Authentication through Hough Signature on G-Let D4 Domain (AHSG – D4)

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***Abstract*—In this paper an authentication technique has been proposed based on G-Let transformation technique. Digital documents are authenticated by embedding Hough transform generated signature, which generated from the original autograph image. Cover image passes through G-Let transformation technique to generate n number of G-Lets. Out of which few selected G-lets are embedded with secret signature, generated by Hough transform technique. Rests of the G-Lets are used for adjustment to minimize the error factor. Experimental results are computed and compared with the existing authentication techniques Li's method, Region-Based method based on SCDFT, which indicates better performance in AHSG-D4, in terms of better by means of Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and Image Fidelity (IF).**

Keywords- Steganography; Peak Signal to Noise Ratio (PSNR). G-Lets; Authentication; Hough transform; Mean Square Error (MSE); Image Fidelity (IF);

I. INTRODUCTION

Security has become an inseparable issue as information technology is ruling the world now. Cryptography is the study of mathematical techniques related aspects of Information Security such as confidentiality, data security, entity authentication and data origin authentication, but it is not the only means of providing information security, rather one of the techniques.

Steganographic communication is difficult to trace and hence it makes the job of the hacker difficult because the hacker now has to track all network communication rather than just encrypted communication. This steganographic feature increases the level of privacy and security by not making the confidential communication invisible. It is also commonly known as 'Disappearing Cryptography'.

Steganography is a technique to hide messages inside other cover media in a way that does not allow any enemy or hackers to detect that there is a secret message present. For Authentication, Secure communication Steganography is very important. One newly developed transformation technique is G-Lets. It is a group of linear transformations related with group theory. Most natural signal decomposition algorithm is G-Lets, which is used for digitized signal without any approximations [2].

This paper proposed a copyright protection and authentication technique AHSG-D4, The cover image is transformed into G-Let domain to generate eight number of G-Lets Out of which few selected G-lets are embedded with secret signature, which is generated by Hough transform technique. Remaining G-Lets are used for minimizing the error factor.

A range of parametric tests are performed and obtained results are compared with most recent techniques such as, SCDFT [4], Li's Method [3] , WTSIC [7], Region-Based [6], AINCDCT [15], IAZT [16], TISAWFD [17], AHSG-D3 [1] and STMDF [5], based on Mean Square Error (MSE), Image Fidelity (IF), Peak Signal to Noise Ratio (PSNR) and Universal Quality Image (UQI) analysis [8] to obtain a comparative result between proposed and existing techniques.

The proposed technique is described in Section-II. Hough transform generated Signature is shown in section-III. Section-IV deals with G-Let Transformation technique with embedding and adjustment followed by authentication. In section-V deals with results are discussion. Conclusions are drawn in section-VI with references cited at end.

II. PROPOSED SCHEME

The proposed AHSG-D4 technique is mainly separated into two key tasks. The task of embedding and adjustment is performed at sender side and the task of authentication is performed at receiver side. For embedding process it takes source/cover image and grayscale autograph to generate stego-image. Hough transformation [12, 13] generates butterfly signature from gray scale autograph image which is considered as secret image. A stream of bits is obtained by converting this butterfly signature into binary form. Source/cover image is transformed through G-Let D4 linear transformation technique [2, 11], which is based on Dihedral group theory in a row major order of 2 x 2 window. As rotations and reflections are only two transformation presented in Dihedral group thus after computation when eight G-Lets are generated, labeled as G-Let 1, G-Let 2, G-Let 3, G-Let 4, G-Let 5, G-Let 6, G-Let 7 and G-Let 8. Out of which G-Let 2 and G-Let 3 are chosen to fetch 2nd and 3rd element of every 2 x 2 window and from previously generated stream of bits, secret bits are embedded. After embedding over 2 x 2 windows, adjustments phase is applied to minimize the error rate and image distortion. Then reconstruction of image is done with embedded G-Lets and the rest of all G-Lets.

A stego-image can be transmitted through mesh network which is the output of reverse G-Let D4 transformation procedure. After receiving the stego-image, the receiver tests the stego-image to check for authenticity. G-Let D4 transformation technique is used to generate total eight numbers of G-Lets; predefined hash is used to fetch the bits from 2nd and 3rd elements of 2 x 2 windows in a row major order from G-Let 2 and G-Let 3. This stream of bits is compared with the Hough transform generated bit stream from the owner's autograph at receiver end. Ownership is verified by comparing these two streams of bits.

