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Robust Digital Image Watermarking based on Hybrid DWT and GWO Optimization Technique

Priyanka Panwar, Ruchi Sharma
Department of Electronics and Communication Engineering VGU University, Jaipur, India.

ABSTRACT
This paper proposes a novel optimization method for digital images in the Wavelet Transform (DWT) domain. Digital image watermarking has demonstrated its proficiency in ensuring illegal confirmation of data. The visibility factor of the watermark is the huge parameter that helps in enhancing the perceptual transparency and robustness of watermarking system. The trade-off between the transparency and robustness is considered as an optimization problem and is explained by applying GWO Optimization technique. The Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), and computational time are evaluated for an arrangement of images using the MATLAB R2014b software.

Keywords: Computational Time, DWT, GWO, MSE, PSNR, Robustness, Transparency,

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I. INTRODUCTION

Digital watermarking is one among the several protection methods which embeds a secret The requirement for digital image copyright protection methods has turned into a crucial substance in multimedia applications because of the quick development of unauthorized access and propagation of original digital objects like sound, video and images. Accordingly multimedia data protection is one of the major challenges and has drawn the consideration of a several researchers towards the improvement of protection approaches. Digital watermarking is one among the several protection strategies which inserts a secret message or important data (watermark) within a host image,[3] video or an audio to keep from unapproved access. The watermark can either be a random signal, an association's trademark symbol, or a copyright message for copy control and verification [2].

Embedding information in a robust and reliable way has lead to the application of frequency domain techniques like discrete cosine or the discrete wavelet transforms. The watermarks are added to the transform coefficients of the image as opposed to adjusting the pixels, therefore making it hard to expel the embedded watermark. All things considered, robust watermarking in spatial domain can be achieved at the cost of explicitly demonstrating the local image characteristics. However, these highlights can be obtained with much ease in the frequency domain.

The two major properties – robustness and imperceptibility are basic in saving the security of images from unapproved utilization. The capacity to detect the watermark image after use of common signal processing distortions is known as robustness. The embedded watermarks are imperceptible both perceptually as well as statistically and do not modify the appeal of the multimedia content that is watermarked. While embedding the watermark into the host image, the strength is kept up without considering the local distribution of the host image. Because of this, specific unnecessary recognizable objects show up in the smooth regions. These deformations decrease as the watermark quality or the visibility factor is diminished. Amid this procedure, be that as it may, the robustness cannot be accomplished. Consequently the watermark must be perceptually formed with reasonable amplification values for DWT sub-bands. The decision of amplification factors can be seen as an optimization problem and tackled using Genetic Algorithm.

M. Ketcham et al., [9] have proposed an inventive DWT watermarking scheme in view of Genetic Algorithms for audio signs. The optimal localization and intensity were obtain using GA and the strategy was discovered robust against editing, low pass filter and additive noise. Ali Al-Haj et al. [11] described an imperceptible and robust digital image watermarking scheme based on a combination of DWT and DCT. Thus, Franco et al.[5], gave a DWT based method for evaluation of fidelity and robustness. These algorithms were equipped for separating the watermark however experienced the issues of unsuitable values of fidelity and robustness to different attacks concentrated in these papers. Zhicheng Wei et al [10] proposed an algorithm that yielded a watermark that is imperceptible to human eyes and robust to different image controls, and the outcomes demonstrated that exclusive some particular positions were the best choice for embedding the watermark. The authors applied GA to train the frequency set for inserting the watermark and compared their approach and the Cox's method [8] to demonstrate robustness. The analysis of GA was limited to JPEG compression attack in this method. In [9], proposed a scheme that does not require the original image on the grounds that the data from the shape particular points of the original image were been memorized by the neural network. This scheme applies the shape particular point's technique and highlights point matching method by genetic algorithm for opposing geometric attacks. In [7] proposed another flexible and effective evaluation instrument based on genetic algorithms to test the robustness of digital image watermarking techniques. Given an arrangement of possible attacks, the method finds the most ideal un-watermarked image in terms of Weighted Peak Signal to Noise Ratio (WPSNR). [11] Proposed an inventive watermarking scheme based on genetic algorithms (GA) in the transform domain considering the watermarked image quality.

In this paper GWO is utilized to adaptively optimize the watermark visibility factor at each chosen DWT sub-band that will enhance the intangibility and robustness of the watermark. The proposed technique uses the standardized correlation of the cover image and the watermarked images as the reason for evaluating the fitness function. The fitness function fills in as the objective function that will be streamlined and looks through the population comprising of appropriate embedding locations of the watermark within the cover image.

