Journal of Information Technology Management

Print ISSN: 2008-5893

Online ISSN: 2423-5059

Digital Watermarking using Dragonfly Optimization Algorithm

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Abstract

In this paper a novel digital watermarking algorithm is proposed**.** The proposed method comprises of a watermarking embedding and extraction algorithm using bio inspired optimization technique. Dragonfly algorithm (DA) is based on the static and dynamic swarming behaviors of dragonflies in nature. The dragonfly algorithm is used to optimize the scaling factor of the watermarking so that an optimal watermark is embedded. Watermarking algorithms take as input a cover image and the message. The cover image in the proposed method is decomposed into sub bands using discrete wavelet transform (DWT). Thereafter, it is converted to discrete cosine blocks (DCT). An optimal scaling factor is required for performing the watermarking. In this paper, DA is used for computing the scaling factor. The DA generated scaling factor is optimal and improves the performance of the watermarking. The inverse DWT and DCT are computed to extract the watermarked image from the cover image. The proposed method is applied on different images to evaluate the performance. The results obtained are compared with other state of the art methods.

Keywords: Image watermarking, Dragonfly optimization, Discrete wavelet transform, Copyright protection.

DOI: 10.22059/jitm.2020.78888

Introduction

Digital watermarking is a popular technique for embedding hidden information into images. It is widely utilized for the protection of copyright. The copyright information is embedded into a digital image. This embedding procedure preserves the image quality. Each watermarking method has a corresponding extraction algorithm. This algorithm is used to extract the watermark for resolving any ownership conflicts. The process involves a cover image which is the carrier and a watermark image that is hidden or embedded in the cover. The watermarked image is embedded into the cover image by means of the watermarking algorithm. The extraction of the message is done using watermarking extraction algorithm. Numerous researchers are working in digital watermarking. The computation of watermarking fall under two major categories these are spatial, and frequency based. The spatial methods work on the location of the watermark on the other hand the frequency base methods work in frequency domain (Khadam et al., 2019). Although the spatial area calculation is straightforward, its power is poor, while the frequency-based watermarking has higher efficiency (Ali et al., 2014). Along these lines, frequency domain watermarking is the primary examination pattern; it is highly reliable for securing copyrights and for verification of images. Frequency based methods are widely being used for digital image watermarking. The commonly used techniques in the frequency domain include DWT and DCT (Bekkouch et al., 2015). The security of singular value decomposition (SVD) is quite efficient (Fazli and Moeini, 2016), yet the computational prerequisites are high. Thus, SVD is normally joined with the change area strategies in the watermarking calculation (Benoraira &Benmahammed, 2015; Divecha & Jani, 2013). in digital watermarking DCT helps in protecting against lossy compression attacks. While the DWT helps in preserving the location properties of the watermark (Strang, 1999). Therefore, a combination of these two methods provides the best solution for digital watermarking (Handito et al., 2018). Multiple watermarking techniques based using SVD in conjunction with DWT and DCT are available in the literature. The improved and modified version of these algorithms are also proposed by several researchers (Furqan et al., 2015). A method based on one level DWT is proposed in which the single level decomposition is computed. Using these decompositions, the watermark is embedded in the cover image (Furqan et al., 2015). In another paper only the low-level wavelet decomposition is used. The watermark is embedded using the Particle Swarm Optimization (PSO). The performance of this method was better (Nandi and Santhi, 2016). Meta heuristic algorithms have proved to be better for computing the optimal value for watermarking. This paper presents a novel watermarking embedding and extraction algorithm using bio inspired optimization technique. Dragonfly optimization algorithm is built on the static and dynamic swarming behaviors of dragonflies in nature. The dragonfly algorithm is used to optimize the scaling factor of the watermarking so that an optimal watermark is embedded. Initially, DWT is used to decompose the cover image into multiple bands. Thereafter, it is converted to discrete cosine blocks (DCT). Finally, the dragonfly algorithm is applied to achieve the optimal value for scaling factor. The inverse DWT and DCT are computed to extract the watermarked image from the cover image.