III. SIGNATURE GENERATION

A special transformation technique named Hough transform [10] is used to generate a signature of an image. Hough transform technique extracts and identifies significant features of image orientation by analyzing dots and lines [9].

Individual pixels are mapped by Hough transform from image domain to a shape in parameter domain [10] that's creates a butterfly like pattern, known as signature. Hough transform passes images of autographs with a range of 0 to 255 pixel values, as selected for proposed work, dependent on hash function.

Gray scale autograph image on passing through Hough transformation with range, and origin as center of image, generates a matrix of rho verses theta, by eq. 1 and eq. 2 where limits are $1 \leq$ theta(θ) < Pi and $-N \leq$ rho(ρ) $\leq N$.

$$\boldsymbol{N} = \left(\left(\frac{\sqrt{\boldsymbol{Row^2+Col^2}}}{\boldsymbol{2}}\right)\right) \quad (1)$$

$$\backslash\rho i = (x * \cos\theta + y * \sin\theta)) \quad (2)$$

A butterfly like structure arise by calculating of rho for each value of theta and incrementing the matrix value of rho verses theta, that unique structure is termed as butterfly signature image as shown in figure 1.

Autograph image of 256 x 256 in dimension **Hough signature**

Fig. 1. Hough transformed based signature generation

IV. G-LET D4 TRANSFORMATION TECHNIQUE

G-Let based secret transmission for document authentication technique has been developed and termed as AHSG-D4. It is the abbreviate form of “Authentication through Hough Signature on G-Let D4 Domain”.

To increases the robustness of the embedding technique, an image is converted from spatial domain to frequency domain using transformation techniques. In AHSG-D4 embedding is used after G-Let D4 transformation technique. A G-Let D4 transformation technique selects finite group transformation so that they are always completely reducible into irreducible representation. The dimension of the irreducible representations follows certain rules [1, 2, 11], as given in eq. 3.

$$\sum_{i=1}^{n} d_i^2 = D_n \qquad (3)$$

Where d_i is the dimension of i^{th} irreducible representation, D_n is the dimension of representation matrix and ‘n’ is the number of irreducible representations. In a dihedral group D_n there are ‘n’ rotation and ‘n’ reflections available. Which generates 2 * n that is 2n matrices one for each transformation. The rotation matrix $R_{(2\pi k/n)}$ and reflection matrix $S_{(2\pi k/n)}$ are shown through eq. 4 and eq. 5 respectively where k is {0, 1, 2 ... n-1}.

$$R_{(2\pi k/n)} = \begin{pmatrix} \cos({}^{2\pi k}/_{n}) & -\sin {}^{2\pi k}/_{n} \\ \sin {}^{2\pi k}/_{n} & \cos {}^{2\pi k}/_{n} \end{pmatrix} \qquad (4)$$

$$S_{(2\pi k/n)} = \begin{pmatrix} \cos {}^{2\pi k}/_{n} & \sin {}^{2\pi k}/_{n} \\ \sin {}^{2\pi k}/_{n} & -\cos {}^{2\pi k}/_{n} \end{pmatrix} \qquad (5)$$

The system can be considered as a unit circle with n number of equal length chords equidistant from the centre of a circle. Computational complexity depends mainly on the number of irreducible representations which is (n+6)/2 for even sized signal and (n+3)/2 for odd sized signal containing ‘n’ components.

Inverse transformation is a reverse process to regenerate the original image through reversible computation of rotational and reflective components. This can be achieved by simple addition of $R_{(2\pi k/n)}$ for all values of $2\pi k/n$ greater than 0 and less than 360 degree. The equation is shown in eq. 6.

$$G[i,j] = (-1).(G_2^T[i,j] + G_3^T[i,j]) \quad (6)$$

Computational complexity of the technique mainly based on the number of irreducible representations which is (n+6)/2 for even sized signal and (n+3)/2 for odd sized signal. Hence the complexity of G-let decomposition is O(n).

