A Robust Dual Watermarking using Grey Wolf Optimization, Selective Encryption and Fast Flexible De-Noising Convolution Neural Network

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Abstract – Digital data interchange in IoT systems has flourished with the advancement of industrial internet technologies. Particularly, more and more digital images created by intelligent and industrial equipment are sent there are security concerns related to the website, server, and cloud. To accomplish this issue, in this article a secure watermarking approach is suggested in this research to effectively improve security, invisibility, and resilience at the same time. The adequate coefficient for information embedding is first determined using an assortment of transform domain techniques Discrete-Wavelet-Transform (DWT), Heisenberg- decomposition (HD), and Tensor-singular-value-decomposition (T-SVD). Using the grey wolf optimization (GWO) approach, we estimated the appropriate embedding factors to provide a reasonable compromise between robustness and invisibility. To enable the suggested approach to offer an additional level of security, a selective encryption technique is used on the watermark image. Moreover, FFDNet—a quick and adaptable de-noising convolutional-neural–network is working to increase the robustness-of-the suggested algorithm. The results demonstrate that the recommended watermarking method generates exceptional imperceptibility, resilience, and security against standard attacks. Additionally, the comparison demonstrates that the suggested algorithm performs better than alternative strategies. The following metrics were reached: 51.6966 dB, 0.9944, 0.9961, and 0.2849 for the peak-signal- to-noise ratio (PSNR), Structural-Similarity-Index (SSIM), number of changing pixels per second (NPCR), and unified-averaged-changed-intensity (UACI) average scores.

Keywords – Watermarking, Robustness, Invisibility DWT, TSVD, HD, Encryption, Optimization, FFDNet.

I. INTRODUCTION

In the multimedia industry, unauthorized communication channels like the Internet make it simple to transmit digital media content very easily, also unrestricted copying of multimedia content is allowed [1][2]. It is simpler to copy or alter shared digital material due to the accessibility of digital image manipulation tools. Furthermore, identity theft is a major problem in every nation, which makes information security research more difficult [3]. The protection of digital content owners against tampering and piracy is therefore significantly dependent on adequate technology. At the moment, watermarking algorithms are a highly advised affordable way to ensure the security of these digital media. Different types of hidden mark(s) are imperceptibly embedded in media during watermarking to preserve its security [4][5]. The following are the main benefits of watermarking: (1) it reduces bandwidth and storage requirements, (2) it resolves copyright violations and ownership conflicts, (3) it offers protection against manipulation, and (4) It functions as a term. The mutually exclusive requirements for broad watermarking techniques are watermark capacity, robustness, and invisibility [6]. It is difficult to offer a reasonable trade-off between these parameters, though. In many real-world applications, security and affordability are also crucial criteria. Depending on the embedding space, watermarking in the transform domain or spatial domain is commonly employed. The spatial domain watermarking systems perform poorly in terms of resilience against attacks while being clear and simple. However, transform domain techniques are very resilient to intrusions [7][8].

Researchers have been working on finding appropriate optimization, encryption, or encryption-compression-based systems to carry out invisible, reliable, and secure watermarking in recent years. The majority of techniques don't meet watermarking criteria when considering balanced trade-offs.

Therefore, in this paper, a fast, flexible de-noising convolutional neural network employing a transformed domain is constructed together with an optimization and encryption-founded watermarking solution. Some of this work's primary contributions are:

1. To carry out our scheme DWT, HD, and T-SVD are combined. This pair contributes to improving the security, invisibility, and resilience of the watermark [9][10][11] Grey Wolf Optimization's methodologies are applied to provide a well-balanced trade-off between resilience and invisibility to determine the optimal embedding strength for mark data embedding. [12].
2. To provide an extra level of security during transmission, Watermark data is encrypted using a selective encryption technique. [13].
3. This approach resolves the problems of copyright infringement and image content integrity problems by hiding text watermarks in cover media using the pseudo magic square technique [14].
4. To increase the resilience of the approach, FFDNet is utilized in the recovered watermark image [15].
5. Experimental research using the Kodak and USI-SIPI datasets validated the effectiveness of the proposed method, indicating that it has promise for secure media applications. [16] [17].

