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A Differential Calculus Based Image Steganography with Crossover

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***Abstract*—**Information security plays a major role in uplifting the standard of secured communications via global media. In this paper, we have suggested a technique of encryption followed by insertion before transmission. Here, we have implemented two different concepts to carry out the above-specified tasks. We have used a two-point crossover technique of the genetic algorithm to facilitate the encryption process. For each of the uniquely identified rows of pixels, different mathematical methodologies are applied for several conditions checking, in order to figure out all the parent pixels on which we perform the crossover operation. This is done by selecting two crossover points within the pixels thereby producing the newly encrypted child pixels, and hence the encrypted cover image. In the next lap, the first and second order derivative operators are evaluated to increase the security and robustness. The last lap further ensures reapplication of the crossover procedure to form the final stego-image. The complexity of this system as a whole is huge, thereby dissuading the third party interferences. Also, the embedding capacity is very high. Therefore, a larger amount of secret image information can be hidden. The imperceptible vision of the obtained stego-image clearly proves the proficiency of this approach.

***Keywords*—**Steganography, Crossover, Differential Calculus, Peak Signal to Noise Ratio, Cross-correlation Coefficient.

I. Introduction

STEGANOGRAPHY [1] primarily, points to the technology of invisible communication. This mainly overcomes the drawback of the trend of just encrypted communication, i.e. cryptography [2]. Unlike cryptography, steganography brings forth various techniques which strive to hide the existence of any hidden information along with keeping it encrypted. Image steganography is a vital wing of this horizon that exploits the perceptibility of human visual system, in order to facilitate secured transmissions. The cover image is the seemingly unimportant image, within which the actual confidential image is to be embedded. On the other side, the stego-image [3] serves to be a carrier for communicating the private image across. Its identicalness with the cover image makes it seemingly unimportant for any outsider to get attracted.

In this paper, we have at first implemented the concept of crossover [4] in order to encrypt the main cover image. The term "Crossover" plays a very significant role in the field of the genetic algorithm. Basically, it appears to be a genetic operator that combines two chromosomes to produce a new chromosome. The main idea behind this is that the newly formed child chromosome may be far better than both the parent chromosomes such that it takes all the best traits from each of its parents. We have applied this technique to the original pixel values of the chosen cover image so as to encrypt itself. Several types of crossover techniques exist in reality amongst which we have implemented the two-point crossover technique (pictorially represented in Fig. 1). Next comes the phase of insertion of the secret image bits into that of the encrypted cover image. In this context, we have put into effect the concepts of differential calculus [5]. The fundamental objective of differential calculus may be pointed out to be the derivatives of a function. Here, both the first and second order derivatives are evaluated, and these values contribute their significant amount of share in figuring out the fashion of insertion. Reapplication of the crossover technique results in the formation of the stego-image.

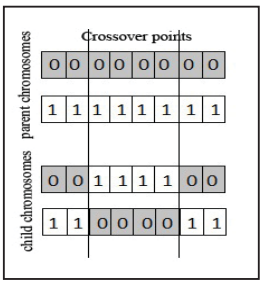

Fig. 1 Two Point Crossover Technique

This paper is catalogued into different sections. Section II highlights some of the previous works done in the field of image steganography. Section III encloses our proposed approach. Section IV discusses the different algorithms that have been used for encrypting and embedding. Section V constitutes the experimental results of the proposed approach. Section VI draws the conclusion.

II. Previous Works on Image Steganography

A. Data Hiding by LSB

One of the most common steganographic methods is data hiding by LSB [6]. Here, the least significant bit, i.e. the LSB's of the pixel values residing in the cover image is directly replaced with that of the bit values of the secret message. Although this method is advantageous, it is still vulnerable to minute changes like cropping and compression of several images.

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B. Data Hiding by PVD

This method is referenced as data hiding by Pixel Value Differencing (PVD) [7] as proposed by [8]. During the embedding phase, the cover image in this case is divided into many non-overlapping blocks involving two connecting pixels. The pixel difference for each pair of block is thereafter modified so as to embed data within. Higher the difference between the accurate pixel values, greater is the modification. Same way of partitioning is carried out on the stego-image in the extraction phase with the aid of the original range table. Based on this approach, [9] has proposed a new way of tri-pixel value differencing method. This new approach seems to be better than the original one in terms of its embedding capacity and PSNR.

