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Using Hybird Genetic Algorithm In Audio Steganography

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Abstract

In this paper, a proposed method for hiding secret data in audio file (.WAV) is introduced. Genetic algorithm has been hybridized with conjugate gradient algorithm which is one of the methods for solving nonlinear unconstrained minimization problem, the hybrid genetic algorithm is used to determine the optimum positions for Least significant bit (LSB) by substituting the least significant bit of each sampling point with a binary message.

Numerical results for the proposed hybrid genetic algorithm on three test function were reported and compared with the results of genetic algorithm, also two measures were used such as BER (Bit Error Rate) and MSE (Mean Square Error) in order to access the performance of the proposed steganography method.

استخدام خوارزمية جينية مهجنة للإخفاء في الصوت

الخلاصة

تم في هذا البحث عرض طريقة مقترحة لإخفاء البيانات السرية في ملفات صوتية ذات الامتداد (.Wav) اذ تم تهجين الخوارزمية الجينية مع إحدى طرائق الاتجاه المترافق لحل المسائل التصغيرية للدوال ذات الأبعاد الكبيرة في الامثلية اللاخطية غير المقيدة ثم استخدام الخوارزمية الجينية المهجنة لتحديد المواقع المثلى لخزن البيانات السرية لطريقة الخلية الثنائية ذات الأقل أهمية Least Significant Bit (LSB) حيث يتم تضمين البيانات ضمن ملفات الصوت الرقمية، إذ تستبدل الخلية الثنائية الأقل أهمية بخلية ثنائية من البيانات السرية.

تم استخدام ثلاث دوال اختبار لمقارنة النتائج العددية للخوارزمية الجينية المهجنة مع الخوارزمية الجينية ، كما تم استخدام المقياسين Mean Square Error (MSE) Error Rate (BER), لغرض قياس كفاءة طريقة الاخفاء المقترحة.

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1: Introduction

Genetic algorithms which have been recently used in solving complicated scientific problems, remain the most recognized and practical form of evolutionary algorithms which are based on stochastic search strategy. These algorithms are able to reach global optima without the dependence on initial guesses, and only using the objective function value.

They are pioneered by John Holland 40 years ago combine selection, crossover, and mutation operators with the goal of finding the best solution to a problem until a specified termination criterion is met. The solution to a problem is called a chromosome. A chromosome is made up of a collection of genes which are simply the parameters to be optimized. Genetic algorithm creates an initial population (a collection of chromosomes), evaluates this population, and then evolves the population through multiple generations in the search for a good solution for the problem at hand (Sun et al., 2006).

Conjugate Gradient (CG) methods represent an important class of unconstrained optimization algorithm. The main advantages of the CG methods are its low memory requirements, its convergence speed and it poses a quadratic termination property in which the method is able to locate the minimizer of quadratic function in a known finite number of iterations. Yet, it can be applied iteratively to minimize non- quadratic functions (Fletcher, 1987).

The history of conjugate gradient method began with seminal paper of Hestenes and Stiefel in 1952 who presented an algorithm for solving symmetric, positive definite linear algebraic systems. In 1964 Fletcher and Reeves extended the domain of application of CG method to non-linear problems (Ahdrei, 2007).

The general form for solving nonlinear unconstrained optimization problem is:

Minimize $f(x)$ (1)

Where f: $R^n \rightarrow R$ is smooth and its gradient $g(x)=\nabla f(x)$ is available.

Conjugate gradient methods are very efficient for solving large-scale unconstrained optimization problems (1). The method proceeds by generating a sequence $\{x_k\}$ as:

$$x_k = x_{k-1} + \alpha_k d_{k-1}, \qquad k=1,2,\ldots \qquad (2)$$

where step size α_k is positive, which is computed by carrying out some line search, the step size α_k guarantees the global convergence in some cases and is crucial in efficiency (Beale, 1988).

The idea of this generating is the concept of conjugate two vectors, in order to determine new directions $(d_0, d_1, \ldots, d_n)$ of search using information related to the gradient of a quadratic function. This equivalent to find x with $\nabla f(x)=0$, in such a way that successive search directions are conjugate with respect to positive definite Hessian matrix G. At each stage k the direction d_k is obtained by combining linearly the gradient $-g_k$ at x_k and the set of directions $\{d_0, d_1, ..., d_{k-1}\}$, (where d_k is conjugate to each element of this set) (Rao, 1994). The direction d_k is computed as follows:

$$d_0 = -g_0$$

$$d_k = -g_k + \beta_k d_{k-1}, \qquad k \ge 1 \tag{3}$$

The search direction assumed to be a descent one, which plays the main role in these methods. In (3) β_k is known as conjugate gradient parameter. Different conjugate gradient algorithms correspond to different choices for the parameter β_k. It is known that choices of β_k affect numerical performance of the method, and hence many researchers studied choices of the parameter β_k. Since 1952, there have been many well-known formulas for the scalar β_k, for example, Fletcher-Reeves (FR) (Fletcher, 1964), Ploak-Ribiére-Polyak (PRP) (Ploak and Ribiére, 1969) , Hestenes-Stiefel (HS) Hestenes and Stiefel, 1952).