The order of the remaining paper is set up as Section 2 the relevant cutting-edge techniques are compiled in "Related works," which is followed by a comprehensive explanation of the encryption, extraction, embedding optimization, and de-noising of recovered data in Section 3 of the recommended approach. Section 4 provides an analysis of the findings, and Section 5 provides a summary of the work.

II. RELATED WORKS

Qingtang et al. [18] created a system for copyright defense of color pictures. First, each component of the cover picture is subjected to the Contourlet transform (CT), which decomposes the chosen LL sub-band into the appropriate block. To strengthen the security of their technique, an encrypted mark is created and then placed in the converted block. It was demonstrated that their approach worked well against frequent attacks.

Chakraborty et al. [19] compared SVD and RSVD-based watermarking techniques in the transform domain. This system first divides the transmission image into numerous sub-bands using DWT, and then DCT is used to convert the chosen sub-band. The single values in the carrier image can also be altered using RSVD. This method's experimental study demonstrates that RSVD outperforms the general SVD-based watermarking strategy regarding speed.

Golda et al. [20] In this work, new methods of water-marking are presented utilizing single- value decomposition (SVD) and discrete wavelet transformation (DWT), and the social group optimization algorithm (SGOA), which has been effectively used to solve image processing issues. Even after switching the input and watermark image parameters, For all four of the simulation examples, the PSNR and SSI stayed unchanged.

Ingaleshwar et al. [21] A potent picture watermarking method known as Water Chaotic Fruit Fly Optimization algorithm-based Deep Convolutional neural network (WCFOA-based Deep CNN) is developed in order to embed the hidden message into the cover media. The incorporating process is carried out via the wavelet transform, and the fitness value evaluation determines which region is optimal.

Pallaw [22] A hybrid watermarking method according to optimization methods inspired by nature, the Slantlet transform, and randomized-singular value decomposition. The watermark image has been encrypted using the XOR encryption technique to increase the X-ray image's authenticity.

Sharma et al. [23] The author of this paper focuses on problems that are essential to security in the most popular domains, such as online picture stores, digital photography copyrighting, etc. Lifting Wavelet Transform (LWT) is used as the baseline in a blind kind of picture watermarking system that is proposed. The watermark is extracted using the coefficients of Hu's Invariant moments as a key. The optimization of the method makes use of a stochastic version of the Firefly algorithm (FA).

Sattarpoor et al. [24] The proposed method uses a Whale- Optimization-Algorithm (WOA) based on the Graph-based-Transform (GBT), Singular-Value- Decomposition (SVD), and Discrete-Wavelet-Transform (DWT), determine the ideal Blocks and embedding coefficient value in the images. The three parameters PSNR and NC in the case of an image attack form the basis of the objective function created for this task.

Lakshmi et al. [25] To protect image copyrights, This article describes a reversible watermarking method using Modified Quadratic Difference Expansion (MQDE) and fractal encryption. Tromino's L-shaped theorem is used to apply fractal encryption to watermarks to increase security. Furthermore, the cover image is subject to Cuckoo Search-Grey Wolf Optimization (CSGWO) to maximize block allocation for the insertion of an encrypted watermark, significantly increasing its imperceptibility.

Sattarpour S [26] The recommended approach, which is based on Graph-Based-Trans-form (GBT), Singular-Value-Decomposition (SVD), and Discrete-Wavelet-Transform (DWT), uses the Whale-Optimization-Algorithm (WOA) to determine the ideal values for the embedding parameters. The cover image is first transformed using the DWT and GBT.

Agarwal, C et al. [27] A new method for embedding watermarks into grayscale pictures that utilizes the Harmony-Search-Algorithm (HSA). The HSA optimizes the Objective Function to produce the optimal Multiple-Scaling-Factors (MSFs) for embedding the watermark coefficients in the most suitable image coefficients in the hybrid transform domain.

Rai, M.et al. [28] The author of this paper proposed to use the Human Visual System (HVS), Fuzzy Inference Systems (FIS), Back Propagation Neural Network (BPNN), and Shark Smell Optimization (SSO) to develop a reliable and secure watermarking system.

Mahto, D.K [29] The best embedding strength factor is found by the algorithm using firefly optimization, which maintains a significant trade-off between robustness and quality. The numerous markings on the various carrier media channels are then hidden using a combination of spatial and transformed domain schemes, with the best strength factor being used.

