



Adaptive Steganography Based on bargain Game

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Abstract

The capacity and security of the confidential message on the channel are two important challenges in steganography. In this paper, a new block steganography model is presented using the bargain method so that a competitive model is introduced. In this game, the blocks are the same players. The bargain is provided with the aim of embedding information without reducing capacity as well as increasing security. The proposed model shows that it can be used both of the special domain and the transform domain, which are two important methods of steganography. For this purpose, an example of a special domain model is introduced in which, in the first step, the image is divided into $n \times n$ blocks, and in the second step using the graph coloring algorithm, pixels are considered to embed confidential information in each block. In the third step, regarding the bargaining method in game theory, each block plays the role of a player, that the competition between players is based on the defined goal function, and in the best blocks in terms of two criteria of capacity and security, which here means each block has a higher security-to-capacity ratio, so it has a higher priority, which is determined based on the bargaining model. Also, information embedded in LSB two bits. An example of a conversion domain method is also shows that security increases without decreasing in capacity. The conclusion is evaluated by three criteria: PSNR, histogram, and ϵ – secure also, 2000 standard images were evaluated and observed that the proposed method improves the block methods of embedding information.

Keywords: Stganography, image, game theory, graph coloring, LSB method

1. Introduction

Game theory is a branch of mathematical economics that considers the resolution of conflicts between players and evaluates the optimality of their strategies. The conflict can relate to different areas of human interest: most often it is related to economics, sociology, political science, and less often it is related to biology, cybernetics and even military affairs. A conflict is any situation in which the interest of two or more participants, traditionally called players, is affected. For each player, there is a certain set of strategies that can apply. Overlapping, the strategies of several players create a certain situation in which each player gets a certain result, called a win, positive or negative. During choosing a strategy, it is important to consider not only getting the maximum profit, but also the possible steps of the enemy, and their impact on the situation. In general, games are divided into two categories: cooperative and non-cooperative. A cooperative game is a conflict in which players can communicate with each other and join groups to achieve the best result. An example of a cooperative game is the Bridge card game, where the points of each player are counted individually, but the pair with the highest amount wins. On the other hand, non-cooperative games describe situations in great detail and produce more accurate results. Cooperatives games look at the whole process of the game. Despite the fact that these two types are opposite to each other, it is quite possible to combine strategies, which can bring more benefits than following either one. Image steganography is one of the most important ways to create security in communication aspects, especially network communication. In addition to increasing steganography

methods, various methods have been presented for steganalysis. Also, for more security and resistance to steganalysis methods, when comparing stego-images with cover-images, such as RS and χ_2 analysis, the graph coloring technique is used to block the image [1]. In order to improve all the methods of block-based steganography, the bargaining model can be used in game theory. The best blocks can be selected for embedding information. Also, by modeling it, the proposed method can be improved. In fact, without reducing the capacity, security will increase. Based on Nash bargaining solution (NBS) [19] [20], the problem can be formalized with a cooperative game. The content-based distortion cost is used to select a particular region function. To minimize distortion, the message is embedded in the region using optimized coding. In general, there is more message embedded in complex textures. Simple texture regions, which embed less or no information, provide better resistance to steganalysis. Regardless, Adaptive content embedding has a problem that it does not meet Kerckhoff's Principle [21]. One of the steganography schemes is based on image blocking for a competitive model between increasing the image quality and keeping the compression constant using the bargaining method [2]. The rest of this paper is organized as follows: section 2 presents a brief summary of related works. Section 3 introduces a fast algorithm for graph coloring. Section 4 introduces a variety of steganography methods and the concepts of security and capacity in images. Section 5 introduces the types of game models in game theory. In Section 6, the proposed method, which includes a message embedding algorithm and a message extraction algorithm is presented. Section 7 provides a comparison between gained results and finally, in section 8, the conclusion is presented.

2. Related work

Pascal and Rainer [9] used the adaptive steganography to introduce a new game-theoretic framework while taking the knowledge of the steganalysis into account. The authors proposed a new framework with based on a stylized cover model for both parties' optimal strategies. They showed that the introduced model had a unique equilibrium of mixed strategy, which related to the heterogeneity of the cover.

Mekala and et.al [8] proposed a game-theoretic framework to learn the adaptive steganography process while capturing the information of the steganalysis into a definition. The authors showed that model approach the structure with a stylized wrap and discover both parties' best plans.

Johnson and et.al [4] suggested a two-player zero-sum game defined as Alice the steganographer and Eve the attacker. In this case, a formula was suggested that determined the best response for all players and minimax strategy.

Yedroudj and et.al [6] proposed a new steganography method based on deep learning and Generative Adversarial Networks (GAN). This method was defined based on three different architectures the 3-player game.

Niu and et.al [5] suggested a method with a high-security steganography algorithm for an H.264 video. The purposed method improves distortion function in the UNIWARD algorithm by using the game theory model.

Li and et.al [3] proposed a competitive model between the steganographer and the attacker depend on the security of practical steganography the gained results showed the existence of a unique mixed strategy Nash equilibrium.

Wu and Zhang [7] studied the non-cooperative games and cooperative games, in order to analyze the parameters for watermarking and found the equilibrium strategies for encoders to individually embed a payload in a cover, and the original cover under constraints. Schottle and Bohme [18] showed that the game theory can be used systematically in the technology of embedding confidential message. It is proved that exit the Nash equilibrium in steganographer and steganalyst in the framework of a hybrid strategy, and the embedding of 2-bit message is implemented. In theory, the possibility of confidential message technology is based on demonstrates game theory.

3. Graph coloring

The graph coloring problem is in the category of NP-hard problems, so there is no polynomial-time algorithm to solve it. regarding the graph coloring problem becomes the problem of the most independent set in the graph so the innovative algorithms presented in this field are varied, however for the sake of simplicity in terms of complexity of the algorithm besides the appropriate speed of the tree-based algorithm to find the most independent set which is used in the graph coloring problem [11].

3.1. Graph coloring algorithm

The different parts of the algorithm are described in the form of an example, considering the following graph shown in Fig. 1 [11].

