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Research

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Non-blind Arnold Scrambled Hybrid Digital Image Watermarking Scheme based on Differential Evolution and DnCNN

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Abstract

Watermarking is to place a message invisibly in the media without damaging it. Transform (frequency) domain based watermarking has received more attention due to its advantages over spatial domain. Many algorithms which utilize SVD, have a false positive problem. Therefore, this study propose a scheme that along with the robustness of the cover image to the various attacks, maintains the imperceptibility of the watermarked image. To achieve these goals, we use three transforms along with Differential Evolution algorithm. Also, to obtain the best multiple scaling factors, we modify the unique values of SVS of the low resolution approximate image which is obtained in the embedding process. To further increase the security of the proposed method, we scrambled the cover image using Arnold's transform. We also did not use the U and V diagonal components in the embedding and extracting steps to prevent false positives.

Keywords: Watermarking; Discrete Cosine Transform (DCT); Singular Value Decomposition (SVD); Differential Evolution (DE); False Positive; DnCNN

1. Introduction

Watermarking means hiding data within a host media which this information can only be extracted with a specific key, and only the person who has done watermarking knows this key. Watermarking data should be invisible to the host media and non-removable to unauthorized users, while easily extractable for authorized users. With the advancement of processor manufacturing technology and with the increasing growth of image processing algorithms, the use of information watermarking has grown significantly and has received much attention [1].

Digital Watermark plays an important role in protecting copyright and non-fraud. Given the insensitivity of human vision and auditory sensing to specific information in digital content, digital watermarks cause adding information hidden in the content with a particular algorithm [2]. Watermarking algorithms work as follows: digital information which can be a logo or even text, is placed inside another digital image called a host image and the hidden information can be received by a person who has the special key. This technology has a wide range of applications and can be used to protect the copyright in audio, video and text, also in medical care, protection of copyright in cyberspace and detection of fraud. [3, 4, 5, 6]. From the challenges in this field, we can point to the robustness of the proposed algorithms against various attacks, especially geometric attacks [7]. In general, watermarking involves two stages. In the first step, the information intended for watermarking is embedded in the media, and then in the second stage, this information is retrieved from the watermarking media [1]. It is expected that the inserted watermarks will not produce side effects on main contents or be easily not identifiable. Also Image watermarking can be used for broadcast monitoring, proof of ownership and content authentication [8].

Watermarking algorithms are generally classified into spatial and frequency domains. The first one is not robust against the attacks, but the latter is preferred under most events [2,8]. Frequency domain watermarking algorithms use transformations such as DFT, DCT and DWT to map image from spatial to frequency domain [8, 9].

Watermarking techniques are presented in two domains of frequency and spatial, which are the most important features of the watermarking system. One of the most important things for watermarking is transparency and robustness. Security and balance of transparency and robustness of watermark are also very important [10].There is a relationship between resistance, impermeability, and watermark capacity. The papers presented in this field try to offer solutions in addition to reducing computational costs so that their algorithm can fulfill other basic requirements of watermarking which include robustness to various attacks and increasing watermarking capacity [11, 12, 13].

Artificial intelligence techniques such as genetic algorithm (GA), differential evolution (DE), neural networks (NN), Clonal Selection algorithm (CSA), and Particle swarm optimization (PSO) can be mentioned as techniques for searching for substrates and optimal coefficients in converting the domain to a watermark embedded with various scaling factors. In addition, these techniques can be referred to as optimization techniques to eliminate some errors [13].

In proposed method, first applying DWT and DCT, we divide the image into non-overlapping blocks to increase the resistance. We name the obtained DC coefficients an approximate low resolution image. The scaling coefficient obtained from DE is inserted in the diagonal matrix S obtained from SVD transform also we use a combination of neural network and deep learning (DnCNN) after propagation for the extracted watermark.

In the following, the third part - Related works –will examine some similar works with our proposed design, and the fourth part – Background – presents algorithms and some transformations used in the proposed design. In the fifth part, the proposed plan is mentioned, which includes flowcharts, expression of embedding and extraction algorithms, and details of DE implementation. Expression of results are given in the seventh part of the article - Experimental results and discussion - and conclusion is stated at the end of the article.

2. Related works

A watermark scheme is presented in [14] using the Firefly optimization algorithm in which the Discrete Wavelet Transform (DWT) algorithm as well as the Singular Value Decomposition (SVD) are used. The binary watermark uses several scalable factors (MSFs) using singular values in unique values of the sub-band coefficients LL3 of the host image. MSFs are optimized using a recently proposed Firefly algorithm which have an optimal performance, so the algorithm is less intrusive and robust. The quality of the extracted and attacked images are measured by the PSNR, and the values obtained for this index are acceptable; the authors claim that they have achieved better results than other methods.

But article [15] stated that in the scheme of article [14] the extracted watermark has not embedded mark. He states that the extracted watermark in the scheme has false-positive detection problem since it is determined by the reference watermark. Therefore, it cannot be used to protect copyright!

The first sub-band of waveform transform coefficients is related to approximation coefficients, which are similar in appearance and form to the original image. If the watermark is placed in low frequency segments, it will be robust to a series of attacks such as filter application, lossy compression and geometric distortions, while embedding at high frequencies will be resistant to attacks such as histogram alignment, gamma correction, brightness adjustment, and contrast [16]. Also, LL coefficients in DCT transform bring the most image energy. [17] We can enter the watermark in each of the described sections of the DWT, but the following two criteria must be considered in selecting the coefficients:

- ✓ After importing the watermark image into the host image, the quality of the watermarked image should be appropriate.
- ✓ It must be possible to extract the watermark image from all watermarked images that are attacked. [18].

Discrete waveform transform has properties such as location-frequency localization, multi-resolution and complexity display, superior modeling of human vision system and linear computation [19], the areas extracted by the DWT transform in the image are such that they can be used to place a watermark without being recognizable to the viewer [20]. DWT has a sensitivity to change direction. Also, it has weak orientation information and there is no phase information in it. [21] DWT, along with other conversion domains such as DCT or SVD, is commonly used to create more resistance [16].

Many algorithms have been proposed in which DCT transform is applied to a host image and then the image is divided into several blocks [20]. In ref. [21], a method is presented in which, the image is divided into 8×8 blocks after applying this transform, which increases the resistance. However, PSNR has a low value in DCT-based watermarking because changing the coefficients in DCT causes a large distortion in the image. But this transform has reported good results against JPEG compression attacks, noise, pixel removal, low-pass filters, wiener and median. Therefore, combining it with other frequency domain algorithms seems desirable to use its advantages along with other transforms advantages.

In [22] Ali et al., have presented a watermarking scheme based on the evolutionary differential optimization algorithm using a combination of DWT and SVD, in which the Eigen vector of DWT sub-band of the cover image is modified with a binary watermark image during the embedding operation. The authors of this paper claim that they have been able to find a solution to the false positive problem. But in [23] SVD is used alone to watermark images.

The false positive caused by the use of SVD extracts a fake watermark from the host image. Several authors have conducted experiments on SVD-based watermarking to find a resistant watermarking scheme. In studies such as [14, 24-36] only singular values of watermarking (or singular values of host image and watermarking) inserted in the host image. Such algorithms, including SVD subspaces (right and left singular vectors), provide accurate information about the image, while these values show the brightness of the image layers produced by the right and left singular vectors, are facing with the problem of false positive detection. The common security challenge faced by watermarking techniques is that the message on which watermarking operations are performed is unreadable to people who are not allowed to read it. Techniques such as Arnold Renderer and chaotic encryption can solve this problem [37].

One of the applications of DCT in watermarking is presented in [38], in which the original image is first divided into 8×8 blocks and then the DCT transform is taken from each block. AC coefficients are selected in each block and their average is calculated. Due to the fact that the watermark is zero and one to embed it, the AC coefficients are changed to a higher or lower than average. In [39], the results show that it is resistant to geometric attacks, its digital watermarking algorithm is presented using DCT and BPNN, in which DCT is used on the cover image with 256×256 size in the embedding process and 32 × 32 in the middle frequency range of the cover image.

In [40], Xiao-bing Kang et al., presented a blind watermarking scheme that is resistant to attacks and simultaneously has good visibility. Based on this algorithm, a new combination of DCT and SVD in the DWT field is presented using the least-square curve fitting and logistic chaotic map. First, using DWT, the host image is split into four subbands, and the resulting LL frequency is again split into non-overlapped blocks. DCT is then applied to each of these blocks, and several specific DCT factors are extracted at specific intermediate frequencies to create a modulation matrix, which is used by modifying its largest singular values in the SVD domain during embedding operation. The authors emphasize that they have been able to provide an algorithm robust to geometric attacks, the extracted image of which has a high visual quality. Recently, algorithms in the field of watermarking have been proposed that have used a combination of transform domain methods, especially DWT, DCT and SVD [41].

