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Current Status: Comparative Analysis Of Optimization Techniques Used In Steganography Schemes

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Abstract: **Steganography has been used immensely in various fields to maintain the confidentiality and integrity of messages transferred via the internet. The need to hide messages has increased with the increase of fraudulent activities in the cyber space. To diminish the number of such cyber crimes a number of optimized and advanced steganographic schemes have been invented by researchers. This paper presents a comparative analysis among the various optimization techniques that have been applied to steganography to achieve better results in terms of quality, capacity and security of stego objects. All the results compared in this paper have been obtained from the application of optimization techniques on gray-scale images and 2- Least Significant Bit (2-LSB) substitution method .Optimization techniques compared in this paper include Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Genetic Algorithm (GA) and also hybrid optimization techniques like PSO-GA, PSO-ACO, GA-ACO. This paper also mentions which optimization technique is best suited for spatial domain image steganography, frequency domain image steganography, watermarking and security against steganalysis techniques based on the studies of research work done previously. The limitations of each optimization technique are provided in this work to help researchers decide which technique to apply in a specific steganography scheme to obtain best results.**

Keywords: **ACO, Frequency domain, GA, Optimization technique, PSO, Spatial domain, stego**

I. INTRODUCTION

Steganography is the method of hiding a file within another file to preserve the confidentiality and integrity of the hidden file from intruders or attacks while being transmitted from the sender's side[34] to the receiver's side[34]. The main emphasis in a steganography technique is that the deformity caused to the cover file due to addition of secret bits should be undetectable and the stego file should have enough potential to withstand attacks so that there is no loss of data during transmission and the intact message can be obtained at the receiver's side. To achieve this goal researchers have used various optimization techniques. An optimization technique selects the best possible solution out of a set of alternative solutions to a given problem based on certain criteria. This paper specifically compares the effect of optimization techniques applied to gray-scale image steganography scheme that used Least significant bit (LSB) substitution method for embedding the secret message. Image steganography can be of two types,[33] namely 1) Spatial domain image steganography and 2) Frequency domain image steganography. In spatial domain image steganography, least significant bit (LSB) positions of pixel values are replaced by bits of secret data directly in order to conceal the secret message in the cover file whereas in frequency domain image steganography the cover image is first transformed into frequency domain using transform methods like Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT) or other transform techniques. The secret bits are concealed in LSB of the frequency coefficients of the cover file.

II. RELATED WORK

Xiaoxia Li et al.[8] in 2007 proposed the encryption of the entire secret message using an optimal substitution matrix obtained using PSO. The method also used modified quantization table instead of standard JPEG quantization table to increase the capacity of the stego image. Saeid Fazli et al. [7] in 2008 improved the method proposed by Li, Wang by using unique optimal substitution matrix for each block of the cover image. Debnath Bhattacharyya et al.[31] in 2009 proposed a novel method DCTIASMTT for DCT[32] based Image authentication and secret message transmission scheme. In 2011 Feno Heriniaina et al.[6] proposed three distinct schemes to improve DCTIASMTT using PSO. In 2013 Punam Bedi et al.[4] proposed to use PSO in spatial domain image steganography to find the best pixel positions in the cover image to embed the secret message in it. P.Aswini et al.[11] in 2015 introduced a technique where the cover image was

preprocessed before hiding the secret message that was encrypted using PSO.

After embedding OPAP is used to enhance the quality. In 2012 K. Kuppusamy et al.[15] proposed an optimal watermarking scheme using PSO in daubechies4 transform. Watermark bits are DCT transformed. IQIM is used to measure the quality of the watermarked image with respect to contrast distortion, luminance distortion, loss of correlation. . Hung Hsu Tsai et al.[25] in 2012 proposed a blind watermarking technique using DWT and based on SVD and SVR. PSO was used to optimize the proposed scheme. Punam Bedi et al.[16]in 2012 applied PSO to biometric image watermarking. Hung Hsu Tsai et al. in the same year proposed a blind watermarking technique using DWT and based on SVD and SVR. PSO was used to optimize the proposed scheme. . Eduardo Vellasques et al. [17] in 2013 used PSO in fast intelligent watermarking scheme. The method is proposed for heterogeneous document images. Hung Hsu Tsai et al.[14] in 2013 proposed zero watermarking scheme with geometric invariants to secure the system against geometrical attacks using SVM classifier. the method used DFT and LPM for finding geometric invariants of images. To find optimal parameters of SVM, PSO was applied.

