IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-10, Oct 2018 E-ISSN: 2347-2693

LSB Substitution and PVD performance analysis for image steganography

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Available online at: www.ijcseonline.org

Accepted: 25/Oct/2018, Published: 31/Oct/2018

Abstract— Image Steganography is data hiding technology to transmit securely significant data in an open channel. In this paper, we present performance analysis of Least Significant Bit (LSB) substitution and Pixel-Value Differencing (PVD) methods commonly used in image steganography. The comparison of these methods is performed by using Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM) and payload values. The 512 x 512 size of colored and gray-scale cover images as Lena, Baboon, Peppers, and Airplane are used in the experimental studies. In the LSB method, the PSNR values are about 51.6, while the PVD method is between 37.83 and 41.28 for colored cover image. In gray-scale images, while PVD is between 38.52 and 41.42, the LSB is about 51.14. In our paper results shows that PSNR and SSIM values are higher in LSB substitution than PVD method. However, PVD method embeds more secret data than LSB substitution method into cover image with less visual perceptibility.

Keywords— LSB, PVD, Image Steganography, Security, Data hiding

I. INTRODUCTION

Steganography is a branch of science, which is unobtrusively storing data in images, text, protocol, audio, and video files. The aim of steganography is to provide secret embedded data undetectable. Image steganography has four basic components as media carrier, secret data, secret key and stego media. In general, the carrier media is called cover image, while the stego media is called stego image. In image steganography studies, it is usually aimed at increasing the embedding capacity (payload) and the stego image quality. PSNR is utilized for measuring quality of stego image. Other image steganography performance criteria include security, imperceptibility, and computational complexity. The best steganography method should provide high PSNR at high capacity, easy to implement and low computational time, high imperceptibility. LSB substitution method is widely used in image steganography due to the fact that it is easy to implement and low computational time. In the LSB substitution method, the embedding capacity is significantly increased by changing the last ‘k’ bits of cover image. In this method, the basic principle to hide data is to change the least significant bit of pixel values of the cover image. There are several studies in the literature that have been proposed by the improvement of the LSB substitution method [1-9].

PVD is another method commonly used in image steganography. In the PVD method proposed by Wu and Tsai in 2003, the main goal is to provide high imperceptibility while increasing capacity [10]. In the PVD method, the difference between two contiguous pixel values is considered when performing data hiding. These pixel value differences determine total embedding capacity in PVD method. Many studies have been proposed in the literature by PVD method [10-15].

In this paper, the traditional LSB substitution and PVD methods are realized and presented the results of colored and gray scale cover images. The rest of the paper is arranged as follows. The LSB substitution and PVD methods are presented in section 2. The experimental results of these methods are analyzed in section 3. In the last section, the results of the article are included.

II. METHODOLOGY

This section presents the algorithms of LSB substitution and PVD methods implemented in the paper.

A. LSB Substitution Method

In the LSB substitution method, the data is hidden by changing the least significant bits of the cover image pixels. LSB substitution provides least computational complexity with considerable quality. As the amount of embedded data increases, the high perceptibility occurs. In the LSB substitution method, firstly, a pixel of the cover image is converted to binary format. In the second step, one byte of the hidden data is converted to binary format. If colored cover image is used, the least significant bit of each of the RGB channels is changed and three bits of data are hidden in one pixel. In gray scale cover image, one bit is embedded in one pixel because it is only one channel. In the study, one-byte data is embedded in three pixels in colored cover image, and eight pixels in gray scale cover image. To extract easily the hidden data by LSB substitution method, the eight of nine bits in the three-pixel colored cover images are used. Therefore, in experimental studies using colored cover image, the data capacity in one pixel (payload) is calculated as 2.67bpp. In gray scale cover image, payload is 1bpp. Figure 1 shows data hiding processes of LSB substitution method.

