Indonesian Journal of Electrical Engineering and Computer Science
Vol. 27, No. 2, August 2022, pp. 1074~1082
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v27.i2.pp1074-1082

An interpolation based steganographic technique with least-significant-bit and pixel value differencing in a pixel block

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Article Info

Article history:

Received Nov 13, 2021
Revised May 19, 2022
Accepted Jun 11, 2022

Keywords:

Data hiding
Least-significant-bit technique
Nearest neighbour interpolation
Pixel value differencing scheme
Steganography

ABSTRACT

Over the past few years, in order to improve the hiding capacity and the peak signal-to-noise ratio (PSNR) value, several steganographic techniques have been developed. Steganography has become a popular technique to transmit secret data through any medium. In image steganography, the human eye cannot easily identify the hidden data which is embedded into the image. Small changes are also not detected by the human eye. High hidden capacity along with high visual quality is provided by the pixel value differencing (PVD) method. This paper first proposes the method of interpolation between the pixel blocks and then applies the least-significant-bit (LSB) substitution technique with the PVD method. At the starting phase, the original image is fixedto a 2x2 block, then the nearest neighbor interpolation (NNI) technique is implemented. In the next phase, the upper left pixel isembedded by the k-bit LSB substitution method along with hidden data. The newly generated neighbouring pixel value is measured. Thus, data is hidden from three directions. Through this paper using two different range tables, the new algorithm is proposed. We observed that in both cases, PSNR and the hiding capacity are improved.

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1. INTRODUCTION

Nowadays, the prime and most important issues are to keep the privacy of personal data at the time of broadcast through a common medium. Most commonly, private data is treated before broadcasting over the media. The handling procedure mainly deviates the main text of the data into an indecipherable method. But one and only legally authorized person can accomplish the reversible procedure on the scrambled information to get back the main data. Numerous data protection procedure has been offered to guard the privacy of the original data. When one proposes any data hiding method, the capacity of hidden bit and the un-detectability by human eyepossessions are to be noticed. In contrast, with cryptography, Steganography [1]-[3] is an alternative method to keep the privacy of the data. It does not change the data to throw it away from the trespasser. In this procedure, the hidden and private data are embedded into an unpredictable carrier or cover-media such asaudio, video, and image. To build up expressive data which is identified as stego-data. It is problematic to differentiate the stego-data in comparison with the main cover dataover a medium over an identified cover medium. The security system based on steganographic techniques is applied in numerous applications similar to military applications, commercial initiatives, multimedia applications and the internet of things (IoT) [4]. In the next section describes the previous research in this area. It also gives the idea who has done the most recent and relevant work. After that, in the third section, the proposed work is discussed.

The proposed work has two phases. In the first phase, the nearest neighbor interpolation is implemented in the image pixel block, after that in the second phase, the k-bit least-significant-bit (LSB) technique with pixel value differencing (PVD) is applied. Also, data extraction method has been introduced. In the fourth section, one mathematical explanation is given where we take a randompixel block and mathematically calculate the stego pixel block andfrom the stego pixel block extracts the data. After that, with the help of sample images using MATLAB, we perform work and produce the result through discussion. Calculate also the PSNR value of the image.

