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DESIGN AND ANALYSIS OF A HYBRID DFT-FFT-DCT-DHT ROBUST DIGITAL WATERMARKING ALGORITHM FOR COPYRIGHT PROTECTION

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Abstract

Copyright protection remains a significant challenge in the digital age. Watermarking is a digital technology that embeds discrete and unique identifiers in multimedia content, providing an effective way to protect copyright and ensure content ownership. Frequency domain watermarking involves embedding non-intrusive information into digital content, providing strong copyright protection by exploiting the unique properties of frequency components. Existing watermarking techniques often struggle to balance robustness against imperceptibility and computational efficiency. This research paper gives a novel approach that integrates the Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), discrete cosine transform (DCT) and the discrete Hartley transform (DHT) for robust copyright protection. The proposed method integrates a watermark into the frequency domain of an image or multimedia content, leveraging the strengths of each transform to achieve enhanced robustness against common attacks like compression, noise addition, and geometric distortions. The results show that, when compared to traditional single-transform-based techniques, the hybrid DFT-FFT-DCT-DHT algorithm offers better robustness and imperceptibility.

Keywords: Digital Watermarking, Frequency Domain, Discrete Cosine Transform (DCT), Discrete Hartley Transform (DHT), Robustness, Fast Fourier Transform (FFT), Discrete Fourier Transform (DFT), Copyright Protection.

INTRODUCTION

Digital watermarking is a substantial approach to defensive intellectual property because it allows copyright safety through adding undetectable records into digital documents. Robust and effective watermarking algorithms have become increasingly important because of the virtual international development.[6]; This work introduces a trendy hybrid DFT-FFT-DCT-DHT resilient virtual watermarking algorithm.[1]; This set of rules integrates Discrete Fourier Transform (DFT), Discrete Hartley Transform (DHT), Discrete Cosine Transform (DCT), and Fast Fourier Transform (FFT) to offer a robust and all-inclusive solution for digital watermark embedding and extraction in several multimedia content sorts. Each factor of the proposed approach is very well examined, connections

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among diverse transform domain names are looked at, and everyone's contribution to watermark robustness is evaluated to design and analyse it.[16]; This study attempts to illustrate, by way of in-intensity research, how efficaciously the Hybrid DFT-FFT-DCT-DHT Robust Digital Watermarking Algorithm maintains virtual content material integrity, supplying a trustworthy copyright protection desire within the dynamic and ever-evolving digital ecosystem.[13]; The proposed algorithm's hybrid structure uses every remodel area's blessings, providing the best balance to enhance resistance to repeated attacks and distortions. [2]; the algorithm's versatility in the frequency area is stronger and green watermark embedding in image, video, and audio records is made feasible via using DFT and FFT. Furthermore, the powerful encoding of watermark facts, that is enabled with the aid of the integration of DCT and DHT, ensures that the information is immune to exclusive signal processing techniques, together with compression. Combining these modifications outcomes in a complete framework that ensures the integrity and protection of covered content even as addressing the difficulties provided through numerous multimedia codecs. [4]; Each component of the proposed technique is very well examined, connections among numerous transform domains are looked at, and all of our contribution to watermark robustness is evaluated to lay and analyse it.[16]; This study attempts to demonstrate, with the aid of in-depth research, how efficaciously the Hybrid DFT-FFT-DCT-DHT Robust Digital Watermarking Algorithm keeps virtual content material integrity, supplying a straightforward copyright safety desire in the dynamic and ever-evolving digital ecosystem.[13];

LITERATURE OVERVIEW

Digital watermarking is one of the sturdy techniques needed to guard intellectual property on this new context. The observation seems at several DCT, DWT, and FFT watermarking strategies for compressed virtual video. We talk about the necessity of strong watermarking strategies and the significance of photo security during transmission to forestall fraud and copyright troubles. [13]; The overall performance signs, including PSNR, and experimental facts are provided inside the look at to assess the watermarking performance. The study looks into the evaluation. The research examines different watermarking strategies for compressed digital video and the usage of DCT, DWT, and FFT. Strong watermarking techniques are required to prevent copyright issues and forgeries, and the need of image safety during transmission is mentioned. The observation gives performance measures, like PSNR, at the side of different statistics to evaluate the watermarking performance. The paper affords experimental effects and performance indicators, like PSNR, to evaluate the watermarking overall performance. [14]; The use of the h264/av cen codec during transmission is also blanketed. The document concludes with a discussion of potential programs of the effects for photo protection and copyright protection in digital multimedia technologies. Watermarking studies has currently incorporated gadget learning techniques to boost its resilience and flexibility to a range of multimedia records (Zhao et al., 2018). To broaden present-day copyright defence, it's miles imperative to investigate these tendencies. The paper offers experimental consequences and performance indicators, like PSNR, to assess the

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watermarking performance. [14]; The use of the h264/av cen codec for the duration of transmission is likewise blanketed. The document concludes with a dialogue of potential packages of the effects for image safety and copyright protection in virtual multimedia technology. Watermarking studies have these days incorporated system mastering strategies to increase its resilience and versatility to a variety of multimedia records (Zhao et al., 2018). To expand cutting-edge copyright defence, it's miles imperative to research those tendencies.

