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A novel watermarking method based on differential evolutionary algorithm and wavelet transform

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Abstract
In this paper, a new Watermarking method based on the optimization framework and discrete wavelet transform (DWT) is presented. In this method, first, the watermark image is divided into several blocks. Then, using differential evolution (DE) algorithm, an appropriate location for each of these blocks is found in the cover image. In the proposed method, the results of the DE algorithm, which is needed for the reconstruction phase are also embedded as a vector in the cover image under the wavelet domain. Also, to achieve the highest PSNR in the reconstruction phase, the optimal values for Alpha-blending coefficients (used in the embedding and extraction process) are determined with the multi-objective DE-based optimization algorithm. Several experiments are presented to illustrate the imperceptibility and robustness of the proposed algorithm against different types of attacks, including salt and pepper, Gaussian, median filtering, rescaling, compression, and rotation. The obtained results are also compared with state-of-the-art methods and show the superiority of the proposed method in most cases.

Keywords Watermarking · Optimization · DE algorithm · DWT · Authentication

1 Introduction

Nowadays, the copyright protection of digital data became a crucial problem due to the growth of digital technology. In this regards, Watermarking is an efficient method to overcome this issue. Digital Watermarking is the process of embedding secret data (watermark) into a multimedia object

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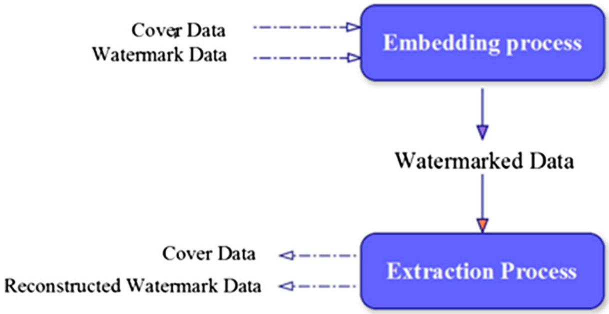


Fig. 1 The Watermarking process

(cover data), so that secret data (watermark) can be detected only by a person who has authorization. Figure 1 shows a general framework for the Watermarking technique.

Imperceptibility and robustness are the main features of any robust Watermarking technique. Generally, Watermarking techniques are categorized as blind Watermarking [12] and non-bind Watermarking techniques [10, 15]. Another approach to categorize Watermarking schemes is the domain of the embedding process. The first type of domain is the spatial domain, and the other one is the frequency domain. Although each domain has determined advantages and disadvantages, however, the frequency domain is more robust than the spatial domain [24]. Least significant bit modification, [17] is one example of the spatial domain which is defined by pixels. Discrete Wavelet Transform (DWT) [9] and Discrete Cosine Transform (DCT) [13] are examples of the frequency domain schemes.

In the literature, several researchers proposed the modern frequency domain techniques for multimedia copyright protection issue [1, 2, 4–6, 8, 11, 14, 20–23, 25]. For instance, Gangadhar et al. [9] presented a Watermarking method based on particle swarm optimization (PSO), SVD decomposition, and DWT transformation. In this paper, low-frequency bands have been chosen to insert the watermark image, and the best location of each block is achieved by the calculation of entropy. The optimization of scaling factors is done by PSO, and results reveal that the authentication of the medical image has been provided.

Also, Moosazadeh and Ekbatanifard [13] suggested a Watermarking algorithm based on teaching-learning-Based optimization (TLBO). In this algorithm, the embedding process has been carried out with respect to the DCT coefficients. Further, the TLBO algorithm is used to determine embedding variables and also to find the best location for inserting the Watermark. Ernawan et al. [5] presented a Watermarking framework based on DCT transformation. The frequency bands of DCT have been considered as the location of watermark in the embedding process. Also, insertion frequencies are determined by the calculation of entropy. Chen et al. [4] tried to present the Watermarking method based on a general non-negative matrix factorization (NMF), which is resistant to common attacks.

Also, Alotaibi and Elrefaei [2] proposed a method for text-image Watermarking that uses two frequency transformation:integer wavelet transform (IWT) and discrete cosine transform (DCT). In this method, first, IWT is applied to the cover image and, then DCT of LL sub-band is calculated with the aim of inserting the watermark. Yao et al. [23] introduced an effective imperceptible Watermarking technique to embed the visible watermark. Here, the location of insertion is adaptively selected by visual perceptual model. Fatahbeygi et al. [8] suggested an approach based on classification and visual cryptography (VC). Robustness of the method is guaranteed by skipping the frail blocks against attacks.

Ramamurthy and Varadarajan [14] and AL-Nabhani [1] used the neural network to improve the image quality in the extraction phase. Taheri [20] proposed a Watermarking method base on the image features and the human vision system (VHS) models. They also used wavelet transform and neural network based regression in their technique. Moreover, for specific purposes, multi-modal Watermarking techniques are considered as another study in the frequency domain. Jagadeesh et al. [11] presented a Watermarking algorithm using the combination of a discrete cosine transform and fuzzy logic concepts. In this paper, the fuzzy algorithm is employed to determine the weighting coefficient in the embedding process.