Dragonfly Algorithm

Dragonfly algorithm is a recently proposed optimization algorithm based on the swarming behavior of dragon flies. The algorithm can be used for solving complex problems. It starts with a set of random solutions and works iteratively to optimize these solutions (Mirjalili, 2016). The behavior of dragon flies comprises of five stages specifically separation, alignment, cohesion, attraction towards food and distraction from the enemy. These five stages are shown in figure 1.

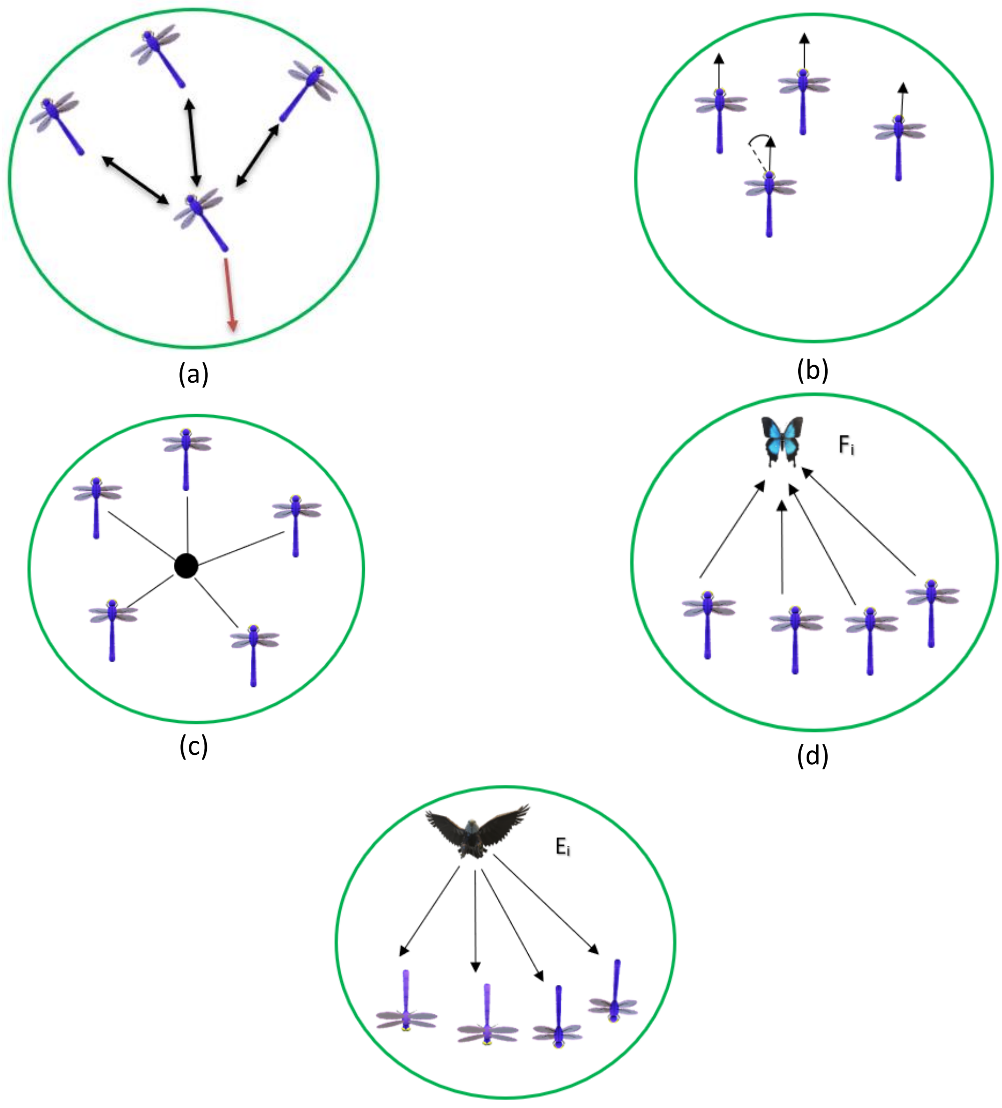

Figure 1. Stages of Dragon Fly Algorithm (a) Separation (b) Alignment (c) Cohesion (d) Attraction to food (e) Distraction from enemy