In dihedral group D_4, four rotations and four reflections are available. Therefore there are 2 * 4 that is eight matrices one for each transformation can be obtained. Thus forward transformation of G-let D4 computation generates eight G-lets. Out of which G-let 1, G-let 2, G-Let 3 and G-let 4 are through rotational transformation and G-let 5, G-let 6, G-Let 7 and G-let 8 are through reflection transformation. The rotation matrix R_θ and reflection matrix S_θ is shown in eq. 7 and eq. 8 respectively where θ belongs to {0, π/2, π, 3π/2}.

$$\left.\begin{aligned} R_0 &= \begin{pmatrix}\cos 0 & -\sin 0\\ \sin 0 & \cos 0\end{pmatrix},\\ R_{(\pi/2)} &= \begin{pmatrix}\cos(\pi/2) & -\sin(\pi/2)\\ \sin(\pi/2) & \cos(\pi/2)\end{pmatrix},\\ R_{(\pi)} &= \begin{pmatrix}\cos(\pi) & -\sin(\pi)\\ \sin(\pi) & \cos(\pi)\end{pmatrix},\\ R_{(3\pi/2)} &= \begin{pmatrix}\cos(3\pi/2) & -\sin(3\pi/2)\\ \sin(3\pi/2) & \cos(3\pi/2)\end{pmatrix}\end{aligned}\right\} \quad (7)$$

$$\left.\begin{aligned} S_0 &= \begin{pmatrix}\cos 0 & \sin 0\\ \sin 0 & -\cos 0\end{pmatrix},\\ S_{(\pi/2)} &= \begin{pmatrix}\cos(\pi/2) & \sin(\pi/2)\\ \sin(\pi/2) & -\cos(\pi/2)\end{pmatrix},\\ S_{(\pi)} &= \begin{pmatrix}\cos(\pi) & \sin(\pi)\\ \sin(\pi) & -\cos(\pi)\end{pmatrix},\\ S_{(3\pi/2)} &= \begin{pmatrix}\cos(3\pi/2) & \sin(3\pi/2)\\ \sin(3\pi/2) & -\cos(3\pi/2)\end{pmatrix}\end{aligned}\right\} \quad (8)$$

G-Let 2 and G-Let 3 in 2 x 2 matrix window is taken for embedding in 2^{nd} and 3^{rd} bit position from LSB randomly based on the hash function. The hash function 'H' is ((col + max_bit) % hig_pos) where col is the column number based on active window and max_bit is the maximum number of bits allowed per byte for embedding and hig_pos is the highest position allowed for embedding from LSB towards MSB. After embedding G-Let 6 and G-Let 7 need adjustment. The difference calculated among original G-Let 2 and embedded G-Let 2 is added to G-Let 6 and the difference calculated among G-Let 3 and embedded G-Let 3 is added into G-Let 7. This adjustment is required to minimize the error rate and maintain the symmetry among rotation and reflection G-Lets.

Adjustment phase at receiver end is required for authentication of the image. At receiver side the stego-image passes through forward G-Let D4 transformation to generate four rotation and four reflection G-Lets. Out of which G-Let 2 and G-Let 3 are fetched in 2x2 window in a row major order. On applying the same hash function the secret bits are extracted and compared with the Hough generated signature of owner's autograph at receiver side, to authenticate the received stego-image.

V. RESULTS AND DISCUSSION

Ten pgm images as cover/source image [14] with ten different autographs [1] have been taken for applying AHSG-D4 to compute the results. The dimension of all cover images are 512 x 512, the dimension of autographs images are 256 x 256 and the dimension of corresponding Hough generated secret butterfly signature are 128 x 128, 181 x 181 and 256 x 256 for 0.5 bpB, 1.0 bpB and 1.5 bpB of payload. Average MSE for 0.5 bpB is 0.245387, for 1.0

bpB is 1.446628 and for 1.5 bpB is 6.649264 with corresponding average PSNR is 54.24145 dB, 46.53031 dB, and 39.90403 dB respectively. The statistical calculation of image fidelity on average shows 0.999988 for 0.5 bpB, 0.999928 for 1.0 bpB and 0.999667 for 1.5 bpB. All cover images are shown in figure 2. Few grayscale autographs with Hough generated secret butterfly signature of dimension 128 x 128 are shown in figure 1.

