Improving PVD-LSB Method in Information Hiding Scheme

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Abstract–The data hiding method based on least-significant-bit (LSB) replacement and pixel-value differencing (PVD) method has been proposed to improve the maximal number of bits embedded in a grayscale image, called PVD-LSB in this paper. However, how to improve the embedding capacity of the PVD-LSB scheme is an active research in recent years. Therefore, this paper proposes a modified PVD-LSB scheme by using the difference detection to embed the secret message twice. Experimental results show the proposed method provides higher embedding capacity than the PVD-LSB scheme. In addition, the proposed method can maintains acceptable fidelity when the embedding capacity is increased.

***Keywords*—Data hiding, LSB, PVD, PVD-LSB**

1. INTRODUCTION

Since information transmission becomes faster, everyone can obtain the digital information easily. Therefore, information security and privacy become a very important issue. Watermarking is an active technology to protect the file by adding extra data in the file. Specially, watermarking has been applied for copyright protection in digital media, such as images, radio and video information [1]. Since it adds extra information without changing the media display, watermarking technique could be used as the technology of data hiding. Generally, there are two kinds of watermarking: one is a visible and the other is invisible. A visible watermark could be shown on the protected material, such as the logo on the lottery tickets. The purpose of the visible watermarking technique is to claim the official authorization. On the other hand, an invisible watermark not only is used in dada hiding for data protection but also does not change the contents of media.

The least significant bit (LSB) technique [2], the PVD technique [3], and the PVD-LSB technique are the well-known invisible watermarking techniques. In the LSB technique, the process of embedding is to replace t LSBs of each pixel with t secret information bits. However, the fidelity of the stego-images with the LSB technique is degraded when the number of secret information bits is increased. The PVD technique is to embed the secret information bits into the two successive pixels of each block. Although the PVD technique can maintains acceptable fidelity, the embedding capacity of the PVD technique has lower than the LSB technique. The PVD-LSB scheme uses the range table to decide the embedding algorithm is the LSB technique or the PVD algorithm. More precisely, the embedding algorithm uses the LSB scheme if the difference value of two successive pixels in each block falls into the lower level; the embedding algorithm uses the PVD scheme if the difference value of two successive pixels in each block falls into the higher level. In this paper, we propose a modified PVD-LSB technique to further improve the embedding capacity of the PVD-LSB technique.

2. PRELIMINARIES

2.1. The PVD Scheme

In general, each pixel value of an 8-bits gray scale image can be quantized to a whole number from 0 to 255. The PVD scheme first partitions the gray scale cover image into several blocks, where each block is composed of two successive pixels. The difference value d_i of two successive pixels (P_i, P_{i+1}) denotes $|P_{i+1} - P_i|$. All possible value of d_i is between -255 and 255. The PVD scheme pick each blocks of a gray scale image and calculates their difference value according to the pick of Fig. 1. Another task is to divide the range from 0 to 255 into several sub-range R_i, as shown in Fig. 2, where R_i represents the ith level of range table. Fig. 2 shows the minimum and maximum value of each level R_i, where 2^n and 2^{n+1}-1, n=0~5, respectively are denoted *as* l_i (lower bound) and u_i (upper bound). Next, the width value w_i of each level R_i can be computed by $w_i = u_i - l_i + 1$, i=0~5. Note that the secret information bits are repressed as binary value {0, 1}.

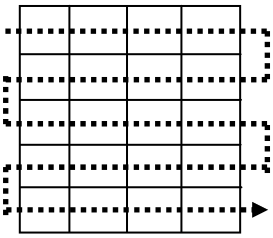

Fig1. Picking pixels ordering.

R_i	$l_i \sim u_i$
R_1	0 ~ 7
R_2	8 ~ 15
R_3	16 ~ 31
R_4	32 ~ 63
R_5	64 ~ 127
R_6	128 ~ 255

Fig2. Range Table.

The detail of embedding process is repressed as follows:

a. The PVD scheme first picks two continuous pixels (P_i, P_{i+1}), and then computes difference value of P_i and P_{i+1} by $d_i = | P_{i+1} - P_i |$.

b. Choosing the level R_i of the range table according to the difference value d_i belongs into which level of the range table. Then, the width value w_i can be calculated.

c. We can compute the number of embedding secret data k_i by the width value w_i, where k_i denotes as

$$k_i = \lfloor \log_2 w_i \rfloor .$$

d. Taking k_i bits to change to decimal value b. For example, k_i =3, we can get the decimal value $(5)_{10}$ if the secret data equaling $(101)_2$.

