# Finding the Best Key Stream by Using Genetic Algorithm for Image Encryption

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## *Abstract*

Because of using images widely in industrial process, it is important to protect the confidential image data from unauthorized access. The RC4 algorithm is selected. The proposed algorithm is used with wavelet transform. The main idea of this paper is to show how genetic algorithm works to give the optimal keys and the influence of each key in the increasing security, several experiments were given to prove that.

**Keywords:** Image, Encryption, RC4 algorithm, Wavelet Transform, Genetic Algorithm.

## *1. Introduction*

The Ciphering of image is actually an important issue. One essential difference between text data and image data is that the size of image data is much larger than the text data. The time is very important factor for the image encryption [1]. Two levels of time are found, the first is the time to encrypt, and the other is the time to transfer images. To minimize it, the first step is to choose a robust and easy method to implement cryptosystem. Two approaches of select encryption where wavelet-based methods are used for compression [2]. The first attempt was to hide the choice of filters, while the second approach of selective encryption was based on wavelet packets and the decomposition tree is keep secret. The use of genetic algorithm is very important tool to find more secure image, where genetic algorithm gives suitable key stream.

In the present work, the RC4 algorithm is developed to encrypt image with wavelet subband images and genetic algorithm.

## *2. Basic Principles*

### 2.1 Encryption

The basic idea of encryption is to modify the message in such away that its content can be reconstructed only by a legal recipient [3]. A discrete-valued *cryptosystem* can be characterized by:

1) A set of possible plaintexts (the original message), $P$.
2) A set of possible ciphertexts (the scrambled message), $C$.
3) A set of possible cipherkeys, $K$.

The basic model of the ciphering system is shown in Figure (1).

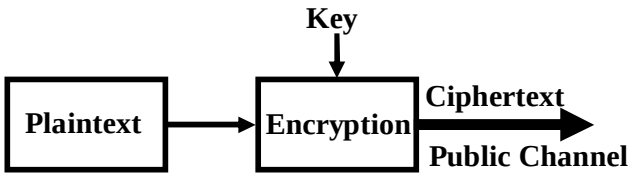



**Figure (1): The Encryption diagram of a cipher**

Two classes of key based encryption algorithms, symmetric (or *secret-key*) and asymmetric (or *public-key*) algorithms [3].

## Symmetric-Key Algorithms

Symmetric key encryption is a key based encryption algorithm in which the same key is used to encrypt sensitive data, used to decrypt the sensitive data. The key must be protected and secured. The key is often called a *secret-key* [4]. Symmetric-key algorithms are broken down according to the structure of the algorithm into *stream cipher* and *block cipher*.

## Stream Cipher

It is symmetric key ciphers which process, the given message (plaintext) bit by bit (as a stream). So *stream ciphers* encrypt each bit of the input data individually before moving on to the next. In our work we used this type of ciphering.

## 2.2 RC4 Algorithm

A secret key *cryptosystem* encrypt image pixel by pixel, with the RC4 algorithm. RC4 convert original image to encrypted image one bit at a time. The simplest implementation of a RC4 is shown in Figure (2) [5]. A key stream generator (sometimes called a *running-key generator*) outputs a stream of bits: $K_1$, $K_2$, $K_3$,..., $K_i$. This key stream is XORed with a stream of plaintext bits, $P_1$, $P_2$, $P_3$,..., $P_i$ to produce the stream of ciphertext bits $C_1$, $C_2$,..., $C_i$.

$$C_i = P_i \oplus K_i \qquad \ldots (1)$$

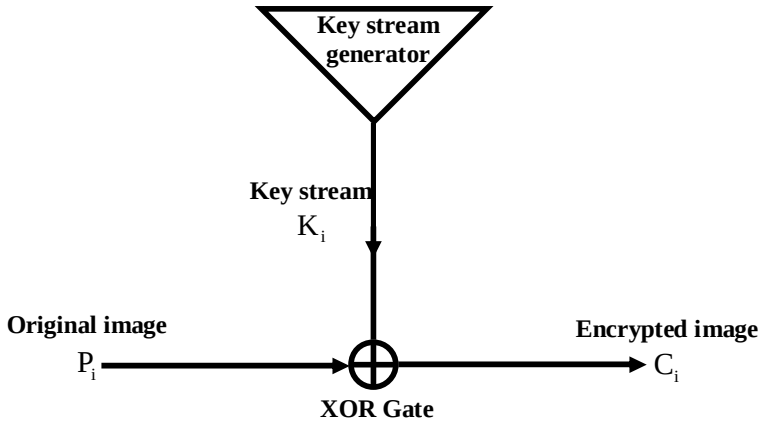



**Figure (2): RC4 Structure**

RC4 system consists of two main parts [6]:
1- Algorithm to generate key stream.
2- XOR gate.

