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Experimental Analysis and Review of "Increased Capacity of Information Hiding"

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Abstract

With the quick progress and extensive use of internet, information transmission faces confronts of security and unauthorized access of secret data. In this situation steganography is considered as gifted approach. Steganography is the science of hidden writing schemes in which the presence of concealed information is not noticeable. This paper is the detailed experimental analysis and review of "Increased Capacity of Information Hiding in Least Significant Bit Method" of steganography. Analysis is based on popular steganalysis tools, image quality measures, security analysis and worst case situation. Experimental result of selected method of steganography is compared with the basic LSB substitution method, direct LSB substitution for two bits, for three bits and for four bits. The results shows the clear evidences of the fact that increased capacity method have preference over the direct LSB substitution, two bit substitution, three bits substitution and four bits substitution. All these results are checked for both the color and grayscale images. Moreover this review and analysis could be a deep understanding of steganography and will be a helpful analysis for presenting new approaches in this field.

Keywords: *Bit Plane Analysis, Gaussian Noise, IQM, Steganography, Steganalysis, Security Analysis, Salt and Pepper Noise, Speckle Noise*

1. Introduction

Steganography is an exceptional loom in the existing era of digital technology. Due to its usefulness it is attaining importance swiftly. Steganography has established a lot of concern in not many years. In analysis of the detail of September 11th, 2001, some people have suggested that Al Qaeda utilize Steganography scheme to synchronize the World Trade Centre assail. But afterwards, nothing was making available as verification. Some scientific and commercial application of the hidden writing includes that it is the most important tool for the secure electronic transmission of important information, document authentication, document tracking, digital election and electronic money. Beside these, information collected in a radar station, or during medical imaging, can be put together with the pictures.

1.1. Steganographic System

A complete steganography system consists of the cover object, stego object, embedding algorithm, extraction process and secret message and sometime a stego key which is used to extract the message from stego object. Embedding of message is performed in the sender side and extraction process is carried out at recipient side. Only the sender and intended recipient know the secret transmission of information.
Figure 1 shows the general framework of the steganographic system.

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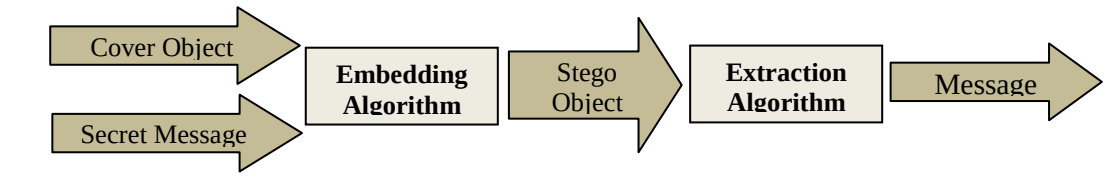


Figure 1. Steganographic System

Explanations of the important terminologies of the stego system are following:

- **Cover Object:** It is the input medium in which concealment of secret data is to be performed. It could be an image, video file, audio file or a text file
- **Stego-Object:** After the concealment of secret data into the cover medium, the cover object becomes the stego-object.
- **Embedding:** Embedding is the process of making a stego-object from a cover object. Or we can define it as the process of concealment of secret message into some digital medium.
- **Extraction:** This is the reverse process of embedding. In this process, the conceded message is recovered from stego-object to read it.
- **Message:** It is the secret information that is to be embedded in the cover object for safe transmission of data from sender to receiver.

2. Methodology

The "Increased Capacity of Information Hiding in LSB's Method" [1] is a dynamic approach of steganography. Instead of hiding message sequentially in the LSB [2, 3, 4, 5, 6] of pixels of an image, as in case of LSB substitution, this method uses the substitution method dynamically and increases the embedding capacity. Important characteristics of this method are summarized as:

- It is simple to implement.
- Create less statistical changes.
- Visual appearance of stego-image is undistinguishable by human perception.
- It's a dynamic approach.
- Increased the embedding capacity up to 4 bits.

Main logic behind this method is the classifications of all 256 shades into four categories which can be describe as:

a. *If* $240 \leq PV_i \leq 255$ *then 4 LSBs will be used for hidding secret bits*
b. *If* $224 \leq PV_i \leq 239$ *then 3 LSBs will be used for hidding secret bits*
c. *If* $192 \leq PV_i \leq 223$ *then 2 LSBs will be used for hidding secret bits*
d. *If* $0 \leq PV_i \leq 191$ *then1 LSB will be used for hidding secret bits*

Where PV_i represent the pixel value at location *i.*
The presentation of these rules can also take the form:

a.
If 4 Most Significant Bits are all 1111 *then 4 LSBs will be used for hidding secret bits.*
b.
*If 3Most Significant Bits are all*111 *then*3 *LSBs will be used for hidding secret bits.*
c.
If 2Most Significant Bits are all 11 *then 2 LSBs will be used for hidding secret bits.*
d. *In all other cases 1 Least significant bits will be used for hidding secret bits.*

The reverse process is used for collecting all the message bits.