C. Data Hiding by GLM

The gray level modification technique, as proposed by [10] generally implies a mapping technique that involves modifying the gray level pixel values. For mapping secret information within an image, it takes into account the concept of odd and even numbers. Depending upon a classic mathematical function, various pixel values are selected, and their respective gray level values are matched up against the bit stream that is to be embedded.

D. Data Hiding by [11]

In this method [11], the host image is broken up into several blocks of similar sizes. In the next stage, embedding of a private image is done at the edges of the obtained blocks by considering the total number of ones seeming to occur in the four leftmost bits of the pixels. Therefore, this approach facilitates data hiding in the spatial domain.

E. Data Hiding by PMM

Pixel mapping method (PMM) [12] is a beneficial method, where a typical mathematical function dependent on the intensity values of the seed pixel comes into play. Based on this, several embedding pixels along with their surrounding eight neighbours are selected. It is checked whether any of the pixel values or their respectively obtained neighbours lies along the boundary region or not. Hiding of data within an image is done by mapping two bit of hidden data into that of the corresponding neighbour pixels.

III. Proposed Approach

Here, we discuss the concepts, encircling our newly proposed novel approach. Here, we have formulated our techniques based on two different concepts. In the very beginning, we have the process of encryption that is solely based on the technique of two-point crossover of the genetic algorithm. Two points (i.e. crossover points) are to be selected from the parent, and all the information bits are swapped between the two parent pixels to generate two completely new child pixels. Several mathematical tactics are used which imply several conditions so as to select all the respective parent pixels. On implementing the said technique, we obtain the encrypted form of our chosen cover image. Next we embed the secret image bits into the previously obtained encrypted image. All unique polynomial functions based on the four MSB's of each of the pixel values are formulated at first. Several operations are next carried out on them. This phase of our proposed approach primarily focuses on an insertion technique that is based on the differential logic of calculus. The first order and second order derivatives of the previously obtained polynomial functions for each case are evaluated eventually. These contribute a significant amount of share in deciding the way of embedding the secret image within a particular cover image. Therefore, a unique fashion of pixel insertion at respective positions is constructed. Since for each of the cases, the polynomials formulated are distinctive, it remains untraceable for all kind of unwanted sources. On reapplying the two-point crossover technique, the final stego-image is obtained. During the retrieval phase, the reverse insertion algorithm is applied on the stego-image. The visual imperceptibility of the obtained stego-image clearly proves the novelty of our proposed approach in the field of steganography. This approach promotes a secured communication in this technologically facilitated world.

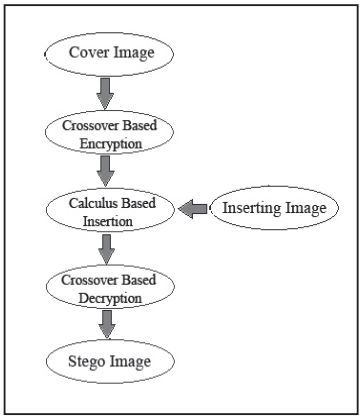

Fig. 2 Embedding Process

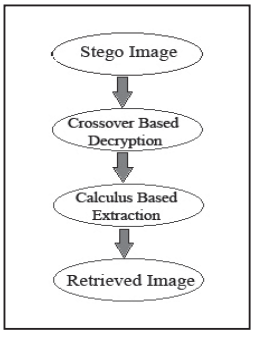

Fig. 3 Extraction Process

IV. Algorithm

A. Embedding Process

This part describes the whole process that takes place in the sender's side (shown in Fig. 2). It includes the encryption as

well as the insertion process. Two different logics have been used to develop the various implementation techniques involved here in this section.

i. Apply the encryption algorithm to the chosen host or cover image.
ii. Implement the insertion algorithm so as to hide the secret image bits within the encrypted cover image.
iii. Reapply the encryption algorithm to obtain the stego-image.

