Internal boundary based Image Steganography

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***Abstract*— The secure transfer of confidential data in the current internet age is a major security concern which has seen the light of day after the emergence of steganography as a prominent data hiding method. Steganography is characterized by three main parameters namely imperceptibility, embedding capacity and robustness. In this technique, we propose a novel image steganography method that not only covers the secret information effectively, but it as well delivers outstanding results for the key steganographic parameters. This method implants the secret information in the 6th, 7th, and 8th least significant bits (LSBs) of the internal boundary pixels in the grayscale cover images to generate high quality stego-images.**

Keywords*— *Steganography, Data Hiding, LSB substitution, Boundary

I. Introduction

In archaic times, confidential data were transferred by hiding it backside of wax tablets, via the abdomen of rabbits, or by engraving it on the scalps of serfs and servants. With the advent of digitization, automated approaches, such as cryptography and steganography, have replaced the traditional methods and are efficiently being used for concealing the confidential data. Steganography, meaning hidden writing, is a Greek term where "steganos" means "covered" and "graphy" means "writing". Steganography is the science of concealing the data by actually concealing the transmission or the communication channel [1]. Steganography in another file hides the confidential data in a way where only the dispatcher and recipient are aware of the presence of confidential information. The data was covered in ancient times by concealing it on the back of tablets of wax, the abdomen of rabbits, or the slaves and servants' scalps. Nowadays, digital approaches are being used for concealing the information. Five parameters are there that mainly express the success to steganographic technique that are: Indistinguishability, Robustness, Payload, Precise Extraction, high PSNR (Peak Signal to Noise Ratio). The steganographic technique is implemented in the areas such as detection of digital content piracy, machine forensics, finding internet illegal activities [2]. Research paper is designed is as follows: Segment II gives the literature survey. Segment III is about literature review. Segment IV is about results and discussions for this paper.

II. Survey of Literature

A. Least Significant Bit (LSB) Technique

Several studies have been reported in literature regarding data hiding in images however majority of the literature focuses on Least Significant Bit (LSB) manipulation. It is important to mention that LSB steganography is a technique of implanting the data (secret information) in the least significant bit of any medium (video, text, image, or audio).

In [3], authors proposed a new technique that improves on the 1 byte least significance technique. The idea is to implant 1 byte of secret message in the 4 bytes on cover medium instead of 8 bytes. In [4], authors proposed a novel method that implants the secret information by using the 7th bit of a selected pixel of an image as an indicator as well as the 7th bit of the succeeding value of the designated picture element. In [5], authors researched two new steganographic methods for spatial domain. Initial approach conceals one bit of secret information per picture element whereas the next approach conceal two bits of secret information per picture element. In [6], researchers presented a steganographic system for RGB images. The key objective of this research is to increase the embedding capacity and provide good imperceptibility using magic LSB substitution and Hash Message Authentication Code (HMAC). In LSB technique [7], the secret information and the cover image are changed into binaries and after that secret information is implanted in the LSBs of the cover image, this embedding procedure does not end until every LSB of cover image is utilized or all the secret information bits aren't implanted in the cover image. In this method [8], an improvement to the classic LSB technique is proposed in which some extra bits are embedded to make the stego-image's histogram look like that of original image. This approach prevents the histogram attack in the embedding procedure of LSB. According to [9], the proposed steganographic methodology is composed of two methods. Using an algorithm called S-DES and a hidden key, the image is secured in the first approach by transforming the image into an encrypted message and then covering up this encrypted message into separate pictures, while the second approach safeguards the image using the S-DES technique and a secret key. The method discussed in [10], is an integration of two dissimilar methods namely MP (Matrix Pattern) and LSB (Least Significant Bit) method, in which the secret information is concealed in the matrix blocks. Research at [11] gives a survey on different steganography approaches for images in spatial and transform fields and the survey of steganalysis approaches that are for finding the secret information inside the image. [12], [13] provide a survey for the LSB embedding techniques.

B. Most Significant Bit (MSB) Technique

MSB technique as the name implies uses the most significant bits (higher order bits) for hiding messages in the cover images.

In [14], study proposes an upgraded algorithm which uses the pixel value predictor approach to mask the hidden message in the cover image's most important bits (MSBs).