III. PROPOSED METHODOLOGY

The design proposed in this study consists of five stages: (a) watermark encryption; (b) watermark embedding process; (c) watermark optimization process; (d) watermark data recovery; and (e) de-noising watermark data. The main idea behind multiple watermark embedding is to use DWT–HD–TSVD to decompose the picture on the cover. The single value of the picture watermark data is then covertly embedded into the lower frequency (LL) sub- band of the cover using the proper scaling factor. Similarly, the hash value of the text watermark is embedded into the HH frequency (HH) sub-band of the cover using the pseudo magic square technique. To bolster the security of the image watermark, we also use a selective encryption method prior to embedding. Additionally, FFDNet is employed to improve the scheme's resilience on the watermark image recovery. **Fig 1** depicts a simplified block diagram of the various procedures using the suggested approach. The suggested method's subsection provides a detailed explanation of the encryption, embedding, optimisation, extraction, and de-noising processes. **Table 1** provides a summary of the annotation

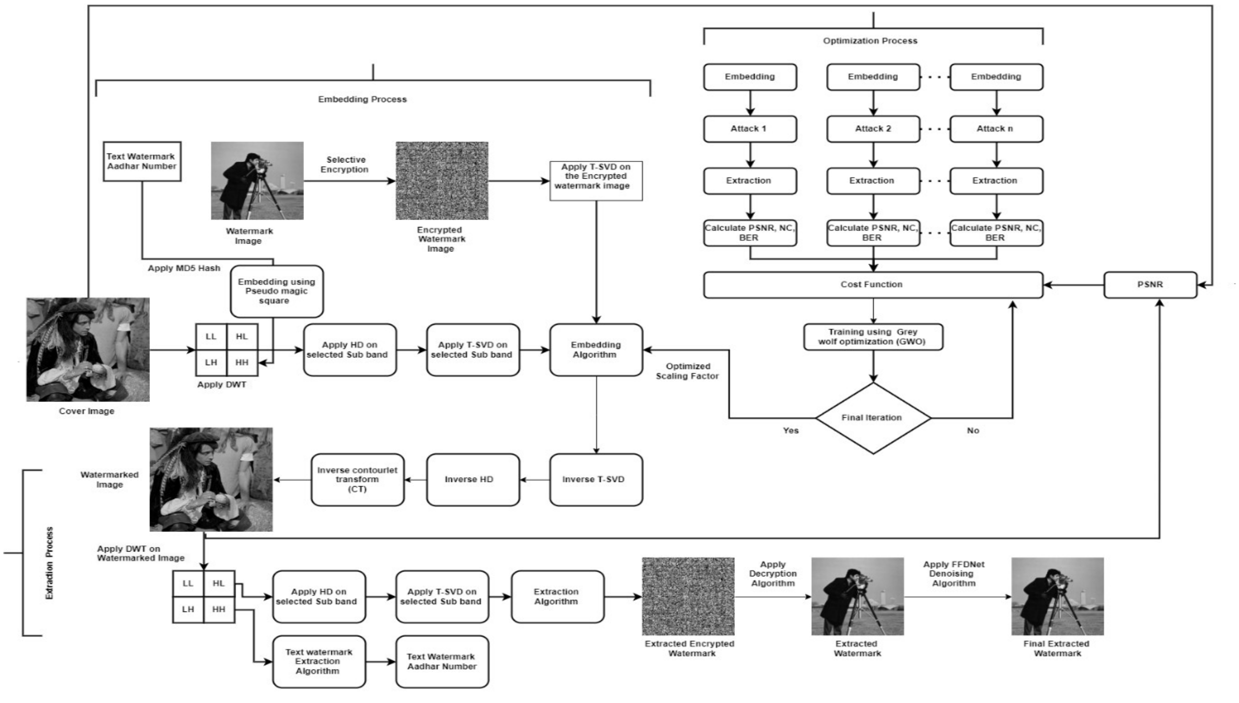

Fig 1. The Proposed Watermark Algorithm**.**

Table 1. Description of notations

Notation	Description	Notation	Description
WI	Watermark Image	EWI	Encrypted Watermark Image
TW	Text Watermark	WCI	Watermarked Image
CI	Cover image		
LL,LH,HL,HH	cover image sub-bands	P, H	He is en-berg and Orthogonal matrix of the cover image
U_H, S_H, V_H,	Diagonal and Orthogonalmatrix of cover image	U_{EWI}, S_{EWI}, V_{EWI},	Diagonal and Orthogonalmatrix of watermark
len	Length of hash value	α	Scaling-factor
PMS	pseudo magic square	$Cost_{fun}$	Cost-function
Num	Total Number of attacks	LLw, LHw,HLw, HHw	Watermarked Image image sub-bands
Pw, Hw	Hessen-berg and Orthogonal matrix of watermarked image	U_{Hw}, SHw, VHw	Diagonal and Orthogonal matrix of watermarked image
RWI	Recovered watermark	RTW	Recovered Text watermark

