Web of Scholars: Multidimensional Research Journal (MRJ)
Volume: 02 Issue: 08 | 2023 ISSN: (2751-7543)
http://innosci.org

A Watermarking Scheme for Digital Images Developed Using Discrete Cosine Transform (DCT)

Ghazwan Jabbar Ahmed
Electronic Computing Center, University of Diyala, Diyala, Iraq

Abstract: *In this research, a grayscale image watermarking approach is introduced, utilizing a discrete cosine transform (DCT) to embed an imperceptible binary watermark image. Diverging from traditional methods that partition the image into non-overlapping 8x8 blocks, the DCT is employed across the entire host image. Following this, specific coefficients from the low-frequency DCT range are selected for the embedding of the watermark.*

In order to attain a harmonious equilibrium between the resilience of the watermark and its inconspicuousness, the intensity of watermarking is controlled through a robustness factor. The precise value of this robustness factor is flexible and can be fine-tuned by the user in accordance with their preferred level of resilience and the attributes of the host image. Assessing the quality of watermarked images involves the computation of peak signal-to-noise ratio (PSNR) and normalized correlation (NC). The conducted simulations and resultant findings highlight the resilience of the proposed methodology, showcasing its efficacy even under a variety of attacks, encompassing JPEG compression, low-pass filtering, and noise distortions.

Keywords: *digital watermarking, copyright protection, JPEG compression, watermarking techniques, normalized correlation, robustness, and imperceptibility, discrete cosine transform.*

1. Introduction

The rapid advancement of computer and interconnected communication structures technologies has facilitated the creation and distribution of digital multimedia, including images, audio, and videos, over the internet with ease and speed. However, this convenience has also given rise to challenges in copyright protection, as these digital contents are susceptible to illegal alterations and unrestricted copying. To address this issue, one of the most effective solutions is the adoption of digital watermarking techniques.

The process of digital watermarking encompasses of embedding particular details, known as a watermark, into the digital multimedia content in a manner that allows for its extraction or identification later on. This method serves diverse objectives, like verifying content authenticity, copyright protection, data integrity detection, confirming ownership, and more.[1-3].

Digital watermarking can be categorized into two main types based on human perception: visible watermarking and invisible watermarking. This work focuses on the latter category. In visible watermarking, the inserted watermark intentionally remains visible to the human eye in the host image, often displaying essential information like TV channel logos or company logos. On the other hand, invisible watermarking involves embedding the watermark in a concealed location, allowing only authorized individuals to extract it. This process ensures that the perceptual content of the watermarked image remains resembling the original image [4-9].

The invisible watermarking scheme's effectiveness relies on two crucial parameters: robustness and imperceptibility. Robustness pertains to the capacity of the watermark to withstand unintentional attacks, such as signal processing operations or intentional attacks. On the other hand, imperceptibility implies The dissimilarity between the watermarked and original images should be imperceptible to human vision [10,11].

Digital watermarking can be implemented using two main approaches: spatial domain or transform domain. In spatial domain algorithms, the watermark is embedded into an image by directly modifying the values of certain pixels in the cover image [12,13]. Conversely, in the transform domain, the watermark is embedded into the transformed coefficients of the host image using transformed algorithms such as discrete cosine transform (DCT) [14,15].

The proposed watermarking technique in this work employs the transform domain, specifically the discrete wavelet transform (DWT) [16,17], or other transform domain algorithms. Transform domain techniques offer several advantages over spatial domain techniques, including enhanced robustness and better control of imperceptibility, making them an appealing choice as supported by various surveys [18-20]. In this study, the transform domain, specifically the DCT algorithm, is utilized in the development of the proposed watermarking approach.

2. Transformation using discrete cosine functions.

Discrete Cosine Transform (DCT) constitutes an orthogonal transformation primarily employed to convert converts a signal from its spatial representation to the frequency domain. A key characteristic of the DCT is its ability to concentrate the majority of signal information in a few low-frequency components while discarding the less perceptually significant parts. Furthermore, the DCT offers several advantages that contribute to its widespread use in the transformation domain, such as strong energy compaction, moderate complexity, and lower bit error rate, among others [21, 22].

Therefore, the DCT effectively reduces the signal information by eliminating redundant data in the transformed signal. Typically, the DCT partitions the image into three separate bands of frequencies, namely low, medium, and bands with high frequency components, as illustrated in Figure (1). The coefficient located at the top-left represents the DC component, while the others denote the AC components [23-28].