1) Encryption Algorithm

The cover image is converted into an encrypted form with the application of a two-point crossover technique of the genetic algorithm. New child pixels are generated in this step, which in process replaces the original parent pixels in the originally selected cover or host image. The output image generated in this step is the intermediate output of the newly specified procedure of ours.

i. Take the host or cover image as input.
ii. Consider the total number of rows (say m) and the total number of columns (say n) of the input image.
iii. Perform a crossover operation between two selected pixels obtained from different methodologies applied to different rows of pixels.
iv. Let i& j be the row and column number of a pixel.
v. Perform a modulo operation considering all the row numbers to figure out the keys responsible for selecting unique pixels for crossover operation.
vi. Check the following conditions (represented in Table I) to find out the pixels for crossover:
vii. Thus, the cover image is encrypted.

TABLE I
SELECTION OF CROSSOVER PIXELS

Condition	Selected Pixels for Crossover
(i%4)==1	Pix(i,j) & Pix(i,j+1)
(i%4)==2	Pix(i,j) & Pix(i,j+2) , Pix(i,j+1) & Pix(i,j+3)
(i%4)==3	Pix(i,j) & Pix(i,j+(n/2))
(i%4)==0	Pix(i,j) & Pix(i,n-j+1)

2) Inserting Algorithm

The logic of differential calculus forms the base of this phase. It helps in inserting the respective bits of the selected secret image into that of the encrypted cover image, thereby completing the embedding process.

i. Take the encrypted image as the input image.
ii. A polynomial function of x (say f(x)) is constructed by considering the four MSB's of the pixel value.
iii. Perform the first order derivative of f(x) (i.e. f'(x)) with respect to x.

$$f'(x) = d/dx\,(f(x)) \tag{1}$$

Putting the value of x=1 in (1), we obtain a unique value for f'(x).

iv. Calculate the sum of digits (say sum) of the position value (say p) of the considered pixel.
v. A polynomial function of y (say f(y)) is generated from the binary represented value of calculated 'sum'.
vi. Evaluate the second order derivative of f(y) (i.e. f''(y)) with respect to y.

$$f''(y) = d^2/dy^2\, f(y) \tag{2}$$

Putting the value of y=1 in (2), we obtain a unique value for f''(y).

vii. Perform bitwise XOR operation between the values obtained from (1) and (2).
viii. Compute the sum of digits of the value obtained from previous XOR operation.
ix. Figure out the value (say 'val') by performing a modulo operation between the values obtained from steps vii and viii.
x. If 'val' comes out to be even, then insert two bits from the confidential image pixel directly into the two LSB's of the cover image pixel. Else, reverse insertion is carried out.
xi. Repeat steps ii to x for every pixel values of the cover image.

B. Extraction Process

This part describes the whole process that takes place in the receiver's side (shown in Fig. 3). It includes the whole procedure of extracting the confidential image from the stego-image.

i. Apply the encryption algorithm on the stego-image.
ii. Implement the extraction algorithm on the image obtained after step i, so as to extract the secret image bits from it.

1) Extraction Algorithm

Reverse procedure is followed at this stage of our approach. The pixels that were operated on during the embedding phase are very delicately treated. The secret bits are very effectively extracted from that of the formed stego-image.

i. Take the stego- image as the input image.
ii. A polynomial function of x (say g(x)) is constructed by considering the four MSB's of the pixel value.
iii. Perform the first order derivative of g(x) (i.e. g'(x)) with respect to x.

$$g'(x) = d/dx\,(g(x)) \tag{3}$$

Putting the value of x=1 in (3), we obtain a unique value for g'(x).

iv. Calculate the sum of digits (say sum) of the position value (say p) of the considered pixel.
v. A polynomial function of y (say g(y)) is generated from the binary represented value of calculated 'sum'.
vi. Evaluate the second order derivative of g(y) (i.e. g''(y)) with respect to y.

$$g''(y) = d^2/dy^2\, g(y) \tag{4}$$

Putting the value of y=1 in (4), we obtain a unique value for g''(y).

vii. Perform bitwise XOR operation between the values obtained from (3) and (4).
viii. Compute the sum of digits of the value obtained from previous XOR operation.
ix. Figure out the value (say 'val') by performing modulo operation between the values obtained from steps vii and viii.
x. If 'val' comes out to be even, then retrieve two bits of the pixel from the stego-image directly and store it in an 8-bit pixel array. Else, reverse retrieval operation is carried out.
xi. Repeat steps ii to x for every pixel values of the stego-image in order to retrieve the secret image.