A. *Mean Square Error (MSE):*

The mean square error is the cumulative squared error between the embedded and the original image. The mathematical formula for MSE is given in eq. 9.

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [\mathrm{X}(i,j) - \mathrm{Y}(i,j)]^2 \qquad (9)$$

where X(i,j) is the original image, Y(i,j) is the embedded image and M,N are the dimensions of the images. A lower value for MSE means lesser error. The detail computation of MSE between original and embedded image, where embedding has been done through AHSG – D4 is given in table 1.

TABLE 1: MSE analysis on embedding through AHSG-D4

Serial No	**Cover Image**	**MSE embedding through AHSG – D4**		
		0.5 bpB	**1.0 bpB**	**1.5 bpB**
1.	Baboon	0.249680	1.404938	6.517292
2.	Boat	0.251434	1.452057	6.487656
3.	Clock	0.220036	1.358295	6.859566
4.	Couple	0.249752	1.472855	6.771999
5.	Elaine	0.251411	1.464241	6.650894
6.	Jet	0.258400	1.463612	6.642910
7	Map	0.249626	1.454067	6.388798
8.	Space	0.216274	1.427341	6.758175
9.	Tank	0.270077	1.573769	6.755974
10.	Truck	0.237183	1.395103	6.659374
Average		***0.245387***	***1.446628***	***6.649264***

B. *Peak Signal to Noise Ratio (PSNR):*

PSNR is a measure of the peak error. The mathematical formula for PSNR is given in eq. 10.

$$\mathrm{PSNR} = 10 * \log_{10}\left({255^2}/{\mathrm{MSE}}\right) \qquad (10)$$

The detail computation of PSNR between original and embedded image, where embedding has been done through AHSG – D4 is given in table 2.

TABLE 2: PSNR analysis on embedding through AHSG-D4

Sl. No	**Cover Image**	**PSNR (dB) embedding through AHSG – D4**		
		0.5 bpB	**1.0 bpB**	**1.5 bpB**
1.	Baboon	54.156974	46.654233	39.990132
2.	Boat	54.126558	46.510967	40.009926
3.	Clock	54.705875	46.800861	39.767837
4.	Couple	54.155713	46.449205	39.823635
5.	Elaine	54.126953	46.474678	39.902003
6.	Jet	54.007879	46.476545	39.907220

TABLE 2: PSNR analysis on embedding through AHSG-D4

Sl. No	Cover Image	PSNR (dB) embedding through AHSG – D4		
		0.5 bpB	1.0 bpB	1.5 bpB
7	Map	54.157903	46.504959	40.076612
8.	Space	54.780755	46.585525	39.832509
9.	Tank	53.815932	46.161395	39.833924
10.	Truck	54.379975	46.684739	39.896469
Average		***54.24145***	***46.53031***	***39.90403***

C. Image Fidelity (IF):

Image fidelity is a parametric computation to quantify the perfectness of human visual perception. The computation formula is given in eq. 11.

$$IF = 1 - \left(\sum_{M,N} (X_{ij} - Y_{ij})^2 / \sum_{M,N} {X_{ij}}^2 \right) \qquad (11)$$

Here M and N is the total number of rows and column respectively, X_{ij} is the original pixel intensity value of image and Y_{ij} is the pixel intensity value after embedding.The detail computation of IF is given in table 3.

TABLE 3 IF analysis on embedding through AHSG-D4

Serial No	Cover Image	IF on embedding through AHSG – D4		
		0.5 bpB	1.0 bpB	1.5 bpB
1.	Baboon	0.999987	0.999924	0.999649
2.	Boat	0.999987	0.999923	0.999658
3.	Clock	0.999994	0.999964	0.999818
4.	Couple	0.999985	0.999910	0.999584
5.	Elaine	0.999988	0.999929	0.999678
6.	Jet	0.999992	0.999953	0.999787
7	Map	0.999993	0.999957	0.999812
8.	Space	0.999987	0.999916	0.999602
9.	Tank	0.999985	0.999914	0.999629
10.	Truck	0.999981	0.999885	0.999452
Average		***0.999988***	***.999928***	***0.999667***

A comparative study has been made along with the existing technique ASHG-D3 of year 2013. The error rate for 0.5 bpB of payload, ASHG-D3 shows 1.00 whereas ASHG-D4 shows 0.25. For 1.0 bpB ASHG-D3 shows 5.84 and that of ASHG-D4 shows 1.45 and for 1.5 bpB ASHG-D3 shows 26.33 where as ASHG-D4 shows 6.65. With higher payload higher gap in error rate noticed. The comparison result of MSE is shown in table 4.