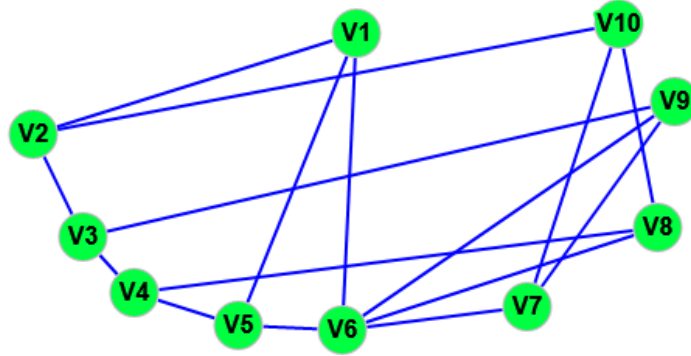


Figure 1: Graph example [11].

1. Introduce the edge table and the complement edge:
2. Selected the most independent set based on tree search. vertex V_1 is considered as the root according to the table of the first step find the complementary edges of the vertex V_1 therefore $V_3, V_4, V_7, V_8, V_9, V_{10}$ are the children of vertex V_1 . This step must run for V_3 so the vertices of $V_5, V_6, V_7, V_8, V_{10}$ are selected. Here, only selected the vertices that are common to both vertices are considered as V_7, V_8 and V_9 . Thus, the subgraph of a tree is obtained, which includes a connected vertex from which most of the independent sets can be obtained. With the above method, all vertices can be obtained in the same way.
3. Now the most path should be chosen which consists two paths $\{V_1, V_3, V_7, V_8\}$ and $\{V_1, V_3, V_7, V_{10}\}$. An optional path is selected for example $\{V_1, V_3, V_7, V_8\}$, that is considered then $MIS_1 = \{V_1, V_3, V_7, V_8\}$.
4. For all three vertices considered in Fig. 1, the most independent set of it can be obtained and aggregated to include all vertices regarding the Eq. 1 to Eq. 4.

$$MIS_1 = \{V_1, V_3, V_7, V_8\} \tag{1}$$

$$MIS_2 = \{V_2, V_4, V_6\} \tag{2}$$

$$MIS_3 = \{V_5, V_9, V_{10}\} \tag{3}$$

$$V_{MIS} = \{MIS_1 \cup MIS_2 \cup MIS_3\} = \{V_1, \dots, V_{10}\} \tag{4}$$

5. Since the largest independent set is 4, so the color number of this graph is 4, which means that the graph can be colored with 4 different colors without any two adjacent vertices having the same color.

3.2. Algorithm 1

3.2.1. Notations used in algorithm 1

Here the definitions of symbols used within the algorithm are presented:

V_{MIS} : Outline sets that include independent sets.

V : A collection of all vertices.

X : Node in progress.

S_X : A set of nodes associated with a node in the X progress.

X_c : Children of X .

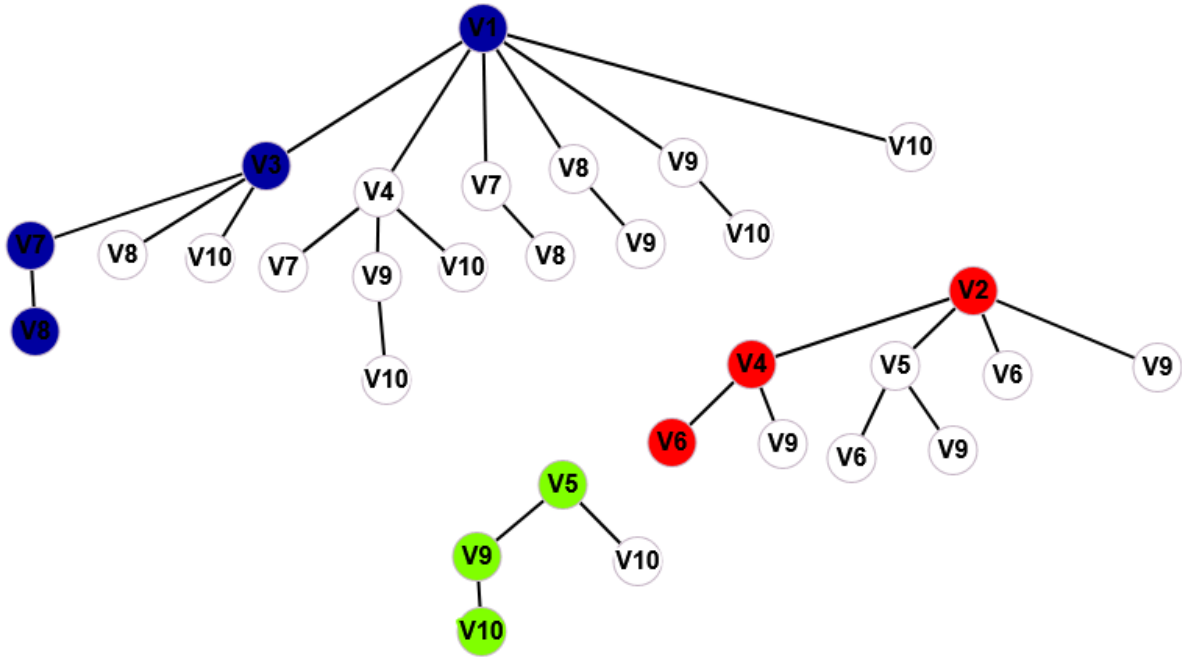


Figure 2: A tree graph for the most independent sets [11].

- N_X : A set of nodes is adjacent to node X .
- i : Variable.
- T_k : k th subgraph.
- MIS_k : k th MIS.
- n : Number of path with the longest length.
- P_L : The longest path from left to right.