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Here the Green Channel acts as a pixel value symbol to mask the hidden message in the RGB cover picture of the 5th and 6th bits of the Blue Channel or Red Channel. If the green channel has even numbers of 1, the blue channel is used for the implantation process otherwise the red channel is used for the embedding process. According to the research in [15], 5th bit of the cover image is for hiding the secret message by using a method known as bit differencing on 5th and 6th bits. If the result that is obtained after differencing of 5th and 6th is not same as the secret message bit, then the bit of the cover image is altered. In numerous circumstances, computer criminals are aware of LSBs and use it for the extraction of the secret information so the use of MSB in this method becomes much more reliable. Another MSB technique in [16] conceals the secret message by means of 1-bit MSB in chaotic manner with the secret image key. 8x8 size matrix blocks are taken from the cover image with the secret key in first block to decide later upcoming position in the image. Research in [17] presents a technique where the secret message is embedded in the MSB of cover image by using LSB of the cover image as an indicator. In [18], the embedding of secret message takes place in bits such as 4th or 5th bit of pixel. This method forms three-pixel groups based on the pixel values which are used for choosing pixels for 4th or 5th bit for embedding purpose. OPAP (Optimal Pixel Adjustment Process) is also used to lessen distortions that are caused due to the embedding procedure. In [19], An approach is suggested that by preprocessing the file, one bit per pixel is hidden in encoded images to prevent errors that upgrade the accuracy of revamped images. In [20], an effective and vibrant implanting algorithm is proposed that not only conceals the secret information but also styles secret text breaking a good annoyance for the hacker and gives an extraction method that efficiently separates the complete secret information exclusive of any loss of a single information. Research techniques in [21], categorize different image steganography methods in addition to giving synopsis, importance, and trials of steganography procedures. [22] uses two approaches namely Pixel Value Indicator and MSB implanting for separating the color image in Red, Green and Blue frequencies. Pixels of Red channel are used as pixel indicator and the embedding takes place in the 5th and 6th bit of either Blue or Green channel depending upon the situation that whether the number of ones in Red channel is even or odd respectively. [23] in this study a revocable information concealing method that is based on Neighbor Mean Interpolation (NMI) using the R-weighted coding method is proposed. [24], in this approach a method is proposed that utilizes the pixel value indicator approach to conceal the secret information in the MSBs of the covering file. [25], In this technique a technique is put forwarded that encodes the secret message bits before implanting it in the LSBs of the cover file. The implanting and the encoding process is done on the basis of MSB values of the RGB and on the concept of odd and even parities for that pixels. [26], In this paper, pixel value differencing has been used for implanting the data in the RGB image. Moreover, for providing more security, different number of bits are used for different pixels. [27], in the approach, an improved method for LSB substitution has been proposed. [28], in this paper a closed loop computing framework is proposed. [29], in this paper a novel method has been introduced that conceals the data within the transform domain of the RGB images.

The point that LSB substitution is better compared to MSB substitution lies in the fact that each bit-plane descending from **MSB** to **LSB** makes a decaying, marginal contribution to the overall information contained in the image. As shown in Fig.1.

Fig.1 Bit Plane Slicing

Therefore, if LSBs are altered that will not make any significant change where as MSB will surely create one.

III. METHODOLOGY

In this research study, we propose a novel steganography technique for embedding the secret message in the LSBs of the internal boundary pixels of the cover image. LSB technique is chosen because it guarantees high imperceptibility as compared to the MSB technique while the internal boundary pixels help in increasing the payload capacity and the robustness of the proposed technique guaranteeing an optimal trade-off between the key parameters.

Proposed technique is essentially a two-step process comprising of image segmentation and LSB substitution. Firstly, region based image segmentation is used to separate the background region of the cover image from its foreground region for the purpose of boundary calculation. The boundary region is computed via edge detection. After performing erosion internal boundaries can be computed. After that internal boundary is computer. LSB substitution is then used for hiding the secret message in the 6th, 7th and 8th least significant bits in the internal boundary pixels of the cover image. It should be noted that the proposed technique is applicable for grayscale images only. The embedding and extraction algorithms to embed and extract the secret message to/from the cover image are discussed in sub-sections 3.1 and 3.2 respectively.