Most algorithms which are used to generate the key streams are based on using the shift registers. Thus, the main component of the key stream generator is the shift register. A shift register can be represented by a sequence of bits. Each time a bit is needed; all of the bits in the shift register are shifted one bit to the right. The new left-most bit is computed as a function of the other bits in the register as shown in Figure (3) [7].

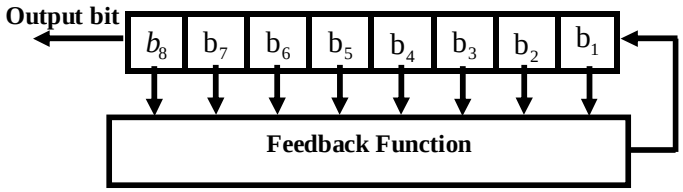



**Figure (3): Feedback Shift Register**

## 2.3 Wavelet Transform

Wavelet transform (WT) in the data processing can be considered as subband decomposition [8]. Figure (4) shows the image wavelet decomposition diagram. The original image $f_L(x,y)$ is firstly filtered on the row by applying filter $H$ (high-pass filter) and $G$ (low-pass filter) and down sampled by keeping one column out of two. Two resulting images, the low-pass $f_L(x,y)$ and high-pass $f_H(x,y)$ outputs are obtained. Then, both of them are filtered along the column and up sampled by keeping one row out of two. It can be obtained one low-pass subband image denoted by $f_{LL}(x,y)$ and three high-pass subband images denoted by $f_{LH}(x,y)$, $f_{HL}(x,y)$ and $f_{HH}(x,y)$, respectively.

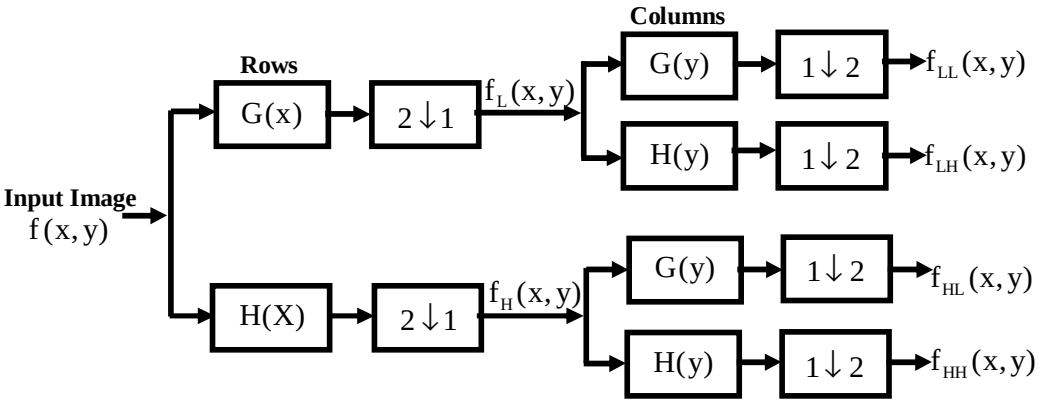



**Figure (4): Image Wavelet Decomposition**

x : Convolve (rows and Columns) with the filter x .

$2\downarrow 1$ : Keep one column out of two.

$1\downarrow 2$ : Keep one row out of two

### 2.4 Genetic Algorithms

Genetic algorithms are adaptive methods which may be used to solve search and optimization problems. They are based on the genetic process of biological organisms [9]. Genetic algorithms operate on encoded representations of the solutions, equivalent to those chromosomes of individuals in nature. Since a chromosome is a sequence of symbols and these symbols have been binary digits. Empirical studies have typically used chromosomes where each symbol represents an integer or a floating point number [10].

## *3. Proposed Algorithm*

### Binary Genetic Algorithm

Because the used of genetic algorithm in this paper is to find the best key stream, and these keys must be binary, therefore the encoding of genetic algorithm is binary. There are many components of genetic algorithm that specified the work of this algorithm, where [10]:

**1- Initialization**

The initial population of chromosomes is generated at random. The chromosomes in the population have a fixed length and represent the value of initial key stream shift register. Ten chromosomes are generated and each chromosome has eight genes. For example:

| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
|---|---|---|---|---|---|---|---|

Shift Register

It represents letter (a) with ASCII code (97).