These stages can be mathematically expressed as follows:

- Separation: During this phase the swarms are away from each other to avoid any collisions. The separation of N swarms is the sum of the separation amid the current individual and j^{th} neighbor X_j. It can be computed using equation (1).

$$S_i = -\sum_{j=1}^{N} X - X_j \tag{1}$$

- Alignment: The swarms align together to move forward collectively. the velocity of each swarm matches with the velocity (V) of the others. Alignment can be computed using eq.(2)

$$A_i = \frac{\sum_{j=1}^{N} V_j}{N} \tag{2}$$

V_j is the velocity of the j_{th} neighbor.

- Cohesion: This is the attraction force of the swarms towards the center. Eq.(3) is used to compute cohesion.

$$C_i = \frac{\sum_{j=1}^{N} X_j}{N} - X \tag{3}$$

- Attraction towards food: All the swarms get attracted towards the food (F). This represented as eq. (4). X^+ represents the position of the food source.

$$F_i = X^+ - X \tag{4}$$

- The distraction outwards an enemy is

$$E_i = X^- + X \tag{5}$$

X^- is the position of the enemy.

Using these five parameters S,A,C,F and E given in eq.(1) to (5) the exploration and exploitation can be achieved. The proper tuning of these parameters helps in finding the optimal solution. Thus, the step vector and position for dragon flies is computed using eq.(6)and (7) respectively.

$$\Delta X_{t+1} = (sS_i + aA_i + cC_i + fF_i + eE_i) \tag{6}$$

$$X_{t+1} = X_t + \Delta X_{t+1} \tag{7}$$

In the above equation *t* is the iteration count and *i* represent the i^{th} fly.

If a dragon fly does not has any neighbor then the levy flight is used to update the position as given in eq.(8).

$$X_{t+1} = X_t + L\acute{e}vy(d) \times X_t \tag{8}$$

where

$$L\acute{e}vy(x) = 0.01 \times \frac{r_1 \times \sigma}{|r_2|^{\frac{1}{\beta}}} \tag{9}$$

r_1 and r_2 are randomly selected numbers in the range [0, 1], β is a constant

$$\sigma = \left(\frac{\Gamma(1+\beta) \times sin\left(\frac{\pi\beta}{2}\right)}{\Gamma\left(\frac{1+\beta}{2}\right) \times \beta \times 2^{\left(\frac{\beta-1}{2}\right)}} \right)^{1/\beta} \tag{10}$$

where $\Gamma(x) = (x-1)!$

Proposed Method

Digital image watermarking comprises of two methods embedding and extraction. In watermarking embedding algorithm the watermark is embedded into the cover image. In the extraction algorithm the watermark is extracted from the cover image. The steps involved in the proposed method are represented in figure 2.

The method takes as input the cover image and the watermark image. The DWT and DCT of the cover image are computed. A robust watermark algorithm requires an optimal value of the scaling factor. Thus, in this paper the dragonfly algorithm is used to obtain the optimal value of scaling factor. In the extraction process, inverse DWT and inverse DCT is computed to extract the watermark.