A. Embedding Algorithm

Input: Grayscale cover image, secret message
Output: Stego-image

1.1 Select the secret message and the cover image.
2.1 Convert the cover image into binary.
3.1 Separate the foreground region from the background with region-based segmentation in the cover image.
4.1 Compute the boundary region in the cover image by edge detection. Compute internal boundary.
5.1 Embed the secret message in the internal boundary pixels (indicated by a high gradient value between the foreground and the background) using three LSBs (6th, 7th

and 8th bit) until the end of secret message is read to generate the final stego-image.

B. Extraction Algorithm

Input: Stego-image
Output: Secret Message

1.1 Read the stego-image and convert it into binary.
2.1 Separate foreground region from the background with the help of region-based segmentation.
3.1 Compute the boundary region in the stego-image by edge detection.
4.1 Extract the secret message by reading the 6th, 7th, and 8th bits of the stego-image from internal boundary pixels (i.e. places where high gradients are observed).

The workflow of the embedding and extraction algorithm is presented in Fig. 2 and 3 respectively.

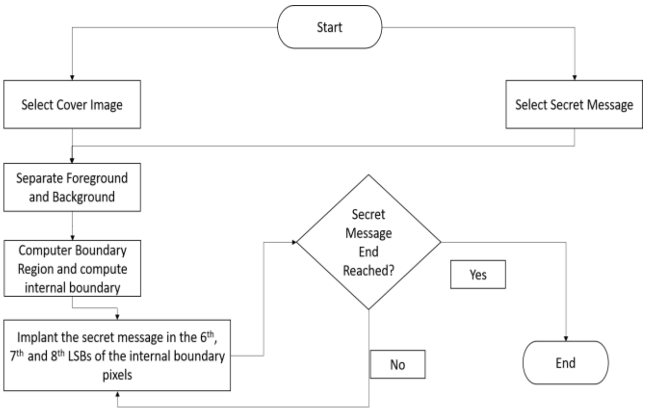

Fig.2 Workflow of Embedding algorithm

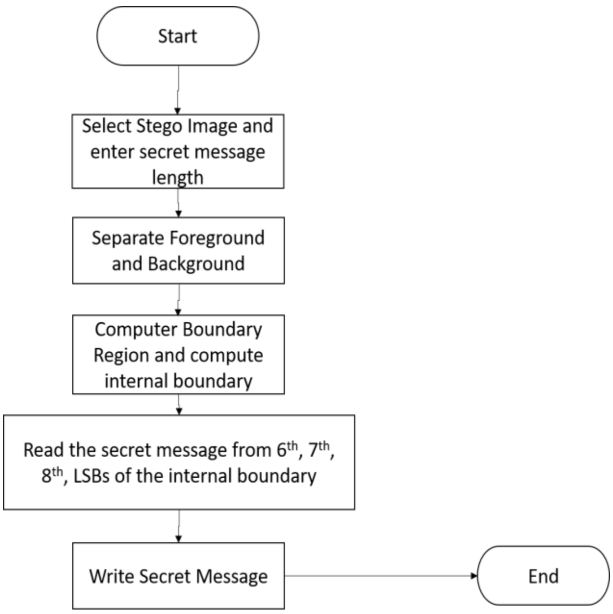

Fig.3 Workflow of Extracting algorithm

IV. Results and Discussion

The proposed method is implemented using MATLAB 2017a. Cover images that are used to evaluate the performance of the proposed method are Lena.png, Bluehills.png, Mandrill.png, Boat.png and House.png as shown in Fig IV.1. The cover images are grayscale png images of size 512x512, 128x256, 512x512, 512x512 and 256x256, respectively.

