A high capacity text steganography scheme based on permutation and color coding

Juvent K. Sadié a,b,c,d, Leonel Moyou Metcheka a,b,c,d and René Ndoundam a, b,c,d,*

*Team GRIMCAPE
1Sorbonne University, IRD, UMMISCO, F-93143, Bondy, France
2CETIC, Yaounde, Cameroon
3Department of Computer Science, University of Yaounde I, P.o. Box 812 Yaounde, Cameroon
4Corresponding author

Abstract

In this paper, we propose a text steganographic scheme based on color coding and permutation. Given a secret message and a cover text, the proposed scheme embed the secret message in the cover text by making it colored, using a permutation algorithm. The stego-text is then sent to the receiver by mail. The results which have been obtained by experiments, show that our model performs a better hiding process in terms of hiding capacity as compared to the scheme of Aruna Malik et al. on which our idea is based.

Keyword

Steganography, text steganography, cover medium, stego-object, permutation, embedding capacity

1. Introduction

The word steganography is of Greek origin and means covered writing. It is the hiding of a message within another (cover medium) such as web pages, images or text, so that the presence of the hidden message is indiscernible. When a message is hidden in the cover medium, the resulting medium is called a stego-object. The key concept behind steganography is that the message to be transmitted should not be detectable with bare eyes. From the definition, Steganography is used to ensure data confidentiality, like encryption. However, the main difference between them is that with encryption, anybody can see that both parties are communicating in secret. Steganography hides the existence of a secret message and in the best case nobody can detect the presence of the message. When combined, steganography and encryption can provide more security. Steganography dates back to ancient Greece, where common practices consisted of etching messages in wooden tablets and covering them with wax. A number of steganographic methods have been introduced on different cover media such as images [1, 2, 3], video files [4, 5] and audio files [6]. In text based steganographic methods, text is used as a cover media for hiding the secret data. Due to lack of large scale redundancy of information in a text file, the human eye is very susceptible to any change between the original and the modified texts. Therefore, text steganography seems to be the most difficult kind of steganography [7], compared to others.
In this paper, we propose a text steganographic scheme based on color coding and permutation. Given a secret message and a cover text, the proposed scheme embed the secret message in the cover text by making it colored, using a permutation algorithm.

The rest of the paper is organized as follows: in section 2, we present some preliminaries and related works. Section 3 concerns the presentation of our scheme. Experimentation is presented in section 4, and finally section 5 is devoted to the conclusion.

2. Preliminaries and related works

In this section, we present some preliminaries that lead us to the comprehension of our scheme. Also, we present related works in the field of text steganography.

2.1. Text Steganography

There are many techniques in text steganography. In syntactical steganography, punctuation marks such as full stop (.), comma (,) etc, are used to hide bits in cover text. The problem with this method is that it requires identification of correct places to insert punctuation [8, 9]. In lexical steganography, words are used to hide secret bits. A word could be replaced by its synonyms and the choice of word to be chosen from the list of synonyms would depend on secret bits. Sms texting is a combination of abbreviated words used in sms [10]. This technique proposes to hide binary data by using full form or its abbreviated form. For instance, to hide 0, full form of the word is used and to hide 1, abbreviated form of word is used [10]. The CSS technique encrypts a message using RSA public key cryptosystem and cipher text is then embedded in a cascading style Sheet (CSS) by using End of Line on each CSS style properties, exactly after a semi-colon. A space after a semi-colon embeds bit 0 and a tab after a semi-colon embeds bit 1 [11].

Anandaprova Majumder and al [12] proposed an approach for text steganography through a technique that uses reflection symmetry of the English alphabet. Ekodeck and Ndoundam [13] proposed different approaches of PDF file based steganography, essentially based on the Chinese Remainder Theorem. Here, after a cover PDF document has been released from unnecessary characters of ASCII code A0, a secret message is hidden in it using one of the proposed approaches, making it invisible to common PDF readers, and the file is then transmitted through a non-secure communication channel.

Aruna Malik and al [14], proposed a high capacity text steganography scheme based on LZW compression and color coding. Their scheme uses the forward mail platform to hide secret data. The algorithm first compresses secret data and then hide the compressed data into the email addresses and also, in the cover message of email. The secret data is embedded in the message by making it colored using a color table. Here below, we present some limits of that scheme.

2.2. Critic and limits

LZW is a lossless compression technique that performs high compression ratio when the source contains repetition pattern. In the LZW based steganographic scheme propose by
Aruna Malik [14], they apply this lossless compression on the secret message to increase the embedding capacity. But in the example proposed, there is no compression. In other words, the size of the compressed text is much greater than the size of the secret. To show this, we will give three different implementation of LZW algorithm applied to the secret message.

