Watermarking System for Medical Images Using Optimization Algorithm

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Abstract

One of the main methods used to provide security for medical records when exchanging these records through open networks is digital watermarking. In order to preserve the privacy of patients, this system also requires a means to secure images. In this paper, a watermarking based on discrete wavelet transform (DWT), and discrete and discrete cosine transform (DCT) in cascade provides more robustness and security. DCT divides the image into low and high-frequency regions, watermarking message can be embedded into low-frequency regions to prevent distortion of the original image. DWT splits the image into four frequency coefficients; horizontal, vertical, approximation, and detailed frequency component. The judgment factors for the strength of the watermark system are robustness, invisibility, and embedded message capacity. Invisibility means transparency of the watermark logo or data in the original or host image without any distortion. Capacity data payload means the size of the embedded image which is related to the amount of data or logo size that will be embedded in the host image. Robustness refers to the capability of the watermark to stand with the host image operations. In this paper, we propose an optimizer to trade-off between robustness, invisibility, and message capacity. Three metrics were employed to assess the results achieved by the proposed approach, namely, Peak Signal-to-Noise Ratio (PSNR), Normalized Cross Correlation (NCC), and Image Fidelity (IF). The achieved results confirmed the effectiveness and superiority of the proposed approach for real-world digital watermarking applications.

Keywords: Digital watermarking; Optimization; Information hiding; Digital security.

1. Introduction

As technology for digital communication improves, large amounts of data may be transferred rapidly across networks [1]. This development has led to the emergence of "smart healthcare" companies that offer remote medical services to the public [2]. To reduce time and ensure a quick medical diagnosis, these services include sending the patient's medical data and photos to distant specialists [3]. When this information is sent via insecure networks, security and privacy risks emerge [4]. When transmitting and receiving a patient's health information for diagnosis or research,

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several regulations and instructions are utilized to protect the patient's confidentiality [5, 6]. Although there are benefits, medical information or photographs could fall into the wrong hands. The importance of data security was highlighted during the COVID-19 pandemic [7-9]. When images are sent, a watermark is superimposed on them. The Watermark can be text, a picture, or a logo that identifies the patient or the medical facility. An essential consideration is that the watermark shouldn't drastically reduce the quality of the original image [10]. Due to the reliable outcomes, it provides, watermarking algorithms are widely used in the biomedical imaging industry. Watermarking secretly embeds a logo or other identifying information within an original or cover image [11].

Optimal performance in watermarking requires a trade-off between the two primary criteria of resilience and invisibility [12]. Optimization methods are used to finish the job quickly and effectively [13]. The best possible embedding level can be obtained using optimization methods [14]. The Block diagram of a simple watermarking system is shown in Figure 1.

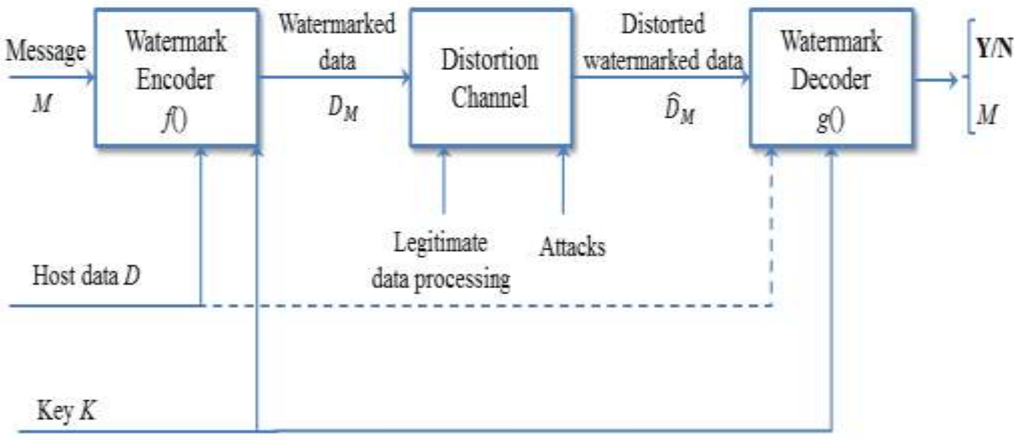

Figure 1: Basic watermarking system

In figure 1 the dotted line indicates the possibility to access the original data in the decoding process which represented informed watermark detection. In case of the absence of original data, the system will be a blind watermark system.

