Robust Digital Image Watermarking based on Hybrid GWO-DWT Technique

Snehlata Maloo1*, Mahendra Kumar2, N. Lakshmi3, and N. K. Pareek4

1, 4Department of Computer Science, MLSU Udaipur (Raj.)
sneha.maloo21@gmail.com, npareek@yahoo.com
2Department of Electrical Engineering, IIT Roorkee, India
miresearchlab@gmail.com
3Department of Physics, MLSU Udaipur (Raj.)
nlakshmi@mlsu.ac.in

Abstract: This paper introduces a grey wolf optimization algorithm for image watermarking in the Wavelet Transform domain. Digital image watermarking (DIW) determines its proficiency in ensuring illegal confirmation of media. The visibility factor of the watermark is the main parameter that helps in enhancing the robustness and perceptual transparency of the DIW. The trade-off between the clarity and robustness is considered as an optimization problem and is explained by applying GWO algorithm. The effectiveness of the proposed scheme is evaluated in terms of PSNR and MSE. The simulation results are carried out using MATLAB R2014b software.

Keywords: GWO, DWT, MSE, PSNR, Robustness, Watermarking.

1. Introduction

Digital image watermarking has been introduced to protect the copyright protection of multimedia. Basic digital watermarking concepts are discussed in [1]–[5]. Authors have proposed a transparent watermarking method for media. Digital image watermarking as an identification code which carry information such as an author’s signature, a company logo, etc. of owner copyright. The requirement for digital image watermarking methods has turned into a crucial substance in multimedia applications because of the fast development of illegal access and propagation of original digital objects like text, image, audio and video.

Digital watermarking have mainly two types of watermark Perceptible and imperceptible. Watermarking of a digital image can be performed in both spatial domain and transform domain. Transform domain transform the data into the transform domain and change selected coefficients to insert the watermark. This technique although has high computational complexity; it is more robust and provides more imperceptibility than spatial domain technique [4][6][7]. Currently, Discrete Fourier Transform, Discrete Cosine Transform, Discrete Wavelet Transform are widely used in transform domain.

Selection of amplification factors may be shown as a development issue which is resolved by applying GA. Recently, M. Ketcham et al., [15] have proposed an original DWT and GA for audio signals. The optimal localization and magnitude were achieved through GA and strategy was discovered powerful against editing, low pass filter and additive noise. In[16], To illustrate robustness and imperceptibility of digital watermarking based on a hybrid DWT and DCT. Thus, Franco et al.[17] gave a DWT method for estimation of reliability and robustness. These method were equipped for separating the watermark. However, experienced the issues of unsuitable values of loyalty and strongnessto different attacks concerned in these papers. Zhicheng Wei et al.[18] proposed a method that derived a watermark that is faint to people’s sight and potent to different image controls. The writers used GA to prepare the frequency set for infix the watermark and compared these approach and the Cox's method [19] to demonstrate strongness. GA result was limited to JPEG compression in this
technique. In [20] proposed another flexible and efficient estimation instrument based on GA to check the potential of this techniques. Also given an arrangement of possible attacks and finds the ideal un-watermarked image regarding WPSNR.

The main contribution of this paper is to present a new watermarking scheme based on DWT and GWO. GWO is utilized to adaptively optimize the watermark visibility factor at each selected DWT sub-band that will enhance the intangibility and robustness. The proposed method uses the standardized correlation of the host image and watermarked images as the reason for estimating the fitness function.

2. Watermarking in Wavelet Domain

The innovation of the DWT technique lives in the manner of robustness and imperceptibility is enhanced the watermark image [17]. The significant goal of wavelet transform method is to deteriorate input media, hierarchically into progression of upcoming low-frequency sub-bands and their related definite sub-bands. Low-frequency sub-band and point by point sub-bands hold the data need to remake low-frequency similarities at the following higher resolution stage [22]. Wavelet techniques give such sort of a superb space and frequency energy compaction and thus DWT has received a mind-boggling enthusiasm for a several signal and image processing applications.

2.1 Watermark Embedding

Now, we take the image for watermarking, initially decompose the image through DWT into two level. Where $B^i_k$ represent the sub-band at level [0,1,2,3] and the orientation $x \in \{0, 1, 2,3\}$ as shown in Fig.1.

![Figure. 1. Decomposition of an image into two levels through DWT technique](image)

The watermark is embedded into the three bands at 0-level by modifying the wavelet coefficients. The idea of adding the watermark is based on experimental result such that the robustious and imperceptibility are adjusted. The experimental result of embedding is weak, which means low robustness, but gives the partial visibility of disturbs added, a higher watermark amplification factor is acknowledged thus compensating for the high frailty. The watermark of dimension $M \times N$ is converted into uni-dimensional antipodal sequenced $(i,j) \in \{+1,-1\}$, where $M$ and $N$ represent the number of rows and columns. The image is partitioned into 2-levels and all the acquired wavelet coefficients at the selected sub-band are partitioned into $n$ segments such that $n = MN$.