Ran-Zan Wang et al.[19] in 1999 presented the use of GA to find the matrix to encrypt the secret message in the cover file. Perceptual modeling was used for concealing the secret data. Chien-Chang Chen et al.[20] in 2007 proposed the use of GA to get the near optimal positions in the cover image to embed the secret image. The method is based on JPEG images. Lifang Yu et al.[23] in 2008 proposed the application of GA to enhance the performance of PM1 steganography scheme in JPEG images. Elham Ghasemi et al.[26] in 2012 proposed the use of GA in a wavelet transform steganography scheme. OPAP was used after embedding of secret message to reduce error. H. Ramezani et al.[28] in 2013 applied contourlet transform GA in a steganography scheme. GA was used to obtained an optimal mapping function. OPAP was employed after embedding the secret message to increase the capacity. Amrita Khamrui, et al.[3] in 2013 presented a DCT based image steganography with the application of GA. Authenticating message is concealed in 2nd and 3rd LSB positions each frequency coefficients except the first. DCT is applied to the sub mask of the cover image in 2x2 blocks. GA is applied to increase the security level of the stego image. M.Soleimanpour et al.[2] in 2013 proposed the use of GA to get a near optimum structure in spatial domain image steganography for the pair-wise LSB matching scheme. Based on GA a dual-state scoring model was structured to find a near optimum solution out of all the permutation orders. . Soumi C. G. et al.[27] in 2014 proposed to apply GA in mosaic image steganography. The mosaic image is imbedded in cover file based on the mapping sequence obtained by GA. The sequence is again permuted using KBRP. Hamidreza Rashidy Kanan et al.[18] in 2014 proposed a method to find the best pixel positions of the host image in spatial domain to conceal the encrypted secret message using GA. The best order of scanning the host image, the best suitable starting point of the scan and the best LSB positions are considered to increase the security, quality and capacity of the host image. Chin-Shiuh Shieh et al.[10] in 2003 proposed a GA based watermarking technique in the frequency domian where GA determines the DCT coefficients where the watermark is hidden in the original image. Frank Y. Smith et al.[9] in 2005 proposed a watermarking and compression method for medical images using GA. The regions of interest (ROI) in the medical image was compressed using lossless technique and the rest of the image was compressed using lossy compression technique. Water mark or other information was embedded around the (ROI) with the help of GA. Diego Sal Diaz et al. [24] in 2005 proposed a technique for enhancing semi-fragile watermark. It is based on the manipulation of image DCT and GA. The method simultaneously minimizes the robustness criteria and the distortion of the watermarked image. Zhicheng Wei et al. [21] in 2006 proposed a technique to improve the image spread spectrum watermark algorithm. The method worked in a 8x8 DCT domain and used GA to choose the AC coefficients for embedding the spread spectrum watermark. Shen Wang et al.[1] in 2010 proposed a steganography method based on GA that would secure the stego object from RS attack. The pixel values of the cover image after the secret message was embedded was modified with the help of GA in order to maintain their statistical characteristics. Amin Milani Fard et al. proposed a secure steganographic scheme based on OutGuess. The method uses OutGuess steganalysis technique and Maximum Absolute Difference for image quality is considered as fitness function of GA.

Khossro Fardad et al.[12] in 2008 proposed the hiding of secret message in the regions of interest of the cover file after transforming the image to frequency domian using DCT. The regions of interest are determined using ACO. Hamid Al-Quaheri et al.[13] in 2010 proposed digital watermarking in Fractional Fourier Domain using ACO. The watermark retrieval is through pheromone trace. The performance is evaluated with RMSE Index. Khaled Loukhaokha [29] in 2013 proposed a watermarking technique that used Multiobjective ACO. The method is based on DWT and SVD. MOACO is used to find the optimal values of MSF that is used to control the trade-off between transparency and robustness of the watermark.

M.Nazir et al.[5] in their work in 2014 proposed a technique for gender classification that worked on real world face images (i.e. images captured under uncontrolled conditions). They clubbed facial local features with clothing features to increase the classification accuracy. They combined PSO with GA to select important features' set that clearly represented the gender.

