit is embedded into two supertrees. Lien and Lin [8] improved Wang's method by using four trees to represent two watermark bits in order to improve visual quality. Wu and Huang [9] embedded the watermark into the supertrees by structure-based quantization method. Compared to the unquantized supertree, the quantized version has strong statistical character in energy distribution, which can be used to extract watermark bits. Tsai [10] enhanced the security of wavelet tree quantization watermarking scheme by adopting the chaotic system. Run etal. [11] embedded a watermark bit in the maximum wavelet coefficient of a wavelet; this is different from those in [7][8][9] which use two trees to embed a watermark bit. And the embedding method modifies the magnitude of the significant difference between the two largest wavelet coefficients in a wavelet tree to improve the robustness of the watermarking. On the other hand, some researches embed a watermark using block-based DWT [12][13][14][15][16][17]. Davoine [12] proposed the watermarking methods based on the triplets and rectangular blocks of significant wavelet coefficients. Zhang et al. [13]divided the original image into blocks and transformed them into a DWT domain. The watermark is embedded by using the mean and the variance of a sub and to modify the wavelet coefficient of a block. Khelifi et al. [14] proposed an adaptive blind watermarking method based on DWT. The host image is separated into non-overlapping blocks classified as uniformor non-uniform blocks using a JND-based classifier. The watermark is embedded in the high sub band of each block according to its classification. In [15], the block-based watermarking in the wavelet domain is proposed. They applied the significant difference between the first and second greatest coefficients to distinguish the bipolar watermark. Verma and Jha [16] Improved significant difference-based watermarking technique using lifting wavelet coefficients. In [17], the embedding algorithm hides a watermark bit in the low-low (LL) subband of a target non-overlap block of the host image by modifying a coefficient of ??component on SVD version of the block. The above-mentioned methods focused on locating the significant DWT component as embedding candidates and formulate appropriate strategy to modulate them without raising perceptual distortion. However, watermark extraction scheme is also critical for watermarking methods. In watermarking process, watermarking constant will plays an important role. It defines the strength of watermarking technique. If the selection of watermarking constant is optimal, it directs to the robust and imperceptible watermarking. Hence, there is a need of proper selection of watermarking constant. Generally artificial intelligence techniques will be used for optimization purpose. In [23], a watermarking approach was proposed based on Genetic Algorithm (GA). In [23], GA was used for the selection of watermarking constant. Recently, particle swarm optimization (PSO) wasevolved into the watermarking system. PSO is an intelligent algorithm that using the stochastic, population-based computer algorithm for problem solving. Zheng [18] applied the PSO to search the embedding location of the integer DCT coefficients in a block to optimize the requirement of imperceptibility and robustness in watermarking. Vahedi [19] utilized the PSO method to search for the optimal energy of embedding watermark to balance the quality and robustness of watermarked image. Hai **??**ao [24] applied PSO for the optimization of scaling factors to improve the robustness of watermarking scheme. 3level DWT is used for feature extraction and PSO for optimization. Though the PSO was used, there is a nonrecoverable information loss due to the 3-level DWT.

3 III. Basics of Watermarking a) Particle Swarm Optimization

PSO is an evolutionary computational model and is developed by Kennedy [20] for problem solving. They simulated birds' swarm behavior in this model, and made every particle in the swarm move iteratively according to its historical experience and the best experience of the whole swarm. At the end of the simulation, the best experience of the whole swarm is the best solution for objective function. The swarm is modeled by particles in d-dimensional search space. Every particle i has its own position?? ???? and velocity ?? ???? . These particles search for optimal value of a givenobjective function iteratively, then keep track of their individualbest positions?? ???? ???????? and find the global position ?? ð ??"ð ??"???? ???????? from allbest positions through a search space.?? ???? = ?? × ?? ???? + ?? 1 × ????????() × ??? ???? ???????? ? ?? ???? ? + ?? 2 × ????????() × (?? ð ??"ð ??"???? ???????? ? ?? ????)**(1)**?? ???? = ?? ???? + ?? ????**(2)**