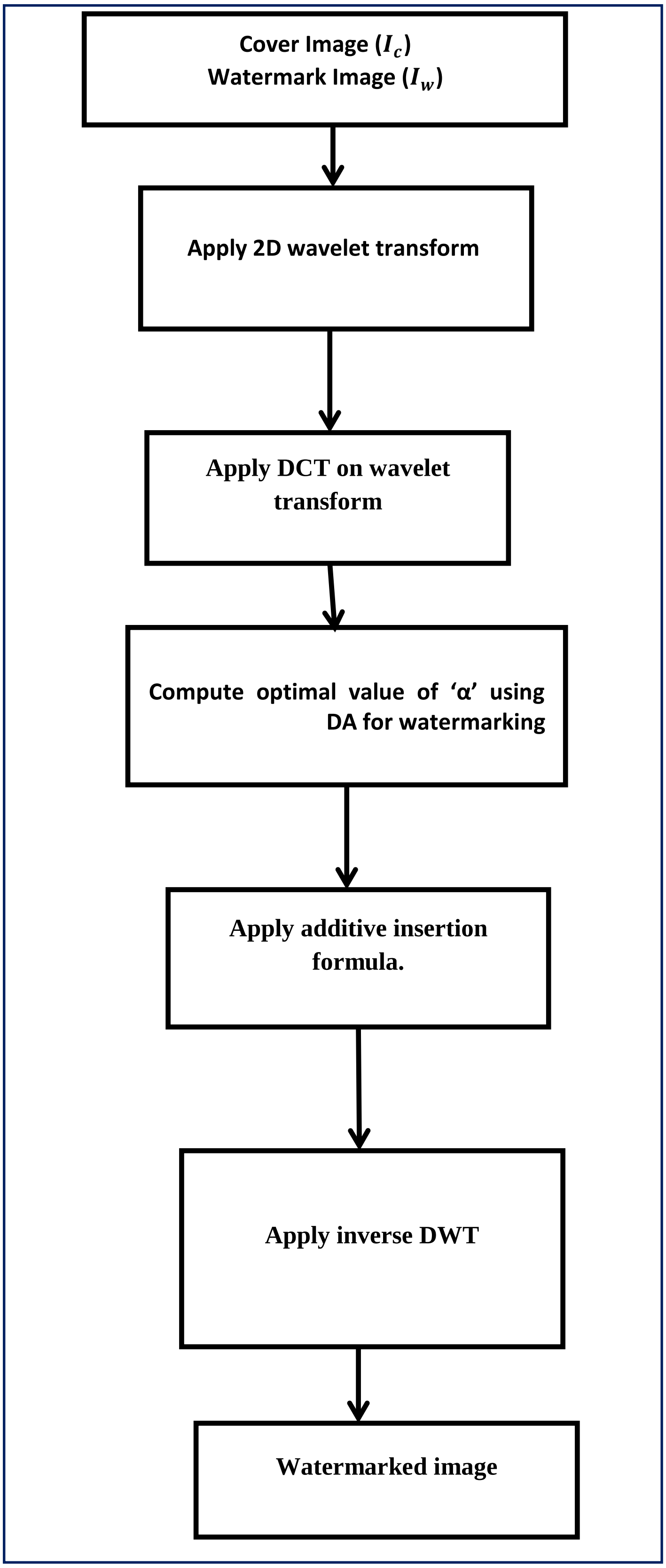

Figure 2. Flow chart of the proposed method

The watermarking algorithm proposed is as follows:

Algorithm 1 : Watermark Embedding Algorithm

Begin

Step 1. Input I_c and I_w

Step 2. Compute the discrete wavelet transform of I_c and I_w using

$$W_\varphi(j_o, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y)\varphi_{j_o m,n}(x,y)$$

$where$ the size of the cover image is $M \times N$

The wavelet decomposition components of I_c and I_w are obtained.

Step 3. The wavelet components are converted into frequency domain using the DCT. Thus, the obtained components in the frequency domain are computed as

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

where

$$\sigma(u) = \begin{cases} 1/\sqrt{2} & u = 0 \\ 1 & u = 1,2,3 \ldots, m-1 \end{cases}$$

$$\sigma(v) = \begin{cases} 1/\sqrt{2} & v = 0 \\ 1 & v = 1,2,3 \ldots, n-1 \end{cases}$$

Step 4. To obtain the optimal position of embedding the dragonfly algorithm is used. The scaling factor (α) is optimized using eq.(6)-(9).