PSO-ACO and GA-ACO have been used many times in other fields but have not much been used in image steganography.

The rest of the paper is organized as follows. Section (III) describes the optimization techniques briefly along with advantages and disadvantages. Section (IV) provides the comparative analysis of the optimization techniques applied to image steganography with results obtained by different researchers. Section (V) concludes the paper.

III. OPTIMIZATION TECHNIQUES

A) Particle Swarm Optimization (PSO)

It is a population based stochastic optimization method. James Kennedy and Russel C. Eberhart in 1995 first explained PSO[30] technique inspired by two concepts. The concepts are flocking and schooling patterns of birds and fish and the concept of evolutionary computation. Each solution in the search space of a given problem is considered as a particle. The solutions or particles are evaluated based on local and global information. The local and global variables associated with the particles are adjusted based on the values of those members that are closest to the target solution at any given moment. The particles flow in the search space to satisfy the objective function and get the optimal solution. The velocities and the positions of the particles are updated with some predefined equations

a)Advantages:

1. Can be used in research and engineering. Based on intelligence
2. Fast process. No overlapping, mutation calculation
3. Easy calculations

b) Disadvantages:

1. Falls into local maxima
2. Cannot solve non-coordinate systems

B) Genetic Algorithm (GA)

It is based on concepts of natural selection and genetics. Initial population is randomly created and it is evolved through the operators namely, selection, crossover, mutation A typical GA requires genetic portrayal of the solution domain and a fitness function to evaluate it.

a)Advantages:

1. Provides multiple solutions to a problem
2. Can solve multi-dimensional, non-continuous, non-differential, non-parametrical problems
3. Easy transfer to existing models

b) Disadvantages

1. Certain optimization problems named variant problems cannot be solved
2. No assurance that GA will give global optimum
3. Time consuming

C)Ant Colony Optimization

The technique is based on behavior of ants in search of food. In ACO technique applied to software, there are software agents or artificial ants that finds the best solution to the optimization problem. The algorithm works based on a pheromone model. The pheromone model has parameters associated with graph components. These components are updated by the ants dynamically.

a)Advantages

1. Good to use in dynamic applications
2. Fast discovery of good solutions with the help of positive feedback
3. Untimely convergence is prevented due to distributed computation

b) Disadvantages

1. Solution (convergence) is guaranteed even though time is not certain
2. Theoretical analysis is hard
3. Sequences of random decisions are dependent

D)Hybrid optimization technique- PSO-GA

The technique is a combination of PSO and GA. Both methods are based on population based stochastic optimization technique. The techniques initialize with a randomly generated population of solutions. In PSO all individuals are considered in each iteration while in GA some individuals are selected and others are eliminated from one generation to another. PSO has memory, knowledge obtained in previous iterations are retained by all particles whereas GA does not retain previous knowledge.

a) Advantages

1. Advantage of both help to achieve better solution
2. PSO is simple but may prematurely converge. GA controls convergence.

b) Disadvantages

1. Disadvantage of the individual techniques are minimized when the techniques are combined.

IV. COMPARATIVE ANALYSIS OF OPTIMIZATION TECHNIQUES

Table 1. Optimization techniques applied to spatial domain image steganography

ISO	GA	ACO	PSO-GA	PSO-ACO	GA ACO
i.Pnam Bedi et al in 2011[4] proposed optimization of image steganography in spatial domain using ISO. PSO was used to find out the optimal pixel position in the cover image to hide the bits of the secret data in order to enhance the quality of the stego object. Results: Cover Image: JET Secret Image: BOAT PSNR: 48. 8 Cover Image: BARBOON Secret image: BOAT PSNR: 48. 1	i. IAN-TAI WANG ET AL.[9] IN 1999 reviewed the use of GA to find the matrix to encrypt the secret message in the cover file. Perceptual modelling was used for concealing the secret data. RESULTS Cover Image: LENA Secret Image: JET PSNR: 44.51 Cover Image: BARBOON Secret Image: JET PSNR: 44.54 ii M.SCHEMANYOUR ET AL. [2] in 2013 proposed the novel GA to get near optimum structure in spatial domain image steganography for the pair-wise LSB matching scheme. Based on GA a dual-tune scoring model was structured to find a near optimum solution out of all the permutation covers. RESULTS Cover Image: CAMERAMAN Secret Image: KUHELPS PSNR:53.1042 Cover Image: BARBOON Secret Image: KUHELPS PSNR: 53. 3F58 iii.Hamidreza Rashidy Kanan et al.[3] in 2014 proposed a method to find the perceptual positions of the host image in spatial domain to conceal the encrypted secret message using GA. The best order of scanning the host image, the best suitable starting point of the scan and the best LSB positions are considered to increase the security, quality and capacity of the host image. Results: Cover Image: JET Secret Image: LENA PSNR:48.13 Cover Image: PEPPER Secret image: LENA PSNR: 4518 iv.Soumi C G et al.[17] in 2014 proposed to apply GA in monochrome image steganography. The mosaic image is introduced in cover file based on the mapping sequence obtained by GA. The sequence is again generated using HSRP. The methods applied to color image steganography. Result: Based on color images	Yes much used in this field	Not much used in this field	No much used in this field	Yes much used in this field