In this study, the watermark is embedded within the low-frequency band to enhance the watermarking scheme's robustness [29, 30]. For an image of size (M × N), the two-dimensional discrete cosine transform (2D-DCT) and inverse discrete cosine transform (2D-IDCT) are defined as follows [30]:

$$F(u,v) = c(u)c(v)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)\cos\frac{\pi(2x+1)}{2M}\cos\frac{\pi(2y+1)}{2N} \qquad (1)$$

$$c(u) = \begin{cases} \sqrt{1/M} & u = 0 \\ \sqrt{2/M} & u = 1,2,3,\dots,M \end{cases} \qquad (2)$$

$$c(v) = \begin{cases} \sqrt{1/N} & v = 0 \\ \sqrt{2/N} & v = 1,2,3,\dots,N \end{cases} \qquad (3)$$

$$f(x,y) = \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} c(u)c(v)F(u,v)\cos\frac{\pi(2x+1)u}{2M}\cos\frac{\pi(2y+1)v}{2N} \qquad (4)$$

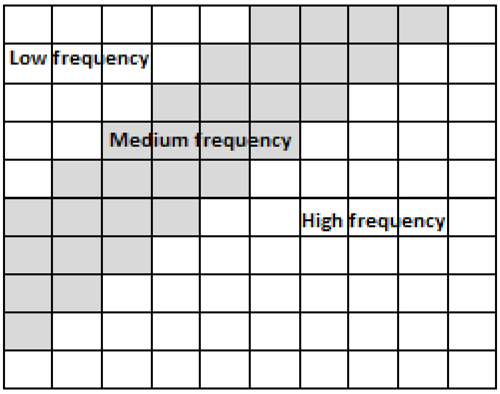


Fig. 1: DCT bands regions

3. The proposed scheme is as follows:

In this study, a watermarking scheme is introduced, aiming to insert a binary watermark image into a grayscale image utilizing the DCT algorithm in the transform domain. The entire image undergoes DCT, and the low-frequency spectrum is employed for embedding the binary bits of the watermark. Specifically, the most significant coefficients, excluding (DC) component situated at position (0,0) in the coefficients matrix, are chosen for watermark embedding. The algorithms for both embedding and retrieving watermarks are provided below.

3.1 The watermark embedding algorithm is as follows:

The process of embedding the watermark can be outlined through the subsequent stages:

1. Parsing the initial grayscale image f with dimensions M × N as well as the binary watermark image W of size q × r..
2. Applying the DCT to the entire M×N image f to obtain the coefficients matrix denoted by F.
3. Choosing the (n) maximum coefficients $C_{max} = \{c_1, c_2, \dots. c_n\}$ from the matrix F excluding the DC term.

$$\text{where: } n = q \times r\,,\; C_{max} \in F\,.$$

4. Embedding an element W(i,j) of the watermark using the chosen coefficients of C_{max} by applying the following equation:

$$c'_k = c_k * (1 + t * \delta) \qquad (5)$$

Where:

c'_k and c_k represent the watermarked and the original coefficients respectively.

$k = 1,2,3, \dots, n\,.$

$$t = \begin{cases} 1, & W(i,j) = 0 \\ -1, & W(i,j) = 1 \end{cases} \text{, where: } 1 \le i \le q\,,\; 1 \le j \le r\,. \qquad (6)$$

δ represents the watermarking strength which is discussed in section 4.

5. Performing the inverse DCT to the altered matrix coefficients F′ to generate the image with the watermark f′.

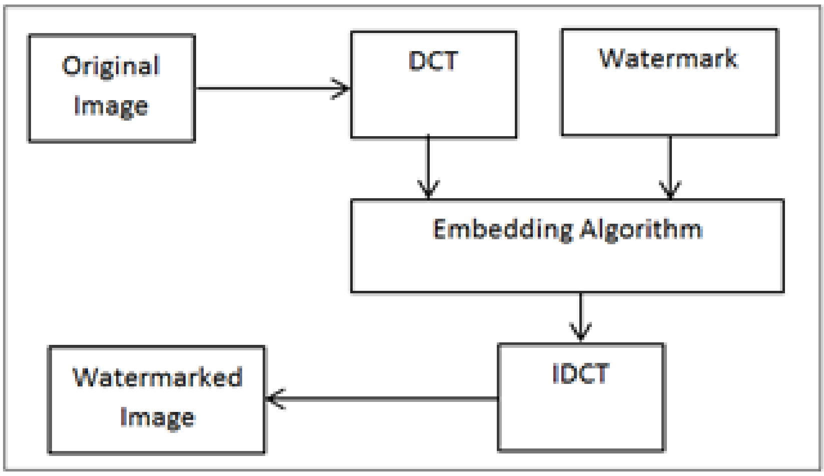


Fig. 2: Algorithm for embedding watermarks

3.2 Extraction of the watermark Algorithm

The process of extracting the watermark can be succinctly described through the subsequent steps:

1. Analyzing the watermarked image denoted as f' and also the original image f.
2. Conducting the (DCT) to the entire watermarked image (f ') and the initial image (f) to produce the coefficients matrices F' and F respectively.
3. Selecting the (n) watermarked DCT coefficients $C'_w = \{c'_{w1}, c'_{w2}, \dots c'_{wn}\}$ from F' that have the same position of the original DCT coefficients $C_{max} = \{c_1, c_2, \dots c_n\}$ in F matrix.
4. let $d_k = (c'_{wk} / c_k) - 1$ (7)

where $k = 1,2,3, \dots, n$.