DE has transparency and resistance to various attacks. Consider an N×N host image, this image can have singular N values that can show a different tolerance for changes. Since we may not have any idea of the sensitivity of the image to different values of the scaling factor, we need to have an algorithm to obtain the optimal scaling factors that get the maximum strength and clarity. Hence, we need a powerful and strong optimization algorithm for this types of goals. Due to the mentioned materials, DE, a new randomized nonlinear optimization algorithm, is used in this paper [42]. Ali et al., [43] have developed an evolutionary differential watermark using DCT, SVD, and Arnold that reconciles stability and non-penetration by exploring multiple scaling factors in a watermarking image.

This paper uses the DC coefficients of each block to create a matrix that is called approximation and then applies the SVD transform to them. It also applies the Arnold transform to the watermark image. This paper uses DE to determine the best multiple scaling factors for the embedding process. It claims that the proposed algorithm is not about the false positive problem in SVD. Article [44] also confirms this claim by not including the name of this article in the table of articles whose proposed algorithm has a false positive problem in SVD, this is also confirmed in [38].

In [44] it is mentioned that the most important feature of SVD is that its factors change a bit against attacks. The use of SVD in image processing includes the advantage that the matrices obtained from SVD transform have no constant dimensions. Matrices can be square or non-square. In addition to this advantage, the singular values of a digital image in this transform undergo less noticeable changes in the face of common attacks. Also, the singular values of an image have inherent algebraic properties of an image [46]. Mixed SVD relatively increases the quality of the reconstructed image by splitting the image into a set of images. This idea has been used instead of SVD to solve the false positive problem in [13].

Arnold's watermarking transform is used to mix images [47] in texturizing the logo to improve security, meaning that the transformed image is used for embedding and the reverse is sometimes used in the extraction operation. [48].

3. Background

3.1. Singular Value Decomposition (SVD)

This transform is considered as a filter in signal and speech processing. It is applied in digital signal processing as follows: 1. Noise reduction 2. Image recovery 3. Estimation of power spectrum and data density. If image A is a real N×N matrix with $r \leq N$ order, then there are N×N matrices of units U and V.

$$A = U \sum V^T, \tag{1}$$

where Σ which is expressed as equation (2), is a diagonal matrix. It should be noted that the diagonal arrays σ_i, $i = 1, \ldots, N$ are called the singular values of matrix A [49].

$$\sum = \mathrm{diag}(\sigma_1, \sigma_2, \ldots \sigma_N) \tag{2}$$

3.1.1. False positive problem in SVD-based watermarking

Many of the methods offered for watermarking in the embedded stage place the singular values of the watermark in the host image, which causes a false positive problem. Most authors take advantage of the fact that SVD sub-spatial can safe keep a significant amount of image information, and the main components of watermarking are embedded in unique values of the host image. Consider two images, A and B. If we apply SVD to these two images, we will have,

$$B \Rightarrow U_B \sum_B V_B^T \text{ and } A \Rightarrow U_A \sum_A V_A^T \tag{3}$$

If we exchange singular values between images A and B, we will have $A \approx U_A \sum_A V_A^T$ and $B \approx U_B \sum_B V_B^T$ respectively. For this reason, if only singular values are embedded in the host image, the false positive problem will always occur in the SVD image-based watermarking. It should be noted that without knowing the main component and right singular vectors, it is impossible to capture the watermarking of any desired reference image [15].

3.2. Arnold Transform

This transform is a powerful efficient iteration method for randomizing elements of any particular array to ensure watermark security. The Arnold transform process is reversed only with a special key or password which prevents unauthorized access to the watermark even after extraction. Because SVD provides better interpolation, this randomization is done to increase the impossibility of infiltrating the watermark image recovered from the image with the attacked watermark.

If we have an image of h height, according to the following equation, after i iteration, the previous pixel position (x, y) becomes the new pixel position (x_i, y_i).

$$\begin{bmatrix} x_i \\ y_i \end{bmatrix} = \begin{bmatrix} 1 & m \\ n & mn+1 \end{bmatrix} \begin{bmatrix} x_{i-1} \\ y_{i-1} \end{bmatrix} \bmod (h) \tag{4}$$

In expression (4), m and n can have any positive integers. In fact, this transform, which is a pixel, has an alternating nature, in other words, it can be said that after a constant number of iterations, the pixels return to their original position. This time period depends on the values of m, n, and h expressed in (4). $(T - i)$ should be repeated on the image before disorder (after extracting the watermark image) [50].

3.3. Differential Evolution

One of the simple evolutionary algorithms (EA) which is relatively fast and stable was introduced by Storn and Price in 1995 called DE [51 and 52]. This algorithm is greedy based on the choice and has differences in creating new candidate solutions and in the rest, it is similar to other evolutionary algorithms [53].It starts with the initial population of NP, i.e. Xi,g and NP i =

1,… and each of the dimensions D, which in the DE index i represents the i-th solution of the population in the G generation. There are three main operations for it, which are summarized below.

- ✓ Mutation: According to each target person, $X_{i,g}$ to generate the disturbed person $V_{i,g}$, the process of mutation begins with random selection of three specific individuals $\{X_{r1}, X_{r2}, X_{r3}\}$ from the current population, which must be different from the target person, $X_{i,g}$ (i.e. r1 ≠ r2 ≠ r3 ≠ i). The difference between the two individuals is added to the third person after scaling with the F∈ scaling agent [0, 1]. Mathematically, it can be obtained as follows [54, 55, 56]:

$$V_{i,G} = X_{r1,G} + F \times (X_{r2,G} - X_{r3,G}) \tag{5}$$

Where i exceeds the range of the number of people.

- ✓ Crossover: It is done between the disturbed person $V_{i,g}$ and the target person $X_{i,g}$ to produce the test person, $T_{i,G.}$ This will depend on a cross-sectional possibility of Cr ∋[0, 1] deciding on the components of the test person. It also commits to k ∋{1, ..., D}, where the test person differs in at least one component. The mathematical equation of the test person generation is as follows [56, 57, and 58]:

$$t_{j,i,G} = \begin{Bmatrix} v_{j,i,G} \text{ if rand } j \le C_r & \vee \quad j = k \\ x_{j,i,G} & \text{otherwise} \end{Bmatrix} \tag{6}$$

Where j exceeds the scope of the problem.

- ✓ Selection: After the test person is assembled, the fitness is evaluated and compared to the person of your choice. This will be done by the selection process, which selects the best person from the target and test people. Theoretically, it can be defined by the following mathematical equation [55, 56, and 57]:

$$X_{i,G+1} = \begin{cases} T_{i,G} & \text{if} \quad f(T_{i,G}) \leq f(X_{i,G} \\ x_{i,G} & \text{otherwise} \end{cases} \tag{7}$$

If the test person is better than the target person, he or she will replace the target person in the next generation, otherwise the person will continue the target. Therefore, each person in the temporary (test) population is compared to the current population compared to their counterpart [53, 54, and 55]. Figure 1 shows the steps of Difference Evolutionary algorithm.

The difference between Differential Evolution (DE) and other evolutionary algorithms:

- The combination of crossover and mutation operation: First, a temporary response is generated using the mutation operator, and then a new response is generated using the crossover operator.
- Mutation operation method: The steps related to the mutation operation are not sampled from a possible known specific distribution. Rather, mutation steps are created in the differential evolution from distance and the differential between the responses in the population.

There are advantages to using a differential vector to determine the step length and direction of mutation in this algorithm, which we decided to prefer this algorithm to other metaheuristic algorithms in our proposed scheme. The following are some of them.

1. The information available in members of the population is generally used to optimize and intelligently populate the optimization and search process.
2. According to the Central Limit Theorem, as the population size increases, the length of the mutation steps will tend to a random quantity with a normal (Gaussian) distribution with null hypothesis.

3. The variance of this distribution also depends entirely on the distribution rate of responses, and the relative distance of the responses is the only factor influencing the step length variance.

As the population increase, so does the length of the step decrease, which will lead to a slower movement of members of the population

3.4. Train and Apply Denoising Neural Networks

DnCNN means denoising convolutional neural networks, which is used for the progress in very deep architecture, learning algorithm, and regularization method into image denoisining, and provides a simple quick solution for image noise removal [55]. In this regard, MATLAB has provided a useful toolbox that we also used. In addition, we first form a neural network according to the original image of the watermarked image and what was first extracted. We consider 200 repetitions for it, and finally, the image is simulated with the obtained weights and the image is denoised.