Where?? denotes the inertia weight, ?? ???? denotes the position of i th particle in the d dimension. ?? ???? is the current position. ?? ???? is the movingdistance in one-step for a particle i and is limited within[?? ?????? , ?? ??????],where ?? ?????? and ?? ?????? are the maximum and the minimummoving distance in one-step, respectively. rand() is a random number function and its values are between 0 and 1.?? ???? ???????? is the bestposition for ?? ???? . ?? ð ??"ð ??"???? ???????? represents the ð ??"ð ??"????th global best position in all particles. c1 and c2 are constants. Eq. (1) is used to calculate the particle' snew velocity that refers to its previous velocity and the relations between the distance of its current position and its own best position and global best position of all particles. Then, the particle updates its new position by Eq. (2).

4 b) Integer Wavelet Transform (IWT)

The main problem with wavelet transform is its inability to reduce the loss of information in the original image. For example, if any one of the block of original image having integer pixel values and transformed through a floating point wavelet transform. If the transformed coefficients are changed during the embedding, then this wavelet transform will not provide any guarantee about the integer values of that particular block. The truncation of floating point values will result in loss of information, i.e., the original image cannot be reconstructed effectively. Furthermore, the conventional wavelet transform is, in practice, implemented as a floating-point transform followed by a truncation or rounding since it is impossible to represent transform coefficients in their full accuracy. To avoid this problem, an invertible integer-to-integer wavelet transform based on lifting [21] is used in the proposed scheme. It maps integers to integers and does not cause any loss of information through forward and inverse transforms. The main advantage with Lifting based wavelet transforms is fast and accuracy. They are easy to implement and also does not require any additional memory.

The forward transform of a typical lifting scheme usually consists of three steps: split, prediction and update. Consider a signal: X = {x(n), n?Z} with x(n)?R. The implementation of the forward transform is illustrated as below: Split: The original signal X is split into two subsets: even indexed samples ?? ?? and odd indexed sample ?? ?? by means of a sample operation:? ?? ?? = ??(2??) ?? ?? = ??(2?? + 1)**(3)**

After the split operation is completed, the odd set and even set are obtained and the two sets are closely correlated. That is, adjacent samples are much more correlated than those far from each other. Itis natural that one can build a good predictor for one set with other set. Prediction: Given the odd indexed samples ?? ?? , a predictor P for the even indexed samples ?? ?? can be designed:?? ?? ? = ??(?? ??)**(4)**

The difference denoted as d between the predicted results and the odd samples is considered as thedetail coefficients of the signal x(n) , and it is expressed as:?? = ?? ?? ? ?? ?? ? = ?? ?? ? ??(?? ??)**(5)**

Update: Knowing the even sample e x and the detail coefficients d, the approximation coefficients c arecalculated using the updating operator U as:?? = ?? ?? + ??(??)**(6)**

The inverse transform can immediately be derived from the forward transform by running the lifting scheme backwards. The block diagram of the lifting scheme is given in Figure 1. c) Singular value Decomposition SVD [22] is an important tool in linear algebra, which is widely applied in many research fields such as principal component analysis, canonical correlation analysis and data compression. LetX denotes a matrix with size M×N. The decomposition for X can bere presented by (2),?? = ? ??(1,1) ??(1,2) ? ??(1, ??) ??(2,1) ? ??(??, 1) ??(2,2) ? ??(??, 2) ? ? ? ??(2, ??) ? ??(??, ??) ? = ?????? ?? = ? ??(1,1) ??(1,2) ? ??(1, ??) ??(2,1) ? ??(??, 1) ??(2,2)

? ??(??, 2) ? ? ? ??(2, ??) ? ??(??, ??) ? × ? ??(1,1) 0 ? 0 0 ? 0 ??(2,2) ? 0 ? ? ? 0 ? ??(??, ??) ? × ? ? ? ? ??(1,1) ??(1,2) ? ??(1, ??) ??(2,1) ? ??(??, 1) ??(2,2) ? ??(??, 2) ? ? ? ??(2, ??) ? ??(??, ??) ? ??**(7)**

called the left eigenvector and right eigenvector, respectively. The two components are also orthogonal matrices, which can be specified by (8),?? ?? = ?? ?? ?? ?? ?? ?? ?? = ?? ?? ?? ?? ??**(8)**