Blockchain as seen in figure 2 is a distributed technology that saves data to keep it unchanged. It also performs all the operations with the engaged users without a third party. [15].

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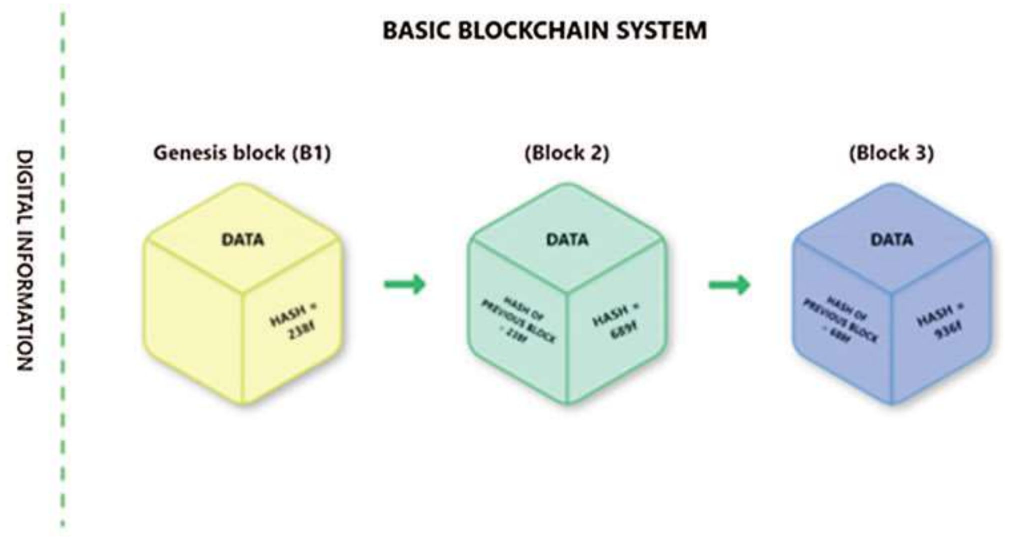

Figure 2: Basic blockchain system

Blockchain technology is used in digital copyright protection [16]. Conventional copyright protection needs private data to be copyright data. The owner of the data saves it on a server. Unfortunately, it will lead to inadequacy, and high cost, and data can be interfered with. It also needs copyright verification because it is needed to prove that this data is original. For all mentioned, blockchain is used to save copyright data. This will simplify the verification operation. Also, blockchain can be used to perform multiple watermarks this is because each block has a permutant timestamp [17].

2. Literature Review

Function as a platform. In recent years [18-22], numerous academics have studied the practice of digital image watermarking. Many medical studies benefit from the advancements made possible by the IoT. An IoT-based method for medical photos is presented [23], with the doctor's signature incorporated into many images for further protection. The approach has some flaws, such as being vulnerable to geometric assaults and unable to identify the capacity data payload. As a result, we employ an alternative optimization strategy to give a trade-off between resilience and size. An approach that uses Ant colony optimization and the light gradient boosting algorithm to reduce computation time is proposed [24]. Discrete cosine transform is utilized for embedding, and the optimizer is then used to determine the best values for the embedding parameters. Watermarking systems use an alternative deep learning method to provide complete automation. To date, no deep learning methods can simultaneously ensure a secure and blind embedding. To solve this problem, we offer a new deep learning-based method [25] that uses automation for both the embedding and extraction of functions. When compared to conventional approaches, the outcomes of this strategy are preferable.

