

Balancing Capacity and Fidelity in Image Multimedia of Steganographic Systems

Chin-Feng Lee⁺, Lin-Chun Lin¹, Shih-Jeng Wang^{1,*}, and Chi-Yao Weng³

⁺Department of Information Management, Chaoyang University of Technology,
Taichung, Taiwan
Email: lcf@cyut.edu.tw

¹Department of Information Management, Central Police University
Taoyuan, Taiwan 333

*Whom correspondence: sjwang@mail.cpu.edu.tw

³Department of Computer Science, National Tsing-Hua University,
Hsinchu, Taiwan

Abstract

Two of new information hiding methods BRL and GRL were proposed by Chang et al in [2]. BRL is more suitable for binary image whereas GRL is better for gray scale. Therefore, Run-Length Coding (RLC) is the main part of this scheme, and the goal of RLC is to hide more information in the image without dropping the quality. In this paper we propose a new information technique by combining the key-concepts of RLC, LSB and pattern-string. In our scheme, we apply the RLC to embed more information and combine the LSB substitute with pattern-string to keep a high image quality. The experimental results show that not only the proposed method is capable of hiding more information, but also still maintains high image quality

Keywords: Run-Length Coding (RLC), Pattern-string, high image quality

1. Introduction

Recently, the internet has become more and more popular. The internet is able to transmit a massive amount of message to other areas. Therefore, encryption technology would become more important in the message transmission via internet. With the rapid computing environment, the encryption technology is usually used to apply so as to safeguard the

information systems. Besides, it is also asked for decreasing the larger computation time for encryption operation. By this circumstance, many scholars have proposed new information hiding techniques that did not emphasize on the encryptions. In other words, there have been more techniques to focus on the safety of transmission but being free of the attention of intentional cryptanalysis. Information hiding means embedded digital information into multimedia. In addition to the transmission of confidential information, it can also be applied to copyright watermarking and digital authentication. In the different applications, information hiding technology can emphasize on different goals, such as capacity, imperceptibility, robustness, and reversibility.

The goal of information hiding, the capacity and imperceptibility are the main of hiding parts [8]. It is easy to know that increase the embedding capacity the image quality will go decreased. Many scholars have proposed to handle this problem. In 2001, Lin et al. [4] proposed the Optimal LSB Substitution algorithm which uses the approach of pixel substitution to improve the quality of the cover image. It also uses genetic algorithm for approximation. In 2003, Chang et al. [3] used Dynamic Programming Strategy to obtain the best possible solution in the best possible time. In 2006, Yang et al. [7] proposed Weighted Bipartite Graph with lower time complexity than Chang et al. [2] Chang et al. [1] also proposed Optimal Pixel

Adjustment process which substantially improved the image quality.

All of the previous methods, they always focus on either hiding more information or reducing the impact of the quality of the stego-image. Therefore, PSRL algorithm has proposed in this paper. The PSRL owns increase the capacity considerably and simultaneously decrease the extent to which the stego-image is damaged, thereby satisfying with the goal of information hiding security. The Pattern-String with Run-Length coding (PSRL) uses two major concepts of the pattern-string LSB and RLC. Our algorithm not only to high repeatability bit binary image, but also to repetitive low-bit gray scale images.

In PSRL technology, the images are denoted as, secret image S that would be hidden information into cover image H . This algorithm treats the image S as a bit stream, performs compression using run-length and optimization using pattern-string and finally uses LSB to hide this image in the Image H . Our algorithm not only possesses the quality to hide large amount of information but also has the ability to retain the image quality. The experimental results show that our proposed have larger embedding capacity and keeping a high quality of stego-images.

The remainder of this paper is organized as follows. Section 2 briefly introduced some related technologies. In Section 3, we describe the new algorithm PSRL. Some compared the experimental results are shown in Section 4. Finally, our conclusions are drawn in Section 5.

2. Review of relevant literatures

In this section, we review the Run length, BRL, GRL, and Patter LSB substitution.

2.1. Run-Length Method

The Run-Length Coding (RLC) technique can be thought of as the number of duplicate information (Run) with original information content (Value) to produce a code (run, value). For example, the bit stream is '1111111111' then the code generated using RLC technique would be given (10, 1). This coding technique is simple, understandable, and easy to code. Therefore, it's usually used in image storage. The RLC technique is highly sensitive to the content of the information and its compression rate depends substantially on the complexity of the image.

