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Particle Swarm Optimization and Discrete Wavelet Transform based Robust Image Watermarking

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Abstract

Objectives: Watermarking technique on digital images with improved robustness and with optimum results can be achieved by using the intelligent technique Particle Swarm Optimization (PSO). Discrete Wavelet Transform (DWT) is used to uncover perceptually significant coefficients from the digital image. **Methods:** PSO is one amongst the efficient techniques in optimizing a problem having many numbers of candidates. This robust technique consists of two stages namely embedding and extraction stages. Insertion of watermark into the image is done at the embedding stage. Before embedding watermark into the image perform DWT and select any one of the bands LL, LH, HL and HH. Initially select the coefficients randomly and the optimal DWT coefficients for embedding the watermark at various positions are identified by PSO. **Findings:** In watermark extraction stage, the embedded watermark is identified by doing the reverse process. Robustness of the digital image watermarks implies the strength of the watermark against various image processing attacks and this can be checked by evaluating Cross Correlation value that is Normalized (NCC) and for fidelity Peak Signal to Noise Ratio (PSNR). It is evident that the robustness of the image is well maintained by this technique. As a further improvement any of the other intelligent technique namely Ant Colony Optimization can be used for optimization evaluation. **Applications:** Digital image watermarking plays a vital role in copyright infringement issues and it helps in predicting the authorized user by the digital signature that is watermarked in the image.

Keywords: Discrete Wavelet Transform, Fidelity, NCC, Particle Swarm Optimization, PSNR, Robustness, Watermarking

1. Introduction

The consequence of watermark has come into existence since the advancement of digital media or content throughout the world. As further improvement these digital media have started delivering through the internet over the peer end communication medium in its own way without any security at the earlier stages. After going through various commemorations these digital contents were delivered in a secured manner over the internet by encrypting. Although they are protected by various methodologies[1] the contents were easily been taken away by unauthorized persons and reproduced or reused by hacking or cracking the encrypted contents. Thus the copyright encroachment[2] occurs which widely caused many problems who really own the content. In order to prevent the digital content to be reused by unauthorized persons new approach called watermarking came into extensive practice. Watermarking is considered as an art of hiding the information related the digital content or the owner of the content in the media[3]. By doing so, copyright protection has been successfully implemented.

1.1 Watermarking

Watermarking plays a vital role in this upcoming era since the world has been digitized in many ways and aspects. In order to make definite of the proprietary of the digital media it is necessary to put out of sight the copyright information, owner details or serial numbers into digital media. Copyright infringement issues were created over internet after the exchange of information digitally.

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In order to put a stop to this problem the digital content contributor had to be in passionate concern not to deliver information without any authority. Hence digital watermarking came into picture to get to the bottom of this issue[4]. Watermarking on digital image is the technique of entrenching[5] the copyright messages or the owner information or the information related to the digital media into it which can be extracted to reveal the identity of the owner in a while. This process is described in the Figure 1. Watermarking can either be visible or invisible[6] to the external users.

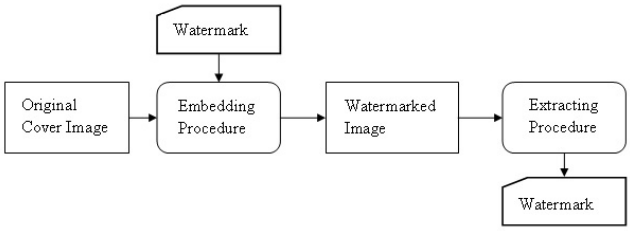

Figure 1. Overview of the watermarking procedure.

1.2 Particle Swarm Optimization

This is an intelligent computational method that produces optimal solution to different problems. This stochastic swarm intelligence is a population related optimization methodology which is initialized with a set of random population. PSO[6] generates the optimum solution after several generations of keep informing the velocity and the position of the particles (population set). PSO concerns with changing the velocity of the particle over the search space towards its pbest and lbest. At every generation individual particles will have its own lbest and gbest value. By keeping track of this gbest and pbest values each individual particles travel towards the optimum result in the search space. PSO shares the information such as gbest, pbest, updated velocity and position to each and every single particle in the search apace. The Formula 1[7] given will describe the updating process of the velocity of each particle over the search space in order to reach the optimum point.

$$V_i(t+1) = \alpha\, V_i + \text{const1}^* \text{ random } * (\text{pb}(t) - x_i(t)) + \text{const2} * \text{random} * (\text{gb}(t) - \text{xi}(t)) \quad (1)$$

Where $V_i(t+1)$ is the updated velocity and α is the search space control parameter called inertia weight. Const1 and const2 are the acceleration constants called cognition and social components which are usually set to 2 respectively. Finally pb is the best known solution of the particle which is achieved so far and gb is known as global best value known by all particles in the search space.

$$P_k(n+1) = P_k(n) + V_i(n+1) \quad (2)$$

The mentioned Formula 2 is used for updating the particle's position accordingly in the provided search space where $X_i(t+1)$ is the updated new position of the particle. In general, PSO is considered to have more similarities in its own way to that of the evolutionary computation techniques such as Genetic Algorithm (GA). They both start with an initial random group of population set and proceeds further with n number of iterations. These population set make the most use of fitness function to evaluate it against each other particle. With the help of random technique these population set searches for the optimum and tend to support local searching of particles with large inertia weight.