Particle swarm optimization can be effectively applied to watermarking systems using the discrete wavelet transform and the discrete cosine transform, as described in [26]. With the help of principal component analysis, it was possible to optimize a blind watermarking method for copyright protection. It employs an advanced Gray Wolf optimizer [27] and runs in the redundant discrete wavelet domain. The proposed method effectively accomplishes stealth and durability. The effectiveness of watermarking techniques has recently been improved with the use of neural networks. In [28], the authors present a method for blind picture watermarking that relies on a thirteen-layer Convolutional neural network. The new method improved the image's resolution, making the watermark more difficult to detect. Ultimately, it's the user's wants that determine the trade-off. The findings demonstrate excellent resistance to geometric and pixel value changes. Over the past few years, a new protocol for watermarking systems called a buyer and seller protocol has emerged to assure the system's security based on blockchain technology [29]. In [30], a neural network-based watermarking architecture is provided, in which the watermark logo is inserted into

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the edge of the host image. High-performance logo extraction is achieved by employing Multilayer perceptron after the data has been inserted using a genetic algorithm-based optimizer. A particle swarm optimizer is used for another safe watermarking approach [31]. This one uses the discrete cosine transform to embed the logo's color into the original image's red, green, and blue channels.

A fuzzy entropy value is used to arrange the three primary colors, and a particle swarm optimizer establishes the optimal embedding performance to strike a balance between stealth and durability. One such hybrid approach [32] uses the discrete cosine transform and the discrete wavelet transforms to carry out the watermarking. In this technique, a two-stage neural network removes the watermark from the source image rather than the host image. Improved stealth and increased system resilience are the results. Discrete cosine transforms, discrete wavelet transform, singular value decomposition, and hologram are all components of [33], a hybrid system designed to secure copyright information. This technique involves the following steps: (1) inserting the watermark logo into the original image's three-color components. Third, the hologram is employed to make the watermark more undetectable and to provide the best performance against noise attacks and encryption. In [34], a watermarking system is proposed that guarantees all the requirements at once. Although relational databases are commonly used for storing and retrieving data, they are not well-suited for storing and retrieving photos; hence several studies [35–37] have relied on blockchain for digital image watermarking as proof of ownership.[38], we see another method that takes advantage of blockchain to spot data manipulation. In [39–46], we see another approach for the digital watermarking of large datasets that uses the blockchain.

3. Mathematical equations of used methods

Discrete Cosine Transform, abbreviated as DCT, is a typical method of visualizing an image as the sum of data points. These numbers represent variously sized and frequency-specific sinusoids. It is employed to disentangle a picture into smaller, more manageable pieces, known as "sub-bands" or "spectral sub-bands," each of which contributes an extraordinary amount to the overall visual quality of the picture. A signal or image can be transformed from the spatial domain to the frequency domain using the discrete cosine transform (DCT). Images are separated into high-frequency and low-frequency components. A low-energy high-frequency component represents reflectivity. A large amount of energy is contained in the low-frequency component, representing the image's brightness. Image compression and watermarking are only two of the many uses for discrete cosine transforms. In Figure 3, we see the DCT in action. When DCT is applied to an image, it transforms from the spatial domain to the frequency domain. It offers several benefits, including a low error rate, a high compression ratio, and a high computational complexity. Using Eqn, we can find the DCT of an N by M image in two dimensions (1).

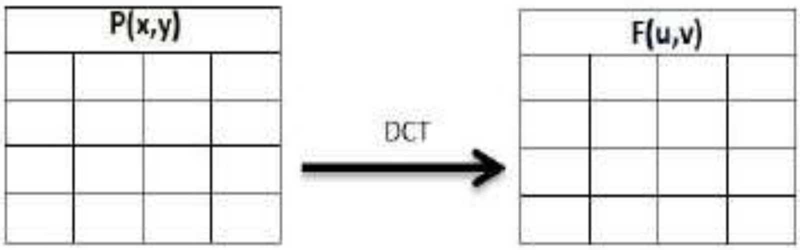

Figure 3: Discrete Cosine Transform

$$F(u,v) = \left(\frac{2}{N}\right)^{0.5} \left(\frac{2}{M}\right)^{0.5} \sum_{i=o}^{N-1} \sum_{j=0}^{M-1} \Lambda(i)\, \Lambda(j) \cos\left[\frac{\pi u}{2N}(2i+1)\right] \cos\left[\frac{\pi v}{2M}(2j+1)\right] f(i,j) \qquad (1)$$

To do what is known as Multi-Resolution Analysis (MRA) on photographs, the relatively young field of wavelet theory provides a mathematical foundation for breaking down an image into its constituent parts at various scales and resolutions. Wavelet transforms are used in this theory to create an image-processing method. These are helpful since they reveal information about the images' frequencies and timestamps. When a 2D wavelet transform is applied, the resulting image is a 4-component sum across all resolutions. Using multi-resolution theory, images and signals can be represented and analyzed in one or more