e. The new difference value d_i' can be calculated by l_i+b. Then, we define and calculate m by

$$m = \frac{|d_i' - d_i|}{2} .$$

f. According to the following equation **(1)**, we can get the two modified pixels (P_i', P_{i+1}') :

$$(P_i', P_{i+1}') = \begin{cases} (P_i + \lceil m \rceil, P_{i+1} - \lfloor m \rfloor), & \text{if } P_i \geq P_{i+1} \text{ and } d_i' > d_i \\ (P_i - \lfloor m \rfloor, P_{i+1} + \lceil m \rceil), & \text{if } P_i < P_{i+1} \text{ and } d_i' > d_i \\ (P_i - \lceil m \rceil, P_{i+1} + \lfloor m \rfloor), & \text{if } P_i \geq P_{i+1} \text{ and } d_i' \leq d_i \\ (P_i + \lceil m \rceil, P_{i+1} - \lfloor m \rfloor), & \text{if } P_i < P_{i+1} \text{ and } d_i' \leq d_i \end{cases} \quad \textbf{(1)}$$

2.2. The PVD-LSB Scheme

The PVD-LSB scheme is based on the PVD scheme and divides the range table into two levels, where two levels are higher level and lower level. Note that the LSB scheme is used in the lower level. In addition, this method uses the value of ***div*** (division) to demarcate the range table into lower level and higher level. For example, setting ***div***=15, the range table can be listed as follows:

R_i	$l_i \sim u_i$	***div* = 15**	**The Embedded methods**
R_1	0 ~ **15**	Lower level	The 3-LSBs scheme
R_2	16 ~ 31	Higher level	The PVD scheme
R_3	32 ~ 63		
R_4	64 ~ 127		
R_5	128 ~ 255		

Fig3. The Range Table of the PVD-LSB scheme.

The embedding process of the PVD-LSB scheme is similar to the PVD scheme. The difference between the PVD-LSB scheme and the PVD scheme is the range table whether it can be divided or not. According to the value of ***div***, the range table can be classified into lower level ($d_i \leqq$ ***div***) and higher level (d_i>***div***). In lower level, this method embeds 3 least-significant bits in two successive pixels, respectively. After the embedding process, the modified pixels of block denotes (P_i', P_{i+1}') and we can compute the difference value of each block by $d_i' = | P_{i+1}' - P_i' |$. If d_i'>***div***, (P_i', P_{i+1}') needs tobe modified by using equation **(2)**, otherwise (P_i', P_{i+1}') does not to modified.

$$(P_i', P_{i+1}') = \begin{cases} (P_i' - 8, P_{i+1}' + 8), & \text{if } P_i' \geq P_{i+1}' \\ (P_i' + 8, P_{i+1}' - 8), & \text{if } P_i' < P_{i+1}' \end{cases} \quad \textbf{(2)}$$

To repeat the operation until d_i' belongs to lower level.

3. PROPOSED METHOD

3.1. Embedding Process

Our proposed method extends and improves technique of PVD-LSB. Many of operative symbols and PVD-LSB are the same. We modify Range Table to Fig4. , and set ***div***=31. Next embedding more data used our proposed method.

The second embedding method we select four continuous pixels respectively like Fig5. , it is denoted ($x_i, x_{i+1}, x_{i+2}, x_{i+3}$), and computes different value is denoted (z_i, z_{i+1}) again. Depending on Range Table we set if z_i and z_{i+1} belong to lower level simultaneously, we embed more two bits in (x_{i+1}, x_{i+2}), the process like Fig5. , and then modify teams of pixels (x_i, x_{i+1}) and (x_{i+2}, x_{i+3}). It has finished our method of embedding after passing process.

R_i	l_i ~ u_i	***div*** = 15	Embedded methods
R_1	0 ~ 15	Lower level	**3-LSB**
R_2	16 ~ **31**		
R_3	32 ~ 63	Higher level	**PVD**
R_4	64 ~ 127		
R_5	128 ~ 255		

Fig4. Range Table of our proposed method.

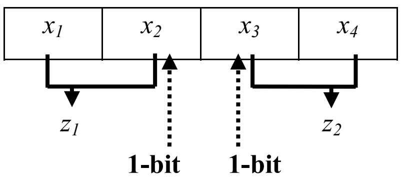

Fig5. Place of embedding and related symbols.