Encryption Process

In this subsection, Selective encryption is used to encrypt the watermark image (WI) in order to increase the system's security. The watermarked image (WI)'s selective key matrix is subjected to an XOR operation to create the encrypted watermark image (EWI). Algorithm 1 provides a detailed explanation of the watermark image encryption process.

Algorithm 1: Encryption of watermark image Input: Watermark Image(WI) **Output:** Encrypted Watermark Image(EWI)
Begin 1. Row ← size(WI,1); 2. Col ← Size(WI,2) 3. TWI ←bit xor(key, WI) 4. EWI ← reshape(TWI,[row col]); **Return Encrypted Watermark Image(EWI)**

Embedding Process

This approach involves providing the embedding mechanism with input in the form of a cover image (CI), watermark image (WI), and hash value of text watermark (TW). As an output, a watermarked image (WCI) is produced. The technique of embedding is explained in depth in Algorithm 2.

Algorithm 2: Embedding Process **Input:** Encrypted Watermark Image(EWI) , Text Watermark (TW) **Output:** Watermarked Image (WCI)
Begin 1. [LL,LH,HL,HH] ← DWT(CI, 'Haar');[P, H] 2. ← HD(LL); 3. $[U_H, S_H, V_H,]$ ← T-SVD(H) 4. $[U_{EWI}, S_{EWI}, V_{EWI},]$ ← T-SVD(EWI) 5. $S_{HEWI} \leftarrow S_H + \alpha \times S_{EWI}$ 6. $H_W \leftarrow U_H \times S_{HEWI} \times V^T_H$ 7. $LL_W \leftarrow P \times H_W \times P^T$ 8. $Hash_{TW}$ MD5(TW) 9. len ← Length ($Hash_{TW}$); 10. HH_W← PMS (HH, $Hash_{TW}$, α , len); 11. WCI← IDWT(LL_W,LH,HL, HH_W, 'Haar') **Return Watermarked Image(WCI)**

Optimization Process

In this section, the calculation of the embedding factor α is explained. A reasonable trade- off between robustness and imperceptibility may be found by using GWO to pick an optimal value for alpha. In equation (1), the fitness function is defined as follows:

$$Cost_{fun} = [\alpha \times (\frac{1}{PSNR})] + [(\frac{1}{sum} \times \sum_{p=1}^{sum} NC(WCI, RWI)_p)] \quad (1)$$

Where "α" is a stabilising factor that aids in balancing the impacts of robustness and imperceptibility. Algorithm 3 provides a summary of the whole procedure for figuring out the appropriate scaling factor for the embedding of a watermark.

Algorithm 3: Optimization-Process
Input: Cover-Image (CI) Encrypted-Watermark-Image(EWI) , Text-Watermark (TW)
Output: α

Begin
1. Num ← Count (attack);
2. [PSNR] ← embedding (CI, EWI, TW);
3. [NC, BER] ← extraction (WCI);
4. for Y ← Num do
5. [NC[Y], BER[Y]] ← extraction (WCI, attack[Y]);
6. end for
7. $Cost_{fun}$← $Cost_{fun}$ ((PSNR, BER, NC), (NC [1], BER [1]) (NC [Sum], BER [Sum]));
8. α ← GWO ($Cost_{fun}$);

Return α

Extraction Process

The technique of reverse embedding is employed to extract the watermark. In this process, the input for the extraction procedure is Watermarked Images (WCI). In order to obtain the final decrypted watermarked image and text watermark, as well as the encrypted watermark and hash value text watermark, Watermarked Images (WCI) are first broken down using the DWT- HD-TSVD extraction algorithm. **Fig 1** describes the watermark extraction process. Algorithm 4 outlines the different extraction process processes