Algorithm 1 Finding Maximal Independent Sets

```

1: procedure INPUT( $G, k$ ) ▷ A direction less graph  $G = (V, E)$ , an integer  $k$ 
2:   A proper  $k$ -coloring of graph  $G$  or display statement of failure.
3:   while ( $V_{MIS} \neq V$ ) do
4:      $1 \leftarrow i$ 
5:      $V_i \leftarrow X$ 
6:     if ( $(N_X \cap S_X) == \emptyset$  and  $X \in V_{MIS}$ ) then
7:       Initialize a Sub Tree  $T_k$  and add vertex  $X$ 
8:       Repeat step 9 to 10 for all neighbors of  $X$ 
9:       For all  $N_X$ : make child  $X_C$  of  $X$  as  $X_C = N_X$ 
10:       $i = i + 1$ 
11:    else
12:      Repeat step 11 to 13 for all  $(V - 1)$ 
13:       $X = X_C \ \forall X_C \in V$ 
14:       $\forall X \in V(X_C = (N_X \cap S_X))$ 
15:    end if
16:    Find number of longest path  $n$ 
17:    if ( $n > 1$ ) then
18:      make it  $MIS_k$  and set  $V_{MIS} = MIS_k$ 
19:      Set  $V = (V - V_{MIS})$ 
20:    end if
21:  end while
22: end procedure

```

4. Definitions of Embedding Methods, Capacity and Security in Image Steganography

In general, steganography methods can be divided into two groups:

1. Spatial domain: In this method, the secret message is embedded directly inside the image pixels.
2. Transform domain: In the transform method, first the image is converted by various transformations such as wavelets or DCT, and then secret information is embedded in it, and finally the conversion is reversed to return to the format image.

4.1. Least Significant Bit

One of the important techniques in the spatial method is the LSB method. That is, confidential information is embedded in the Least Significant bits of image pixels. For example, if a color image is considered that consists of 24 bits, ie 3 pixels of 8 bits of red, green, and blue. The secret message is embedded in the last bit of every 8-bit value so that in one 512x512 image, the maximum image capacity is 786432.

4.2. Capacity

The maximum amount that can be embedded in the original image, assuming that the image quality does not decrease. Capacity depends entirely on the steganography design and can be used to determine how much information can be embedded in each cover image.

4.3. Security

The concept of security in steganography means that the attacker cannot distinguish between the original image and the stego image, since embedded information makes a difference. The term peak signal-to-noise ratio (PSNR) is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation. There are many methods and criteria and one of the most widely used and important methods is the use of PSNR(Peak Signal to Noise Ratio), that shows the amount of variation between the

original image and the stego image in which the information is embedded (Eq. 5). The closer it is to number 100, the harder it is for the attacker to detect and the higher the security of the steganography method.

$$PSNR = 10 \log \frac{L^2}{\sqrt{MSE}} dB \quad (5)$$

where L = maximum value, MSE = Mean Square Error [22].

$$MSE = \frac{1}{N} \sum_{i=1}^N |I - I'|^2 \quad (6)$$

where I = original value, I' = stego value and N = number of samples [22].

5. Game Theory

Game theory as a scientific discipline studies the relationship between people who are guided by mismatched (and sometimes opposite) motives. As well as traditional games such as poker, chess, football, and many others, game theory studies such serious relations as market competition, arms race, environmental pollution. In-game theory, all these serious relationships are called games, since in the mentioned areas, as the games, the result depends on the decisions (strategies) of all participants. Furthermore, game theory is a mathematical discipline that is used in many areas of human activity (economics, military affairs, biology, etc).

5.1. Game types

1. *Cooperative / non-cooperative game*: A cooperative game is a conflict in which players can communicate with each other and join groups to achieve the best result. An example of a cooperative game is the Bridge card game, where the points of each player are counted individually, however, the pair with the highest amount wins. On the other hand, non-cooperative games describe situations in great detail and produce more accurate results. Cooperatives consider the process of the game generally. Despite the fact that these two types are opposite to each other, it is quite possible to combine strategies, which can bring more benefits than following either one.
2. *Zero-sum and non-zero-sum*: A zero-sum game is a game in which the gain of one player is equal to the loss of another. For example, a banal dispute: if you won the amount of N , then someone lost the same amount of N . In a game with a nonzero sum, the total price of the game can change, thus bringing benefit to one player without taking away its price from another. As an example, chess is perfect here: by turning a pawn into a queen, the player "A" increases the total sum of his pieces, while not taking anything away from the player "B". In games with a nonzero sum, the loss of one of the players is not a prerequisite, although such an outcome is not excluded.
3. *Parallel and sequential*: A parallel game is a game in which the players make moves at the same time, or the move of one player is unknown to the other until the end of the general cycle. In sequential play, each player has information about his opponent's previous move before making his choice. And it is not at all necessary for the information to be complete, which leads to the next type. With complete or incomplete information These types are a subset of sequential games.
4. *Metagames* These games are the lemmas of the game theory. They are not useful on their own, however, it is applied in the context of a conflict, expanding its set of rules. In any conflict, different types can be combined to define the rules of the game, to make it a cooperative, sequential, zero-sum game or a metagame with incomplete information.
5. *Practical problems* Of course, one should also point out the existence of certain limits of application of the analytical tools of game theory. In the following cases, it can only be used on condition of additional information. Firstly, this is the case when players have different ideas about the game in which they participate, or when they are not sufficiently informed about the capabilities of each other. For example, there may be unclear information about a competitor's payments (cost structure). If too complex information is not characterized by incompleteness, then the experience of similar cases can be applied, taking into account certain differences.

Secondly, game theory is difficult to apply to many equilibrium situations. This problem can arise even during simple games with a simultaneous choice of strategic decisions. Thirdly, if the situation for making strategic decisions is very difficult, then players often cannot choose the best options for themselves. For example, several enterprises may enter the market at different times, or the reaction of enterprises already operating that may be more difficult than being aggressive or friendly. It has been experimentally proven that when the game is expanded to ten or more stages, the players are no longer able to use the appropriate algorithms and continue the game with equilibrium strategies.

5.2. The bargaining game on block-based image

This method can be used in all methods of image steganography in which the image is divided into blocks and then confidential information is embedded inside the original image, and while maintaining the capacity of the method, security is improved. In this case of studies, the graph coloring technique has been used to embed information in each image block with the aim of keeping the image capacity constant and image security should be increased. Game theory is a mathematical tool for modeling a variety of problems. In this paper, using the bargaining model in the type of cooperative games, game theory creates a trade-off between capacity and security. In this plan, each block that is displayed with B_i is in competition with other blocks in embedding information, so that the confidential message is embedded only in blocks that increase security while maintaining capacity. The game model is as follows:

1. *Player*: An image is divided into N blocks, each block acting as a player. Each block competes with the other blocks to embed internal secret message.
2. *Strategies*: A player's strategy is how to embed secret message bits that the security maximizing and fixed the capacity of the image. Suppose the original bits for the image is S and the fixed capacity is C , each block's bits for representing the embed secret message is s_i . Then, the maximum permitted number of bits for the embedded image is $S \times C$; the total bits requested by the N blocks should be no more than $S \times C$. It can be formulated as shown in Eq. 7:

$$\sum_{i=1}^N s_i \leq S \times C \quad (7)$$

3. *Utility*: utility function for every block is considered as the security of block. Top security under some fixed capacity is more preferable. The utility function is a combination of all the image blocks and the characteristic of each block that is the product of the capacity is composed of PSNR as shown in Eq. 8.

$$u = (u_1(B_1, X_1), u_2(B_2, X_2), \dots, u_N(B_N, X_N)) \quad (8)$$

4. *Initial utility*: can be define by characteristic value of each blocks in block methods as shown in Eq. 9.

$$u^0 = (u_1^0(B_1, X_1^0), u_2^0(B_2, X_2^0), \dots, u_N^0(B_N, X_N^0)) \quad (9)$$

According to the bargaining game in game theory, the standard form two player of which is defined [17]:

$$\begin{aligned} & \max((x_1 - v_1)(x_2 - v_2)) \\ & (x_1, x_2) \in F \\ & x_1 \geq 0, x_2 \geq 0 \end{aligned} \quad (10)$$

Now the bargaining game for the defined problem can be introduced as shown in Eq. 11.

$$\begin{aligned} & \max \prod_i^N (u_i(B_i, X_i) - u_i^0(B_i^0, X_i^0)) \\ & s.t \sum_{i=1}^N s_i \leq S \times C \end{aligned} \quad (11)$$

So that s_i depends on B_i and X_i . In Eq. 10 structure optimization problem can be solved by Lagrangian multiplier method [10]. The way of how to select the parameters is given in the following subsection.

5.3. Block embedding

There are several methods for steganography within images, but one of the most widely used techniques is to embed within image blocks. Image blocking takes place in both the special domain and the transform domain. In this paper, two steganography methods are selected, one of which is in the special domain [1], and the other in the transform domain [12], and the initial parameters are determined according to the bargain game model.

6. Our Proposed approach

Our goal in this paper is to improve two steganography algorithms based on bargaining algorithm in game theory.

6.1. special domain case

Douiri and et.al proposed a new algorithm for embedding information by graph coloring method on black and grayscale images [1]. This method has two major problems:

1. Very low speed due to the graphing method on image blocks which suggest using the coloring algorithm 1 instead of using the existing algorithm in the algorithm that the proposed algorithm improves the speed.
2. Using appropriate blocks to embed information, which is solved based on the bargaining method in game theory, which increases security while maintaining image capacity. In Eq. (11) the parameter of X_i depends on the value of PSNR and capacity, which is considered the division of image blocks B_i and assuming the embedded information in 2-bit LSB per pixel (byte) that are shown as follows through Eq. 12 to Eq. 16.

$$c_i = (\text{Card}(CH_i)) \times 2 \quad (12)$$

$$d_{psnr} = PSNR_i - \text{Average}(PSNR) \quad (13)$$

$$d_c = c_i - \text{Average}(c) \quad (14)$$

$$u_i(B_i, X_i) = d_{psnr} + d_c \quad (15)$$

$$u_i^0(B_i, X_i^0) = d_{psnr}^0 + d_c^0 \quad (16)$$

Where $n \times n$ is, the segmented blocks of the main image play the role of the players in the Eq. 11. c_i is capacity i -th block, B_i player i -th which is the same as the image block i -th. $\text{Average}(PSNR)$ is $PSNR$ average of all image blocks. $\text{Average}(c)$ is c average of all image blocks. d_{psnr} is difference $\text{Average}(PSNR)$ average of $PSNR$ block i -th. d_c is difference $\text{Average}(c)$ average of c block i -th. $PSNR_i$ is $PSNR$ block i -th. In this case $PSNR$ and capacity are according to Duria and et.al [1].

6.2. algorithm bargain for example special domain

The proposed algorithm is to determine the priority of embedding information in image blocks. If the confidential message is equal to the total capacity of the image, this algorithm is not applicable and is used when the confidential message is less than the total capacity of the original image. In this method, a preprocessing is performed on the image and based on the size of information that is to be embedded in the image, blocks are selected, then the information is embedded only in the specified blocks. In this algorithm, it is assumed that the blocks in which the information is not embedded are much less than the blocks in which the information is embedded, so the index of the blocks in which the information is not embedded must be sent to the receiver. As can be seen, this proposed method does not change the data extraction algorithm and only changes the way the information is embedded. It should be noted that if the maximum image capacity is used to embed information, the proposed algorithm is extra.

Algorithm 2 algorithm bargain

```

1: procedure INPUT( $I, M$ ) ▷  $I$  Gray scale image,  $M$  expanded message from the original message
2:   Give A matrix of pixels ( $N_1 \times N_2$ ) associated to the image
3:   Divide  $I$  in the form of  $N$  blocks  $H_l$  of same size
4:    $l = 1$ 
5:   while  $l \leq N$  and  $M \neq \emptyset$  do
6:     Calculate  $s^l = \lceil (\sum |p_i^l - p_{i+1}^l| / (\text{card}(H_l) - 1)) \rceil$ 
7:     Give the associated graph to each block  $H_l$ 
8:     Apply Algorithm 1 for  $H_l$ 
9:      $p'_{CH_l} = p_{CH_l} + 2LSB(m)$  ▷ Hide the message  $m$ 
10:    for  $i = 1$  to  $\text{card}(CH_l)$  do ▷ Adjusting block  $H_l$ 
11:       $add = p'_i - p_i$ 
12:       $p_{\text{nodestar}(i)} \leftarrow p_{\text{nodestar}(i)} + add$ 
13:    end for
14:     $M \leftarrow M - 2\text{bits-LSB}$ 
15:     $l \leftarrow l + 1$ 
16:     $c_l$ 
17:    Calculate  $u_l^0(B_l, X_l^0)$ 
18:  end while
19:  Apply Eq 11.
20:   $L = \text{Lenght}(m)$ 
21:  Select the highest priority blocks based on total capacity
22:  return  $i_1, i_2, \dots, i_j$  ▷ Index of the blocks that are inside it does not embed any information
23: end procedure

