Towards Design and Implementation of Discrete Transform Image Coding based Document Authentication Techniques

Abstract submitted for the degree of Doctor of Philosophy (Engineering)
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By

MADHUMITA SENGUPTA

Under the supervision of

Dr. JYOTSNA KUMAR MANDAL

Professor
Computer Science & Engineering

Department of Computer Science and Engineering
University of Kalyani, Kalyani, Nadia
West Bengal, India

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Technology brings home facilities moulded with some troubles. Under the ongoing process of development those troubles demands for new research and development of new technology. Internet, Mobile, Telecommunication, Electronic documentation are the middle aged technology which comes with many security problems such as secret data communication, copyright protection, ownership of document and many more. These security problems were tried to be sorted out through cryptography and steganography. This thesis is purely steganographic work where digital documents in the form of images are taken as input and converted to signals. Those signals are transformed through image coding techniques into frequency domain. Frequency coefficients are embedded based on required payload and selected band. That stego-image is authenticated for the sake of copyright protection, ownership identification or ownership verification. The secret transmitted through stego-image is extracted to regenerate the secure message. This technology facilitates to achieve security with a permissible degradation of quality of stego-image. The results of the work proposed are computed and compared with statistical tests to verify the quality of the schemes. The cover document/image when compared with stego-document/image through human visual perception mechanisms approved all the technique. As the human vision is a complex neurophysiological process it varies human to human, thus few statistical parameters are also computed for all the proposed techniques to justify the usefulness of the work. This thesis is a collaboration of steganography and image coding were five different types of transform techniques are applied followed by embedding to ensure the authenticity. The transform techniques used are to convert image from spatial domain into its frequency coefficients like cosine transform, Z-transform, Haar wavelet transform, G-Let transform, Hough transform and Daubechies wavelet transform for the purpose of secret message transmission, copyright protection and self document authentication.

In modern society where facts in the form of data or information appears maximum times in digital form, likewise image, audio, video and text documents, needs a strong security. This security may demand authenticity, legitimacy, copyright protection, document authentication, ownership verification, or secret message transmission through unsecured communication channel. To protect the facts in any of the digital domain proposed steganographic algorithms are available in research domain.

The objective of the proposed work is to implant techniques of steganography in frequency domain through image coding. Varieties of recently developed image coding techniques were used for generating algorithms of authentication. All the image coding used in this proposed work are discrete in nature and based on non convoluted image coding techniques to develop the novel techniques of document authentication. The image coding and decoding techniques used in this thesis are Cosine transform, Z-transform, Haar wavelet transform, G-Lets transform and Daubechies wavelet-transform for document authentication. The main objectives of this proposed work are-

- Making complex image coding systems as easy to implement as possible in terms of computation by compromising the computational environment making few parameters predetermined.
- Fabricating and implementing novel steganographic techniques for document authentication in frequency domain by using discrete transform image coding in two ways. Design these techniques in a manner so to provide secret message transmission and ownership verification both.
- Design the techniques in a manner to overcome the flaws and false generation of secret messages.
- Compare the proposed techniques with existing techniques with respect to parameters such as mean square error, peak signal to noise ratio, image fidelity, universal quality index and structural similarity index measurement to find out the most optimal technique.

Twelve document authentication techniques are proposed on the basis of five different image coding technique, the names were 'Traditional DCT', 'AINCDCT', 'IAHTSSDCT', 'IAZT', 'IAHZ', 'WTSIC', 'ATFDWT', 'TISAWFD', 'ATGT', 'AHSG', 'ATFDD' and 'AHSDT'. Such techniques can work for both document authentication and secret message transmission.

Traditional DCT: A novel discrete cosine transform based secret message transmission technique for document authentication, where image is converted into DCT coefficients through traditional discrete cosine transform technique followed by embedding and reverse computation.

AINCDCT: A novel non-convoluted discrete cosine transform based secret message transmission technique for document authentication, where non-convoluted DCT frequency coefficients of gray scale images are computed and acted as carrier of secret message followed by adjustment. Gray scale images are transformed in a non-convoluted manner prior to embedding.

IAHTSSDCT: A novel non-convoluted discrete cosine transform based work on gray scale images. Were the cover image passes through Hough transformation based on a hash function to generate unique signature treated as secret watermark. DCT coefficients of 2 x 2 masks are generated in a form of matrixes in a non overlapping row major order of the cover image. The third AC coefficient of every mask is selected as a carrier of the secret invisible watermark followed by adjustment for self authentication.

