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Scrutiny of Steganalysis for Flipping Steganography Method

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Abstract

Steganography is the skill of hiding data inside other information in such a way that it is hard or even impossible to tell that it is there. There are many different carriers for steganography but the most popular is digital images. In recent times, there it has been supposed that terrorist cells are using steganography to hide their clandestine policies, and consequently it is fetching increasingly significant to notice the images that contain steganography such that we can decrease criminal action. This counter-technique is known as steganalysis. In comparison to the importance of papers that examine either steganography or steganalysis methods, this paper presents in-depth metaphors of steganalysis.

Keywords: Flipping; IQM; RS; security analysis; steganograph; steganalysis; substitution.

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1 Introduction

Digital image steganography is emerging in use and appliances [1]. In areas where cryptography and strong encryption are being banned, people are using steganography to evade these rules and to send these messages clandestinely [2]. With the extensive use and profusion of steganography tools on the Internet, law enforcement establishment have anxiety in the trafficking of illegal information and data from side to side web page images, audio, and other files. Techniques of detecting concealed information and analyzing the general logic behind these tools are vital in detecting these actions. The result of steganalysis system depends on what the steganalyst desires to realize. For example, one steganalyst might just desire to identify whether two parties are communicating. Whereas another steganalyst might desire to identify how two parties are communicating. Image Steganalysis system first detect that whether the system is a stego-image or not. Further processing i.e. to modify the embedded message or destroy the message is done after that.

In this paper some well known steganalysis methods for least significant bit flipping method are discussed theoretically and practically. To evaluate the effect of embedding and different steganalysis techniques, 20%, 50%, 70% and 100% embedding rate is implemented.

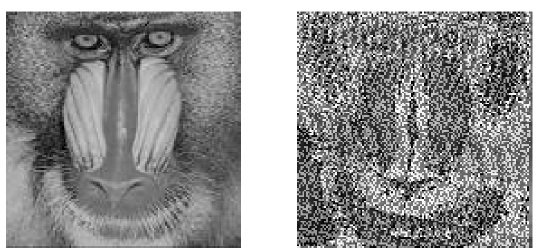
The rest of the paper is arranged as section 2 includes detail of some steganalysis methods, section 3 includes discussion and experimental results, section 4 includes conclusion and references re mentioned in the last section.

2 Steganalysis

This section gives the detail of steganalysis methods for flipping also called substitution [3, 4] method of steganography:

2.1 Steganalysis using visual analysis [5]

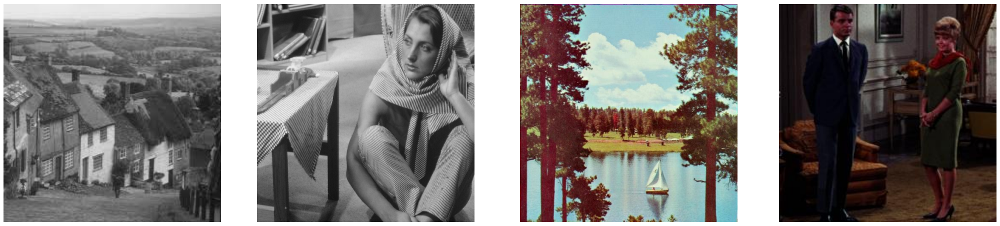
Small change in pixel value, increment or decrement by one, creates least change in statistical properties of the image. This change in statistical measure is so small that visually it cannot be detected by human eye. If the most significant bit (MSB) is used instead of LSB, the distortion will be clearly visible for human perception. Fig. 1 shows the effect of visual change at great extinct. Fig. 1 (a) is the cover image and (b) is the stego-image.



(a)Cover image **(b) Stego-image**

Fig. 1. Effect of visual change

Fig. 2 shows the visual appearance of the two cover images (CI) used for the experiment. Fig. 2 (a) is the Barbara Gray Cover image having dimensions 89x119 and (b) is the Baboon Color Cover image having dimensions 131x131. All the experimental results are shown for these two images.



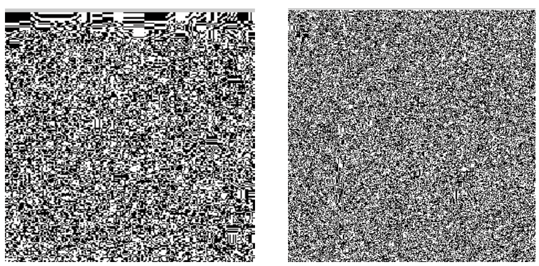
(a)Gold Hill **(b) Barbara** **(c) Sail Boat on Lake** **(d) Couple**

Fig. 2. Cover images used in experimental analysis

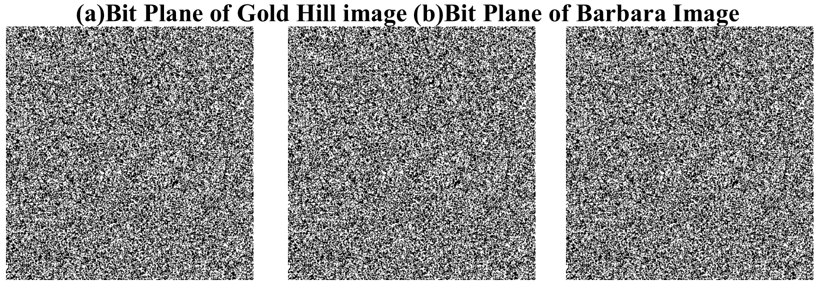
2.2 Steganalysis using bit plane analysis: [5]

The LSB substitution replaces the LSBs of the image with the bit stream of the message in series until the entire message had been embedded. Bit plane analysis recognize whether or not a supposed image has been subjected to this kind of embedding, the steganalyst will be looking to obtain a visual inconsistency for the first L pixels where L is the length of the message. It is value nothing though, that the accurate value for L will not be made visible until the visual attack successfully point out signs of embedding.