$$\beta_k^{FR} = \frac{\|g_k\|^2}{\|g_{k-1}\|^2} \quad , \quad \beta_k^{PRP} = \frac{g_{k+1}^T y_k}{\|g_k\|^2}, \quad \beta_k^{HS} = \frac{g_k^T y_{k-1}}{d_{k-1}^T y_{k-1}} \tag{4}$$

Where $\|.\|$ means the Euclidean norm and, $y_{k-1} = g_k - g_{k-1}$.

2: Previous Work

Genetic Algorithms are sometimes very poor in terms of convergence performance. To improve the efficiency of genetic algorithms, some hybrid genetic algorithms are developed by combining genetic algorithms with heuristic search strategy based on gradient such as conjugate gradient ((Sun et al., 2006).

In (Kumar and Debroy, 2006) Kumar and Debroy used the conjugate gradient method and a hybrid optimization scheme involving conjugate gradient method and genetic algorithm to calculate the weights in the neural network model. The hybrid optimization scheme helped in finding optimal weights through a global search.

In (Tantar, et al., 2007) Tantar, et al proposed parallel hybrid genetic algorithm (GA) for solving the structure prediction problem. Conjugated gradient-based Hill Climbing local search is combined with the GA, in order to efficiently deal with the problem by using the computational grid.

In (Zhou-Shun et al., 2008) Zhou-Shun et al proposed an algorithm which combines the local searching ability of conjugate gradient method with global search ability of GA organically. This algorithm changes the problem of solving the linear equations into the problem of equivalent differential by searching the most optimization solution.

In (Li, et al., 2009) Li, et al proposed a hybrid genetic algorithm which combines the conjugate gradient method with genetic algorithm to improve the performance of genetic algorithm for cable forces optimization.

In (Xie and Liu, 2010) Xie and Liu proposed a hybrid genetic algorithm for geo-physical inversion. According to the properties of the genetic algorithm and the conjugate gradient algorithm, the method has the attributes of the global-convergence of the genetic algorithm and the fast convergence of the conjugate gradient.

In (Ahmed, 2013) Ahmed developed a hybrid genetic algorithm (GA) for obtaining a heuristically optimal solution to the traveling salesman problem. A hybrid GA is developed by incorporating a new local search algorithm to the simple GA in order to obtain a heuristic solution to the problem.

3. New proposed hybrid genetic method

The steps of the new proposed hybrid genetic method are:

i- Create Initial Population:

The population consists of a number of individuals detected by the algorithm designer and according to the nature of the problem. The population has been detected by 12 individuals which are generated randomly. The chromosome consists of 12 number of values which are decimals.

ii- Fitness Evaluation:

The next step, after creating a population, is to calculate the fitness value of each member in the population because each chromosome is a candidate for an optimal solution. The fitness of a solution is a measure that can be used to compare solutions to determine which is better. The fitness functions in this work are the three test functions **Powell**, **Osp (Oren and Spdicato)** and **Diagonal4 Function**.

iii- Selection:

In this phase, we have to create a new population from the current generation. The selection operation determines which parent chromosomes participate in producing offspring for the next generation.

The most common way is to set the selection probability equal to (Al-Namy, 2006):

$$Pro\,(x) = \frac{f\left(x_i(t)\right)}{\sum_{i=1}^{pop\_size} f\left(x_i(t)\right)} \tag{5}$$

f(x): fitness value of chromosome.

i: chromosome number.

t: population number.

selection of a new population with respect to the probability distribution based on fitness values.

iv- Crossover Operator:

Crossover is usually applied to selected pairs of parents. single-point crossover is the most basic crossover operator, where a crossover point is selected randomly, and two parent chromosomes are interchanged at this point**.** The crossover rate (CR) (which equal 1 in this work) is the parameter that will define the expected number of chromosomes which undergo the crossover operation. If crossover rate is set to 1, all chromosomes in the population will be included into the crossover operation**.**

v- Mutation:

The most common way of implementing mutation is the order changing mutation (which is used in this work), two positions are chosen randomly in the chromosome and exchange their values with a probability equals to a very low (which is equal to 0.08 in this work). The mutation rate is usually kept low so good chromosomes obtained from crossover are not lost.

vi-Hybridization step:

After mutation, a new population had been created. Each chromosome in the new population is initial point for conjugate gradient method, then the hybridization with conjugate gradient starts. The steps of conjugate gradient eq. (2), (3) are executed to generate a new population to start genetic algorithm again until the stopping criterion is satisfied.

vii-Stop Criterion: The stopping criterion decides whether the algorithm continue in searching or stop. The stop criterion here depends on two approaches: generations number or minimum function value.

