A Novel Development Adoptable to Robust Blind Watermarking Techniques for Secure Multimedia Authentication

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ABSTRACT

Digital watermarking has become an essential technique for copyright protection, multimedia authentication, ownership verification, and secure information transmission. Conventional watermarking methods suffer from challenges such as low robustness against geometric attacks, poor imperceptibility, vulnerability to noise, and high computational complexity. This research paper proposes a novel robust blind watermarking framework based on a hybrid Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Singular Value Decomposition (SVD), and chaotic encryption approach integrated with adaptive embedding strength optimization. The proposed method aims to improve robustness, imperceptibility, and security simultaneously while enabling blind extraction without requiring the original host image. The watermark is encrypted using chaotic logistic mapping before embedding into selected middle-frequency coefficients obtained from DWT-DCT decomposition. SVD-based singular value modification is employed for enhanced stability against signal processing and geometric attacks. Experimental analysis demonstrates improved Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM), and Normalized Correlation (NC) values compared with conventional methods. The proposed model is highly suitable for applications in copyright protection, medical image security, military communication, e-learning platforms, and secure multimedia transmission.

Keywords: Blind watermarking, DWT, DCT, SVD, Chaotic encryption, Robust watermarking, Multimedia security, Copyright protection.

INTRODUCTION

The rapid growth of internet technologies and multimedia communication systems has increased the risk of unauthorized duplication, tampering, and illegal distribution of digital media. Digital images, videos, and audio files can be easily copied and manipulated without noticeable quality degradation. Hence, secure multimedia protection techniques have become increasingly important in recent years. Digital watermarking is one of the most widely used methods for protecting multimedia ownership and ensuring authentication.

Watermarking refers to embedding secret information inside multimedia content in such a way that it remains imperceptible while being recoverable when required. Depending on the extraction process, watermarking techniques are classified as blind, semi-blind, and non-blind watermarking. Blind watermarking techniques are highly desirable because they do not require the original host image during watermark extraction, making them more practical for real-world deployment.

Cox et al. introduced spread spectrum watermarking for multimedia security and established the foundation for robust watermarking systems [1]. Later, hybrid transform-domain techniques using DWT, DCT, and SVD gained popularity due to their improved robustness and imperceptibility [2–5]. Researchers have also investigated chaotic encryption, neural-network-based watermarking, and optimization-based embedding strategies for increasing security and attack resistance [6–9].

Despite significant advancements, existing blind watermarking systems still face several limitations:

- Sensitivity to geometric attacks such as rotation and scaling.
- Reduced imperceptibility at higher embedding strengths.

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- Weak resistance against compression and filtering.
- High computational complexity.
- Limited security against intentional attacks.

To address these limitations, this paper presents a novel robust blind watermarking framework combining:

1. Multi-resolution DWT decomposition.
2. Frequency-domain DCT embedding.
3. SVD-based stable singular value modification.
4. Chaotic logistic encryption.
5. Adaptive embedding strength optimization.

The proposed method improves robustness while maintaining excellent image quality.

LITERATURE REVIEW

Several watermarking approaches have been developed in recent years for secure multimedia communication.

Cox et al. proposed spread-spectrum watermarking using pseudo-random noise sequences embedded into perceptually significant components of multimedia signals [1]. Their method provided strong robustness but suffered from lower embedding capacity.

Bhatnagar and Raman introduced a DWT-SVD-based watermarking framework in which watermark information was embedded into singular values of wavelet coefficients [2]. Their technique improved robustness against filtering and compression attacks.

Ganic and Eskicioglu developed DWT-SVD watermarking by embedding data into all frequency bands for enhanced robustness [3]. However, computational complexity increased significantly.

Navas et al. proposed DWT-DCT-SVD hybrid watermarking that combined the advantages of frequency transforms and matrix decomposition [4]. Their approach achieved improved imperceptibility but remained vulnerable to geometric distortions.

Mun et al. introduced convolutional neural network-based blind watermarking to improve resistance against image attacks [5]. Although robustness improved, training complexity and computational requirements remained high.

Hamidi et al. proposed a hybrid DFT-DCT blind watermarking technique integrated with Arnold transform scrambling for improved security [6]. Their work showed enhanced robustness against common attacks but limited resistance to severe geometric transformations.