4. The Proposed Algorithm

As mentioned, DWT transform is robust, and since the strength of the embed process depends on the signal energy, and most of this energy is in low-frequency areas, placing a watermark in this frequency band causes it be resistant to digital signal processing (DSP) attacks [56, 57]. However, the human eye is sensitive to changes in this frequency [58]. DCT is able to place the copyright energy signal in all pixels. So embedded copyright will be invisible. Therefore, after analyzing the image up to a level and then taking the DCT transform, it further increases the stability and security of the watermark without significantly reducing the cover image quality against digital signal processing (DSP) attacks [56].

This makes changes invisible to human as well. In general, the combination of DWT and DCT together can compensate for each other's weaknesses [59]. Therefore, at the beginning of our proposed scheme, we analyze the host image to a level by DWT, and then apply the DCT transform to the obtained LL1 to minimize the tangibility and increase the resistance and security of the watermark. But as mentioned in part 3, after applying DCT transform to host image, if we divide it into non-overlapping 8×8 blocks, it will increase its resistance to the various attacks mentioned in that section. After applying DCT transform, we divide it into non-overlapping 8×8 blocks to make the resistive and watermarked scheme as invisible as possible.

In Section 2. Background, SVD transform is described. The properties of this transform for watermarking can be extracted acceptably when the watermarked image is distorted due to various geometric attacks due to its resistance to geometric attacks [50]. For this reason, in the next step, we apply the SVD transform to the DC coefficients obtained.

As mentioned in previous section, DE is a new random non-linear robust and rapid simple evolutionary algorithm which is used to create scaling factor. In the following, we will explain the embedding and extraction of watermark, and obtaining the optimal scaling coefficients using the DE algorithm.

Figure 1 shows Flowchart of the Embedding algorithm and Figure 2 shows Flowchart of the extraction algorithm.

4.1. Embedding Process

The embedding process algorithm is that in the first step, DWT transform is applied to the host image in one level, so once the image is parsed by this LL1 transform, the result is divided to non-overlapping 8×8 square blocks to increase the stability. Then the DCT transform is taken from it and the resulting matrix is called A. The SVD transform is then applied to A. As a result, the symmetric matrices U, V and the diagonal matrix S are obtained.

$$A=USV^T \tag{8}$$

$$S_1 = S + \lambda W \tag{9}$$

Next, the scaling coefficient λ (in the form of a diagonal matrix) is obtained using the differential evolution algorithm, and the Arnold transform is taken from the watermark image and W watermark is formed. Equation (9) is used to obtain S_1. The SVD transform is reapplied to the matrix S_1 and we will have three matrices U_w, S_w and V_w, so that S_1 will be equal to:

$$S1 = U_W \; S_W \; V_W \tag{10}$$

We obtain the A_W matrix by changing the DC values by multiplying the U, S_W and V^T matrices.

$$A_W = US_WV^T \tag{11}$$

Modified DC values are embedded in the corresponding blocks. Then IDCT and IDWT are calculated and the blocks are merged to get the I_W watermarked image. Ten different attacks are applied to the extracted image and NC is calculated for them. The cost function is also calculated for them and this circle is repeated until the termination criterion is met. And the person who has the least fit of the final generation is selected for embedding the watermark.Figure 1 shows Flowchart of the Embedding algorithm.

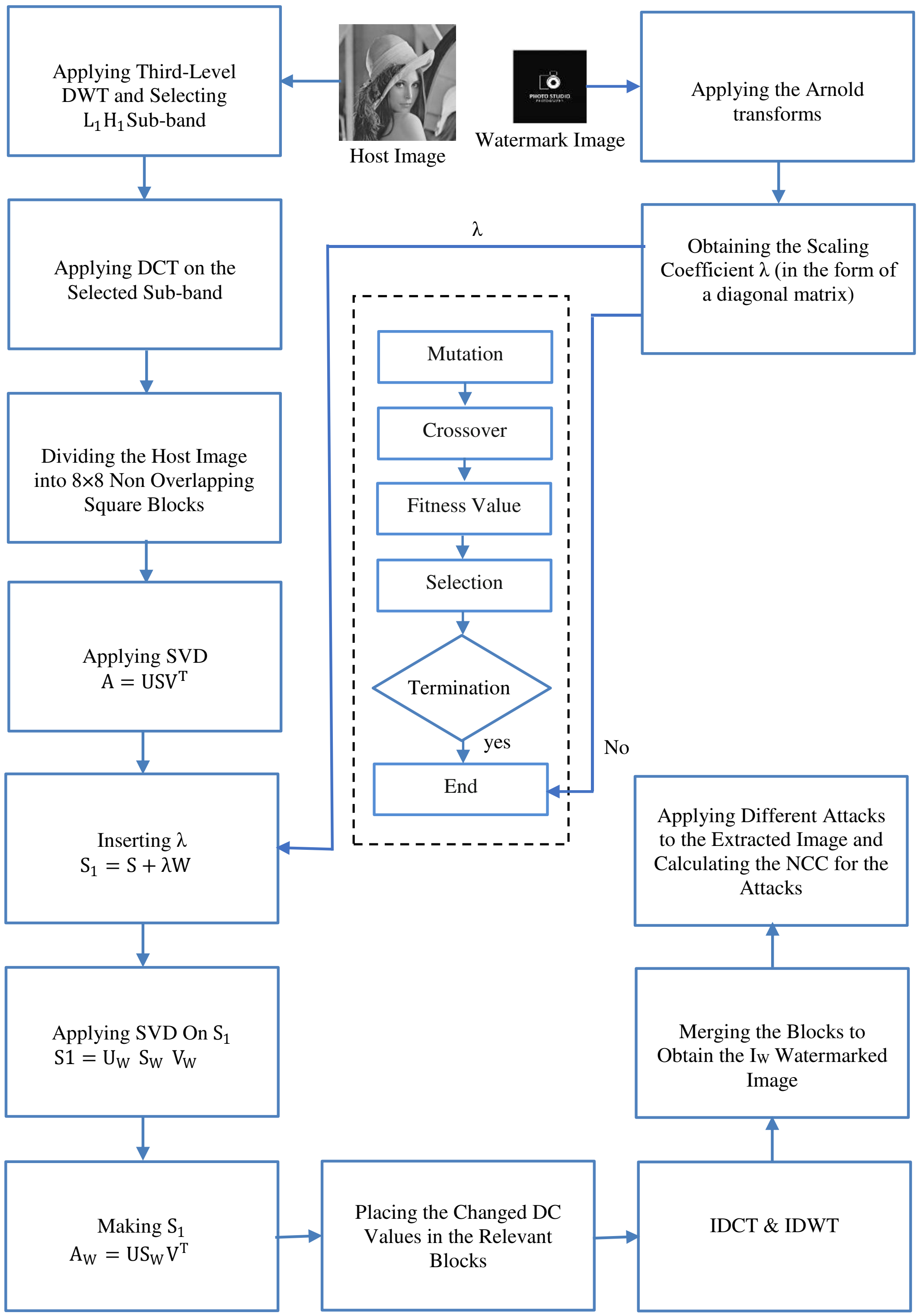


Figure 1. Flowchart of the Embedding algorithm.

4.2. Extraction Process

To extract an image on which watermark image is embedded, it is called a watermarked image. As in the first embedding step, the DWT is first taken on one level of the watermarked image to obtain L_1L_1sub-band, and then the DCT is taken from it. The resulting image is then divided into non-overlapping 8×8 square blocks, and the DC value is obtained from each matrix. (Like the embedding section). Then the SVD transform is applied and A_W^* is obtained which results in relation (12). S_1^* and W^* are obtained according to Equations 12 and 14.

