

Optimized DWT SVD Based Image Watermarking Scheme Using Particle Swarm Optimization

Megha Bansal[1(✉)], Anurag Mishra[2], and Arpita Sharma[2]

[1] Department of Computer Science, University of Delhi, New Delhi, India
megha.cs.du@gmail.com
[2] Deen Dayal Upadhyaya College, University of Delhi, New Delhi, India
anurag_cse2003@yahoo.com, asharma@ddu.du.ac.in

Abstract. The robust watermarking techniques have gained popularity over last decade as more and more digital contents are being shared over Internet. This increase in data transmission also poses greater risk of various attacks which hamper data authenticity, integrity and quality. Therefore, efficient mechanisms are required that can handle robust transmission of digital data while honoring the Digital Right Management (DRM) protection measures of copyrighted content. In this paper, we explore an optimized Particle Swarm Optimization (PSO) based watermarking scheme on digital images in the hybrid Discrete wavelet transform (DWT) and Singular value decomposition (SVD) transform. The watermark is embedded in the host images by using both single scaling and multiple scaling factors for optimizing the visual quality of the signed images viz-a-viz robustness. Eight gray-scale and six colored images are used to carry out the experiments. Comparison of the proposed watermarking scheme with other techniques ascertain the proposed scheme outperforms others and it also fulfills all requisite conditions to be a robust and optimized watermarking scheme.

Keywords: Image watermarking · Transform domain · Discrete wavelet transform · Singular value decomposition

1 Introduction

In recent years, there is a vast increase in the amount of digital data communicated across the network. This has raised the security concerns related to authenticity and ownership of the data across Internet. Watermarking has emerged out as one of the solutions to above problems. Digital watermarking is a process for copyright protection and owner identification and verification in which a copyright data is embedded into the cover image as watermark in an invisible or visible manner that can be extracted later without much degradation of the cover signed image and the watermark [1, 2].

In this regard, visual quality of the signed images and robustness of the embedding scheme are two important parameters to quantify the performance of the watermarking scheme. Since both parameters are inversely related to each other, in lieu of this, watermarking can be visualized as an optimization problem. Cox et al. [1] proposed

© Springer Nature Switzerland AG 2020
O. Gervasi et al. (Eds.): ICCSA 2020, LNCS 12254, pp. 862–877, 2020.
https://doi.org/10.1007/978-3-030-58817-5_61

three groups to classify most commonly used watermarking schemes: Robust, Fragile, and Semi-fragile. Robust watermarking schemes are used for copyright protection and are resilient against compression, geometric and counterfeit attacks [3]. The fragile and semi fragile techniques are used when the focus is on image integrity and authenticity. The watermark is embedded in fragile framework in such manner that any attempt to modify signed image will result in complete distortion of the watermark. The semi fragile watermarks are developed to harness benefits of both robust and fragile framework. When the embedding process is carried out in the spatial domain of image, it leads to fragile watermarking. Such kind of watermarking results in directly changing the bits of the host image, thus, ease the implementation but compromises on the robustness of scheme against various attacks [3, 4]. On the other hand, watermarking in the transform domain results in embedding the watermark in the frequency domain coefficients of host image and has been found to be a more robust watermarking scheme. Out of various frequency domain techniques like Discrete Fourier Transform (DFT) [5, 6], Discrete Cosine Transform (DCT) [7, 8, 26] and Discrete Wavelet Transform (DWT) [9, 10, 25, 33], DWT has been found to achieve an imperceptible watermarking along with high robustness [1]. Xianghong et al. [29] proposed DWT in conjunction with vector transform as watermark embedding scheme. They have used single scaling factor for embedding the watermark in host image. These techniques have further been used in collaboration with other techniques like Singular value decomposition (SVD) [2, 11, 23, 27] for better watermarking efficiency.

The secure transmission of digital images has greatly evolved from the initial proposed algorithms like DFT, DCT to more sophisticated soft computing techniques like artificial neural networks, fuzzy logic systems, support vector machines along with HVS model [12–16, 24]. Mishra et al. [17] have proposed watermarking scheme based on characteristics of human visual model. They have exploited three HVS features and fed them into FIS. They have also integrated a single layer feed-forward neural network known as extreme machine learning to generate the watermark. They claimed that their scheme is capable to implement real time watermarking applications.

The last decade has seen numerous applications having origin in nature inspired techniques to efficiently solve optimization problems. Hybridization of different meta-heuristic techniques – Genetic Algorithm (GA), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) and nature inspired algorithms like Spider monkey, Cuckoo search and Artificial Bee Colony optimization along with transform domain techniques have also been explored and reported. Lai et al. [18] presented tiny genetic algorithm in conjunction with the SVD transform domain. In their work, they used tiny-GA to compute the values of embedding scaling factors to optimize the parameters of watermarking algorithm. Agarwal et al. [19] proposed their watermarking scheme using cuckoo search algorithm. In their scheme, they have embedded the watermark in different coefficients of the host image using multiple scaling factors which they have optimized using CSA. Loukhaoukha et al. [30] have used multi-objective ant colony optimization technique in LWT-SVD domain while Ishtiaq et al. [32] have proposed the Particle Swarm Optimization technique to find the optimal values for multiple scaling factors. Mishra et al. [20] have presented their widely cited hybrid watermarking scheme in DWT domain using famous Firefly Optimization for gray-scale images. They have decomposed LL3 sub-band coefficients into singular