```

Algorithm 3 Embedding

```

1: procedure INPUT( $I, m, i_1, i_2, \dots, i_j$ ) ▷  $I$  Gray scale image,  $m$  a message to hide,  $i_1, i_2, \dots, i_j$  Index of the blocks that are inside it does not embed any information
2:   Give A matrix of pixels ( $N_1 \times N_2$ ) associated to the image
3:   Divide  $I$  in the form of  $N$  blocks  $H_l$  of same size
4:    $l = 1$ 
5:   while  $l \leq N$  and  $m \neq \emptyset$  and  $l \neq i_1, i_2, \dots, i_j$  do
6:     Calculate  $s^l = \lceil (\sum |p_i^l - p_{i+1}^l| / (\text{card}(H_l) - 1)) \rceil$ 
7:     Give the associated graph to each block  $H_l$ 
8:     Apply Algorithm 1 for  $H_l$ 
9:      $p'_{CH_l} = p_{CH_l} + 2LSB(m)$  ▷ Hide the message  $m$ 
10:    for  $i = 1$  to  $\text{card}(CH_l)$  do ▷ Adjusting block  $H_l$ 
11:       $add = p'_i - p_i$ 
12:       $p_{\text{nodestar}(i)} \leftarrow p_{\text{nodestar}(i)} + add$ 
13:    end for
14:     $m \leftarrow m - 2\text{bits-LSB}$ 
15:     $l \leftarrow l + 1$ 
16:  end while
17:  return Stego-image  $I'$ 
18: end procedure

```

Algorithm 4 Extracing

```

1: procedure INPUT( $I', i_1, i_2, \dots, i_j$ ) ▷  $I'$  Gray scale image
2:   Divide  $I'$  in the form of  $N$  blocks  $H_l$  of same size
3:    $l = 1$ 
4:   while  $l \leq N$  and  $l \neq i_1, i_2, \dots, i_j$  do
5:     Calculate  $s^l = \lceil (\sum |p_i^l - p_{i+1}^l| / (\text{card}(H_l) - 1)) \rceil$ 
6:     Give the associated graph to each block  $H_l$ 
7:     Apply Algorithm 1 for  $H_l$ 
8:     Extract 2bits-LSB secret data in  $CH_l$ 
9:      $m \leftarrow m + 2\text{bits-LSB}$ 
10:     $l \leftarrow l + 1$ 
11:  end while
12:  return  $m$  ▷ a secret message
13: end procedure

```

6.3. transform domain case

Keshavarzi and et.al [12] proposed a new method in embedding message based on integer wavelet transform using block standard deviation. In the first step, three levels of integer wavelet transform are taken on the image, and in the second step, confidential message is stored in the middle frequencies so that it is divided into 2×2 blocks and stored within a selected threshold within the selected block. In order to improve the algorithm, the game theory bargaining method is used so that security is improved without reducing the capacity. In the proposed method, after the image is divided into 2×2 blocks and the threshold of the selected block is passed, based on the game theory bargaining problem, the information is stored inside each block. Using appropriate blocks to embed information, which is solved based on the bargaining method in game theory, which increases security while maintaining image capacity. Based on Eq. 11 the parameter of X_i depends on the value of PSNR and capacity, is due to the division of image blocks B_i and assuming the embedded information in 2-bit LSB HL and LH sub-bands shown in Eq. 17 to Eq. 20 as follows:

$$c_i = (n \times n) \times 2 \quad (17)$$

$$d_{psnr} = PSNR_i - \text{Average}(PSNR) \quad (18)$$

$$d_c = c_i - \text{Average}(c) \quad (19)$$

$$u_i(B_i, X_i) = d_{psnr} + d_c \quad (20)$$

$$u_i^0(B_i, X_i^0) = d_{psnr}^0 + d_c^0 \quad (21)$$

Where $n \times n$ is, the segmented blocks of the HL and LH sub-bands after that three integer wavelet transform play the role of the players in Eq. 11. c_i is capacity of i -th block, B_i is the i -th player which is the same as i -th block. $\text{Average}(PSNR)$ is $PSNR$ average of all image blocks. $\text{Average}(c)$ is c average of all image blocks. d_{psnr} is difference $\text{Average}(PSNR)$ average of $PSNR$ i -th block. d_c is difference $\text{Average}(c)$ average of c i -th block. $PSNR_i$ is PSNR i -th block. In this case, PSNR and capacity are according to Keshavarzi and et.al [12].

6.4. algorithm bargain for example transform domain

The proposed algorithm is to determine the priority of embedding information in image blocks. If the confidential message is equal to the total capacity of the image, this algorithm is not applicable and is used when the confidential message is less than the total capacity of the original image. In this method, a preprocessing is performed on the image and based on the size of information that is to be embedded in the image, blocks are selected, then the information is embedded only in the specified blocks. In this algorithm, it is assumed that the blocks in which the information is not embedded are much less than the blocks in which the information is embedded, so the index of the blocks in which the information is not embedded must be sent to the receiver. As can be seen, this proposed method does not change the data extraction algorithm and only changes the way the information is embedded. It should be noted that if the maximum image capacity is used to embed information, the proposed algorithm is extra.

Algorithm 5 algorithm bargain

```

1: procedure INPUT( $I, R, T_{max}$ )   $\triangleright$   $I$  image,  $R$  Random message that contains all image blocks,  $T_{max}$  is Threshold,  $k$ 
   key
2:    $IWT(IWT(IWT(I)))$   $\triangleright$  3 integer wavelet transform levels on  $I$ 
3:   Divide  $HL$  and  $LH$  to  $N$  blocks  $2 \times 2$  that is  $b_i$ 
4:    $i = 1$ 
5:   while  $i \leq N$  and  $m \neq \emptyset$  do
6:     for  $j = 1$  to  $j \leq 4$  do
7:       if  $b_{i,j} \geq 0$  then  $b'_{i,j} = b_{i,j} - ((b_{i,j}) \bmod 4) + 2LSB(m)$ 
8:       else
9:          $b'_{i,j} = -(|b_{i,j}| - (|(b_{i,j})| \bmod 4) + 2LSB(m))$ 
10:      end if
11:       $m \leftarrow m - 2bits - LSB$ 
12:    end for
13:    Calculate  $T_i$ 
14:    if  $T_{max} > T_i$  then
15:       $2LSB(m)$  will be embedded in the next block
16:    else
17:    end if
18:     $c_i$ 
19:    Calculate  $u_i^0(B_i, X_i^0)$ 
20:     $i \leftarrow i + 1$ 
21:  end while
22:  Apply Eq 11.
23:   $L = \text{Lenght}(m)$ 
24:  Select the highest priority blocks based on total capacity.
25:  return  $i_1, i_2, \dots, i_j$   $\triangleright$  Index of the blocks that are inside it does not embed any information
26: end procedure