$$A_W^* = U^* S_W^* V^{*T} \tag{12}$$

$$S_1^* = U_W \; S_W^* \; V^{*T} \tag{13}$$

$$W^* = \frac{S_1^* - S}{\lambda} \tag{14}$$

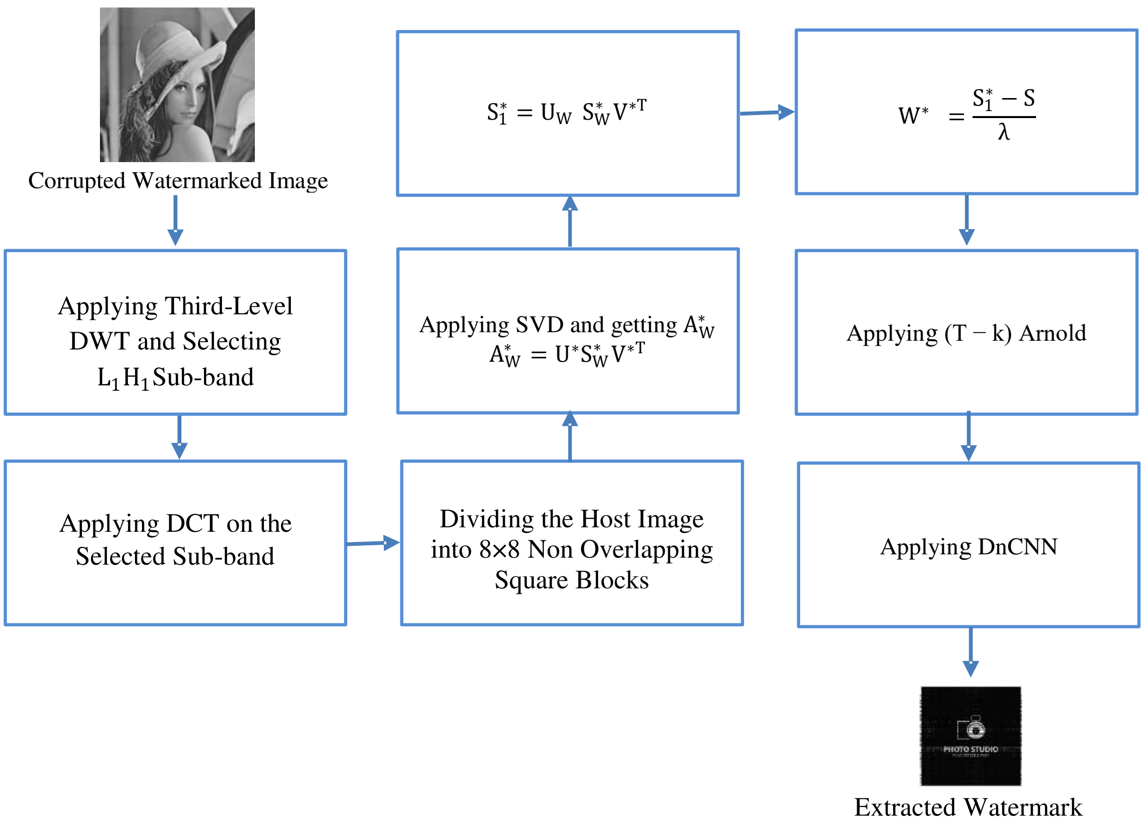


Figure 2. Flowchart of the extraction algorithm.

Applying $(T - k)$ Arnold transform is applied to W^*, and finally the DnCNN algorithm is applied to the resulting image and the watermark is extracted. Figure 2 shows Flowchart of the Embedding algorithm.

4.3. DE Implementation Details

As mentioned in the previous sections, the resilience of watermarking is a fundamental and important issue. In this proposed plan, this issue was defined as an optimization problem. Given the characteristics of DE, a powerful algorithm is needed to obtain scaling factors that can improve strength while minimizing image quality. Therefore, an evolutionary algorithm was decided to use among the various optimization algorithms.

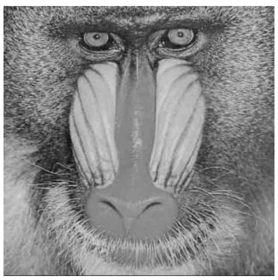
Since each single value has a different tolerance, the single scaling factor will have no justification for the watermarking in which the SVD is used. In addition, the unique values (SVS) of the approximate low-resolution image obtained in the third embedded step were modified in the embedded process with this algorithm.

The steps for this algorithm in this design are as follows:

1. The primary population is produced with a random number generator.
2. Attacks is applied to the hidden image.
3. For each main DE loop, mutation and crossover are applied to each individual.
4. Watermarking images are prepared after the extraction process among these rotten watermarking images.
5. The amount of fitness, which is calculated below, is shown in formula (15) and is calculated for each person. Minimum values of this formula are selected and people with lower fitness values are selected for the next generation. In total, the loop is repeated 200 times, and as mentioned, each individual with the least fitness in the final generation is selected for the watermark embedding process.

5. Experimental Results and Discussion

In this area, watermark security is a very important factor. Therefore, to increase the security of the watermarked image in the Extract stage, we use the Arnold conversion. We also use the denoising convolutional neural network (DnCNN) to improve the quality of the output image in the last stage. The performance of watermark algorithm has been evaluated in terms of watermarked image quality (PSNR) and watermarked image strength (NC) and SSIM. The host image on the gray scale is considered to be 512 × 512, and the logo image 256×256 on the gray scale. MATLAB 2018 and Microsoft Surface Pro Core i5 are used to test the strength of extracted watermarks. Figure 3 shows eight host images respectively, that have been attempted to use both conventional and more serious MATLAB images to better evaluate the proposed algorithm. The watermark image used in Figure 4 are also shown.


A


B


C


D


E


F


G


H

Figure 3.Host Images used. A: Baboon, B: Barbara, C: Cameraman, D: F-16, E: Lena, F: Man, G: Parkavenue, H: Peppers.

Figure 4.Watermark Image (Logo).

To evaluate the performance of the proposed algorithm, we used three more-commonly-used criteria. SSIM evaluates the structural similarity between the host and the watermark images.and the Normalized cross-correlation (NC) criterion, which indicates the watermark stability and $\hat{X}$ is calculated between the X watermarked image and the extracted image [60]. We also used the PSNR, which focuses mainly on the visual similarity between the original image and the watermarked image, and usually both images must appear in such a way that there is no major distinction between them [61].

Equation 15 is used to calculate the amount of fitness that should be minimized. In this equation, W and W* are equal to the original watermarking and watermarking images. N also represents the number of attacks, which in our design is equal to 10. NC represents the correlation rate obtained through Equation 16, where X and $\hat{X}$ represent the original and processed images. Equation17, which indicates the amount of signal to noise, n is equal to the height or width of the image and X_{max} is the maximum possible value of the image. NC (I, I_W), which is equal to Imperceptibility in Equation 15.

$$\text{Minimize } f = \frac{N}{\sum_{i=1}^{N} NC(W,W_i^*)} - NC(I, I_W) \tag{15}$$

$$NC(X,\hat{X}) = \frac{\sum_i \sum_j X(i,J)\ \hat{X}(i,J)}{\sqrt{\sqrt{\sum_i \sum_j X(i,j)^2}}\ \sqrt{\sqrt{\sum_i \sum_j \hat{X}(i,j)^2}}} \tag{16}$$

$$PSNR = 10\log_{10}\left(\frac{(X_{MAX})^2}{1/(n\times n)\sum_i \sum_j (X(i,j)-\hat{X}(i,j))^2}\right) \tag{17}$$

Table 1. parameters of the DE algorithm

Population size	10
Scaling factor primary	0.5
Scaling factor secondary 1	0.4
Scaling factor secondary 2	0.3
Crossover rate	0.5
Iteration	200

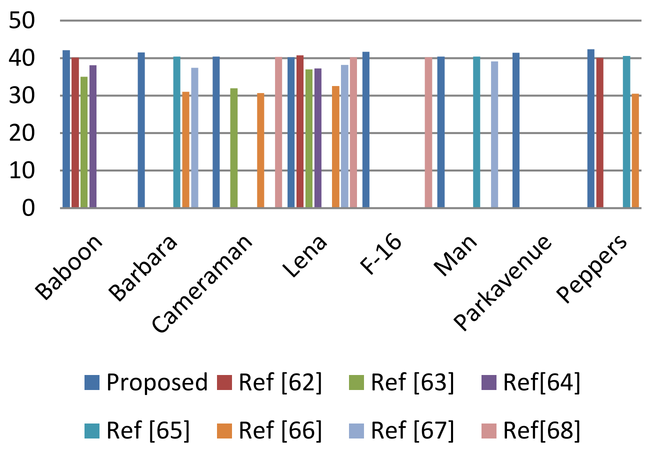
We have tried to use both relatively old and newer references with algorithms somehow consistent with our proposed design, for comparison. That's why several references are listed in the tables in this section, and due to the large number of our host images, some of cells in the tables that are for comparison are empty! Table 1 shows the parameters of the DE algorithm in our design.NC, PSNR, SSIM are the most popular comparison factors in this field, so we use them in evaluating proposed method. The calculation formula for these parameters was introduced in the previous section. As mentioned, NC represents the correlation rate and shows how correlated the extracted image is after applying the proposed algorithm to the original image in which no watermark is placed.

The closer the number is to 1, the better the algorithm works. As can be seen in the relevant table, the total values for our design are very good, which indicates that our proposed scheme has performed better than the compared sources. The PSNR also shows the signal-to-noise ratio between the host image and the image extracted after applying the algorithm, which for all images is almost higher than the comparative reference, which is more desirable. SSIM also shows the similarity of the image before embedding the watermark and the embedded one, and the closer it is to 1, the better the performance of the algorithm will be. As can be deduced from Table 2, this is an acceptable value for all extracted images in our scheme.