values using SVD to embed the watermark. They have nicely analyzed the use of Multiple Scaling Factors (MSFs) for embedding the watermark in the images. The MSFs are generated through Firefly Algorithm by using an Objective Function (Obj) which is composed of the PSNR and all image processing operations they used to attack the signed images. Their results were superior to all other such schemes falling in the same category. Abdelhakim [31] have suggested a combination of DCT with Artificial Bee Colony for the optimization of watermarking scheme. They claimed that their proposed technique minimized the error between optimal and predicted solutions for watermark embedding. Kuppusamy et al. [21] have proposed a PSO based watermarking algorithm in daubechies4 transform domain. They employed various attacks over the signed images and claimed good results of their scheme using IQIM. Loukhaoukha et al. [22] have hybridized multi-objective particle swarm optimization technique with SVD in wavelet domain for watermarking. They showed significant improvement in their results with the use of MSFs for watermark embedding.

Image watermarking is performed by using embedding strength ($\propto$) which can be either single valued i.e. Single Scaling Factor (SSF) or there can be multiple values of the embedding strength i.e., Multiple Scaling Factors (MSFs). The SSF takes constant numerical value for every coefficient of the host image for watermarking purpose. Thus, it does not consider variations in the physical parameters like contrast and intensity of the host image. However, it has been seen that different regions of image vary in their structural and physical properties which disturbs the visibility of the signed image especially in the smoother regions [1, 4, 14]. Thus, MSF plays an important role in optimizing the results for an efficient watermarking scheme. The MSF considers different values for different coefficients of host image and thus, embedding the watermark with lesser strength in smoother areas as compared to the high intensity areas of the host image.

In this paper, we propose an optimized hybrid watermarking scheme using DWT-SVD based on PSO technique. We have carried out the watermark embedding using both the SSF and MSF in gray-scale and colored images for the sake of comparison. Our proposed scheme further examines the robustness parameter by employing various image process attacks which are also used in the Objective Function. This Objective Function happens to be a linear function of PSNR value of signed image and sum of Normalized Correlation (NC) values for attacked images. The research paper is organized as follows:

It presents the brief introduction of PSO along with its necessary mathematical inputs in Sect. 2. The Sect. 3 comprises of the proposed embedding and extraction schemes. Section 4 contains our experimental results and their analysis on the basis of its comparison with other hybrid schemes. Section 5 concludes the whole work.

2 Particle Swarm Optimization

PSO is a population-based global optimization technique modelled by Kennedy and Eberhart [28]. PSO is a meta-heuristic technique that is based on co-operative and social characteristics of evolution like flocking of birds, insects swarming as compared to other evolutionary strategies like genetic algorithms that use competitive aspects like

survival of the fittest. PSO involves creating a diffuse population (known as swarm) of individuals (termed as particles) that tend to move in the search space and clustering in areas where local minima are located. In each iteration, particles learn from their surroundings and on that basis, update their positions and velocities which are based on the combination of best positions found by that particle (personal best, pbest) and also, the best position value achieved by entire swarm (global best, gbest).

Listing 1. Pseudo-Code of PSO

Input: a) An objective function $obj(x),\ x = [x_1, x_2, \ldots, x_m]^T$

b) A random population (swarms) of particles s_i, $i = 1, 2, \ldots, n$

c) Inertial weight: $w = 1$, acceleration constants: $\emptyset_1 = 1, \emptyset_2 = 2$

d) Uniformly distributed random vectors: $r_1, r_2 = [0,1]$, maximum number of iterations: $maxItr$

Begin
  for each s_i
    generate a random position vector $P_i = U(low, high)$
    if $obj(pbest_i) > obj(gbest)$
      $gbest \uparrow pbest_i$
    end if
    generate a random velocity vector $V_i = U(-|high - low|, |high - low|)$
  end for
  while $(t < maxItr)$ *or* $(StopCriterion)$
    for each s_i
      Compute its velocity
        $V_i^{(t+1)} = wV_i^{(t)} + \emptyset_1 r_1 (pbest_i - P_i^{(t)}) + \emptyset_2 r_2 (gbest - P_i^{(t)})$
      Update its position
        $P_i^{(t+1)} = P_i^{(t)} + V_i^{(t+1)}$
      if $obj(P_i) > obj(pbest_i)$
        $pbest_i \uparrow P_i$
      end if
      if $obj(pbest_i) > obj(gbest)$
        $gbest \uparrow pbest_i$
      end if
  end for
  end while
End

With each iteration, particles tend to move closer and converge towards a single point. The output generated by PSO largely depends on the values of parameters used like inertial weight *w*, maximum number of iterations used *maxItr* and the acceleration

constants $\varnothing_1$ and $\varnothing_2$. As the process terminates, the best solution is denoted by gbest which provides the optimal solution.