Where ?? ?? and ?? ?? are identity matrices with size M×M and N×N,respectively. The component S is a singular value matrix in SVDdomain, and is a diagonal matrix with non-negative real numbers,?? ???? = ? ??(1,1) 0 ? 0 0 ? 0 ? ? 0 ? ? ? 0 ? ??(??, ??) ?**(9)**

Where ??(1,1) ? ??(2,2) ? ??(3,3) ? ? ??(??, ??) ? 0

5 IV. Proposed Watermarking Scheme

The complete details of the proposed approach are illustrated in this section. The proposed approach is accomplished in two phases, embedding phase and extracting phase. The respective block diagrams for embedding and extracting in shown in figure. The block diagram shown in figure.2 (a) describes the embedding procedure of proposed watermarking approach. Here, the PSO is used twice for the selection of watermarking constant alpha (?). Generally, the singular values of LL sub-band are much more than the singular value of remaining sub-bands such as LH, HL and HH. So, two watermarking constants are derived through PSO. They are designated as ? ???? and ? ?? , ?? ? ????, ????, ???? for embedding of singular values of LL sub-band of Host image (X) with singular value of LL band of watermark image (W) and the embedding of remaining bands respectively. Since, it is already revealed that, as the value of watermarking constant increases, it increases the robustness but decreases the quality. Also, the LL band having fewer variations whose effect will be less on the watermark, the watermarking constant ? ???? will be chosen as high compared to ? ?? . For both, PSO gives the optimized value such that there will be a tradeoff between the robustness and imperceptibility. The details procedure of embedding is described below:

Step 1: Decompose the Host image (X) through IWT into the four sub-bands such as LL, LH, HL and HH.

Step 2: Perform SVD for LL band and also for remaining bands as?? ???? ?? = ?? ???? ?? ?? ???? ?? (?? ???? ??) ??**(10)**?? ?? ?? = ?? ?? ?? ?? ?? ?? (?? ?? ??) ?? , ?? ? ????, ????, ????**(11)**

Step 3: Decompose the watermark image (W) through IWT into the four sub-bands such as LL, LH, HL and HH.

Step 4: Perform SVD for LL band and also for remaining bands as?? ???? ?? = ?? ???? ?? ?? ???? ?? (?? ???? ??) ??**(12)**?? ?? ?? = ?? ?? ?? ?? ?? ?? (?? ?? ??) ?? , ?? ? ????, ????, ????**(13)**

Step 5: Modify the singular values (?? ??) of every band of host image by embedding the singular values (?? ??) of every band of watermark image as?? ???? ???? = ?? ???? ?? +? ???? ?? ???? ?? (**14**)?? ?? ???? = ?? ?? ?? +? ?? ?? ?? ?? , ?? ? ????, ????, ????**(15)**

Where ?? ???? ???? are the singular values of LL band of watermarked image, ?? ?? ???? are the singular values of remaining bands of watermarked image. ?is the scaling factor (? ???? = 0.05 for LL sub-band embedding and ? ?? = 0.005 for embedding the remaining bands (LH,HL and HH)).

Step 6: apply inverse SVD on the altered singular values of all bands. The new bands are denoted as ???? ???? , ???? ???? , ???? ???? , ???? ????

Step 7: The watermarked image is then obtained after applying the inverse IWT on the four sets of modified IWT coefficients.???? = ?????? ?1 (???? ???? , ???? ???? , ???? ???? , ???? ????)**(16)**

Where, WI represents the watermarked image.

6 b) Extraction Procedure

Figure **??**2 (b) describes the extraction procedure of the proposed watermarking technique. Here, the extraction is applied to extract the watermark image and also the host image. The main intention of IWT is to reduce the information loss. Here, the same IWT is applied on the distorted watermarked image denoted as ???? * . The same optimization procedure is carried out here through PSO to find the efficient watermarking constant for both LL band extraction and remaining bands extraction. The complete procedure is described below:

Step 1: decompose the distorted watermarked image ???? * through IWT into sub-bands such as LL, LH, HL and HH.