TABLE 4: Comparison of MSE with existing technique (AHSG-D3)

Technique(s)	Average Mean Square Error (MSE)		
	0.5 bpB	1.0 bpB	1.5 bpB
AHSG – D3	1.0001215	5.8418408	26.3295430
AHSG – D4	0.245387	1.446628	6.649264

The Peak Signal to Noise Ratio (PSNR) for 0.5 bpB of payload, AHSG-D3 shows 48.13dB and that of AHSG-D4 shows 54.24. For 1.0 bpB AHSG-D3 shows 40.47 and that of AHSG-D4 shows 46.53 and for 1.5 bpB AHSG-D3 shows 33.93 and that of AHSG-D4 shows 39.90. The Comparison result of PSNR is shown in table 5.

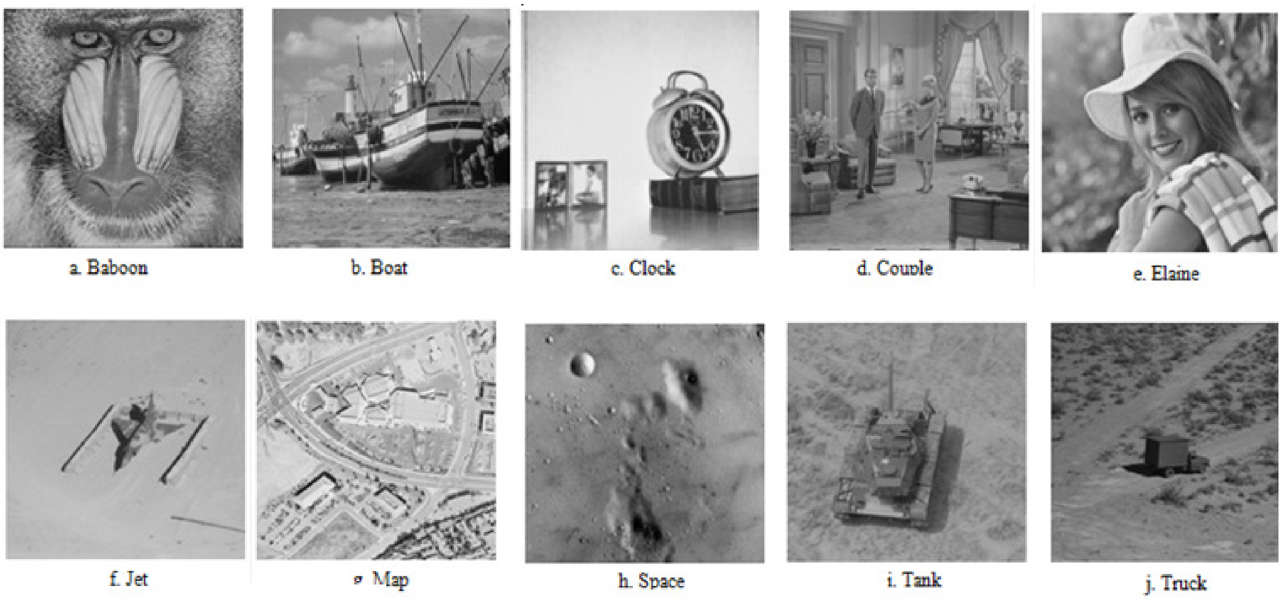

Fig. 2. Cover images of dimension 512 x 512 in pgm

TABLE 5: Comparison of PSNR with existing technique (AHSG-D3)

Technique(s)	**Average Peak Signal to Noise Ratio (PSNR)**		
	0.5 bpB	**1.0 bpB**	**1.5 bpB**
AHSG – D3	48.13036	40.46691	33.92845
AHSG – D4	54.24145	46.53031	39.90403

The average image fidelity value for 0.5 bpB of payload for ASHG – D3 shows 0.999943 and that of ASHG – D4 shows 0.999988. In case of 1.0 bpB IF obtained for ASHG – D3 is 0.999667 and that of ASHG – D4 as 0.999928, and for 1.5 bpB ASHG – D3 obtain 0.998497 IF value and that of ASHG – D4 shows 0.999667. The comparison result of IF is shown in table 6.