Algorithm 4: Extraction Process Input: Watermarked Image (WCI)
Output: Recovered watermark (RWI), Recovered Text watermark (RTW),

Begin
1. [LLw,LHw,HLw,HHw] ← DWT(WCI, 'Haar');
2. [Pw, Hw] ← HD(LLw);
3. [U_{Hw}, S_{Hw}, V_{Hw}] ← T-SVD(Hw)
4. S_H V_H ← $\frac{S_{Hw} - S_H}{\alpha}$
5. Y' ← [U_{EWI}× S_H V_H× V^T_{EWI}]
6. EWI ← [P × Y' × P^T]
7. RWI ← Decrypt(EWI)
8. RTW ← PMS(HHw)

Return Watermarked Image(WCI)

The De-Noise Process

To improve the resilience of the recovered watermark, FFDNet is employed. A pre-trained, quick, and adaptable de-noising convolutional-neural-network is embed with the deep learning toolkit. Algorithm 5 provides a summary of the de-noising process for recovered data.

Algorithm 5: De-noising process Input:

Recovered watermark (RWI)

Output: Final Recovered watermark (FRWI)

Begin
1 Net=denoisingnewtork (FFDNet)
2 FRWI =denoisingnewtork (RWI, Net)

Return Final Recovered watermark (FRWI)

IV. EXPERIMENTAL ANALYSIS &RESULTS

A thorough analysis of the outcomes from the suggested resilient digital watermarking technique is given in this section. To complete the recommended task, a 2.30 GHz PC running Windows 10 with 16 GB of RAM and a 1 TB hard drive were used. The proposed algorithm was validated utilizing the USI-SIPI and Kodak datasets presented in **Fig 2** are all of the 512 x 512 grayscale **Fig 3** displays the watermark and cover images where the watermark image size is 256 × 256 and 60-bit of a hash value of text watermark is taken for embedding. We conducted an invisibility analysis using Peak-Signal-Noise-Ratio (PSNR) and Structural- Similarity-Index-Measure (SSIM) [10], as well as a robustness analysis using Normalized-Coefficient (NC) [10] and Bit-Error-Rate (BER) to assess and validate the suggested approach [10]. The robustness and invisibility of the suggested technique are shown in **Table 2** for 15 test photos from the Kodak and USI-SIPI datasets. The test image's greatest PSNR value was **53.1572** dB, and it was noted that their average PSNR value was **51.6966** dB. Comparably, the test images' maximum SSIM value was **0.9988**, and it was noted that their average SSIM value was **0.9944**. Furthermore, the NC and BER values in every situation are 1 and 0, in that order The average UACI score is 0.2849 and the average NPCR is 0.9961, demonstrating the encryption system's strong security features. Consequently, the outcomes displayed in this table demonstrate the promising nature of the recommended approach.

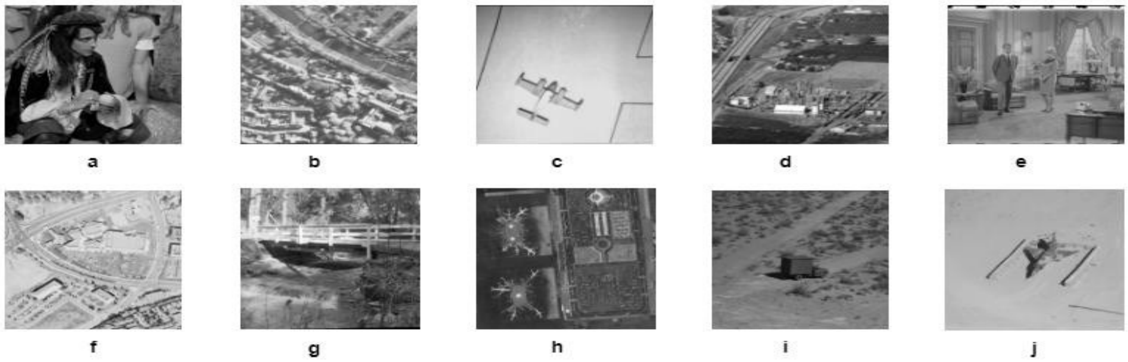

Fig 2. A few of The Host Images.