```

Algorithm 6 Embedding

```

1: procedure INPUT( $I, m, T_{max}, k, i_1, i_2, \dots, i_j$ )    ▶  $I$  image,  $m$  a message to hide,  $T_{max}$  is Threshold,  $k$  key,  $i_1, i_2, \dots, i_j$ 
   Index of the blocks that are inside it does not embed any information
2:    $AES_{OFBENC}(m, k)$ 
3:    $IWT(IWT(IWT(I)))$     ▶ 3 integer wavelet transform levels on  $I$ 
4:   Divide  $HL$  and  $LH$  to  $N$  blocks  $2 \times 2$  that is  $b_i$ 
5:    $i = 1$ 
6:   while  $i \leq N$  and  $m \neq \emptyset$  and  $i \neq i_1, i_2, \dots, i_j$  do
7:     for  $j = 1$  to  $j \leq 4$  do
8:       if  $b_{i,j} \geq 0$  then  $b'_{i,j} = b_{i,j} - ((b_{i,j}) \bmod 4) + 2LSB(m)$ 
9:       else
10:         $b'_{i,j} = -(|b_{i,j}| - (|b_{i,j}| \bmod 4) + 2LSB(m))$ 
11:       end if
12:        $m \leftarrow m - 2bits - LSB$ 
13:     end for
14:     Calculate  $T_i$ 
15:     if  $T_{max} > T_i$  then
16:        $2LSB(m)$  will be embedded in the next block
17:     else
18:     end if
19:      $i \leftarrow i + 1$ 
20:   end while
21:   return Stego-image  $I'$ 
22: end procedure

```

Algorithm 7 Extracing

```

1: procedure INPUT( $I', T_{max}, k, i_1, i_2, \dots, i_j$ )    ▶  $I'$  stego-image
2:   Divide  $I'$  in the form of  $N$  blocks  $H_l$  of same size
3:    $IWT(IWT(IWT(I)))$     ▶ 3 integer wavelet transform levels on  $I$ 
4:   Divide  $HL$  and  $LH$  to  $N$  blocks  $2 \times 2$  that is  $b_i$ 
5:    $i = 1$ 
6:   while  $i \leq N$  and  $i \neq i_1, i_2, \dots, i_j$  do
7:     Calculate  $T_i$ 
8:     if  $T_{max} < T_i$  then
9:       for  $j = 1$  to  $j < 4$  do
10:         $c \leftarrow c + 2bits - LSB(b_{i,j})$ 
11:       end for
12:     end if
13:      $i \leftarrow i + 1$ 
14:   end while
15:    $AES_{OFBDEC}(c, k)$ 
16:   return  $m$     ▶ a secret message
17: end procedure

```

7. Experimental results

The source codes, including the verification of the results and the speed measurement, can be compiled on Linux systems (tested with gcc 4.4.7 on RHEL 6.5), however, we primarily used MS Windows for testing. The speed improvement was measured on a Windows 8.1 Fujitsu S792 notebook equipped with Intel Core i7 having 2 cores

running at 3 GHz and 8 GB of memory. The code was compiled using MS Visual Studio 2013. We produced a x64 binary in the Release mode with the default parameters. Based on the proposed algorithms in two domains of special and transform domain, the results of comparisons are evaluated separately in each case.

7.1. Result special domain

7.1.1. PSNR

The experiments were performed based on the proposed method on famous gray scale images with different dimensions such as 128×128 , 256×256 and 512×512 . In this analysis, which compares the original image and the coded image based on PSNR, the results were compared with Duria and et.al [1], and the results are shown in Table 1.

Table 1: The results of the proposed algorithm in special domain Comparison of PSNR

Cover image	Capacity(bit)	(Duria)	(propose)
Baboon 512×512	564544	44.39	48.71
Baboon 256×256	233472	38.86	41.29
Baboon 128×128	155648	35.52	38.51
Lake 512×512	676832	38.11	41.68
lake 256×256	311296	37.95	40.74
lake 128×128	233472	35.27	38.56
Couple 512×512	689120	42.76	45.93
Couple 256×256	307200	40.09	44.60
Couple 128×128	182624	37.54	41.06

7.1.2. Histogram analysis

In this section in Fig. 3, 5 and 7, the images are compared visually and examined in Fig. 4, 6 and 8 histograms of the original image and the steganography image.