2. RELATED WORKS

The most commonly used steganographic method isthe LSB substitution method. The pixel value differencing method was primarilyannounced by Wu and Tsai [1] where the edge region of the image is considered to hide more data in comparison with a smoother region. The change of edge region cannot be detected by the human eye. Thus, data hiding in the edge region of an image is the main working principle of PVD technique. Initially, a 2×2 block of image is used for the PVD technique and later the block size is expanded to increase the hiding capacity [2]. In the 2×2 block size of the image there are the total of three diagonal edges that are measured [3]. To identifythe differences, Chang and Tseng [4] proposed the differences of the pixel values with the help of multiple adjacent pixels. The position of insertion of data can be randomized and based on the undisclosed messages [5]. Next, the calculation based on the directionally neighboring pixel increases the data hiding capacity for a 2×2 pixel block [6], [7]. By using two different reference range tables by Chen [8] proposed a new PVD based image steganography technique. Liao *et al*. [9] proposed an adaptive LSB substitution method with the PVD method. A combination of LSB and PVD creates a new hybrid steganography approach implemented in a 1×3 pixel block proposed by Khodaei and Faez [10], Swain [11] and Pradhan *et al.* [12] established that compared to 2×2 sized block of image, the 2×3 sized block of image gives better performance in the hybrid approach. Swain [13] suggested the adaptive PVD method by taking the horizontal, vertical, and diagonal edgesof the pixel. The presentation of the PVD method by taking 6-pixel blocks are appeared in Pradhan *et al*. [14]. The image edge region complexity can be enhanced by using different adaptive methods. The following Table 1, shows the comparative analysis [1]-[11] of different hiding method using PVD techniques. In this paper, at the starting phase, the original image is fixed to a 2×2 block, then the nearest neighbor interpolation technique is implemented. In the second phase, the steganographic scheme with the 3×3-pixel block uses LSB and PVD techniques. Two variants of range table are used for both peak signal-to-noise ratio (PSNR) and to increase data bit capacity. In a probable encryption technique, it is significant that confidential addresses recognize it when they see the encrypted message [15]-[19]. The data within the cover should not be distorted radically and merge with the embedded data [20], [21]. Embedded data should be kept away from detection to a great extent [22]-[24]. Embedded data has to be directly encoded into the media to keep data consistency [25], [26]. The following Table 1, shows the comparative analysis [1]-[11] of different hiding method using PVD techniques.

Table 1. Comparative study of data hiding method using PVD technique [1]-[11]

Reference No.	Parameters			Advantages
	Security	Capacity	Distortion	
[1]	moderate	moderate	moderate	PVD method is introduced
[2]	moderate	low	high	Stego-image quality is better due to change in size of pixel block
[3]	high	high	high	Tri-way PVD is introduced
[4]	high	high	moderate	New Direction of PVD
[5]	high	low	high	Random position is used to hide data
[6]	high	high	high	Embedding capacity and image quality increased
[7]	high	high	high	Payload capacity & image quality high
[8]	high	moderate	high	Range table calculation is different
[9]	moderate	moderate	high	LSB+PVD used
[10]	high	moderate	high	LSB+PVD used in 1X3 pixel block
[11]	high	high	high	Hybrid steganography introduced

3. PROPOSED METHOD

The algorithm of data embedding is separated into two segments. In first, the 2×2 pixel block is installed by using an image interpolation method and in the second phase, the k-bit LSB steganography scheme is applied.the algorithm has two sections; i) interpolation phase and ii) data embedding phase. Interpolation phase uses the nearest neighbor interpolation method. Data embedding phase uses k-bit interpolation method.

3.1. Interpolation phase

The cover image is split into 2×2 non-convergence block by raster scan method. Then, alter the pixel block to 3x3 in size by using nearest neighbor interpolation procedures. Consider all four-neighbor pixel, Px, P (0,1), P (1,0), and P (1,1). First find out the highest pixel value, suppose, it is p_{max}. then, compute p_r as (p_{max}+ (p_x+p(0,1))/2)/2, measure p_l as (p_{max}+ (p_x+p(1,0))/2)/2 and finally, determine p_c as (p_l+p_r)/2). Also consider p (1,2) and p (2,1). After interpolation the original image block is shown in Figure 1.

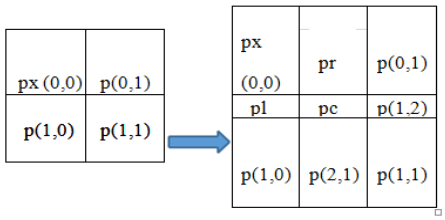


Figure 1. Nearest neighbour interpolation method

3.2. Data embedding phase with k-bit LSB technique

Step 1: here, the value of k is 3. First secret k bit data isembedded with the earliest pixel value (p_x) and the latest pixel value (p'_x) is formed. Next, calculate the equivalent decimal value of K-bit LSB (L) and also determine the decimal equivalent of K-data bit A. Measure the difference d=L–A. For pixel value adaptation, apply the following n (1).

$$p'_x = \begin{cases} p'_x + 2^k, if\ d > 2^{k-1}\ and\ 0 \le p'_x + 2^k \le 255 \\ p'_x - 2^k, if\ d < -2^{k-1}\ and\ 0 \le p'_x - 2^k \le 255 \\ p'_x, otherwise \end{cases} \quad (1)$$

Step 2: calculate the pixel differences between current pixel with the right, left and corner pixel as d_1, d_2, $d_3$by using (2)-(4).

$$d_1 = |p'_x - p_4| \quad (2)$$

$$d_2 = |p'_x - p_c| \quad (3)$$

$$d_3 = |p'_x - p_1| \quad (4)$$

Step 3: the quantization range table for type 1isshown in Table 2 and for type 2 in Table 3.