5. Extracting the watermark W^e by making the judgment of d_k :

$$W^e(i.j) = \begin{cases} 0, & d_k > 0 \\ 1, & d_k \le 0 \end{cases} \quad (8)$$

where: $1 \le i \le q$, $1 \le j \le r$.

Figure 3 illustrates the watermark extraction algorithm.

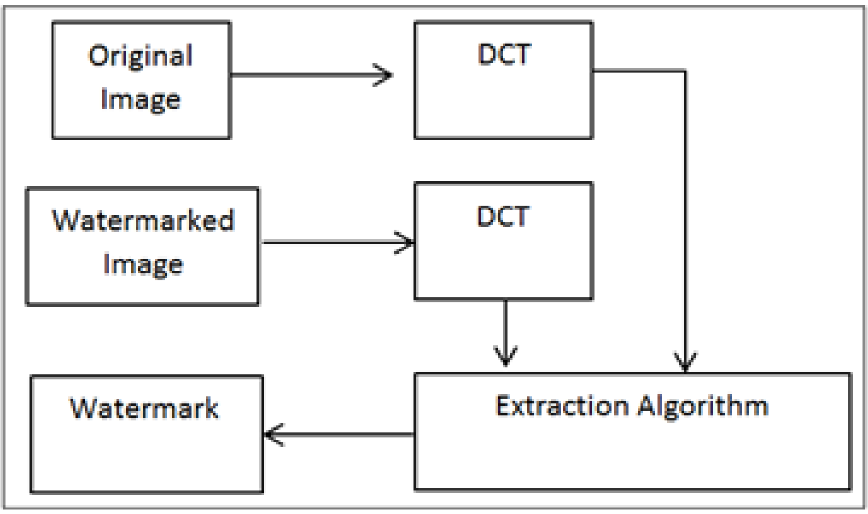


Fig. 3: Algorithm for extracting watermarks

4. The obtained outcomes and performance analysis are presented as follows:

The evaluation of watermarking techniques typically involves measuring both robustness and imperceptibility. In this study, three commonly used grayscale images, namely Boats, Baboon, and Goldhill, each with a size of (512x512), were selected as the cover images to embed a binary watermark image sized (30x40), as depicted in Figure (4).

(a) Boats (b) Baboon (c) Goldhill (d) watermark

Fig.4: Test images

The robustness of the proposed watermarking scheme is assessed by examining its strength against widely employed signal processing operations, including JPEG compression at various quality factors (QF), low-pass filtering, and noise attacks. To estimate the robustness, the normalized correlation (NC) criterion is utilized. Watermark robustness is measured by calculating the level of resemblance between the initial watermark (W) and the extracted watermark (W^e). A normalized correlation value of 1 indicates that the extracted watermark perfectly matches the original one. As the difference between the two images increases, the normalized correlation value decreases, which is defined by the following equation [31].

$$\mathrm{NC} = \frac{\sum_{i=1}^{q}\sum_{j=1}^{r}(W(i,j)\times W^{e}(i,j))}{\sum_{i=1}^{q}\sum_{j=1}^{r}(W(i,j))^{2}} \qquad (9)$$

The imperceptibility of the suggested watermarking scheme is assessed by evaluating the visual quality of the watermarked image using the peak signal-to-noise ratio (PSNR) criterion. A higher PSNR value indicates a higher level of watermark imperceptibility in the cover image. The PSNR is described by the following equation [17]:

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

Where, MSE is given by:

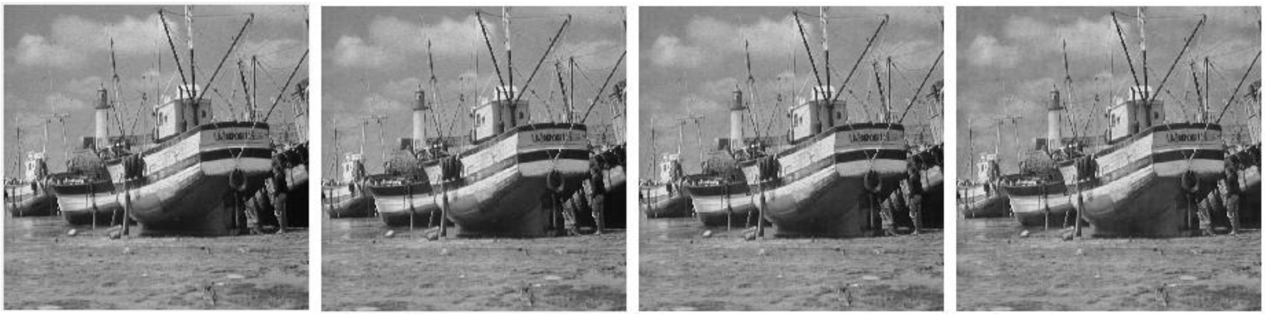
$$\mathrm{MSE} = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N}(I(x,y) - I'(x,y))}{M\times N} \qquad (11)$$

In general, there is a balance between resilience and inconspicuousness in watermarking techniques. Higher robustness can be achieved, but it may come at the expense of imperceptibility due to the additional signal introduced. Conversely, aiming for high imperceptibility may lead to reduced robustness. Striking the right balance between these two requirements is essential in watermarking.