3. Tools Used for Analysis and Review

Tools used for the analysis and review include Image Quality Measures, Histogram Analysis, Security Analysis, Bit Plane Analysis, Worst Case Analysis and Noise Level Estimation.

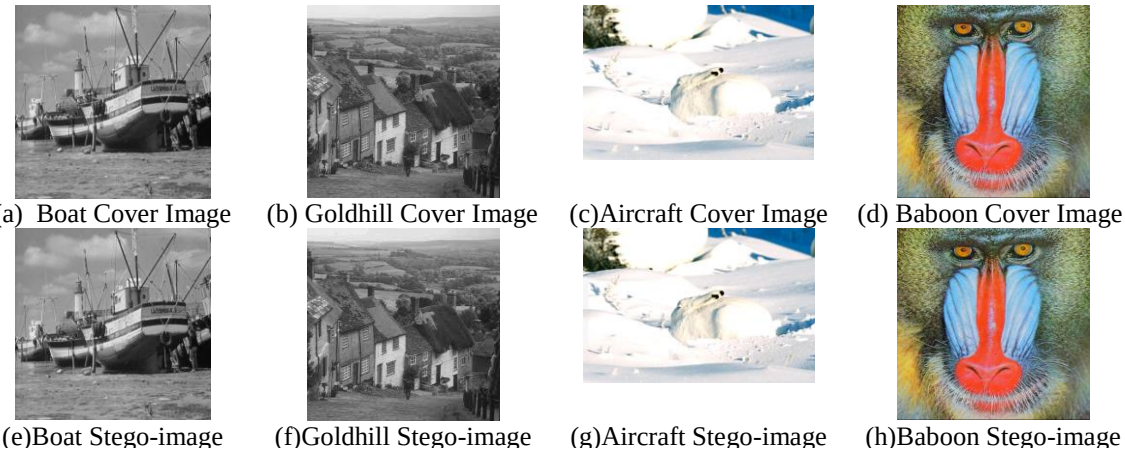
Brief overview of these tools is mentioned below:

- **Visual Appearance [3, 4, 5, 6, and 7]:** This is the stego-image appearance by human perception.
- **Image Quality Measure [3, 4, 5, 6, 7, 8, 9, 10, 11, 12]:** Most widely used image quality measures for steganography , including Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Universal Image Quality Index (UIQI), Structural Similarity Index Measure (SSIM), Image Fidelity (IF), Normalized Cross Correlation (NCC), Average Difference (AD) etc are used for the evaluation.
- **Histogram Analysis [3, 4, 5, 6, and 7]:** After the concealment of secret data into the cover medium, the cover object becomes the stego-object.
- **Security Analysis [3, 4, 5, 6, 7, and 13]:** For Security analysis Paterson Correlation Coefficient, Jacaard Measure, Intersection Coefficient Measure, Bhattacharya and Chi-Square Measure are computed between the normalized histograms of cover image and stego images.
- **Bit Plane Analysis [3, 4, 5, 6, and 7]:** A greyscale image has eight bit planes. Each bit plane has a correlation with the other bit plane. Process of substitution will create a change in the bit plane that will be visible in bit plane analysis.
- **Worst Case Analysis:** In this analysis the possibility when the selected steganography scheme gives the bad result is analyzed.
- **Noise Level Estimation:** Most common noise such as salt and pepper noise, Gaussian noise and speckle noise are added in the stego image to check the level of noise in which the embedded message remain secure, can be recovered and lost.

4. Experimental Results and Discussion

This section presents the experimental results and discussion for the standard grayscale and cover images. Figure2 shows the visual appearance of the cover and stego images.

Figure 2 (a), (b), (c), and (d) are the cover images used fir experiments. In Figure 2(a) is the grayscale Boat image having dimensions 512x512, (b) is the grayscale Goldhill image with 225x225 dimensions, (c) is the color Aircraft image having dimensions 594x400 and (d) is the color Baboon image with 512x512 dimension. Figure 2 (e) is the stego-Boat image, (f) is the stego-Goldhill image, (g) is the stego-Aircraft image and (h) is the stgo-Baboon image.