Step 2: Perform SVD for LL band and also for remaining bands as?? ???? ???? * = ?? ???? ?? ?? ???? ?? (?? ???? ??) ?? (**17**)?? ?? ???? * = ?? ?? ?? ?? ?? ?? (?? ?? ??) ?? , ?? ? ????, ????, ????**(18)**

Step

Step 4: then the distorted bands will be obtained by performing SVD on the obtained singular values of all bands as ?? ???? * , ?? ???? * , ?? ???? * , ?? ???? * .

Step 5: Then the final watermark can be extracted by applying inverse IWT on the obtained distorted wavelet bands as?? * = ?????? ?1 (?? ???? * , ?? ???? * , ?? ???? * , ?? ???? *)**(21)**

Where ?? * is the extracted watermark.

7 V. Simulation Results

In this section, the performance of proposed approach was analyzed under various experiments. For performance evaluation, the considered host mages and watermark images are shown in figure. The NC is also used for the evaluation of fitness function of PSO. The fitness function of PSO is defined asð ??”ð ??”???????????? ??? ?? ? = 1 ? ??????????ð ??”ð ??”??(???? ??) ???? ?? = 1 ?? ???????????? ? ????(??, ?? ?? * ,??) ?? ???????????? ??=1**(26)**

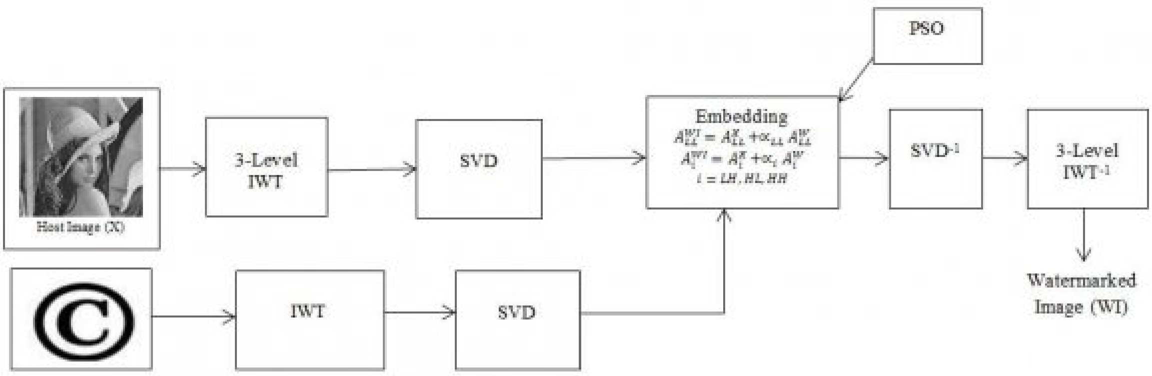
Where ?? ?? * ,?? represents the extracted watermark through the proposed approach characterized by the position of the j th particle. The smaller fitness value means the better robustness. Let, ?? ???????????? signifies the number of attacks, here the ?? ???????????? is set to 8. Because, totally eight types of attacks are simulated in the simulation.

Performance metrics was evaluated for both No attack and Attack scenarios. At each and every stage, the proposed approach was compared with the conventional3-level DWT based watermarking using PSO **??**24]. Complete attacks are applied on the watermarked images and the obtained results are shown below. From the above figures,it can be observed that, the proposed approach having an optimal performance.

To further analyze the performance of proposed approach, a smilar case study was performed by embeddi embendding Logo into the Baboon image and the From the above figures, it can be observed that, for every case, the proposed approach having otimal PSNR, NC and SSIM compared to DWT-PSO **??**24]. Due to the dual optimization of watermarking constnat at LL band and at remaining bands, the proposed approach achieved a better performance compared to conventional approach. Along with this, the quality of extracted watermark is also increased. The enhanced quality is represneted with PSNR. Compared to the conventional approach, the proposed approach ibtained higher PSNR in all cases.