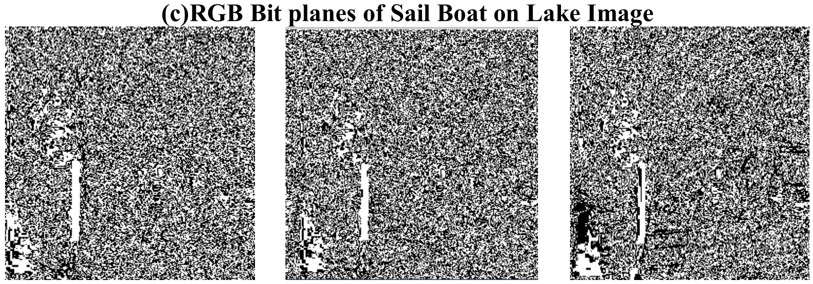
Fig. 3 shows bit planes of the grayscale and color images used in experiment.



(a)Bit Plane of Gold Hill image (b)Bit Plane of Barbara Image



(c)RGB Bit planes of Sail Boat on Lake Image



(d)RGB Bit planes of Couple Image

Fig. 3. Clear bit planes of the cover images used in experimental test

2.3 Rs analysis [5]

The RS is also based on the detail that the content of all bit planes of an image are correlated with the other. 8 bit per pixel images have correlation between the LSB plane and the remaining bit planes. When a message is substituted in the LSB plane, it creates randomness, and correlation between the LSB planes with other bit planes is decreased or lost. The RS steganalysis uses discrimination function f and a flipping operation F to create grouping g of pixels. These grouping g are classifying into three categories depending on how the flipping operation F changes the value of the discrimination function f.

Regular (RG): if $f(F(g)) > f(g)$ then $g \in RG$

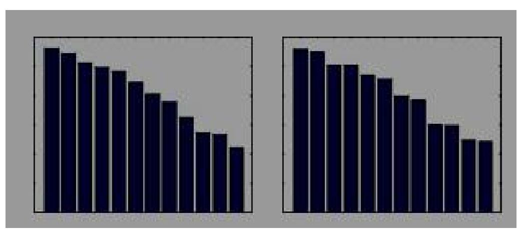
Singular (SG): if $f(F(g)) < f(g)$ then $g \in SG$

Unchanged (UG): if $f(F(g)) = f(g)$ then $g \in UG$

F(g) is the applying F on g. In original images, LSB flipping mask to the pixels in the group increase the discrimination function f and total number RG in an image will be larger than SG. But the randomness of the LSB plane after substitution makes the dissimilarity of RG and SG to zero, as the length of embedding message increases.

2.4 Steganalysis using histogram analysis

LSB substitution creates pair of values (POV) which can be detected in steganalysis. Fig. 4 shows the effect of substitution on the histogram. Fig. 4 (a) shows the histogram of cover image. Fig. 4 (b) shows the histogram of stego-image.



(a)Origina Imge (b) Stego-Image

Fig. 4. Histogram of cover image and stego-image

Figs. 5, 6 and 7 shows the histograms of cover images used in experiment. For color images RGB histogram is shown. Histograms also show the minimum pixel value of the image, maximum pixel value of the pixel in the image and maximum number of pixels having the same color.

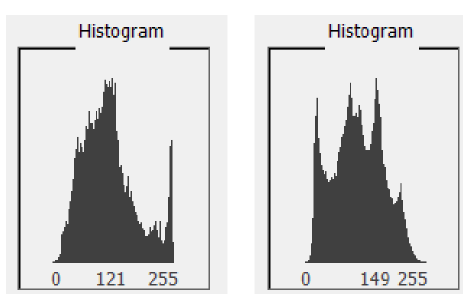


Fig. 5. histogram of gold hill and barbra image

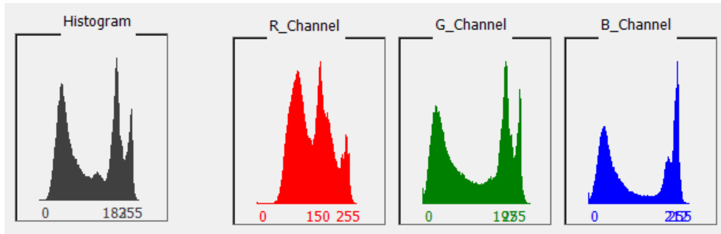


Fig. 6. Histogram of sail boat on lake image

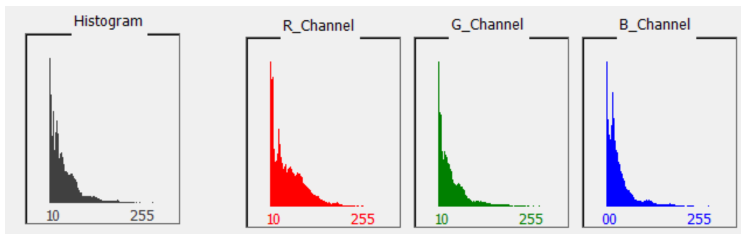


Fig. 7. Histogram of couple image

2. 5 Steganalysis by image quality measure [6,7,8,9,10]

This section gives the mathematical definitions and description of the image quality measures used for steganalysis. If $OI(x, y), x = 0,1,2, \ldots, N-1$ and $y = 0,1,2, \ldots, M-1$ and $SI(x, y), x = 0,1,2, \ldots, N-1$ and $y = 0,1,2, \ldots, M-1$ are the pixel pattern of the input original image OI and the stego-image SI, $N \times M$ represent the dimensions of OI and SI, μ_{OI} is the mean of original image, μ_{SI} is the mean of the stego-image, σ_{OI} is the standard deviation of original image, σ_{SI} is the standard deviation of the stego-image, σ^2_{OI} is the variance of the original image, σ^2_{SI} is the variance of the stego-image, σ_{OISI} is the covariance between original and stego-image and H_{OI} and H_{SI} are the value of bin of histogram of original image and stego-image respectively. Then image quality measures can be defined as following:

2.5.1 Mean absolute error

Mathematically it is defined as:

$$MAE = {}^{1}/_{NM} \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} |OI(x, y) - SI(x, y)| \quad (2.1)$$

Its ideal value is 0. It shows its ideal value if and only if OI=SI.