- **Outlines of the Hybrid Genetic Algorithm**

Step1: Create initial population randomly, k=0, n.
Step2: Calculate fitness function for each chromosome in the population.
Step3: [**New population**] Create a new population by repeating the following steps until a new population is complete.

- **(Selection)** Select two parent chromosomes from a population according to their fitness.
- **(Crossover**) **(recombination**)] Crossover the parents to form a new offspring (children).
- **(Mutation)** Mutate new offspring using order change at random position.

Step4: Let x_k=new population, Set k=k+1**.**
Step5: if k=1 then $d_0=-g_0$, where g is the gradient vector else continue**.**
Step6: $x_k=x_{k-1}+\alpha d_{k-1}$ where α is a step size which is equal to 0.001.
Step7: Calculate fitness function for each chromosome in the population,
then find minimum function value.
Step8: If k=n or minimum function value is very small then stop; print Minimum function value, otherwise continue.
Step9: $d_k=-g_{k-1}+\beta_k*d_{k-1}$, where β_k is FR formula as defined in eq.(4), go to step 3.

4: Steganography

Steganography is science of hiding information by embedding messages within others, seemingly harmless messages.

Steganography means “covered writing” in Greek. As the goal of steganography is to hide the presence of a message and create a covert channel (Jonjen and Triesch, 2004).

The fundamental requirement for a steganographic method is imperceptibility which means that the secret messages should not be discernible to the human eye. There are two other requirements, one is to maximize the embedding capacity, and the other is security(Al-Jobori, 2011).

In the field of steganography, some terminologies have been developed, like cover, embedded and stego object

The term cover is used to describe the original, innocent message, data, audio, still image, video and so on.

The information to be hidden in the cover data is known as the embedded data. The stego object is the data containing both the cover signal and the embedded information. Sometimes, the process of putting the hidden, or embedded data into the cover data known as embedding, see figure (1), (Hopper, 2004).

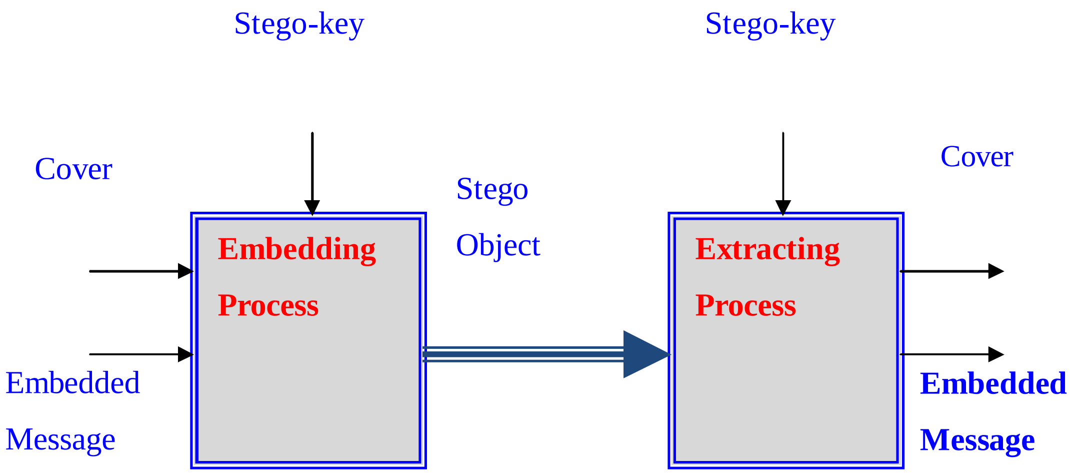

Figure (1): General Steganography System .

4.1: Steganography in Audio

Because of the range of the Human Auditory System (HAS), data hiding in audio signals are especially challenging. The HAS perceives over a range of power greater than one billion to one and range of frequencies greater than one thousand to one. When performing data hiding on audio, one must exploit the weaknesses of the HAS, while at the same time being aware of the extreme sensitivity of the human auditory system (Nori, 2006).