And detail of embedding process is repressed by following:

a. According to Fig4. Range Table and technique of "Hybrid PVD-LSB" to embed secret information, and finished first embedding and modifying.

b. Selecting respective team of four continuous pixels ($x_i, x_{i+1}, x_{i+2}, x_{i+3}$), and computing different value (z_i, z_{i+1}) like $z_i = | x_{i+1} - x_i |$ and $z_{i+1} = | x_{i+3} - x_{i+2} |$.

c. Next depending on discriminant equation **(3)** to determine to embed more two bits or not. And we class new team of pixels as ***a***∋(x_i, x_{i+1}') and ***b***∋(x_{i+2}', x_{i+3})

$$\begin{cases} \text{If } z_i \text{ and } z_{i+1} \in \text{lower level} \\ \text{embedded 2bits in } x_{i+1} \text{ and } x_{i+2}\ , \\ \text{If } z_i \text{ and } z_{i+1} \notin \text{lower level} \\ \text{Maintain the status quo} \quad . \end{cases} \quad \textbf{(3)}$$

d. For having been embedded 2-bits team of four pixels we compute different value again, new different value can be compute as $z_i' = | x_{i+1}' - x_i |$ and $z_{i+1}' = | x_{i+3} - x_{i+2}' |$, if z_i' or z_{i+1}' is smaller than ***div***, we modify pixels by discriminant equation **(4)** as follow, and repeat action until different value smaller than ***div***.

$$\begin{cases} (x_1'', x_2'') = \begin{cases} (x_1'-16, x_2'+16), & if\ x_1' \geq x_2' \\ (x_1'+16, x_2'-16), & if\ x_1' < x_2' \end{cases} \\ (x_3'', x_4'') = \begin{cases} (x_3'-16, x_4'+16), & if\ x_3' \geq x_4' \\ (x_3'+16, x_4'-16), & if\ x_3' < x_4' \end{cases} \end{cases} \quad \textbf{(4)}$$

e. For instance, assume two teams of four pixels we set as Fig6. and secret data is like following:
Secret Data: 111001010001011110011011 1

100	50	30	10	225	255	0	29

Fig6. Pixels of example we supposed.

First, we pick two continuous pixels respectively and compute different value between them, after action we can get [d_1, d_2, d_3, d_4=50, 20, 30, 29]. We contrast different value with Fig4. According to Range Table the adapted embedding methods can be found [PVD, LSB, LSB, LSB]. Therefore, embedding data is incised as [11100, 101000, 101111, 001101]. After first embedding process we get new pixels [105, 45, 29, 8, 229, 255, 6, 29].
In second process we class two teams of pixels [105, 45, 29, 8], [229, 255, 6, 29], and compute new different value by [z_1, z_2= 60, 21] and [z_3, z_4= 26, 23]. Though **(3)** checking which can be embedded add 2-bits or not. So z_3 *and* z_4 can be embedded 2-bits, and z_1, z_2 are unable.

3.2. Extracting Process

It is easy to recover original secret data when receiver gets cover image, according to Range Table Fig4. We can be extracted information, and detail of extracting process is repressed by following:

a. Depending on sequence of Fig1. To take pixels and set four pixels a team [y_1, y_2, y_3, y_4]. Next, also compute different w_i value between them, by following: w_1=｜y_2- y_1｜, w_2=｜y_4- y_3｜.

b. We check on that if w_1 and w_2 belong to lower level simultaneously, using our method to extract secret information ; first process to extract y_2 and y_3 2-bits of 4_{th}-LSB in all pixels of image. The extracting information is placed on hindmost the complete secret information.

c. Next, we use PVD-LSB scheme to obtain remnant secret information; according to different value w_i. We recycle to extract information by Range Table Fig4. , and depend on discriminant equation **(5)** to extract secret information. In this extracting section, the extracting information is placed on front of the complete secret information.

$$\begin{cases} If \;\; d_i \in lower \;\; level \\ extract \;\; 3-LSB \;\; individual \;, \\ If \;\; d_i \in higher \;\; level \\ extract \;\; by \;\; PVD \;\; method \;. \end{cases} \tag{5}$$

4. EXPERIMENTAL RESULTS

In experimental results, we choose two cover images which are Lena and Baboon to embed the information bits, where the size of cover image is selected as 256 by 256 pixels. We use three method which are the PVD scheme, the PVD-LSB scheme, and the propose method to compare each other. The detail results show in Fig. 7 and Fig. 8.

In information hiding studies, judging norm not only observes secret capability but also quality after hiding etc, and we use PSNR (peak signal noise rate) to judge our stegoimage quality. The PSNR compute process as following equation **(6)**:

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{255^2}{\mathrm{MSE}}\right) \;\; (\mathrm{dB}) \tag{6}$$

among of **(6)** MSE (Mean Square Error) can be computed by equation **(7):**

$$MSE = \frac{1}{m^2}\sum_{i=1}^{m}\sum_{i=1}^{m}(a_{ij} - d_{ij})^2 \tag{7}$$

a is pixel of stegoimage and b is pixel of cover image. They must be the same place in image, and m is number of image pixels.