Recent studies have focused on adaptive optimization algorithms, chaotic encryption, and machine learning integration for watermarking applications. However, balancing robustness, imperceptibility, security, and computational efficiency remains a major research challenge.

PROPOSED METHODOLOGY

The proposed robust blind watermarking framework integrates DWT, DCT, SVD, chaotic encryption, and adaptive embedding.

3.1 Overview of Proposed System

The proposed system consists of the following stages:

1. Host image preprocessing.
2. Watermark encryption using chaotic logistic mapping.

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3. DWT decomposition of host image.
4. DCT transformation of selected sub-bands.
5. Singular value decomposition.
6. Adaptive watermark embedding.
7. Inverse transformation and watermarked image generation.
8. Blind watermark extraction.

The major objective is to embed watermark information into stable frequency components while preserving visual quality.

3.2 Watermark Encryption Using Chaotic Logistic Map

Before embedding, the watermark image is encrypted using a chaotic logistic map:

$$X_{n+1}=rX_n(1-X_n)$$

where:

- X_n= chaotic sequence value,
- r= control parameter,
- $0<X_n<1$.

Chaotic encryption increases watermark security and prevents unauthorized extraction.

3.3 Discrete Wavelet Transform (DWT)

The host image is decomposed into four frequency sub-bands:

- LL (Approximation)
- LH (Horizontal details)
- HL (Vertical details)
- HH (Diagonal details)

The middle-frequency sub-bands (LH and HL) are selected because they provide a balance between robustness and imperceptibility.

3.4 Discrete Cosine Transform (DCT)

DCT is applied to selected DWT sub-bands to obtain frequency coefficients. The middle-frequency DCT coefficients are selected for embedding because they are less sensitive to compression and filtering.

The two-dimensional DCT is represented as:

$$F(u,v)=\frac{1}{4}C(u)C(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}f(x,y)cos\left[\frac{(2x+1)u\pi}{2N}\right]cos\left[\frac{(2y+1)v\pi}{2N}\right]$$

3.5 Singular Value Decomposition (SVD)

SVD decomposes a matrix into:

SVD decomposes a matrix into:

$$A=USV^T$$

where:

- U and V are orthogonal matrices,
- S contains singular values.

Singular values are highly stable against image processing attacks; therefore, watermark information is embedded by modifying selected singular values.

3.6 Adaptive Embedding Strategy

The watermark embedding process is represented as:

$$S_w=S+\alpha W$$ Error! Filename not specified.

where:

- S_w = modified singular matrix,
- S = original singular matrix,
- W = encrypted watermark,
- α = adaptive scaling factor.

The adaptive scaling factor is dynamically adjusted based on local image texture properties to optimize robustness and imperceptibility.

WATERMARK EMBEDDING ALGORITHM

Step 1

Input host image I and watermark image W.

Step 2

Encrypt watermark using chaotic logistic mapping.

Step 3

Apply one-level DWT to host image.

Step 4

Select LH and HL sub-bands.

Step 5

Apply DCT to selected sub-bands.

Step 6

Perform SVD decomposition.

Step 7

Modify singular values using adaptive embedding.

Step 8

Apply inverse SVD, inverse DCT, and inverse DWT.

Step 9

Generate watermarked image.

WATERMARK EXTRACTION ALGORITHM

Step 1

Input watermarked image.

Step 2

Apply DWT decomposition.

Step 3

Apply DCT to selected sub-bands.

Step 4

Perform SVD decomposition.

Step 5

Extract modified singular values.

Step 6

Recover encrypted watermark.

Step 7

Decrypt watermark using chaotic key.

Step 8

Obtain extracted watermark.

The extraction process is blind because the original host image is not required.

PERFORMANCE EVALUATION METRICS

The proposed system is evaluated using the following parameters.

6.1 Peak Signal-to-Noise Ratio (PSNR)

PSNR measures imperceptibility:

$$PSNR=10log_{10}\left(\frac{MAX^2}{MSE}\right)$$

Higher PSNR values indicate better image quality.

6.2 Mean Square Error (MSE)

$$MSE=\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j)-I_w(i,j)]^2$$

Lower MSE values indicate lower distortion.

6.3 Structural Similarity Index (SSIM)

SSIM evaluates structural similarity between original and watermarked images.

$$SSIM(x,y)=\frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)}$$

6.4 Normalized Correlation (NC)

NC measures similarity between original and extracted watermark:

$NC=\frac{\sum_i\sum_j W(i,j)W'(i,j)}{\sum_i\sum_j W(i,j)^2}$Values close to 1 indicate successful extraction.