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resolutions. It draws on methods from other disciplines to create a new whole. Sub-band encoding is borrowed from DSP, while quadrature mirror filtering originates in pyramidal imaging theory. Multi-Resolution Analysis describes the theoretical framework for dealing with many resolutions simultaneously (MRA). Using MRA, you can see if alternative picture resolutions can pick up on previously invisible details. An iterative series of scaled-down versions of the input image are generated mathematically. The resolution is increased by a factor of 2 at each step. Then, for an image f (x, y) with dimensions M by N, the discrete wavelet transform is

$$w_{\phi}(j_0, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=o}^{M-1} \sum_{y=0}^{N-1} f(x, y) \phi_{j_0,m,n}(x, y) \quad (2)$$

$$w_{\psi}^{i}(j_0, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=o}^{M-1} \sum_{y=0}^{N-1} f(x, y) \psi_{j,m,n}^{i}(x, y) \quad (3)$$

where, j_0 is an arbitrary starting scale and the w_{ϕ} (j_0, m, n) coefficients define an approximation of $f(x, y)$ at scale j_0. The $w_{\psi}^{i}(j, m, n)$ coefficients add horizontal, vertical, and diagonal details for scales greater than j_0. Generally, $j_0 = 0$ is selected and N = M = 2^j so that j = 0, 1, 2, . . . j – 1 and m=n=0,1,2,….$2^j - 1$. Figure 4 shows the decomposition of an image using two-level DWT.

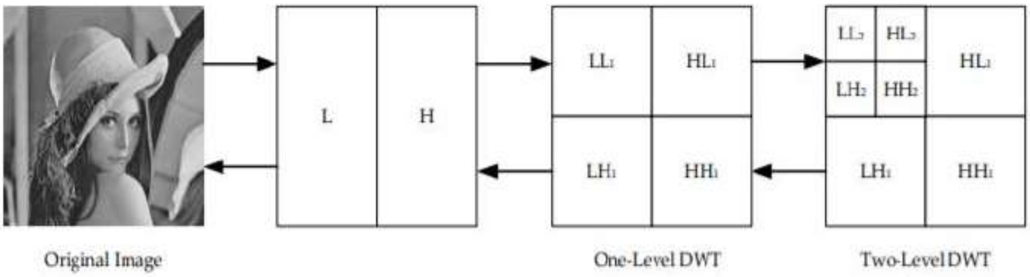

Figure 4: Two-level DWT

4. Proposed optimizer

The proposed optimization approach is based on a mathematical model. Here are some equations used to model the grasshoppers' swarming behavior:

$$X_i = S_i + G_i + A_i \quad (4)$$

where X_i defines the position of the i-th grasshopper, S_i is the social interaction, G_i is the gravity force of the i-th grasshopper, and A_i shows the wind advection. The random behavior of the algorithm is achieved by adding random variables $r_1, r_2,$ *and* r_3 in the range [0, 1]. Thus, Equation 1 can be rewritten as;

$$X_i = r_1 S_i + r_2 G_i + r_3 A_i \quad (5)$$

$$S_i = \sum_{j=1}^{N} s(d_{ij}) \hat{d}_{ij} \quad (6)$$

Where d_{ij} is the distance between i-th and j-th

$$d_{ij} = |X_j - X_i| s \quad (7)$$

S is the designed function.

5. Proposed watermarking system

Image in a digital format with watermarking, a picture is secretly inserted within another, more difficult-to-extract image. There are two phases to the watermarking process: embedding and detection. When creating a watermarked image, the watermark image is embedded within the cover image. The scaling

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factor is the most crucial aspect of creating a secure and efficient watermark. The robustness and efficiency of the algorithm are improved by computing the optimal value of the scaling factor. Using the proposed optimizer, we can calculate the scaling factor in the suggested method. Cover and watermark images' DCT coefficients are adjusted for embedding by the scaling factor. With the extraction method, we can get the watermark with minimal damage. We use inverse DWT and inverse DCT to extract the data. Figure 5 is a flowchart depicting the proposed procedure.