We compare two methods with the proposed method and the experimental results are shown in Table 1. We observe that our method has high embedding quantity than others in Table1. . Because our method add more 2-bits on the PVD-LSB scheme, and it has some cases belong to 4-LSB, for this condition we modify team of pixels and made their different values belong to lower level. So our method can get more embed information to conforms to the human vision.

The additional embedding 2-bits we place at 2_{th} and 3_{th} pixels, in fact we can set other three conditions that are 1_{th}-3_{th}, 2_{th}-4_{th} and 1_{th}-4_{th} in reasonable scope, it is not large difference after testing.

5. CONCLUSION

In this paper, we have proposed method improves the embedding capacity of the PVD-LSB scheme. Compared with the PVD and PVD-LSB scheme, the proposed method can embed more information bits and maintains acceptable fidelity when the embedding capacity is increased. In addition, using the proposed method to embed the information bits can maintain the PSNR at least 30dB.

REFERENCES

[1] 呂慈純、陸哲明、張真誠, 多媒體安全技術, 全華圖書股份有限公司, 2007.

[2] Z. Wang, C. F. Lin and J. C. Lin, “Image hiding by Optimal LSB substitution and genetic algorithm,” *Pattern Recognit.*, vol. 34, no. 3, pp. 671-683, 2000.

[3] Da-Chun Wu , Wen-Hsiang Tsai, “A steganographic method for images by pixel-value differencing”, Pattern Recognition Letters, v.24 n.9-10, p.1613-1626, 01 June 2003.

[4] H. C. Wu , N. I. Wu , C. S. Tsai and M. S. Hwang ,"Image steganographic scheme based on pixel-value differencing and LSB replacement methods", *Proc. Inst. Elect. Eng., Vis. Images Signal Process.*, vol. 152, pp. 611 2005.

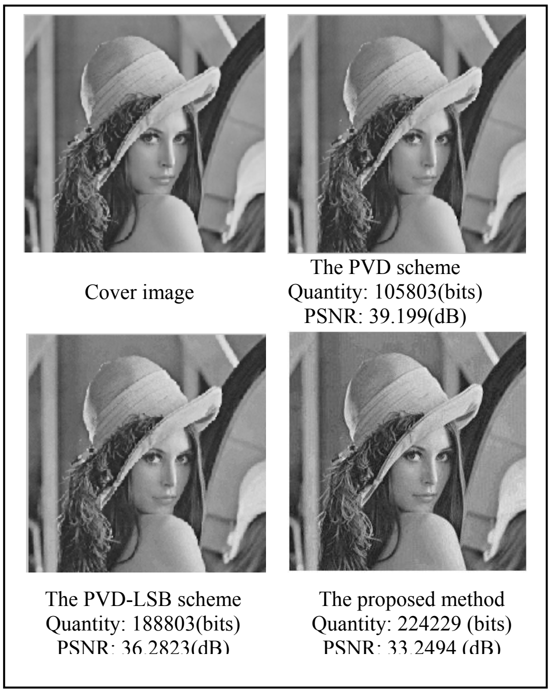

Fig.7 Experimental results by using the cover image of Lena.

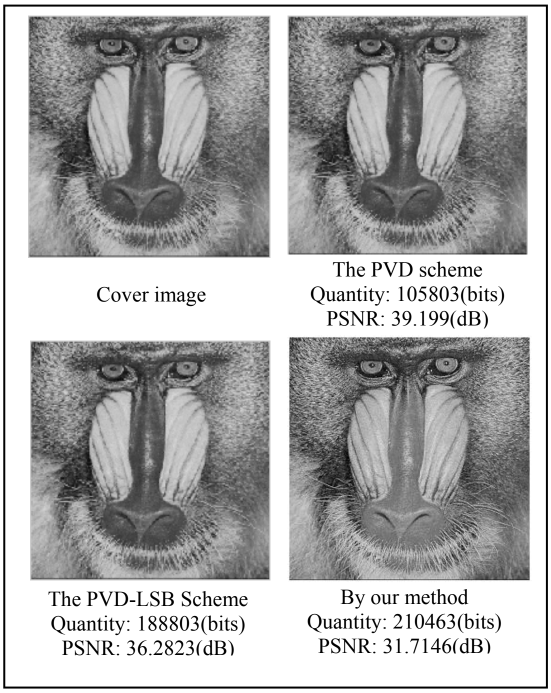

Fig.8 Experimental results by using the cover image of Baboon.

Table 1 Compared with the PVD scheme and PVD-LSB scheme.

Method	**The PVD scheme**		**The PVD-LSB scheme**		**The proposed method**	
Cover image name / Judging norm	Quantity	PSNR	Quantity	PSNR	Quantity	PSNR
Lena	105803	39.199	182890	36.7706	224229	33.2494
Baboon	112405	33.1244	188803	34.7706	210463	31.7146