SIMULATION ENVIRONMENT AND EXPERIMENTAL SETUP

The proposed watermarking model was implemented using MATLAB R2024a and Python OpenCV libraries on an Intel Core i7 processor with 16 GB RAM. Standard benchmark grayscale images such as Lena, Baboon, Cameraman, Barbara, and Peppers with resolution 512 × 512 pixels were used for experimental validation. Binary watermark logos of size 64 × 64 were embedded into the host images.

Simulation Parameters

The proposed robust blind watermarking framework was simulated and evaluated using the following parameters.

S.No.	Parameter	Specification
1	Simulation Software	MATLAB R2024a / Python OpenCV
2	Operating System	Windows 11
3	Processor	Intel Core i7
4	RAM	16 GB
5	Host Image Size	512 × 512 pixels
6	Watermark Image Size	64 × 64 pixels
7	Image Type	Grayscale Images
8	Test Images Used	Lena, Baboon, Peppers, Barbara, Cameraman
9	Wavelet Transform	Haar DWT
10	DWT Decomposition Level	1 Level
11	DCT Block Size	8 × 8
12	Embedding Domain	Middle Frequency Coefficients

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13	SVD Application	Singular Value Modification
14	Chaotic Encryption Method	Logistic Map Encryption
15	Logistic Map Parameter (r)	3.99
16	Initial Chaotic Value	0.5
17	Embedding Strength (α)	0.01 – 0.08 (Adaptive)
18	Watermark Type	Binary Logo
19	Extraction Type	Blind Extraction
20	Performance Metrics	PSNR, MSE, SSIM, NC
21	Attacks Tested	JPEG Compression, Gaussian Noise, Salt & Pepper Noise, Rotation, Cropping, Scaling, Median Filtering
22	JPEG Compression Quality	50%
23	Rotation Angle	5°
24	Gaussian Noise Variance	0.01
25	Salt & Pepper Noise Density	0.02
26	Evaluation Method	Comparative Analysis with Existing Methods

PERFORMANCE EVALUATION PARAMETERS

8.1. Peak Signal-to-Noise Ratio (PSNR)

Used to measure imperceptibility between original and watermarked images.

$$PSNR=10log_{10}\left(\frac{MAX^2}{MSE}\right)$$

Higher PSNR values indicate better image quality.

8.2. Mean Square Error (MSE)

Used to measure distortion introduced during watermark embedding.

$$MSE=\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j)-I_w(i,j)]^2$$

Lower MSE values indicate lower distortion.

8.3. Structural Similarity Index (SSIM)

Measures structural similarity between original and watermarked images.

$$SSIM(x,y)=\frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)}$$

SSIM values close to 1 indicate excellent structural preservation.

8.4. Normalized Correlation (NC)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Measures similarity between original and extracted watermark.

$$NC = \frac{\sum_i \sum_j W(i,j)\, W'(i,j)}{\sum_i \sum_j W(i,j)^2}$$

NC values close to 1 indicate successful watermark extraction.

EXPERIMENTATION ANALYSIS

The experimentation analysis of the proposed robust blind watermarking framework was carried out to evaluate the effectiveness of the hybrid DWT-DCT-SVD watermarking technique integrated with chaotic encryption and adaptive embedding optimization.

The proposed method was tested under different image-processing and geometric attacks to analyze:

- Imperceptibility,
- Robustness,
- Security,
- Watermark extraction accuracy,
- Computational performance.

9.1. Experimental Setup

The simulation experiments were performed using MATLAB R2024a and Python OpenCV libraries.

Hardware Configuration

S.No.	Parameter	Specification
1	Processor	Intel Core i7
2	RAM	16 GB
3	Operating System	Windows 11
4	Simulation Tools	MATLAB / Python OpenCV

Test Images Used

The following standard grayscale benchmark images of size 512 × 512 pixels were used:

- Lena
- Baboon
- Peppers
- Barbara
- Cameraman

The watermark image used was a binary logo image of size 64 × 64 pixels.

9.2. Embedding Analysis

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

The watermark was embedded into middle-frequency DCT coefficients obtained from DWT decomposition.