In this study, the intensity of watermarking is regulated by a factor (δ), representing the robustness factor, to achieve the desired balance between robustness and imperceptibility. By increasing the

Web of Scholars: Multidimensional Research Journal (MRJ)
Volume: 02 Issue: 08 | 2023 ISSN: (2751-7543)
http://innosci.org

value of (δ), a higher level of robustness can be attained, but it may also result in decreased watermarked image quality, and vice versa. The user has the flexibility to adjust the value of (δ) according to the desired robustness level and the specific attributes of the host image. The visual impact of changing the robustness factor (δ) value on the watermarked Boats image is demonstrated in Figure 5.



(a) Original (b) δ = 0.05, PSNR = 41.53 (c) δ = 0.1, PSNR = 35.51 (d) δ = 0.2, PSNR = 29.49

Fig. 5: (a) The initial Boats image, along with watermarked Boats images denoted as (b, c, and d), employing varying values of δ.

The impact of varying the value of δ on the performance of the proposed scheme with different attacks is depicted in Table 1and Table 2. From these tables and Figure 5, it can be observed that the selection of the robustness factor δ is critical in maintaining the quality of the cover image and the strength of the watermark. For this study, a carefully selected value of (δ=0.1) was used.

Figures 5 and 6 depict the extracted watermark from the watermarked Boats image after undergoing various attacks, including JPEG compression, low-pass filtering, and different types of noise.

A comprehensive performance analysis of the proposed scheme is presented in Table 3 using the test images.

Table 1 Performance analysis using JPEG compression and applying low-pass filtering attacks.

Images	δ	No attack		Average filter (3×3)		Median filter (3×3)		JPEG (QF=20) compression		JPEG (QF=40) compression		JPEG (QF=60) compression	
		PSNR	NC	PSNR	NC	PSNR	NC	PSNR	NC	PSNR	NC	PSNR	NC
Boats	0.01	55.51	1.0000	28.84	0.9137	30.95	0.7108	30.47	0.6155	32.72	0.7152	34.16	0.7522
	0.05	41.53	1.0000	28.59	0.9742	30.64	0.9507	30.15	0.8890	32.20	0.9798	33.46	1.0000
	0.1	35.51	1.0000	27.95	0.9798	29.73	0.9966	29.29	0.9776	30.91	1.0000	31.79	1.0000
	0.15	31.99	1.0000	27.07	0.9798	28.53	1.0000	28.15	0.9978	29.34	1.0000	29.96	1.0000
	0.2	29.49	1.0000	26.09	0.9854	27.25	1.0000	26.95	1.0000	27.82	1.0000	28.23	1.0000
Baboon	0.01	56.71	1.0000	22.36	0.9070	22.85	0.4888	24.64	0.6031	26.85	0.6883	28.70	0.7175
	0.05	42.73	1.0000	22.32	0.9552	22.84	0.7231	24.58	0.8722	26.74	0.9854	28.54	0.9955
	0.1	36.71	1.0000	22.20	0.9664	22.75	0.8890	24.39	0.9776	26.43	0.9989	28.07	1.0000
	0.15	33.18	1.0000	22.01	0.9709	22.58	0.9496	24.08	0.9966	25.95	1.0000	27.38	1.0000
	0.2	30.69	1.0000	21.76	0.9753	22.34	0.9753	23.68	1.0000	25.36	1.0000	26.58	1.0000
Goldhill	0.01	53.91	1.0000	29.76	0.9316	31.62	0.6323	30.74	0.5975	32.83	0.6771	34.19	0.7007
	0.05	39.93	1.0000	29.37	0.9563	31.18	0.9395	30.36	0.8475	32.21	0.9630	33.35	0.9933
	0.1	33.91	1.0000	28.45	0.9675	29.97	0.9865	29.27	0.9686	30.69	0.9989	31.46	1.0000
	0.15	30.39	1.0000	27.29	0.9742	28.48	0.9966	27.94	0.9955	28.93	1.0000	29.43	1.0000
	0.2	27.89	1.0000	26.07	0.9776	26.98	0.9989	26.60	1.0000	27.28	1.0000	27.61	1.0000

Table 2. Performance analysis with different noise attacks .