IAZT: A novel discrete Z- transform based secret message transmission technique for document authentication, where Z frequency coefficients of gray scale images are acted as carrier of secret message. Z frequency coefficients computed prior to embedding in the form of a + jb, by evading complex trigonometric computations. The technique shows best performance while embedding secret in real or imaginary coefficients of HF band followed by adjustment, termed as, 'IAZT-Real HF' and 'IAZT- Imaginary HF' respectively.

IAHZ: A novel non-convoluted Z- transform based self authentication of documents achieved, where secret image/watermark is generated through Hough transform of the VF band of cover image after forward Z transform. The Hough transform generates the butterfly like signature of the VF band coefficient values. No external information is required for embedding or authentication. The selected coefficients for embedding were real or imaginary Z- coefficients and termed as 'IAHZ-Real' and 'IAHZ-Imaginary'.

WTSIC: A novel authentication technique, where discrete Haar wavelet coefficients through forward Haar transformation are generated based on non-overlapped 4 x 4 mask, in the form of two dimensional matrixes in a row major order and represented in four quadrant labelled as A-band', 'V-band', 'H-band' and 'D-band'. Out of four, three bands were embedded with external information for secret transmission and document authentication.

ATFDWT: A novel non convoluted discrete Haar wavelet based authentication technique, where coefficients are generated based on non-overlapped 2 x 2 mask, in a row major order and represented in four quadrant labelled as A-band', 'V-band', 'H-band' and 'D-band'. Out of four, three bands were embedded with external information followed by adjustment for secret transmission and document authentication.

TISAWFD: A novel non convoluted discrete Haar wavelet transform based self authentication technique proposed for document authentication without external information. The information for self authentication captured automatically from secret cameras or CCTV footage. From this information captured through secret cameras or CCTV footage, iris are fetched and enhanced through scaling. Iris images are then transformed into signature through Hough transform and hide itself inside the documents/images in any of the three frequency components generated by Haar wavelet transform using a secret key and a hash function.

ATGT: A novel discrete G-Let based secret message transmission techniques for document authentication proposed in D3 and D4 domain termed as ATGT-D3 and ATGT-D4. This authentication technique works on gray scale images using 2 x 2 mask based window in row major order. The rotation G-Lets of degree greater than zero and less than 360 were used for embedding and adjustment.

AHSG: A novel discrete G-Let based self document authentication proposed in D3 and D4 domain termed as AHSG-D3 and AHSG-D4. This authentication technique works on gray scale images using 2 x 2 mask based window in row major order. The reflection G-Lets of degree greater than zero and less than 360 were used for embedding and adjustment.

ATFDD: A novel discrete Daubechies transform based secret message transmission techniques for document authentication works on gray scale images using a 4 x 4 non overlapping mask based window in row major order. Every mask generates four frequency bands of 2 x 2 each after forward Daubechies transformation. The four

bands generated after forward Daubechies transformation are 'Average band' with low frequency coefficients, 'Vertical band' and 'Horizontal band' with middle frequency coefficients and 'Diagonal band' with higher frequency coefficients. The coefficients of every band are equally eligible to act as a pocket for secret bits, here third coefficient of all the four bands are selected to store secret bits followed by reverse computation to generate stego-image.

AHSDT: A novel discrete Daubechies transform based self document authentication technique without external information with varying payload proposed. Where the information for self authentication taken automatically from the DF-band of cover image as converted into Hough transforms generated butterfly signature. This butterfly signature hides itself inside the document/image in any of the bands except AF-band computed from the cover document/image through forward Daubechies wavelet transformation.

For the formulation of the results twenty gray scale and twenty color images were used in the thesis. All the images were of 512 x 512 in dimension. The results are computed to analysis the evaluation of the techniques. The analytical measurements used are the mean square error, peak signal to noise ratio, image fidelity, universal quality index and structural similarity index measurement. The visual parameter for quality analysis is histogram. The analysis of original and embedded histogram of image proves the evaluation of techniques visually.

The performance analyses of the ten proposed techniques were shown in figure 1 and domain wise best technique performance were shown in figure 2 on the basis of PSNR value calculated in decibel.