Table 2: Optimization techniques applied to watermarking

PSO	GA	ACO	PSO-GA	PSO-ACO	GA-ACO
i. K. Kappaswamy et al.[13] in 2012 proposed an optimal watermarking scheme using PSO in discrete cosine transform. Watermark was DCT transformed. UQI is used to measure the quality of the watermarked image with respect to contrast distortion, luminance distortion, loss of correlation. Results: Original Image: LENA Watermark: UBUNDU LOGO PSNR: 63.4596 (without attack) Uniform noise: noise 5% PSNR: 54.1488 ii. Sanjay Rajet al.[14] in 2012 applied PSO in a multimodal biometric image watermarking. An individual's face was watermarked in his fingerprint and also with the demographic data. PSO selected the best DCT coefficients of the face image. Results: Original Image: HUMAN FACE Watermark: FINGERPRINT PSNR: 49.89 iii. Eduardo Vellasques et al.[17] in 2013 used PSO in fast intelligent watermarking scheme. The method is proposed for heterogeneous document images. Solutions obtained through PSO are maintained in GMM which reduces the computation time increment to solve problems. Results: provided with databases in paper iv. Hong Hoa Thai et al. [25] in 2012 proposed a blind watermarking technique using DWT and based on SVD and SVR. PSO was used to optimize the proposed scheme. Results: Watermarked image: BARBOON Uniform Noise: 3% PSNR: 26.63 v. Hong Hoa Thai et al.[24] in 2013 proposed zero watermarking scheme with geometric invariants to secure the system against geometrical attacks using SVM classifier. The method used DFT and LPM for finding geometric invariants of images. To find optimal parameters of SVM, PSO was applied. Results: provided in tablet in the paper based on steganalysis techniques	i. Chin-Shiuh Shieh et al.[10] in 2003 proposed a GA based watermarking technique in the frequency domain where GA determines the DCT coefficients where the watermark is hidden in the original image. Results: Watermarked Image: LENA PSNR: 38.19 ii. Craig T. Smith et al.[9] in 2003 proposed a watermarking and compression method for medical images using GA. The regions of interest (ROI) in the medical image was compressed using lossless technique and the rest of the image was compressed using lossy compression technique. Water mark or other information was embedded around the (ROI) with the help of GA. Results: Watermarked Image: Heart PSNR: 38.28 iii. Diego Sal Dias et al.[24] in 2005 proposed a technique for enhancing semi-fragile watermark. It is based on the manipulation of image DCT. The method simultaneously maximizes the robustness content and the distortion of the watermarked image. Results: provided with images in paper iv. Zhicheng Wei et al.[21] in 2006 proposed a technique to improve the image spread spectrum watermarking algorithm. The method worked in a 8x8 DCT domain and used GA to choose the AC coefficients for embedding the spread spectrum watermark. Result: Image: GOLDHILL PSNR: 58 at=5	i. Khaled Loukhaoukha [29] in 2013 proposed a watermarking technique that used Multiobjective ACO. The method is based on DWT and SVD. MOACO is used to find the optimal values of MSF that is used to control the trade-off between transparency and robustness of the watermark. Result: Cover Image: LENA Secret Image: PSNR:50.843 Cover Image: CAMERAMAN Secret Image: PSNR:50.114 ii. Hameed Al-Qaderi et al.[15] in 2010 proposed digital watermarking in Fractional Fourier Domain using ADO. The watermark retrieval is through performance trace. The performance is evaluated with RMSE Index.	Not much used in water-marking yet	Not much used in water-marking yet	Not much used in water-marking yet