Images	δ	Gaussian noise (μ=0,ν=0.001)		Gaussian noise (μ=0,ν=0.005)		Salt and pepper (0.5%)		Salt and pepper (1%)		Speckle noise (0.5%)		Speckle noise (1%)	
		PSNR	NC	PSNR	NC	PSNR	NC	PSNR	NC	PSNR	NC	PSNR	NC
Boats	0.01	29.98	0.771	23.03	0.5964	28.41	0.6962	25.21	0.6984	28.34	0.6300	25.35	0.6087
	0.05	29.71	0.9383	23.00	0.8038	28.16	0.9383	25.23	0.8778	28.19	0.8845	25.28	0.8509
	0.1	28.90	0.9966	22.77	0.9249	27.83	0.9865	24.99	0.9776	27.65	0.9899	25.01	0.9619
	0.15	27.87	1.0000	22.51	0.9720	26.77	1.0000	24.69	0.9955	26.86	1.0000	24.58	0.9877
	0.2	26.73	1.0000	22.11	0.9944	25.99	1.0000	24.16	0.9978	25.93	1.0000	24.01	1.0000
Baboon	0.01	29.96	0.6626	23.03	0.6020	28.59	0.7063	25.48	0.6525	27.60	0.6312	24.61	0.6143
	0.05	29.77	0.9339	22.96	0.7836	28.33	0.9159	25.27	0.8587	27.50	0.8812	24.57	0.8173
	0.1	29.15	0.9955	22.82	0.9249	27.75	0.9933	25.05	0.9619	27.16	0.9854	24.39	0.9417
	0.15	28.29	1.0000	22.60	0.9630	27.09	1.0000	24.72	0.9966	26.59	0.9966	24.09	0.9843
	0.2	27.31	1.0000	22.32	0.9966	26.34	1.0000	24.34	1.0000	25.93	1.0000	23.70	0.9966
Goldhill	0.01	29.98	0.6558	23.04	0.5684	28.22	0.6704	25.49	0.6513	29.39	0.6435	26.45	0.5953
	0.05	29.66	0.9182	22.95	0.7769	28.08	0.9193	25.29	0.8442	29.12	0.9025	26.29	0.8229
	0.1	28.72	0.9922	22.73	0.9025	27.62	0.9731	25.00	0.9596	28.35	0.9865	25.86	0.9518
	0.15	27.53	1.0000	22.40	0.9742	26.78	0.9955	24.36	0.9776	27.26	0.9989	25.22	0.9944
	0.2	26.27	1.0000	21.94	0.9854	25.55	1.0000	23.75	0.9978	26.09	1.0000	24.50	0.9944