In some studies, hidden text and watermark image are simultaneously embedded in the cover image [18, 25]. Zear et al. [25] combined different frequency domain transforms, including DCT and DWT with SVD decomposition. In this scheme, the sub-bands LL3, LH2 and, LH1 of wavelet transform are selected for text and image watermark embedding, respectively. This method sufficiently reduces the required bandwidth and memory and also provides a secure infrastructure to the reliable transmission of considered media. In the existing Watermarking approaches, the embedding capacity and resistant against different attacks rely on the proper selection of location for embedding each block and the optimization of the parameters in the embedding phase.

In the present paper, a new digital image Watermarking technique for embedding the watermark in the cover image is presented based on the differential evolution algorithm and wavelet transform. In this technique, the cover and watermark image is divided into the same blocks. Then, using the multi-objective differential evolution (DE) optimization algorithm, an appropriate location of each block of watermark image is found in the cover image, so that the watermarked and retrieved images get the highest PSNR, simultaneously. Also, by using the DE algorithm the best value for parameters of Alpha-blending technique, used in the embedding phase, is obtained.

Therefore, the contribution of the proposed method:

- Employing intelligent algorithms in the process of finding a proper location for each block of the Watermark image. Compared to non-smart methods that are very time-consuming especially in the case of large-scale problems (as an instance, to embed 256 blocks of the watermark image in the cover image, they need to solve a problem with 256! Modes), intelligent algorithms such as DE reduce the computational time significantly by considering the image as a general and unique system. These methods produce a near-optimal response by generating an initial population which does not need to examine all possible modes.
- In this method, each block is embedded based on the effect of the current location on other blocks and the PSNR of the Watermarked and extracted images, simultaneously. The proposed method has threshold parameter (psnr0) for a minimum acceptable PSNR and keeping a balance between PSNR of embedding and extraction process which depends on user preferences and is set by them. In other words, the flexibility of the scheme is augmented by introducing a threshold. The psnr0 must be chosen so that the problem remains feasible. The framework will deliver the requested quality as long as the problem remains feasible.
- DE optimization algorithm, in addition to the location of each block, determines the optimal value for parameters of the Alpha-blending technique, which is used in embedding and extraction processes.

The rest of this paper is organized as follows: in section 2, we provide some preliminaries, including DWT transform and optimization concepts. In section 3, the new proposed Watermarking approach is presented. The experimental results and performance comparison are given in section 4. Finally, section 5 includes the conclusion and further directions.

2 Preliminaries

2.1 DWT transform

Wavelet transform is a powerful mathematical tool used in most modern data analysis techniques. Wavelets are a set of mathematical functions which are used for decomposing a signal into different frequency components [7]. This set of function is constructed by time shifting and scaling of a preliminary model (or mother wavelet) named ψas below:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right), \tag{1}$$

where a and b are scaling and shifting parameters, respectively. Wavelet transforms divide into two continuous (CWT) and discrete categories. The CWT transform produces infinite coefficients that need large storage in the computer system. So, the researchers use the DWT transform in the application. In DWT, the frequency space is divided base on high and low-subband frequencies. The lower frequencies are the principal coefficients in DWT transform, which means we can consider them as an approximation of all data. In the second level, the approximation component is divided into two subbands. In Fig. 2, a vector is decomposed into one-level by the 1-D discrete wavelet transform defined by [7].

$$w_f(a,b) = \int_{-\infty}^{+\infty} x(t)\psi_{a,b}(t)dt. \tag{2}$$

Since the matrices have two dimensions, the DWT has to be applied twice, which is called the two-dimensional DWT. Therefore, in the two-step, DWT transform is performed on rows and then on columns, respectively. The two-dimensional DWT transform divides a matrix into four different frequency bands, including LL, LH, HL, and HH. Here, the LL and HH bands hold the low-frequency information (low pass filter) and high-frequency information (high-pass filter), respectively. Also, with this partitioning, the intermediate frequency information will be included in HL and LH subbands. The LL subband is considered as an approximation of the original matrix, while HL, LH, and HH represent details of it. We show the 1 level 2D-DWT in Fig. 3 in which D and H are high pass and low pass filters, respectively. Similarly, we

