International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 5, No.5 (Sep. 2016)
http://dx.doi.org/10.12785/ijcds/050505

Apply Bee Colony Optimization for Image Steganography with Optical Pixel Adjustment

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Received 15 Dec. 2015, Revised 29 Mar. 2016, Accepted 22 May 2016, Published 1 Sep. 2016

Abstract: In the recent two decades steganography or data hiding is widely used for concealing secret data instead of using encryption methods. It is used to hide image into a cover media without noticing the presence of the hidden message. Steganography's technique problem is the distortion obtained in the stego-image. This paper presents a new steganography techniques that decreases the stego-image distortion as well as increasing its secrecy. The proposed technique uses Bee Colony Optimization (BCO) along with the well-known Least Significant Bit (LSB) steganography algorithm. The secret image is embedded using LSB algorithm then the BCO with Optimal Pixel Adjustment process (OPAP) algorithm is used to find the best block matching matrix and then find the optimal substitution in the cover image. The calculated PSNR (Peak Signal to Noise Ratio) and MSB (mean square error) show that the proposed algorithm give big quality improvement over the traditional LSB (Least Significant Bit) algorithm and make the proposed technique more robust against attacks.

Keywords: Data hiding, image steganography, Optimal Pixel Adjustment, Bee Colony Optimization, Stego image, Cover image

1. Introduction

Data hiding is a technique used to protect information from interference and obstruction. It is used to embed secret messages into a cover-media such that unintended recipients do not suspect that the cover medium contains hidden data; this science is called "steganography ". Image used for inserting and hiding secure data is called 'cover images' while the image in which secret bits are inserted is known as 'stego-image'. Steganography jobs at most carry out on variants storage cover media like text, image, audio or video [1].

The main purpose of steganography is hiding a secret message and in the best case anyone cannot expect or guess that the parties are communicating in secret. Steganography becomes more appropriate than encryption in field of data security because using encryption anybody can know that both parties are communicating secret message and try to decrypt the message [2]. Powerful Steganography should met the following conditions:

- *undiscoverability:* which means that no procedure exists to distinguish that a work contains hidden information
- *Capacity:* refers to amount of data that can be inserted in the cover image. The maximum ratio of capacity between the data hiding and cover is 1:2
- *Robustness*: refer to the number of modifications the stego-image can withstand before an opponent can destroy the hidden information.

The term "Steganalysis" mean the process of detection of stenographic communications, and "stenographic" is a storage mechanism designed to give the user a very high level of protection against being compelled to disclose its contents. Steganography and steganalysis are closely intertwined.

Steganography uses two schemes to hide information. These schemes can be classified according to the format of the cover image and are known as spatial domain embedding and transform domain embedding. The spatial domain techniques use direct

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replacement. The transform domain techniques convert image into coefficient using (Fourier transform, DCT, wavelet, etc.) [3].

The main concept of image stenography is shown in figure (1). Assume that the sender wants to send via Stenographic transmission, an image to a receiver. The sender starts with a cover image(C). A Stenographic algorithm combines the cover image(C) with the secret image(S) to create the stego-image that hide secret image. The algorithm may use a stenographic key (stego key), which add additional secrecy to the process. In the receiver side, the receiver does opposite operation to extract secret image again. The output of the Stenographic algorithm is the stego image. The cover image and stego image must be of the same data type.

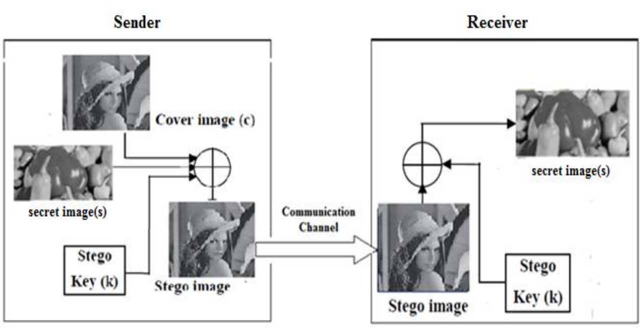

Figure 1. Image Stenography embedding scheme

Least significant Bit (LSB) is a spatial domain technique which is widely used by many researchers. This method is basically has two types (LSB replacement and LSB matching). In both cases data to be hidden is represented in binary form and embedded in the least bits of a pixel in the cover image.