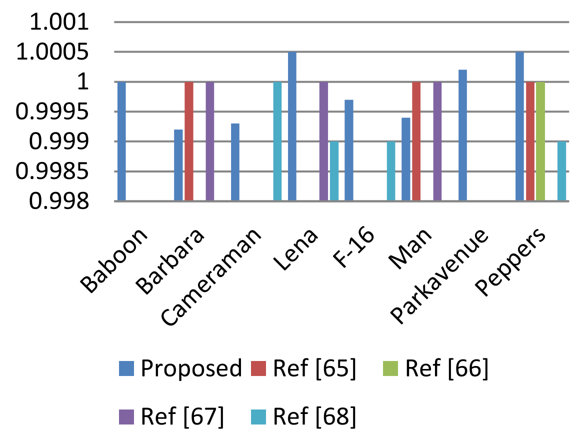
In order to make it easier for the readers to check the results, in addition to mentioning the results in the table, they are also expressed in the form of graphs. The 5 to 7 graphs show the PSNR, NC, and SSIM values before the attacks in the proposed scheme and the reference for different images, respectively.

Table 2. NC, PSNR and SSIM values with watermark logo image

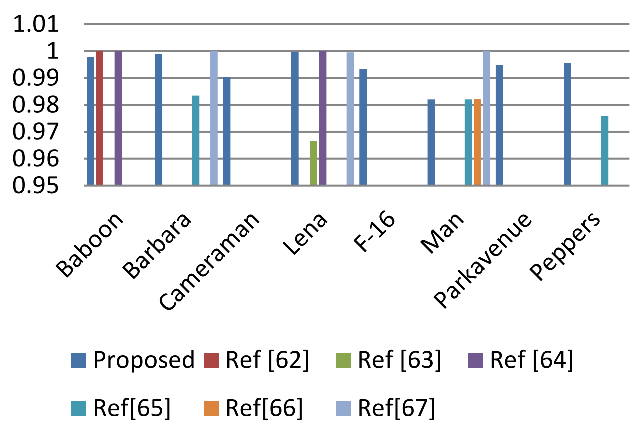
Image	Algorithm	PSNR(dB)	NC	SSIM
Baboon	Ref [62]	40.17	--	0.9998
	Ref [63]	35	--	--
	Ref [64]	38.12	--	1
	Proposed	42.0786	1.0000	0.9978
Barbara	Ref [65]	40.4	1	0.9834
	Ref [66]	31.05	--	--
	Ref [67]	37.42	1.0000	0.9999
	Proposed	41.4769	0.9992	0.9989
Cameraman	Ref [63]	32	--	--
	Ref [66]	30.64	--	--
	Ref [68]	40.31	1	--
	Proposed	40.3866	0.9993	0.9903
Lena	Ref [62]	40.74		
	Ref [63]	37	--	0.9667
	Ref [64]	37.23	--	1
	Ref [66]	32.58	--	--
	Ref [67]	38.18	1.0000	0.9995
	Ref[68]	40.22	0.999	--
	Proposed	40.0621	1.0005	0.9996
F-16	Ref[68]	40.20	0.999	
	Proposed	41.6661	0.9997	0.9933
Man	Ref[65]	40.4	1	0.9820
	Ref[67]	39.12	1	1.0000
	Proposed	40.4337	0.9994	0.9820
Parkavenue	Proposed	41.3878	1.0002	0.9947
Peppers	Ref [62]	40.10		
	Ref [65]	40.6	1	0.9758
	Ref [66]	30.54	--	--
	Ref [68]	40.05	0.999	--
	Proposed	42.3833	0.9994	0.9955



Figures5. Graphs of PSNR values



Figures6. Graphs of NCvalues



Figures 7. Graphs of SSIM values

Table 2 shows the PSNR values along with NC and SSIM before attacking the watermarked image compared to other references. In all three cases, our scheme obtained acceptable results and outperformed the other references.As can be seen, the best PSNR, NC and SSIM values for the watermark logo are obtained Peppers, Lena and Baboon for the 42.3833, 1.0005 and 0.9978 images, respectively. Compared to other references. The results of some articles selected for comparison may have been better in some cases, but our algorithm has outperformed in other cases. Reference [62] lists two values for PSNR, and we listed the value that we considered most appropriate for our scheme for comparison. Reference [64] used a 32×32 watermark image, so it's natural that it somehow outperformed in some attacks, but in the case of PSNR, our proposed scheme outperformed significantly. This reference also didn't mention the exact value of its attacks. Figures 5 to 7 also show the same values for better representation using bar graphs.

Resistance to attack is one of the watermark important factors, so that the value of NC is measured after applying an attack to the watermarked image with the host image, and the closer this value is to 1, the better the performance of the algorithm. We performed 16 common attacks in this area on the watermarked image. The results are as follows. The 3 to 6 Tables show the attacks on 8 images of Barbara, Lena, Man and Peppers with the logo watermarked image, and the best result in these tables for attacks JPEG 70 and image Barbara and baboon with NC values is 1.0398 and 1.0110. In this case, it can be seen that in general, our scheme has better results compared to the compared references.

Table 3. NC value after various attacks with the logo watermarked image

Image	Baboon			Barbara		
	Proposed	Ref [65]	Ref [67]	Proposed	Ref[62]	Ref [64]
Average 3	1.0048	--	--	1.0055	--	0.9991
Gaussian (0.001)	0.9625	0.9991	0.9997	0.9662	0.8956	0.9999
Gaussian (0.005)	0.9563	--	--	0.9597	0.8956	--
Histogram	0.8631	0.7528	--	0.8820	0.9986	0.9895
Median filter 3×3	1.0014	0.9696	--	1.0035	0.9801	0.9998
Median filter 5×5	1.0006	--	--	1.0036	0.9010	--
Salt & pepper (0.001)	0.9900	0.9939	--	0.9997	0.9337	--
Salt & pepper (0.005)	1	--	--	0.9964	0.8388	--
Rotation 90	0.8252	--	--	0.9213	--	--
Rotation 180	0.8160	--	--	0.9203	--	--
Scaling (0.5)	1.0004	--	0.9968	1.0005	0.8388	--
Scaling (0.8)	1.0004	--	--	1.0005	0.8955	--
Sharpening	0.9867	0.9854	0.9991	0.9622	0.9696	--
JPEG 25	1.0327	--	--	1.0319	--	--
JPEG 30	1.0344	0.9994	--	0.9317	0.9959	--
JPEG 70	1.0398	--	0.9612	1.0110	1	--

To better evaluate our scheme, we decided to use standard image processing images that are more common in articles, along with images that have been less used in articles so far, so that readers who refer to our article in the future can evaluate it. For example, park-avenue is a standard image that is rarely used in articles due to its poor results in image processing tests, so we did not find an article to compare it with. In fact, our scheme is a new one that is not found in recent years articles, so it was impossible to find sources that are new and widely similar, so we decided to use schemes that have somehow used SVD conversion or other time domain conversions or select schemes that are new or use evolutionary processing algorithms for comparison. For this reason, some of the table cells selected for comparison are left blank.Table 3 shows the NC values for Barbara and Baboon after 16 attacks. The best result for these two images is the JPEG 70 attack for these two images with values 1.0398 and 1.0110. In the case of Baboon, both references obtained a better result for Gaussian's attack. In the case of Barbara's image, both references obtained a relatively better result for the Histogram attack, but a total of 16 attacks outperformed according to the values listed in Table 2 of our scheme.

Table 4 deals with attacks on Lena watermarked image. We have been able to get the best results in Jpeg and Average attacks, and compared to other references, our scheme has outperformed in all attacks. However, the results related to Median Filter attacks is also very desirable in our scheme. Regarding the reference [68], the value mentioned for the Scaling attack is 0.7, but considering that we used the value 0.8 and the results were much better, we decided to mention it.