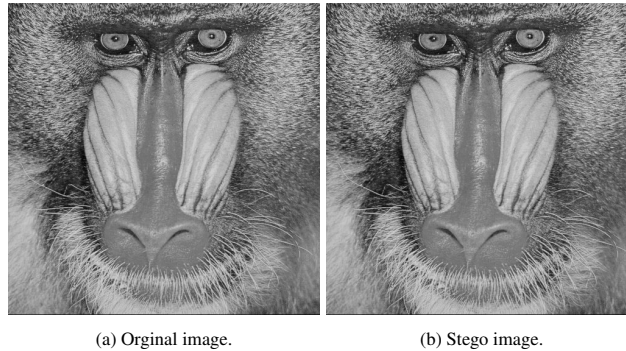


Figure 3: Comparison of original image and stego baboon image

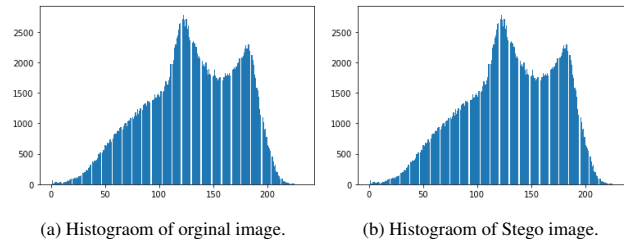


Figure 4: Comparison between the histograms of original baboon image

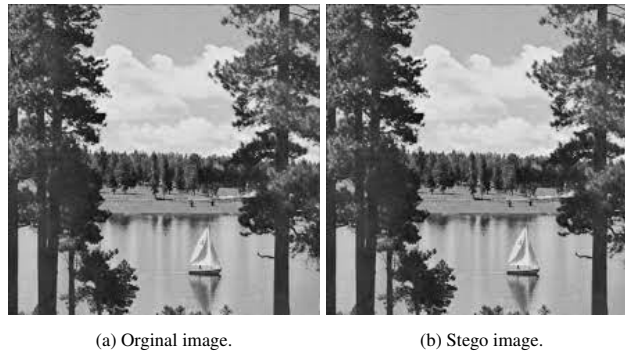


Figure 5: Comparison of original image and stego baboon image

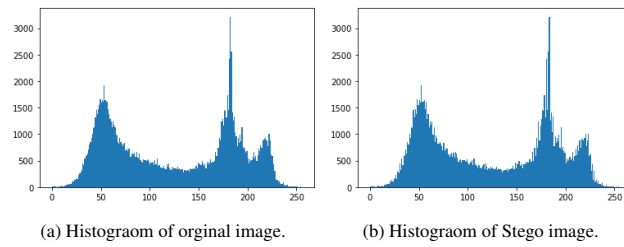


Figure 6: Comparison of histograms original and stego lake image

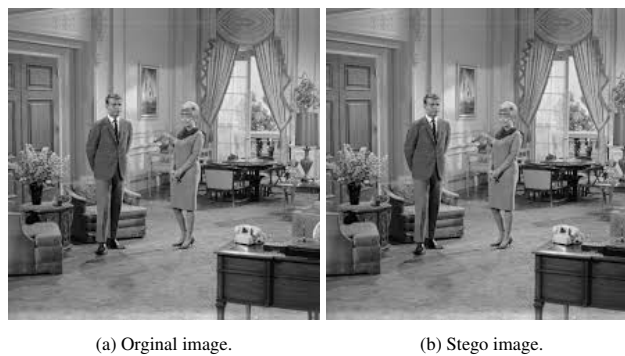


Figure 7: Comparison of original image and stego couple image

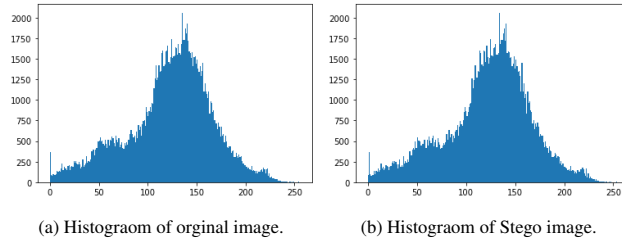


Figure 8: Comparison of histogram original image and stego couple image

7.1.3. Analyze 2000 different images

In this analysis, 2000 images are steganographed with Duria algorithm [1] and our proposed algorithm and the outcomes are in terms of PSNR and capacity.

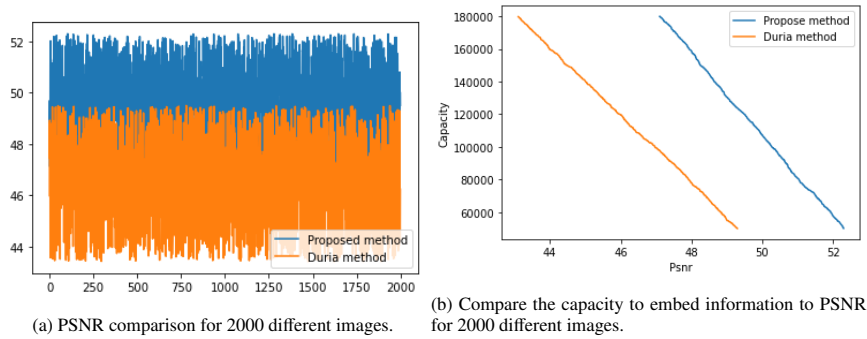


Figure 9: Comparisons between Duria method [1] and our proposed method

7.1.4. Security of steganographic

There are many definitions for comparing the security of cryptographic methods. Here is one of the most popular methods used to compare the security of steganography. ϵ -secure $\epsilon > 0$, if the relative entropy between probability distribution of cover image (P_C) and stego-image (P_S) are at most ϵ . Then the detectability $D(P_C||P_S)$ is defined by: $D(P_C||P_S) = \int P_C \log \frac{P_C}{P_S}$. Thus, for a completely secure stego system, $D = 0$ and if $D \leq \epsilon$ then stego system is named ϵ -secure. In table 2 the proposed method is compared in ϵ -secure terms of.

Table 2: Test Results propose algorithm in special domain Comparison of ϵ -secure

Cover image	Capacity(bit)	(Duria)	(propose)
Baboon 512×512	564544	3.27E-04	2.39E-04
Lake 512×512	676832	3.64E-04	2.77E-04
Couple 512×512	689120	3.92E-04	2.95E-04

7.2. Result transform domain

7.2.1. PSNR

The experiments were performed based on the proposed method on famous gray scale images with different dimensions such as 128×128 , 256×256 and 512×512 . In this analysis, which compares the original image and the coded image based on psnr, the results were compared with Keshavarzi and et.al [12], and the results are compared in terms of PSNR and capacity in Table 3.

Table 3: The results of the proposed algorithm in transform domain Comparison of PSNR($T_{max} = 1$ and 300000 bits)

Cover image	Capacity(bit)	(Keshavarzi)	(proposed)
Lena 512×512	300000	43.76	45.95
Lena 256×256	300000	41.91	43.68
Lena 128×128	300000	38.27	41.14
man 512×512	300000	44.18	47.08
man 256×256	300000	42.71	45.19
man 128×128	300000	40.46	42.26
Peppers 512×512	300000	43.86	48.22
Peppers 256×256	300000	41.52	45.56
Peppers 128×128	300000	38.03	42.37

7.2.2. Histogram analysis

In this section in Figure 9, 11 and 13 images in terms They are compared visually and examined in Figure 10, 12 and 14 histograms of the original image and the steganographed image.