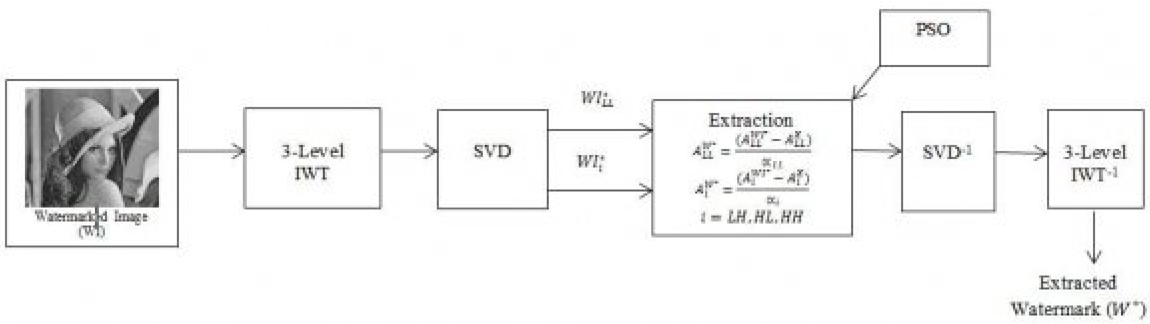
8 VI. conclusion

In this paper, a new image waterarking approach was proposed based on Integer wavelet transform and particle swarm optimization. The main objective of IWT is to reduce the information loss which is the main drawback with conventional folating point wavelet ransforms. PSO is utilized to optimize the strength of watermarking constnat such that there should be a tradeoff between the robustness and the imperceptibility. Simulation is carreid out over various images and also over various attacks. An optimized alpha value is selected by considering all the attacks through PSO algorithm. In this approach, the alpha optimization is carried out for two phases, one is for low varinat information (LL band) and another is for high varinat information (LH,HL and HH bands). The range of watermarking constnat derived through PSO for LL band is high compared to the watermarking constant of remaining bands. The sumulation results also revealed that the proposed approach is robust for all types of atacks compared with conventional approach. [1]



1

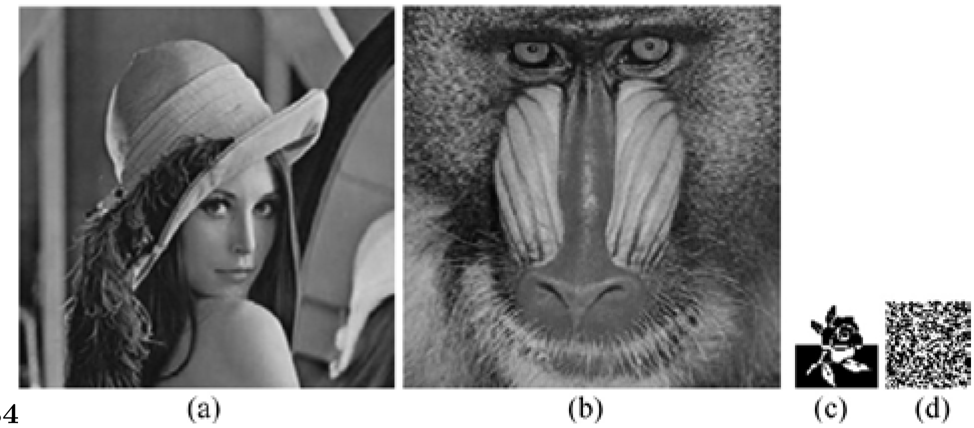
Figure 1: Figure 1 :



2

Figure 2: Figure 2 :

Figure 3:



34

Figure 4: Figure 3 :Figure 4 :

5678910111213

Figure 5: Figure 5 :Figure 6 :Figure 7 :Figure 8 :Figure 9 :Figure 10 :Figure 11 :Figure 12 :Figure 13 :