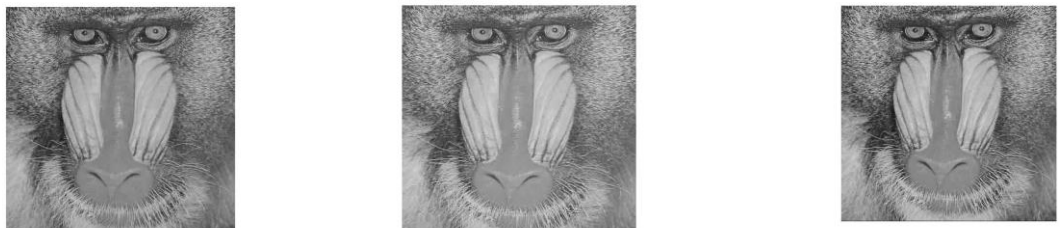
Table 4. NC value after various attacks with the logo watermarked image

Image	Lena					
	Proposed	Ref [62]	Ref [63]	Ref [64]	Ref [67]	Ref [68]
Average 3	1.0018	--	--	--	0.9990	0.8830
Gaussian (0.001)	0.9629	0.9983	--	0.9990	0.9997	0.9376
Gaussian (0.005)	0.9558	--	0.9971	--	--	--
Histogram	0.8859	0.8176	--	--	0.9999	--
Median filter 3×3	0.9997	0.9971	0.9828	--	0.9995	0.9572
Median filter 5×5	1.0008	--	--	--	--	--
Salt & pepper (0.001)	0.9981	0.9868	--	--		--
Salt & pepper (0.005)	0.9942	--	0.9892	--	--	--
Rotation 90	0.8661	--	--	--	--	--
Rotation 180	0.8759	--	--	--	--	--
Scaling (0.5)	0.9989	--	--	0.9954	--	0.9958
Scaling (0.8)	0.9989	--	--	--	--	--
Sharpening	0.9910	0.9891	--	0.9987		0.9732
JPEG 25	0.9729	--	--	--	--	--
JPEG 30	1.0382	0.9982	--	--		--
JPEG 70	1.0186	--	0.9981	0.9525	--	--

Table 5. NC value after various attacks with the logo watermarked image

Image	Man			Peppers			
	Proposed	Ref [65]	Ref [67]	Proposed	Ref [62]	Ref [65]	Ref [68]
Average 3	1.0066	--	0.9994	1.0027	--	--	0.293
Gaussian (0.001)	0.9402	0.9516	0.9999	0.9609	--	0.9229	0.993
Gaussian (0.005)	0.9330	0.9320	--	0.9547	--	0.8813	0.834
Histogram	0.4933	0.9973	0.9899	0.7317	0.8579	0.9959	--
Median filter 3×3	1.0019	0.9945	0.9999	1.0002	0.998	1	--
Median filter 5×5	1.0053	0.9472	--	1.0006	--	0.960	--
Salt & pepper (0.001)	0.9963	0.9516	--	1	0.9782	0.8813	1
Salt & pepper (0.005)	0.9881	0.9320	--	0.8958	--	0.9229	--
Rotation 90	1	--	--	0.8248	--	--	--
Rotation 180	1	--	--	0.8441	--	--	1
Scaling (0.5)	0.9992	0.8815	--	0.9988	--	0.8388	1
Scaling (0.8)	0.9992	0.9559	--	0.9988	--	0.8955	0.528
Sharpening	0.9716	0.9830	--	0.9895	0.9877	0.9581	1
JPEG 25	0.8907	--	--	0.8803	--	--	--
JPEG 30	0.9129	0.9959	--	0.8878	0.9989	0.9856	--
JPEG 70	0.9386	1	--	0.8698	0.9979	--	--

In Table 5, unlike the previous table, Man and Peppers images have relatively weaker results in Jpeg attacks, with the best results being Rotation, Median Filter, and Average. In Peppers, the best results were Salt & pepper, Average, and Median filter. In tables 4 and 5, except for the results related to the reference [67], better results have been obtained than other references. It should be noted that if the Gaussian (0.001) and Histogram attacks had weaker results than the reference [67], but better results have been obtained for the parameters listed in Table 2 and the Average and Median filter attacks. And it should also be noted that this reference used a watermark image size 64×64 and a quarter of the watermark image size of our scheme and used less host images compared to our results.



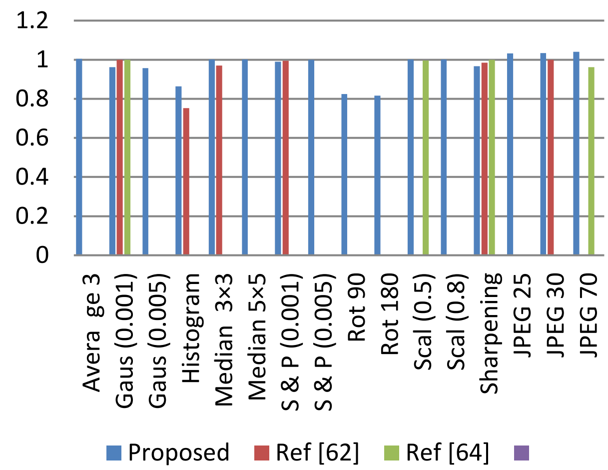
A) JPEG 25 B) JPEG 30 C) JPEG 70

Figure 8. Applying the Jpeg attack to the image extracted with the logo watermark.

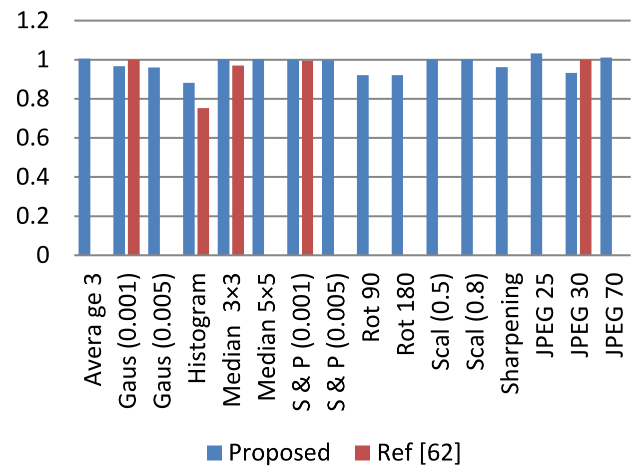
As can be seen in Figure 8, the extracted image did not change significantly in quality after the Jpeg attack, and according to the results, the proposed scheme can be called resistant to the Jpeg attack. In Table 6, all the results obtained from the compared references are better.

Table 6. NC value after various attacks with the logo watermarked image

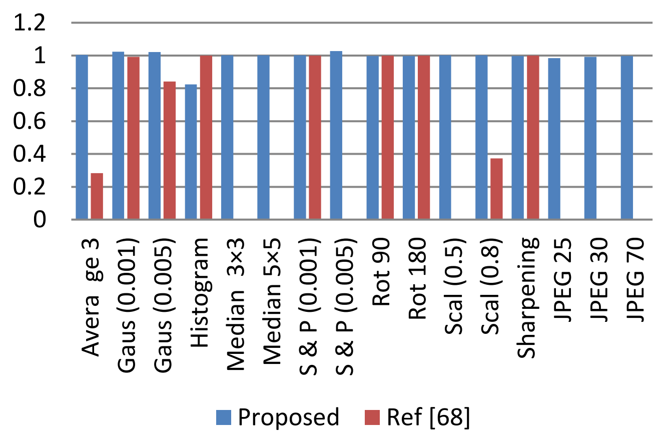
Image	cameraman		F-16		parkavenue
	Proposed	Ref [68]	Proposed	Ref [68]	Proposed
Average 3	1.0045	0.283	1.0028	0.268	1.0039
Gaussian (0.001)	1.0237	0.993	0.9827	0.998	0.9553
Gaussian (0.005)	1.0209	0.841	0.9782	0.853	0.9474
Histogram	0.8242	1	1.0003	1	0.6549
Median filter 3×3	1.0013	--	1.0006	--	0.9988
Median filter 5×5	1.0013	--	1.0008	--	0.9963
Salt & pepper (0.001)	1.0009	1	1	1	0.8121
Salt & pepper (0.005)	1.0266	--	0.9989	--	0.9470
Rotation 90	0.9975	1	1	1	0.8633
Rotation 180	0.9988	1	1	1	0.8739
Scaling (0.5)	1.0010	-	1.0003	--	0.9997
Scaling (0.8)	1.0010	0.373	1.0003	0.467	0.9997
Sharpening	0.9970	1	0.9941	1	0.9723
JPEG 25	0.9851	--	0.9370	--	0.7845
JPEG 30	0.9928	--	0.9526		0.8051
JPEG 70	0.9972	--	0.9480		0.8208