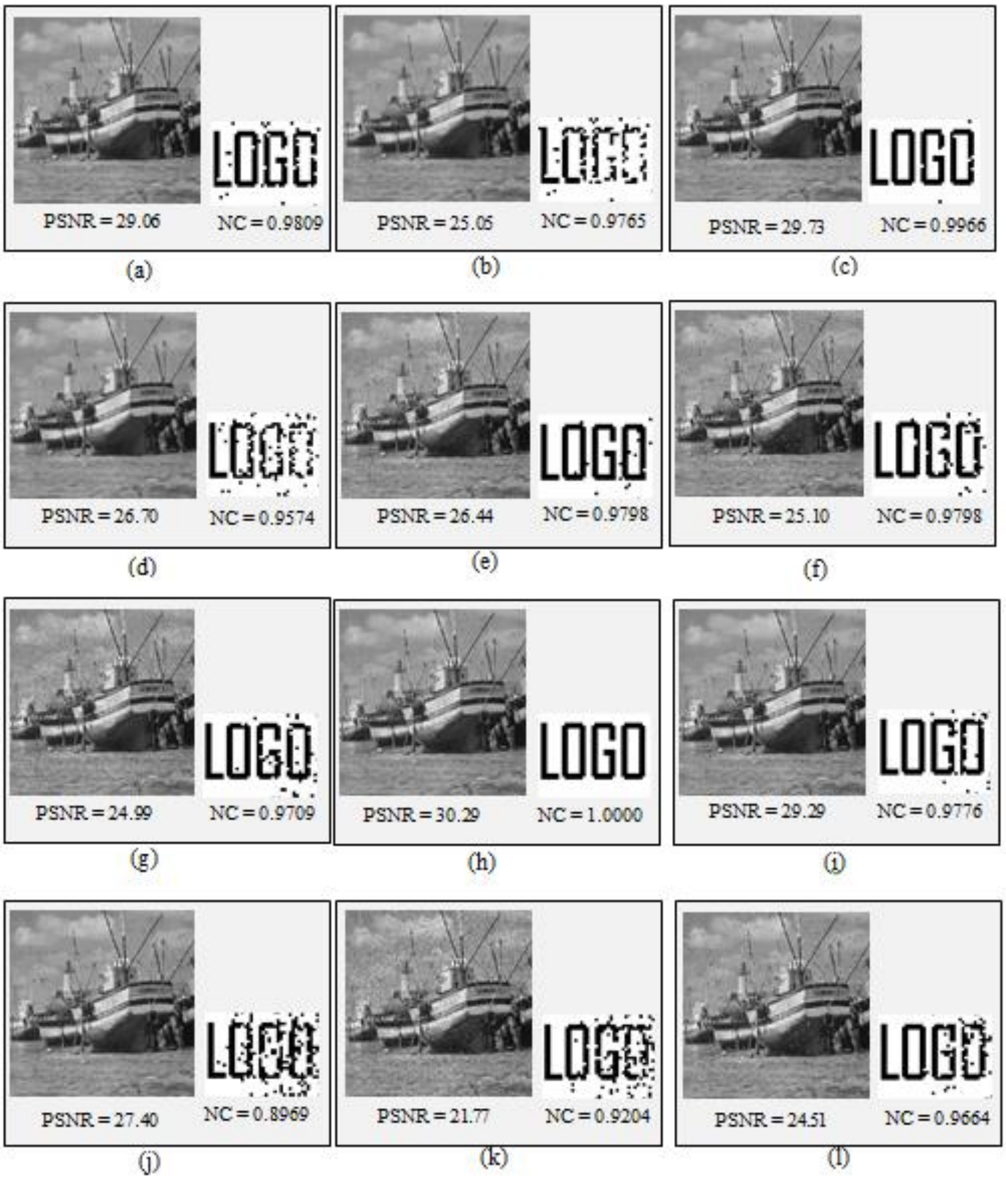


Fig. 6. The watermarked Boats images were subjected to various attacks, and the corresponding extracted logo watermark images are shown for each case:

(a) Average filter (3x3),

(b) Average filter (5x5),

(c) Median filter (3x3),

(d) Median filter (5x5),

(e) noise following a Gaussian distribution (μ=0, v=0.002),

(f) Salt and pepper noise (1%),

(g) Speckle noise (1%),

(h) JPEG compression QF=30%,

(i) JPEG compression QF=20%,

(j) JPEG compression QF=10%,

(k) Mixed noise: salt and pepper noise (1%), Gaussian noise (μ=0, v=0.001), and granular noise (1%), (l) JPEG compression QF=50% with salt and pepper noise (1%).

Table 3. Performance evaluation and comparison

Attack	Parameter	Images					
		Boats		Baboon		Gold-hill	
		PSNR	NC	PSNR	NC	PSNR	NC
No attack		35.51	1.0000	36.71	1.0000	33.91	1.0000
Median filter	(3×3)	29.73	0.9966	22.75	0.8890	29.97	0.9865
Median filter	(5×5)	26.70	0.9574	20.40	0.8094	27.89	0.9484
Average filter	(3×3)	27.95	0.9798	22.20	0.9664	28.45	0.9675
Average filter	(5×5)	25.05	0.9765	20.12	0.9608	26.13	0.9630
Gaussian noise	(μ=0,ν=0.003)	24.84	0.9518	24.93	0.9596	24.76	0.9406
Gaussian noise	(μ=0,ν=0.006)	22.03	0.9182	22.08	0.9114	21.97	0.8868
Gaussian noise	(μ=0,ν=0.01)	19.95	0.8565	19.96	0.8397	19.92	0.8587
Salt and peppers noise	(density = 0.01)	25.07	0.9720	25.10	0.9652	24.89	0.9518
Salt and peppers noise	(density = 0.02)	22.25	0.9372	22.26	0.9316	22.05	0.8957
Salt and peppers	(density = 0.03)	20.63	0.9036	20.49	0.9137	20.35	0.8991
Speckle noise	(density = 0.01)	24.99	0.9552	24.38	0.9395	25.86	0.9585
Speckle noise	(density = 0.02)	22.21	0.8935	21.51	0.8756	23.21	0.9025
Speckle noise	(density = 0.03)	20.55	0.8677	19.86	0.8475	21.61	0.8666
JPEG compression	(QF=10)	27.40	0.8969	22.63	0.8823	27.61	0.8498
JPEG compression	(QF=20)	29.29	0.9776	24.39	0.9776	29.27	0.9686
JPEG compression	(QF=30)	30.29	1.0000	25.53	0.9978	30.14	0.9922
JPEG compression	(QF=40)	30.91	1.0000	26.43	0.9989	30.69	0.9989
JPEG compression	(QF=50)	31.37	1.0000	27.22	1.0000	31.07	1.0000

5. Conclusion

This document introduces an imperceptible watermarking approach for grayscale images based on DCT. The scheme utilizes the low-frequency region of DCT bands for embedding a binary watermark image. By adjusting the robustness factor (δ) value, users can control the watermarking strength according to their desired level of robustness and the characteristics of the host image.