Table 2. Range table for type 1

Range	R=[0-7]	R=[8-15]	R=[16-31]	R=[32-63]	R=[64-127]	R=[128-255]
Hidden capacity (in bit)	3	3	3	3	4	4

Table 3. Range table for type 2

Range	R_i=[0-7]	R_i=[8-15]	R_i=[16-31]	R_i=[32-63]	R_i=[64-127]	R_i=[128-255]
Hidden capacity (in bit)	3	3	4	5	6	6

Step 4: from the tables; find the range R_x, where d_1, d_2 and d_3 are present. According to the table also determine the no. of bits (t_{x1}, t_{x2}, t_{x3}) that can be hidden and also obtain the lower bounds l_1, l_2, l_3.

Step 5: now, from the secret data bit-stream take t_{x1}, t_{x2}, t_{x3} bits continuously and convert them to equivalent decimal values namely b_1, b_2, b_3 respectively. Then calculate the new difference:

$$d_1' = 1_1 + b_1 \quad (5)$$

$$d_2' = 1_2 + b_2 \quad (6)$$

$$d_3' = 1_3 + b_3 \quad (7)$$

Step 6: calculate the new stego pixel values p”$_r$, p”’$_r$for p_r. Similarly, p”$_l$, p”’$_l$for pl and p”$_c$, p”’$_c$ for p_c by using the following formula.

$$p''_r = p'_x - d_1'$$
$$p'''_r = p'_x + d_1'$$
$$p''_c = p'_x - d_2'$$
$$p'''_c = p'_x + d_2'$$
$$p''_1 = p'_x - d_3'$$
$$p'''_1 = p'_x + d_3'$$

Step 7: now, determine the new values as shown in:

$$p'_r = p''_r, \text{if } |p_r - p''_r| < |p_r - p'''_r| \text{ and } 0 \le p''_r \le 255 \quad (8)$$

$p'''r$, otherwise

$$p'_c = p''_c, \text{if } |p_c - p''_c| < |p_c - p'''_c| \text{ and } 0 \le p''_c 255 \quad (9)$$

p”’c, otherwise

$$p'_1 = p''_1, \text{if } |p_1 - p''_1| < |p_1 - p'''_1| \text{ and } 0 \le p''_1 \le 255 \quad (10)$$

p'''_1, otherwise:
the pixel block is as shown in Figure 2. Figure 2(a) show initial pixel block and Figure 2(b) stego pixel.

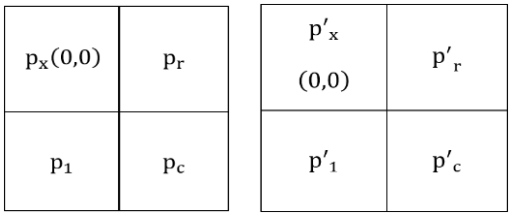


Figure 2. 2×2 pixel block using nearest neighbour interpolation (a) initial pixel block and (b) stego pixel block

3.3. Data extracting process

Cover image split into 2x2 non- convergence block by raster scan method. Suppose, we take the pixel block then follow the steps.
Step 1: Calculate the pixel difference values:

$$d'_1 = |p'_r - p'_x|$$
$$d'_2 = |p'_c - p'_x|$$
$$d'_3 = |p'_1 - p'_x|$$

Step 2: Find the range R_x, where d’$_1$, d’$_2$and d’$_3$belongs. According to the table also determine the no. of bits (t_{x1}, t_{x2}, t_{x3}) that can be hidden and also obtain the lower bounds l_1, l_2, l_3 from the range table.
Step 3: Determine the Secret data bit stream by using the following formulas.

$$S_1 = d'_1 - 1_1 \quad (11)$$

$$S_2 = d'_2 - 1_2 \quad (12)$$

$$S_3 = d'_3 - 1_3 \quad (13)$$

Now convert the values of S_1, S_2 and S_3 into t_{x1}, t_{x2} and t_{x3} binary bits respectively.