Here $H$, $V$ and $D$ assign to the horizontal, vertical and diagonal wavelets respectively. The DWT function of size $M \times N$ is then

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

$$\omega_j^i(j, m, n) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) \phi_{j, m, n}^i(x, y)$$

(1)
The $W\phi(j_0, m, n)$ is the closeness in initial scale $j_0$. $W\psi(j, m, n)$ means the horizontal, vertical and diagonal details at scales $j \geq j_0$. Where $j_0 = 0$, $j = 0, 1, 2, ..., j-1$ and $m = n = 0, 1, 2, ..., 2^j - 1$. By using Eq. (1) and (2), the $f(x, y)$ obtained by the inverse DWT

$$f(x, y) = \frac{1}{\sqrt{MN}} \sum_m \sum_n W\phi(j_0, m, n)\phi_{j_0, m, n}(x, y)$$

$$+ \frac{1}{\sqrt{MN}} \sum_{i=H, V, D} \sum_{j=j_0} \sum_m \sum_n W\psi^i(j, m, n)\psi_{j, m, n}^i(x, y)$$

When a level-1 DWT is used, the image is divided into four subparts of low, middle and high frequencies-HL1, LL1, LH1 and HH1 sub-bands. The sub-bands labeled LH1, HL1 and HH1 indicate the more exceptional scale wavelet coefficients. The LL1 sub-band keep the estimate image.

Fig 2-3: Watermark (2) Embedding Process, and (3) Extracting process

2.2 WATERMARK DETECTION

The DWT is a blind method and it does not need the original image for detection of watermark. This method is utilized on the embedded image, and sub-band to choose which watermark was embedded. The correlation between the cover and the extracted image is then processed as

$$\rho = \frac{\sum_{i,j} I_i' I_j}{\sqrt{\sum_{i,j} I_i^2} \sqrt{\sum_{i,j} I_j^2}}$$

where, $I$ denote the original and $I'$ stands for extracted watermarks. Each calculated correlation value and average correlation is compared. If it happens that the calculated value is more prominent than the mean, then extracted watermark bit is considered as 0, else if the calculated value is less than way, and taken as 1 [16]. In the end, the watermark image is restructured by applying the extracted bits, and the likeness between the original and the watermarked image is described.

3. Grey Wolf Optimizer (GWO) Algorithm

This section is presented a brief mathematical formation of GWO algorithm as follows step by step:

Grey wolf optimization is a new Meta heuristic technique proposed for solving many multi-model functions. Grey wolves inspire it. Grey Wolves Optimizer have four types such as $\alpha$, $\beta$, $\delta$, and $\omega$ are engaged to derive the administration of hierarchy of grey wolves. The process of this method are hunting, searching for prey, encircling prey and attacking prey.

Social behavior: Hierarchy exists in the pack. $\alpha$ is the decision maker and the leader. $\beta$ and $\delta$ assist $\alpha$ in decision making. Rest of the wolves($\omega$) are as follows.

Encircling prey: As referred before, grey wolves encircle prey during the hunt. To encircling behavior, the following formulas are designed.

$$\tilde{D} = |\tilde{C} \cdot \tilde{X}_p(t) - \tilde{X}(t)|$$

$$\tilde{X}(t+1) = \tilde{X}_p(t) - \tilde{A} \cdot \tilde{D}$$

where, $t^{-}$ signifies the current iteration, $\tilde{A}$ & $\tilde{C}$ - are coefficient vectors, $\tilde{X}_p$ - is the position vector of the prey, $\tilde{X}$ - denotes the position vector of a grey wolf.
The vectors $\vec{A}$ and $\vec{C}$ are calculated as

\[ \vec{A} = 2\vec{a} \cdot r_1 - \vec{a} \]
\[ \vec{C} = 2 \cdot \vec{r}_2 \]  

(3)

Where elements of $\vec{a}$ are continuously decreased from 2 to 0 throughout iterations and $r_1, r_2$ are random variable in [0,1]

**Hunting behavior:** Group hunting behavior is of equal interest in studying optimization.
1. Finding, chasing and approaching the prey.
2. Ongoing/applying, encircling, and harassing the prey until it stops moving.
3. Attacking the prey.