**2- Evaluation**

In Evaluation step, we will find the fitness function, the fitness function is very important in order to obtain good encryption results. The evaluation function used in this work is based on correlation (corr) that measures the similarity between the original image and encryption image, it is between 0 and 1, and then the correlation can be defined as [3]:

$$\text{corr (fitness function)} = \frac{\sum_{r=1}^{N}\sum_{c=1}^{M}(I_1(r,c)-\bar{I}_1)(I_2(r,c)-\bar{I}_2)}{\sqrt{\left[\sum_{r=1}^{N}\sum_{c=1}^{M}(I_1(r,c)-\bar{I}_1)^2\right]\left[\sum_{r=1}^{N}\sum_{c=1}^{M}(I_2(r,c)-\bar{I}_2)^2\right]}} \quad \ldots(2)$$

where:

$I_1(r,c)$ : is the value of pixel at $(r,c)$ of the original image.

$\bar{I}_1$ : is the mean of the original image that

$$\bar{I}_1 = \frac{1}{MN}\sum_{r=1}^{N}\sum_{c=1}^{M} I_1(r,c) \quad \ldots(3)$$

$I_2(r,c)$ : is the value of the pixel at $(r,c)$ of encryption image.

$\bar{I}_2$ : is the mean of the encryption image that

$$\bar{I}_2 = \frac{1}{MN}\sum_{r=1}^{N}\sum_{c=1}^{M} I_2(r,c) \quad \ldots(4)$$

M: height of the image.

N: width of the image.

$r$ and $c$ : row and column numbers.

3- **Selection Operator**

Selection is the process of choosing two parents from the population for crossing. The strategy that is used here is Roulette Wheel Selection.

4- **Crossover Operator**

Crossover is the main genetic operator. It operates on two individuals at a time and generates two offsprings. 1-point crossover (1X) used in our work as in Figure (5).

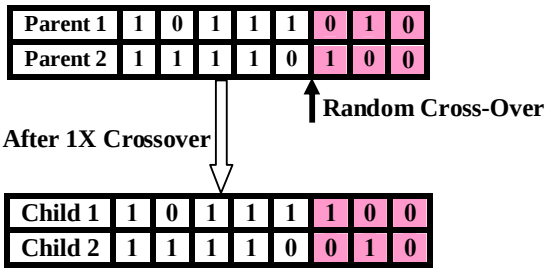



**Figure (5): 1X Crossover Operation**

**5- Mutation Operation**

Mutation is a random change of one or more genes. Every chromosome is simply scanned gene by gene and with a mutation rate (Pm) a gene is changed/swapped, i.e. $0 \Rightarrow 1$ and $1 \Rightarrow 0$ [11].

**6- Elitism**

During our study, we used Holland technique in which offspring are replaced with poor chromosomes in population [12]. The child replaces the parent after applying crossover and mutation.

**7- Stopping Criterion**

The genetic algorithm iteratively performs its operators on each generation of individuals to produce new generation. This loop continues until a predetermined number of generations to be run.

## *4. Proposed Model Operation*

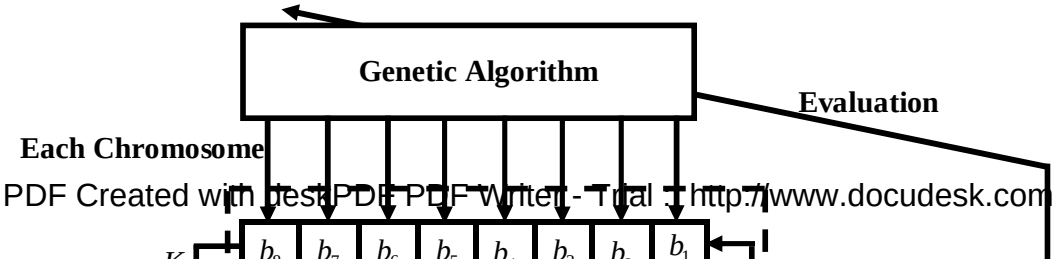
The operation of the system is as follow:

Input the original image to the system, by using switches $S_0$ and $S_1$ will get two cases:

Case 1: if the $S_0$ is close and $S_1$ is open, then the original image will be transform by wavelet transform to approximation and details images. After that the transformer image convert to stream of bits and XORed with key stream bits, and result the encrypted image, this encrypted image may be not the best, therefore; this will again convert to pixels and correlated with the original image to give the fitness function of the genetic algorithm that gives another key stream and after that another encrypted image this process will stop directly after we get the good encryption.