4. MATHEMATICAL EXPLANATIONS

Consider the cover image pixel block of 2×2. Now, applying nearest neighbour interpolation (NNI) method. Now, p_{max}=140 and p_x=90.

p_r=(140+(90+140)/2)/2=138
p_l=(140+(90+110)/2)/2=120
p(1,2)=(140+(140+80)/2)/2=125
p_c=(128+120)/2=124
p(2,1)=(140+(110+80)/2)/2=118

90	140
110	80

→

90	128	140
120	124	125
110	118	80

After that start he procedure of data embedding. Take 2×2 Pixel block, i.e,

90	128
120	124

Here k value=3 and consider data bit stream 111001110011 as secret data.

p_x=90=$(01011010)_2$

Now, after 3 bit LSB substitution we get $p'_x=(01011101)_2=(93)_{10}$.

After adjustment, $p'_x=93 - 2^3 =93-8=85$. Now, the pixel differences are,

d_1=|85-128|=43

d_2=|85-124|=39

d_3=|85-120|=35

Determine the total no. of hidden bits and also the lower range from the range table. From the bit stream, 111001110011 we calculate b_1, b_2, b_3 value,

b1=(111)2=7, b2 = (001)2=1, b3=(110)2=6

$d_1'=l_1+b_1=32+7= 39$
$d_2'=l_2+b_2=32+1=33$
$d_3'=l_3+b_3=32+6=38$

The hidden data bit are (111001110)2.

Now, to get the new pixel value after boundary condition checking:

$p'_r=124$, $p'_c=118$, $p'_l=123$

after data embedding the generated stego-pixel block,

85	124
123	118

Now, start the procedure of data extraction.

$d'_1=|124-85|=39$
$d'_2=|118-85|=33$
$d'_3=|123–85|=38$

Again, determine the total no. of hidden bits and also the lower range from the range table,

S_1=39-32=7=(111)2
S_2=33-32=1=(001)2
S_3=38–32=6=(110)2

After data extraction we get $(111001110)_2$.

5. RESULT AND DISCUSSION

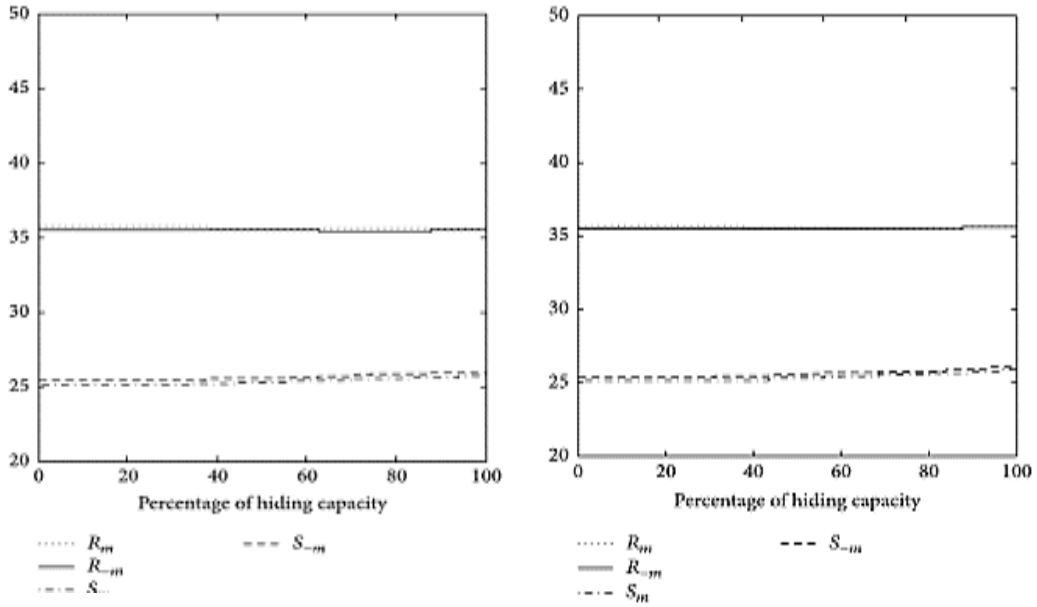
Here, we take 3 sample cover images, like Lena, Boat and Baboon, and 756,035 data bits are hidden. The proposed algorithm is verified by MATLAB.As a result, the stego-image is detected. Following are the details of the cover images and stego images. The gray scale images are considered as cover image in Figure 3. The results for the proposed techniques as shown in Figure 4 and Figure 5. The proposed technique and the existing techniques such as Khodaei and Faez (2012) [10] and Swain *et al.* (2016) [11] have been showed in table 4 using Type 1 and Table 5 using Type 2.