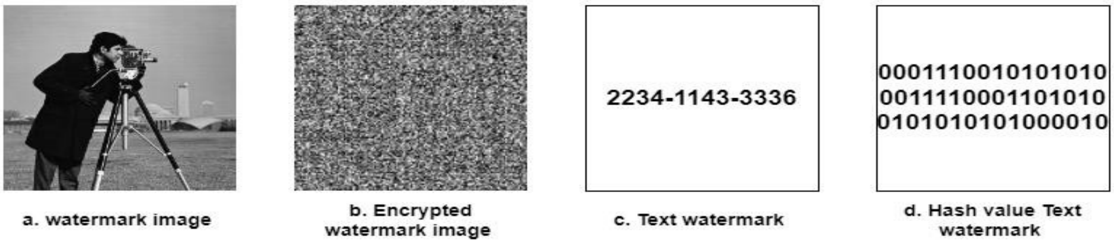

Fig 3. Watermark Data.

Table 2. Evaluation of performance using the Kodak and USISIPI datasets

Test Images	**PSNR**	**SSIM**	**NC**	**BER**	**NPCR**	**UACI**
15 Test images from Kodak and USI-SIPI datasets	51.7117	0.9985	1	0	0.9972	0.2889
	53.1572	0.9904	1	0	0.9967	0.2895
	52.0324	0.9904	1	0	0.9964	0.2892
	52.1001	0.9922	1	0	0.9968	0.2803
	51.8797	0.9967	1	0	0.9988	0.2819
	51.7523	0.9962	1	0	0.9992	0.2986
	51.1222	0.9936	1	0	0.9942	0.2807
	52.1022	0.9940	1	0	0.9932	0.2801
	50.3346	0.9966	1	0	0.9950	0.2889
	52.4598	0.9922	1	0	0.9970	0.2898
	50.6632	0.9912	1	0	0.9976	0.2805
	51.8892	0.9972	1	0	0.9926	0.2813
	50.7766	**0.9988**	1	0	0.9954	0.2813
	50..7722	0.9948	1	0	0.9956	0.2813
	51.7722	0.9944	1	0	0.9958	0.2813
Average Score	**51.6966**	**0.9944**	**1**	**0**	**0.9961**	**0.2849**

Additionally, to measure the outcomes the NC and BER are assessed for various Attack types, and **Table 3** displays the average scores for 15 test images from USI-SIPI and Kodak datasets. **Fig 4** and **Table 3** show that all Attacks that are taken into consideration reach an NC with a satisfactory score or NC ≥ 0.7. Similar to this, the average BER score obtained is zero, except cropping attack. The NC and PSNR comparison analysis scores, when compared to a number of other pertinent approaches, are displayed in **Fig 5** and **Table 4**, respectively. **Fig 5** demonstrates the excellent performance and encouraging outcomes that our average NC achieves and **Table 4** shows that the obtained PSNR score performs better than the more modern methods. To assess the encryption scheme's security properties, a histogram analysis is employed. The frequency distribution of the picture pixel is displayed by the histogram assessment (refer to **Fig 6**). The encrypted image displays consistent histograms (**Fig 6[b]**), demonstrating the encryption algorithm's high level of security.