V. Experimental Results

This section engulfs the experimental results relating to our proposed approach. The novelty of this approach is laid on several benchmark techniques. First of all is the embedding capacity, i.e. the capacity of embedding or hiding data. Secondly comes the quality of stego-image or rather the imperceptibility of the stego-image. Peak Signal to Noise Ratio (PSNR), Cross correlation coefficient, Mean, Standard Deviation, Entropy are some of the evaluated benchmarks.

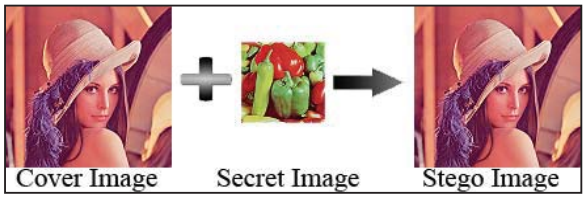

Fig. 4 Embedding of Secret Image

TABLE II
Comparison of Embedding Capacity

IMAGE	IMAGE SIZE	PVD	GLM	PMM	New Method
LENA	128x128	**	2048	2393	4096
	256x256	**	8192	10012	16384
	512x512	50960	32768	45340	65536
PEPPER	128x128	**	2048	2860	4096
	256x256	**	8192	11694	16384
	512x512	50685	32768	46592	65536

(**All the images that were used in case of PVD approach, are of size 512x512).

Below we present a few comparative studies of our specified approach with that of various other existing approaches such as data hiding by LSB, PVD, GLM, PMM. We have figured out the values of embedding capacity [13], Mean Squared Error, Peak Signal to Noise Ratio [14], Similarity Measure [15] in reference to all of the methods. Also, several image parameters, namely mean [16], standard deviation [17] and entropy [18] have been computed for each of the individual components of the cover and stego-images. (For computing all these values, we have applied all the above-specified methods on some of the standard images, namely, Lena, Pepper, Baboon, Airplane).

A. Embedding Capacity

The embedding capacity of the chosen host or cover image can be defined as the maximum amount of secret information that can be embedded within it, in order to convert itself into an imperceptible stego-image.

A comparative study based on the embedding capacity of the different applied methods is displayed in Table II.

B. Peak Signal to Noise Ratio (PSNR)

PSNR actually measures the quality of the image. It compares the original cover image with that of the stego-image, i.e. it computes the percentage of the stego-image to that of the cover image. Consider an original cover image C(i,j), that contains M by N (where M==N) pixels and a stego-image S(i,j), where S is generated after embedding the secret image. Therefore, Mean squared error (MSE) of the stego-image can be evaluated as (5):

$$MSE = \frac{1}{(M * N)} \sum_{i=1}^{M} \sum_{j=1}^{N} [C(ij) - S(ij)]^2 \quad (5)$$

Now, the PSNR can be computed from the above-obtained values of MSE using (6):

$$PSNR = \frac{10 \log_2 \left(255^2\right)}{MSE} db \quad (6)$$

Based on the PNSR values, we next present a comparative study (enclosed in Table III) of our proposed approach with some of the other existing approaches:

TABLE III
Comparison of PSNR Values

IMAGE	IMAGE SIZE	PVD	GLM	PMM	New Method
LENA	128x128	36.20	30.50	49.03	45.06
	256x256	35.00	33.20	50.35	45.17
	512x512	41.79	35.50	54.15	44.83
PEPPER	128x128	38.70	38.00	47.94	44.81
	256x256	35.00	37.20	48.37	44.65
	512x512	40.97	34.00	54.15	44.52

The encryption method or rather the implemented crossover technique used on the uniquely chosen pixels adds a layer of secrecy to the whole procedure.

Next, we have displayed a special exclusive comparison of the PSNR values obtained, by the invocation of the proposed procedure, with and without the omission of the added security layer, i.e. the encryption technique. Table IV reveals the same.

The above obtained values of PSNR, clearly shows that there is almost negligible or rather no significant changes in the values attained for each of the unique cases of the images. Thenceforth, this new proposed method, without distorting the imperceptibility of the image, elevates the security level to a greater extent, thereby preserving its novelty.