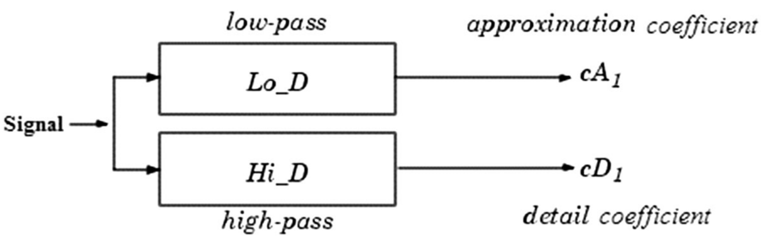


Fig. 2 One- level 1D-DWT

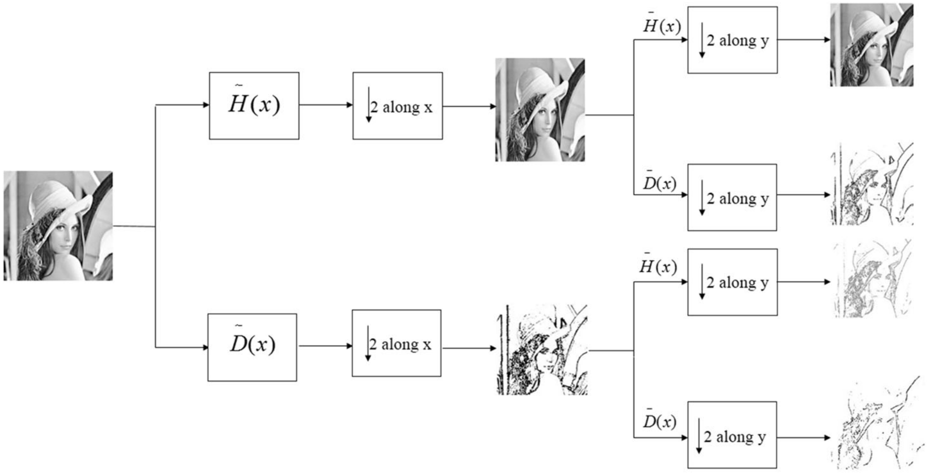


Fig. 3 Two level 2D-DWT

can decompose the low-frequency subband into sub-level frequency regions LL2, LH2, HL2, and HH2. This approach can be continued up to any arbitrary level with wavelet transform.

2.2 The DE algorithm

To obtain an accurate analysis of the phenomena in science and engineering, these phenomena often formulated as mathematical models [3]. However, apart from linear models, explicit solutions to most non-linear cases can hardly be found. Therefore, optimization methods become essential in the applications of mathematical models. Recently, the evolutionary algorithms such as DE have been suggested (by Stone et al. [19]) to find approximate solutions to such problems. In the following, we will explain some optimization concepts of the DE algorithm. The general form of an optimization problem is as follows:

$$\min_{x \in \Omega \subseteq \mathbb{R}^d} \quad f(x) \tag{3}$$

$$\text{subject to} \quad h(x) = 0,$$

$$g(x) \geq 0,$$

where f is the objective function and h and g are functions related to equality and inequality constraints, respectively. The vector x^* belongs to the feasible region of the problem (3) is a global minimizer if

$$\forall x \in \Omega \Rightarrow f\left(x^*\right) \leq f(x). \tag{4}$$

In this paper, we apply the DE algorithm to obtain numerical solutions to the optimization problems. The first step of the DE algorithm is to generate an initial population randomly. Then, a suitable mutation is applied to this initial population.

In i$^{\text{th}}$ iteration, for the distinguished indices, k_1, k_2 and k_3, the new member of the population, x_{mat}, obtains from a three-term recurrence relation as below:

$$x_{mat} = x_{k_1} + F \times (x_{k_2} - x_{k_3}), \tag{5}$$

where$F \in [0.1{,}0.9]$ is the mutation factor. In the next step, the algorithm generates a new population. Here, at least one of the children must be mutated in the form of the below relation:

$$x_{new} = \begin{cases} x_{mat} \ cr > rand or \ i = z, \\ x_i \ \ otherwise, \end{cases} \tag{6}$$

where *rand~U*(0, 1), and *cr* is a control parameter in interval (0, 1). Finally, each new member compares with her mother, and if it has a less cost, it will be replaced from the generation by the algorithm. Otherwise, the mother member is transferred to the new generation. In Fig. 4, we briefly describe this algorithm.

3 The proposed watermarking method

In this section, first, we design an appropriate optimization problem, and then we apply the DE algorithm to obtain a new Watermarking approach. In this approach, the predetermined Watermark and cover images are divided into same $n \times n$ blocks. Therefore, the Watermark image (with size$M \times N$) contains $\frac{M \times N}{n^2}$ blocks that will be placed in the blocks of the cover image. The location of each block of the Watermark image will be determined by the DE optimization algorithm in such a way that the Watermarked and recovered images have the highest PSNR, simultaneously.

In the proposed method, after the determination of proper location for each block based on the DE algorithm, embedding and extraction phases will be carried out by Alpha-blending technique [16]. In this technique, the process of embedding has the following formulation:

$$Watermarked = k \times cover + q \times Watermark \tag{7}$$

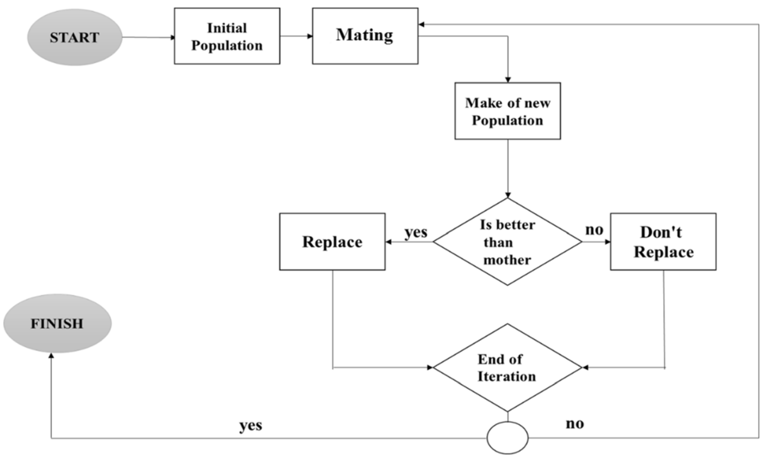


Fig. 4 Diagram of the DE algorithm

in which k and q are the coefficients of Watermark and cover images, respectively. According to (7), for $k \approx 1$ and $q \approx 0$ the watermarked image almost identical to cover image. Also, in the extraction process, we have