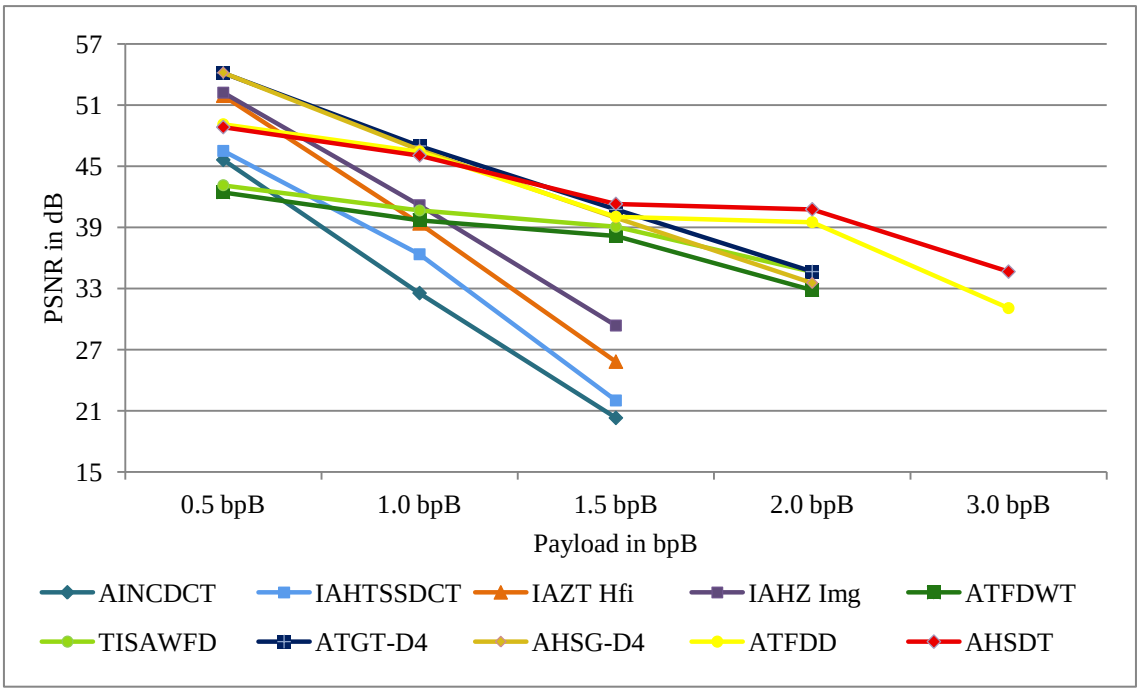

Figure 1: Performance analysis of proposed technique(s) in terms of PSNR (dB) versus payload