The RLC technique can make a stream of consecutive same information bits condensed into one group. For instance, there is a continuous stream of 200

zero's then it can be encoded as (200, 0), thus compressing 200 bits into a group. The lossless compression rate almost trend to 90%. In dealing with large number of duplicated data almost no other algorithm works better than RLC. But when the data has small number of duplicities like '1010101' then this coding will substantially increase the amount of data to be transmitted. And thus the coding will not adoptive using the RLC.

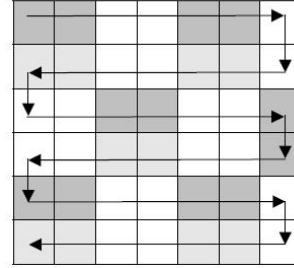


Figure 1: The scanning manner of Zig-Zag

2.2. BRL (hiding Bitmap files by Run-Length)

BRL is one of the algorithms proposed by Chang et al. [2] which is used to hide secret information (Binary image) into gray scale image. The secret information is encoded using RLC, and two pixels of the cover image are used to hide one pair of the RLC code and used Zig-Zag scanning manner to divide the image into several non-overlapping blocks of two pixels, which is shown in Figure 1. The embedded produce is shown as follows.

- Step 1. Divided cover image into non-overlapping two-pixel blocks by Zig-Zag scan.
- Step 2. Set the two-pixel block of the first pixel is V_i and the second pixel is C_i which they are used least significant bit of V_i and C_i to hide the value and run of the RLC.
- Step 3. Set an appropriate value of k to maintain reasonable image quality.
- Step 4. To Calculate R_i by using function $R_i = C_i \bmod k$ or $C_i = k * Q_i + R_i$, where $Q_i = C_i / k$, and $k > R_i > 0$.
- Step 5. Put the i -th RLC value into V_i such that $V_i = \text{run_value}_i$
- Step 6. Calculate C_i in each blocks by substep:
 - 6.1. Calculate the value of sign .
 - IF ($R_i = \text{run_count}_i - 1$)
 $\text{sign} = 0$;
 - ELSE IF ($R_i < \text{run_count}_i - 1$)
 $\text{sign} = 1$;
 - ELSE ($R_i > \text{run_count}_i - 1$)
 $\text{sign} = -1$;

- 6.2. Calculate the value of a, b .
- $$a = C_i + (\text{sign})|(run_count_i - 1) - R_i|$$
- $$b = C_i - (\text{sign})(k - |(run_count_i - 1) - R_i|)$$
- 6.3. Calculate the value of C_i' .
- IF $(|C_i - a| \leq k/2)$
- $$C_i' = a;$$
- ELSE $C_i' = b;$

All of the non-overlapping blocks (V_i, C_i) are been replaced into (V_i', C_i') , then embedded produce has been finished

2.3. GRL (hiding General files by Run-Length)

The BRL algorithm is very simple and easy to implement but when the secret image may be a color image or gray scale image instead of binary bitmap image. The compression rate will decreased considerably, if the secret data don't have high duplicated bit stream. Therefore, Chang et al. [2] proposed another algorithm, called GRL, to solve this problem. Using this algorithm can produce a good compression rate even for complex color images. GRL hides fixed-bits n of the secret data in every group of two pixels. In GRL algorithm, it only used the Eq. (1) to embedded secret message.

$$f(S_n) = \sum_{i=0}^{n-1} b_i C_{N(i)}^i \quad (1)$$

For instance, the secret data $S_n = (101001)_2$ will be hidden into a pair of pixels (43, 58). Since S_n contain three 1's therefore V_i has be changed from 43 to 45 to satisfy the Eq. (2), where $n = 6$ and $k = 3$. Using the Eq. (1) to calculate value of $f(S_n)$, we have

$$f(101001) = \sum_{i=0}^{6-1} b_i C_{N(i)}^i$$

$$= b_1 \times C_{N(1)}^1 + b_2 \times C_{N(2)}^2 + b_3 \times C_{N(3)}^3 + b_4 \times C_{N(4)}^4 + b_5 \times C_{N(5)}^5$$

$$= 0 \times C_1^1 + 0 \times C_1^2 + 1 \times C_2^3 + 0 \times C_2^4 + 1 \times C_3^5$$

$$= 13$$

Finally, we used Eq. (3) to compute the C_i' . Thus, the value C_i is changed from 58 to 53 to finding the proper remainder of 53 divided by C_3^6 . The result of pair pixels (43,58) is changed to (45, 53) after embedding secret data $(101001)_2$.