In have anticipated a method for digital image watermarking in the Discrete Wavelet Transform (DWT). By applying GA they tried to solve the trade off between the transparency and robustness and taking them into account as an optimization problem. Their work yields a low robustness but with higher value of invisibility. In their paperwork had proposed a novel invisible watermarking technique using hybrid HWT and GA. The novelty has been proved by the selection of optimum coefficients using the genetic algorithm and Haar Wavelet Transform. Using this hybrid optimization technique the imperceptibility has been improved on various kinds of images by embedding the watermark at both the horizontal and vertical coefficients after evaluating them. In they have proposed a technique which embeds the watermark into each block of the image after performing the DWT. Using Genetic Algorithm the robustness has been improved but embedding of watermark statically has degraded the fidelity to a greater extent. Because of the usage of block based DWT there are many design constraints in using the Genetic Algorithm. In[8] proposed a novel Hybrid PSO, namely (HPSO) technique in order to solve the problem of premature convergence by merging both the natural selection and mutation operator. HPSO improves the performance of easily broken watermarking based on DCT which consequences in enhancing both the eminence of the extracted watermark and watermarked image. In[9]

have made a study about the digital image watermarking technique. This study helps in understanding the visible and invisible watermarking techniques as well as the performance of the watermarking procedure towards various attacks. In[10] have proposed Nature Inspired Algorithms NIAs that need to be examined more in detail and that has to be preserved safely. By using GPSO the watermark embedding has been made easier but the robustness of the watermark was not mainly concerned. Though GPSO renders more efficient and optimum points the fidelity and imperceptibility was not improved to a greater extent. From the paper[11] it is mentioned that the proposed methodology does not have need of the original cover image because their space information will be recorded prior and this information will be stored in the Neural Network. They have proposed a matching algorithm for this space information and the feature points in order to put a ceiling to the geometric attacks. The fuzzy-Neuro system yields a better result when considering the PSNR values. In[12,13] they have provided information regarding the video watermarking techniques for improving the security while transmitting through internet. Though for higher threshold values the robustness and fidelity values are higher.

2. Proposed Methodology

A robust technique was proposed which combines the Discrete Wavelet Transform and the Swarm Intelligent techniques (Particle Swarm Optimization). This technique renders better performance compared to the previous techniques.

2.1 Watermarking Procedure

The watermarking procedure involves the decomposition of the original cover image into its equivalent sub bands of frequency bands and the detailed bands with the help of Discrete Wavelet Transform. The coefficients obtained after the DWT were taken as input for the Particle Swarm Optimization technique. These DWT coefficients were considered as the particle in the search space and they update their velocity and position accordingly to find the optimum points essential for embedding the watermark. The watermarking procedure consists of two stages namely embedding (including watermark into the image) and extraction (getting the watermark and original image) stage. The overall procedure that was illustrated has been portrayed in a pictorial format in the Figure 2 which brings out the complete watermarking procedure with sample mimic pictures in it.

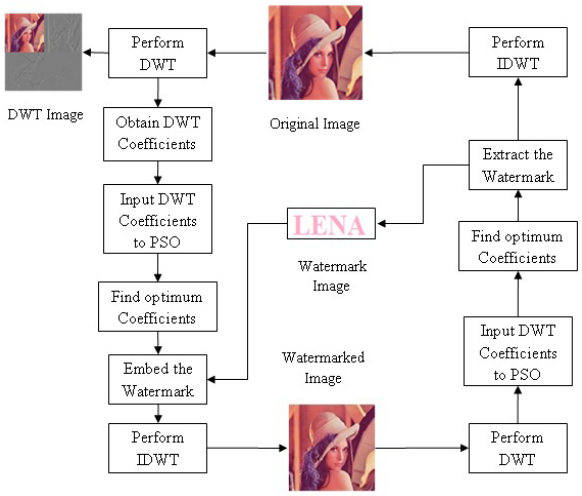

Figure 2. Procedure for watermarking process in an image.

2.1.1 Embedding Stage

The original image is processed by DWT and the obtained coefficients are given as input to the Particle Swarm Optimization technique which produces the optimal results. Embedding process takes place once the optimum solution has been identified.

Algorithm

- Partition the original image into sub bands by applying DWT.

$$y[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k]$$

- Obtain the DWT coefficients.
- Input these DWT coefficients to the Particle Swarm Intelligence algorithm.
- Update the position and Velocity of the particles (DWT coefficients) in the given population set:

$$V_i(t+1) = \alpha\ V_i + \text{const1}^* \text{ random } ^* (pb(t) - x_i(t)) + \text{const2} ^* \text{random} ^* (gb(t) - xi(t)) \quad (1)$$

$$P_k(n+1) = P_k(n) + V_i(n+1) \quad (2)$$

- Calculate the length (n) of the image that is to be watermarked.
- Find out n optimum points using the swarm intelligence (PSO) from the original image.