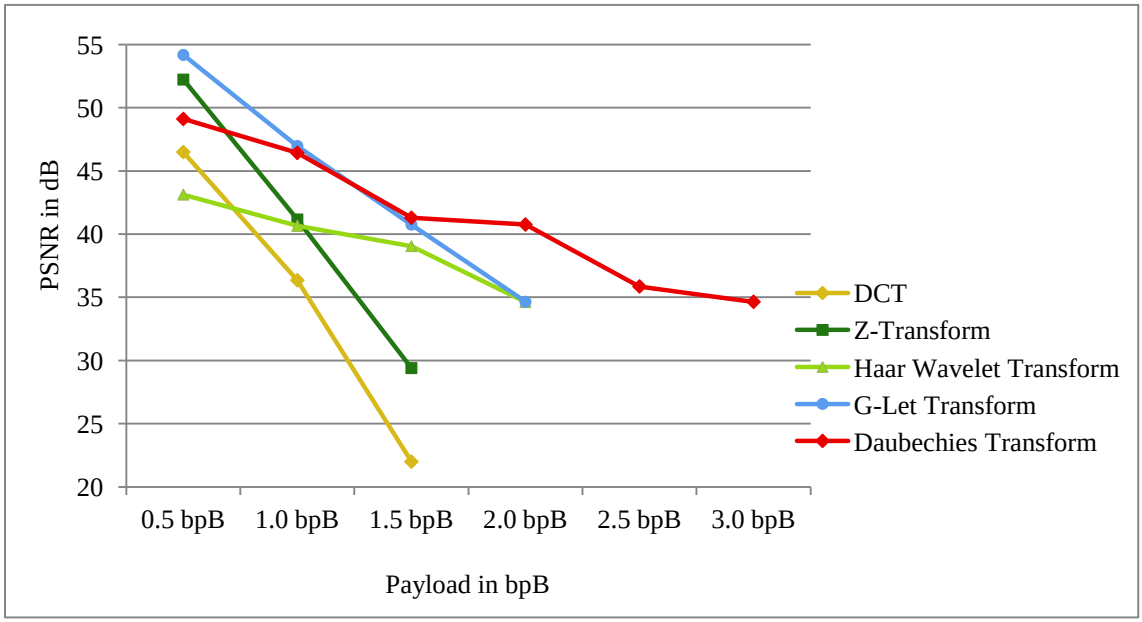

Figure 2: Performance analysis of Daubechies wavelet transform, G-Let transform, Haar wavelet-transform, Z-transform and Cosine Transform based authentication technique with varying payload in bpB

On comparison among all the proposed techniques five best authentication technique are seen one each from different transform domain. It is seen that self authentication techniques are far more robust in nature than external secret embedding based authentication techniques. Authentication techniques proposed in the thesis are of varying tolerance level shown with respect to payloads. All best five techniques from each transform domain are shown in graph plotted in figure 3.

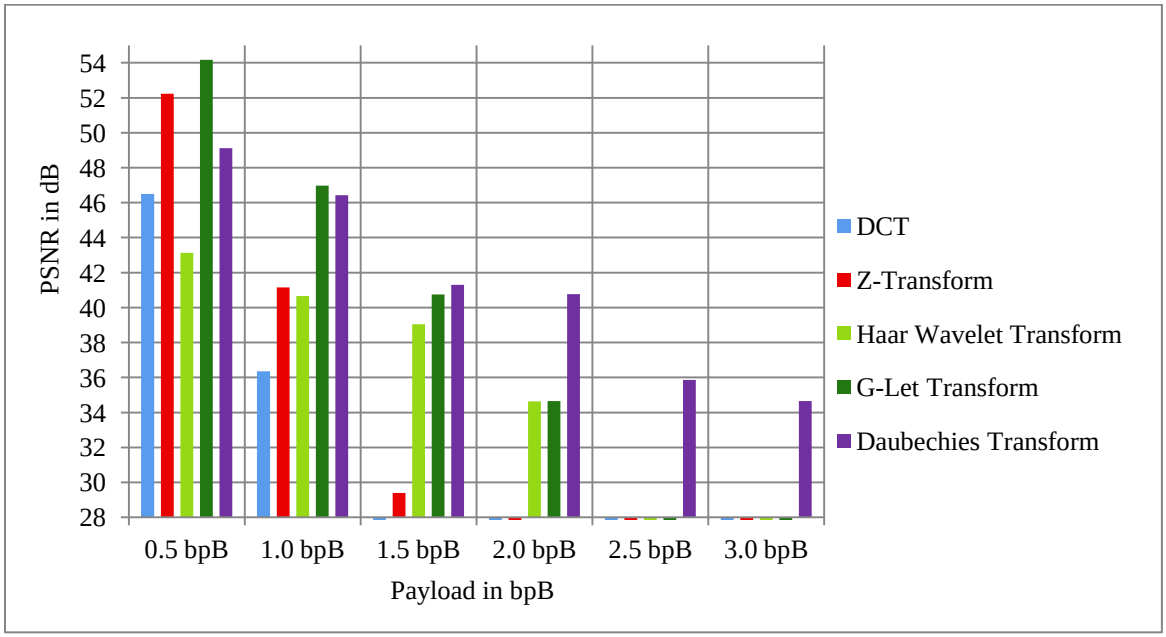

Figure 3: PSNR plotted versus payloads for five different transform based authentication techniques

For the payload of 0.5 bpB the sequence of transform domain in ascending order based on performances by the value of PSNR calculated in decibel are shown in figure 4. It shows that for the lowest payload of 0.5 bpB, Haar wavelet transform based authentication technique performs the worst and the G-Let transform based authentication technique performs the best out of the entire five transform domain based authentication techniques.

Haar wavelet transform → DCT → Daubechies transform → Z-transform → G-Let transform

Figure 4: Performance of transform domain in ascending order for 0.5 bpB of payload

For the payload of 1.0 bpB the sequence of transform domain in ascending order based on performances by the value of PSNR (dB) are shown in figure 5. It shows that for the payload of 1.0 bpB, discrete cosine transform based authentication technique performs the worst and the Daubechies transform based authentication technique performs the best out of the entire five transform domain based authentication techniques. It is also seen that Haar wavelet transform based authentication techniques perform better than Z-transform based authentication techniques.