TABLE IV
COMPARISON OF PSNR VALUES FOR TWO SPECIAL CASES

IMAGE	IMAGE SIZE	New Method without Cross Over	New Method with Cross Over
LENA	128x128	45.10	45.06
	256x256	45.25	45.17
	512x512	44.89	44.83
PEPPER	128x128	44.51	44.81
	256x256	44.39	44.65
	512x512	44.27	44.52
BABOON	128x128	43.75	43.69
	256x256	43.99	43.96
	512x512	44.50	44.49
AIRPLANE	128x128	44.90	44.91
	256x256	44.43	44.44
	512x512	44.41	44.42

C. Mean and Standard Deviation

For a set of pixel values, the term arithmetic mean is used to specify the central value of all the discrete set of pixels.

TABLE V
IMAGE PARAMETERS FOR ORIGINAL AND STEGO-IMAGE

IMAGE	SIZE	COMPONENT	COVER IMAGE			STEGO-IMAGE		
			MEAN	ST. DEVIATION	ENTROPY	MEAN	ST. DEVIATION	ENTROPY
LENA	512X512	R	180.22	13.34	7.25	180.29	13.30	7.25
		G	99.05	14.18	7.59	98.95	14.17	7.58
		B	105.41	8.40	6.97	105.11	8.40	6.91
	256X256	R	180.00	13.48	7.28	180.06	13.44	7.28
		G	98.84	14.16	7.63	98.73	14.15	7.61
		B	105.19	8.55	6.99	104.90	8.54	6.93
	128X128	R	179.75	13.78	7.32	179.81	13.75	7.32
		G	98.70	14.55	7.65	98.59	14.55	7.65
		B	104.97	8.86	7.03	104.68	8.85	6.98
PEPPER	512X512	R	149.80	8.44	7.35	149.99	8.45	7.33
		G	115.69	10.58	7.59	115.61	10.55	7.60
		B	66.78	9.55	7.13	66.78	9.54	7.13
	256X256	R	149.58	8.55	7.37	149.78	8.55	7.38
		G	115.54	10.52	7.59	115.46	10.47	7.60
		B	66.67	9.54	7.14	66.67	9.54	7.14
	128X128	R	149.36	8.74	7.38	149.58	8.75	7.36
		G	115.61	10.42	7.58	115.53	10.38	7.61
		B	66.61	9.78	7.14	66.62	9.78	7.15
BABOON	512X512	R	137.38	10.06	7.75	137.44	10.05	7.75
		G	128.85	7.63	7.47	128.75	7.63	7.45
		B	113.18	15.26	7.78	112.89	15.26	7.73
	256X256	R	137.41	11.68	7.66	137.47	11.67	7.65
		G	128.89	8.50	7.37	128.78	8.52	7.35
		B	113.21	17.05	7.70	112.91	17.05	7.64
	128X128	R	137.45	12.91	7.56	137.51	12.91	7.55
		G	128.94	9.09	7.29	128.83	9.09	7.28
		B	113.24	18.23	7.62	112.94	18.24	7.57

The mean (μ) of a digitized image '$a\,[m,n]$' having 'Λ' pixels is denoted by (7):

$$\mu = \frac{1}{\Lambda}\sum_{m,n=1}^{\Lambda} a\,[m,n] \tag{7}$$

The standard deviation (σ) is a measure, used to quantify the amount of dispersion or variation for a set of the pixel values (8):

$$\sigma = \sqrt{\frac{\sum_{m,n=1}^{\Lambda} a^2[m,n] - \Lambda\mu^2}{\Lambda - 1}} \tag{8}$$

D. Entropy

In information theory, the term 'entropy' is defined as the average amount of information enclosed in each of the messages received. Here, the messages are characters drawn from a distribution or data stream. Hence, entropy characterizes the uncertainty about our source of information.

$$\text{Entropy} = -\sum_i P_i \log_2 P_i \tag{9}$$

where, 'P_i 'is the probability that the discrepancy between the two adjacent pixels is equivalent to 'i' (9).

We, next present a distinctive comparative study (shown in Table V) between the original cover image and its respective stego-image against several image parameters such as mean, standard deviation and entropy. Here, RGB represents the red green and blue components for each of the respective images.

E. Similarity Measure

The similarity between a chosen cover image and its respective stego-image can be accounted for, by computing its corresponding normalized cross-correlation coefficient. The normalized cross-correlation coefficient can be calculated by using (10):

$$r = \frac{\sum (C(i,j) - m_1)(S(i,j) - m_2)}{\sqrt{\sum (C(i,j) - m_1)^2}\sqrt{\sum (S(i,j) - m_2)^2}} \tag{10}$$

Here, 'C' is the Cover image, 'S' is its corresponding Stego-image, 'm1' is the mean pixel value of the cover image, 'm2' is the mean pixel value of the stego-image.