$$W_R = \frac{1}{q}(k \times cover - Watermarked) \tag{8}$$

where W_R is extracted watermark image. Although, we use the Alpha-blending technique in embedding and extraction phases base on (7) and (8). However, we add the coefficients k and q to the optimization problem as the decision variables. Therefore, the embedding and extraction process in the proposed algorithm will be performed with optimal coefficients. In the following, we describe the formulation of the optimization problems corresponding to the proposed method.

3.1 The optimization problems corresponding to the proposed method

Here, to find the appropriate location for each block of the watermark image in the cover image, we propose a placement algorithm. In this algorithm, first, an optimization problem is formulated then the DE algorithm is used to solve it. Consider the control parameter $\boldsymbol{psnr}0$ as acceptable lower bound for PSNR in the embedding and extraction phase. Here, we try to preserve the constraints such that Watermarked and Watermark get their maximum possible PNSR values. In this regard, suppose A, z, C and z_p are the cover, Watermark, Watermarked, and extracted Watermark images, respectively.

Accordingly, we define two constraints as:

$$h_1 = \begin{cases} 0, \mathrm{PSNR}(C, A) \geq \mathrm{psnr}t_0, \\ psnr0 - PSNR(C, A), otherwise, \end{cases} \tag{9}$$

$$h_2 = \begin{cases} 0, \mathrm{PSNR}(z, z_p) \geq \mathrm{psnr}t_0, \\ psnr0 - PSNR(z, z_p), otherwise. \end{cases} \tag{10}$$

Now, by considering the constraints (9) and (10), we define the objective function as below:

$$fit = -\left(k_1 PSNR(C, A) + k_2 PSNR(z, z_p)\right) + k_{p_1} h_1 + k_{p_2} h_2, \tag{11}$$

wherek_1 and k_2 are weight coefficients which specify the importance of constraints, and k_{p_1} and k_{p_2} are penalty coefficients. Since the PSNR of embedding and extraction processes both of them have the same importance for us, in the following we set $k_1 = k_2 = 0.5$. Now, we minimize the objective function (11) by the DE algorithm. The DE method is one of the powerful optimization algorithms in which the mating of a new population is carrying out in the form of the gene by gene. In fact, the DE algorithm is not a vector optimization technique like PSO, and this feature is compatible with our proposed watermarking scheme. Accordingly, in each iteration, the proposed algorithm finds the proper place of each decision variable (gene) in the cover image with the only gene by gene operations. The point is that this could decrease the computational complexity of the method compared with the vector procedure in which the other genes is useless.

The outputs of this algorithm are including proper locations of each block and the optimal values of the coefficients of Alpha-blending technique. Now, for the extraction stage, we mention these optimal values as a text string in the Watermarked image. We do this by DWT transform in the frequency domain on the watermarked image similar to [18] with some modification. Unlike [18] which the insertion coefficient, k', is considered by trial and error, here, we calculate this coefficient so that the Watermarked image takes the highest PSNR. Accordingly, we design an objective function as below:

$$fit = -PSNR(watermarked, cover) + k_p h_3, \tag{12}$$

in which

$$h_3 = \begin{cases} 0, PSNR(Watermarked, cover) \geq \text{psnr}t_0, \\ psnr0 - PSNR(Watermarked, cover), otherwise. \end{cases} \tag{13}$$

In the next section, we will describe this process, completely.

3.2 Watermark embedding algorithm

In this process, first, we divide both cover image and Watermark image into the same blocks. Then, we optimize the objective function (11) by the DE algorithm. The output of the DE algorithm is a vector which contains suitable locations for each block of Watermark image and also the optimal values of the Alpha-blending coefficients to apply on it. Base on this optimal vector, the Watermark image will be cluttered before embedding phase. One of the image cryptography methods is scrambling, which changes the location of pixels according to a reversible equation. Hence, the encrypted image is obtained, and in the decoding step, the location of each pixel is achieved. In the proposed method, this concept has been performed in blocks level, and the security has been considered using this technique. Figure 5 shows a Watermark image and a cluttered image before embedding. Now, the embedding phase is done using the Alpha-blending technique with optimal coefficients k and $q$for each block as below:

$$Watermarked = k \times cover + q \times Watermark. \tag{14}$$

Fig. 5 Watermark image (left) and cluttered Watermark image (right)