DCT → Haar wavelet transform → Z-transform →Daubechies transform → G-Let transform

Figure 5: Performance of transform domain in ascending order for 1.0 bpB of payload

For the payload of 1.5 bpB the sequence of transform domain in ascending order based on performances by the value of PSNR (dB) as shown in figure 6. It is seen that for the payload of 1.5 bpB, discrete cosine transform based authentication technique performs the worst and the Daubechies wavelet transform based authentication technique performs the best out of the five transform domain based authentication techniques. It also seen that Z-transform based authentication techniques perform better than Haar wavelet transform based authentication techniques. Thus as the payload increases from 1.0 bpB to 1.5 bpB the transform domain changes its position in the run of betterment.

DCT → Z-transform → Haar wavelet transform → G-Let transform → Daubechies transform

Figure 6: Performance of transform domain in ascending order for 1.5 bpB of payload

For the payload of 2.0 bpB the sequence of transform domain in ascending order based on performances by the value of PSNR are shown in figure 7. It is seen that for the payload of 2.0 bpB, discrete cosine transform and Z-transform based authentication technique losses its tolerance level and the performance is worst, that of Daubechies transform based authentication technique performs the best among the other transform domain based authentication techniques. It is also seen that for 2.0 bpB of payload Haar

wavelet transform based authentication techniques and G-Let transform based authentication techniques perform very similar.

DCT → Z-transform → Haar wavelet transform → G-Let transform → Daubechies transform

Figure 7: Performance of transform domain in ascending order for 2.0 bpB of payload or higher

For the higher payload of 2.5 bpB or 3.0 bpB the tolerance levels of discrete cosine transform, Z-transform, Haar wavelet transform and G-Let transform based authentication techniques decrease below 30 PSNR calculated in decibel whereas Daubechies wavelet transform based authentication shows performances above 34 dB. From these discussions it may be concluded that for lower payload the G-Let transform based document authentication techniques are superior then other, whereas, for higher payload Daubechies transform based document authentication techniques perform the best.

The proposed techniques described in the thesis are all worth in their domain based on the payload and capacity of tolerance. Twelve techniques of document authentication proposed in the thesis are 'Traditional DCT', 'AINCDCT', 'IAHTSSDCT', 'IAZT', 'IAHZ', 'WTSIC', 'ATFDWT', 'TISAWFD', 'ATGT', 'AHSG', 'ATFDD' and 'AHSDT' categorized under five sections. The comparison of all the techniques with few existing techniques are shown in table 1 and the graphical representation of the same are shown in figure 8.

Table 1.Comparison among proposed and existing techniques for varying payload(s)

Technique	**Payload (bpB)**	**PSNR (dB)**
Yen Shun Chen (2010)	-	26.90
Li's method (2008)	0.13	28.68
SCDFT (2008)	0.12	30.10
Piyu Tsai T8 (2012)	0.0117	31.96
Luo's method (2011)	0.3	41.16
Traditional DCT (2011)	0.5	44.69
AINCDCT (2011)	0.5	45.61
IAHTSSDCT (2011)	0.5	46.49
IAZT Imaginary HF (2013)	0.5	51.91
IAHZ Imaginary coefficients(2014)	0.5	52.21
WTSIC (2010)	0.5	42.28
ATFDWT (2011)	0.5	42.43
TISAWFD (2011)	0.5	43.12
ATGT – D4	0.5	54.15

Technique	Payload (bpB)	PSNR (dB)
AHSG – D4 (2013)	0.5	54.17
ATFDD	0.5	49.10
AHSDT	0.5	48.82
AINCDCT (2011)	1.0	32.53
IAHTSSDCT (2011)	1.0	36.35
IAZT Imaginary HF(2013)	1.0	39.38
IAHZ Imaginary coefficients(2014)	1.0	41.16
WTSIC (2010)	1.0	39.58
ATFDWT (2011)	1.0	39.69
TISAWFD (2011)	1.0	40.64
ATGT– D4	1.0	46.97
AHSG – D4 (2013)	1.0	46.59
ATFDD	1.0	46.42
AHSDT	1.0	46.04
WTSIC (2010)	1.5	38.02
ATFDWT (2011)	1.5	38.16
TISAWFD (2011)	1.5	39.04
ATGT – D4	1.5	40.74
AHSG – D4 (2013)	1.5	39.94
ATFDD	1.5	40.03
AHSDT	1.5	41.29
WTSIC (2010)	2.0	32.78
ATFDWT (2011)	2.0	32.84
TISAWFD (2011)	2.0	34.62
ATGT – D4	2.0	34.64
AHSG – D4 (2013)	2.0	33.53
ATFDD	2.0	39.50
AHSDT	2.0	40.76
ATFDD	2.5	33.01
AHSDT	2.5	35.86
ATFDD	3.0	31.06
AHSDT	3.0	34.64