II. DIGITAL IMAGE WATERMARKING

The concept of digital image watermarking is to include a watermark image into the host image to be watermarked such that the watermark image is unobtrusive and secure, which is capable of recovering mostly or totally using proper cryptographical measures.

2.1 WATERMARK EMBEDDING

Let the image to be watermarked be initially decomposed through DWT into two levels. Let B_l^x denote the sub-band at level = 0,1,2,3 and the orientation x ∈ {0, 1, 2,3} as shown in Fig.1.

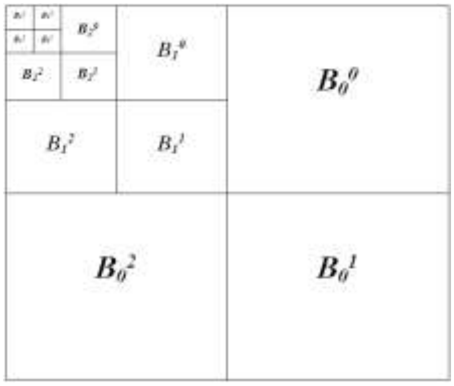


Fig.1. Decomposition of an image into two levels through DWT technique

The watermark is inserted into the three detail bands at level 0 by modifying the wavelet coefficients. The choice of inserting the watermark into this level was based on experimental tests such that the robustness and invisibility are compromised. The result of insertion is poor, resulting in a low robustness, but given the low visibility of disturbs added, a higher watermark amplification factor is allowed thus compensating for the high fragility.

The watermark information of dimension M1 x M2 is transformed into a unidimensional antipodal sequence d(i,j) ∈ {+1,-1}, where M1 and M2 indicate the number of rows and columns. The input image is decomposed into two levels and all the obtained wavelet coefficients at the chosen sub band are divided into n segments such that n = M1M2. The average value of each segment is computed and removed from all of the wavelet coefficients to facilitate the embedding process. The sub band coefficients are then modified according to,

$$\tilde{B}_l^x(i, j) = \tilde{B}_l^x(i, j) + \alpha w^x(i, j) d^x(i, j)$$

where, α is the global parameter representing the watermark amplification and w^x(i,j) is the weighting function that considers the local sensitivity of the image to noise. The weighing function is chosen such that, w^x(i,j) = q_l^x(i,j)/2 where q_l^x((i,j) is the quantization step for a DWT coefficient at location (i,j). Disturbs having a greater value than q_l^x(i,j)/2 are expected recognizable and those beneath are most certainly not. This sort of an approach permits to add each DWT coefficient to the maximum unperceivable watermark level [5]. The IDWT process is then applied to the DWT transformed image including the altered sub bands to create the watermarked host image.

All watermarks contain some critical data, so watermark can't be put away in the file header since anybody from the PC can get the digital editing and would have the capacity to change over the fundamental data and can expel the watermark in the meantime. Thus, the watermark should be embedded to the multimedia signals.

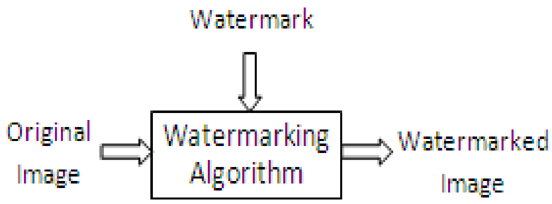


Fig 2: Watermark Embedding Process

2.2 WATERMARK DETECTION

The DWT approach applied is a blind process and consequently does not require the original image for watermark detection. The DWT is applied to the watermarked image and the sub band to which the watermark was embedded is chosen. The correlation between the original watermark and the extricated watermark is then processed as

$$\rho = \frac{\sum_{i=1}^{N} I.I'}{\sqrt{\sum_{i=1}^{N} I.^2}\sqrt{\sum_{i=1}^{N} .I'^2}}$$

where *I* and *I'* represent the original and, the extracted watermarks respectively. Each of the computed correlation value is then contrasted with a mean correlation. In the event that the computed value is more prominent than the mean then the extracted watermark bit is considered as 0, else if the computed value is lesser then it is taken as 1 [11]. Finally the watermark image is reconstructed using the extracted bits and the likeness between the original and the watermarked image is determined.