2.2.1. The LZW Algorithm with initial dictionary fixed and known

This algorithm [16] starts by initializing the dictionary with the 256 characters of the ASCII code from 0 to 255. The output codes start at a minimum bit size equal to 9 and in general, as long as the indexes considered are strictly inferior to $n = 2^k - 1$, we can represent them on $k$ bits. When the first integer greater than or equal to $2^k - 1$ is met, the sequence 1...1 (k times bit 1) and continue with coding the integers on $k + 1$ bits. Applying this method to the following secret message: "underlying physiological mechanisms", we obtain the outputs presented in Table 1. The binary compressed text is obtained by converting the indexes of the output column of the array to 9 bits: 001110101 001101110 001100100 001100101 001110010 001101100 001111001 001101001 001101110 001100110 001110000 001110001 001110011 0011100100 001101111 001101101 001100111 001101001 001100011 001100001 001101100 000100000 001101101 001100101 001100011 001101000 001100001 001101110 001100101 001101111 001101001 001100111 001101001 001100011 001100001 001101110 001100101 001101111 001101001 001100011 001100001 001101110 001100101 001101111. Hence, the size of the output is 35*9 = 315 bits.

| Buffer | input-char | Output | New Item |
|--------|------------|--------|----------|
| u      | n          | 117    | 256=un   |
| n      | d          | 110    | 257=nd   |
| d      | e          | 100    | 258=de   |
| e      | r          | 101    | 259=er   |
| r      | l          | 114    | 260=rl   |
| l      | y          | 108    | 261=ly   |
| y      | i          | 121    | 262=yi   |
| i      | n          | 105    | 263=in   |
| n      | g          | 110    | 264=ng   |
| g      |            |        | 265=g    |
| p      | h          | 112    | 266=ph   |
| h      | y          | 104    | 268=hy   |
| y      | s          | 121    | 269=ys   |
| s      | i          | 115    | 270=si   |
| i      | o          | 105    | 271=io   |
| o      | l          | 111    | 272=ol   |
| l      | o          | 108    | 273=lo   |
| o      | g          | 111    | 274=og   |
| g      | i          | 103    | 275=gi   |
| i      | c          | 105    | 276=ic   |
| c      | a          | 99     | 277=ca   |
| a      | l          | 97     | 278=al   |
Table 1: Extended dictionary and LZW output with initial dictionary fixed and known.

| Index | char |
|-------|------|
| 1     | u    |
| 2     | n    |
| 3     | d    |
| 4     | e    |
| 5     | r    |
| 6     | l    |
| 7     | y    |
| 8     | i    |
| 9     | g    |
| 10    | space |
| 11    | p    |
| 12    | h    |
| 13    | s    |
| 14    | o    |
| 15    | c    |
| 16    | a    |
| 17    | m    |

Table 2: Initial Dictionary

2.2.2. The LZW algorithm with sharing of the initial dictionary

In this version [15], initial dictionary contains only the character of the secret message. The output code is represented on height bits. The particularity of this implementation is from the initial dictionary which must be shared between the two parties in order to be able to decompress the binary code. Table 2 presents the initial dictionary for the same secret message:
Here are the output code: 1 2 3 4 5 6 7 8 9 10 11 12 7 13 8 14 6 14 9 8 15 16 6 10 17 4 15 12 16 2 8 13 17 13 and in binary we have: 00000001 00000010 00000011 00000100 00000101 00000110 00000111 00001000 00001001 00001010 00001011 00001100 00001101 00001110 00001111 00010000 00010001 00010010 00010011 00010100 00010101 00010110 00010111 00011000 00011001 00011010 00011011 00011100 00011101 00011110 00011111 00100000 00100001 00100010 00100011 00100100 00100101 00100110 00100111 00101000 00101001 00101010 00101011 00101100 00101101 00101110 00101111 00110000 00110001 00110010 00110011 00110100 00110101 00110110 00110111 00111000 00111001 00111010 00111011 00111100 00111101 00111110 00111111.

Hence, the size of the output is the sum of the size of initial dictionary and the output code: 17 + 35 = 52 bytes = 416 bits.

### 2.2.3. The Unix compress command

The ncompress package [17] is a compression utility available on Linux which contains the compress command for fast compression and decompression using LZW algorithm. The algorithm behind this command is explained at page 153 of the data compression book [15]. The initial dictionary size is 512 and the minimum output code size is 9 bits. This package can be installed by using the command "sudo apt-get install ncompress". Based on the Ubuntu 16.04 platform, this command produces a file with .Z extension as compress file. By applying this command "compress -v source.txt" to the secret message contained in text source file with the -v option, the given output indicates that there is no compression and the .Z file size is 44 bytes 352 bits.