All of the developed algorithms take advantage of the perceptual properties of the human auditory system (HAS) in order to add a message into a host signal in a perceptually transparent manner. Hiding additional information into audio sequences is a more tedious task than that of images, as Human Auditory System (HAS) is more sensitive than Human Visual System (HVS) (Juhi and Asha, 2012).

The digital sound is obtained from the analog sound by converting it to digital domain. This process implies two sub processes: Sampling and Quantization. Sampling is the process in which the analogue values are only captured at regular time intervals. Quantization converts each input value into one of the discrete values. The most popular file formats for sounds are the Windows Audio-Visual (WAV) and the Audio Interchange File Format (AIFF) (Kriti and Pradeep, 2010).

There are numerous methods used to hide information inside of Picture, Audio and Video files. The two most common methods are phase coding and Least Significant bit (LSB) (Gunjan and Puja, 2012).

- **Phase coding**

The technique is based on the human ear as noise sensitivity only for differential phase variation, but relative insensitivity to initial phase. Thus, the sound file is divided into blocks and each block's initial phase is modified by using the embedded message, preserving the subsequent relative phase shifts. This is one of the best techniques with respect to the perceived signal to noise ratio.

- **Least Significant bit**

Least significant bit (LSB) coding is the simplest way to embed information in a digital audio file. By substituting the least significant bit of each sampling point with a binary message, LSB coding allows for a large amount of data to be encoded.

Among many different data hiding techniques proposed to embed secret message within audio file, the LSB data hiding technique is one of the simplest methods for inserting data into digital signals in noise free environments, which merely embeds secret message-bits in a subset of the LSB planes of the audio stream

Sampling technique followed by Quantization converts analog audio signal to digital binary sequence. In this technique LSB of binary sequence of each sample of digitized audio file is replaced with binary equivalent of secret message

4.2: New Approach for Steganography in Audio

In this work, steganography in audio is used **w**hich is one of the steganography types via cover.

We divided the cover (which is audio) into parts to embed the secret message (which is a text or audio) in an optimized method using the hybrid genetic algorithm in order to find the best positions for LSB (Least Significant Bit) technique.

Before applying the hybrid genetic algorithm **the initial population** and the **fitness function** must be determined. when the cover divided into parts, each part represents **a chromosome**. The length of each chromosome is the length of the message. **Each gene** in the chromosome represents a position that corresponds to a numerical value in the audio data file.

The fitness function is the Short Time Energy function (which is one of the methods that is used to extract the feature of the signal) **:**

$$E = \sum_{m=1}^{M} x^2(m) \qquad (6)$$

Where M is the number of genes in the chromosome.
x is the corresponding numerical value of each gene (position) in audio data file.

The objective is to find the positions with maximum Short Time Energy function value to hide the message in.

The following steps are used to embed a secret message in audio file (cover):

a. The data in the audio file which is digital converted to Binary .
b. If the message is text each character in the message is converted to Asciicode, then to binary form, or to binary form directly if the message is audio.
c. Replaces the optimum positions in audio using LSB with the binary form of the message .

- **Outlines of the New Steganography in Audio Method**

Step 1: Input the audio file (cover**).**
Step 2:Create the initial population .
Step3: Apply the steps of the hybrid genetic algorithm to find the best Positions for hiding ..
Step4: Replaces the LSB of audio with the binary form of the message in the best positions.

5: Discussion and Numerical Results

a- Numerical Results for the Hybrid Algorithm

In order to assess the performance of the new hybrid algorithm, some generalized selected well-known test functions, Powell function, Osp (Oren and Spdicato**)** function, and Diagonal4 function are used.

All programs are written in MATLAB version 2007a. The comparative performances for this hybrid algorithm are evaluated by considering minimum function value or number of generations.

The initial population is randomly chosen so the first stopping criterion which is the number of generations is used to determine the best minimum for each test function. After determining the best minimum for each function, the second stopping criterion which is the best minimum is used to determine the number of generations to reach the best minimum.

The formula for calculating the scalar β_k in step9 in the hybrid algorithm is the formula in eq. (4) which is called Fletcher Reeves (FR) formula. Fifty trials are carried out for each test function and numerical results for each test function are concluded out of these trials. The numerical results for each test function are:

1-Powell function: The first stop criterion**,** when the number of generations reach 5000 generation, the minimum values for this function out of 50 trials are:

$$1E-14 \leq \min \leq 1E-11$$

The second stop criterion , when the minimum value the for this function is:

$$\min \leq 1\times E-14$$

The numerical results to reach the minimum ($\min \leq 1\times E-14$) out of 50 trials are shown in table (1).