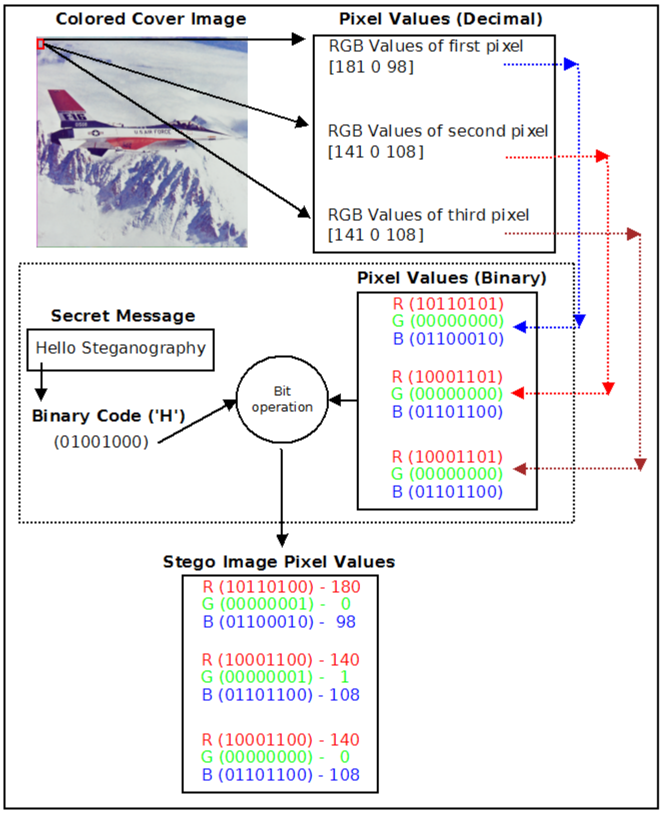


Figure 1: LSB substitution algorithm for colored cover image

B. PVD Method

In the PVD method, the cover image is divided into blocks consisting of two non-overlapping pixels. Data embedding is performed by considering the values between two consecutive pixels in each block. In this method, the little difference between two consecutive pixels indicates that the block is on a smooth area, otherwise the edges of the block. The edge areas are more preferable to embed data because the differences in these areas are higher than the smooth areas. The high difference value of edge areas tolerates large changes, so the stego image is less noticeable in the PVD method than the LSB method. The PVD method offers high capacity and quality stego image.

In PVD algorithm, firstly two consecutive pixels are taken from the cover image and the difference is calculated. In the colored cover image, the difference between the same color channels of two consecutive pixels is calculated as dc. Using this difference value in Table 1 determines which range is entered and the maximum number of bits that can be embedded. The lower value in the corresponding range and the numerical value (S) of the embedded data are added and the two consecutive pixel difference (ds) in the stego image is obtain. Then the difference between dc and ds is calculated as m. The pixel values of the stego image are found using this information in equation 1. Cover image consecutive pixels Pi ve Pi+1, stego image consecutive pixels Pi′ and Pi+1′ is expressed.

$$(P_i', P_{i+1}') = \begin{cases} if\,((P_i \geq P_{i+1}) and (d_s \leq d_c)) \rightarrow P_i - ceil(\frac{m}{2}), P_{i+1} + floor(\frac{m}{2}) \\ if\,((P_i < P_{i+1}) and (d_s > d_c)) \rightarrow P_i - floor(\frac{m}{2}), P_{i+1} + ceil(\frac{m}{2}) \\ others \rightarrow P_i + ceil(\frac{m}{2}), P_{i+1} - floor(\frac{m}{2}) \end{cases} \quad (1)$$

Table 1: Range table of PVD

	R1	R2	R3	R4	R5	R 6
Lower Value (l)	0	8	16	32	64	128
Upper Value (u)	7	15	31	63	127	255
Capacity (n)	3	3	4	5	6	7

Figure 2 shows an example of implementing the PVD algorithm.