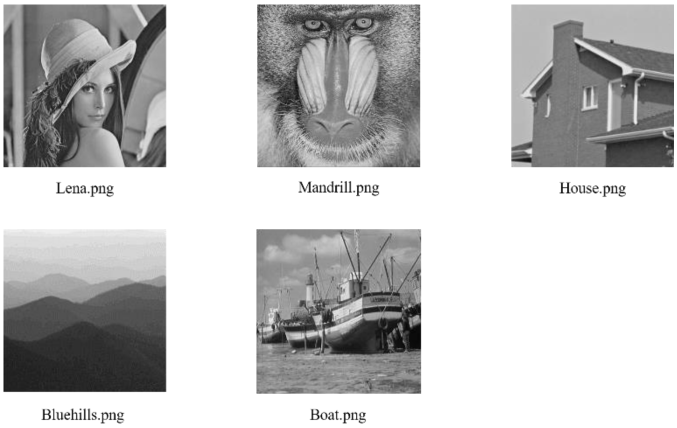

Fig.4 Cover images

The stego-images (corresponding to the cover images) generated via the proposed method are depicted in Fig IV.2.

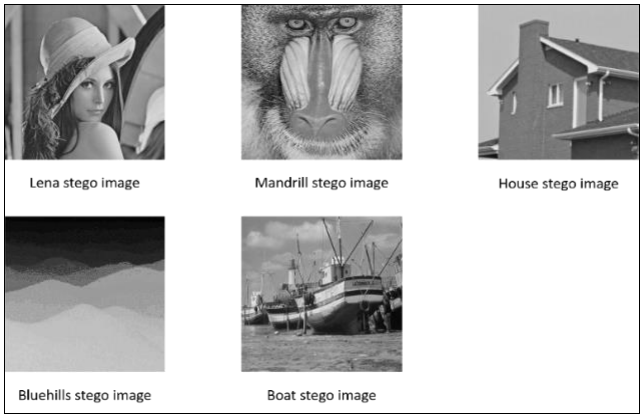

Fig.5 Generated Stego Images

Fig IV.2 clearly reveals that the generated stego-images are completely identical to the cover images (depicted in Fig. 4) and are indistinguishable by the human eye. This implies that the quality of the images is not altered by implanting the secret message. Moreover, the use of 3 LSBs i.e. 6th, 7th and 8th bit for hiding the secret message delivers high payload capacity to this technique and the use of boundary pixels guarantee better security. The validation results of the proposed technique in terms of imperceptibility, robustness and payload capacity are presented and discussed ahead.

A. PSNR and MSE

Imperceptibility of the generated stego-images is evaluated in terms of PSNR values where a higher PSNR signifies a superior quality stego-image. The PSNR is in turn calculated on the basis of MSE (Mean-squared error) values. The MSE and PSNR values for the stego-images can be mathematically calculated using eq (1) and eq (2) respectively.

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \qquad (1)$$

where mxn denotes the noise-free grayscale stego-image I and K denotes its noisy approximation. With MSE being calculated, PSNR (in db) is calculated as:

$$PSNR = 20.\log_{10}(MAX_I) - 10.\log_{10}(MSE) \qquad (2)$$

B. *Payload Capacity*

The payload or the embedding capacity of this steganography method can be determined mathematically using eq (3).

Payload Capacity = Number of internal boundary pixels x 3 (3)

The PSNR, MSE and Capacity values obtained for the stego-images generated via proposed technique (depicted in Fig. 5) are summarized in Table 1.

Table 1. PSNR, MSE and Capacity values for Stego-images

S.#	Stego Image	PSNR	MSE	Capacity
1	Lena	64.154	0.0125	4755
2	Mandrill	72.439	0.0037	7668
3	House	72.552	0.0036	2856
4	Bluehills	68.047	0.010	2178
5	Boat	64.6688	0.0221	6522

Table 1 shows that the PSNR and MSE values are very good as the PSNR is above 45 decibels (db) and the MSE values are nearly zero. Moreover, the payload capacity of is also sufficiently good due to the use of 3 LSBs. The superiority of the proposed technique against other state-of-the-art techniques can be further established via a comparative analysis of the PSNR results obtained via proposed technique (Table 1) with the PSNR values of other steganography techniques (discussed in section 2). The comparative analysis is presented in Table 2.