3 Proposed Method

In the proposed scheme, host image (I) of 512 $\times$ 512 and binary watermark (W) of size 32 $\times$ 32 are used for embedding and extraction process. The embedding is carried out in the transform domain by partitioning the host image into sub-bands using 4 -level DWT and decomposing the coefficients using SVD as explained in Sect. 3.1. The extraction process is executed as the reverse procedure of embedding and is explained in Sect. 3.2 in detail.

3.1 Watermark Embedding

In the embedding process, the bits of the host image are altered according to the values of the coefficients of watermark to be inserted. Figure 1 represents the procedure through block diagram. A good embedding is determined by the visual quality of the signed images. The metric PSNR measures peak signal to noise ratio and determines the quality of embedding. Higher values of PSNR reflects higher visual quality of the signed images. It is given by the equation:

$$PSNR = 10log_{10}\left(\frac{I_{max}^2}{MSE}\right) \tag{1}$$

where, I_{max} defines the maximum pixel intensity for image I and MSE denotes mean square error.

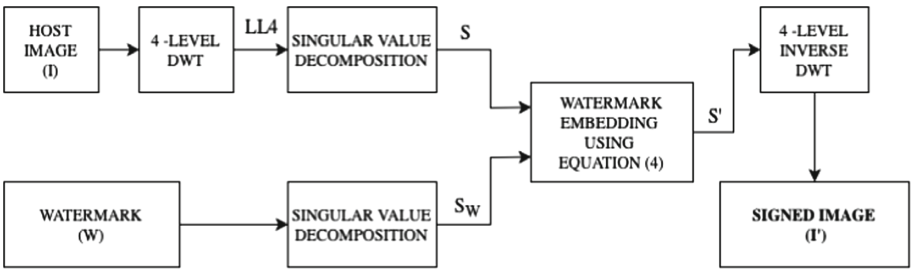

Fig. 1. Block diagram of watermark embedding

`Listing 2. Embedding Process`

- Decompose the host image using 4 -level DWT HAAR wavelet transform into four sub-bands: LL4, LH4, HH4, HL4.
- For good robustness, use LL4 sub-band for watermark embedding.

- For unique feature extraction, perform SVD on LL4 sub band of host image and obtain S using equation:

$$[USV] = SVD(LL4) \tag{2}$$

- Apply SVD on the watermark (W) used to achieve singular value matrix (S_w) using following equation:

$$[U_w S_w V_w] = SVD(W) \tag{3}$$

- Embed the watermark coefficients (S_w) into the obtained coefficients of host image (S) using equation:

$$S' = S + \propto . S_w \tag{4}$$

where, $\propto$ represents the embedding scaling factor that needs to be optimized.

- Obtain modified coefficients using equation given below:

$$LL4' = \left[US'V^T\right] \tag{5}$$

- Perform IDWT on the above modified coefficients resulting into signed image.

3.2 Watermark Extraction

This process recovers the extracted watermark from the signed image. The process is represented through the block diagram in Fig. 2. A good watermark extraction scheme should be robust to the image processing attacks. To measure the robustness of the scheme, NC (W, W') (normalized cross-correlation) coefficient is computed for the original watermark (W) from host image and the recovered watermark (W′) from the signed image using the equation:

$$NC\left(W, W'\right) = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[W(i,j) * W'(i,j)\right]}{\sum_{i=1}^{m}\sum_{j=1}^{n}[W(i,j)]^2} \tag{6}$$

The values closer to 1 indicate good recovery of the watermark from the signed image and hence, high robustness of the watermarking scheme.

Listing 3: Extraction Process

- For recovery, apply 4- level DWT on the host image and signed image.
- Retrieve LL4 and $LL4'$ sub band coefficients from both the images respectively.

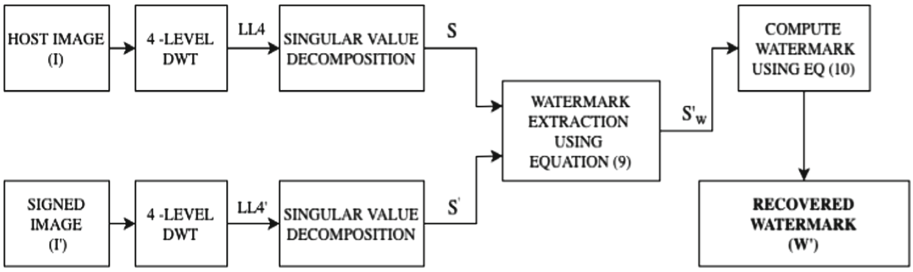

Fig. 2. Block diagram of watermark extraction.

- Apply SVD on above calculated coefficients and obtain corresponding singular values S and S' values using the following equations:

$$[USV] = SVD(LL4) \tag{7}$$

$$[U'S'V'] = SVD(LL4') \tag{8}$$

- Extract the singular values of the watermark (S'_w) through formula given by equation:

$$S'_w = (S' - S)/ \propto \tag{9}$$

- Recover the watermark (W') using equation given below:

$$W' = \left[U_w S'_w V_w^T\right] \tag{10}$$

3.3 PSO Based Watermarking Algorithm for Scaling Factor Optimization

In this scheme, the watermark coefficients are embedded in the host image using the multiple scaling factor ($\propto$). This embedding is performed in the transform domain using discrete wavelet transform and singular value decomposition. The MSF $' \propto'$ is optimized using PSO algorithm.