The performance of the suggested approach is evaluated by subjecting the watermarked test images to various attacks, including average filter, median filter, speckle noise, salt and pepper noise, Gaussian noise, and JPEG compression at different quality factors. As demonstrated in Figure 6, the perceptual quality of the watermarked image is well-preserved and can be controlled by the robustness factor (δ) value, as shown in Figure 5. Moreover, the extracted watermark retains its high quality in terms of NC, even under certain types of attacks, as depicted in Figs. 4(b) and 4(c).

The utilization of the low-frequency region of DCT bands enhances the proposed scheme's performance, enabling it to achieve both robustness and imperceptibility even under various attacks, as evidenced by the results in Tables 3-5.

References

1. M. Abdullatif, A. M. Zeki, J. Chebil, and T. S. Gunawan, "Properties of digital image watermarking," 2013 IEEE 9th International Colloquium on Signal Processing and its Applications, 8 - 10 Mac. 2013, Kuala Lumpur, Malaysia.
2. A DISCRETE COSINE TRANSFORM BASED WATERMARKING SCHEME FOR COLOR IMAGE USING YCbCr SPACE Adel Jalal Yousif Assistant Lecturer, Electronic computer center, University of Diyala, Diyala, IraqVol. 22, No.06, November 2018 ISSN 2520-0917
3. M. Pradeep Kumar, M. V. Gudur, R. Shreeshayana and D. S. Sriramu, "VLSI implementation of Digital Watermarking Technique for security and authentication of Digital Data," 2021 International Conference on Smart Generation Computing, Communication and Networking (SMART GENCON), Pune, India, 2021, pp. 1-6, doi: 10.1109/SMARTGENCON51891.2021.9645910.
4. Yusnita Yusof and Othman O. Khalifa, "Digital Watermarking For Digital Images Using Wavelet Transform," IEEE International Conference on Telecommunications and Malaysia International Conference on Communications, May 2007, Penang, Malaysia.
5. K. J. Giri, M. Ahmad Peer, and P. Nagabhushan, "A Robust Color Image Watermarking Scheme Using Discrete Wavelet Transformation," Int. J. Image, Graph. Signal Process., vol. 7, no. 1, pp. 47–52, 2014.
6. C. Dai, "Analysis on Digital Watermarking Technology and Its Applications," 2022 International Conference on Data Analytics, Computing and Artificial Intelligence (ICDACAI), Zakopane, Poland, 2022, pp. 200-204, doi: 10.1109/ICDACAI57211.2022.00048.
7. Y. Duang, Y. Wang, C. Cao and X. Zhang, "Research on Digital Watermarking Algorithm Based on Discrete Cosine Transform," 2022 15th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI), Beijing, China, 2022, pp. 1-6, doi: 10.1109/CISP-BMEI56279.2022.9980072.
8. G. Azizoğlu and A. N. Toprak, "A novel reversible fragile watermarking in DWT domain for tamper localization and digital image authentication," 2021 9th International Symposium on Digital Forensics and Security (ISDFS), Elazig, Turkey, 2021, pp. 1-6, doi: 10.1109/ISDFS52919.2021.9486339.
9. M. Pradeep Kumar, M. V. Gudur, R. Shreeshayana and D. S. Sriramu, "VLSI implementation of Digital Watermarking Technique for security and authentication of Digital Data," 2021 International Conference on Smart Generation Computing, Communication and Networking (SMART GENCON), Pune, India, 2021, pp. 1-6, doi: 10.1109/SMARTGENCON51891.2021.9645910.
10. T. Huynh-The, O. Banos, S. Lee, Y. Yoon, and T. Le-Tien, "Improving digital image watermarking by means of optimal channel selection," Expert Syst. Appl., vol. 62, pp. 177–

189, 2016.

11. Y. Yusof and O. O. Khalifa, "Imperceptibility and robustness analysis of DWT-based digital image watermarking," 2008 International Conference on Computer and Communication Engineering, Kuala Lumpur, Malaysia, 2008, pp. 1325-1330, doi: 10.1109/ICCCE.2008.4580820.

12. M. S. Islam and U. P. Chong, "A Digital Image Watermarking Algorithm Based on DWT DCT and SVD," Int. J. Comput. Commun. Eng., vol. 3, no. 5, pp. 356–360, 2014.

13. J. Li, X. Zhang and Q. Yang, "Adaptive main-lobe clutter suppression algorithm based on data selection in spatial domain for small-aperture high-frequency surface-wave radar," IET International Radar Conference (IET IRC 2020), Online Conference, 2020, pp. 831-835, doi: 10.1049/icp.2021.0696

14. A. Kumar and Anuradha, "A Novel Watermarking Algorithm for Color Images Based on Discrete Wavelet Transform," Int. J. Comput. Electr. Eng., vol. 6, no. 4, pp. 303–306, 2014.