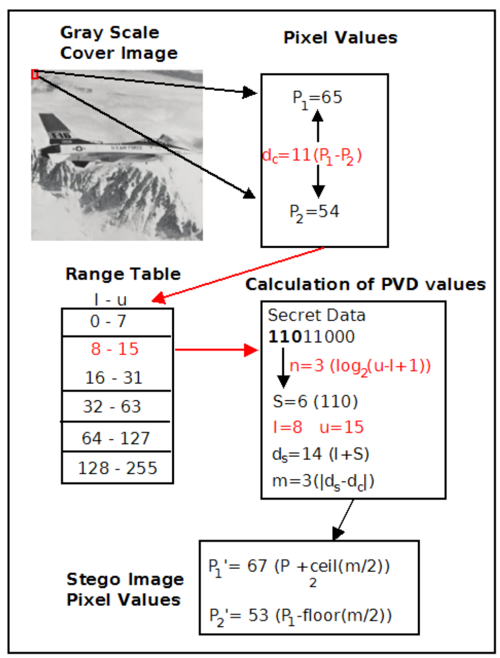


Figure 2: PVD algorithm for gray scale cover image

III. EXPERIMENTAL STUDY

In the experimental studies, 512x512 in size Lena, peppers, baboon and fruits colored and gray scale cover images are utilized. In the LSB substitution method, an average of 2.67 bpp data is embedded into the colored cover image and 1 bpp data is embedded into the gray scale cover image and the results are presented. In the PVD method, the consecutive two pixel values are checked and the maximum data is embedded between 4.66 and 5.36 bpp for colored cover image.

In this paper, PSNR, SSIM and payload performance criteria are used. The equation 2 shows that calculation of the PSNR value [16].

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{\mathrm{Max}^2}{\mathrm{MSE}}\right) \quad (2)$$

SSIM gives the similarity rate of cover and stego image. The equation 3 provides SSIM value [17].

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c1)(\sigma_x^2 + \sigma_y^2 + c2)} \quad (3)$$

Table 2 shows the embedding capacity, PSNR and SSIM results obtained by two methods for four different colored cover images. In the LSB method, the PSNR values are about 51.6, while the PVD method is between 37.83 and 41.28.

Table2: Comparison of LSB substitution Method and PVD Method for color cover image

Cover Image	LSB substitution Method			PVD Method		
	Payload (bpp)	*PSNR*	*SSIM*	*Payload (bpp)*	*PSNR*	*SSIM*
Lena	2.67	51.656	0.9998	4.7088	41.283	0.9981
Baboon	2.67	51.654	0.9997	5.3627	37.829	0.9945
Pepper	2.67	51.619	0.9998	4.7177	40.934	0.9980
Airplane	2.67	51.653	0.9970	4.6699	40.611	0.9751

Table 3 presents the results obtained using LSB substitution and gray scale cover image in PVD methods. In the PVD method the maximum data is embedded between 1.55 and 1.74 bpp. In the LSB method, the PSNR values are about 51.14, while the PVD method is between 38.52 and 41.42.

Table3: Comparison of LSB substitution Method and PVD Method for gray cover image

Cover Image	LSB substitution Method			PVD Method		
	Payload (bpp)	*PSNR*	*SSIM*	*Payload (bpp)*	*PSNR*	*SSIM*
Lena	1	51.141	0.9960	1.563	41.417	0.9728
Baboon	1	51.148	0.9987	1.744	38.529	0.9876
Pepper	1	51.140	0.9963	1.554	41.392	0.9748
Airplane	1	51.150	0.9956	1.563	40.311	0.9674

Figure 3 shows the original image and histogram of the airplane colored cover imagine, and the stego images and histograms obtained using the LSB substitution and PVD method. The comb effect is clearly seen in the histogram of the stego image obtained by LSB substitution method, but not in PVD method.