2.5.2 Peak absolute error

Mathematically it is defined as:

$$PAE = {}^{1}/_{NM} \frac{\sum_{x=0}^{N-1} \sum_{y=0}^{M-1} |OI(x, y) - SI(x, y)|}{\max(OI(x, y))\ for\ x = 0,1,2, \ldots, N-1\ and\ y = 0,1,2, \ldots, M-1} \quad (2.2)$$

Its ideal value is 0. It shows its ideal value if and only if OI=SI.

2.5.3 Normalized absolute error

Mathematically it is defined as:

$$NAE = \frac{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}|OI(x,y) - SI(x,y)|}{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}|OI(x,y)|} \quad (2.3)$$

It's ideal value is 0. It shows its ideal value if and only if OI=SI.

2.5.4 Maximum difference

Mathematically it is defined as:

$$MD = max|OI(x,y) - SI(x,y)| \text{ where } x = 0,1,2,\ldots,N-1, y = 0,1,2,\ldots,M-1 \quad (2.4)$$

Its ideal value is 0. It shows its ideal value if and only if OI=SI.

2.5.5 Mean square error

Mathematically it is defined as:

$$MSE = {}^{1}/_{NM}\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(OI(x,y) - SI(x,y)\right)^2 \quad (2.5)$$

Its ideal value is 0. It shows its ideal value if and only if OI=SI.

2.5.6 Normalized square error

Mathematically it is defined as:

$$NSE = \frac{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(OI(x,y) - SI(x,y)\right)^2}{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(OI(x,y)\right)^2} \quad (2.6)$$

Its ideal value is 0. It shows its ideal value if and only if OI=SI.

2.5.7 Signal to noise ratio

Mathematically it is defined as:

$$SNR = 10log_{10}\left(\frac{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}OI(x,y)^2}{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(OI(x,y) - SI(x,y)\right)}\right) \quad (2.7)$$

Its result is infinity if both the images are identical.

2.5.8 Peak signal to noise ratio

Mathematically it is defined as:

$$PSNR = 10log_{10}\left(\frac{(max(x,y))^2 \text{ where } x = 0,1,2,\ldots N-1 \text{ and } y = 0,1,2,\ldots,M-1}{MSE}\right) \quad (2.8)$$

Its result is infinity if both the images are identical. However, higher the PSNR, better the quality of the image.

2.5.9 Structural information

Mathematically it is defined as:

$$Structural\ Information = St\_I(OI,SI) = \frac{2\sigma_{OISI}}{\sigma_{OI}+\sigma_{SI}} \quad (2.9)$$

Its result are in range of [0,1].

2.5.10 Normalized cross correlation

Mathematically it is defined as:

$$NCC = \frac{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(OI(x,y) * SI(x,y)\right)}{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(OI(x,y)\right)^2} \quad (2.10)$$

Its result are in range of [0,1].

2.5.11 Structural content

$$SC = \frac{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(SI(x,y)\right)^2}{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(OI(x,y)\right)^2} \quad (2.11)$$

Its result are in range of [0,1].

2.5.12 Average difference

$$AD = {}^{1}/_{NM}\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(OI(x,y) - SI(x,y)\right) \quad (2.12)$$

Its result are in range of [0,1]. Ideal value is 0.

2.5.13 Universal image quality index

On the basis of luminance, contrast and structural information UIQI is:

$$UIQI(OI,SI) = l(OI,SI) * C(OI,SI) * SI(OI,SI) \qquad (2.13)$$

It can also be defines as:

$$UIQI(OI,SI) = \frac{4\mu_{OI}\mu_{SI}\mu_{OISI}}{(\mu^2_{OI} + \mu^2_{SI})(\sigma^2_{OI} + \sigma^2_{SI})} \qquad (2.14)$$

Its result range in [-1, +1].-1 is the worst case result and +1 is the best case result.

2.5.14 Structural similarity index measure

$$SSIM(OI,SI) = \frac{(2\mu_{OI}\mu_{SI} + C_1)(2\sigma_{OISI} + C_2)}{(\mu^2_{OI} + \mu^2_{SI} + C_1)(\sigma^2_{OI} + \sigma^2_{SI} + C_2)} \qquad (2.15)$$

Where C_1 and C_2 are constant defined as:

$$C_1 = (K_1L)^2 \text{ where } K_1 = 0.01 \text{ and } L = 2^{\#\text{ of bits per pixel}} \qquad (2.16)$$

$$C_2 = (K_2L)^2 \text{ where } K_2 = 0.03 \text{ and } L = 2^{\#\text{ of bits per pixel}} \qquad (2.17)$$

Its result range in [-1, +1].-1 is the total mismatch condition and +1 is the best match result.

2.6 Stego-sensitive threshold close color pair signature [11]

LSB substitution creates the randomness and this randomness change the number of close color pair and unique color. The close color pair (CCP) and the unique color (UC) are calculated as:

Two color $(\text{red}_1, \text{green}_1, \text{blue}_1)$ and $(\text{red}_2, \text{green}_2, \text{blue}_2)$ are close if

$$|red_1 - red_2| = 1, |green_1 - green_2| = 1 \text{ and } |blue_1 - blue_2| = 1 \qquad (2.18)$$

or

$$(red_1 - red_2)^2 + (green_1 - green_2)^2 + (blue_1 - blue_2)^2 \leq 3 \qquad (2.19)$$

Two color $(\text{red}_1, \text{green}_1, \text{blue}_1)$ and $(\text{red}_2, \text{green}_2, \text{blue}_2)$ are unique if

$$|red_1 - red_2| = 1 \text{ or } |green_1 - green_2| = 1 \text{ or } |blue_1 - blue_2| = 1 \qquad (2.20)$$

R is the ratio of close color pairs (CCP) with unique colors (UC) of the original image.

$$R = {}^{CCP}/_{UC} \qquad (2.21)$$

After the substitution the ratio R' will be computed as:

$$R' = {}^{CCP'}/_{UC'} \tag{2.22}$$

Where CCP' and UC' are the close color pair and unique color of the stego-image and $R' > R$
The percentage change PC in R is given by:

$$PC = ((R - R') * 100)/R \tag{2.23}$$

The threshold is calculated as:

$$T = {}^{PC}/_{SSIM} \tag{2.24}$$

where SSIM is the structural similarity index measure.
The value of threshold T is different for original image and stego image which is a differentiating factor for original and embedded image. If m<T then the image is stego-image.