LSB method has average embedding capability since it depend on hiding data on LSB bits. LSB change in values of each pixel in the cover image which are increased or decreased or kept unmodified depending of the value of the data to be hided. LSB has two problems; the distortion and the data to be hidden can be easily discovered. LSB lead to more distortion during embedding operation which results in degradable image quality. Since all operations are performed on least significant bit, it is also easy to detect the cover image value changes [3] and extract the hidden information. In order to decrease distortion the optimal Pixel Adjustment process (OPAP) can be used to enhance LSB method [4]. The OPAP adjusts all the pixels of the image optimally to reduce the error difference between the cover and stego image. In this paper a new steganography method that enhance the LSB substitution is proposed. This method increase the amount of data hided and decrease the distortion in the cover image. The method is based on Bee Colony Optimization (BCO) [5]. BCO is a swarm algorithm which is effective in finding optimal solution. The algorithm simulates the behaviors of the real bees in finding food source. BCO is used to find the best block location and best pixel location to hide the information using optimal pixel adjustment process (OPAP). It is one of artificial intelligence optimization methods and it shown that it decrease the distortion remarkably.

In the reset of the paper, section 2 presents related work. The LSB method is presented in Section 3. The proposed algorithm is shown in Section 4. Experimental results are given in Section 5 and conclusions are described in Section 6.

2. Related Work

Steganography had recently become a field of research for many researchers. Shaohuiet et al. [6] presented paper in text steganography by extracting features of image using wavelet and DFT transform and then apply neural network to reach a high statistical feature vector.

Chang C. C. et al [7] apply image steganography using LSB matching method. First a matching process between the secret message and the cover image is performed and then embedding takes place based on the maximum similarity. Wu, M.-N., et al [8] used image hiding with LSB algorithm and introduced global optimal substitution and local optimal substitution. Global method needs the same substitution matrix for whole blocks, so it records fewer amounts of data. Local method uses various substitution matrices for every block with PSNR equal to 33.0296. Avcibaset et al. [9] proposed a steganography scheme based on binary similarity measures and quality metrics as features for image steganalysis which is dependent on statistics of marked and unmarked images. Lyu and Farid [10] applied a linear discriminating analysis and Support Vector Machine (SVM). They also extend their technique to color images for the one-class SVM, where the use of phase statistics enhances the analysis.

Liuq I, et al [11] proposed method to extract five types of features for cover image : image complexity, image entropy, higher-order statistics of the histogram of the nearest neighbors, probabilities of the equal neighbors, and correlation features of different types. They employ the SVM, recursive feature elimination, and a Dynamic Evolving Neuro-Fuzzy Inference System (DENFIS). Hossein M. et al [12] proposed Steganalysis approach using LSB of gray scale images using both spatial and Gabor features.

Amirtharajan R. [13] proposed hiding information within image in LSB and Optimal Pixel Adjustment Process, thereby making the secret information more secure and conceited. He applied Optimum Pixel Adjustment Process (OPAP) coupled with Pixel Indicator (PI) technique and Pixel value differencing (PVD) for color image. Gerami P. at el [14] used Image steganography with LSB and apply particle swarm intelligence to find the local optimal block for hiding. Sabir M. d. [15] proposed image steganography that uses genetic algorithm to enhance of embedding capacity and security. Gawadel Rupali [16] presented steganography and encryption message over network. The method is based on sending message gradually between network nodes over internet. They first encrypt the secret message, and then embed it into identification field of IP header. Zheng Huang and et al [17] proposed a new algorithm for image to hide a large amount of secret data presented by secret color image. The algorithm is based on different size image segmentations (DSIS) and modified least significant bits (MLSB), where the DSIS algorithm has been applied to embed a secret image randomly instead of sequentially. Most these methods implement steganography using LSB or some modified method based on LSB. However, when using 1 LSB or 2 LSB of the cover image the hiding might not be noticed but this need a very large cover image, in order to use reasonable size cover image it is necessary to use 4 LSB which results in a distortion in the cover image and make detection and interception more easy so the system become less secure. Therefore an efficient method that assigns the image to be hided efficiently without disturbing the cover image and distribute the hidden data randomly is needed.