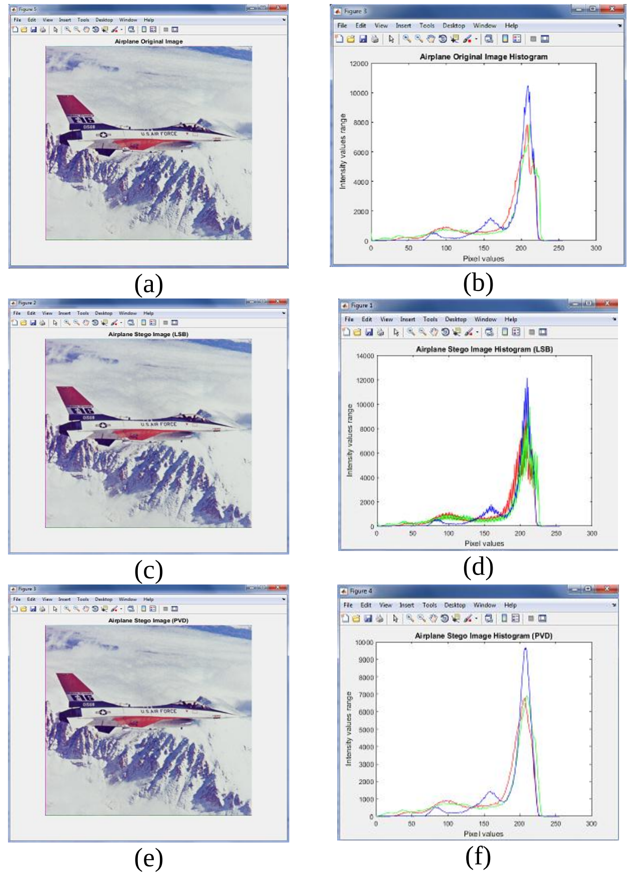
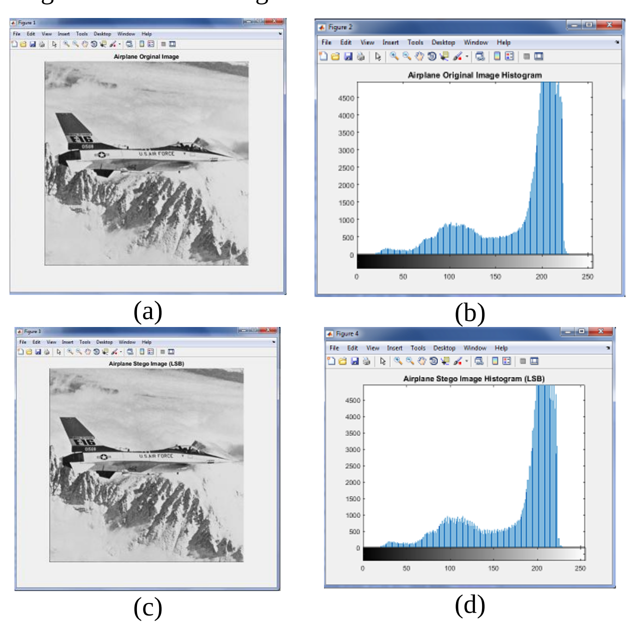
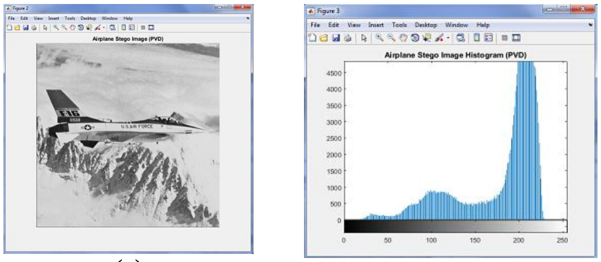


Figure 3: The result of color scale cover image (a) airplane original image, (b) original image histogram, (c) stego image LSB, (d) stego image LSB histogram, (e) stego image PVD and (f) stego image histogram PVD

Figure 4 presents the original image and histograms of the airplane gray-scale cover image, and the stego images and histograms obtained using the LSB and PVD method.





(e) (f)

Figure 4: The result of gray scale cover image (a) airplane original image, (b) original image histogram, (c) stego image LSB, (d) stego image LSB histogram, (e) stego image PVD and (f) stego image histogram PVD

IV. CONCLUSION AND FUTURE SCOPE

In the article, comparative performance analysis of LSB substitution and PVD methods used in image steganography is performed. According to LSB substitution method, the algorithm which is performed by using PVD method makes the process of embedding more data in cover image safely. However, LSB substitution method gives higher PSNR and SSIM values than PVD method. When a small amount of data is to be embedded into cover image, it is preferable to use the LSB substitution method because it is easier to perform. The use of the PVD method would be more appropriate if the high amount of data is hidden.

In future studies, it is possible to work on methods in which obtain high embedding data capacity and PSNR value using the positive aspects of PVD and LSB substitution methods.

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