TABLE 6: Comparison of IF with existing technique (AHSG-D3)

Technique(s)	**Average Image Fidelity (IF)**		
	0.5 bpB	**1.0 bpB**	**1.5 bpB**
AHSG – D3	0.999943	0.999667	0.998497
AHSG – D4	0.999988	0.999928	0.999667

A comparative study has also been made with the existing techniques such as Li's method [3], SCDFT [4], AINCDCT [15], IAZT [16], WTSIC [7], TISAWFD [17] and AHSG – D3 [1]. The results are shown in table 7 with the graphical representation of data shown in figure 3.

TABLE 7. Comparison of AHSG-D4 with existing techniques

Technique	**Payload (bpB)**	**PSNR (dB)**
Li's method (2008)	0.13	28.68
SCDFT (2008)	0.12	30.10
AINCDCT (2011)	0.5	45.61
IAZT Real HF (2013)	0.5	51.87
WTSIC (2010)	0.5	42.28
TISAWFD (2011)	0.5	43.12
AHSG – D3 (2013)	0.5	48.13

TABLE 7. Comparison of AHSG-D4 with existing techniques

Technique	Payload (bpB)	PSNR (dB)
AHSG – D4	0.5	54.17

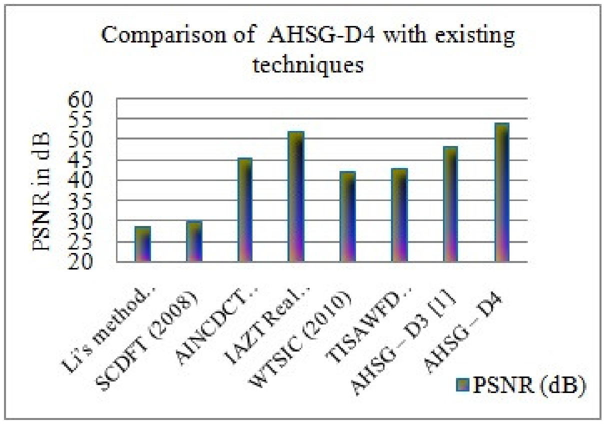

Fig. 3. Pictorial analysis of PSNR in dB on comparison with existing techniques

VI. CONCLUSSION

On analysis of the above experimental results AHSG – D4 technique shows better performances than existing AHSG – D3 technique. Logically, a lower value for MSE means lesser error, and a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. By applying AHSG – D4 technique resultant error rate is less than AHSG – D3 technique by approximately 0.75 for 0.5 bpB, 4.40 for 1.0 bpB and 19.68 for 1.5 bpB. Similarly, in AHSG – D4 technique resultant PSNR value computed in dB is higher than AHSG – D3 technique. In AHSG – D4 the PSNR value is incremented by 6.11 for 0.5 bpB, 6.06 for 1.0 bpB and 5.98 for 1.5 bpB. On comparison with other existing techniques ASHG – D4 techniques shows better performance in terms of MSE, PSNR and IF.

ACKNOWLEDGEMENT

The author expressed deep sense of gratitude to the Department of CSE, University of Kalyani where the computational resources are used for the work.

REFERENCES

[1] Sengupta, M., & Mandal, J. K. (2013, September 27–28). Authentication through Hough transformation generated Signature on G-Let D3 Domain (AHSG). Presented in first international conference on Computational Intelligence: Modeling, Techniques and Applications (CIMTA- 2013), Proceedings published with Procedia Technology, Elsevier, 10,121-130. ISSN 2212-0173, website: www.sciencedirect.com.

[2] Rajathilagam, B., Rangarajan, M., Soman, K.P., "G-Lets: A New Signal Processing Algorithm", International Journal of Computer Applications (0975 – 8887) Volume 37– No.6, Published by Foundation of Computer Science, New York, USA, doi : 10.5120/4609-6591, January 2012.