Step 5. Embed I_w into I_c using the following insertion equation:

$$I'(i,j) = I(i,j) + (\alpha \times W(i,j))$$

where I' is the DWT coefficient of the watermarked image. I is the DWT coefficient of the original image. W is the DWT coefficient of the watermark image

Step 6. The watermarked image (I_{wi}) is obtained by computing the inverse DWT of the image obtained in step 5.

End

Whenever there is requirement of extracting the watermark the watermark extraction algorithm can be used. The extraction algorithm is the reverse of the embedding algorithm. The proposed extraction algorithm is as follows:

Algorithm 2 : Watermark Extraction Algorithm

Begin

Step 1. Input the watermarked image

Step 2. Compute the discrete wavelet transform of the watermarked image using

$$W_{\varphi}(j_o, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y)\varphi_{j_o m,n}(x, y)$$

$where$ the size of the cover image is $M \times N$

The wavelet decomposition components of I_c and I_w are obtained.

Step 3. Compute inverse DCT as follows:

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

where

$$\sigma(u) = \begin{cases} 1/\sqrt{2} & u = 0 \\ 1 & u = 1,2,3 \ldots, m - 1 \end{cases}$$

$$\sigma(v) = \begin{cases} 1/\sqrt{2} & v = 0 \\ 1 & v = 1,2,3 \ldots, n - 1 \end{cases}$$

Step 4. Obtain watermark image using the insertion formula used in embedding process

$$W = \frac{I'(i, j) - I(i, j)}{\alpha}$$

Step 5. The image obtained in step 4 is the DWT of the watermark image. Thus,

$$I_w = IDWT(W)$$

The inverse DWT is computed to obtain the original watermark image.

End

Experiments and Results

In this section the experiments and results are discussed. The method is implemented in Matlab 2017a. The performance of the proposed method is evaluated both quantatively as well as qualitatively. The results of the proposed method are compared with three other state of the art methods. Figure 3 shows the visual results of applying the proposed method on four different methods. A good watermarking algorithm is the one that produces the watermarked image with minimum effect on visual quality.