2.7 Steganalysis by image quality measure

This section gives the mathematical definitions and description of the security measures used for steganalysis. If $OI(x,y), x = 0,1,2,\ldots,N-1$ and $y = 0,1,2,\ldots,M-1$ and $SI(x,y), x = 0,1,2,\ldots,N-1$ and $y = 0,1,2,\ldots,M-1$ are the pixel pattern of the input original image OI and the stego-image SI, $N \times M$ represent the dimensions of OI and SI, μ_{OI} is the mean of original image, μ_{SI} is the mean of the stego-image, σ_{OI} is the standard deviation of original image, σ_{SI} is the standard deviation of the stego-image, σ^2_{OI} is the variance of the original image, σ^2_{SI} is the variance of the stego-image, σ_{OISI} is the covariance between original and stego-image and H_{OI} and H_{SI} are the value of bin of histogram of original image and stego-image respectively. Then security analysis measures can be defined as following:

2.7.1 Paterson cross correlation [12]

$$PCC = \frac{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}(OI(x,y) - \mu_{OI})(SI(x,y) - \mu_{SI})}{\sqrt{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}(OI(x,y) - \mu_{OI})^2 \sum_{x=0}^{N-1}\sum_{y=0}^{M-1}(SI(x,y) - \mu_{SI})^2}} \tag{2.25}$$

2.7.2 Spearman's rank correlation [12]

$$SRCC = 1 - \frac{6\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(Rank_{OI}(x,y) - Rank_{SI}(x,y)\right)^2}{N \times M((N \times M)^2 - 1)} \tag{2.26}$$

It can also be defined as:

$$SRCC = \frac{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}(OI(x,y) - \mu_{OI})(SI(x,y) - \mu_{SI})}{\sqrt{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}(OI(x,y) - \mu_{OI})^2 \sum_{x=0}^{N-1}\sum_{y=0}^{M-1}(SI(x,y) - \mu_{SI})^2}} \tag{2.27}$$

2.7.3 Jaccard measure [12]

$$d_{Jaccard}(H_{OI}, H_{SI}) = \frac{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1} H_{OI}(x,y)H_{SI}(x,y)}{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(H_{OI}(x,y)\right)^2 + \sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left(H_{SI}(x,y)\right)^2 - \sum_{x=0}^{N-1}\sum_{y=0}^{M-1} H_{OI}(x,y)H_{SI}(x,y)} \tag{2.28}$$

Where d is function that computes Jaccard coefficient between H_{II} and H_{RI}.

2.7.4 Intersection [12]

$$d_{Intersection}(H_{OI}, H_{SI}) = \sum_{x=0}^{N-1}\sum_{y=0}^{M-1} min\left(H_{OI}(x,y), H_{SI}(x,y)\right) \tag{2.29}$$

Where d is function that computes Intersection between H_{OI} and H_{SI}.

2.7.5 Bhattacharya [12]

$$d_{Bhattacharya}(H_{OI}, H_{SI}) = \sqrt{1 - \frac{1}{\sqrt{1/_{NM}\sum_{x=0}^{N-1}\sum_{y=0}^{M-1} H_{OI}(x,y)\sum_{x=0}^{N-1}\sum_{y=0}^{M-1} H_{SI}(x,y)}}\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\sqrt{H_{OI}(x,y)H_{SI}(x,y)}} \tag{2.30}$$

Where d is function that computes Bhattacharya between H_{OI} and H_{SI}.

2.7.6 Chi-square [12]

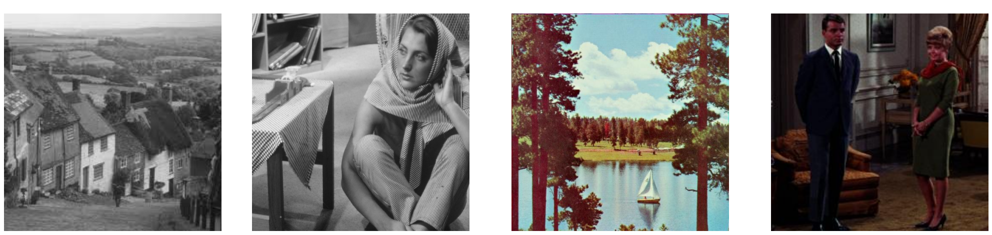
Mathematically it is defined as:

$$d_{Chi-square}(H_{OI}, H_{SI}) = \sum_{i=1}^{N} \frac{\left(H_{OI}(i) - H_{SI}(i)\right)^2}{H_{OI} + H_{SI}} \tag{2..31}$$

Its ideal value is 0. It shows its ideal value if and only if OI=SI.

3 Results and Discussion

This section gives the experimental results and discussion for grayscale and color images. Fig. 8 shows the result of visual appearance of stego image with 20% embedding rate.



(a)Gold Hill **(b) Barbara** **(c) Sail Boat on Lake** **(d) Couple**

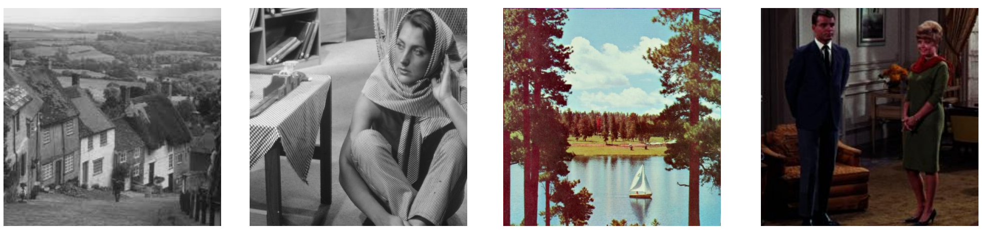
Fig. 8. Stego-images with embedding rate of 20%

Fig. 9 shows the result of visual appearance of stego image with 50% embedding rate.