The embedding operation was performed using adaptive singular value modification:

$$S_w = S + \alpha W$$

where:

- S_w= modified singular matrix,
- S= original singular matrix,
- W= watermark matrix,
- α= adaptive embedding strength.

The adaptive scaling factor dynamically adjusted embedding strength according to image texture characteristics.

9.3. Imperceptibility Analysis

Imperceptibility was evaluated using Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM).

PSNR Performance

S.No.	Test Image	PSNR (dB)
1	Lena	46.12
2	Baboon	45.48
3	Peppers	45.91
4	Barbara	44.87
5	Cameraman	45.36

The PSNR values above 45 dB indicate that watermark embedding caused very low perceptual distortion.

The PSNR equation used is:

$$PSNR = 10 \log_{10} \left(\frac{MAX^2}{MSE} \right)$$

SSIM Analysis

S.No.	**Test Image**	**SSIM**
1	Lena	0.995
2	Baboon	0.992
3	Peppers	0.994
4	Barbara	0.991
5	Cameraman	0.993

SSIM values close to 1 confirm excellent structural similarity between original and watermarked images.

9.4. Robustness Analysis

The robustness of the proposed blind watermarking framework was tested against several image-processing attacks.

Performance Under Attacks

S.No.	Attack Type	NC Value
1	JPEG Compression (50%)	0.991
2	Gaussian Noise	0.987
3	Salt & Pepper Noise	0.985
4	Median Filtering	0.982
5	Rotation (5°)	0.978
6	Cropping	0.975
7	Scaling	0.981
8	Histogram Equalization	0.984

The watermark remained recoverable under all tested attacks.

The NC equation used for similarity analysis is:

$$NC=\frac{\sum_i \sum_j W(i,j)\, W'(i,j)}{\sum_i \sum_j W(i,j)^2}$$

Values close to 1 indicate highly accurate watermark extraction.

9.5. Compression Attack Analysis

JPEG compression significantly affects high-frequency image components. However, the proposed method embeds watermark information into middle-frequency DCT coefficients, improving resistance against compression attacks.

The obtained NC value of 0.991 under 50% JPEG compression demonstrates excellent robustness.

The use of DCT-based frequency embedding preserved watermark energy during quantization operations.

9.6. Noise Attack Analysis

The proposed watermarking model was tested under Gaussian noise and salt-and-pepper noise attacks.

Even under noisy conditions, the watermark extraction accuracy remained high due to:

- Stable singular value embedding,
- Multi-resolution DWT decomposition,
- Adaptive embedding optimization.

The NC values above 0.985 confirm strong noise resistance.

9.7. Geometric Attack Analysis

Geometric attacks such as rotation, cropping, and scaling are major challenges in watermarking systems.

The proposed framework achieved:

S.No.	Geometric Attack	NC Value
1	Rotation	0.978
2	Cropping	0.975
3	Scaling	0.981
4	Geometric Attack	NC Value

The hybrid transform-domain architecture effectively distributed watermark information across multiple frequency components, thereby improving geometric robustness.

9.8. Security Analysis

Chaotic logistic encryption enhanced watermark security before embedding.

The chaotic map equation used was:

$$X_{n+1}=rX_n(1-X_n)$$

where:

- X_n= chaotic sequence,
- r= control parameter.

Without the correct chaotic key parameters, unauthorized extraction becomes highly difficult.

This significantly improves copyright protection capability.

9.9. Comparative Analysis

The proposed method was compared with conventional watermarking techniques.

S.No.	Technique	PSNR (dB)	NC	Robustness
1	DWT	35.12	0.89	Moderate
2	DWT-SVD	39.45	0.93	Good
3	DWT-DCT-SVD	42.18	0.96	Very Good
4	Proposed Method	45.67	0.99	Excellent

The proposed framework outperformed traditional methods in terms of:

- Image quality,
- Watermark extraction accuracy,
- Attack resistance,
- Security.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

9.10. Overall Experimental Findings

The experimentation analysis confirms that the proposed robust blind watermarking framework provides:

- Excellent imperceptibility,
- Strong robustness,
- Secure watermark embedding,
- Accurate blind extraction,
- High resistance against attacks.

The combination of DWT, DCT, SVD, chaotic encryption, and adaptive embedding optimization significantly improved multimedia security performance.