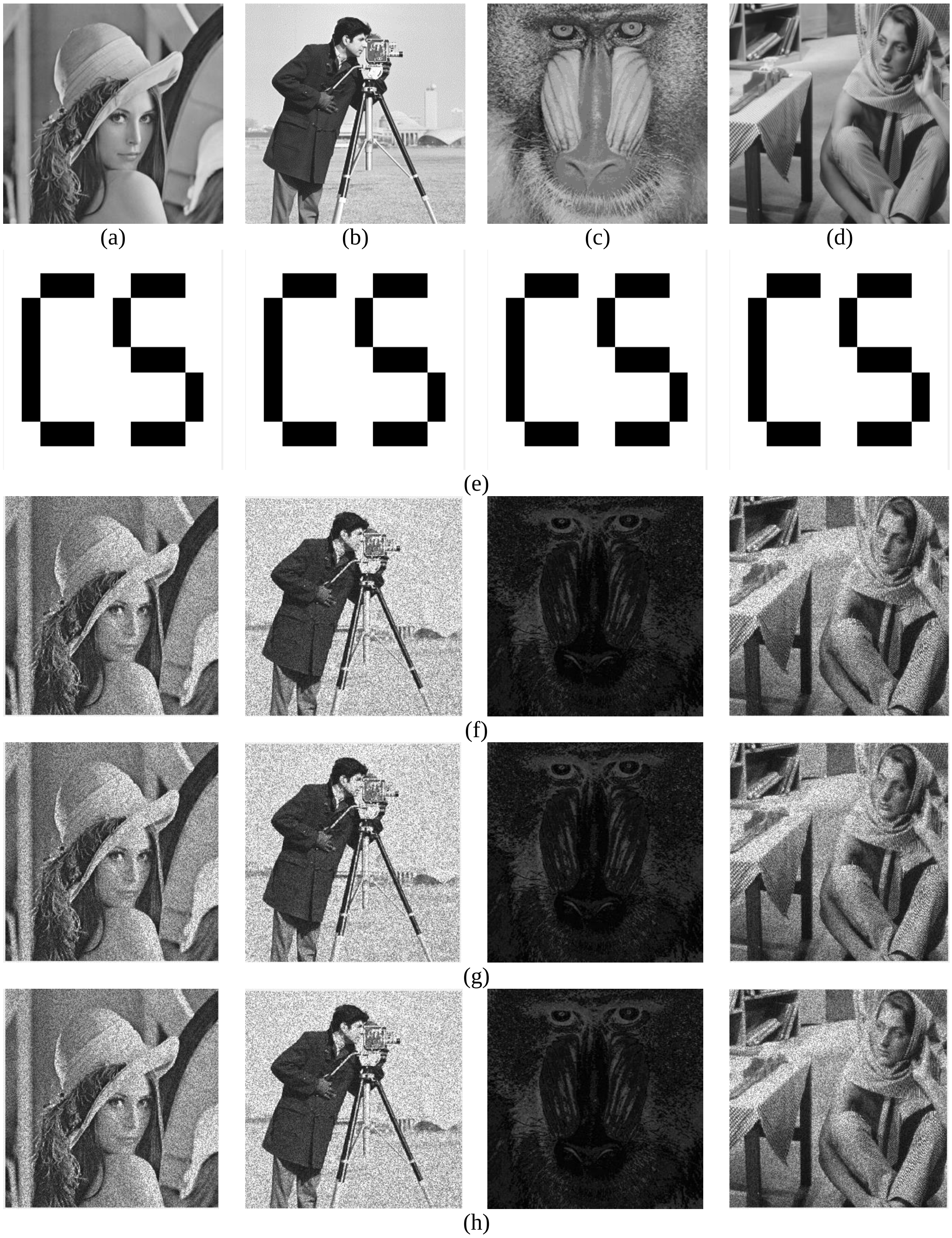

Figure 3. Cover Images (a) Lena (b) Cameraman (c) Baboon (d) Barbara(e)Watermark image (f) Watermark embedding Result (DWT+DCT+BFO) (g) Watermark embedding Result (DWT+DCT+PBFO) (h) (f) Watermark embedding Result (Proposed Method)

The proposed method is compared with two other state of the art methods. The first method uses DWT, DCT and Bacterial Foraging Optimization (BFO) for watermarking (Bharati et al., 2018). The other method is an improved method that hybridizes Particle Swarm Optimization (PSO) with BFO (Bharati et al., 2018). Both these methods are compared with the proposed method. The watermarking results obtained are measured using the metrics that determine the quality of the proposed method. The metrics that are used for measuring the quality are Peak Signal to Noise Ratio (PSNR), Mean Absolute Error (MAE) and Mean Square Error (MSE). In case of watermarking the best method is the one which has high PSNR values but low MSE and MAE values. PSNR, MAE and MSE may be computed as follows:

$$PSNR = 10\ log_{10}(S/N) \tag{11}$$

$$MAE = \frac{\sum_{m,n}\left[I_{0(m,n)} - I_{w(m,n)}\right]}{M * N} \tag{12}$$

$$MSE = \frac{\sum_{m,n}\left[I_{0(m,n)} - I_{w(m,n)}\right]^2}{M * N} \tag{13}$$

where $M \times N$ 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.

Table 1. Experimental Results

	DWT+DCT+BFO	DWT+DCT+PBFO	Proposed Method
(a) Lena Image			
PSNR	43.6	45.5	49.9
NCC	0.0039	0.0039	0.0039
IF	-1.4664e-04	-3.8026e-05	-8.7464e-05
(b) Cameraman Image			
PSNR	40.1	44.0	51.2
NCC	0.0039	0.0039	0.0039
IF	-1.9436e-04	-7.9619e-05	-1.9525e-05
(c) Baboon Image			
PSNR	32.3	36.2	44.2
NCC	0.0039	0.0035	0.0028
IF	-0.0059	-0.0024	-5.9966e-04
(d) Barbara Image			
PSNR	43.7	43.6	49.5
NCC	0.0039	0.0038	0.0036
IF	-1.5734e-04	-3.7773e-04	-4.0663e-05