2-Osp (Oren and Spdicato) function: The first stop criterion**,** when the number of generations reach 5000 generation, the minimum

$$1E-6 \leq \min \leq 1E-4$$

The second stop criterion, when the minimum value for this function is:

$$\min \leq 1\times E-4$$

the results to reach the minimum ($\min \leq 1\times E-4$) out of 50 trials are shown in table (2).

3-Diagonal4 Function: The first stop criterion**,** when the number of generations reach 5000 generation, the minimum values for this function out of 50 trials are:

$$1E-12 \leq \min \leq 1E-10$$

The second stop criterion, when the minimum value for this function is:

$$\min \leq 1\times E-12$$

the results to reach the minimum the results to reach the minimum ($\min = 1\times E-12$) out of 50 trials are shown in table (3).

Comparison between new hybrid genetic algorithm and genetic algorithm is shown in Table (4) with respect to the minimum value, which shows the efficiency of the hybrid genetic algorithm.

Table(1)
Numerical Results (Powell Function)

No. of Trails	Minimum	No. of generations
6	Failed	------
2	$(1E-13)$	5000
42	$(1E-14)$	3884, 3872, 4080, 3831, 4228, 4310,4003, 3727, <u>3718</u>, 4181,4097, 4137,3897, 4421, 4003, 4339, 4999, 4298, 4228, 3976, 3955, 4845, 4170, 4069, 4374, 4431, 4486, 3746, 4255, 3855, 3966, 4257, 4464, 4167, 3878,4427, 4610, 3983, 4139, 4250, 3483, 4018.

Table(2)
Numerical Results Osp (Oren and Spdicato) Function)

No. of Trails	Minimum	No. of generations
16	$(1E-03)$	5000
34	$(1E-04)$	83, 183,74,123,113,106,155, 3699, 89, 379, 2936,147, 4459,101, 633, 163, 97, <u>67</u>,70, 132, 162, 115, 77, 487, 139, 75, 107, 130, 267, 156, 3122,102, 4294 , 2467.

No. of Trails	Minimum	No. of generations
6	$(1E-11)$	5000
6	$(1E-10)$	5000

2	$(1E-09)$	5000
1	$(1E-08)$	5000
35	$(1E-12)$	4520,4370,4151,4076,3409,4320,4462,4661,4737,4517, 4173, 4956,4895,,4997,4556,4324,3720,4977,4662,4701, 4987,4536,4624,3920,4981,4462,4631, 4998, 4631, 4798, 4445,4985,4329,3987,4267.

Table(3)
Numerical Results (Diagonal4 Function)

Table (4)
Comparison Between Hybrid Genetic Algorithm and Genetic Algorithm

Function	**Hybrid Genetic Algorithm(HGA) minimum**	**GA minimum**
1-Powell	$(1E-14)-(1E-11)$	0.667248567724685
2-Osp.	$(1E-6)-(1E-4)$	0.146460647330478
3-Diagonal4	$(1E-12)-(1E-10)$	0.853013845034343

b- Numerical Results for the New steganography Method

First The cover used was (سورة الإخلاص) and the secret message was text "a friend in need is a friend indeed". After converting this message to binary , it's length became 280 bit, so we need 280 positions to hide the message in.

After applying hybrid genetic algorithm to find the best positions, the message embed in these positions. **Mean square error** and the **Bit-Error Rate** are used to measure the efficiency of this method, where

$$MSE = \sum_{I=1}^{n} (y1 - y2)^2 / n \qquad (7)$$

y1, y2 is the cover before and after embedded the message respectively.

The Bit-Error Rate is defined as:

$$BER = \frac{\text{Error extracted bits}}{\text{Total embedded bits}} \tag{8}$$

In our case, the mean square was (0.00669850). The Bit-Error Rate was zero , it means that the message is completely restored.

Second we took the cover (سورة الفاتحة) and the secret message was audio the word (يارب). After converting this message to binary, 128000 positions are needed to hide it, at least 4 chromosome are needed, that means 512000 positions from the cover, because of the exestuation time, the positions are determined by taking the permutation of the number 128000. The mean square was (0.0151). The Bit-Error Rate was zero , it means that the message is completely restored.

6: Conclusions

Hybridization of GA, with CG-algorithm, characterized by giving global convergence property (maximum or minimum) from genetic algorithm further to control random in genetic algorithm.

An application of hybridized algorithm in stenganography field shows the efficiency of this hybrid algorithm, by providing good, efficient positions for hiding the data from hackers and sent to the destination in a safe manner**.**

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