15. M. S. Rana, M. M. Hasan and S. K. Sinha Shuva, "Digital Watermarking Image Using Discrete Wavelet Transform and Discrete Cosine Transform with Noise Identification," 2022 2nd International Conference on Intelligent Technologies (CONIT), Hubli, India, 2022, pp. 1-4, doi: 10.1109/CONIT55038.2022.9847745.

16. B. L. Gunjal and S. N. Mali, "Comparative Performance Analysis of DWT-SVD BasedColor Image Watermarking Technique in YUV, RGB and YIQ Color Spaces," Int. J. Comput. Theory Eng., vol. 3, no. 6, pp. 714–719, 2011.

17. M. S. Rana, M. M. Hasan and S. K. Sinha Shuva, "Digital Watermarking Image Using Discrete Wavelet Transform and Discrete Cosine Transform with Noise Identification," 2022 2nd International Conference on Intelligent Technologies (CONIT), Hubli, India, 2022, pp. 1-4, doi: 10.1109/CONIT55038.2022.9847745.

18. M. K. Sinha, R. Rai, and P. G. Kumar, "Literature Survey on Digital Watermarking," International Journal of Computer Science and Information Technologies, vol. 5, no. 5, pp. 6538–6542, 2014.

19. M. Singh, A. Singhal, and A. Chaudhary, "Digital Image Watermarking Techniques: A Survey," International Journal of Computer Science and Telecommunications vol. 7, no. 6, pp. 111–124, 2014.

20. S. Malshe, H. Gupta, and S. Mandloi, "Survey of Digital Image Watermarking Techniques to achieve Robustness," Int. J. Comput. Appl. (0975, vol. 45, no. 13, pp. 1–8, 2012.

21. Bhupendra Ram," Digital Image Watermarking Technique Using Discrete Wavelet Transform And Discrete Cosine Transform", Int. J. Adv. Res. Tec., Volume 2, Issue4, April-2013 ISSN 2278-7763.

22. R. Eswaraiah, S. Alekya Edara, and E. Sreenivasa Reddy, "Color Image Watermarking using DWT and DCT Coefficients of R, G, B Color Components," Int. J. Comput. Appl., vol. 50, no. 8, pp. 38–41, 2012.

23. V. S. Member and P. A. Thangavelu, "DC Coefficients Based Watermarking Technique for color Images Using Singular Value Decomposition," Int. J., vol. 3, no. 1, pp. 8–16, 2011.

24. R. Singh, "A Robust Color Image Watermarking using Combination of DWT and DCT," International Journal of Computer Applications, 4th International IT Summit Confluence 2013, pp. 11–14, 2013.

25. M. S. Rana, M. M. Hasan and S. K. Sinha Shuva, "Digital Watermarking Image Using Discrete Wavelet Transform and Discrete Cosine Transform with Noise Identification," 2022 2nd International Conference on Intelligent Technologies (CONIT), Hubli, India, 2022, pp. 1-4, doi: 10.1109/CONIT55038.2022.9847745.
26. M. A. E. Abdalla, A. A. Abdo and A. O. Lawgali, "Utilizing Discrete Wavelet Transform and Discrete Cosine Transform for Iris Recognition," 2020 20th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Monastir, Tunisia, 2020, pp. 283-286, doi: 10.1109/STA50679.2020.9329312.
27. A. Akman and S. Cekli, "Design of Approximate Discrete Cosine Transform Architecture for Image Compression with HEVC Intra Prediction," 2020 12th International Conference on Electrical and Electronics Engineering (ELECO), Bursa, Turkey, 2020, pp. 155-158.
28. A. Solyman, T. Ismail and H. Attar, "Dual Mode Multicarrier Communication System Based on Discrete Fractional Cosine Transform and Discrete Fourier Transform," 2022 International Engineering Conference on Electrical, Energy, and Artificial Intelligence (EICEEAI), Zarqa, Jordan, 2022, pp. 1-5, doi: 10.1109/EICEEAI56378.2022.10050457.
29. B. P. Mishra, H. N. Pratihari, and P. Das, “DCT Based Grey Scale Still Image Watermarking Using 1-D Walsh Code and,” International Journal of Emerging Trends & Technology in Computer Science (IJETTCS,) vol. 4, no. 2, 2015.
30. W. Y. Chen and S. Y. Huang, “Digital Watermarking Using DCT Transformation,” National Chin-Yi University Library, China, pp. 173-184, 2012.
31. M. M. Jawad, E. H. Ali, and A. J. Yousif, “A Fuzzy Random Impulse Noise Detection and Reduction Method Based on Noise Density Estimation,” International Journal of Scientific & Engineering Research, Vol. 5, Iss. 3. April 2014.