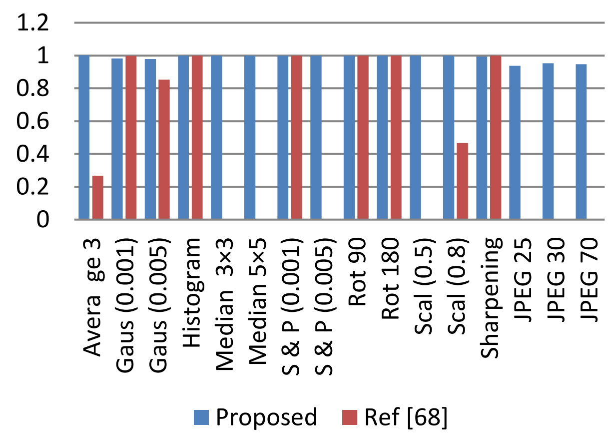
A)Baboon



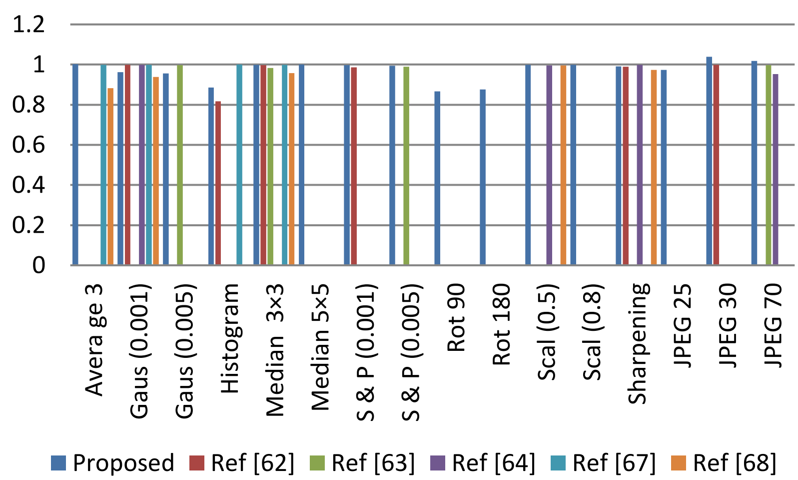
B) Barbara



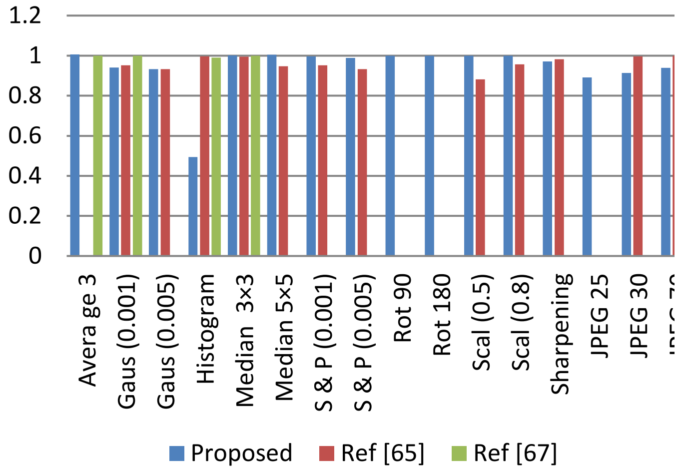
C) Cameraman



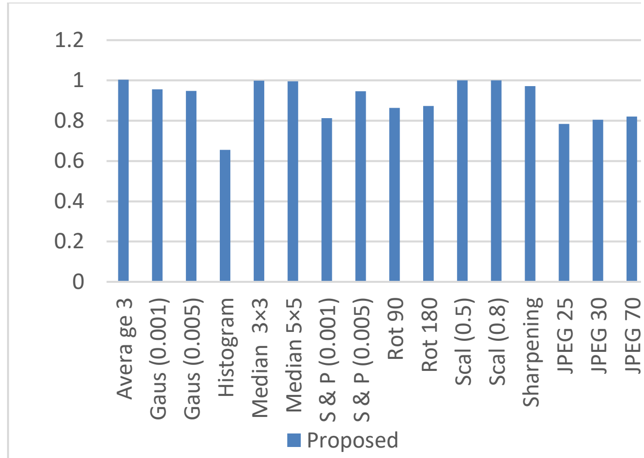
F-16



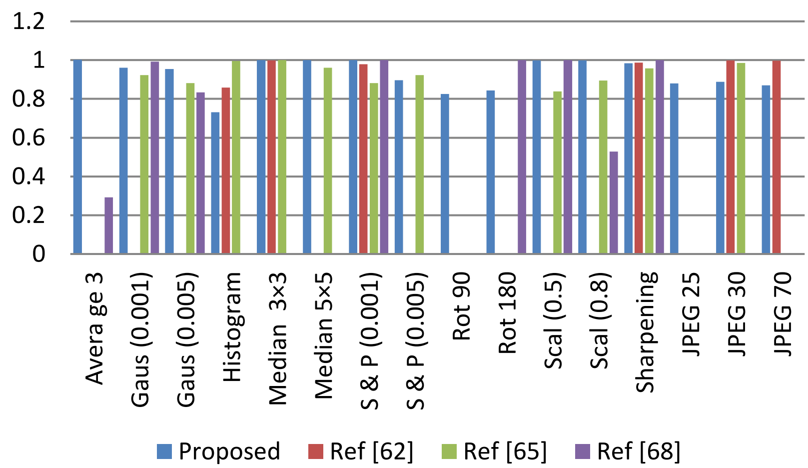
E) Lena



F)Man



G)Parkavenue

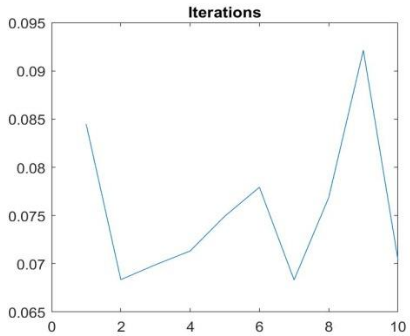


H)Peppers

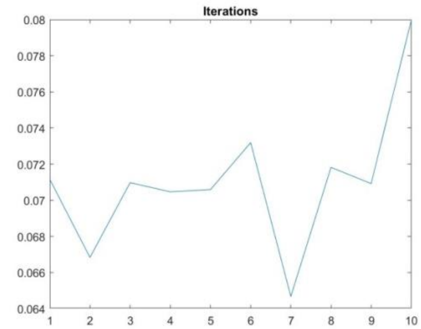
Figures 9. Graphs of NC values after different attacks.

Figure 9 shows Graphs of NC values after different attacks and Figure 10 shows the fitness diagram for Iterations for all 8 host images with the logo Watermarked image. The pseudo code for this section is below for a better understanding of the reader. Given the minimum fitness selection, the best performance is seen for images Baboon and Man. Also average time for embedding operations in the proposed scheme equal with 50874.97568 Second.

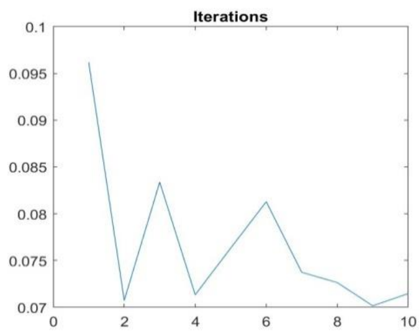
Plot (Delta DCT. fitness), title ('Iterations');



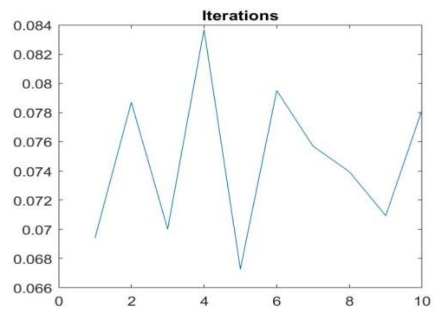
A)Baboon



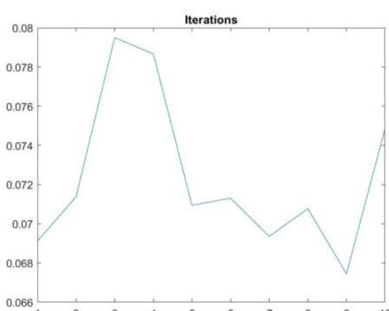
B)Barbara



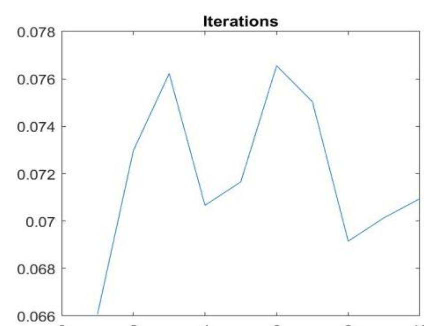
C)Cameraman



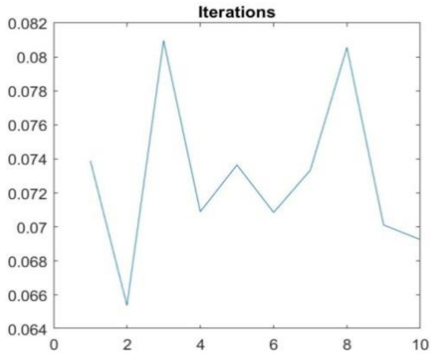
D) F-16



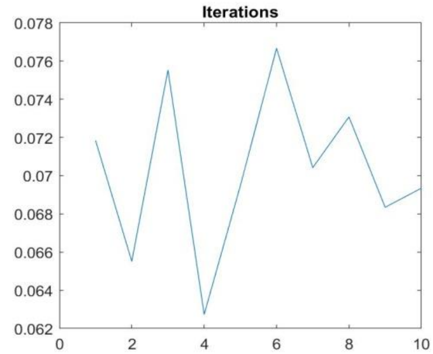
E)Lena



F)Man



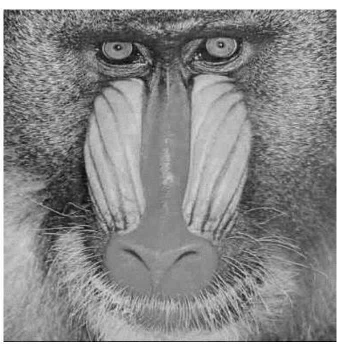
G)Parkavenue



H)Peppers

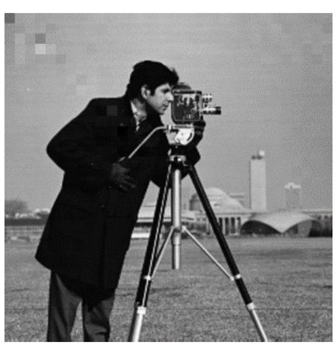
Figure 10. The fitness diagram for Iterations

The names of images watermarked with the logo image and their charts have been extracted are written below the charts.