(a)Gold Hill **(b) Barbara** **(c) Sail Boat on Lake** **(d) Couple**

Fig. 9. Stego-images with embedding rate of 50%

Fig. 10 shows the result of visual appearance of stego image with 70% embedding rate.



(a)Gold Hill **(b) Barbara** **(c) Sail Boat on Lake** **(d) Couple**

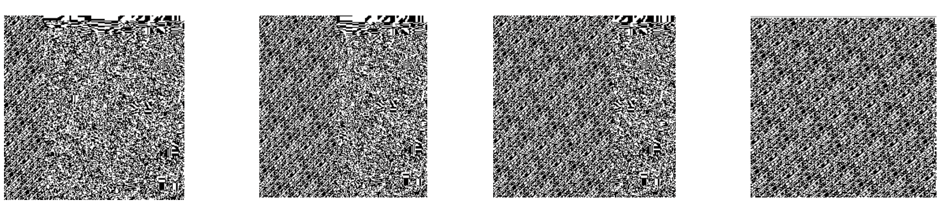
Fig. 10. Stego-images with embedding rate of 70%

Fig. 11 shows the result of visual appearance of stego image with 100% embedding rate.

(a)Gold Hill **(b) Barbara** **(c) Sail Boat on Lake** **(d) Couple**

Fig. 11. Stego-images with embedding rate of 100%

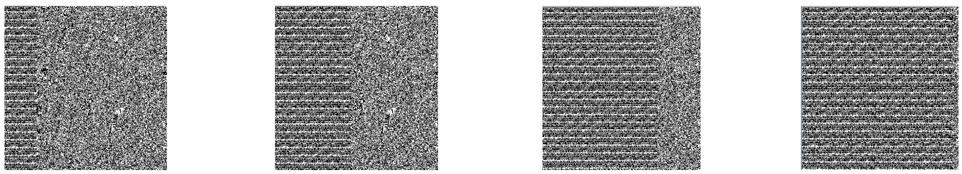
Fig. 12 shows the result of bit plane analysis of Gold Hill stego image with 20%, 50%, 70% and 100% embedding rate. (a) is the stego Gold Hill image with 20% embedding rate, (b) is the stego Gold Hill image with 50% embedding rate, (c) is the stego Gold Hill image with 70% embedding rate and (d) is the stego Gold Hill image with 100% embedding rate.



(a) 20%Embedding **(b) 50%Embedding** **(c) 70%Embedding** **(d) 100%Embedding**

Fig. 12. Bit planes of stego-gold hill image

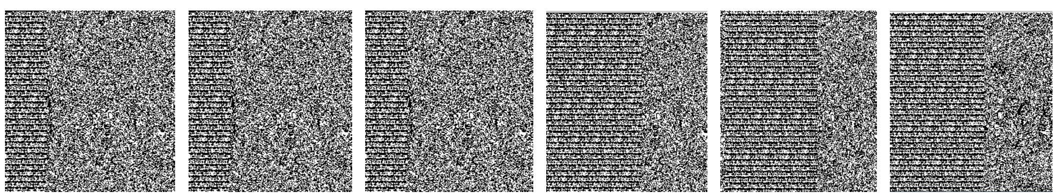
Fig. 13 shows the result of bit plane analysis of Barbara stego image with 20%, 50%, 70% and 100% embedding rate. (a) is the stego-Barbara image with 20% embedding rate, (b) is the stego-Barbara image with 50% embedding rate, (c) is the stego-Barbara image with 70% embedding rate and (d) is the stego-Barbara image with 100% embedding rate,



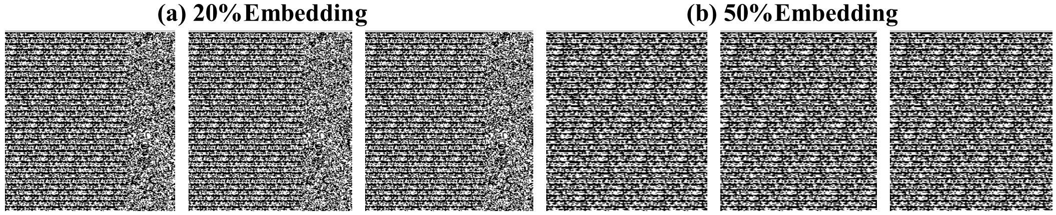
(a) 20%Embedding **(b) 50%Embedding** **(c) 70%Embedding** **(d) 100%Embedding**

Fig. 13. Bit planes of stego-barbara image

Fig. 14 shows the result of bit plane analysis of Sail Boat on Lake stego image with 20%, 50%, 70% and 100% embedding rate. Bit plane shows the RGB (red, green, blue) plans separately. Fig.14 (a) is stego-image with 20% embedding rate (b) shows stego-image with 50% embedding rate, (c) is stego-image with 70% embedding rate and (d) shows after 100% embedding rate.