Finally the table 3 shows the comparison in bit between the original text size and the output size after the compression using the three different approaches of LZW implementation: The LZW Algorithm with initial dictionary fixed and known, The LZW algorithm with sharing of the initial dictionary and The Unix compress command.

| Secret message | Output size 1 | Output size 2 | Output size 3 |
|----------------|--------------|--------------|--------------|
| 280            | 315          | 416          | 352          |

**Table 3**: Secret message size comparison

From Aruna and al. paper [14], the size obtained was 264 bits, but we have proven above that there is no compression for this example. This is the principal limit of this steganographic scheme, where for some messages the reduction of the message size will not be possible.

Our paper uses:

The idea of color coding contained in the paper of Aruna Malik and al [14];

The permutation generation method of W. Myrvold and F. Ruskey [19];

to present a new scheme where the secret message embedding capacity is better than the scheme of Aruna Malik and al [14].

### 2.3. Permutation Generation Methods
Permutation is one of the most important combinatorial objects in computing, and can be applied in various applications, for example, the scheduling problems. Permutation generation can form the basis of a backtracking program to solve any problem involving reordering a set of items. It is well-known that, for \( n \) distinct items, the total number of permutations is \( n! \).

Permutation generation has a long history. Surveys in the field have been published in 1960 by D.H. Lehmer [20]. Several authors [19, 21, 22, 23] have since developed many methods to generate all the possible permutations of \( n \) elements.

Also, several works [13, 24, 25, 26, 27] in steganography taking advantage of permutations have been done. In particular, H. Hioki [26] in 2013, proposed a permutation steganography, which is an effective method for hiding messages provided where the contents of cover objects are not affected by the rearrangement of their elements.

In their paper, W. Myrvold and F. Ruskey [19] proposed a ranking function for the permutations on \( n \) symbols which assigns a unique integer in the range \([0, n! - 1]\) to each of the \( n! \) permutations. Also, they proposed an unranking function for which, given an integer \( r \) between 0 and \( n! - 1 \), the value of the function is the permutation of rank \( r \). Their algorithms are presented below [19].

2.3.1. Unranking function

First of all, recall that a permutation of order \( n \) is an arrangement of \( n \) symbols. An array \( \pi [0 \ldots n-1] \) is initialized to the identity permutation \( \pi[i] = i \), for \( i = 0, 1, \ldots n-1 \).

**Procedure** unrank \((n, r, \pi)\) [19].
**Begin**
if \((n > 0)\) then
    \(\text{swap}(\pi[n-1], \pi[r \mod n])\);
    unrank\((n-1, \lfloor r / n \rfloor, \pi)\);
**end**
**Note:**
1- \(\text{swap}(a, b)\) exchanges the values of variables \( a \) and \( b \).
2- \(\lfloor a \rfloor\) is the whole lower part of \( a \).

2.3.2. Ranking function

To rank, first compute \( \pi^{-1} \). This can be done by iterating \( \pi^{-1}[\pi[i]] = i \), for \( i = 0, 1, \ldots, n-1 \).
In the algorithm below, both \( \pi \) and \( \pi^{-1} \) are modified.

**function** rank \((n, \pi, \pi^{-1})\):integer [19].
**begin**
if \((n = 1)\) then return(0)  end;
\(s:=\pi[n-1]\);
\(\text{swap}(\pi[n-1], \pi[\pi^{-1}[n-1]])\);
\(\text{swap}(\pi^{-1}[s], \pi^{-1}[n-1])\);
return \((s+n.\text{rank}(n-1, \pi, \pi^{-1}))\);
**end**;

3. Scheme Design

In this section, we present the details of our scheme.
3.1. Embedding Algorithm

**Input:**
- C: the cover text;
- M: the secret message to embed;
- The key \( \pi \): the initial permutation of n colors;
- e: the e-mail address of the receiver;