Listing 4: PSO based watermarking scheme

- Create an initial population of *n* swarms randomly, where each particle has position vector of size *mxm*. This corresponds to the size of binary watermark used.

- For each particle of swarm s_i:
  - i) Perform watermark embedding in the host image using algorithm in Listing 2. MSF $'\propto'$ used in Eq. (4) is optimized by PSO algorithm given in Listing 1.
  - ii) Generate T different attacked signed images by executing T image-processing attacks on obtained signed image I'.
  - iii) Perform watermark extraction on all attacked signed images using the watermark extraction algorithm given in Listing 3.
  - iv) Calculate the visual quality of signed image I' using PSNR by Eq. (1) and robustness of the watermarking scheme using $\mathrm{NC}(\mathrm{W}, \mathrm{W}')$ values for the attacked signed images using Eq. (6).
  - v) Finally, compute the value of objective function of the swarm using the function given by following equation:

$$\mathrm{Obj} = \mathrm{PSNR} + \delta * \left[\mathrm{NC}\left(\mathrm{W}, \mathrm{W}'\right) + \sum\nolimits_{1}^{n} \mathrm{NC}\left(\mathrm{W}, \mathrm{W}'\right)\right] \tag{11}$$

where, δ is the weighting factor for NC $(\mathrm{W}, \mathrm{W}')$ values. This factor is required to create balance in the equation since PSNR value largely outweighs NC $(\mathrm{W}, \mathrm{W}')$ values.

- Update each swarm's global position with the best value according to the objective function value achieved above.
- Optimize the swarms using the algorithm given in Listing 1.
- Repeat the above steps till termination criteria are met.

4 Experimental Results

Experiments are performed on eight 512 × 512 gray scale host images: Baboon, Boat, Lena, Cameraman, Parrots, Tiger, Jumbo and Cosmological Cabbage. Embedding is done using 32 × 32 binary image as watermark. The PSO parameters: $w = 1$, $\varnothing_1 = 1, \varnothing_2 = 2$, maxItr = 1 0 and swarm size (n) = 20 are set. MATLAB 2018 is used to perform the experiments on MacBook Air 1.6 GHz Intel Core i5 on macOS Catalina version 10.15.4.

4.1 Effect of SSF and MSF Over Visual Quality of Signed Images

The use of SSF results in embedding the watermark with same strength in the entire host image. Table 1 compiles the PSNR and NC $(\mathrm{W}, \mathrm{W}')$ values of the four gray scale signed images used in the present work. These four test images are used by us as other researchers have used the same test images and this becomes a mandatory criterion to present a comparative assessment of various other schemes vis-à-vis the proposed one. Table 2 compiles the PSNR and NC $(\mathrm{W}, \mathrm{W}')$ values of four additional gray scale signed images used in our work without any such comparison.

Table 1. Compilation and comparison of PSNR and NC (W, W') values of host image and signed image between proposed technique and existing state of art techniques of PSNR Values of Signed Images

Image	Algorithm	PSNR (DB)	NC (W,W')
Baboon	Suggested scheme (SSF)	56.8489	1.000
	Suggested scheme (MSF)	60.9734	1.000
	Loukhaoukha et al. (2011) (MSF)	52.379	1.000
	Ishtiaq et al. (2010) (MSF)	44.9624	NA
	Xianghong et al. (2004) (SSF)	49.075	0.999
Boat	Suggested scheme (SSF)	52.5321	1.000
	Suggested scheme (MSF)	56.6840	1.000
	Loukhaoukha et al. (2011) (MSF)	54.810	1.000
	Ishtiaq et al. (2010) (MSF)	50.1586	NA
	Xianghong et al. (2004) (SSF)	49.075	1.000
Lena	Suggested scheme (SSF)	55.8539	1.000
	Suggested scheme (MSF)	59.2610	1.000
	Loukhaoukha et al. (2011) (MSF)	47.718	1.000
	Ishtiaq et al. (2010) (MSF)	48.105	NA
	Xianghong et al. (2004) (SSF)	49.075	1.000
Cameraman	Suggested scheme (SSF)	54.4182	1.000
	Suggested scheme (MSF)	57.8539	1.000
	Loukhaoukha et al. (2011) (MSF)	48.902	1.000
	Ishtiaq et al. (2010) (MSF)	NA	NA
	Xianghong et al. (2004) (SSF)	49.075	1.000

A close observation of the data compiled in Table 1 reveals that embedding the watermark using the MSF strategy gives better results as compared to the SSF strategy in proposed scheme. We also compare our MSF and SSF results with the same of other schemes belonging to the similar category. Clearly, our results outperform the results presented by other state of art works. This is found true both the PSNR and NC (W, W') parameter of the signed images. Table 2 further compiles results of PSNR and

Table 2. Compilation of PSNR AND NC (W, W') values for four additional signed images

Image	PSNR (SSF scheme) (dB)	PSNR (MSF scheme) (dB)	NC (W,W') (SSF scheme)	NC (W,W') (MSF scheme)
Parrots	58.3182	61.3738	1.000	1.000
Tiger	57.2842	60.4191	1.000	1.000
Jumbo	54.5351	55.3924	1.000	1.000
CosmologicalCabbage	52.6182	54.0521	1.000	1.000

NC $\left(W, W^{'}\right)$ parameters for four more gray scale images used in our work both for SSF and MSF strategies. In this case also, the MSF strategy outperforms the SSF strategy. The PSNR values for all four signed images are better placed for MSF while the NC $\left(W, W^{'}\right)$ parameter is already found to be maximum (NC $\left(W, W^{'}\right)$ = 1.000) both for SSF and MSF strategies. This again proves that MSF is better in comparison to SSF for all eight gray-scale images used in the proposed scheme.