$$k = V_i' \bmod (n + 1) \quad (2)$$

$$f(S_n) = C_i' \bmod C_k^n \quad (3)$$

2.4. Pattern LSB Substitution

Pattern LSB substitution has been proposed by Yang et al. [6]. The main concept of algorithm is to use a pattern to record the LSB replacement process. The algorithm is shown as following.

Step 1. Divide the confidential and the cover images H and secret image S into same sized n segments and use the cover image to hide them. Note, the length of pattern-string is n and inverse all bits of the secret image S are denoted S' .

Step 2. $H = H_0 H_1 \dots H_{n-1}$

$$S = S_0 S_1 \dots S_{n-1}$$

$$S' = S'_0 S'_1 \dots S'_{n-1}$$

$$P = p_0 p_1 \dots p_{n-1}$$

Where $p_i = 0$ or $1, i = 0, 1, \dots, n-1$.

Step 3. FOR $i = 0$ TO $n-1$

IF $MSE_{HS_i} \leq MSE_{HS'_i}$ THEN

$p_i = 0$

ELSE

$p_i = 1$

Step 4. FOR $i = 0$ TO $n-1$

IF $p_i = 0$ THEN

hide S_i into H_i

ELSE

hide S'_i into H_i

Step 5. Output pattern-string P .

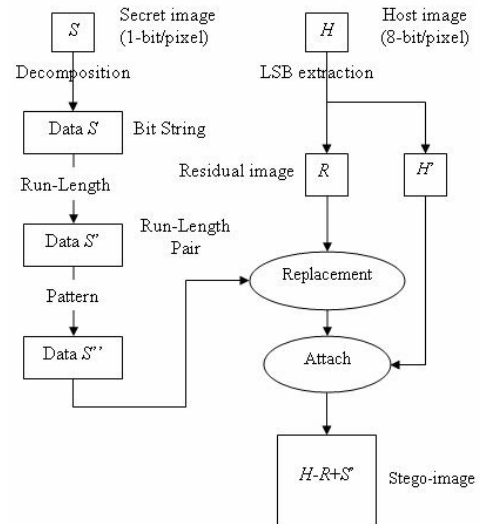


Figure 2: The flowchart of PSRL

3. Our Proposed Scheme

All of the preliminary algorithms achieved the goal of information hiding. The algorithms are designed to engage in more capacity and better quality of the hidden information, where not only the computation time is saved but also prevent the output images from being detected. At the same time this could provide more information hiding capacity and thereby drastically reduce the transmission capacity. In this paper we proposed a new PSRL algorithm which maintains a balance between the capacity and the image quality, by combining the Run-Length algorithm and the Pattern LSB algorithm. PSRL algorithm can be applied for 1-bit bitmap images and be extended to any type of images. RLC is used to compress the secret images and transfer it into pattern-string. In order to keep a high quality, LSB will be used in our proposed. The PSRL flow chart is shown in Figure 2. And the embedded produce is present as follows:

- Step 1. Select a binary bitmap image.
 Step 2. Convert bitmap into bit stream.
 FOR $i = 0$ TO S -Width
 FOR $j = 0$ TO S -Height
 (Bit String) $S += (\text{pixel}) S$
 Step 3. Use RLC to compress the bit stream.
 Value = $S[0]$
 Count = 0;
 FOR $i = 0$ TO S -Length
 IF $S'[i]$ Equal to Value
 Count ++;
 ELSE
 RunLength-addPair(Value, Count)
 Value = $S[i]$
 Count = 0
 Step 4. Divide each RLC into n segments and express it in binary format.
 FOR $i = 0$ TO RunLength-Length
 (Bit String) $S' += \text{RunLength-Count}$
 (Bit String) $S' += \text{RunLength-Value}$
 Step 5. Calculate the value of P_i , and determine data string S' .
 FOR EACH Pattern
 FOR $i = 0$ TO n
 IF $S'[i]$ Equal to $R[i]$
 $P[i] = 0$
 ELSE
 $P[i] = 1$
 FOR EACH Pattern
 IF $P[i]$ Equal to 1
 FOR $j = 0$ TO n
 $S''[j] = \text{not } S''[j]$
 Step 6. Hide the data stream S' in the LSB of the

cover image H to get H' .