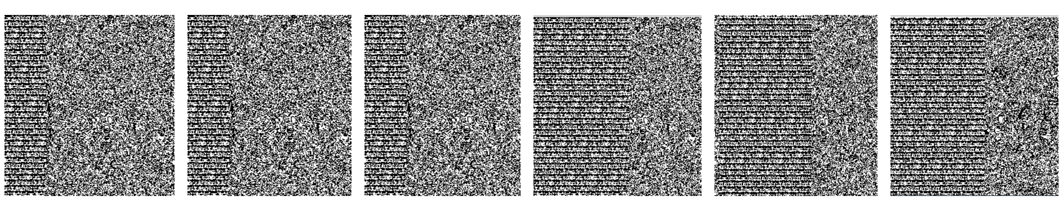
(a) 20%Embedding **(b) 50%Embedding**



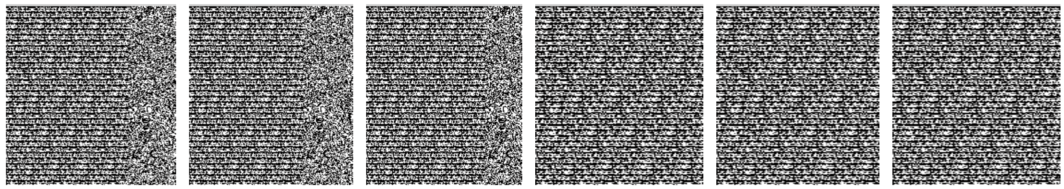
(c) 70%Embedding **(d) 100%Embedding**

Fig. 14. Bit planes of stego-sail boat on lake image

Fig. 15 shows the result of bit plane analysis of Couple stego image with 20%, 50%, 70% and 100% embedding rate. Bit plane shows the RGB (red, green, blue) plans separately. Fig.15 (a) is stego-image with 20% embedding rate (b) shows stego-image with 50% embedding rate, (c) is stego-image with 70% embedding rate and (d) shows after 100% embedding rate.



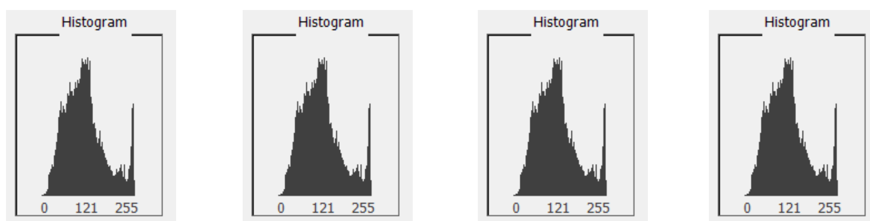
(a) 20%Embedding **(b) 50%Embedding**



(c) 70%Embedding **(d) 100%Embedding**

Fig. 15. Bit planes of stego-couple image

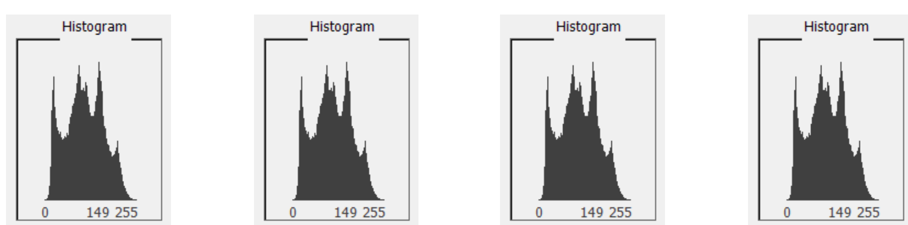
Fig. 16 shows the result of histogram of Gold Hill stego-image with 20%, 50%, 70% and 100% embedding rate. (a) is the histogram of stego-Gold Hill image with 20% embedding rate, (b) is the histogram of stego-Gold Hill image with 50% embedding rate, (c) is the histogram of stego-Gold Hill image with 70% embedding rate and (d) is the histogram of stego-Gold Hill image with 100% embedding rate.



(a)20% Embedding **(b) 50% Embedding** **(c) 70% Embedding** **(d) 100% Embedding**

Fig. 16. Bit planes of stego-gold hill image

Fig. 17 shows the result of histogram of Barbara stego-image with 20%, 50%, 70% and 100% embedding rate. (a) is the histogram of stego-Barbara image with 20% embedding rate, (b) is the histogram of stego-Barbara image with 50% embedding rate, (c) is the histogram of stego-Barbara image with 70% embedding rate and (d) is the histogram of stego-Barbara image with 100% embedding rate.



(a)20% Embedding (b)50% Embedding (c)70% Embedding (d)100% Embedding

Fig. 17. Bit planes of stego-barbara image

Fig. 18 shows the result of RGB histogram of Sail Boat on Lake-stego-image with 20%, 50%, 70% and 100% embedding rate. (a) is the histogram of stego- Sail Boat on Lake image with 20% embedding rate, (b) is the histogram of stego- Sail Boat on Lake image with 50% embedding rate, (c) is the histogram of stego-Sail Boat on Lake image with 70% embedding rate and (d) is the histogram of stego- Sail Boat on Lake image with 100% embedding rate.

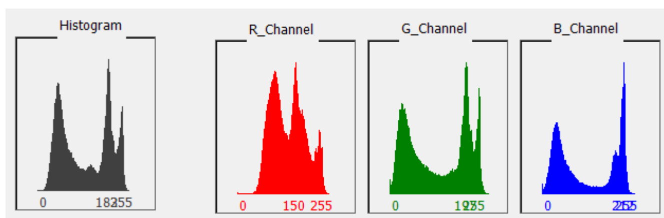
Fig. 19 shows the result of RGB histogram of Couple-stego-image with 20%, 50%, 70% and 100% embedding rate. (a) is the histogram of stego- Couple image with 20% embedding rate, (b) is the histogram of stego- Couple image with 50% embedding rate, (c) is the histogram of stego- Couple image with 70% embedding rate and (d) is the histogram of stego- Couple image with 100% embedding rate.

Table 1 shows the result of image quality measures for Gold Hill image after 20%, 50%, 70% and 100% embedding rate.

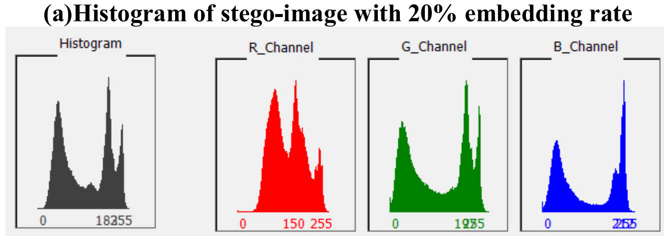
Table 2 shows the result of image quality measures for Barbara image after 20%, 50%, 70% and 100% embedding rate.

Table 3 shows the result of image quality measures for Sail Boat on Lake Image after 20%, 50%, 70% and 100% embedding rate.