4.2 Effect of SSF and MSF Over the Robustness of Watermarking Scheme

In the next part of this work, the next two tables compile the results for robustness studies carried out over these eight signed images by considering both SSF and MSF strategies. This is carried out to make an assessment of these embedding strategies over the robustness of the embedded watermark. Due to paucity of space and formatting issues, these results are divided into two tables – Table 3 and 4 respectively. The six image processing attacks being used in this work are - JPEG compression (with 10%, 20% and 30% compression ratios or QF = 0.9, 0.8 and 0.7 respectively), Noise addition (Salt & Pepper noise and Gaussian noise 5% each), Filtering (Gaussian filter and Median filter with Aperture size = 3), Cropping ((i) Crop the center of signed image with window size = 64 × 64 and replace it with the same window of the host image and (ii) Crop the corner of signed image with window size = 64 × 64 and replace it with the same window of the host image), Histogram Equalization, Scaling (reducing the signed image to half and then resizing it back to original size).

Table 3. Compilation of NC (W, W') values of gray scale signed images after various attacks

Image / Attacks	Baboon		Boat		Lena		Cameraman	
	SSF	MSF	SSF	MSF	SSF	MSF	SSF	MSF
JPEG (Q = 0.9)	0.9808	0.9841	0.9654	0.9759	0.9751	0.9818	0.9711	0.9897
JPEG (Q = 0.8)	0.9728	0.9795	0.9527	0.9727	0.9742	0.9769	0.9604	0.9778
JPEG (Q = 0.7)	0.9687	0.9724	0.9421	0.9614	0.9648	0.9702	0.9508	0.9622
Salt & Pepper Noise (5%)	0.9357	0.9672	0.8911	0.9238	0.9345	0.9601	0.9094	0.9274
Gaussian Noise (5%)	0.9489	0.9756	0.9032	0.9304	0.9387	0.9711	0.9105	0.9408
Gaussian Filtering (3x3)	0.9282	0.9576	0.9049	0.9304	0.9133	0.9416	0.9023	0.9404
Median Filtering (3x3)	0.9013	0.9453	0.8849	0.9131	0.8917	0.9379	0.8911	0.9299
Cropping (crop 64 x 64 center and replace with host image)	0.9557	0.9786	0.9297	0.9334	0.951	0.9617	0.9445	0.9531
Cropping (crop 64 x 64 corner and replace with host image)	0.9576	0.9733	0.9305	0.9417	0.9534	0.9687	0.947	0.9529
Histogram Equalization	0.9012	0.9107	0.8621	0.8859	0.8902	0.9074	0.8702	0.8913
Scaling (5 1 2 > 2 5 6 > 5 1 2	0.9939	0.9977	0.9912	0.9928	0.9930	0.9956	0.991	0.9929

A close observation of Table 3 and Table 4 clearly indicates that the NC (W, W') parameter values using MSF strategy for various image processing attacks are better as compared to SSF strategy. A high numerical value of the NC (W, W') parameter indicates that the watermark recovery out of the signed images is quite good which indicates a high robustness of the proposed scheme. Therefore, it can be deduced that our DWT-SVD hybrid transform based PSO watermarking scheme is suitable for optimizing the twin parameters of visual quality of signed grayscale images and the robustness of the watermark embedding scheme in the same. The use of the PSO based optimization of the Multiple Scaling Factors for embedding under DWT-SVD hybrid transform is primarily responsible for this outcome.

Table 4. Compilation of NC (W, W') values of gray scale signed images after various attacks (contd…)

Image / Attacks	Parrots		Tiger		Jumbo		CosmologicalCabbage	
	SSF	MSF	SSF	MSF	SSF	MSF	SSF	MSF
JPEG (Q = 0.9)	0.9711	0.9801	0.9586	0.9797	0.9692	0.9704	0.9439	0.9582
JPEG (Q = 0.8)	0.9613	0.9797	0.9492	0.9667	0.9544	0.9623	0.9296	0.9459
JPEG (Q = 0.7)	0.9405	0.9523	0.9073	0.9586	0.9070	0.9302	0.8921	0.9017
Salt & Pepper Noise (5%)	0.9181	0.9279	0.9216	0.9405	0.9086	0.9274	0.8867	0.9059
Gaussian Noise (5%)	0.9077	0.9488	0.9080	0.9416	0.9106	0.9311	0.9090	0.9393
Gaussian Filtering (3x3)	0.9434	0.9579	0.9181	0.9345	0.9075	0.9296	0.8987	0.9305
Median Filtering (3x3)	0.9374	0.9591	0.9096	0.9273	0.8933	0.9125	0.8809	0.9170
Cropping (crop 64 x 64 Center and replace with host image)	0.9602	0.9721	0.9591	0.9656	0.9426	0.9574	0.9371	0.9603
Cropping (crop 64 x 64 Corner and replace with host image)	0.9522	0.9678	0.9611	0.9703	0.9326	0.9420	0.9347	0.9534
Histogram Equalization	0.9032	0.9102	0.8993	0.9015	0.8785	0.8929	0.8020	0.8577
Scaling (5 1 2 > 2 5 6 > 5 1 2	0.9945	0.9981	0.9942	0.9977	0.9939	0.9969	0.9917	0.9957