For instance, the secret information (string) is "11111111111111111111000000000000001111111111111111111". This data is compressed by using the Run-Length algorithm to get data groups (18, 1), (15, 0), (20, 1). Then, transfer each part of Run-Length group into binary format, is shown as following, where all the Run's are written by follow the Length's "00010010 00001111 00010100 1 0 1".

Assuming $n=8$, we must to divide LSB string into groups of 8-bits, where LSB string comes extracting LSB bits from the cover image H . So, we have the LSB String "10111110111000011011101110". After data transfer has been finish, we should calculate S^{-1} , which is the inverse of the Secret String (S), the results are shown as follows.

H :	10111111	01110000	11011101	11000000
S :	00010010	00001111	00010100	10100000
S^{-1} :	11101101	11110000	11101011	01000000

According to Step 5, we compare the residual bit and string bit to get the pattern-string P .

H :	10111111	01110000	11011101	11000000
S :	00010010	00001111	00010100	10100000
S^{-1} :	11101101	11110000	11101011	01000000
P :	1	0	0	1

We will get be hidden sting S' from choosing the pattern sting and either Secret sting (S) or inverse Secret sting (S^{-1}).

H :	10111111	01110000	11011101	11000000
S :	00010010	00001111	00010100	10100000
S^{-1} :	11101101	11110000	11101011	01000000
P :	1	0	0	1
S' :	11101101	00001111	00010100	01000000

Finally, hiding the hidden string S' into the LSB of the cover image H . When all of the secret information S' be hidden, the embedding produce is complete.

4. Experimental Results

In our experiment, we used two grey cover images (Lena and Baboon) with size 512×512 , shown in Figure 3. And two binary secret images with size 256×256 , shown in Figure 4. We applied PSNR (peak signal-to-noise ratio) to evaluation various algorithms such as BRL, GRL, simple LSB and PSRL. In PSRL algorithm the image quality is controlled by the pattern

length n . Therefore, if we enhance the pattern length n , PSNR values will be decreased, that relationships between pattern length n and PSNR values are shown in Figure 5.

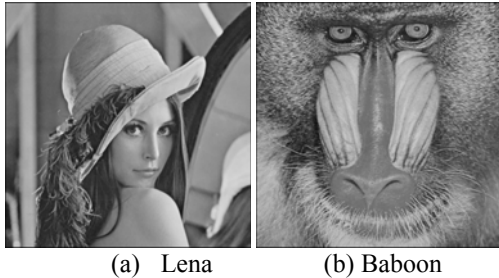


Figure 3 Two cover images with size 512×512

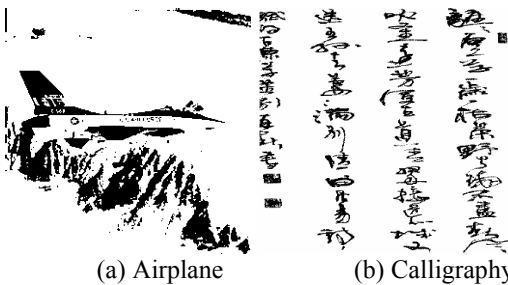


Figure 4 Two secret images of binary with size 256×256

To evaluate the performance of proposed scheme and compare with other scheme, such as BRL, GRL and Simple LSB, the result shown in Table 1. From Table 1 we know that 1-bit bitmap images in our scheme have the highest PSNR value than other scheme. In case of the image ‘Airplane’, the highest PSNR value for BRL algorithm is 47.64, 48.68 for BRL, GRL, and 42.83 for simple LSB which is less than the worst case of PSRL that is 55.11. Therefore, from these PSNR values that PSRL not only has a higher capacity but also has a good image quality.

5. Conclusions

In this paper, we have proposed a new information hiding technique, which embedded a large amount of the information and take a high quality of stego images. In our scheme, called PSRL (Pattern String Run-Length), combine RLC with pattern-string skills. That can be achieved high capacity by the RLC techniques. Therefore, we are able to achieve embedded large capacity on simple black and white images and gray images than previous methods. In addition, we also use the concept of pattern-string that not only reduces the computational complexity but also raises the image quality. According to the experimental result, we not only have a larger capacity but also keep a high quality of stego images.