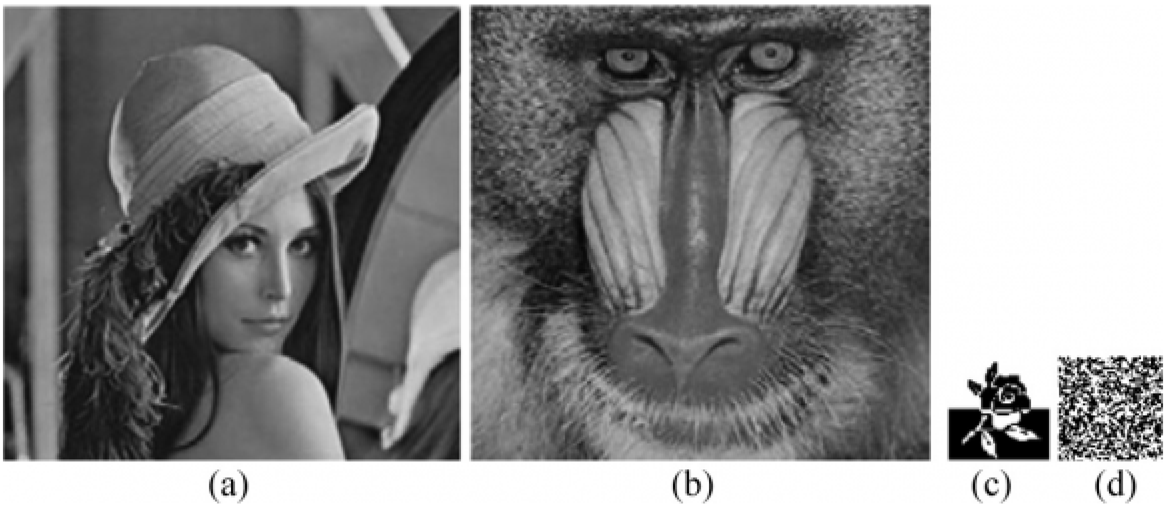


Figure 6:

1415

Figure 7: Figure 14 :Figure 15 :

16

Figure 8: Figure 16 :

1718 

Figure 9: Figure 17 :Figure 18 :

19 

Figure 10: Figure 19 :

20 

Figure 11: Figure 20 :

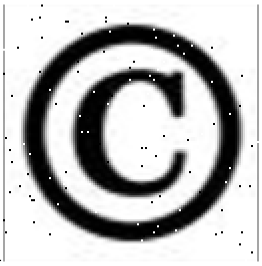
21 

Figure 12: Figure 21 :

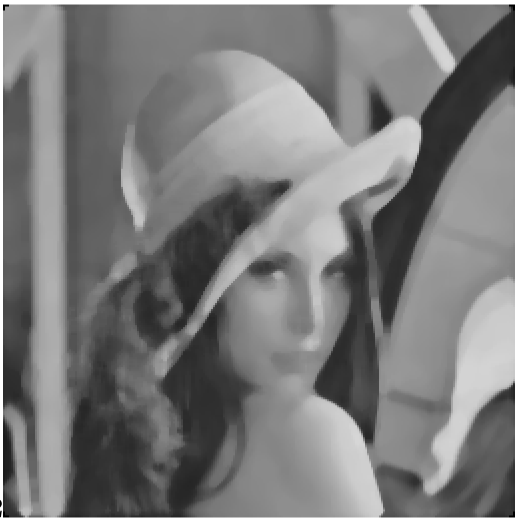
22 

Figure 13: Figure 22 :

?? * and

?? ?? ?? *) of watermark image form the singular values of distorted watermarked image as

?? ???? ?? * = (?? ???? ???? * ? ???? ??? ???? ??) (19)

?? ?? ?? * = (?? ?? ???? * ? ?? ??? ?? ??)

[Note: , ?? ? ????, ????, ????]

Figure 14:

1

Metric	Lena With Logo			Lena with Rose
	Conventional[24]	proposed	Conventional[24]	proposed
MSE	1.2910	0.8380	0.9951	0.7573
PSNR	47.0215	48.8982	48.3305	49.3382
NC	0.9788	0.9812	0.9875	0.9898
SSIM	0.9829	0.9842	0.9795	0.9836

Figure 15: Table 1 :

2

Attack			Conventional[24]			Proposed Approach		
	MSE	PSNR	NC	SSIM	MSE	PSNR	NC	SSIM
GNA	1.7205	45.7742	0.8792	0.9612	1.2018	47.3325	0.8812	0.9621
SPA	2.6590	43.8836	0.9442	0.9122	1.4960	46.3814	0.9585	0.9422
MFA	1.6895	45.8531	0.9405	0.9296	1.2384	47.2021	0.9563	0.9386
HEA	229.19	24.5287	0.8588	0.9137	123.21	27.2241	0.8823	0.9274
RA	763.60	19.3021	0.8563	0.8752	456.80	21.5335	0.8797	0.8831
CEA	106.53	27.8557	0.9208	0.9585	70.7490	29.6336	0.9298	0.9589
CA	1030.0	17.9992	0.6566	0.8069	846.91	18.8524	0.7238	0.8093
SA	14.0240	35.9989	0.9691	0.9751	13.8416	36.1328	0.9721	0.9788