4.3 Study of PSO Optimization Over Colored Images

In the previous sections, we have established that for eight different gray scale images, the PSO based optimization scheme operating under DWT-SVD hybrid transform is found comparatively better for watermark embedding. To further test the effectiveness of our proposed scheme, we extend our research work to six compressed colored images depicted in Fig. 3, working with SSF and MSF strategies. These images are – Parrot, Baboon, Tiger, Lena, Jumbo and Cosmological Cabbage, all compressed as Jpeg compression standard. It is important to note that the use of compressed copyright material is one of the major important requirements of Digital Rights Management (DRM). Therefore, we use these images in Jpeg compressed domain for testing our watermarking scheme. We tabulate the obtained results for PSNR and NC (W, W') in Table 5. Table 6 compiles the robustness studies data over the six colored images for SSF and MSF strategies. It is found that the results as obtained for the eight grayscale images reported in Sect. 4.2 and 4.3 above are repeated with MSF strategy out casting the SSF strategy in this case as well. Hence, it can be concluded that the PSO optimization has fairly performed well for colored images also. We conclude that the use of

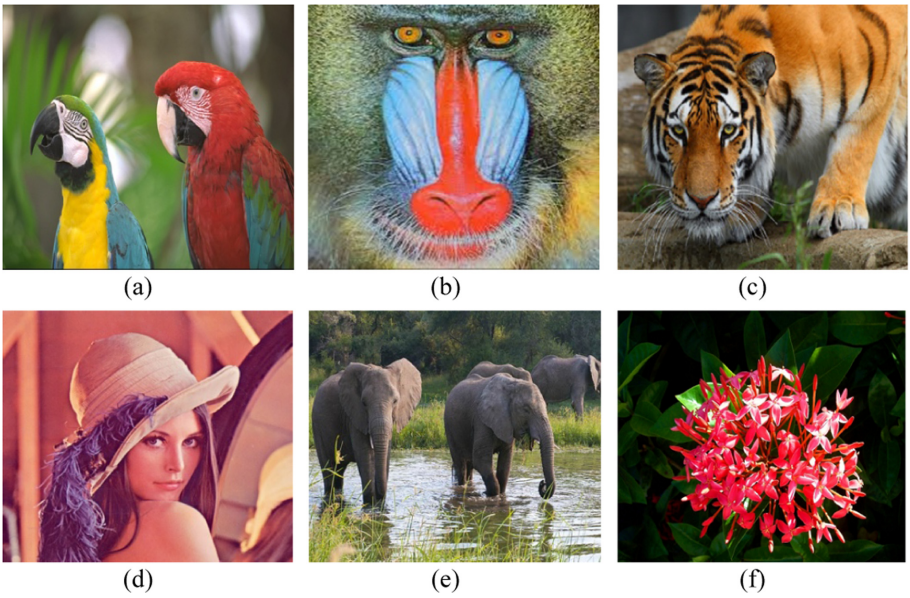

Fig. 3. Color host images a) Parrots.jpg, b) Baboon.jpg, c) Tiger.jpg, d) Lena.jpg, e) Jumbo.jpg and f) CosmologicalCabbage.jpg (Color figure online)

Table 5. Compilation of PSNR and NC (W, W') values of colored images under SSF and MSF strategies

Image	PSNR (SSF scheme) (dB)	PSNR (MSF scheme) (dB)	NC (W,W') (SSF scheme)	NC (W,W') (MSF scheme)
Parrots	60.7181	64.8534	1.000	1.000
Baboon	57.6204	63.6811	1.000	1.000
Tiger	59.8275	62.7539	1.000	1.000
Lena	60.0043	61.7653	1.000	1.000
Jumbo	55.2116	57.8201	1.000	1.000
Cosmological Cabbage	55.8022	58.4118	1.000	1.000

PSO optimization in DWT-SVD hybrid transform domain working with MSF embedding strategy is a good candidate for grayscale and compressed colored image watermarking. In the proposed scheme, all performance metrics have been verified and evaluated viz-a-viz., state of the art techniques and it has been found to outperform all of them.