Original multimedia and watermark are the inputs to the algorithm. The watermarked data or image is the product by the algorithm which comprises of the secret key and the original data. Properties of a watermark depend on the applications to be used. The most critical necessity for a good digital watermarking scheme can be summarized as:

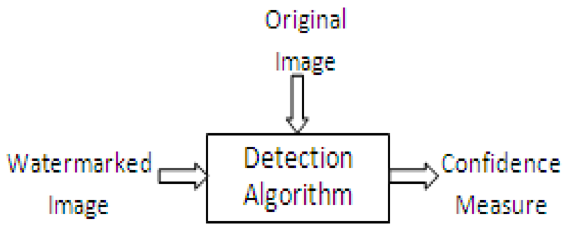


Fig 3: Watermark Extraction Process

Grey Wolf Optimizer (GWO)

A. *About Grey Wolf*:

Grey wolf optimization is a new Meta heuristic algorithm proposed for solving many multi model functions. It's inspired by grey wolves. Four types of grey wolves such as α, β, δ, and ω are employed to derive the leadership of hierarchy of grey wolves. The main steps are hunting, searching for prey, encircling prey and attacking prey.

B. Wolf behavior in nature:

Social behavior:

Hierarchy exits in pack . α is the leader and decision maker. β and δ assist α in decision making. Rest of the wolves(ω) are followers.

- *Encircling prey:*

As mentioned above, grey wolves encircle prey during the hunt. In order to mathematically model encircling behavior the following equations are proposed:

Where:

t- Indicates the current iteration,

$\vec{A}$ & $\vec{C}$ - are coefficient vectors,

$\vec{X}_P$ - is the position vector of the prey,

$\vec{X}$ - indicates the position vector of a grey wolf.

The vectors $\vec{A}$ and $\vec{C}$ are calculated as follows:

$$\vec{A} = 2\vec{a} \cdot \vec{r}_1 - \vec{a}$$

$$\vec{C} = 2 \cdot \vec{r}_2$$

……. (2)

where components of $\vec{a}$ are linearly decreased from 2 to 0 over the course of iterations and r_1, r_2 are random vectors in [0,1]

- *Hunting behavior:*

Group hunting behaviour is of equal interest in studying optimization.

A. Tracking, chasing, and approaching the prey.
B. Pursuing, encircling, and harassing the prey until it stops moving.
C. Attacking the prey.

We save the first three best solutions obtained so far and oblige the other search agents (including the omegas) to update their positions according to the position of the best search agent. The following formulas are proposed in this regard.

$$\left.\begin{aligned} \vec{D}_{\alpha} &= \left|\vec{C}_1 \cdot \vec{X}_{\alpha} - \vec{X}\right| \\ \vec{D}_{\beta} &= \left|\vec{C}_2 \cdot \vec{X}_{\beta} - \vec{X}\right| \\ \vec{D}_{\delta} &= \left|\vec{C}_3 \cdot \vec{X}_{\delta} - \vec{X}\right| \end{aligned}\right\} \quad \text{.......(3)}$$

$$\left.\begin{aligned} \vec{X}_1 &= \vec{X}_{\alpha} - \vec{A}_1 \cdot (\vec{D}_{\alpha}) \\ \vec{X}_2 &= \vec{X}_{\beta} - \vec{A}_2 \cdot (\vec{D}_{\beta}) \\ \vec{X}_3 &= \vec{X}_{\delta} - \vec{A}_3 \cdot (\vec{D}_{\delta}) \end{aligned}\right\} \quad \text{.......(4)}$$

$$\vec{X}(t+1) = \frac{\vec{X}_1 + \vec{X}_2 + \vec{X}_3}{3} \quad \text{.......(5)}$$

C. Advantages over other techniques:

Easy to implement due to simple structure.

Less storage requirement than the other techniques.

Convergence is faster due to continuous reduction of search space and Decision variables are very less (α, β and δ).

It avoids local optima when applied to composite functions also.

Only two main parameters to be adjusted (a and C).