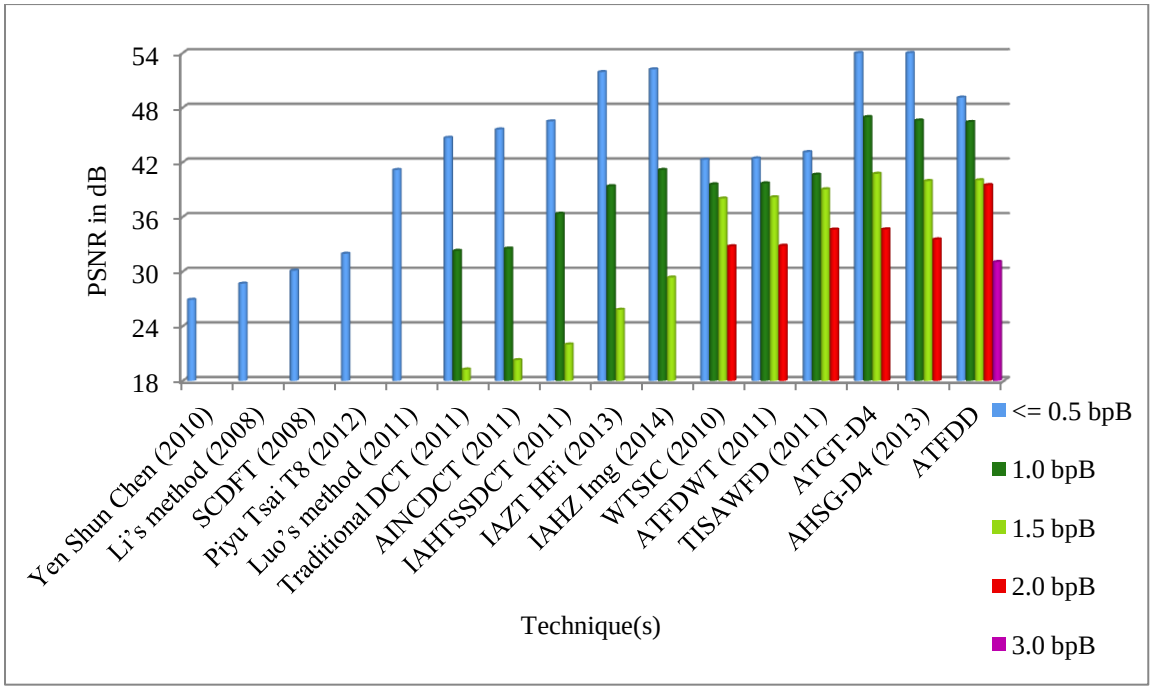

Figure 8: Comparison of PSNR versus payload for proposed and existing techniques

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International Journal

1. Madhumita Sengupta, J. K. Mandal, (2013). Hough Signature based Authentication of image through Daubechies Transform technique (HSADT). *Computer Society of India Journal of Computing, 2*(1). 83-89.
2. Madhumita Sengupta, J. K. Mandal, (September, 2013). 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.
3. Madhumita Sengupta, J.K. Mandal, (April, 2013). Wavelet based Authentication/Secret Transmission through Image Resizing (WASTIR). *AIRCC, Signal & Image Processing: An International Journal (SIPIJ), 4*(2), 59 – 68. ISSN: 0976 - 710X (Online); 2229 - 3922 (print), doi: 10.5121/sipij.
4. Madhumita Sengupta, J. K. Mandal, (July-August 2012). An Authentication Technique in Frequency Domain through Daubechies Transformation (ATFDD). *International Journal of Advanced Research in Computer Science (IJARCS), 3*(4). 236-242. ISSN No. 0976-5697.
5. Madhumita Sengupta, J. K. Mandal, (Sep-Oct 2011). 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.
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International Conference