(a) Boat Cover Image (b) Goldhill Cover Image (c)Aircraft Cover Image (d) Baboon Cover Image

(e)Boat Stego-image (f)Goldhill Stego-image (g)Aircraft Stego-image (h)Baboon Stego-image

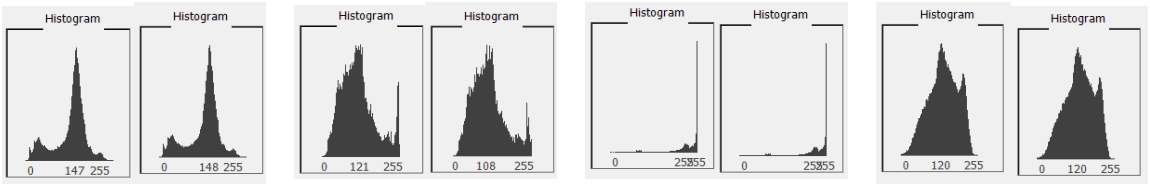
Figure 2. Cover and Stego Images

Table 1 shows the result of image quality measures for the grayscale and color images. Image Quality Measures are computed between the cover images and their respective stego images of Figure 1.

Table 1. Result of Image Quality Measures

Measure	Boat	Goldhill	Aircraft	Baboon
MSE	0.20956	1.01076	0.71826	0.07635
PSNR	54.9178	48.03786	49.40476	58.6463
UIQI	0.99995	0.99979	0.99985	0.99999
SSIM	0.99995	0.99979	0.99985	0.99999
IF	0.99999	0.99993	0.99999	0.99999
AD	0.01816	0.05191	0.05550	0.00489
NCC	0.99987	0.99955	1	0.95959
MD	5	2.66666	8.33333	1

Figure 3 (a), (b), (c), and (d) are the histograms of the cover images used for experiments. In Figure 2(a) is the histogram of grayscale Boat cover and stego image (b) shows the histogram of grayscale Goldhill cover and stego image, (c) shows the histogram of color Aircraft cover and stego image and (d) shows the histogram of color Baboon cover and stego image



(a) Boat Image (b)Goldhill Image (c)Aircraft Image (d) Baboon Image

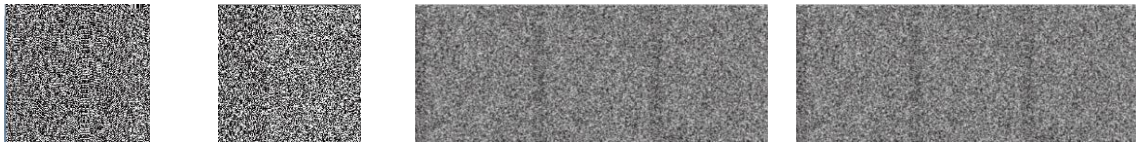
Figure 3. Histograms of Cover and Stego Images

Table 2 shows the result of security analysis for the grayscale and color images. Security analysis measures are computed between the normalized histograms of cover images and their respective stego images of Figure 1.

Table 2. Result of Security Analysis

Measure	Boat	Goldhill	Aircraft	Baboon
Jaccard Measure	0.99999	0.99993	0.99999	0.99996
Intersection Coefficient	0.99924	0.99717	0.99968	0.99975
Correlation Coefficient	0.99995	0.99979	0.99989	0.99998
Chi-Square	0.00081	0.00455	0.00163	0.00030
Bhattacharya	0.00123	0.00283	0.00129	0.00115

Figure 4 shows the LSB bit plane of the stego images. Figure 4 (a) is the LSB bit plane of stego Boat image, (b) is the LSB bit plane of Golghill image, (c) is the LSB bit plane of stego Aircraft image and (d) is the LSB bit plane of stego Baboon image.



(a) Boat Image (b)Goldhill Image (c)Aircraft Image (d) Baboon Image

Figure 4. LSB Bit Plane of Stego Images

Table 3, shows the investigation of all the grayscale levels for formulating the rules for the worst case situation.