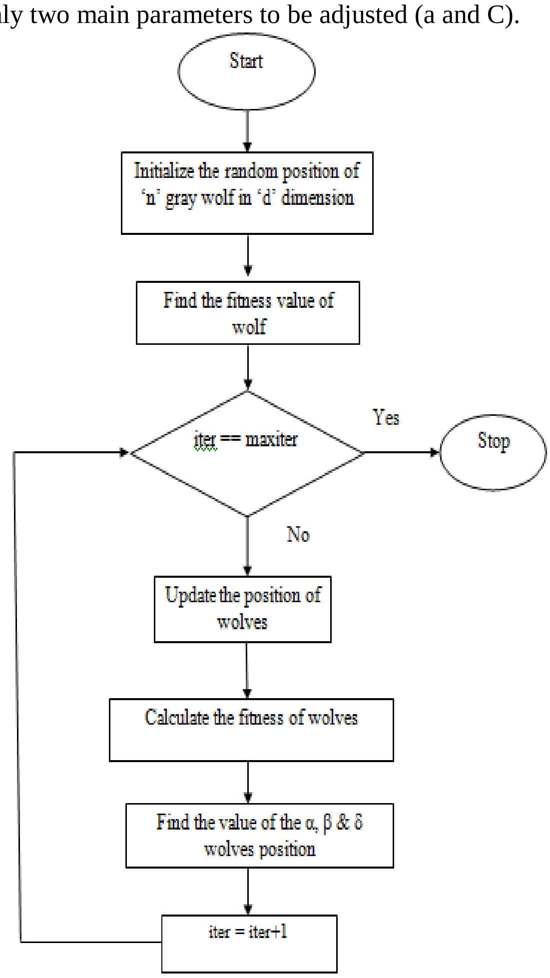


Fig. 3: Flowchart of GWO algorithm

III. IMPLEMENTATION

In digital image watermarking, the population is instated by choosing an arrangement of random positions in the cover image and embeddings the watermark image into the selected positions. The ideal answers for digital watermarking using DWT are acquired based on two key factors: the DWT sub-band and the value of the watermark amplification factor [11]. The GWO algorithm searches its population for the most ideal arrangement with all possible combinations of the DWT sub-bands and watermark amplification factors. The genetic algorithm methodology will attempt to locate the particular sub-band that will give concurrent perceptual transparency and robustness. So as to enhance the robustness of the algorithm against attacks, the watermark strength or the amplification factor α ought to be improved, yet this factor differs on each sub-band.

The objective function also known as the fitness function is a combination of the Peak Signal to Noise Ratio (PSNR) and the correlation factor ρ (α * NC) and is given as,

Fitness function = PSNR + 100 * ρ

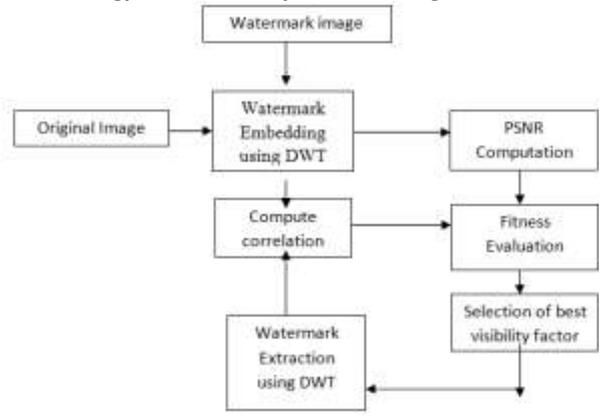
Where, PSNR is computed as,

$$\text{PSNR}=10\log\left(\frac{MAX_i^2}{MSE}\right)$$

Where, MSE denotes the mean square error between the original and watermarked image and MAXi = the maximum pixel value of the image which is generally 255 in the experiment since pixels were represented using 8 bits per sample.

Here, the correlation factor is the product of Normal Correlation (NC) and the watermark strength factor α. The fitness function increments proportionately with the PSNR value, however NC is the key factor adding to the robustness and eventually, the fitness value increments with the robustness measure. The correlation factor ρ has been increased by 100 since its normal values fall in the range 0 ~ 1, where as PSNR values may achieve the value of 100.

The fitness function is evaluated for every one of the people in the population and the best fit individual alongside the comparing fitness value are obtained. Genetic operators like crossover and mutation are performed on the chosen parents to produce new offspring which are incorporated into the population to shape the people to come. The entire process is repeated for a few generations until the point when the best arrangements are acquired. The correlation factor ρ measures the similarity between the original watermark and the watermark extricated from the attacked watermarked image (robustness). The technique for executing digital image watermarking using GA is demonstrated as follows. The flow chart of the methodology is additionally shown in Fig.4.



IV. EXPERIMENTAL RESULTS:

Original image is bike.jpg as shown fig. 4.

Fig.5: Original image

Embedding watermark image cherry.jpg as shown fig. 5.

Fig.6: Watermark image

Table 1: Proposed watermarking Technique

S.No.	Algorithm	MSE	PSNR	Alpha
2.	**GWO- 2 level DWT**	**0.0024**	**61.1483**	0.2086

IV. CONCLUSION

This work gives Digital image watermarking based on 2 Level Discrete Wavelet Transform (DWT) with GWO, table1 demonstrates the effectiveness of proposed technique as PSNR and MSE.

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