The alpha wolves are guided the hunting process. The beta and delta wolves may compete in hunting after alpha wolf. Therefore, we save the initial three sound solutions achieved so far and oblige the other search operator to bring up to date their positions according to the area of the best search operator. The under mentioned equations are as follows.

\[ D_a = \left[ C_1 \cdot \vec{X}_a - \vec{X} \right] \]
\[ \vec{D}_\beta = \left[ C_2 \cdot \vec{X}_\beta - \vec{X} \right] \]
\[ \vec{D}_\delta = \left[ C_3 \cdot \vec{X}_\delta - \vec{X} \right] \]

(3)

\[ \vec{X}_1 = \vec{X}_a - \vec{A}_1 \cdot (\vec{D}_a) \]
\[ \vec{X}_2 = \vec{X}_\beta - \vec{A}_2 \cdot (\vec{D}_\beta) \]
\[ \vec{X}_3 = \vec{X}_\delta - \vec{A}_3 \cdot (\vec{D}_\delta) \]

(4)

\[ \vec{X}(t+1) = \frac{\vec{X}_1 + \vec{X}_2 + \vec{X}_3}{3} \]

(5)

3. Proposed GWO-DWT Technique

In DIW, the population is initiated by selecting an arrangement of random points in the host media and embedding the watermark image into chosen area. The ideal answers for digital watermarking of DWT are acquired based on two basic factors: 1) the DWT sub-band and 2) the coefficient of the watermark amplification factor [16]. The GWO algorithm is examined its population for the ideal preparation with all possible outcomes of the DWT sub-bands and watermark amplification factors. The GWO methodology will attempt to locate the particular sub-band that will give concurrent perceptual transparency and robustness. To enlarge the strongnes of the algorithm against attacks, the strength of watermark or the amplification factor $\alpha$ ought to be improved, yet this factor differs on each sub-band.

The fitness function is a combination of the PSNR and the correlation factor $\rho$ ($\alpha \ast NC$) which is given as

\[ \text{Fitness function} = \text{PSNR} + 100 \ast \rho \]

where, PSNR=10log $\left( \frac{\text{MAX}_i^2}{\text{MSE}} \right)$, Mean squared error between original and watermarked image and $\text{MAX}_i$ = the maximum pixel value of the image is 255 in the result. since pixels were denoted by using 8 bits per sample.

The flow-chart of the methodology is illustrated in Fig. 4.

4. Experimental results

In this section, we have displayed experimental results obtained on the “bike” and “cherry” images as in cover image is bike.jpg as shown Fig. 5 and embedding watermark image cherry.jpg as shown Fig. 6. The proposed scheme is effective compared to GA-DWT in terms of MSE and PSNR. Which is observed from Table-1. The robustness of proposed technique is evaluated under various attacks on
watermarked image. In the presence of attacks, the proposed scheme is performed well as depicted in Table-2.

![Diagram of watermark embedding and extraction process using DWT](Image)

**Fig 4:** Watermark embedding and extraction Process using DWT

![Original Image](Image)

**Fig.5:** Original image

![Watermark Image](Image)

**Fig.6:** Watermark image

**Table 1:** Proposed Technique

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Algorithm</th>
<th>MSE</th>
<th>PSNR</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>GA-3 level DWT</td>
<td>0.0332</td>
<td>34.2261</td>
<td>0.2042</td>
</tr>
<tr>
<td>2.</td>
<td>GWO-2 level DWT</td>
<td>0.0024</td>
<td>61.1483</td>
<td>0.2086</td>
</tr>
</tbody>
</table>

**Table 2:** Proposed watermarking Technique with attacks

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Attacks</th>
<th>MSE</th>
<th>PSNR</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Without</td>
<td>0.0024</td>
<td>61.1483</td>
<td>0.2086</td>
</tr>
<tr>
<td>2.</td>
<td>Compression with q=90</td>
<td>0.0174</td>
<td>41.1765</td>
<td>0.2086</td>
</tr>
</tbody>
</table>
### 3. Compression with q=80  
0.0195 40.0417 0.2086

### 4. Compression with q=50  
0.0247 37.7024 0.2086

### 5. Compression with q=30  
0.0292 36.0357 0.2086

### 6. Salt and pepper (0.001)  
0.0218 38.9543 0.2086

### 7. Salt and pepper (0.005)  
0.0514 30.3668 0.2086

### 6. Conclusion

This paper address a novel GWO-DWT watermarking Scheme. The visibility factor for watermarking scheme is optimized using GWO algorithm. The DWT-GWO technique is efficient and better over DWT-GA scheme as shown in Table 1. The adequacy and efficacy of DWT-GWO is evaluated in the presence of various attack on the watermarked images as depicted in Table 2. In future, this work will be extended with the new evolutionary optimization technique for acquired robust value of visibility factor.

### REFERENCES