Table 6. Compilation of NC (W, W') values over colored signed images after attacks under SSF and MSF strategies

Attacks/Image	Parrots		Baboon		Tiger		Lena		Jumbo		CosmologicalCabbage	
	SSF	MSF	SSF	MSF	SSF	MSF	SSF	MSF	SSF	MSF	SSF	MSF
JPEG (Q = 0.9)	0.9827	0.9915	0.9817	0.9908	0.9601	0.9841	0.9722	0.9869	0.9787	0.9821	0.9678	0.9765
JPEG (Q = 0.8)	0.9704	0.9844	0.9701	0.9802	0.9540	0.9713	0.9687	0.9742	0.9644	0.9706	0.9495	0.9634
JPEG (Q = 0.7)	0.9635	0.9736	0.9621	0.9742	0.9480	0.9673	0.9513	0.9681	0.9455	0.9703	0.9267	0.9356
Salt & Pepper Noise (5%)	0.9294	0.9493	0.9192	0.9472	0.9276	0.9511	0.9285	0.9605	0.9230	0.9521	0.9064	0.9330
Gaussian Noise (5%)	0.9335	0.9634	0.9264	0.9521	0.9474	0.9586	0.9384	0.9646	0.9453	0.9552	0.9195	0.9483
Gaussian Filtering (3x3)	0.9681	0.9829	0.9407	0.9643	0.9527	0.9814	0.9498	0.9785	0.9501	0.9792	0.9183	0.9571
Median Filtering (3x3)	0.9536	0.9663	0.9334	0.9575	0.9482	0.9710	0.9403	0.9648	0.9416	0.9702	0.9226	0.9536
Cropping (crop 64 x 64 center and replace with host image)	0.9723	0.9833	0.9636	0.9823	0.9661	0.9771	0.9628	0.9739	0.9523	0.9711	0.9498	0.9643
Cropping (crop 64 x 64 corner and replace with host image)	0.9766	0.9811	0.9688	0.9805	0.9584	0.9786	0.9604	0.9788	0.9566	0.9748	0.9512	0.9666
Histogram Equalization	0.9190	0.9279	0.9052	0.9197	0.9016	0.9172	0.9032	0.9204	0.8919	0.9110	0.8877	0.8990
Scaling (5 1 2> 2 5 6> 5 2	0.9962	0.9992	0.9933	0.9956	0.9955	0.9984	0.9930	0.9965	0.9949	0.9978	0.9940	0.9966
Sharpening	0.9785	0.9910	0.9801	0.9908	0.9536	0.9708	0.9762	0.9899	0.9475	0.9628	0.9491	0.9652

We attribute better results obtained by us to the use of the hybrid objective function used to optimize the PSO technique. This objective function is a linear combination of the PSNR and the image processing attacks used in this work. This function has resulted in better optimization of the MSF for PSO based watermarking scheme.

5 Conclusion

The paper proposes an optimized PSO based watermarking scheme working in hybrid DWT-SVD transform domain. The PSO is used to determine the Multiple Scaling Factor (MSF) based embedding strength further used to embed the watermark in the image coefficients on the basis of its structural and physical properties. The experimentation is carried out over eight gray-scale and six colored images of the size 512×512. The Objective function proposed by Mishra et al. which is a linear combination of the PSNR and six different image processing attacks is used to run the PSO algorithm. The optimized value of the MSFs so generated by the PSO is used to embed the watermark in the selected low frequency coefficients of the host images. The signed images so obtained are found to exhibit very high visual quality and the watermark embedding scheme is also found to be quite robust. The proposed watermarking scheme outperforms several other identical schemes with the observed results. It is found that the PSO based scheme carried out in hybrid DWT-SVD transform domain is

very successful to optimize the MSF parameters in accordance with various regions of the test images. Additionally, the visual quality of the signed images and the robustness parameter NC are also found to be well balanced due to its use. We attribute this exceling performance of our scheme to the use of particle swarm optimization technique in collaboration with the objective function used.

References

1. Cox, J., Kilian, J., Leighton, F.T., Shamoon, T.: Secure spread spectrum watermarking for multimedia. IEEE Trans. Image Process. **6**(12), 1673–1687 (1997)
2. Liu, R., Tan, T.: An SVD-based watermarking scheme for protecting rightful ownership. IEEE Trans. Multimed. **4**(1), 121–128 (2002)
3. Nikolaidis, N., Pitas, I.: Robust image watermarking in the spatial domain. Signal Process. **66**(3), 385–403 (1998)
4. Liu, J.-C., Chen, S.-Y.: Fast two-layer image watermarking without referring to the original image and watermark. Image Vis. Comput. **19**(14), 1083–1097 (2001)
5. Lin, C.-Y., Wu, M., Bloom, J.A., Cox, I.J., Miller, M.L., Lui, Y.M.: Rotation, scale, and translation resilient watermarking for images. IEEE Trans. Image Process. **10**(5), 767–782 (2001)
6. Solachidis, V., Pitas, L.: Circularly symmetric watermark embedding in 2-D DFT domain. IEEE Trans. Image Process. **10**(11), 1741–1753 (2001)
7. Hernandez, J.R., Amado, M., Perez-Gonzalez, F.: DCT-domain watermarking techniques for still images: detector performance analysis and a new structure. IEEE Trans. Image Process. **9**(1), 55–68 (2000)
8. Patra, J.C., Phua, J.E., Bornand, C.: A novel DCT domain CRT-based watermarking scheme for image authentication surviving JPEG compression. Digit. Signal Process.s **20**(6), 1597–1611 (2010)
9. Dawei, Z., Guanrong, C., Wenbo, L.: A chaos-based robust wavelet-domain watermarking algorithm. Chaos Solitons Fractals **22**(1), 47–54 (2004)
10. Meerwald, P., Uhl, A.: Survey of wavelet-domain watermarking algorithms. In: Security and Watermarking of Multimedia Contents III, pp. 505–516 (2001)
11. Liu, F., Liu, Y.: A Watermarking algorithm for digital image based on DCT and SVD. In: 2008 Congress on Image and Signal Processing, pp. 380–383 (2008)
12. Agarwal, C., Mishra, A., Sharma, A.: Gray-scale image watermarking using GA-BPN hybrid network. J. Vis. Commun. Image Represent. **24**(7), 1135–1146 (2013)
13. Mei, S.C., Li, R.-H., Dang, H.-M., Wang, Y.-K.: Decision of image watermarking strength based on artificial neural-networks. In: Proceedings of the 9th International Conference on Neural Information Processing (ICONIP 2002) (2002)
14. Li, Q., Yuan, C., Zhong, Y.-Z.: Adaptive DWT-SVD domain image watermarking using human visual model. In: 9th International Conference on Advanced Communication Technology (2007)
15. Mishra, A., Goel, A., Singh, R., Chetty, G., Singh, L.: A novel image watermarking scheme using extreme learning machine. In: 2012 International Joint Conference on Neural Networks (IJCNN) (2012)
16. Motwani, M. C., Motwani, R.C., Harris, F.C.: Wavelet based fuzzy perceptual mask for images. In: 2009 16th IEEE International Conference on Image Processing (ICIP) (2009)