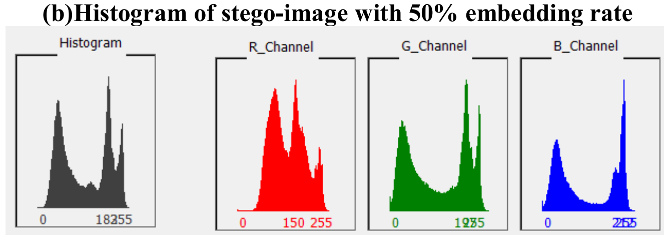
Table 4 shows the result of image quality measures for Couple after 20%, 50%, 70% and 100% embedding rate.



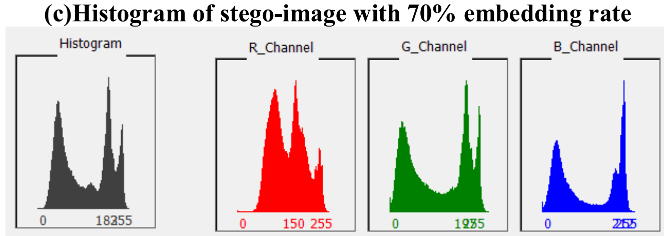
(a)Histogram of stego-image with 20% embedding rate



(b)Histogram of stego-image with 50% embedding rate



(c)Histogram of stego-image with 70% embedding rate



(d)Histogram of stego-image with 100% embedding rate

Fig. 18. RGB Histogram of stego-sail boat on lake image

Table 1. Result of IQMs for stego-gold hill image

	Image quality measures	20%	50%	70%	100%
1	Mean absolute error	0.2044	0.4412	0.6622	0.8806
2	Peak absolute Error	0.0009	0.0019	0.0028	0.0037
3	Normalized absolute error	0.0081	0.0039	0.0059	0.0078
4	Maximum difference	1	1	1	1
5	Mean square error	0.4088	0.8824	1.324	1.7613
6	Normalized square error	2.7253	5.8826	8.8292	0.0001
7	Signal to noise ratio	45.6457	42.3042	40.5407	39.3025
8	Peak Signal to noise ratio	52.0155	48.6741	46.9105	45.6723
9	Structural information	0.9999	0.9998	0.9997	0.9996
10	Normalized cross correlation	0.9999	0.9997	0.9995	0.9994
11	Structural content	0.9999	1	1	1
12	Average difference	0.0149	0.0409	0.0687	0.0872
13	Universal image quality index	0.9999	0.9998	0.9997	0.9996
14	Structural similarity index measure	0.9999	0.9998	0.9997	0.9996

Table 2. Result of IQMs for stego-barbara image

	Image quality measures	20%	50%	70%	100%
1	Mean absolute error	0.1976	0.4554	0.7103	0.7972
2	Peak absolute error	0.0008	0.0019	0.0029	0.0033
3	Normalized absolute error	0.0017	0.0041	0.0063	0.0071
4	Maximum difference	1	1	1	1
5	Mean square error	0.3951	0.9109	1.4206	1.5945
6	Normalized square error	2.6537	6.1182	9.5415	0.0001
7	Signal to noise Ratio	45.6414	42.1337	42.1337	39.7023
8	Peak signal to noise ratio	52.1636	48.5359	48.5359	45.1045
9	Structural information	0.9999	0.9998	0.9997	0.9996
10	Normalized cross correlation	0.9999	0.9997	0.9996	0.9994
11	Structural content	1	1	1	1
12	Average difference	0.0206	0.0463	0.0732	0.0817
13	Universal image quality index	0.9999	0.9998	0.9997	0.9996
14	Structural similarity index measure	0.9999	0.9998	0.9997	0.9996

Table 3. Result of IQMs for stego-sail boat on lake image

	Image quality measures	20%	50%	70%	100%
1	Mean absolute error	0.1501	0.1662	0.1702	0.1706
2	Peak absolute Error	0.0007	0.0008	0.0009	0.0010
3	Normalized absolute error	0.0070	0.0073	0.0077	0.0079
4	Maximum difference	0.6666	0.6666	0.6666	0.6666
5	Mean square error	0.1600	0.1662	0.1689	0.1700
6	Normalized square error	0.0002	0.0003	0.0005	0.0007
7	Signal to noise ratio	39.1585	39.1585	39.1407	39.1025
8	Peak signal to noise ratio	54.0255	54.0258	54.0260	54.0280
9	Structural information	0.9999	0.9998	0.9997	0.9996
10	Normalized cross correlation	0.9999	0.9998	0.9997	0.9996
11	Structural content	1	1	1	1
12	Average difference	0.0101	0.0251	0.0266	0.0270
13	Universal image quality index	0.9999	0.9998	0.9997	0.9996
14	Structural similarity index measure	0.9999	0.9998	0.9997	0.9996

Table 4. Result of IQMs for stego-couple image

	Image quality measures	20%	50%	70%	100%
1	Mean absolute error	0.2501	0.2662	0.2702	0.2706
2	Peak absolute error	0.0009	0.0010	0.0013	0.0014
3	Normalized absolute error	0.0080	0.0083	0.0087	0.0089
4	Maximum difference	0.6666	0.6666	0.6666	0.6666
5	Mean square error	0.2600	0.2662	0.2689	0.2700
6	Normalized square error	0.0001	0.0002	0.0003	0.0003
7	Signal to noise ratio	38.9585	38.9585	40.5407	39.3025
8	Peak signal to noise ratio	53.0155	53.0158	53.0260	53.0280
9	Structural information	0.9999	0.9998	0.9997	0.9996
10	Normalized cross correlation	0.9999	0.9998	0.9996	0.9995
11	Structural content	1	1	1	1
12	Average difference	0.0201	0.0351	0.0366	0.0370
13	Universal image quality index	0.9999	0.9998	0.9997	0.9996
14	Structural similarity index measure	0.9999	0.9998	0.9997	0.9996

Table 5 shows the result of security analysis for Gold Hill image after 20%, 50%, 70% and 100% embedding rate.