To rebuild the cluttered image in the phase of extraction, we insert the optimal vector of the DE algorithm in the watermark image. Accordingly, the arithmetic compression method is used to augment the capacity of text watermark in the embedding process. For compression, first, the optimal vector is converted into a binary string, and then an arithmetic compression is applied to it. Finally, all zero components get the value −1. Simultaneously, a 1-level DWT transform is applied to the Watermarked image and the domains HL1 and LH1 are selected for insertion of the compressed text vector. In fact, we start the insertion process from HL1, and we move the remaining characters to the sub-band LH1 by below equations:

$$HL1(x,y) = HL1(x,y) \times \left(1 + k^{'} \times bit\_melen\_i\right), \tag{15}$$

$$LH1(x,y) = LH1(x,y) \times \left(1 + k^{'} \times bit\_melen\_i\right), \tag{16}$$

where $bit\_melen\_i \in \{-1, 1\}$ are bits of the binary vector and $k^{'}$ is the insertion coefficient. In (12), with considering the maximum PSNR value of the Watermarked image, the DE algorithm gives an optimal value for $k^{'}$. Finally, we take an inverse DWT transform from Watermark and the value of $k^{'}$ is placed in the center of the watermarked image as key. We use $k^{'}$ in extraction phase. In Fig. 6, the Watermark embedding diagram has been shown.

3.3 Watermark extraction algorithm

After receiving an image by the decoder, first, the value of $k^{'}$ is extracted from the center of the received watermarked image as below:

$$k^{'} = recived\_Watermarked\left(\frac{size(row)}{2}, \frac{size(colum)}{2}\right) \tag{17}$$

In the embedding phase of the proposed method, the insertion of the text (the optimal vector) was performed on the Watermarked image and not in the empty part of the cover image. So, after extracting the text, the watermarked image should be returned to the original state. To extract the bits of compressed text, 1-level DWT is taken on the sub-bands HL1 and LH1 as below:

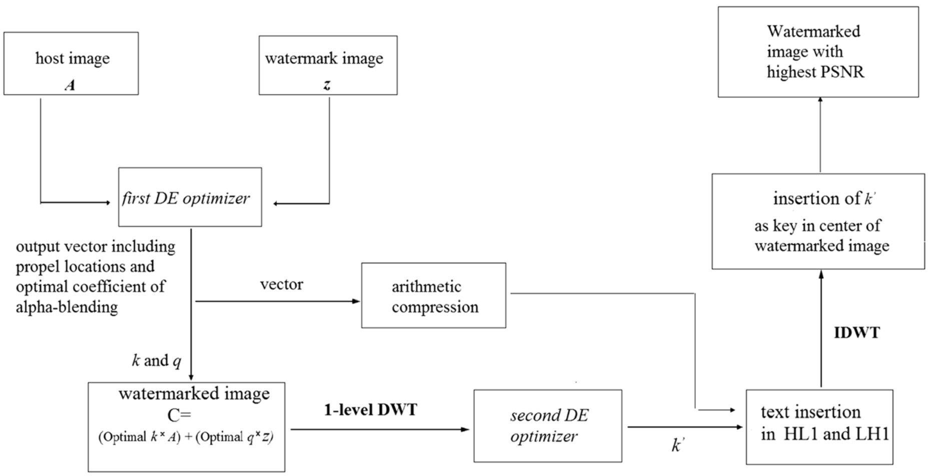


Fig. 6 Watermark embedding diagram

$$bit\_melen\_i = \frac{HL1_{cover}(x,y) - HL1_{Watermarked}(x,y)}{k' HL1_{Watermarked}(x,y)}, \tag{18}$$

$$bit\_melen\_i = \frac{LH1_{cover}(x,y) - LH1_{Watermarked}(x,y)}{k' LH1_{Watermarked}(x,y)}. \tag{19}$$

After extracting the compressed data, it is decoded by the arithmetic decoding, and the pixel value for the Watermarked image should return to the original state by:

$$HL1_{new}(x,y) = \frac{HL1_{Watermarked}(x,y)}{1 + k' \times bit\_melen\_i}, \tag{20}$$

$$LH1_{new}(x,y) = \frac{LH1_{Watermarked}(x,y)}{1 + k' \times bit\_melen\_i}. \tag{21}$$

Now, by the optimal values for$k$ and q, the block of Watermark image is extracted by using Alpha-blending extraction formula as:

$$RW = \frac{1}{q}(k \times cover - Watermarked). \tag{22}$$

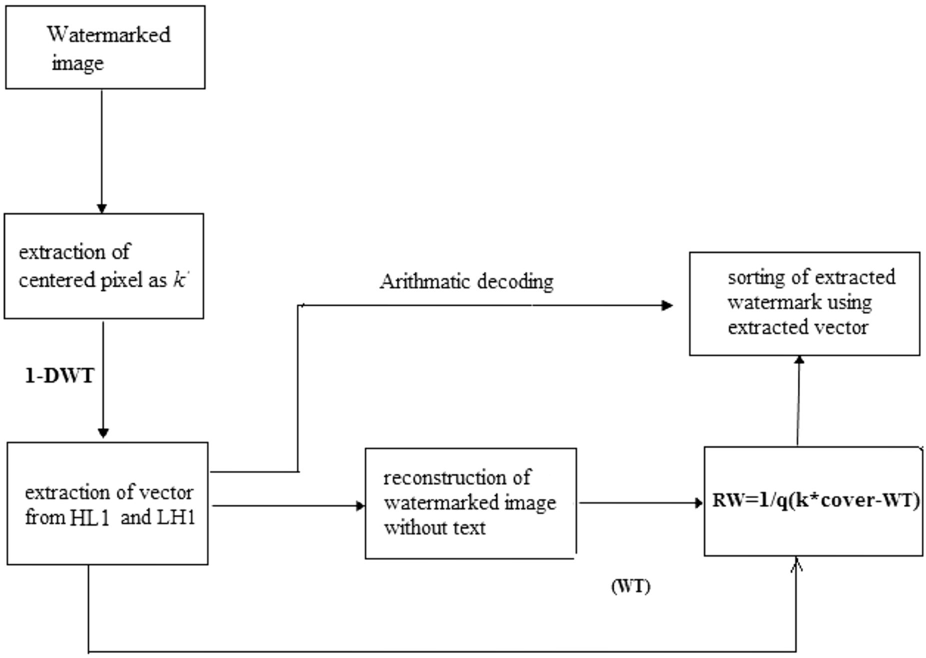
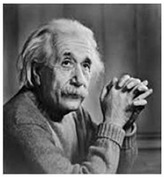
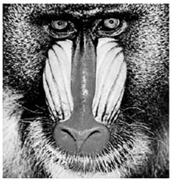
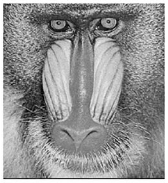


Fig. 7 The Watermark extraction diagram

Table 1 PSNR and SSIM for Watermarked images with 256 × 256 size

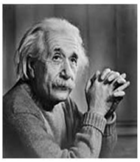
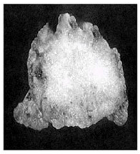
Cover	Watermark	Watermarked	k'	PSNR	SSIM
			3.187×10^{-3}	66.31	0.9931
			65.61×10^{-4}	66.35	0.9934
			35.67×10^{-2}	58.42	0.9824
			5.639×10^{-2}	83.16	0.9968
			1.039×10^{-2}	67.75	0.9939

Here, *RW* blocks are cluttered, should be rearranged according to the extracted vector (text data). In Fig.7, we illustrate the Watermark extraction diagram.

4 Experimental results

To evaluate the performance of the proposed method, in this section, we consider different types of cover and Watermark images with the size 256 × 256. The size of each block is 16 × 16. Accordingly, the experiments will be simulated with the software MATLAB on a PC with Intel Core i5, CPU 1.6 GHz, and RAM 8 GB. As already

Table 2 PSNR values for extracted Watermark images

Extracted watermark image					
PSNR	223.63	196.30	216	98	215.67

mentioned, in the proposed method, the output of the DE algorithm is embedded in the Watermarked image as text vector with an arithmetic compression method to increase the embedding capacity. Here, we consider this text vector with at most 190 characters. Furthermore, similar to any evolutionary algorithm, we set the number of repetitions at least 200 for all performances, and the initial population in the DE algorithm is ten times the number of decision variables. Also, psnr0 was set to 45 dB in the experimental results. We use the criteria peak signal to noise ratio (PSNR), Structural Similarity Index Measure (SSIM) and Normalized Correlation Coefficient (NC) to evaluate the performance of the proposed method.

The PSNR value calculated as:

$$PSNR = 10log_{10}\left(\frac{(Max(intensity))^2}{\sqrt{MSE}}\right), \tag{23}$$

where $Max(intensity) = 255$ and MSE is mean square error that is defined by:

$$MSE = \sum_{i=1}^{M}\sum_{j=1}^{N}\frac{\left[I(i,j)-I'(i,j)\right]^2}{M \times N}. \tag{24}$$

Also, the $SSIM$ criteria is determined as:

$$SSIM(x,y) = \frac{\left(2\mu_x\mu_y + c_1\right)\left(2\sigma_{xy} + c_2\right)}{\left(\mu_x^2 + \mu_y^2 + c_1\right)\left(\sigma_x^2 + \sigma_y^2 + c_2\right)}, \tag{25}$$

whereμ_x and μ_y are the average of original and Watermarked image, respectively. Also, σ_x^2 and σ_y^2 are the variance of original cover and Watermarked image with the covariance σ_{xy}. Here, c_1 and c_2 are free parameters. Finally, the value of $NC \in [0, 1]$ of watermark image is calculated as below:

Table 3 The mean of PSNR and SSIM for different images

Mean of SSIM for extracted watermark image	Mean of SSIM for watermarked image	Mean of PSNR for extracted watermark image	Mean of PSNR for watermarked image
0.9971	0.9910	192.48	68.398