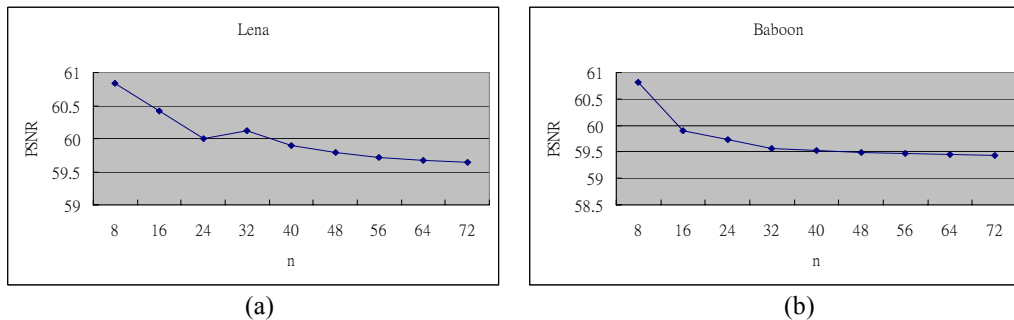


Figure 5: The relationships between n and PSNR using our proposed scheme: (a) Lena ; (b) Baboon.

Table 1: Comparison various scheme of PSNR values using Lena and Baboon as the cover images.

Cover image		Lena		Baboon	
algorithm	parameter	Airplane	Calligraphy	Airplane	Calligraphy
BRL	$K = 4$	47.64	47.63	48.90	48.08
	$K = 6$	45.38	45.40	45.50	45.48
	$K = 8$	43.62	43.65	43.41	43.39
GRL	$ S_n = 4$	48.68	49.09	48.70	49.12
	$ S_n = 5$	46.70	47.46	46.68	47.43
	$ S_n = 6$	43.40	44.67	43.38	44.68
Simple LSB	2bit-LSB	42.83	42.76	42.80	42.73
	3bit-LSB	35.91	35.81	35.93	35.81
PSRL	$K = 8$	56.02	54.66	60.80	58.71
	$K = 16$	55.58	54.26	59.89	59.59
	$K = 32$	55.31	53.95	59.46	58.99
	$K = 64$	55.11	53.76	59.40	58.68

References

- [1] C. K. Chan and L. M. Chen. "Hiding Data in Images by Simple LSB Substitution," *Pattern Recognition*, Vol. 37, No. 3, pp. 469-474, 2004.
- [2] C. C. Chang, C. Y. Lin, and Y. Z. Wang, "New Image Steganographic Methods Using Run-Length Approach," *Information Sciences*, Vol. 176, No. 22, pp. 3393-3408, 2006 .
- [3] C. C. Chang, C. S. Chan, and J. Y. Hsiao, "Finding Optimal Least-Significant-Bit Substitution in Image Hiding by Dynamic Programming Strategy," *Pattern Recognition* Vol. 36, pp. 1583-1595, 2003.
- [4] C. F. Lin, R. Z. Wang, and Z. C. Lin, "Image hiding by optimal LSB substitution and genetic algorithm," *Pattern Recognition*. Vol. 34, No. 3, pp. 101-113, 2001
- [5] F. A. P. Petitcolas, and S. Katzenbeisser, "Information Hiding Techniques for Steganography and Digital Watermarking," Artech House, London, 2000.
- [6] C. H. Yang, C. H. Tung, and C.Y. Weng, "Information Hiding Using Pattern LSB Approach," *Proceeding of the 16th National Information Security Conference*, R.O.C, Taiwan, pp. 234-241, June, 2006.
- [7] C. H. Yang and S. J. Wang, "Weighted Bipartite Graph for Locating Optimal LSB Substitution for Secret Embedding, " *Journal of Discrete Mathematical Sciences & Cryptography*, Taru publications, India, Vol. 9, pp. 153-164, 2006.
- [8] C.H. Yang, C.Y. Weng, S.J. Wang, and H.M. Sun, "Adaptive Data Hiding in Edged Areas of Images with Spatial LSB Domain Systems," *IEEE Transactions on Information Forensics and Security*, Vol. 3, Issue 3. pp. 488-497, Sept. 2008.