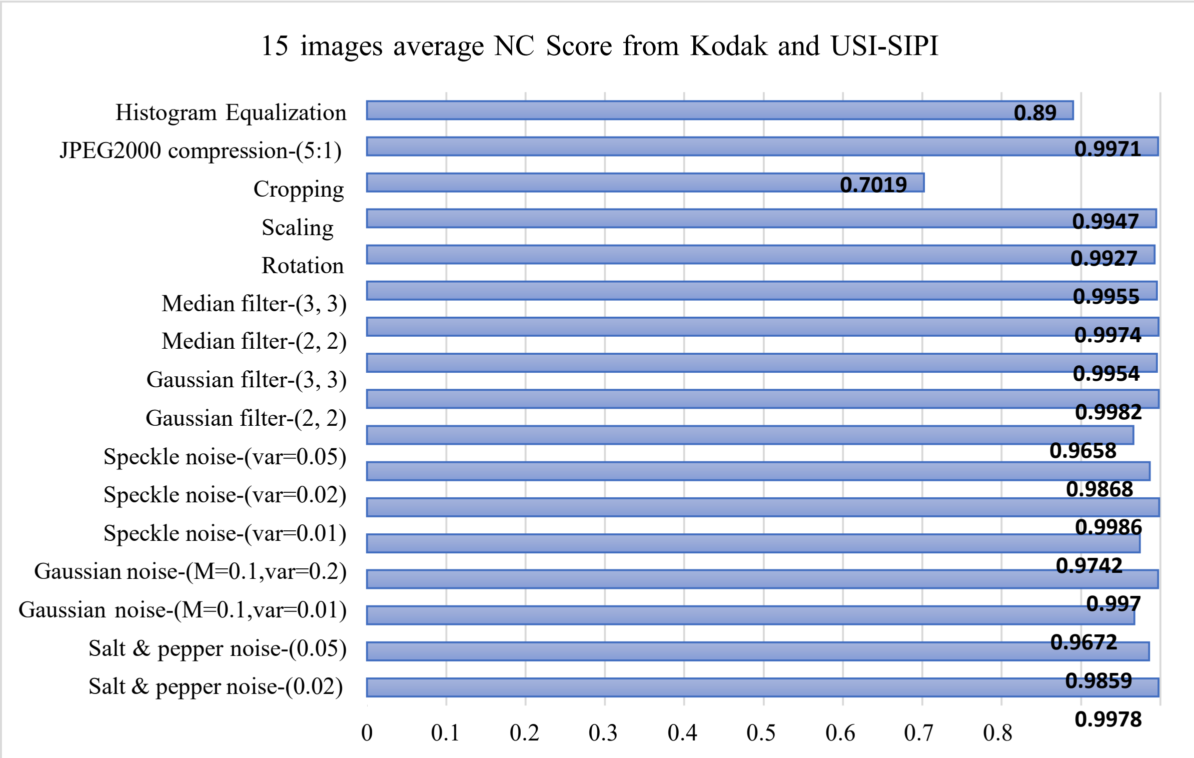

Fig 4. The Retrieved Watermark's NC for A Suggested System Under Different Attacks.

Table 3. The retrieved watermark's NC for a suggested system under different attacks

Attacks	**Average BER Score for 15 images from the USI-SIPI and Kodak datasets**
Salt & pepper noise-(0.01)	0
Salt & pepper noise-(0.02)	0
Salt & pepper noise-(0.05)	0
Gaussian noise-(M=0.1,var=0.01)	0
Gaussian noise-(M=0.1,var=0.2)	0
Speckle noise-(var=0.01)	0
Speckle noise-(var=0.02)	0
Speckle noise-(var=0.05)	0
Gaussian filter-(2, 2)	0
Gaussian filter-(3, 3)	0
Median filter-(2, 2)	0
Median filter-(3, 3)	0
Rotation	0
Scaling	0
Cropping	40.6192
JPEG2000 compression-(5:1)	0
Histogram Equalization	0