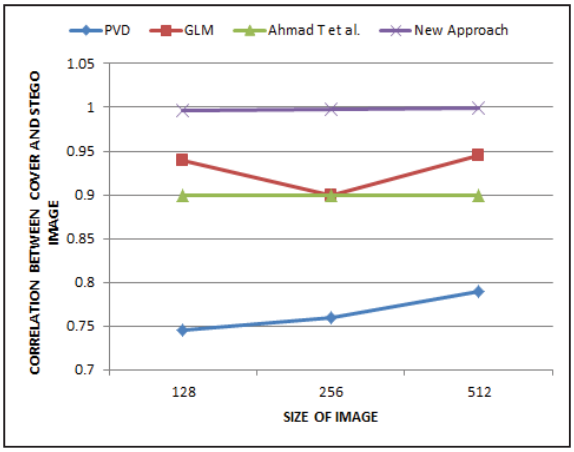

Fig. 5 Comparison of Similarity Measure

From the obtained results, we clearly notice that our proposed approach is certainly adept in its domain. The embedding capacity is huge in comparison to the other approaches, and is therefore very much significant in the field of steganography.

From Fig. 5, it can be concluded that the obtained stego-image highly resembles the cover image. The calculated PSNR value doubtlessly signifies that the quality of the image is well maintained. The imperceptibility of the secret image within the cover image is thus well defined and maintained.

The changes in all the estimated values of the image parameters before and after embedding, appears to be insignificant, thereby maintaining the consistency in the imperceptibility phenomenon.

VI. Conclusion

In this paper, we have proposed a steganographic approach that highly ensures security in transmission. The concept of encrypting the cover image before embedding secret data into it, adds a level of secrecy [19] to it. The implementation of the two-point crossover [20] technique is distinctly advantageous since this generates all unique child pixels. Also, the way of selection of the parent pixels vary according to the several implemented mathematical conditions, thereby ensuring the formation of a secured encrypted cover image [21]. In the next lap, i.e. during the embedding process, all uniquely formed polynomial functions are generated, and the differential calculus [22] operations are implemented. This adds another layer of secrecy to it, since there is almost no chance for any hacker to break through it. The huge embedding capacity of this approach is its prime advantage. Also, the imperceptibility of the stego-image is well maintained, hence not alluring any third party interest. Insignificant changes in the PSNR values before and after imbibing the encrypting algorithm, undoubtedly proves that the layer of secrecy is well incorporated without any distortion of the image. There is almost no noticeable shift in the computed statistical values of mean, standard deviation [23] and entropy [24] with respect to the cover and stego-images, thereby approbating the significant imperceptibility. The insertion or embedding technique of our approach is a modified form of data hiding by LSB [25] model. A significant amount of increment of the embedding capacity is noticed in the experimental results. Further modification can be done on it so as to increase its embedding capacity further.

Acknowledgment

Steganography has a huge contribution in this modern world with ever changing technologies. In reference to this context, we would sincerely like to express our gratitude to all the previous research works carried out in this field, whose researches have played a very appreciable role in the particular work done in this paper.