Table 5. Result of security analysis for stego-gold hill image

Security analysis	20%	50%	70%	100%
3.1 Paterson cross correlation	0.9999	0.9999	0.9997	0.9998
3.2 Spearman's rank correlation:	0.9999	0.9999	0.9997	0.9998
3.4 Jaccard measure [12]:	0.9999	0.9999	0.9999	0.9998
3.5 Intersection [12]:	0.9990	0.9979	0.9967	0.9957
3.6 Bhattacharya [12]:	0.0021	0.0030	0.0037	0.0045
2.15 Chi-square:	0.0018	0.0039	0.0059	0.0078

Table 6 shows the result of security analysis for Barbara image after 20%, 50%, 70% and 100% embedding rate.

Table 6. Result of security analysis for stego-barbara image

Security analysis	20%	50%	70%	100%
3.1 Paterson cross correlation	0.9999	0.9998	0.9997	0.9996
3.2 Spearman's rank correlation:	0.9999	0.9998	0.9997	0.9996
3.4 Jaccard measure [12]:	0.9999	0.9999	0.9999	0.9998
3.5 Intersection [12]:	0.9990	0.9978	0.9965	0.9961
3.6 Bhattacharya [12]:	0.0023	0.0032	0.0043	0.0045
2.15 Chi-square:	0.0018	0.0040	0.0063	0.9971

Table 7 shows the result of security analysis for Sail Boat on Lake Image after 20%, 50%, 70% and 100% embedding rate.

Table 7. Result of security analysis for stego-sail boat lake image

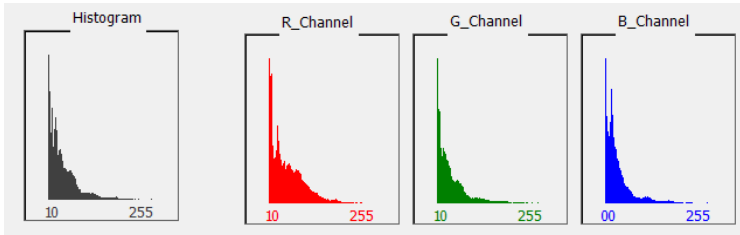
Security analysis	20%	50%	70%	100%
3.1 Paterson cross correlation	0.9999	0.9998	0.9997	0.9996
3.2 Spearman's rank correlation:	0.9999	0.9998	0.9997	0.9996
3.4 Jaccard measure [12]:	0.9999	0.9999	0.9998	0.9998
3.5 Intersection [12]:	0.9998	0.9993	0.9991	0.9990

3.6 Bhattacharya [12]:	0.0024	0.0035	0.0043	0.0051
2.15 Chi-square:	0.0014	0.0023	0.0034	0.0039

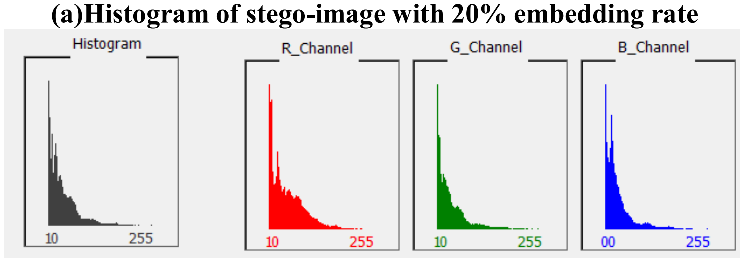
Table 8 shows the result of security analysis for Couple image after 20%, 50%, 70% and 100% embedding rate.

Table 8. Result of security analysis for stego-couple image

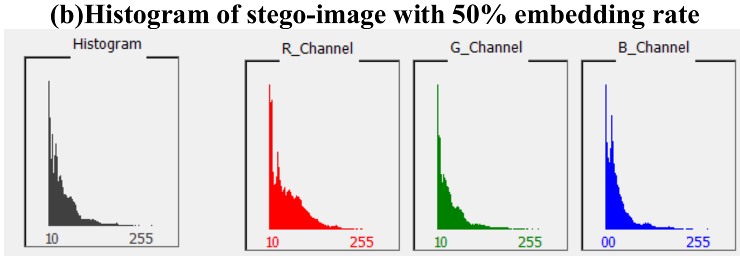
Security analysis	20%	50%	70%	100%
3.1 Paterson cross correlation	0.9999	0.9999	0.9998	0.9997
3.2 Spearman's rank correlation:	0.9999	0.9999	0.9998	0.9997
3.4 Jaccard measure [12]:	0.9999	0.9998	0.9997	0.9996
3.5 Intersection [12]:	0.9997	0.9996	0.9996	0.9995
3.6 Bhattacharya [12]:	0.0021	0.0036	0.0041	0.0053
2.15 Chi-Square:	0.0012	0.0017	0.0021	0.0029



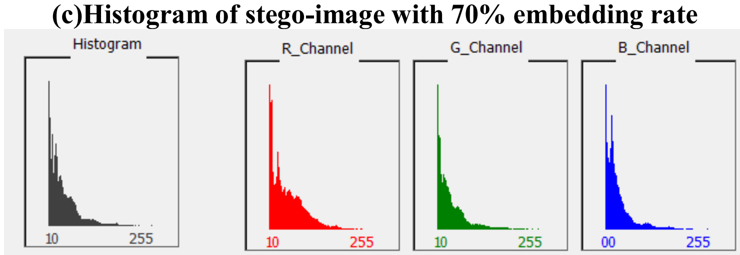
(a)Histogram of stego-image with 20% embedding rate



(b)Histogram of stego-image with 50% embedding rate



(c)Histogram of stego-image with 70% embedding rate



(d)Histogram of stego-image with 100% embedding rate

Fig. 19. RGB histogram of couple image

5 Conclusion

This paper is an attempt to give detail experimental study and analysis of steganalysis. Flipping method of hidden writing could be hit by these mentioned steganalysis tools. All this results and discussion are the clear fact about saying that substitution is a good, simple and effective method of steganography but it is at risk as many steganalysis methods have been projected for this. The paper is a perfect analysis for those who are doing research to present a new method of steganography. And for the beginners this is an ideal investigation of the effect of substitution in the LSB in the images and its detection using steganalysis tools.

Competing Interests

Authors have declared that no competing interests exist.

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