Table 3: Optimization techniques applied to frequency domain image steganography

PSO	GA	ACO	PSO-GA	PSO-ACO	GA-ACO
i. In 2007, Xiaoxia Li, Jianjun Wang [8] proposed a steganographic method based upon JPEG and PSO. The secret message was first encrypted using optimal substitution matrix determined by PSO. Modified quantization table was used which allowed more secret bits to be embedded in cover object. Results: Cover Image: LENA Secret Image: TEXT IMAGE(128x72) PSNR: 37.06 Capacity: 73728 ii. Feno Heriniaina Rabevohitra[6] and Yan Sang in 2011 proposed three new schemes for improving the method of DCTLSBMT1. The three schemes had three distinct objective function. Results: Cover Image: BABOON Secret Image: PLANE PSNR PSO1: 51.2014 PSNR PSO2: 57.1888 PSNR PSO3: 51.1798 iii. Saeid Fazli and Majid Kiamini [7] applied Particle Swarm Optimization to find optimal substitution matrix to encrypt secret message in each block of cover image to enhance the quality of the stego object in their work in 2008. The results were compared with (Joint Photographic Expert Group) JPEG , (JPEG Quantization Table Modification) JQTM method and Li and Wang's work and the proposed work outperformed all of them. Results: Cover Image: LENA Secret Image: IMAGE TEXT PSNR: 37.58 Capacity: 67584 Time: 28.90 sec iv. P.Aswini et al.[11] in 2015 introduced a technique where the cover image was preprocessed before hiding the secret message that was encrypted using PSO. After embedding OPAP is used to enhance the quality. Results: Cover Image: LENA PSNR: 59.21	i. Chien-Chang et al.[10] in 2003 proposed the use of GA to get the near optimal positions in the cover image to embed the secret image. The method is based on JPEG images. Results: Watermarked Image: LENA PSNR 42.45 after 100 generations ii. Lifang Yu et al.[23] in 2008 proposed the application of GA to enhance the performance of PM1 steganography scheme in JPEG images. Results: provided with graphs in paper iii. Elham Ghasemi et al.[25] in 2012 proposed the use of GA in a wavelet transform steganography scheme. OPAP was used after embedding of secret message to reduce error. Results: Cover Image: LENA(512X512) PSNR: 46.63 iv. H. Rasmouni et al.[28] in 2013 applied contourlet transform GA in a steganography scheme. GA was used to obtained an optimal mapping function. OPAP was employed after embedding the secret message to increase the capacity. Results: Cover Image: LENA PSNR: 45.30, Capacity: 58. 36% v. Amrita Khamrui, et al.[3] in 2013 presented a DCT based image steganography with the application of GA. Authenticating message is concealed in 2nd and 3rd LSB positions each frequency coefficients except the first. DCT is applied to the sub mask of the cover image in 2x2 blocks. GA is applied to increase the security level of the stego image. Results: Cover Image: LENA(512x512) PSNR: 44.78	i. Khosro Fardoll et al.[12] in 2008 proposed the hiding of secret message in the regions of interest of the cover file after transforming the image to frequency domain using DCT. The regions of interest are determined using ACO.	Not much used in this domain	Not much used in this domain	Not much used in this domain

V. CONCLUSION

Researchers have used optimization techniques in steganography to improve the security of the hiding technique in order to make the stego image more resistant to attacks, enhance the quality of the stego image so that the existence of the hidden file remains unknown and also to increase the capacity of the stego image to hide more important data. This paper portrays the degree to which enhancement of quality, capacity and security have been obtained by researchers with the application of optimization techniques to image steganography. A comparative analysis of the optimization techniques applied to spatial domain image steganography, frequency domain image steganography, watermarking is provided in this paper. It also mentions about the optimization algorithms applied to these fields to secure the steganography schemes against steganalysis techniques. This paper will give a glimpse of the work that has been done in these fields till the current time and will assist researchers in selecting appropriate optimization techniques for suitable problems.

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