A)Baboon

B)Barbara



C)Cameraman

D) F-16

E)Lena

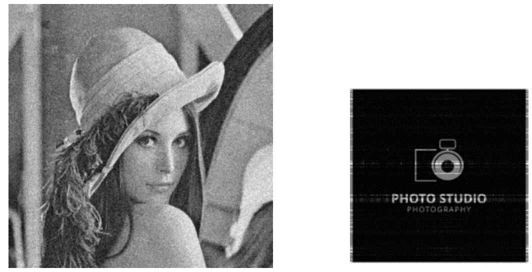
F)Man

G)Parkavenue

H)Peppers

Figure 11. The embedded images with the logo watermarked image.

The indistinguishability of the image in which the watermark is located is one of the basic features of watermarking. Figure 11 shows all the images in the test in which the watermark of the logo is embedded. None of the images have undergone a noticeable change and the watermark cannot be recognized by the human vision system (HVS). As a result, our proposed scheme has good visual clarity.



A) Average 3

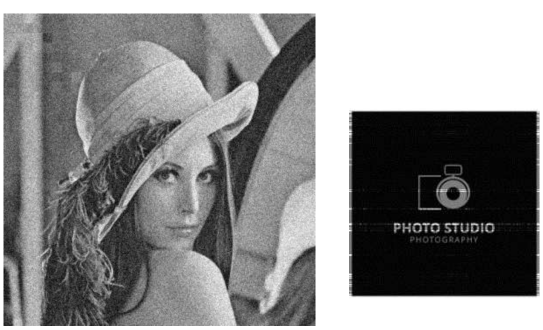
B) Gaussian (0.001)

C) Gaussian (0.005)

D) Histogram

E)Median filter 3×3

F)Median filter 5×5



G)Salt & pepper

I)Rotation 90

J)Rotation 180

K) Scaling (0.5)

L) Sharpening

M) JPEG 25

N) JPEG 30

O) JPEG 70

Figure 12. Watermarked images along with extracted watermark.

Figure 12 shows the watermarked image that was attacked along with the extracted watermark. The image on the left shows the watermarked image and the image on the right shows the extracted image, below which is the type of attack. As can be seen, the quality of the extracted watermarks and watermarked images are all acceptable, and the extracted watermark of the images that have been attacked by Average and Scaling have a relatively better quality.As can be deduced from the results, our proposed scheme has good quality in the logo extracted image from the watermarked image, and the results obtained for NC after applying several attacks for different images is good. Also, as you can see, the SSIM, PSNR and NC values are good after embedding the watermark images, and our scheme has outperformed than the compared references. As mentioned, false positive is one of the main problems of algorithms that use SVD transform. This problem occurs when these types of algorithms embed only singular values of the watermark image in the host image, and when extracting the watermark image, these values are obtained from the host image without the help of the original watermark image and embedding the main watermark components in the host image helps to avoid this problem [68].

Ref [64], published in 2022, presents an optimization-based algorithm based on integer wavelet transform (IWT) and SVD. 3 out of 4 images compared are common .There is a slight difference in the case of NC, which is probably due to the trending of the numbers discussed in the results of this paper. However, in the case of PSNR values, our scheme works better and has a relatively significant difference. Regarding the NC values expressed for Ref [64], the type of attack was not specified precisely. For example, it is not clear how much Gaussian attack was performed! We tried to consider the most common value for the results of this paper, although there was no significant difference between the different values in our scheme. Overall, this algorithm seems to outperform our scheme in this attack.

When extracting, some algorithms act as follows: if the host image is equal to A and the watermark image is equal to B, by applying SVD to these two images, we will have $A = U_A \sum A \ V_A^T$ and for image B we have $B = U_B \sum B \ V_B^T$ and if we change the singular values between these two images we have $A = U_A \sum B \ V_A^T$ and $B = U_B \sum A \ V_B^T$ in which case false positive will happen. That's why we did not use such an idea.

In fact, in our scheme λ is a stability factor and according to this relation $\sum + \propto W = U_W \sum_W V_W^T$. The values $\sum$ are modified by $\sum W$ in the host image. We maximize λ to minimize the false positive problem [69], and diagonal matrices containing important information UW and VW are used as keys in the watermark extraction process. These matrices contain very important information about the image. Also, placing the main components of the watermark in the original image and multiplying λ by singular values modifies these coefficients and applying the Arnold function to the watermark image, as well as using the SVD transform for the second time on S1 also solve the false positive problem. Avoiding the use of U and V diagonal components in the embedding and extracting stages also helps to prevent this phenomenon [70], so we used these measures in the proposed design.

As mentioned in the reference [71], this type of algorithm is a method lacking false positive, which has a problem of low PSNR and non-resistance to attacks compared to some latest methods. We have largely eliminated these two problems of this type of algorithm to present the proposed algorithm.

6. Conclusions

In our proposed method, a new compounding method based on DWT, DCT and SVD is proposed for watermark due to the outperformance of this type of compound in terms of impermeability, robustness to DWT, DCT and SVD that are applied separately. DE is used intelligently to find multiple scaling factors. Also in this scheme, singular values with low image quality approximation are replaced by non-overlapping 8×8 blocks of cover image with singular values of watermark image to provide better stability against attacks. To improve image watermarking strength, the combination of neural network and deep learning (DnCNN) after propagation is used for extracted watermark to achieve higher normal correlation (NC) values and higher watermark quality extracted with visual clarity. The security and confidentiality of the watermark image is provided by using the Arnold transform before embedding in the cover image. Also, as mentioned, this scheme does not have major problem that using SVD has in different algorithms, i.e. false positive. Evidence to these claims are various results that have been compared with different algorithms in this field. In fact, we were able to present an SVD-based scheme using DE, with no false positive problem, with acceptable results against various attacks after placing the watermarked image, and the PSNR and NC values of the watermarked images were also considered desirable. In addition, the watermarked image was not recognizable from the perspective of a human observer and the watermarked image had a good quality.

In fact, we were able to present an SVD-based scheme using DE, with no false positive problem, with acceptable results against various attacks after placing the watermarked image, and the PSNR and NC values of the watermarked images were also considered desirable. In addition, the watermarked image was not recognizable from the perspective of a human observer and the watermarked image had a good quality.We plan to increase the PSNR value for different images in future work by maintaining the false positive problem.

7. ABBREVIATIONS

Table 7 summarizes the abbreviations used in this article.

Table 7.List of Abbreviations

PSO	Particle Swarm Optimization
CSA	Clonal Selection Algorithm
DCT	Differential Evolution
DE	Differential Evolution
DnCNN	Denoising Convolutional Neural Network
DWT	Discrete Wavelet Transform
GA	Genetic Algorithm
PSNR	Peak Signal-To-Noise Ratio
SSIM	Structural Similarity Index
NCC	Normalized Cross-Sectional Correlation
NN	Neural Networks
SVD	Singular Value Decomposition

8.DECLARATIONS

8.1. ETHICS APPROVAL AND CONSENT TO PARTICIPATE
Not applicable

8.2. CONSENT FOR PUBLICATION
Not applicable

8.3. AVAILABILITY OF DATA AND MATERIAL
Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

8.4. COMPETING INTERESTS

The authors declare that they have no competing interests.

8.5. FUNDING

Not applicable.

8.6. AUTHORS' CONTRIBUTIONS

Ali Amiri developed the main idea, conducted the experiments and wrote the original manuscript. Hamidreza Rashidy Kanan, Ph.D.supervised the experiments and modified the manuscript.
All authors have read and approved the final manuscript.

8.7. ACKNOWLEGEMENTS

Not applicable.

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