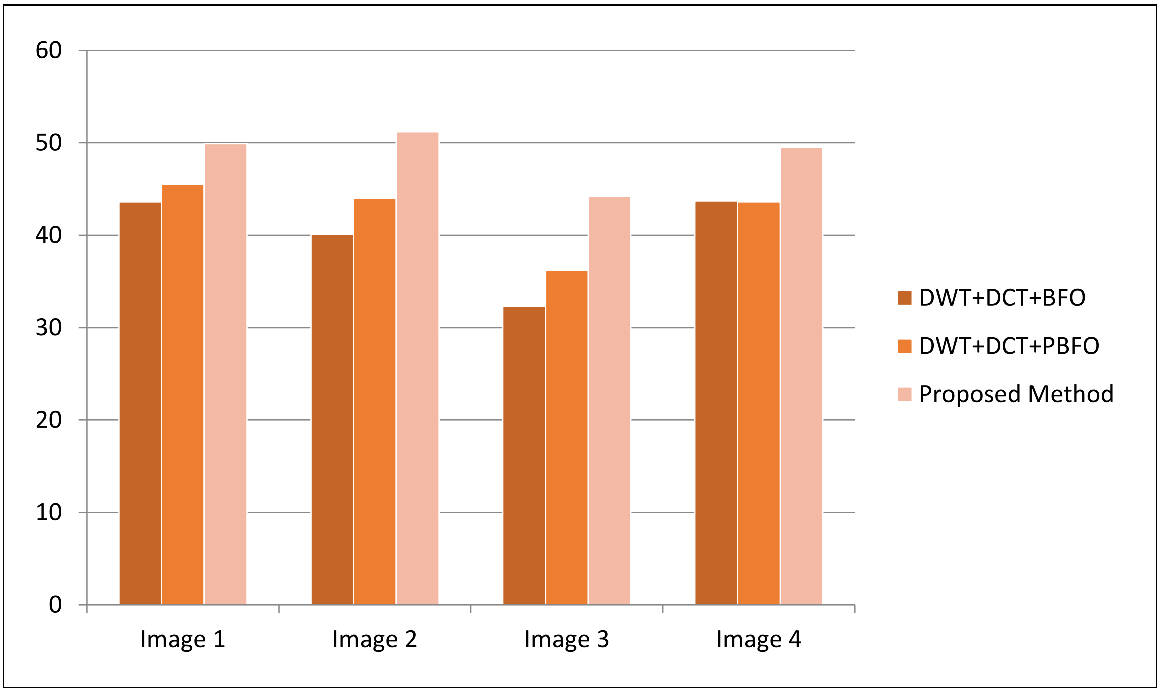

Figure 4. Comparison of PSNR values

The comparative results of the proposed method with other state of the art of the method are shown in figure 4. The results establish that the proposed method works better than the other methods. Thus, it can be effectively used for the purpose of digital watermarking in images.

Conclusion

With the advent of internet technology, the requirement of digital watermarking has increased significantly. This paper presents a robust and effective watermarking technique using meta-heuristic algorithm. The proposed method uses DWT and DCT for watermarking the image along with dragon fly optimization. Scaling factor is a very important factor in watermarking. It is used to adjust the coefficients of DWT and DCT for the watermark. Dragon Fly optimization inspired by the swarm behavior of dragon flies is used for computing the scaling factor. DA computes the optimal value of the scaling factor. Thus, the proposed algorithm is robust and effective. The results obtained from the proposed method are compared with other state of the art methods. Performance of the proposed method outperforms the existing methods.

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Bibliographic information of this paper for citing:

Sharma, Satender; Chauhan, Usha; Khanam, Ruqaiya & Singh, Krishna Kant (2020). Digital Watermarking using Dragonfly Optimization Algorithm. *Journal of Information Technology Management*, Special Issue, 36-47.