RS analysis of Lena image using type 1 and Type 2 shows in Figure 6. RS analysis of Baboon image using type 1 and Type 2 shows in Figure 7, PDH analysis of Lena image using type 1 and Type 2 shows in Figure 8 and PDH analysis of Baboon image using type 1 and Type 2 shows in Figure 7 respectively.

Figure 3. Cover image

Figure 4. Stego-image (using type 1)

Figure 5. Stego-image (using type 2)



(a) (b)

Figure 6. RS analysis curve for Lena image (a) using Type 1 (b) using Type 2

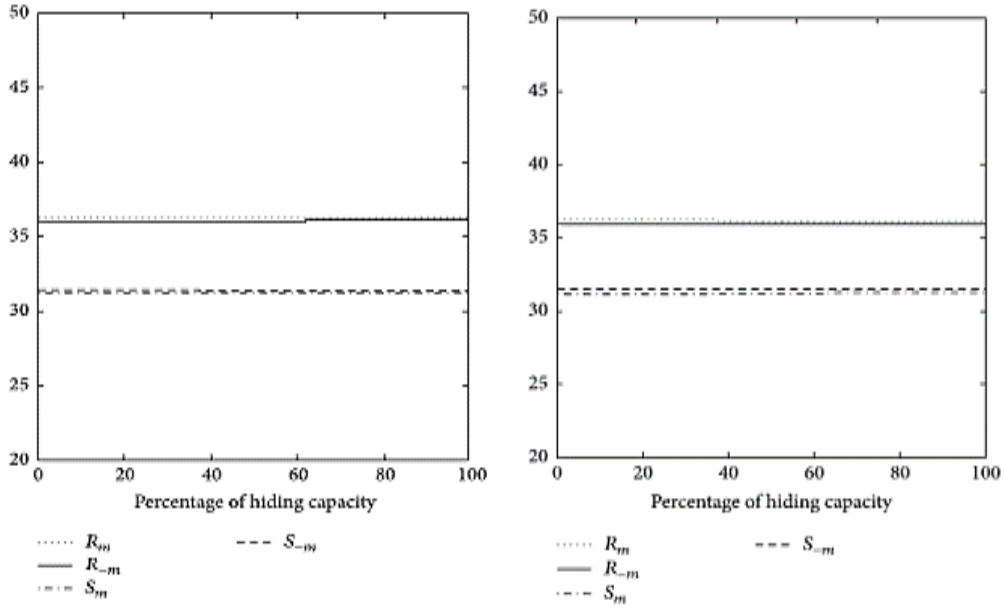


Figure 7. RS analysis curve for baboon image (a) using type 1 and (b) using type 2