17. Agarwal, C., Mishra, A., Sharma, A.: Digital image watermarking in DCT domain using fuzzy inference system. In: 2011 24th Canadian Conference on Electrical and Computer Engineering (CCECE) (2011)
18. Lai, C.C.: Corrigendum to 'A digital watermarking scheme based on singular value decomposition and tiny genetic algorithm'. Digit. Signal Process. **23**(4), 1333 (2013)
19. Mishra, A., Agarwal, C.: Toward optimal watermarking of grayscale images using the multiple scaling factor based cuckoo search technique. In: Bio-Inspired Computation and Applications in Image Processing, pp. 131–155. Elsevier (2016)
20. Mishra, A., Agarwal, C., Sharma, A., Bedi, P.: Optimized gray-scale image watermarking using DWT SVD and firefly algorithm. Exp. Syst. Appl. **41**(17), 7858–7867 (2014)
21. Kuppusamy, K., Thamodaran, K.: Optimized image watermarking scheme based on PSO. Proc. Eng. **38**, 493–503 (2012)
22. Loukhaoukha, K., Nabti, M., Zebbiche, K.: A robust SVD-based image watermarking using a multi-objective particle swarm optimization. Opto-Electron. Rev. **22**(1), 45–54 (2014). https://doi.org/10.2478/s11772-014-0177-z
23. Huang, F., Guan, Z.-H.: A hybrid SVD-DCT watermarking method based on LPSNR. Pattern Recogn. Lett. **25**(15), 1769–1775 (2004)
24. Agarwal, C., Mishra, A., Sharma, A.: A novel gray-scale image watermarking using hybrid Fuzzy-BPN architecture. Egypt. Inform. J. **16**(1), 83–102 (2015)
25. Ohnishi, J., Matsui, K.: Embedding a seal in to a picture under orthogonal wavelet transform. In: IEEE International Conference on Multimedia and Computing System, Hiroshima, Japan, pp. 514–521 (1996)
26. Bors, A.G., Pitas, I.: Image watermarking using DCT domain constraints. In: IEEE International Conference on Image Processing, pp. 231–234 (1996)
27. Araghi, T.K., Manaf, A.A.: An enhanced hybrid image watermarking scheme for security of medical and non-medical images based on DWT and 2-D SVD. Future Gener. Comput. Syst. **101**, 1223–1246 (2019)
28. Kennedy, J., Eberhart, R.: Particle swarm optimization. In: 1995 IEEE International Conference on Neural Networks, Perth, Australia, pp. 1942–1948. IEEE Service Center, Piscataway (1995)
29. Xianghong, T., Lu, L., Lianjie, Y., Yamei, N.: A digital watermarking scheme based on DWT and vector transform. In: Proceeding of International Symposium on Intelligent Multimedia, Video and Speech Processing, pp. 635–638 (2004)
30. Loukhaoukha, K., Chouinard, J.Y., Taieb, M.H.: Optimal image watermarking algorithm based on LWT–SVD via multi-objective ant colony optimization. J. Inf. Hiding Multimed. Signal Process. **2**(4), 303–319 (2011)
31. Abdelhakim, A.M., Abdelhakim, M.: A time-efficient optimization for robust image watermarking using machine learning. Exp. Syst. Appl. **100**, 197–210 (2018)
32. Ishtiaq, M., Sikandar, B., Jaffar, A., Khan, A.: Adaptive watermark strength selection using particle swarm optimization. ICIC Express Lett. **4**(5), 1–6 (2010)
33. Loukhaoukha, K., Refaey, A., Zebbiche, K.: Ambiguity attacks on robust blind image watermarking scheme based on redundant discrete wavelet transform and singular value decomposition. J. Electr. Syst. Inf. Technol. **4**(3), 359–368 (2017)