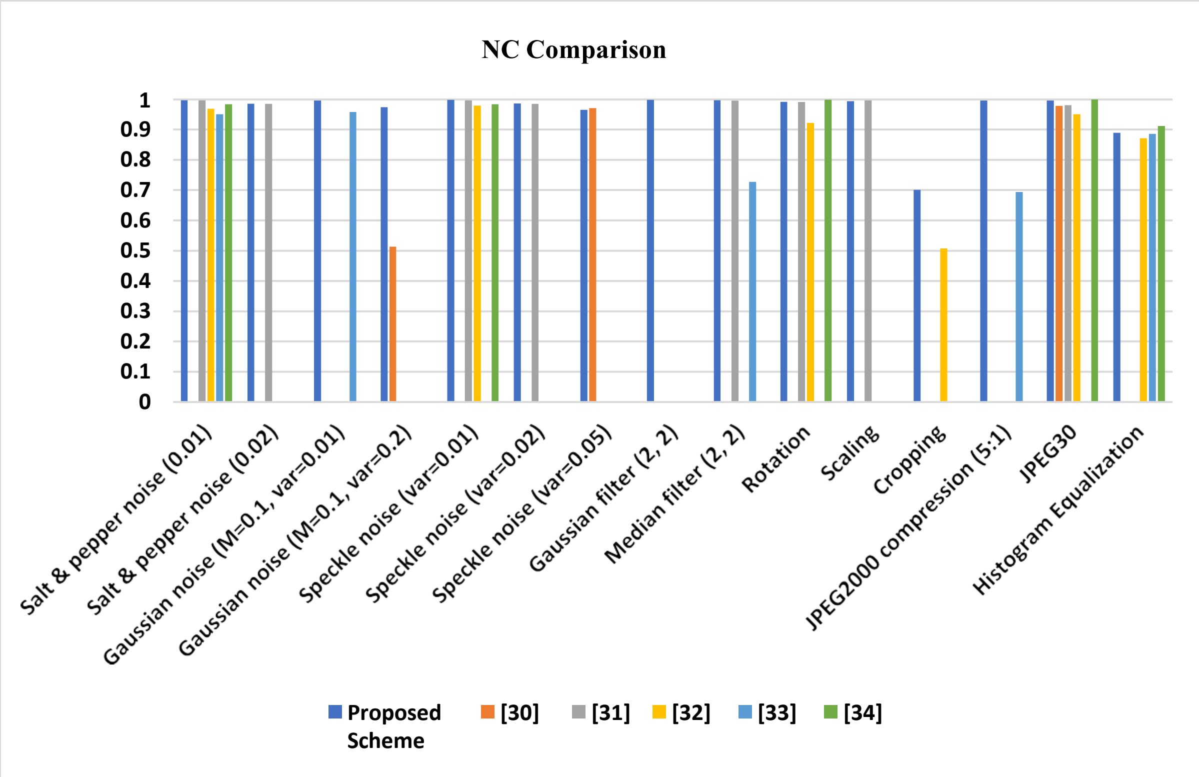

Fig 5. The Suggested Scheme's Comparative Analysis of NC Values.

Table 4. Comparison based on PSNR

Performance measure	Imperceptibility Results (PSNR (dB))				
	Proposed algorithm	[30]	[32]	[33]	[34]
PSNR(in dB)	51.6966	48.522	38.3532	48.99	43.39

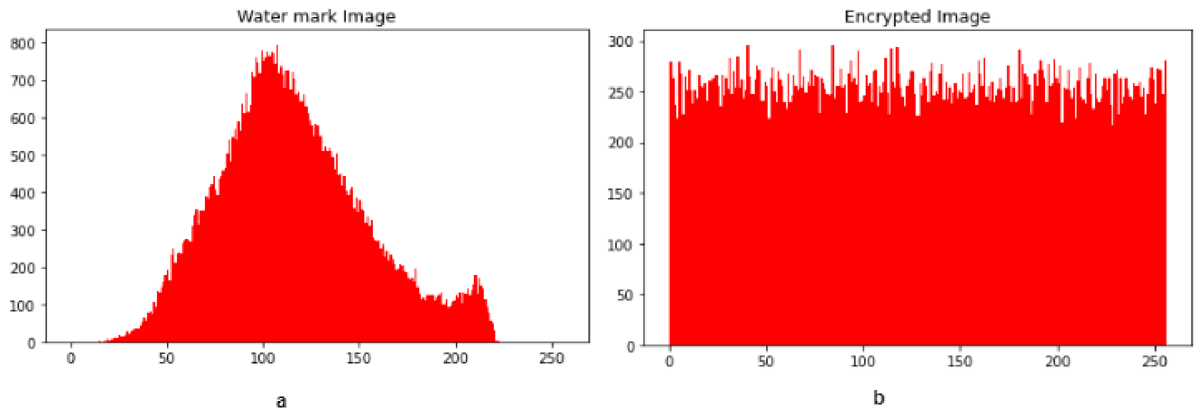

Fig 6. Histogram Analysis of Image as a) Watermark, b) Encrypted Watermark.

V. CONCLUSION

This work presents a powerful copyright protection and authentication method using grayscale images using DWT-HD-TSVD. Additionally, the approach embeds text watermarks using the magic square algorithm and adds selective encryption for extra authentication. The GWO algorithms examined the trade-off between resilience and invisibility. Additionally, to strengthen the suggested approach, the recovered watermark makes use of a quick and adaptable de-noising convolutional neural network (FFDNet). The suggested work was evaluated for performance against a range of threats through assessments of its robustness, security, and visibility. The results demonstrate a considerable improvement in the robustness of our approach when compared to standard techniques. The suggested approach offers high concealing efficiency in addition to an extra degree of information security. We would like to assess the scheme's performance in the future by utilizing AI/ML approaches in addition to encryption and compression techniques, in order to maximize performance and capacity.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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Competing Interests

There are no competing interests

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