**Output:**
- C': the stego-message;

begin
1. Compute \( m, \) the binary representation of M;
2. Compute \( t = \lceil \log_2(n!) \rceil \);
3. Divide \( m \) into \( p \) blocks of \( t \) bits each, \( b_1, b_2, \ldots, b_p \);
4. Divide C into \( k \) blocks of n characters each \( c_1, c_2, \ldots, c_k \);
5. For each block \( b_i, 1 \leq i \leq p \):
   a. compute \( \text{Nperm}(b_i) \), the decimal representation of \( b_i \);
   b. compute \( \pi' = \text{unrank}(n, \text{Nperm}, \pi) \), the permutation corresponding to the number \( \text{Nperm} \).
   c. color each character of \( c_i \) by the corresponding color given by the permutation \( \pi' \) and obtain the string \( c_i' \);
   d. compute \( C' := C'||c_i' \); where \( a||b \) is the concatenation of \( a \) and \( b \).
6. If the next character is EOF (End of File) then

Begin
a. Use e to send \( C' \) by mail to the receiver;
end;
Else
begin
a. Color the next character with a color different of permutation colors. This color is shared by the sender and the receiver. However, this color will not be very distant from the others.
   b. Randomly color the rest of characters of C by the colors of colors table, until get the EOF character;
   c. Use e to send \( C' \) by mail to the receiver;
end;
End.

3.2. Retrieval Algorithm

**Input:**
- C': the stego-text;
- \( \pi \): the initial permutation of n colors;

**Output:**
- M: the secret message;

begin:
1. Retrieve all characters colored by the permutation colors, until get a color different from those of the colors table, or get the EOF character. Let’s call them \( C'' \);
2. Divide \( C'' \) into \( p \) blocks of n characters each \( c_1, c_2, \ldots, c_p \);
3. For each block \( c_k, 1 \leq k \leq p \):
   a. use the color order of characters to compute the relative permutation, that we call \( \pi' \).
   b. compute the number \( \text{Nperm} = \text{rank}(n, \pi', \pi^{-1}) \);
   c. compute \( m'=(\text{Nperm})_2 \), the binary representation of \( \text{Nperm} \);
   d. compute \( M := M||m' \);
end;
4. Experimentation

In this section, we present some experimentations of our scheme. First, we propose a theoretical estimation of our embedding capacity for \( n \) colors. Secondly, we present a practical experimentation in the case of 10, 16, 32 and 64 colors, based on example 1 and figure 5 of [14]. These colors are given in figure 1, figure 2, figure 3 and figure 4.

In order to present our embedding capacity, we use as cover text and secret message those of example 1 and figure 5 of Aruna Malik and al [14].

4.1. Theoretical estimations

The table 4 present the embedding capacity \( 100* (P/n) \) of our scheme in the case of \( n \) colors. This theoretical estimation is based on the our embedding algorithm.

| \( n \) | \( M = \log_2(n!) \) | \( P = M/8 \) | \( 100* (P/n) \) (embedding capacity) |
|-------|-----------------|-------------|----------------------------------|
| 10    | 21              | 2.6         | 26.25%                           |
| 16    | 44              | 5.5         | 34.37%                           |
| 20    | 61              | 7.6         | 38%                              |
| 32    | 117             | 14.6        | 45.63%                           |
| 60    | 272             | 34          | 56.67%                           |
| 64    | 295             | 36.9        | 57.66%                           |

Table 4: Theoretical estimations of the proposed scheme

Remark: As far as the space characters of the stego-text are not colored, the embedding capacity can decrease in the experimentations.

Figure 1: table of 10 colors

Figure 2: The table of 16 colors
4.2. Experimentation 1

Here, the secret message is:

*underlying physiological mechanisms*

and the cover text is:

*Only boats catch connotes of the islands sober wines only ships wrap the slips on the cleats of twining lines only flags flap in tags with color that assigns only passage on vessels*

Here we present the embedding process.

1- We compute the binary representation of the secret and obtain the following result:

\[
01110101 \ 01101110 \ 01100100 \ 01100101 \ 01110010 \ 01101100 \ 01111001 \ 01101110 \ 01101111 \ 01100110 \ 01100101 \ 01100011 \ 01100001 \ 01101100 \ 01101001 \ 01100011 \ 01101000 \ 01100001 \ 01101110 \ 01101001 \ 01100011 \ 01101000 \ 01100001 \ 01101110 \ 01101001 \ 01100011 \ 01101000 \ 01100001 \ 01101110 \ 01101001
\]

2- We compute \( t = \lceil \log_2(10!) \rceil = 21 \);

3- The binary secret is then divided into blocks of 21 bits each. For instance, the first block \( b_1 = 011101010110110110011000 \) and the second block \( b_2 = 10001100101011001001 \), ...