Case 2: if the $S_0$ is open and $S_1$ is closed, the same procedures above but without wavelet transform.

The full diagram is shown in Figure (6).



## *5. Experimental Results*

Two 256*256 images, boat and birds, 8-bit grayscale images are used in these experiments. As shown in table (1), in the two images the encryption was taken on the image without wavelet transform (Full encryption) and with 1-level wavelet transforms (partial encryption). In the full encryption we used the genetic algorithm for 5 cycles but in partial encryption, there are two cases of genetic algorithm, first, the number of cycles is zero (no genetic algorithm) and, second, the number of cycles is 5 (5 genetic cycles).Figure (7) and Figure (8) explain these procedures . The parameters of genetic algorithm are as follow:

Pc=0.83

Pm=0.23

No.of cycle=5.

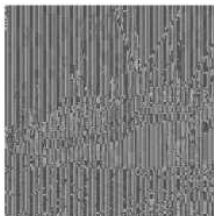
**Table (1): Encryption Results**

| Boat | Full Encryption | | Partial Encryption | | | |
|---|---|---|---|---|---|---|
| No. of Genetic Cycle | 5 | | 0 | | 5 | |
| Initial Key stream | (11110101) | | (01110011) | | (10000010) | |
| | Time (sec) | corr | Time (sec) | corr | Time (sec) | corr |
| | 152.844 | 0.0012 | 5.1 | 0.5932 | 32.672 | 0.0282 |
| Birds | Full Encryption | | Partial Encryption | | | |
| No. of Genetic Cycle | 5 | | 0 | | 5 | |
| Initial Key stream | (10011110) | | (01110011) | | (00010001) | |

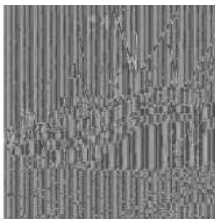
a) Original Image

b) Wavelet Subband Images

c) Encryption Subband Image (Without Genetic Algorithm)



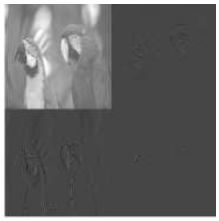
d) Encryption Subband Image (With Genetic Algorithm)



e) Encryption Full Image (With Genetic Algorithm)

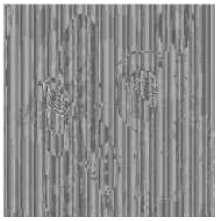
**Figure (7) Resulting Images of Boat**

a) Original Image

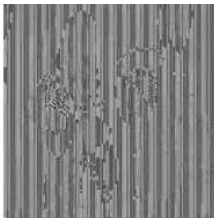


b) Wavelet Subband Images

c) Encryption Subband Image (Without Genetic Algorithm)



d) Encryption Subband Image (With Genetic Algorithm)



e) Encryption Full Image (With Genetic Algorithm)

**Figure (8) Resulting Images of Birds**

## *6. Conclusion*

The experimental results shows that the type of image and the wavelet transform as well as the suitable keystream all these factors influence the encryption process. The genetic algorithm gives here the best encryption, although in the full image the genetic algorithm finds the best initial key stream that makes the correlation approach to zero (high encryption), but it takes more time. In the partial image (after wavelet transform) reduces the time but the correlation will be larger than the previous state, the last case is the partial image with manually selection of initial key stream (without genetic algorithm) this case reduces the time, with bad encryption. Without genetic algorithm we may take initial key that is not good to encrypt the image, but the use of genetic algorithm gives always suitable results. The much smaller correlation leads to more difference between the two images and then more secure.

The proposed algorithm may be used in many future works, one of these works is the modified RC4 with wavelet transform.

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**أيجاد أفضل سلسلة مفتاح بِواسطة الخُوارزمية الجينية لتشفير الصُورة**

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**البصرة–العراق**

***المُستخلص***

بِسبب ألأستخدام الواسع للصُور في العمليات الصناعية، لذلك فانه منَ المُهم حماية معلومات الصُور من حالأت الدخول غير المسمُوحة. لقد استُخدمت خوارزمية ال RC4 مع التحويل المُويجي. أنَ الفكرة الأساسية من هذا البحث هي لبيان عمل الخوارزميةِ الجينية في أيجاد افضل سلسة للمفاتيح وتأثير كُل مفتاح في زيادة سرية الصُورة، وقد أُخذت عدة تجارب لتوضيح هذا الغرض.