[3] Li Yuancheng, Xiaolei Wang, "A watermarking method combined with Radon transform and 2D-wavelet transform", IEEE, Proceedings of the 7th World Congress on Intelligent Control and Automation, June 25 - 27, Chongqing, China, 2008.

[4] T. T. Tsui, X. –P. Zhang, and D. Androutsos, Color Image Watermarking Usimg Multidimensional Fourier Transformation, IEEE Trans. on Info. Forensics and Security, vol. 3, no. 1, pp. 16-28, 2008.

[5] J. K. Mandal, Madhumita Sengupta, “Steganographic Technique Based on Minimum Deviation of Fidelity (STMDF)”, IEEE, Second International Conference on Emerging Applications of Information Technology (EAIT 2011), print ISBN: 978-1-4244-9683-9, doi: 10.1109/EAIT.2011.24, pp- 298 – 301, 2011.

[6] A. Nikolaidis, I. Pitas, “Region-Based Image Watermarking”, IEEE Transactions on Image Processing, Vol. 10, NO. 11, pp. 1721-1740, November 2001.

[7] J. K. Mandal, Madhumita Sengupta, “Authentication /Secret Message Transformation Through Wavelet Transform based Subband Image Coding (WTSIC)”, IEEE, International Symposium on Electronic System Design, pp 225-229, ISBN 978-0-7695-4294-2, Bhubaneswar, India, Print ISBN: 978-1-4244-8979-4, doi 10.1109/ISED.2010.50, 2010.

[8] M. Kutter , F. A. P. Petitcolas, A fair benchmark for image watermarking systems, Electronic Imaging '99. Security and Watermarking of Multimedia Contents, vol. 3657, Sans Jose, CA, USA, January 1999. The International Society for Optical Engineering.

[9] V.F. Leavers, “Shape detection in computer vision using the hough transformation”, Springer-Verlag, Berlin, 1992, 201 pages, ISBN- 3-540-19723-0, Published online by Cambridge University Press 09 Mar 2009, doi: 10.1017/S0263574700016210.

[10] P.V. C. Hough. A Method and Means for Recognizing Complex Patterns. US Patent: 3,069,654, Dec. 1962.

[11] Rajathilagam, B., Rangarajan, M., and Soman, K.P., G-lets: Signal Processing Algorithm Using Transformation Groups, IEEE Trans. Imag. Proc., 2011.

[12] Madhumita Sengupta, J. K. Mandal, “Authentication in Wavelet Transform Domain through Hough Domain Signature (AWTDHDS)” UGC-Sponsored National Symposium on Emerging Trends in Computer Science (ETCS 2012), ISBN number 978-81-921808-2-3, pp 61-65, (2012).

[13] Madhumita Sengupta, J. K. Mandal “Image Authentication using Hough Transform generated Self Signature in DCT based Frequency Domain (IAHTSSDCT)”, IEEE, ISED- 2011, Kochi, Kerala, pp- 324-328, DOI 10.1109/ISED.2011.43,(2011).

[14] Allan G. Weber, The USC-SIPI Image Database: Version 5, Original release: October 1997, Signal and Image Processing Institute, University of Southern California, Department of Electrical Engineering. http://sipi.usc.edu/database/(accessed on 25thJan, 2013).

[15] Madhumita Sengupta, & J. K. Mandal, "Authentication of Images through Non Convoluted DCT (AINCDCT)".Published in first IEEE International Conference on Communication and Industrial Application (ICCIA 2011).1 - 4. doi: 10.1109/ICCIndA.2011.6146672, December, 2011.

[16] Madhumita Sengupta, & J. K. Mandal, Image Authentication through Z-Transform with Low Energy and Bandwidth (IAZT). International Journal of Network Security & Its Applications (IJNSA) of AIRCC, 5(5), 43–62. doi:10.5121/ijnsa.2013.5504. 2013, September.

[17] Madhumita Sengupta, & J. K. Mandal, "Transformed IRIS Signature fabricated Authentication in Wavelet based Frequency Domain (TISAWFD)". International Journal of Advanced Research in Computer Science (IJARCS), 2(5), 486- 490. ISSN No: 0976-5697, Sep-Oct 2011.