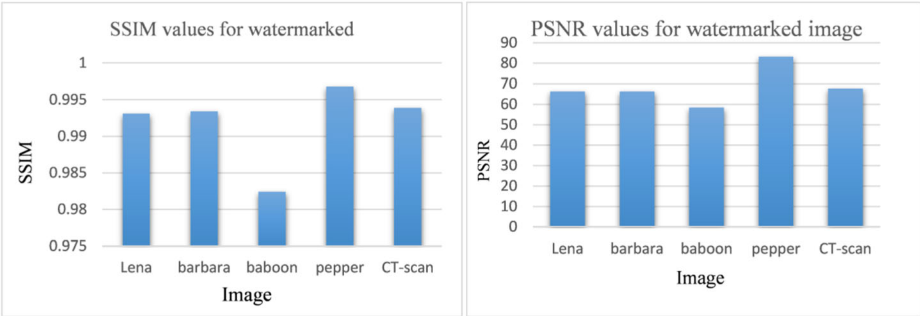


Fig. 8 SSIM for Watermarked image (left) and PSNR for Watermarked image (right)

$$NC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} w(i,j)w'(i,j)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}[w(i,j)]^2}\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}[w'(i,j)]^2}}, \tag{26}$$

where, w and w' present the original watermark image and the retrieved watermark image, respectively.

In the following, PSNR is used to measure the visual quality of both Watermarked and retrieved images. However, SSIM is used only to evaluate the quality of Watermarked images. Moreover, the robustness of Watermarked image is measured by calculation of NC value for Watermark image against common attacks such as Rotation, Gaussian noise, Median Filtering, Salt and Peppers, and JPEG compression. In these experiments, some of the popular cover and Watermark images have been used and placed in Table 1. In this table, the coefficient k' for text embedding along with PSNR and SSIM values also have been shown. Since the proposed method uses the intelligence optimization method, the algorithm has been executed 10 times for each embedding process and then an average of achieved values has been considered as PSNR in Table 1. Referring to this table, the Watermarked images achieve good visual quality and high values of PSNR and SSIM. In Table 2, the extracted Watermark image and also their PSNR values, for watermarked images related to Table 1, have been computed. In Table 2, the obtained PSNR values imply that the extraction process has been successfully done.

In Table 3, we calculate the average of PSNR and SSIM for employing different watermark images. According to this table, Watermarked images have excellent visual quality, and it is

Table 4 The comparison of Average and Standard deviation of PSNR (dB) of the proposed method and existing method on their corresponding data

Existing methods		Proposed method
Gangadhar et al. (2018) [9]	45.2 ± 2.5	64.3 ± 2.0
Thanki et al. (2019) [22]	52.9 ± 1.4	68.9 ± 3.2
Alotaibi et al. (2019) [2]	57.5 ± 1.7	69.2 ± 2.8
Zear et al. (2018) [25]	28.7 ± 0.9	68.7 ± 0.6
Singh et al. (2018) [18]	33.2 ± 1.0	67.3 ± 1.0

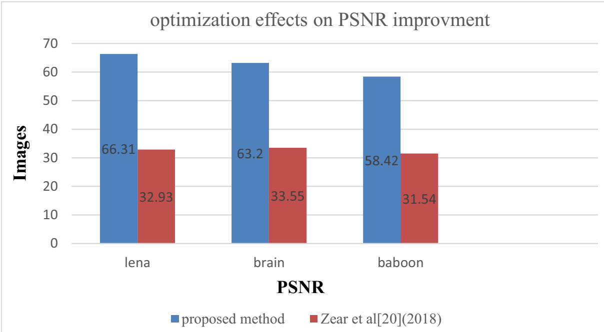


Fig. 9 The comparison of PSNR of watermark extraction

difficult to find the difference between the cover and watermarked image with human visual sight. Figure 8 has demonstrated the SSIM and PSNR of various watermarked pictures utilizing presented approach.

The performance of the proposed method has been evaluated by measuring imperceptibility and robustness. Table 4 demonstrates the imperceptibility results of the presented scheme compared to some state-of-the-art algorithms. It should be noted, to achieve an accurate comparison, results have been tested separately with images of each mentioned reference. This comparison illustrates that the average of PSNR for the watermarked image in the presented method is 69.2586 dB; meanwhile, the maximum rate for the case comparisons is 57.5460 dB. One of the reasons behind this improvement is that here we utilize an objective function that considers maximizing of PSNR in the embedding and extraction phase, simultaneously. In this process, each block is embedded in the associated block of the cover image so that the PSNR in the Watermarked and extracted images get their maximum values, simultaneously. So, we can say that the objective function has properly been considered which converge to the upper bound of the PSNR and this property enhances the visual quality of the proposed method. Additionally, in the proposed method, a PSNR threshold (psnr0) has been defined which guarantees the user preferences and augments the flexibility of the presented approach. On account of the mentioned reasons, in experimental results, in each comparison, the watermarked image is quite near to the original image in the visual impression. These two pictures are indistinguishable when seen solely with eyes. That's to mention this algorithm improves the imperceptibility well.

