1. INTRODUCTION

Steganography (information hiding) is a technique to hide secret messages in a host media called cover media. In today’s world of digital communication, this is accomplished by embedding the covert message in a carrier medium such as an image, video, or sound file. The goal of steganography is not only to ensure secret messages transferred secretly, but also to make the transferred secret messages undetectable. It is the art of invisible communication, and provides a plausible deniability to secret communication. Steganography takes advantage of the inherent weaknesses of human perception by subtly altering the characteristics of the carrier (Cheddad, Curran & Kevitt, 2010; Ge, Gao & Wang, 2007; Di et al., 2003).

The basic structure of steganography is made up of three components: the carrier, the message, and the key. The carrier can be a painting, a digital image, or an mp3; it is the object that will ‘carry’ the hidden message. A key is used to decode/decipher/discover the hidden message (Nabavian, 2010).

In image steganography almost all data hiding techniques try to alter insignificant information in the cover image. For instance, a simple scheme proposed by Lee and Chen (2000), is to place the embedding data at Least Significant Bit (LSB) of each pixel in the cover image. The altered image is called stego-image. Altering LSB doesn’t change the quality of image to human perception but this scheme is sensitive a variety of image processing attacks like compression, cropping etc. The LSB insertion methods are common due to their simplicity and large capacity.
In order to overcome the problem of LSB technique of robustness, many researchers proposed different techniques to hide data in higher LSB layer (Chan & Chang, 2001; Chi-Kwong & Cheng, 2004; Chi-Shiang, 2009). Many other genetic algorithm (GA) based approaches to information hiding have been proposed (Chan & Lyu, 2005; Maity & Nandi, 2004; Wang, Yang, & Niu, 2010; Mazdak et al., 2009; Fard et al., 2006). Also, in 2010, Ching-Sheng and Shu-Fen utilized Ant Colony Optimization (ACO) algorithm to construct an optimal LSB substitution matrix.

All previous stego methods are homogeneous, in which the same bit positions in the pixels of the cover image are used. For example in the LSB method, only least significant bits are used to hide data, but it has been shown that this method is weak in term of security. Also, using higher layers will affect the quality of the cover images. Thus, in order to overcome the problems of the previous methods, a new stego class has been proposed in by Awad and Jubori (2010), which is called non-homogeneous, in which the secret data can be hidden in different bit positions of different pixels. Also, a Genetic Simulated Annealing algorithm (GSA) has been proposed for non-homogeneous information hiding. This algorithm, as has been shown by the experimental results, is effective but inefficient because of the need for long chromosomes, large population size, and large number of generations to find the optimal solution.

In this paper, different techniques are employed, and a number of algorithms are presented and studied for hiding secret information using images. The techniques used are GA and ACO, and three algorithms are proposed: GA-GA, Random-ACO, and GA-ACO. Thus, the objectives of this work are:

- Designing an efficient and effective algorithm for information hiding.
- To compare between GA and ACO in terms of efficiency and effectiveness in solving the information hiding problem.

2. PROBLEM FORMULATION

Given a cover image $H$ of size $(\text{imgsize} \times \text{imgsize})$ pixels, each pixel $P_{ij}$ is of size $n$ bits, thus, $P_{ij} = p_{i0}^{j}, p_{i1}^{j}, ..., p_{in-1}^{j}$. $M$ is the secret message to hide which is of size $\text{leng}$ bits. Therefore, we need $\text{leng}$ pixels from $H$, $P_{0}^{0}, P_{1}^{0}, ..., P_{\text{leng}-1}^{0}$, to hide the message bits $m_{0}, m_{1}, ..., m_{\text{leng}-1}$. Each pixel is used to hide one bit from $M$, and any bit in the pixel can be used to be replaced by the message bit.

This problem can be formulated as directed graph $G = (V, E)$ as shown in Figure 1. This graph consists of the set of nodes (vertices) $V$; these nodes represent the bits of the cover image pixels selected to hide data, and $E$ is the set of edges that represent the next possible pixel bits to be replaced by the information bits, i.e. it is a matrix representing the connections between nodes. The matrix $E_{\text{leng,n}}$ can be defined as follows.

$E_{ij}$ is the difference between the original pixel $P_i$ and the sego pixel, in which, the bit $p_{ij}$ is substituted by $m_i$, for all $i = 0..\text{leng}-1$, and $j = 0..n-1$.

It is clear that:

Number of nodes in the graph = $\text{leng} \times n + 1$ (1)

Number of edges in the graph = $n^{\text{leng}-1} + n$ (2)

Thus, the problem solution space size is equal to the number of edges, which is the number of possible sets of pixel bits that can be selected to hide data, i.e., the number of possible paths from the source node to the last pixel bit node in the graph $G$. The optimal solution for this problem is the set $S$ of pixel bits ($\text{leng}$ bits) to be substituted by the information bits, such that MSE value is the minimum and Peak Signal to Noise Ratio (PSNR) is the highest. Therefore, there are: $n^{\text{leng}-1} + n$ feasible solutions, hence the search space grows exponentially when $\text{leng}$ increases.
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