Figure 10: Comparison of original image and stego baboon image

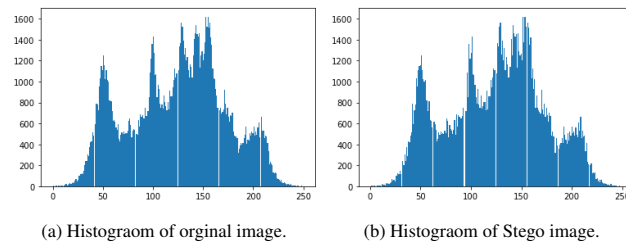


Figure 11: Comparison of histogram original image and stego lena image

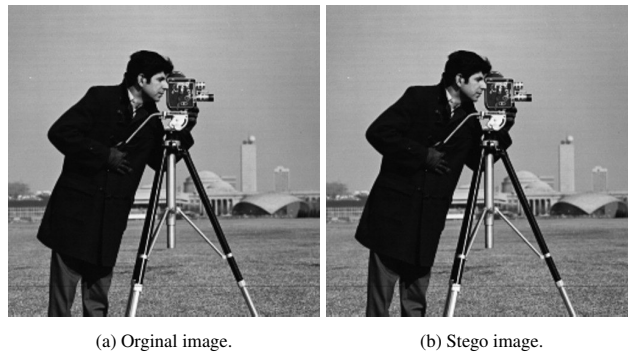


Figure 12: Comparison of original image and stego man image

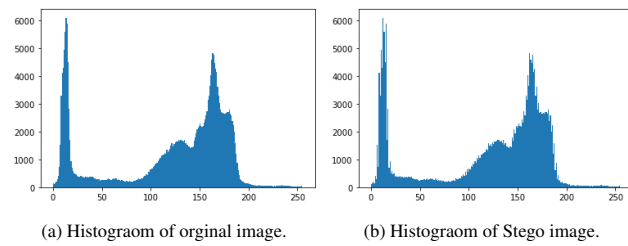


Figure 13: Comparison of histogram of original image and stego man image

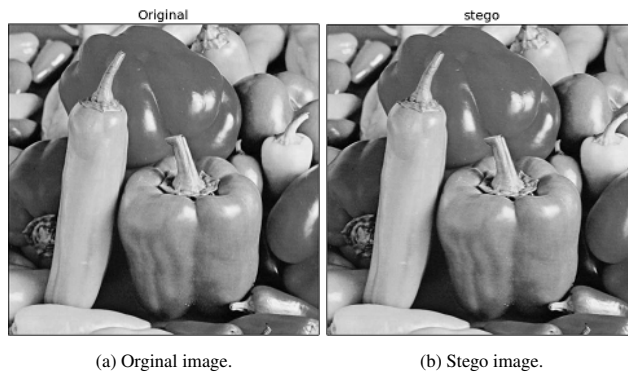


Figure 14: Comparison of the original image and stego peppers image

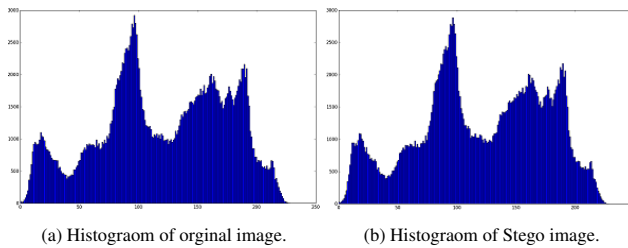


Figure 15: Comparison of the histogram of original image and stego peppers image

7.2.3. Analyze 2000 different images

In this analysis, 2000 images are steganography with Keshavarzi algorithm [12] and the proposed algorithm and compared in terms of PSNR and capacity.

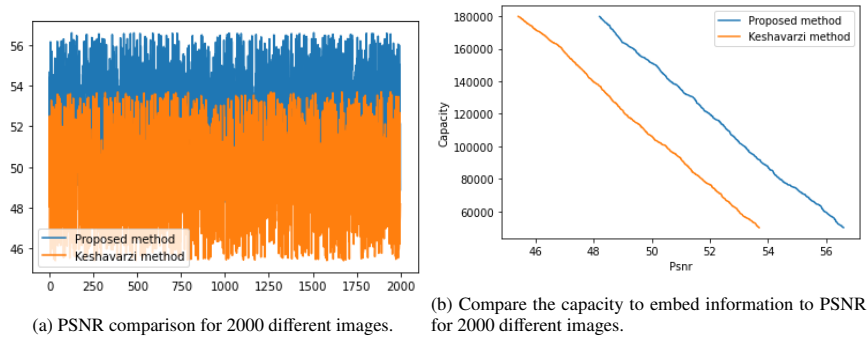


Figure 16: Comparisons between Keshavarzi method [12] and proposed method

7.2.4. Security of steganographic

There are many definitions for comparing the security of cryptographic methods [13][14][15]. Here is one of the most popular methods used to compare the security of cryptographic. ϵ -secure $\epsilon > 0$, if the relative entropy between probability distribution of cover image (P_C) and stego-image (P_S) are at most ϵ . Then the detectability $D(P_C||P_S)$ is defined by: $D(P_C||P_S) = \int P_C \log \frac{P_C}{P_S}$. Thus, for a completely secure stego system, $D = 0$ and if $D \leq \epsilon$ then stego system is named ϵ -secure. In Table 4 The proposed method is compared in ϵ -secure terms of [16].

Table 4: The results of the proposed algorithm in transform domain Comparison of ϵ -secure ($T_{max} = 1$ and 300000 bits)

Cover image	Capacity(bit)	(Keshavarzi)	(propose)
Lena 512×512	300000	1.96E-04	1.12E-04
Man 512×512	300000	1.94E-04	1.09E-04
Peppers 512×512	300000	1.99E-04	1.25E-04

8. Conclusion

This paper proposed a new game model, using the Nash bargaining method and presenting a game model in order to embed information inside the image, which is improved without reducing the security capacity and also it can be used for all block methods in general. The block methods were compared in two different domains, special domain and transform domain. In the special domain, in addition to the bargaining method, a faster algorithm was proposed for graph coloring, which is much faster than the previous algorithm in [1]. As in the algorithms that have been studied as the cases study, with the least change in the structure of the algorithm, according to Tables 1, 2, 3, 4, higher security can be achieved than the previous method proposed in [1] [12]. In order to prove the improvement in the proposed methods, in general, three well-known methods were examined. The first method is based on the PSNR criterion, which is shown in Tables 1 and 3. The second method is based on the histogram and visually shown in Figures 4, 6, 8, 11, 13 and 15. The third method is based on the safe ϵ -secure which are shown in Table 2 and Table 4. Finally, 2000 standard images were examined, the results of which are shown in Figures 9 and 16.

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