7. Suman Mahapatra, J. K. Mandal, Madhumita Sengupta. (8^{th} – 9^{th} January, 2015). Authentication in Higher Region of Convergence of Z Transform Domain (AHRocZ). *Second International Conference on INformation Systems Design and Intelligent Applications - 2015 (INDIA-2015).* Springer AISC – 340.
8. J. K. Mandal, Mandrita Saha, Pragati Mandal, Madhumita Sengupta, Tandra Pal, Mrinal Kanti Bhowmik. (19^{th} – 21^{st} December, 2014). Adaptive Partial Image Encryption Technique based on Chaotic Map. IEEE, Fourth *International Conference of Emerging Applications of Information Technology (EAIT 2014),* Kolkata, India.
9. Madhumita Sengupta, J. K. Mandal, Sakil Ahamed Khan. (12^{th}-14^{th} December, 2014) Image Authentication in Frequency domain through G-Let Dihedral Group D3 (IAFD-D3). *Emerging ICT for Bridging the Future - Proceedings of the 49th Annual Convention of the Computer Society of India (CSI-2014),* Springer AISC Series - 337. Vol. 1, 145-152. 978-3-319-13728-5 (Online).
10. Madhumita Sengupta, J. K. Mandal, Arindam Sarkar and Tamal Bhattacharjee. (14^{th} – 15^{th} November, 2014). KSOFM Network Based Neural Key Generation for Wireless Communication. *International Conference on Frontiers of Intelligent*

Computing: Theory and applications (FICTA 2014) at Bhubaneswar, AISC-328, Vol. 2, 207- 215, DOI: 10.1007/978-3-319-12012-6_23.

11. Madhumita Sengupta and J. K. Mandal, (13th -15th December, 2013). Color Image Authentication through Visible Patterns (CAV). *ICT and Critical Infrastructure: Proceedings of the 48th Annual Convention of CSI,* Springer 2014 AISC-249 – Vol. II, 617- 625, doi: 10.1007/978-3-319-03095-1_67.

12. Madhumita Sengupta and J. K. Mandal, (10th – 12th December, 2013) "G-Let based Authentication/Secret Message Transmission (GASMT)", *IEEE, 4th International Symposium on Electronic System Design ISED- 2013, NTU Singapore,* ISBN - 978-0-7695-5143-2, 186 – 190, doi: 10.1109/ISED.2013.44.

13. Madhumita Sengupta and J. K. Mandal, (27th -28th September, 2013). Authentication through Hough transformation generated Signature on G-Let D3 Domain (AHSGD). *International Conference on Computational Intelligence: Modeling, Techniques and Applications (CIMTA- 2013),* Procedia Technology, Elsevier, Vol. 10, ISSN 2212-0173, 121-130.

14. Madhumita Sengupta, P. Mandal, Tanmoy Das and Abhijit Dey, (27th -28th September, 2013). A Novel Hash based Technique for Thermal Image Authentication. *1st International conference on Computational Intelligence: Modeling, Techniques and Applications (CIMTA- 2013),* Procedia Technology, Elsevier, Vol. 10, ISSN 2212-0173, 147-156.

15. Madhumita Sengupta and J. K. Mandal, (18th -20th February, 2013). Image coding through Z-Transform with low Energy and Bandwidth (IZEB). *The Third International Conference on Computer Science and Information Technology (CCSIT- 2013),* Bangalore, India, ISSN: 2231 - 5403, ISBN: 978-1-921987-00-7, DOI: 10.5121/csit.2013.3625, Computer Science & Information Technology (CS&IT), AIRCC, 225-232.

16. Madhumita Sengupta and J. K. Mandal, (1st -2nd December, 2012). Self Authentication of image through Daubechies Transform technique (SADT) *First International Conference on Intelligent Infrastructure, CSI- 2012, 47th Annual National Convention,* Organised by: CSI Kolkata Chapter, Proceedings published by Tata McGraw Hill Education Private Limited, ISBN(13):978-1-25-906170-7, ISBN(10): 1-25-906170-1, 249-252.

17. Madhumita Sengupta, J. K. Mandal, (26th -28th December, 2011). Authentication of Images through Non Convoluted DCT (AINCDCT). *IEEE First International Conference on Communication and Industrial Application (ICCIA-11).* Organised by: Narula Institute of Technology, 1 - 4, doi: 10.1109/ICCIndA.2011.6146672.