References

[1] S. Bhattacharyya, G. Sanyal, “Hiding Data in Images Using Pixel Mapping Method (PMM)”, 'Security and Management', CSREA Press, pp. 683-689, 2010.
[2] R. Chandramouli, M. Kharrazi, N. Memon, “Image Steganography and Steganalysis Concepts and Practice”, Ton Kalker; Ingemar J. Cox & Yong Man Ro, ed., 'IWDW, Springer, pp. 35-49, 2003.
[3] T. Morkel, J. H. P. Eloff, M. S. Olivier, “An Overview of Image Steganography”, Paper presented at the meeting of the ISSA, Pretoria, South Africa, pp. 1-11, 2005.
[4] T. Kumar, A. Pareek, J. Kirori, M.S. Nehra, “Development of Crossover and Encryption based Text Steganography (CEBTS) Technique”, Emerging Trends in Computing and Communication, lecture notes in Electrical Engineering, vol 298, 2014 pp. 103-111.
[5] T. Apostol, Wiley, “Calculus.2. Multi-variable Calculus and Linear Algebra, with Applications to Differential Equations and Probability”, 1969.
[6] J. Fridrich, M. Goljan, and R. Du, “Detecting LSB Steganography in Color and Gray-Scale Images,” Magazine of IEEE Multimedia Special Issue on Security, pp. 22-28, Nov. 2001.
[7] BU Long, HU Bo. “An improved steganographic method by pixel value differencing,” Journal of circuits and systems, 11(3), pp. 9-13, 2006.
[8] Wang Chung-Ming, Wu Nan-i, Tsai Chwei-shyong, et al. “A High Quality Steganographic Method with Pixel Value Differencing and Modulus Function,” Journal of Systems and Software, pp. 150-158, 2008.
[9] P Huang. K.C. Chang., C.P Chang. and T.M Tu. “A Novel Image Steganography Method Using Tri-way Pixel Value Differencing”. Journal of Multimedia, 3, 2008.
[10] V. Potdar, E. Chang. “Gray Level Modification Steganography for Secret Communication”. IEEE International Conference on Industrial Informatics, Berlin, Germany, pp. 355–368, 2004.
[11] Ahmad T. Al-Taani., Abdullah M. AL-Issa, “A Novel Steganographic Method for Gray-Level Images”. International Journal of Computer, Information, and Systems Science, and Engineering, pp. 3, 2009.
[12] S. Bhattacharyya, A. Khan, A. Nandi, A. D. Malakar, S. Roy and G. Sanyal, “Pixel Mapping Method (PMM) Based Bit Plane Complexity Segmentation (BPCS) Steganography” at WICT (World Congress on Information and Communication Technologies), 2011.
[13] T.-H. Lan; M. F. Mansour, & A. H. Tewfik, Robust High Capacity Data Embedding, in 'ICIP', pp. 581-584, 2000.
[14] A. Almohammad, G. Ghinea., “Stego-image Quality and the Reliability of PSNR” Image Processing Theory, Tools and Applications, IEEE, 2010.
[15] S. Bhattacharyya, G. Sanyal, “Study and Analysis of Quality of Service in Different Image Based Steganography using Pixel Mapping Method”, International Journal of Applied Information Systems (UAIS)-ISSN: 2249-0868, pp. 42-57, 2012.
[16] N. Sai, R. C. Patil, “Image Retrieval using Equalized Histogram Image Bins Moments” International Journal on Signal & Image Processing 2 (1), 4, 2011.
[17] E. Verhulp, B. Rietbergen, R. Huiskes, “A Three-Dimensional Digital Image Correlation Technique for Strain Measurements in Microstructures”, Journal of Biomechanics 37 (9), 1313—1320, 2004.
[18] R. Lundin, S. Lindskog, “An investigation of entropy of selectively encrypted bitmap images” in 'CASoN', IEEE, pp. 238-243, 2012.
[19] S. Hemalatha, U. D. Acharya, A. Renuka, P. R. Kamath, “A Secure and High Capacity Image Steganography Technique”, CoRR abs/1304.3629, 2013.
[20] D. C. Rupa, B. Saijyothi, P. S. Avadhani, “A Novel Approach Text Steganography using cheating text by Genetic Operator Crossover”, IJARCS, Vol 2, 01/2011.
[21] C. Cachin, “An Information-Theoretic Model for Steganography”, IACR Cryptology ePrint Archive, pp. 28, 2000.
[22] A. Dermoune, “Differential calculus relative to some point processes”, Statistics & Probability Letters 24 (3), 233-242, 1995.
[23] G. A. K. Mahesh D. Pawar, V. P. Pawar, “Study and Performance Analysis of De-Blurring Techniques for Distorted Medical Images”, indian streams research journal 4 (4), 2014.
[24] E. N. Kirsanova, M. G. Sadovsky, “'Entropy Approach to Comparison of Images”, Open Syst. Inform. Dynam.8 (2), 183-200, 2001.
[25] Dr. V. Vijayalakshmi, Dr. G. Zayaraz, and V. Nagaraj, “A Modulo Based LSB Steganography Method”, international conference on

control, automation, communication and energy conservation, 4th-6th June 2009, pp. 1 – 4, 2009.