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A Robust Watermarking Technique Based On Hybrid PSO

Parvinder Singh, Sheetal Khokhar

Abstract: **This paper presents a robust image watermarking technique usingWeight ImprovedParticle Swarm Optimization. The concept of WIPSO makes the technique intelligent because the watermark is embedded into the image adaptively, depending on the test image. Significant difference of wavelet coefficients quantization method has been used for embedding watermark that provides robustness and makes the technique blind. The watermark is embedded in the predetermined bit plane in the given lower frequency sub bands by adjusting the values of the wavelet coefficients. Hybrid of Particle Swarm Optimization (PSO) gives more promising results than PSO.**

*Keywords:*Watermark, WIPSO, Significant coefficients, Fitness function.

I. Introduction

Though digital data is widely used for exchanging information over network and today all the service providers provide their services in digital form but still there exist some security issues that prove to be fatal when it comes to a safe and authorized communication. These issues are related to unrestricted duplication and dissemination of copyrighted materials. Owners of original data fear of unauthentic distribution of their data. In order to deal with such issues watermarking comes to aid. Watermarking is a technique to hide some authorized marker in todigital data that is imperceptible to the viewer [1]. This marker is usually some logo, signature or some secret information that proves the ownership of the host data.

Parvinder Singh, Sheetal Khokhar
Dept. of Computer Science,
DCRUST, Murthal

Several techniques have been proposed for multimedia protection ([2]-[12]).

Wang et al. [13] proposed a watermarking technique based on significant difference of wavelet coefficients quantization (SDWCQ) that was given by Lin et al. [14]. In addition authors used concept of particle swarm optimization to optimize the fitness function. All the three sub bands, HH3, LH3 and HL3, have been used to embed the watermark. But in this papersub bands of different levels are used for embedding purpose i.e., HH3, HL2 and LH2. Embedding watermark on different bit-planes enhances robustness of fragile watermark [15].This paper proposes a technique based on SDWCQ which uses WIPSO, a hybrid of PSO, to optimize the fitness function.

II. PSO and WIPSO

A. *PSO*

Particle Swarm Optimization (PSO) is an evolutionary computation model that was introduced by Kennedy and Eberhart in 1995 [16]. This model is inspired by birds' swarm behavior. PSO is an intelligent optimization algorithm. Every particle of the swarm moves iteratively in such an order that it finds its best position using its own best experience and best experience of the whole swarm. Each particle updates it position and velocity according to following equations.

$$v_{mn} = w \times v_{mn} + c1 \times rand(\ ) \times (p_{mn}^{best} - x_{mn}) + c2 \times rand(\ ) \times \left(p_{gmn}^{best} - x_{mn}\right) \quad (1)$$

$$p_{mn} = p_{mn} + v_{mn} \quad (2)$$

Here w denotes the inertia weight, x_{mn} is the current position. v_{mn}denotes moving distance of the particle in one step. rand() is a random number function and its value is between 0 and 1. c1 and c2 are constants. p_{mn}^{best} is the best position for p_{mn}. p_{gmn}^{best} is the global best position. Eq.(1) is used to update the velocity of the particle and position is updated using (2).

B. WIPSO

Weight Improved Particle Swarm Optimization is based on the improved function of weight parameter. It bears an advantage over PSO that its convergence speed is faster [17]. To get the better solutions the PSO is improved by adjusting weight parameter, social and cognitive factors.

$$c1 = c1_{max} - \left(\frac{c1_{max} - c1_{min}}{maxit}\right) \times itr \quad (3)$$

$$c2 = c2_{max} - \left(\frac{c2_{max} - c2_{min}}{maxit}\right) \times itr \quad (4)$$

$$w = w_{max} - \left(\frac{w_{max} - w_{min}}{itr}\right) \times (maxit) \quad (5)$$

$$w^{new} = w_{min} + w \times rand\_num \quad (6)$$

w_{max}, w_{min}: initial and final weights,
$c1_{max}$, $c1_{min}$: initial and final cognitive factors,
$c2_{max}$, $c2_{min}$: initial and final social factors,
maxit: maximum iteration number,
itr: current iteration number,
rand_num: random number between 0 and 1.