Figure 16: Table 2 :

3

Attack		Conventional[24]				Proposed Approach		
	MSE	PSNR	NC	SSIM	MSE	PSNR	NC	SSIM
GNA	2.4591	44.2231	0.8282	0.9589	1.9330	45.5685	0.8598	0.9591
SPA	3.2422	43.0224	0.9331	0.9222	1.6824	45.8714	0.9399	0.9286
MFA	2.1114	44.8852	0.9453	0.9274	1.9753	45.1744	0.9467	0.9387
HEA	210.45	24.8993	0.8788	0.9093	125.99	27.1274	0.8998	0.9228
RA	1039.5	17.9627	0.8590	0.8741	601.68	20.3371	0.8887	0.8896
CEA	141.03	26.6382	0.9418	0.9591	72.3853	29.5343	0.9485	0.9596
CA	1060.6	17.8574	0.6798	0.8092	667.63	19.8854	0.7028	0.8154
SA	21.2506	34.8571	0.9703	0.9755	13.4213	36.8519	0.9722	0.9783

Figure 17: Table 3 :

4

		1
		0.95
		0.9
	Correlation (NC)	0.75
		0.8
		0.85
	Normalized	0.65
		0.7
		0.6
Year 2017		NA GNA
		0.5
		0.55

32

SSIM 0.82 0.84 0.86 0.88 0.9 0.92 0.94 0.96 0.98 1

NA GNA

0.8

Attack	MSE			
		Conventional[24] PSNR NC 48.3883 0.9898 44.2809 0.8305 43.0802 0.9354 44.9430 0		
NA	2.8002			
GNA	4.3210			
SPA	5.1245			
MFA	4.2130			
HEA	212.30			
RA	1041.02	18.0205		0.8613
CEA	143.254	26.6960		0.9441
CA	1064.20	17.9152		0.6821
SA	23.1005	34.9149		0.9726

Figure 18: Table 4 :

[Barni et al. ()] 'A DCT domain system for robust image watermarking'. M Barni , F Bartolini , V Cappellini , A Piva . *Signal Processing* 1998. 66 (3) p. .

[Lee et al. ()] 'A hybrid watermarking technique applied to digital images'. Z.-J Lee , S.-W Lin , S.-F Su , C.-Y. Lin . *Applied Soft Computing* 2008. 8 (1) p. .

[Vahedi et al. ()] 'A new approach for image watermarking by using particle swarm optimization'. E Vahedi , C Lucas , R A Zoroofi , M Shiva . *Proceedings of IEEE ICSPC*, (IEEE ICSPCDubai) 2007. p. .

[Kundur and Hatzinakos ()] 'A robust digital image watermarking method using wavelet-based fusion'. D Kundur , D Hatzinakos . *Proceedings of the International Conference on Image Processing*, (the International Conference on Image Processing) 1997. 3 p. .

[Lien and Lin ()] 'A watermarking method based on maximum distance wavelet tree quantization'. B K Lien , W H Lin . *Proceedings of the 19th Conference on Computer Vision, Graphics and Image Processing*, (the 19th Conference on Computer Vision, Graphics and Image Processing) 2006.

[Tao and Zain ()] 'A wavelet-based particle swarm optimization algorithm for digital image watermarking'. Hai Tao , Jasnimohamad Zain . *Integrated Computer-Aided Engineering* 2012. 19 p. .

[Tsai and Cheng ()] 'Adaptive signal-dependent audio watermarking based on human auditory system and neural networks'. H.-H Tsai , J.-S Cheng . *Applied Intelligence* 2005. 23 (3) p. .

[Zhang et al. (2004)] 'An adaptive blockbased blind watermarking algorithm'. G Zhang , S Wang , Wen . *Proceedings of the 7th International Conference on Signal Processing*, (the 7th International Conference on Signal Processing) August 2004. IEEE. p. .