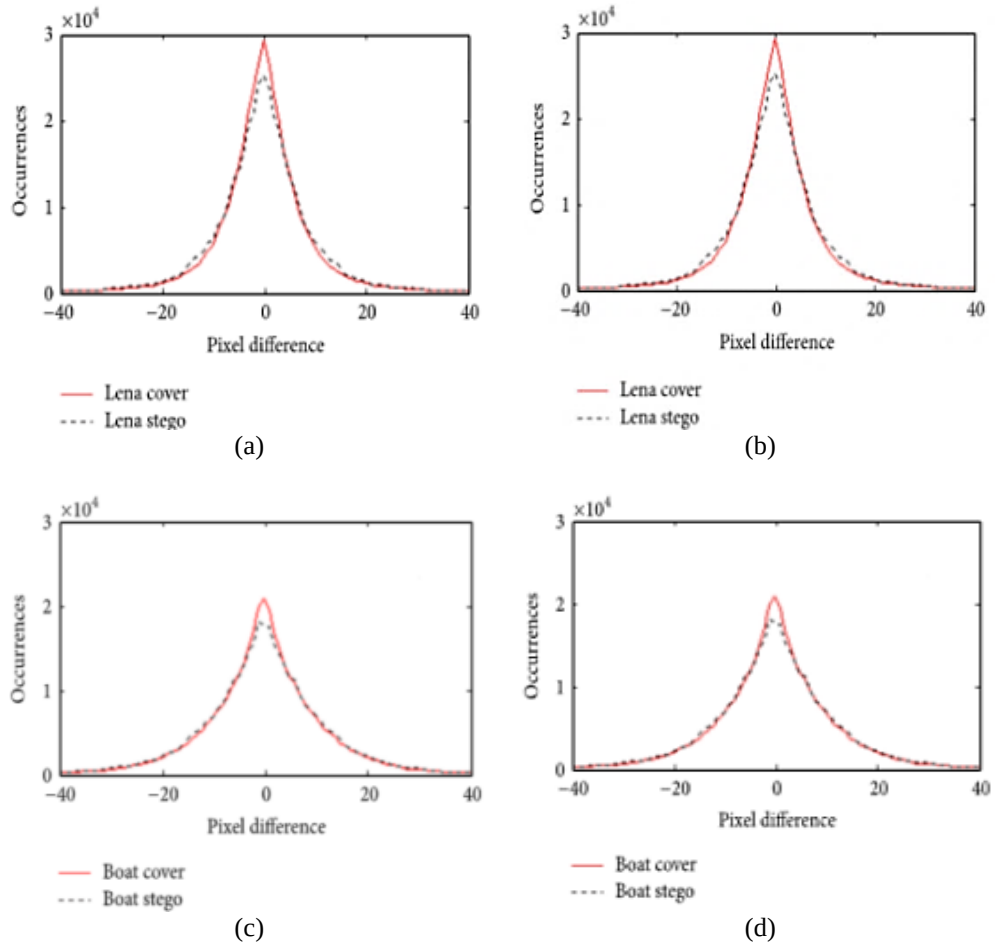


Figure 8. PDH analysis (a) Lena image using type 1, (b) Lena image using type 2, (c) boat image using type 1, and (d) boat image using type 2

Table 4. Comparison the proposed technique with the other techniques for type 1, k=3

Images 512×512 Gray image	Khodaei and Faez [10]		Swain [11]		Proposed	
	PSNR	Capacity	PSNR	Capacity	PSNR	Capacity
Lena	42.34	2375278	42.83	2361875	42.86	2365795
Boat	39.75	2391994	38.38	2370147	39.38	2370158
Baboon	37.59	2443361	34.98	2393475	35.56	2427365

Table 5. Comparison the proposed technique with the other techniques for type 2, k=3

Images 512×512 Gray image	Khodaei and Faez [10]		Swain [11]		Proposed	
	PSNR	Capacity	PSNR	Capacity	PSNR	Capacity
Lena	41.58	2345786	42.14	2312546	42.78	2356174
Boat	37.84	2312748	38.24	2298716	38.84	2313146
Baboon	35.52	2398674	35.16	2385186	35.64	2398762

6. CONCLUSION

The principle of image interpolation with LSB substitution and PVD steganography process is measured by i) RS analysis and ii) pixel difference histogram (PDH) analysis. In this paper, both the LSB and PVD are used along with nearest neighbor interpolation. The interpolation is operated on a 2x2 pixel block and a 3x3 pixel block is then generated. Next, LSB and PVD are applied. After interpolation, the new pixel value is used for the difference calculation with its consecutive neighbour. Using the difference, with the help of a range table, the PVD is implemented. Here multiple edge directionsare applied, so, PDH analysis makes no difference. So, the data hiding capacity and PSNR value give satisfactory results. The secret data can also be in compressed form. One data compression technique was also added with the data hiding technique. To transmit the information toa user authentication method will be present in the proposed algorithm. Besides, there must be no chances of distortion within the generated stego-image.

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