Table 3. Investigation of Gray Levels for Worst Case Analysis

Category	**Total Levels**	**%age**	**Embedding**	
			No Change	Change
Category -1: 0-191	192	75.29	50%	± 1 50%
Category -2:192-223	32	12.55	50%	$\pm 1, \pm 2, \pm 3$ 50%
Category -3:224-239	16	6.27	50%	± 1 or ± 2 or ± 3 ± 4 or ± 5 or ± 6 or ± 7 50%
Category -4:240-255	16	6.27	50%	± 1or ± 2 or ± 3 ± 4 or ± 5 or ± 6 or ± 7 *or* ± 8 or ± 9 or ± 10 ± 11 or ± 12 or ± 13 or ± 14 or ± 15 or ± 16 50%

From Table 3, following situation are deteccted for the worst case:

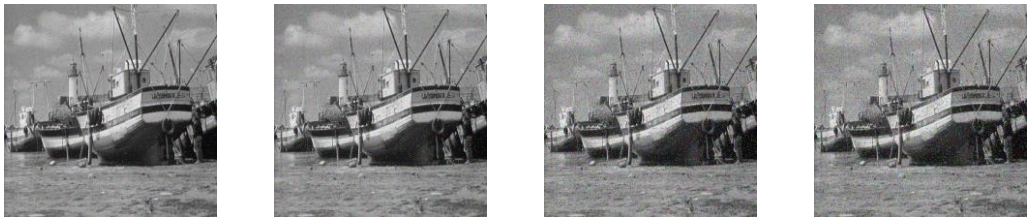
1. When an image in which secret message is going to be conceled, have more pixels of category 4.
2. For 0-191 levels, worst case is the situation when
   - Most of the pixels in image have those gray level which creates change in pixel value.
   - Substitution of bit creates always increment of 1.
   - Substitution of bit creates always decrement of 1.
3. For 192-223 levels, worst case is the situation when
   - Most of the pixels in image have those gray level which creates change in pixel value.
   - Substitution of bit creates always increment of 1 or 2.
   - Substitution of bit creates always decrement of 1 or 2.
4. For 224-239 levels, worst case is the situation when
   - Most of the pixels in image have those gray level which creates change in pixel value.
   - Substitution of bit creates always increment of 1 or 2 or 3 or 4 or 5 or 6 or 7.
   - Substitution of bit creates always decrement of 1 or 2 or 3 or 4 or 5 or 6 or 7.
   - Image have more pixels where substitution creates greater change 3, 4, 5, 6, 7
5. For 240-255 levels, worst case is the situation when
   - Most of the pixels in image have those gray level which creates change in pixel value.
   - Substitution of bit creates always increment of 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16.
   - Substitution of bit creates always decrement of 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16.
   - Image have more pixels where substitution creates greater change 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16.

Table 4 shows the estimation of most common types of noises. Level of noise at which message remain secure, can be recovered or lost are estimated.

Table 4. Estimation of Noise Level

Noise	Remain Secure	Recoverable	Lost
Gaussian	0.0000005	0.0000006-0.000001	0.000002
Salt and Pepper	0.01	0.03-0.06	0.07
Speckle	0.000001	0.000002	0.000003

Figure 5, shows the stego Boat image with salt and pepper noise having density at which secret information remain secure, recoverable and lost.



(a) Density 0.01 (b) Density 0.02 (c) Density 0.05 (d) Density 0.06

Figure 5. Stego-Boat Images with Salt and Pepper Noise

which secret information remain secure, recoverable and lost.

(a) Density 0.01 (b) Density 0.02 (c) Density 0.05 (d) Density 0.06

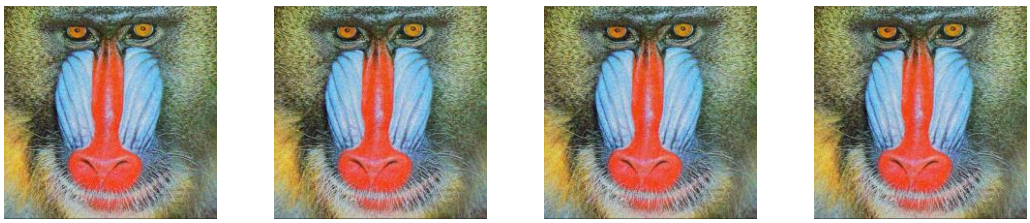
Figure 6. Stego-Aircraft Images with Salt and Pepper Noise

Figure 7 shows the stego Goldhill image with Gaussian noise having variance at which secret information remain secure, recoverable and lost.

(a) Variance 0.0000006 (b) Variance 0.0000006 (c) Variance 0.0000006 (d) Variance 0.0000006

Figure 7. Stego-Goldhill Images with Gaussian Noise

Figure 8 shows the stego Baboon image with Gaussian noise having variance at which secret information remain secure, recoverable and lost.