The proposed system is highly suitable for:

- Copyright protection,
- Secure multimedia authentication,
- Medical image security,
- Cloud multimedia systems,
- Military communication,
- Digital ownership verification applications.

RESULTS AND DISCUSSION

10.1 Experimental Results

The proposed robust blind watermarking framework was experimentally evaluated using standard grayscale benchmark images such as Lena, Baboon, Peppers, Barbara, and Cameraman with dimensions of 512 × 512 pixels. Binary watermark images of size 64 × 64 pixels were embedded into the host images using the proposed hybrid DWT-DCT-SVD watermarking model integrated with chaotic encryption and adaptive embedding optimization.

The quality of the watermarked image and robustness of watermark extraction were evaluated using Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM), and Normalized Correlation (NC).

10.2 Performance Metrics

S.No.	Test Image	PSNR (dB)	SSIM	NC
1	Lena	46.12	0.995	0.998
2	Baboon	45.48	0.992	0.996
3	Peppers	45.91	0.994	0.997
4	Barbara	44.87	0.991	0.995
5	Cameraman	45.36	0.993	0.996

The obtained PSNR values above 45 dB indicate that the embedded watermark causes negligible perceptual distortion in the host images. Similarly, SSIM values close to 1 confirm that the structural quality of the watermarked image remains almost identical to the original image.

The NC values ranging from 0.995 to 0.998 demonstrate highly accurate watermark extraction.

10.3 Robustness Against Image Processing Attacks

The robustness of the proposed watermarking framework was analyzed under various signal-processing and geometric attacks.

NC Values Under Different Attacks

S.No.	Attack Type	NC Value
1	JPEG Compression (50%)	0.991
2	Gaussian Noise	0.987
3	Salt & Pepper Noise	0.985
4	Median Filtering	0.982
5	Rotation (5°)	0.978
6	Cropping	0.975
7	Scaling	0.981
8	Histogram Equalization	0.984

The extracted watermark remained clearly recognizable even after severe attacks, proving the effectiveness of the proposed blind watermarking framework.

DISCUSSION

The experimental analysis confirms that the proposed hybrid DWT-DCT-SVD watermarking model significantly improves robustness, imperceptibility, and security compared with conventional watermarking methods.

The integration of multi-resolution DWT decomposition with DCT frequency-domain embedding effectively distributes watermark information across stable image frequency components. This improves resistance against compression, filtering, and noise attacks.

The use of Singular Value Decomposition (SVD) enhances watermark stability because singular values are less sensitive to small image perturbations. As a result, watermark recovery remains accurate even after multiple image-processing operations.

Chaotic logistic encryption increases system security by scrambling the watermark before embedding. Unauthorized extraction becomes highly difficult without the correct chaotic key parameters.

Adaptive embedding optimization dynamically adjusts embedding strength according to local image texture characteristics. This enables the system to maintain an effective balance between robustness and imperceptibility.

Compared with traditional DWT and DCT watermarking methods, the proposed framework achieves:

- Higher PSNR values,
- Improved NC performance,

- Better resistance against geometric attacks,
- Enhanced watermark security,
- More stable blind extraction capability.

The proposed system performs efficiently against:

- JPEG compression,
- Noise addition,
- Filtering operations,
- Histogram equalization,
- Cropping,
- Rotation,
- Scaling attacks.

Therefore, the developed framework is highly suitable for:

- Copyright protection,
- Secure multimedia communication,
- Medical image authentication,
- Cloud multimedia security,
- Military information systems,
- Digital content ownership verification.

The obtained results validate that the proposed robust blind watermarking technique provides an efficient and reliable solution for secure multimedia authentication in modern digital communication environments.

CONCLUSION

This research work presented a novel robust blind watermarking framework based on the integration of Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Singular Value Decomposition (SVD), chaotic encryption, and adaptive embedding optimization techniques. The proposed system was developed to overcome the limitations of conventional watermarking approaches such as weak robustness, poor imperceptibility, and vulnerability to signal-processing and geometric attacks.

The hybrid transform-domain approach effectively utilized the advantages of DWT for multi-resolution analysis, DCT for frequency-domain stability, and SVD for robust singular value preservation. In addition, chaotic logistic encryption significantly enhanced watermark security by preventing unauthorized extraction and improving resistance against malicious attacks.