3. Image Hiding with Least Significant Bit (LSB) Algorithm

The Least Significant Bit (LSB) is one of main techniques in spatial domain image Steganography. The LSB is the lowest significant bit in the byte value of the image pixel. The LSB based image steganography embeds the secret in the least significant bits of pixel values of the cover image [16]. In the extraction process, the LSB of the selected cover-elements are extracted and used to reconstruct the secret message, the general algorithm for LSB is as follows [17]:

Input:

- Take the grayscale secret image (**S**)
- Standard cover original grayscale cover-image

of $m*n$ represented as:

$$C = \{C_{ij} | 0 \le i \le m, 0 \le j \le n, C_{ij} \in \{0,1,2,\ldots..255\} \ldots\ldots\ldots\ldots. (1)$$

for i =1 to Length (m) **do**

Compute index$_{ji}$ to store the i^{th} message bit of m

$S_{ji} \leftarrow \text{LSB}(C_{ji}) = m_i$

end for Output: stego-object ***S***

Generic LSB-based extraction algorithm [16]

Input: cover **C**

For i=1 to Length (m) **do**

Compute index$_{ji}$ to store the i^{th} message bit of m

$$LSB(C_{ji}) \leftarrow (S_{ji})$$

end for output: secret image

Figure (2) shows how simple least significant bits are embedded secret image size (128*128) within cover image size (256*256) applied r = 4.

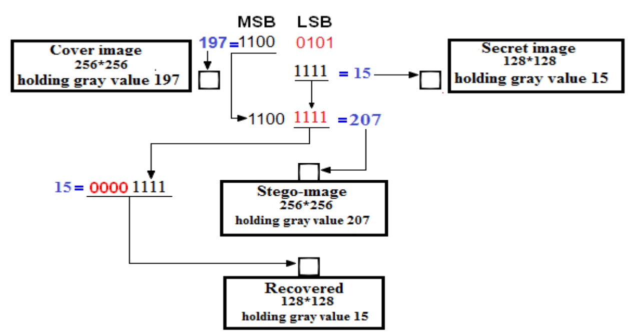

Figure 2. Simple least signification bit steganography

4. Proposed Algorithm

Before explaining the proposed technique, the Optimal Pixel Adjustment is illustrated first to make the proposed technique clear.

A. *Optimal pixel Adjustment process (OPAP)*

OPAP is used to improve efficiency and enhance the visual quality of the stego-image generated by LSB substitution [18].

The major cause of applying OPAP is to reduce distortion in the cover image caused by embedding the secret image. OPAP method modifies the values of pixels after concealing secret image into cover image. It enhances the quality of the stego-image. The procedures of hiding are illustrated in the following steps:

1. Initial, the secret image (S) is embedded using LSB algorithm with extract r=4 of the cover image(c) as illustrated in section 3.

2. The Least significant bits (LSB) are substituted in each pixel of cover image.
3. Let $\boldsymbol{x}$ be the value of the pixel after the substitution in step 2. The $\boldsymbol{x_1}$ pixel is the value of last $\boldsymbol{n}$ bits of the pixel and x_2 is the value of n bits hidden in that pixel. In the end, x is converted to binary and written back to the pixel as illustrated before.
4. OPAP is used to reduce error between the cover image and stego-image. The OPAP algorithm is described as following:

Let: p_i value of i'th pixel of cover image.
p_i' value of i'th pixel of the stego-image which is achieved by simple LSB.
p_i''value of i'th pixel of the stego-image which is achieved after using OPAP algorithm.
$\delta = p_i' - p_i$ (Embedding error between these two pixels).

The value of **p** and **δ** will change according to the following three conditions:

Case 1: $(2^{k-1} < \delta_i < 2^k)$: if $p_i' \geq 2^k$ then

$p'' = p_i' - 2^k$ otherwise $p_i'' = p_i'$.

Case 2: $(-2^{k-1} \leq \delta_i < 2^{k-1})$: $p_i'' = p_i'$.

Case 3: $(-2^k < \delta_i < -2^{k-1})$: *if* $p_i' < \delta_i < 256 - 2^k$, then $p_i'' = p_i' + 2^k$ *otherwise* $p_i'' = p_i'$.