4- We divide the cover text into blocks of 10 characters. For instance, the first block \( c_1 = \text{Only boats c} \), the second block \( c_2 = \text{atch connot} \), ...
5- We color the cover text:
- For the block \( b_1 = 01110101011011001100 \), \( N_{\text{perm}} = 961996 \), its decimal representation.
- The permutation relative to 961996 is given by \( \pi' = \text{unrank}(10, 961996, \pi) = 3 \ 8 \ 5 \ 2 \ 1 \ 4 \ 9 \ 0 \ 7 \ 6 \), \( \pi = 0 \ 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \), with the corresponding colors given by figure 1.
- The block \( c_1 = \text{Only boats c} \) is colored relatively to the permutation \( \pi' \). We then obtain the color text given by figure 5.
- For the block \( b_2 = 100011001010111001001 \), \( N_{\text{perm}} = 1152457 \), its decimal representation.
- The permutation relative to 1152457 is given by \( \pi' = \text{unrank}(10, 1152457, \pi) = 2 \ 9 \ 1 \ 6 \ 3 \ 8 \ 4 \ 5 \ 0 \ 7 \), \( \pi = 0 \ 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \), with the corresponding colors given by figure 1.
- The block \( c_2 = \text{atch connot} \) is colored relatively to the permutation \( \pi' \). We then obtain the color text given by figure 5.

The process is the same, and finally we obtain the stego-text given by the figure 6. That stego-text is then sent by mail to the receiver.

\[
\begin{array}{c}
\text{Only boats c} \\
\text{atch connot}
\end{array}
\]

**Figure 5: The Stego-Text**

![Text showing only boats catch connotes of the islands sober wines only ships wrap the slips on the cleats of twining lines only flags flap in tags with color that assigns only passage on vessels](image)

**Figure 6: The Stego-Text of example 1.**

With this example:
- in the case of 10 colors, the embedding capacity is 20.58 %;
- with 16 colors, the embedding capacity is 25.5 %.
- With 32 colors, the embedding capacity is 29.5 %
- with 64 colors, the embedding capacity is 45.45 %.

**4.3. Experimentation 2**

In the example of figure 5 [14], the secret message is:

*behind using a cover text is to hide the presence of secret messages the presence of embedded messages in the resulting stego-text cannot be easily discovered by anyone except the intended recipient.*

and the cover-text is:

*in the research area of text steganography, algorithms based on font format have advantages of great capacity, good imperceptibility and wide application range. However, little work on steganalysis for such algorithms has been reported in the literature. based on the fact that the statistic features of font format will be changed after using font-format*
based steganographic algorithms, we present a novel support vector machine-based steganalysis algorithm to detect whether hidden information exists or not. This algorithm can not only effectively detect the existence of hidden information, but also estimate the hidden information length according to variations of font attribute value. As shown by experimental results, the detection accuracy of our algorithm reaches as high as 99.3% when the hidden information length is at least 16 bits. Our scheme present experimentation based on different colors number.

In the case of 10 colors, We apply our embedding algorithm and obtain the following stego-text, given by figure 7.

Figure 7: The Stego-Text

With this example:

- in the case of 10 colors, the embedding capacity is 22.32%.
- With 16 colors, the embedding capacity is 29.64%.
- With 32 colors, the embedding capacity is 38%.
- With 64 colors, the embedding capacity is 44%.

The table 5 compares our scheme and the scheme of Aruna and al [14] in terms of embedding capacity for 10 colors, based on example 1 and figure 5 of [14].

|       | Our scheme | The scheme of Aruna and al [14] |
|-------|------------|---------------------------------|
| Example 1 | 20.58%     | 6.03%                           |
| Example of figure 5[14] | 22.32% | 13.43% |

Table 5: Comparaison between our scheme and the scheme of Aruna [14] in terms of embedding capacity, for 10 colors.

Based on this table 5 and on figure 8, it is evident that our scheme performs a capacity of 22.32% in comparison to Aruna and Malik [14] Satir and Isik [18] which achieves only 13.43 % and 6.92% respectively for the same secret message and cover text. Also, based on the experimentations, the embedding capacity increases with the number of colors.
5. **Conclusion**

In this paper, we have proposed a text steganographic scheme based on color coding and permutation. Given a secret message and a cover text, the proposed scheme embed the secret message in the cover text by making it colored, using a permutation algorithm. Theoretical experimentation show that our scheme have an embedding capacity of:

- 27.23% for 10 colors;
- 34.37% for 16 colors;
- 45.93% for 32 colors;
- 57.66% for 64 colors.

Also, practical experimentation for 10 colors, based on figure 5 of paper of Aruna and al [14], shows that our scheme performs a better embedding capacity in comparison to the scheme of Aruna and al [14], Satir and al [18] which achieves only 13.43 % and 6.92% respectively for the same secret message and cover text.

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