The following are descriptions of each stage of the proposed procedure:

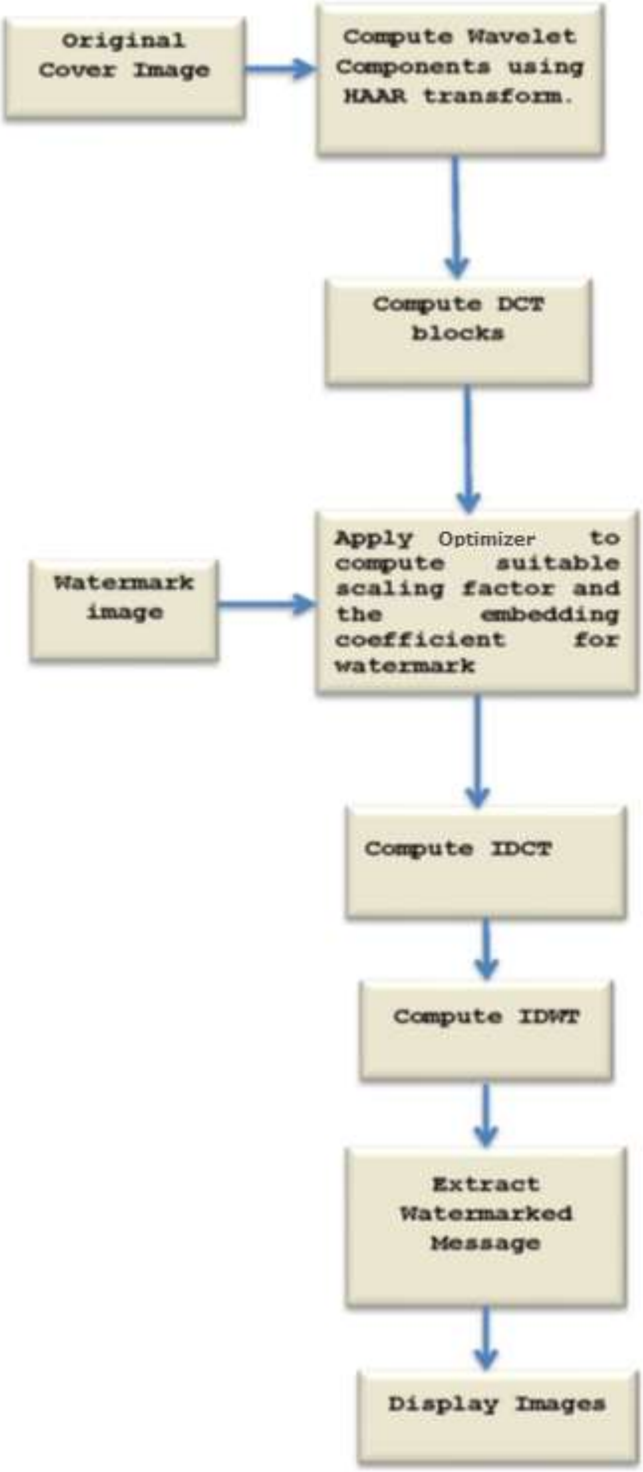

Figure 5: Flowchart of the proposed method

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1- The cover image (I_c) and watermark images (I_w) are initially used for the watermarking process.

2- The wavelet transform of the cover image is computed using Haar Wavelet transform using Equation (6). The application of a two-dimensional Haar Wavelet Transform produces the approximation; details in horizontal, vertical, and diagonal components are then computed. The discrete wavelet transforms of the cover image (I_c) of size M × N are then;

$$W_{\phi}(j_0, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y)\phi_{j_0,m,n}(x, y) \quad (8)$$

3- The wavelet transform is converted into the frequency domain by applying the DCT transform. This is computed as follows:

$$F(u, v) = \sigma(u)\sigma(v) \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} g(i, j) . \cos\left[\frac{(2i+1)u\pi}{2m}\right] \cos\left[\frac{(2j+1)v\pi}{2n}\right] \quad (9)$$

The inverse of DCT is computed using

$$G(m, n) = \sigma(u)\sigma(v) \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} F(u, v) . \cos\left[\frac{(2i+1)u\pi}{2m}\right] \cos\left[\frac{(2j+1)v\pi}{2n}\right] \quad (10)$$

4- Grasshopper Optimization Algorithm is used to find an optimized scaling factor and the coefficient for embedding the watermark.