Velocity update equation for WIPSO can be written as follows.

$$v_{mn} = w^{new} \times v_{mn} + c1 \times rand(\ ) \times (p_{mn}^{best} - x_{mn}) + c2 \times rand(\ ) \times (p_{gmn}^{best} - x_{mn}) \quad (7)$$

Here a new value of weight (w^{new}) is used in each iteration. This new value of weight is calculated using (6).

III. The Proposed Method

Embedding algorithm

Watermark is a sequence of bipolar bits and each bit is embedded in to a randomly chosen block of coefficients of sub bands from predetermined bit plane.The coefficients of wavelets from sub bands HH3, HL2 and LH2 are divided in to blocks of seven. These groups are randomly chosen using a seed as suggested in [14]and as many blocks are chosen as there are number of watermark bits. Random selection enhances the security. Embedding of watermark is done in different bit planes of the original image because it increases invisibility of the watermarked image and the robustness of the watermark. Embedding data in these sub bands of different levels provide better robustness as compared to embedding in sub bands of same level [13]. SDWCQ technique is used for embedding purpose. Significant difference of each selected group is calculated using significant coefficients. These coefficients are then quantized using following equations. If significant difference is greater than average significant difference then largest coefficient (max_t) is quantized with (8), otherwise with (9).sec_t is the second largest coefficient of the block.

$$max_t^{new} = \begin{cases} max_t + T_t, if(max_t - sec_t) < \Delta \\ max_t,\ if((max_t - sec_t) \geq \Delta \end{cases} \quad (8)$$

$$max_t^{new} = sec_t \quad (9)$$

Δ is the average of the significant differences of all the N_w blocks.$\mathrm{max_t}$ and $\mathrm{sec_t}$ are the significant coefficients.

T_t is a variable threshold value that is calculated using PSO in [13]. But here this variable value is calculated using WIPSO.Optimal value of threshold is calculated from the fitness function [18].

A parameter y is used as a decision value during extraction process and is calculated as

$$y = floor\left(\frac{1}{N_w \times \alpha} \sum_{q=1}^{N_w \times \alpha} \varphi_q\right) \quad (10)$$

Where $\varphi_1 \leq \varphi_2 \leq \varphi_3 \ldots \leq \varphi_q$ are ordered significant differences, $0 \leq \alpha \leq 1$ and is sensitive to the ratio of two kinds of binary bits in watermark. Extraction of watermark is done using following equation.

$$w_p = \begin{cases} 1 & if(max_t' - sec_t') \geq y \\ 0 & otherwise \end{cases} \quad (11)$$

Here $\max_t'$ and $\sec_t'$ are the significant coefficients of the watermarked image. If significant difference in received image is greater than y then watermark bit is taken to be 1, otherwise the bit is 0.

Normalized Correlation Coefficient (NC) is a factor that is used to measure the robustness of the watermark. Its value lies between 1 and -1. Higher the value of NC, more robust is the watermark. It is calculated using following equation,

$$NC(w,w') = \frac{1}{N_w}\sum_{t=0}^{N_w} w_t \times w_t' \quad (12)$$

$w_t$is the embedded watermark bit and w_t' is the extracted watermark bit from the watermarked image.

Fitness function is defined using image quality parameter and robustness factor. It is defined as

$$\rho = \emptyset + \sum_{q=1}^{3} \tau_q \quad (13)$$

Here ρ is the fitness function that is optimized using WIPSO. $\emptyset$defines quality of watermarked image i.e. PSNR and τ is the NC factor. In (12) each τ corresponds to NC values in three attacks namely average filter 5×5, median filter 5×5 and cropping ¼.

PSNR of a watermarked image gives measure of its quality. High value of PSNR means less amount of noise is present in the original image.

$$\emptyset = \frac{PSNR}{100} \quad (14)$$

$$PSNR = 10 \times log_{10}\frac{255\times255}{MSE} dB \quad (15)$$

$$MSE = \frac{1}{H\times W}\sum_{x=0}^{H-1}\sum_{y=0}^{W-1}[o\_image(x,y) - w\_image(x,y)]^2 \quad (16)$$

Here $o\_image(x,y)$ is the pixel value of the original image and $w\_image(x,y)$ is the pixel value of watermarked image. H and W are height and width of the image respectively.