Table 2. Comparative Analysis of with State-of-the-Art Techniques in terms of PSNR

S.#	Technique	Category	Image	Type	PSNR
1	[15]	LSB	**Lena**	Grayscale	49.37
2	[16] 1 bit scheme			Color	51.63
3	[16] 2 bit scheme			Color	49.90
4	[19]			Color	50.93
5	[21]			Color	46.64
6	[22]			Color	43.63
7	[23]			Color	47.51
8	[28]			Color	47.5897
9	[29]			Grayscale	40.81
10	[34]	MSB		Color	39.566
11	[35]			Grayscale	42.26
12	[36]			Color	42.447
13	[37]			Grayscale	51.17977
14	[38]			Grayscale	57.58
15	[39]			Color	53.7317
16	[40]			Color	48.0002
17	[42]	Hybrid		Color	54.27
18	[43]			Color	62.73
19	**Proposed**	LSB		Grayscale	**53.01**
20	[15]	LSB	**Mandrill**	Grayscale	49.38
21	[16] 1 bit scheme			Color	51.64
22	[16] 2 bit scheme			Color	49.88
23	[21]			Color	40.26
24	[22]			Color	38.33
25	[23]			Color	45.13
26	[26]			Gray	32.6719
27	[28]			Color	36.3637
28	[29]			Grayscale	41.74
29	[34]	MSB		Color	39.573
30	[36]			Color	42.451
31	[37]			Grayscale	51.1803
32	[39]			Color	53.7882
33	[40]			Color	61.7972
34	**Proposed**	LSB		Grayscale	**54.1279**
35	[22]	LSB	**House**	Color	41.22
36	[23]			Color	46.77
37	**Proposed**	LSB		Grayscale	**50.18**
38	[22]	LSB	**Boat**	Color	41.30
39	[23]			Color	46.42
40	**Proposed**	LSB		Grayscale	**53.197**
41	[33]	MSB	**Bluehills**	Grayscale	41.367
42	**Proposed**	LSB		Grayscale	**51.675**

Table 2 clearly reveals that our proposed technique achieves nice PSNR values for the genreated stego-images as compared to all the techniques.

The results given in Table 2 for different approaches are cited from the previous research articles of authors.

C. Robustness

This technique is also strong against statistical strikes and offers better security against steganalysis attacks. The security of proposed research can be validated by comparing the means values of the original cover images and the generated stego-images and via histogram analysis. Minimum difference in the mean values of the two images guarantees better security. The mean values of the original cover images and the stego-images generated are depicted in Table 3.

Table 3. The Mean Values of Stego-images and Original Cover Images

S.#	Image	Original Image	Stego Image
1	Lena image	124.0504	124.0502
2	Mandrill image	138.7426	138.7425
3	House image	137.9846	137.9855
4	Bluehills image	124.1266	124.1108
5	Boat image	129.7079	129.7077

It can be seen from the results in Table 3 that the mean values of the stego-images and original images are almost identical and do not differ significantly which implies that it offers better security. It is also robust against histogram steganalysis as the histograms of the cover image Lena and the generated stego-image are nearly identical and do not depict any detectable fluctuations as depicted in Fig.6 and Fig. 7.

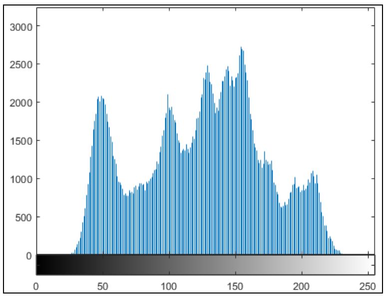

Fig.6 Histogram of cover image lena

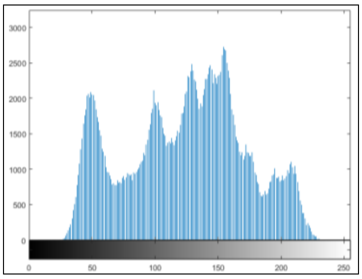

Fig.7 Histogram of stego Image lena

V. CONCLUSION AND FUTURE WORK

In this research work, we presented a novel steganographic technique proposed to embed the secret message in the cover image using boundary based LSB substitution with 3 LSBs. Our proposed technique achieves an optimal trade-off for the key steganographic parameters and delivers state-of-the-art results with high imperceptibility, payload capacity and robustness as compared to other existing methods.

In future, we intend to extend this technique for RGB images and explore MSB and hybrid substitution techniques for embedding the secret messages.

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