5- Apply the insertion additive technique of watermarking

6- To obtain the watermarked image X we compute the inverse DWT of I′.

7- The watermark can be extracted by applying the inverse of the additive formula.

6. Experimental results

The proposed method is based on Grasshopper Optimization Algorithm for digital watermarking on images. The experiments are carried out on three different cover images (Figure 6). The embedding message or watermark image used is shown in Figure 7.

Figure 6: Cover Images (a) Coins (b) Moon (c) Tire

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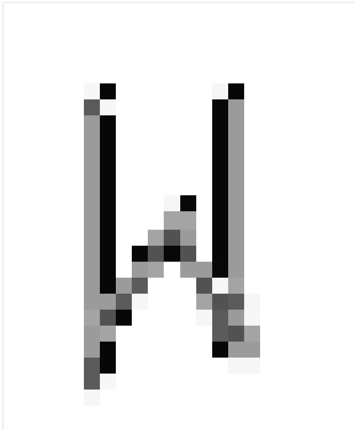

Figure 7: Embedding Message

Against two alternative approaches that are considered to be the best available, the suggested method is evaluated. DWT, DCT, and Bacterial Foraging Optimization (BFO) are used in the first watermarking technique [17]. The alternative way is a refinement of Particle Swarm Optimization (PSO) that incorporates Basic Feature Optimization (BFO) [17]. The new approach is evaluated in comparison to the two existing methods. The quality of the suggested method is assessed by measuring the watermarking outcomes. Peak Signal Noise Ratio (PSNR), Mean Absolute Error (MAE), and Mean Square Error (MSE) are the quality measures employed (MSE). The optimum watermarking technique is one with a high peak signal-to-noise ratio (PSNR) yet a low mean squared error (MSE) and means absolute error (MAE).

The following formulas can be used to determine PSNR, MAE, and MSE: $PSNR = 10\log_{10}(\frac{S}{N})$ (11)

$$MAE = \frac{\sum_{m,n}[I_{o(m,n)} - I_{W(m,n)}]}{M*N}$$ (12)

$$MSE = \frac{\sum_{m,n}[I_{o(m,n)} - I_{W(m,n)}]^2}{M*N} \quad (13)$$

where M× N is the size of the image, $I_{0(m,n)}$is the intensity of the (m,n) pixel in the original image and$I_{w(m,n)}$ is the intensity of the (m,n) pixel in the watermarked image. The comparative analysis of the proposed method is summarized in Table 1. It can be observed that the proposed method gives the best result for all three test images. The PSNR value for the proposed method is high compared to the other methods.

Table 1: Comparison between results

Image	Metric	DWT	DWT+DCT	DWT+DCT+BFO	Proposed Method
Coins	PSNR	23.7910	46.1489	49.9037	54.9569
	NCC	0.0021	0.0040	0.0039	0.0038
	IF	-0.0196	-3.816e-5	-1.60055e-5	-5.0153e-6
Moon	PSNR	24.6273	46.3850	49.7929	54.9623
	NCC	0.0020	0.0040	0.0040	0.0039
	IF	-0.0204	-4.5625e-5	-2.0817e5	-6.3310e-6
Tire	PSNR	24.5919	46.4982	50.1133	55.5396
	NCC	0.0020	0.0040	0.0039	0.0037
	IF	-0.0160	-3.4643e-5	-1.5070e-5	-4.3198e-6

6. Conclusion

This paper introduces a bio-inspired algorithm-based digital watermarking strategy for protecting valuable images. The watermarking scaling factor is calculated with the help of the proposed optimization

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algorithm. The DWT and DCT coefficients used to embed the watermark into the cover image are scaled using the scaling factor. The suggested method is reliable and efficient, which yields the best possible scaling factor. To test the efficacy of the strategy, experiments are carried out. Two other state-of-the-art approaches are used to evaluate the given results. First, we have a method that uses DWT, DCT, and BFO to watermark photos. The second employs a hybridized optimization technique and is an enhanced algorithm. The hybridized strategy integrates PSO with BFO. Compared to the other two approaches, the proposed strategy produces low MSE while maintaining a high PSNR. As a result, the created method can be effectively implemented in real-world scenarios.

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