(a) Variance 0.0000006 (b) Variance 0.0000006 (c) Variance 0.0000006 (d) Variance 0.0000006

Figure 8. Stego-Baboon Images with Gaussian Noise

Figure 9 shows the stego Goldhill image with Speckle noise having variance at which secret information remain secure, recoverable and lost.

(a) Variance 0.000001 (b) Variance 0.000002 (c) Variance 0.000003

Figure 9. Stego-Goldhill Images with Speckle Noise

Figure 10 shows the stego Aircraft image with Speckle noise having variance at which secret information remain secure, recoverable and lost.

(a) Variance 0.0000006 (b) Variance 0.0000006 (c) Variance 0.0000006

Figure 10 Stego-Aircraft Images with Speckle Noise

5. Comparison and Discussion with Simple LSB Substitution

Substitution method directly replaces the message bit with the least significant bit of the pixel. Table 5 shows the comparison between the LSB substitution and increased capacity method.

Table 5. Comparison of LSB Substitution and Increased Capacity Method

LSB Substitution	Increased Capacity Method
Static Method	Dynamic
Fix number of bits can be hidden.	Increased capacity is achieved.
Histogram creates pair of values.	Dynamic procedure removes pair of values.
LSB bit plane shows the clear change due to replacement of bits.	LSB bit plane have some change but it is not static.
As the message bits are in LSB, so they can be collected to recover the secret message easily.	Message bits are not only in the LSB.

6. Comparison and Discussion with 2 LSB

In 2LSB substitution, two least significant bits are replaced with two message bit. In this method the capacity of hiding become twice as compare to basic LSB substitution. Table 6, shows the comparison between the LSB substitution for two bits and increased capacity method.

Table 6. Comparison of LSB Substitution and Increased Capacity Method

2 LSBs Substitution	Increased Capacity Method
Static Method	Dynamic
Fix number of bits can be hidden.	Increased capacity is achieved.

Histogram creates pair of values.	Dynamic procedure removes pair of values.
2 LSBs bit planes shows the clear change due to replacement of bits.	LSB bit plane have some change but it is not static.
Statically hides the message bits are in the two LSBs, so they can be collected to recover the secret message easily.	Message bits are not only in the LSB.
Change in image quality measure of the image is greater.	Creates least change in image quality measure of the image.

7. Comparison and Discussion with 3 LSB

In 3LSB substitution, three least significant bits are replaced with two message bit. In this method the capacity of hiding become thrice as compare to basic LSB substitution. Table 7 shows the comparison between the LSB substitution for three bits and increased capacity method.

Table 7. Comparison of three LSB substitution and Increased Capacity Method

3 LSBs Substitution	**Increased Capacity Method**
Static Method	Dynamic
Fix number of bits can be hidden.	Increased capacity is achieved.
Histogram creates pair of values.	Dynamic procedure removes pair of values.
Three LSB bit planes shows the clear change due to replacement of bits.	LSB bit plane have some change but it is not static.
Gives poor result of image quality measures.	Image quality measures are very good.
Visual appearance degraded.	Visual appearance is excellent.

8. Comparison and Discussion with 4 LSB

In 4LSB substitution, four least significant bits are replaced with four message bits. In this method the capacity of hiding become four times as compare to basic LSB substitution. Table 8, shows the comparison between the LSB substitution for four bits and increased capacity method.

Table 8. Comparison of four LSB Substitution and Increased Capacity Method

4 LSBs Substitution	**Increased Capacity Method**
Static Method	Dynamic
Fix number of bits can be hidden.	Increased capacity is achieved.
Histogram creates pair of values.	Dynamic procedure removes pair of values.
Four LSBs bit planes shows the clear change due to replacement of bits.	LSB bit plane have some change but it is not static.
Gives poorest result of image quality measures.	Image quality measures are very good.
Visual appearance degraded at great extinct.	Visual appearance is excellent.

9. Conclusions

This paper presents the detail review and analysis of "Increased Capacity of Information Hiding" method of steganography. From the experimental results and comparison it is clear that the increased capacity method will be the best selection for hiding the larger amount of data in the digital images. Direct substitution of four bits, three bits, two bits or one bit have many drawback including these substitution are static and creates repetitive structure for change that could be detected easily. In case of three and four bits, the results are very poor. While in case of increased capacity method, embedding capacity have been increased up to 4 bits in such a way the changes are not noticeable. Beside these this analysis provide the detailed review of selected method which could be a great source for understanding the plus point and negative aspects of the method and also to project new schemes in this field.

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