- Embed the watermark into the obtained optimum points of the original image
- Calculate PSNR value for original and watermarked images.

2.1.2 Extraction Stage

Extracting the watermark from the image with greater imperceptibility by applying the reverse steps of embedding stage is described here. Original cover image and the embedded watermark are retrieved. NCC value is computed for the extracted watermark and original image.

Algorithm

- Partition the obtained watermarked image interested in sub bands by applying DWT.

$$y[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k]$$

- Obtain the DWT coefficients.
- Input these DWT coefficients to the Particle Swarm Intelligence algorithm.
- Update the position and Velocity of the particles (DWT coefficients) in the given population set:

$$V_i(t+1) = \alpha\ V_i + \text{const1}^* \text{ random } * (pb(t) - x_i(t)) + \text{const2} * \text{random} * (gb(t) - xi(t)) \quad (1)$$

$$P_k(n+1) = P_k(n) + V_i(n+1) \quad (2)$$

- Compute the number of optimum points (n) that had been watermarked.
- Extract the embedded watermark that is present at the optimum points from the watermarked image.
- Compute the Normalized Cross Correlation value for the extracted watermark.

2.2 Robustness Evaluation

The error function and performance are continuously monitored by efficiently calculating the PSNR value and NCC value.

$$PSNR = 10\log_{10}\left(\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}(F(i,j))^2}{\sum_{i=1}^{N}\sum_{j=1}^{N}(f(i,j)-F(i,j))^2}\right) \quad (4)$$

Where,

- f (i, j) - initial image pixels.
- F (i, j) – watermark pixels of image at (i,j)th location.

$$NCC = \frac{\sum_{x=1}^{N}\sum_{y=1}^{N}(I(x,y)-IM)(I'(x,y)-I'M)}{\sqrt{\sum_{x=1}^{N}\sum_{y=1}^{N}(I(x,y)-IM)^2\sum_{x=1}^{N}\sum_{y=1}^{N}(I'(x,y)-I'M)^2}} \quad (5)$$

Where,

- I (x, y) – watermark pixels at (x, y)th location.
- I'(x, y) - watermarked pixel from extracted image.
- IM - mean value of initial image.
- I'M - mean value of the final image.

3. Results and Discussion

The watermark that has to be embedded in to the original cover image has been placed in to imperceptible pixel position. This has been achieved with the help of DWT. The optimum points chosen based on the swarm intelligence has rendered a greater effect in the context of watermarking. The optimum output obtained using PSO is shown in the Figure 3. Also from the below table it is evident that the images even after undergoing various kinds of attacks like scaling, cropping, additive noise, rotation etc. the quality of embedding the watermark has not been deviated. Table 1 shows the result yield by the GA method proposed by. Comparison between two methods was accomplished with the help of calculating and checking the MSE and PSNR values of the corresponding images. Table 2 provides the results of MSE and PSNR values obtained using PSO.

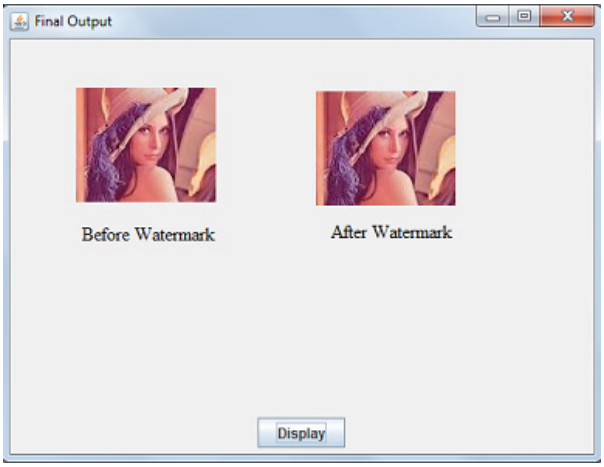

Figure 3. Final result of the watermarking process.

4. Conclusion

The use of Particle Swarm Intelligence in the watermarking process makes it efficient both in the embedding and

extraction phase. PSO technique for finding the optimum coefficients, along with DWT makes the watermark invisible in the image and robust to various watermark attacks in the image. Also this guarantees the imperceptibility of the image and this method outperforms various other techniques. From the experimental results it is evident that the robustness of the image is well maintained by this technique. For further improvement any of the other intelligent technique namely Ant Colony Optimization can be used for optimization evaluation.

Table 1. Robustness of images over various attacks using GA

	No. of Iterations	MSE values	PSNR values
Lena	10	3.3476	42.88347
Lena _ scaled	16	3.9899	42.12118
Lena _ cropped	32	4.1024	42.00042
Lena _ Rotated	34	4.2921	41.80411

Table 2. Robustness of images over various attacks using PSO

	No. of Iterations	MSE values	PSNR values
Lena	16	4.0339	25.8513
Lena _ scaled	20	2.3475	31.0891
Lena _ cropped	12	3.6991	25.4750
Lena _ Rotated	21	4.6138	26.4346

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