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20. J. K. Mandal and Madhumita Sengupta, (19th -20th Feb, 2011). Steganographic Technique Based on Minimum Deviation of Fidelity (STMDF). *IEEE, Second International Conference on Emerging Applications of Information Technology*

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21. J. K. Mandal, Madhumita Sengupta, (20^{th} -22^{nd} December, 2010). Authentication/Secret Message Transformation through Wavelet Transform based Subband Image Coding (WTSIC). *IEEE, International Symposium on Electronic System Design 2010 Bhubaneswar, India,* ISBN 978-0-7695-4294-2, doi 10.1109/ISED.2010.50. Print ISBN: 978-1-4244-8979-4, 225-229.
22. Madhumita Sengupta, J. K. Mandal, (19^{th} – 20^{th} November, 2010). Self Authentication of color image through Wavelet Transformation Technique (SAWT). *Proceeding of International Conference on Computing and Systems ICCS-2010, University of Burdwan,* ISBN 93-80813-01-5, 151-155.

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23. M. Mallick, Madhumita Sengupta and J. K. Mandal, (20^{th} February, 2015). Authentication through Hough Signature on G-Let D4 Domain (AHSG – D4), *National Conference on Computational Technologies – 2015 (NCCT'15)*, Organized by North Bengal University. Proceedings *published with International Journal of Computer Science and Engineering. 3*(1), 59 - 67, e-ISSN: 2347-2693.
24. Madhumita Sengupta, J. K. Mandal, (25^{th} August, 2012). Survey on Steganography based on Wavelet Domain. *One Day National Seminar on Intellectual Property Rights and Patent Laws, IPRPL-2012, Organized by: The Greater Kolkata College of Engineering and Management, Baruipur,* 71 - 77.
25. Madhumita Sengupta and J. K. Mandal, (15^{th} – 16^{th} March, 2012). Ownership Verification in Wavelet Domain (OVWD). *Second National Conference on Computing and Systems (NaCCS 2012), Organized by Dept. of Computer Science, University of Burdwan,* ISBN: 978-93-80813-18-9, 224 – 228.
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27. Madhumita Sengupta, J. K. Mandal, (30^{th} – 31^{st} August, 2013). Steganography on Thermal Images in Wavelet Domain (STWD). *IETE Zonal Seminar on "ICT in present Wireless Revolution: Challenges and Issues (ICTWR-2013)", Organized By: The Institution of Electronics and Telecommunication Engineers, Kolkata Centre.*

Unpublished Work

28. J. K. Mandal and Madhumita Sengupta. A novel authentication Technique in frequency domain based on G-Let D3 Transformation (ATGT). IJPS, Inderscience, ***(Submitted)***
29. Image Authentication through Hough-transform based signature in Z-domain (IAHZ).
30. Authentication of image through Hough Signature on Daubechies Transform (AHSDT)

List of Papers Presented

International Conference

1. S. Mahapatra, J. K. Mandal, Madhumita Sengupta. (8^{th} – 9^{th} January, 2015). Authentication in Higher Region of Convergence of Z Transform Domain (AHRocZ). Second International Conference on INformation Systems Design and Intelligent Applications - 2015 (INDIA-2015). Springer AISC – 340.
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5. Madhumita Sengupta and J. K. Mandal. (18^{th} -20^{th} February, 2013). Image coding through Z-Transform with low Energy and Bandwidth (IZEB). The Third International Conference on Computer Science and Information Technology (CCSIT- 2013), Bangalore, India, ISSN: 2231 - 5403, ISBN: 978-1-921987-00-7, DOI: 10.5121/csit.2013.3625, Computer Science & Information Technology (CS&IT) AIRCC, 225-232.
6. Madhumita Sengupta and J. K. Mandal. (1^{st} -2^{nd} December, 2012). Self Authentication of image through Daubechies Transform technique (SADT). First International Conference on Intelligent Infrastructure, CSI- 2012, 47th Annual National Convention, Organised by: Computer Society of India, Kolkata Chapter, Proceedings published by Tata McGraw Hill Education Private Limited, ISBN(13):978-1-25-906170-7, ISBN(10): 1-25-906170-1, 249-252.
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Dr. JYOTSNA KUMAR MANDAL
SUPERVISOR

MADHUMITA SENGUPTA
CANDIDATE