Figure 9 shows that the PSNR of the images Lena, brain, and baboon have been surged up around twice as high as the results presented in [25]. To be more precise, there is a difference

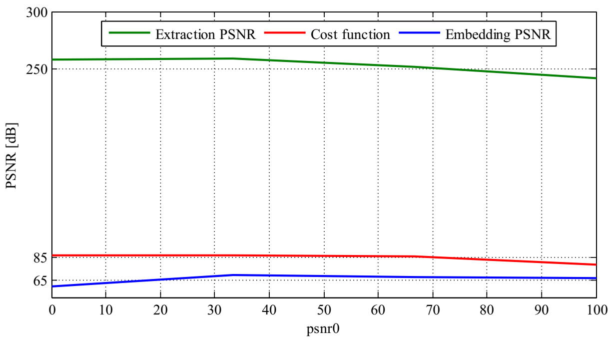


Fig. 10 The different psnr0 and measured embedding and extraction PSNR along cost function

Table 5 The comparison of robustness (using NC criteria) of the proposed algorithm with state-of-the-art methods

Attacks	Proposed method	Singh et al. (2018) [18]	Zear et al. (2018) [25]	Ernawan et al.[6] (2018)	Ernawan et al. [5] (2018)	Thanki et al. [22](2019)	Gangadhar et al. (2018) [9]	Ghafoor et al. (2012) [10]
Gaussian noise (M = 0,V = 0.001)	0.9987	0.9663	0.9466	0.5587	0.9393	0.9837	0.9985	0.8287
Rotation(2°)	0.9512	0.9081	0.4442	–	–	–	0.9983	0.8534
Rotation(20°)	0.6936	–	–	0.5864	–	0.4798	–	–
Median Filtering[2 2]	0.9929	0.8707	0.0123	–	–	–	–	0.8307
Median Filtering[3 3]	0.9914	–	–	0.6026	0.9854	0.4576	–	–
Salt and Peppers (d = 0.01)	0.9836	0.8670	0.7747	0.7062	0.8314	0.9834	0.8416	0.8227
Salt and Peppers (d = 0.001)	0.9847	–	0.9658	0.7056	–	0.9831	–	–
Rescaling	0.8994	0.8434	0.7902	0.5798	–	0.5051	0.7476	0.8393
JPEG compression (QF = 50)	0.9831	–	–	0.6382	0.9990	0.9639	–	–

of 33.38 dB, 29.65 dB, and 26.88 dB respectively, in the PSNR of pictures with the utilization of the proposed strategy compared to the one presented in [25]. This significant increment of PSNR could be attributed to the well-functioning of the proposed optimization framework.

Figure 10 demonstrates the different psnr0 and measured output PSNR for embedding and extraction process. Considering the alpha-blending formulation, if the rate of embedding PSNR is high, the rate of PSNR for the extraction process follows a subtractive trend which has contradictory behavior (green and blue curves). Actually, psnr0 keeps the balance between PSNR of embedding and extraction process. If the psnr0 is not defined, the PSNR of the embedding process will be decreased and converges to a relative minimum and instead, the PSNR of extraction is very high, hence the psnr0 must be defined to keep a balance and avoid the converging to a relative minimum. If psnr0 is selected too large while the inherent quality of the watermark image is low, the quality of the extracted image will not be guaranteed, because it is out of a feasible region. The reduction of the cost function for large psnr0 shows that the problem is infeasible for large psnr0. Hence, Referring to this figure, If the psnr0 is reasonably selected the rate of PSNR is high and acceptable for embedding and extraction simultaneously.

Another crucial feature of Watermarking algorithms is their ability to resist different attacks such as Rotation, Gaussian noise, Median Filtering, Salt and Pepper noise and JPEG compression. As we have known, wavelet-based approaches specially DWT are robust over common attacks. Moreover, in the proposed method, the best location of each block has been selected to the embedding process. Hence, noise influences have been reduced by this perspective. Table 5 illustrates the results of the extracted watermark image after applying various types of benchmark attacks which have been compared to state-of-the-art methods [5, 6, 9, 10, 18, 22, 25, and]. Referring to Table 5, we can see that the proposed method obtains the maximum NC value 0.9987 for the Gaussian noise. However, this method has the minimum NC value 0.6936 related to Rotation(20°) attack. Generally, the NC Average value 0.9330 for all the attack is higher than 0.90, which we can say that the robustness of the method is excellent. In some case, the watermark image is partially degraded under JPEG compression and rotation compared to the other methods. However, the extracted image is recognizable because these kinds of attack modify the indexed reference values that can hold the watermark location values of the hidden values [1].

5 Conclusion

In this paper, a novel Watermarking technique based on optimization concepts and DWT transform has been presented for copyright protection of grayscale images. Accordingly, we have successfully applied the intelligent differential evolution (DE) algorithm to improve the performance of the Watermarking approach. Here, the DE algorithm was used to find the suitable location of each block from the Watermark image into the cover image, and also for determining an optimized value of the coefficient for text embedding in DWT method. Extensive experimental results illustrate that the Watermarked image can show acceptable robustness against commonattacks such as Rotation, Gaussian noise, Median Filtering, Salt and Peppers and JPEG compression.

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