[Surya Prakasa et al.] 'An Efficient Genetic Algorithm Based Gray scale Digital Image watermarking for Improving the Robustness and Imperceptibility'. R Surya Prakasa , Dr P Rao , Kumar . *International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) -2016*,

[Run et al. ()] 'An efficient wavelet-tree-based watermarking method'. R.-S Run , S.-J Horng , W.-H Lin , T.-W Kao , P Fan , M K Khan . *Expert Systems with Applications* 2011. 38 (12) p. .

[Mohammad et al. ()] 'An improved SVD based watermarking scheme for protecting rightful ownership'. A A Mohammad , A Alhaj , S Shaltaf . *Signal Processing* 2008. 88 (9) p. .

[Khelifi et al. ()] 'An improved wavelet-based image watermarking technique'. F Khelifi , A Bouridane , F Kurugollu , A I Thompson . *Proceedings of the IEEE Conference on Advanced Video and Signal Based Surveillance (AVSS '05)*, (the IEEE Conference on Advanced Video and Signal Based Surveillance (AVSS '05)Como, Italy) 2005. IEEE. p. .

[Wang et al. ()] 'An intelligent watermarking method based on particle swarmoptimization'. Y.-R Wang , W.-H Lin , L Yang . *Expert Systems with Applications* 2011. 38 (7) p. .

[Tsai et al. ()] 'An SVDbased image watermarking in wavelet domain using SVR and PSO'. H.-H Tsai , Y.-J Jhuang , Y.-S Lai . *Applied Soft Computing* 2012. 12 (8) p. .

[Tsai and Sun ()] 'Color image watermark extraction based on support vector machines'. H.-H Tsai , D.-W Sun . *Information Sciences* 2007. 177 (2) p. .

[Davoine (2000)] 'Comparison of two wavelet based image watermarking schemes'. F Davoine . *Proceedings of the International Conference on Image Processing (ICIP '00)*, (the International Conference on Image Processing (ICIP '00)Vancouver, Canada) September 2000. IEEE. 3 p. .

[Tsai and Wang ()] 'Genetic-based adaptive image watermarking using local image and image features'. H.-H Tsai , W.-Y Wang . *Imaging Science Journal* 2006. 54 (2) p. .

[Wu and Huang (2007)] 'Image watermarking using structure based wavelet tree quantization'. G.-D Wu , P.-H Huang . *Proceedings of the 6 th IEEE/ACIS International Conference on Computer and Information Science (ICIS '07)*, (the 6 th IEEE/ACIS International Conference on Computer and Information Science (ICIS '07)) July 2007. IEEE. p. .

[Verma and Jha ()] 'Improved watermarking technique based on significant difference of lifting wavelet coefficients'. V S Verma , R K Jha . *Signal, Image and Video Processing*, 2014.

[Zheng et al. ()] 'Optimal robust image watermarking based on PSO and HVS in integer DCT domain'. Y Zheng , C H Wu , Z M Lu , W H &ip . *International Journal of Computer Sciences and Engineering System* 2008. 2 (4) p. .

[Kennedy and eberhart ()] 'Particle swarm optimization'. J Kennedy , R &eberhart . *Proceedings of IEEE international conference on neural networks*, (IEEE international conference on neural networksPerth, WA) 1995. p. .

[Tsai (2009)] 'Security enhancement by adopting the chaotic system for wavelet tree based digital image watermarking'. M J Tsai . *Proceedings of the 16th IEEE International Conference on Image Processing (ICIP '09)*, (the 16th IEEE International Conference on Image Processing (ICIP '09)) November 2009. IEEE. p. .

[Calderbank et al. ()] 'Wavelet transforms that map integers to integers'. A R Calderbank , I Daubechies , W Sweldens , B L Yeo . *Appl. Comput. Harmonics Anal* 1998. 5 (3) p. .

[Wang and Lin ()] 'Wavelet tree quantization for copyright protection watermarking'. S.-H Wang , Y.-P Lin . *IEEE Transactions on Image Processing* 2004. 13 (2) p. .