PSNR value is divided by 100 in order to make it comparable with NC values to use in (13). When the fitness function is optimized using WIPSO, it provides better results than PSO. Social and cognitive factors are initialized and weight factor keeps on changing iteratively. The convergence speed of the algorithm is faster. A suitable value of T_t is calculated that depends on the significant difference as well as host image.

IV. Experimental Results

A number of attacks [19](geometric and non-geometric) are simulated over the watermarked image to check its robustness and invisibility of watermark is also checked by calculating PSNR values. Experimental results show that proposed technique outperforms the existing technique that is proposed in [13]. Social factors are initialized to 1.5 and 2.1. Cognitive factors are set to 1.2 and 2.2. Maximum and minimum values of weight are also initialized to 0.9 and 0.4 respectively. 100 iterations are carried out with population size of 50. Test images are obtained from online image database [20]. Experiments are performed on images of size 1024 x 1024. Watermark is taken to be binary with size 64 x 64 bits. NC values of watermark from proposed technique, under different attacks, are compared to the results of existing technique. Figure 1(a)-(c) show original image, watermarked image using existing technique and watermarked image using proposed technique. Figure 2(a)-(c) show the images for watermark. Figure 3 shows the comparison between PSO and WIPSO in terms of search space. Search space of WIPSO is wider than PSO due the improved use of weight factor. Hence convergence speed is faster and solutions are better by using WIPSO.

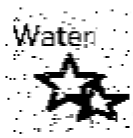
(a) (b)

(c)

Figure 1:Man images (a) Original image, (b) Watermarked image using technique in [13] and (c) Watermarked image using proposed technique.

(a)

(b)



(c)

Figure 2: Watermark images (a) Embedded Watermark, (b) Extracted watermark using technique in [13] and (c) Extracted watermark using proposed technique.

Table 1 shows the PSNR values comparison for various images using existing and proposed techniques. Table 2 presents the robustness comparison of various attacks on a host image in terms of NC factor.

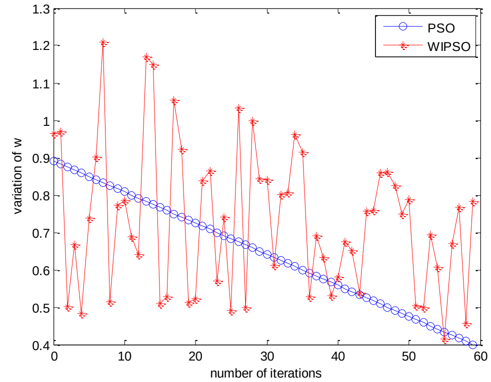


Figure 3: Comparison in variation of inertia weight factor in PSO and WIPSO.

V. Conclusion

When an image is transmitted over the network then it is unavoidable that the image is tampered by communication noise. In this paper we give a technique that enhances the tolerance of image to various malicious attacks.Simulation results show that proposed technique is an improvement over existing technique using PSO. WIPSO outperforms the PSO because it considers the weight factor that influences convergence speed and accuracy of the solution. WIPSO gives faster and better solution. Secondly, the embedding of watermark in sub bands from different levels provides more robustness to the watermark and also increases the invisibility of watermark in the host image.

Table 1. PSNR values comparison for different images

Technique / Test image	Wang [13]	Proposed
Airport	42.73	45.72
Man	42.26	44.57
Bridge	40.48	42.73
Truck	43.30	46.16
Map	39.32	41.93

Table 2. Comparison of N C values under various attacks.

Attacks / Tech.	Salt & pepper noise	Cutting	Rotation	Histogram equalization	Median filtering
	.8%	One corner	0.25 degree		3 x 3
Wang [13]	0.58	0.87	0.52	0.76	0.62

Proposed	0.68	0.92	0.55	0.81	0.68

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