The OPAP algorithm is used after hiding the information with LSB substitution. It is computed according to the similarity between the blocks of the cover image and the embedded image. The result of this transformation is using the optimal substitution matrix for each block and result in increasing the peak signal to noise ratio (PSNR) values [19].

B. Bee Colony Optimization (BCO)

Bee colony optimization is one of the artificial intelligence techniques applied for both combinatorial optimization and continuous optimization. It is based on evolutionary computing and can be used in solving steganography problems. In BCO system, artificial bees fly around in a multidimensional search space and some (employed and onlooker bees) choose food sources and adjust their positions depending on the experience of themselves and their nest mates. Some (scouts) fly and choose the food sources randomly without using experience. If the nectar amount of a new source is higher than that of the previous one in their memory, they memorize the new position and forget the previous one. Thus, BCO system combines local search methods, carried out by employed and onlooker bees, with global search methods, managed by onlookers and scouts, attempting to balance exploration and exploitation process [20]. The BCO algorithm is shown in figure (3).

BCO initialization parameters used in this paper for the following:
- Number of employed bees equal 20.
- Number of onlooker bees (m > n) equal 40
- Max. iteration number equal 250
- initial value of penalty parameter for jth agent (α_j =0.03)
- Length of ejection chain neighborhood (EC-Length =12)
- Fitness Function (for minimization)

$$d_{ij} = \sqrt{\sum_{k=1}^{n} (x_{ik} - x_{jk})^2} \text{ ....(2)}$$

*1. Initialize parameters **(n**: no. of bees, **m**: no. of sites selected out of v visited sites, **e:** no. of better sites out of m , **nep**: no. of bees recruited for best e sites , **nsp**: no. of bees employed for other (m-e) selected sites, **ngh**: initial size of patches which includes site and its neighborhood and stopping criterion)*
2. Construct initial Employed Bee Colony solutions by using Greedy Randomized Adaptive Search Heuristic (GRAH)
3. Evaluate fitness value for each bee
4. i=0
5. Repeat
6. N=0
7. Repeat
a. Apply Shift neighborhood
*b. select **m** sites for Shift neighborhood search.*
c. Recruit bees for selected sites (more bees for best e sites) and evaluate fitness.
d. select the fittest bee for each site.
e. Assign the (n-m) reminding bees to random search
f. Find best Onlooker, replace with respective Employed Bee
if fit(Best Onlooker) < fit(Employed)
g. Find best Feasible Onlooker, replace with Best solution,
if fit (Best Feasible Onlooker)< fit(Best)
h. N=N+1.
i. Ejection -Chain Neighborhood
8. Until (N=Employed Bee)
9. i=i+1
10. Until (i=Max Iteration)

Figure 3. BCO basic algorithm

C. OPAP with Bee Colony Optimization (BCO)

BCO has been used to find optimal pixel position in the cover image for hiding the secret image. In other words they used BCO to find the similarity between the cover image and the secret image in order to make less distortion [21]. A lot of optimization problems have been solved by BCO and the results illustrate that BCO is effective and quick. In this paper, BCO is used for detecting the optimal substitution matrices. As mentioned above, the bee algorithm is moved by the natural foraging behavior of honey bees to find the optimal solution [22]. BCO algorithm decreases the distortion in cover image after embeds the message inside it. LSB is applied for cover image according to the content of message. The algorithm is as follow:

1. Read cover image (C)
2. Read secret image (S).
3. Normalize the two images (cover and secret), the cover is 256*256. The secret image is 128 *128 to transfer the secret image confidentially.
4. Extract the cover image 4 bit LSB and substitute the secret image to it. Initially, partition cover image into two parts, the rightmost bit which embedded **k= 4** bits of each pixel of the cover image is retrieved to constitute the residual image and the four leftmost bits of each pixel is also retrieved to form the MSB. Secret image **S** is decomposed to a new secret image **S'**.
5. Extract the highest (r=4) bits of the original image to get the residual image (R). Each pixel of S' is 4 bit value of each pixel of S. Figure (4) shows the process of decomposing secret image to S' and dividing cover image to R and L.