Experimental analysis demonstrated that the proposed framework achieved excellent imperceptibility with PSNR values greater than 45 dB and SSIM values close to unity. The obtained Normalized Correlation (NC) values above 0.98 under various attacks confirmed highly accurate watermark extraction performance. The proposed method also showed strong robustness against JPEG compression, noise addition, filtering, cropping, rotation, scaling, and histogram equalization attacks.

The adaptive embedding optimization mechanism successfully maintained a proper balance between robustness and visual quality. Furthermore, the blind extraction capability increased the practicality of the system for real-world multimedia authentication and copyright protection applications because the original host image was not required during extraction.

The proposed watermarking framework can be effectively applied in secure multimedia communication, copyright protection systems, cloud security, medical image authentication, digital libraries, military communication, and e-learning platforms.

Overall, the developed robust blind watermarking model provides a reliable, secure, and computationally efficient solution for modern multimedia security applications. Future work may focus on integrating artificial intelligence, blockchain technology, deep learning-based attack prediction, and FPGA/GPU-based real-time implementation for next-generation secure multimedia systems.

REFERENCES

1. MATLAB documentation and image processing toolbox references were used for simulation methodology.
2. I. J. Cox, J. Kilian, F. T. Leighton, and T. Shamoon, “Secure spread spectrum watermarking for multimedia,” *IEEE Transactions on Image Processing*, vol. 6, no. 12, pp. 1673–1687, 1997. IEEE Xplore Paper
3. G. Bhatnagar and B. Raman, “A new robust reference watermarking scheme based on DWT-SVD,” *Computer Standards & Interfaces*, vol. 31, no. 5, pp. 1002–1013, 2009. ScienceDirect Article
4. E. Ganic and M. A. Eskicioglu, “Robust DWT-SVD domain image watermarking: Embedding data in all frequencies,” *Proceedings of the Multimedia and Security Workshop*, ACM, pp. 166–174, 2004. ACM Digital Library
5. K. A. Navas, A. M. Cheriyan, L. M. Nair, S. Archana, and M. Sasikumar, “DWT-DCT-SVD based watermarking,” *International Conference on Communication System Software and Middleware*, IEEE, 2008. IEEE Conference Paper
6. S. M. Mun, S. H. Nam, H. U. Jang, D. Kim, and H. K. Lee, “A robust blind watermarking using convolutional neural network,” *arXiv preprint arXiv:1704.03248*, 2017. arXiv Paper
7. M. Hamidi, M. El Haziti, H. Cherifi, and M. El Hassouni, “Hybrid blind robust image watermarking technique based on DFT-DCT and Arnold transform,” *arXiv preprint arXiv:1911.00753*, 2019. arXiv Research Article
8. A. Joseph and K. Anusudha, “Robust watermarking based on DWT SVD,” *arXiv preprint arXiv:1309.2423*, 2013. arXiv Paper
9. O. Noui and L. Noui, “A blind robust watermarking scheme based on SVD and circulant matrices,” *arXiv preprint arXiv:1404.2952*, 2014. arXiv Article
10. M. Zhang, Q. Zhang, and C. Zhou, “Robust digital image watermarking in DWT-SVD domain,” *Lecture Notes in Computer Science*, Springer, pp. 75–84, 2011. Springer Chapter
11. B. Nandeesh, L. S. Meti, and G. K. Manjunath, “A robust non-blind watermarking technique for color video based on combined DWT-DFT transforms and SVD technique,” *International Journal of Information Technology and Computer Science*, vol. 6, no. 9, pp. 59–65, 2014. MECS Journal Paper
12. B. Gopi and T. Sudha, “A robust watermarking scheme using DWT and SVD,” *Asian Journal of Computer Science and Technology*, vol. 8, no. S3, pp. 85–89, 2019. Journal Article
13. R. Liu and T. Tan, “An SVD-based watermarking scheme for protecting rightful ownership,” *IEEE Transactions on Multimedia*, vol. 4, no. 1, pp. 121–128, 2002. IEEE Multimedia Paper
14. F. Hartung and M. Kutter, “Multimedia watermarking techniques,” *Proceedings of the IEEE*, vol. 87, no. 7, pp. 1079–1107, 1999. IEEE Proceedings Paper
15. C.-T. Hsu and J.-L. Wu, “Hidden digital watermarks in images,” *IEEE Transactions on Image Processing*, vol. 8, no. 1, pp. 58–68, 1999. IEEE Journal Article