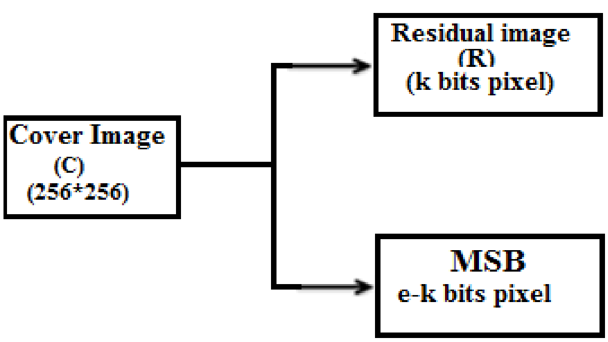

Figure 4. decompose cover image

6. Decompose the residual image and secret image in to blocks.
7. Apply OPAP on stego-image using BCO to increase the inaudibility for this method, search for the best block matching matrix and then search for different optimal substitution pairs. The basic algorithm for BCO shown in figure (3) [22].

At last, the summary of the algorithm for image hiding using LSB with OPAP (see figure (5)) is as follow:

Step 1: Read cover image and secret images

Step 2: a. Decompose the secret image (S) in to 256*256 while decompose secret imager 1n to 128*128 (while r = 4)

b. Divide the cover image into MSB (denote it L) and residual image (denote it R) and divide it into 32*32 blocks.

c. Divide the secret image (S) in to 32*32 blocks.

Step3: Apply OPAP and BCO to find block most similar S and R.

Step 4: Extracted T is the least significant bit of cover image after replaced blocks by secret image.

Step 5: Embedded the result for step 3 in (R) using LSB to obtain the image denoted E.

Step 6: Merge T and L to obtain stego-image.

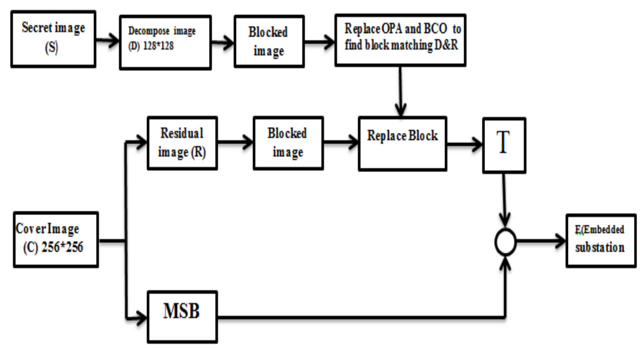

Figure 5. the OPAP algorithm with ACO

5. EXPERIMENTAL RESULTS

The proposed algorithm is designed and implemented in the MATLAB 10. In order to evaluate and compare the proposed algorithm with Simple LSB method, PSNR (Peak Signal to Noise Ratio) and MSB (mean square error) of stego-image are measured and listed for each cover image. The experimental evaluation used two set of images:

- Cover image were 256*256, 8 bit image with 255 grayscale. Different cover images (Lena, Baboon, boat and Barbara) were used which are shown in Figure 6.
- Different Secret images with size 128*128 were used (pepper, football, penguins and Koala) which are shown in Figure 7.

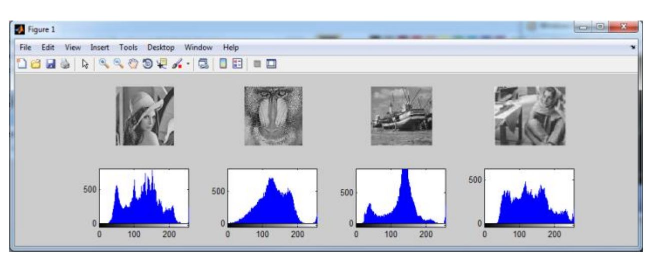

Figure 6. The cover images before embedding secret image and their histogram

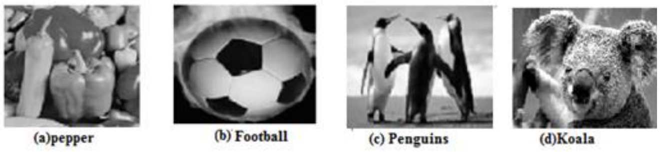

Figure 7. The secret images

The PSNR and MSE formula used to measure the quality of stego-images. It is the most popular measurements that are used in all steganography works. Because many signals have very wide dynamic range, PSNR is usually expressed in terms of a logarithmic decibel scale. The formula is as follows [23, 24]:

$$PSNR = 10log_{10}\frac{255^2}{MSE}\ db \dots\dots\dots\dots\dots\dots (3)$$

$$MSE = \left(\frac{1}{M.N}\right)\sum_{x=q}^{M=1}\sum_{y=0}^{N=1}(P(x,y) - P'(x,y))^2 \dots\dots\dots\dots\dots. (4)$$

Where M and N represent image size ***P(x,y)*** represent pixel **x, y** of the first image and ***P'(x,y)*** resent the pixel ***x,y*** from the second image.

The PSNR and MSE of the stego-image for different cover images and using pepper as a secret image are shown in table (1).

TABLE(1) PERFROME OF COVER IMAGES

Algorithm type	Cover image	Secret image	PSNR (db)	MSE(db)
Simple LSB	Lena	pepper	36.8306	0.07236
OPAP	Lena	pepper	39.42021	0.06815
Simple LSB	Baboon	football	35.9223	0.08137
OPAP	Baboon	football	38.6228	0.07316
Simple LSB	boat	penguins	39.984	0.05447
OPAP	Boat	penguins	44.005	0.04126
Simple LSB	Barbara	Koala	32.5836	0.07436
OPAP	Barbara	Koala	36.2345	0.06947

Table (1) display PSNR and MSE values derived from OPAP algorithm and simple LSB algorithm. From the table the proposed method give better values of PSNR and MSE also all the PSNR values greater than 35db while human visual system is unable to distinguish the gray scale images with PSNR more than 3S dB. Figure (8) shows the histogram of PSNR for the cover image.

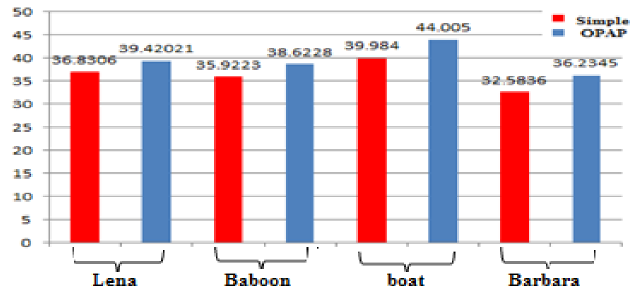

Figure 8. PSNR histogram for Stege- images

The histogram of the stego-image is shown in figure (9). Comparing figure (9) with figure (6), it is shown that histogram is of the stego-image is almost same as that of the cover image which indicate that the proposed method is very effective in hiding the secret image and decreasing the distortion.

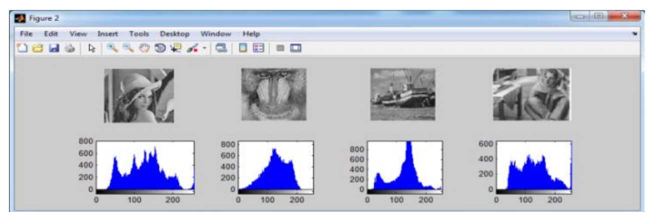

Figure 9. The stego- images and their histogram

6. CONCLUSION

In this paper a novel steganography technique is presented. It is based on Least Significant Bit (LSB) enhanced by Bee Colony Optimization (BCO*)* algorithm and the optimal pixel Adjustment Process **(**OPAP) algorithm. The BCO and OPAP are combined and used to find the best block matching matrix and then find the optimal substitution of secret image in order to increase the quality of the stego-image. In this approach the secret image was divided into 32*32 blocks and compared with the cover image to find the best block matching matrices which provide higher PSNR.

The experimental results showed that the proposed method produces better PSNR when compared with traditional methods (LSB). As a result the stego-image gets better imperceptibility with the same load. The better quality of stego-image makes it hard for unauthorized person to know that there is embedded secret image in the cover image. This is very useful and can be used for concealing secret data instead of using encryption methods. As a future work our system can be enhanced by adding Security layers and consider multiple file hiding.

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