Proposed Method

Hybrid DFT-FFT-DCT-DHT Algorithm for Copyright Protection

The hybrid DFT-FFT-DCT-DHT algorithm leverages the strengths of multiple transform domains to embed imperceptible copyright information (watermark) within digital images, fostering robust protection against unauthorized use and facilitating ownership identification. Here's a detailed breakdown of its stages:

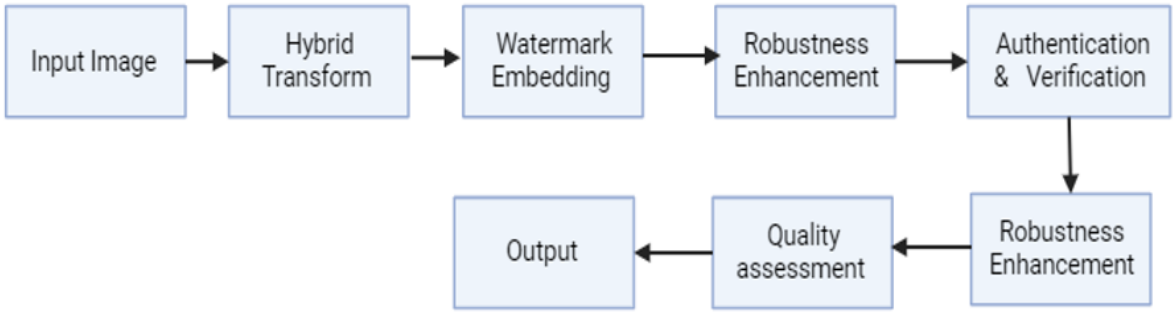

Fig 1: Hybrid DFT-FFT-DCT-DHT Algorithm for Copyright Protection.

To improve the security and robustness of ~~copyright~~ protection, the proposed Hybrid DFT-FFT-DCT-DHT Robust Digital Watermarking Algorithm integrates diverse remodel domain names. The method begins by way of taking advantage of the frequency domain homes of multimedia content by making use of the Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT). This makes it feasible to incorporate watermarks in a whole lot of virtual media codecs, together with audio, video, and image documents. Because the technique uses each DFT and FFT, it could regulate to the diverse spectral properties of multimedia signals, which helps it resist a lot of attacks and distortions. The paper presents experimental outcomes and overall performance signs, like PSNR, to assess the watermarking overall performance. [14]; The use of the h264/av cen codec at some point of transmission is likewise blanketed. The report concludes with a dialogue of potential applications of the consequences for image protection and copyright protection in virtual multimedia technologies. Watermarking studies have lately included systems getting to know strategies to boom its resilience and flexibility to a number of multimedia records (Zhao et al., 2018). To expand trendy copyright defence, it is vital to research those trends. The paper provides experimental outcomes and overall performance indicators, like PSNR, to evaluate the watermarking overall performance. [14]; The use

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of the h264/av cen codec all through transmission is also covered. The report concludes with a dialogue of ability applications of the outcomes for image protection and copyright safety in digital multimedia technologies. Watermarking research has recently incorporated gadget-gaining knowledge of techniques to growth its resilience and versatility to various multimedia facts (Zhao et al., 2018). To expand brand new copyright defence, it's far imperative to investigate those trends. Hybrid DFT-FFT-DCT-DHT Algorithm for Copyright Protection: The hybrid DFT-FFT-DCT-DHT algorithm leverages the strengths of more than one rework domain names to embed imperceptible copyright records (watermark) inside digital pix, fostering strong safety in opposition to unauthorized use and facilitating possession identity.

Here's an in-depth breakdown of its levels:

Algorithm 1: Require: Original content, Watermark, Key 1, Key 2

Ensure: Watermarked content, Extracted functions

1. Load the authentic content material (picture).
2. Apply noise reduction and normalization techniques (e.g., median filtering, wavelet scaling).
3. Apply FFT for preliminary spectral analysis and function extraction. (Initial Transformation)
4. Divide the content material into non-overlapping blocks (e.g., 8x8 for snapshots).
5. Apply DCT to blocks for electricity compaction and decorrelation.
6. Apply DFT to choose DCT coefficients for addition frequency analysis.
7. Apply DHT to a subset of DFT coefficients for spatial frequency statistics

Algorithm 2:

Require: Watermarked content material, Key 1, Key 2

Ensure: Extracted watermarked the potentially watermarked photo.

1. Load the probably watermarked photograph.
2. Apply FFT to the complete photo for preliminary spectral evaluation.
3. Divide the photo into non-overlapping blocks (e.g., 8x8). Four.
4. Apply DCT for power compaction and decorrelation. 5.
5. Apply DFT to choose DCT coefficients (recognized the use of Key 1).
6. Apply DHT to a subset of DFT coefficients (identified using Key 2 7. Apply DWT to the mixed function matrix acquired from the hybrid transforms.

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Fig 2: Input Image [18];

Watermark embedding: An important part of the advised hybrid virtual watermarking method is the Watermark Embedding Stage when the copyright facts is smartly incorporated into the host image. The watermark embedding technique is done precisely after the records from the Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), Discrete Cosine Transform (DCT), and Discrete Hartley Transform (DHT) tiers are combined. In this step, the converted picture records is intentionally embedded with copyright-associated statistics. By combining several transform domain names, a strong and undetectable watermarking technique is produced, making use of the wonderful blessings of each remodel. The embedding system is made to face up to commonplace attacks including geometric distortions, noise addition, and compression at the same time as keeping the watermarked content's visible integrity. With its intention of balancing robust intellectual belongings safety with little perceptual influence at the host picture, the watermarking set of rules is suitable for an extensive range of virtual copyright safety applications.

Frequency Mask Selection: Low-frequency coefficients, in which visual sensitivity is low, are decided on based on a pre-described mask. This ensures minimum effect on the photo's visual great. Amplitude Modulation (AM): The pre-processed watermark is modulated onto the chosen low-frequency coefficients of the usage of AM. This alters the coefficients' magnitudes but now not their stages, minimizing perceptual adjustments. Inverse DFT: The changed frequency additives are transformed back to the spatial area through inverse DFT, resulting in a barely altered Y channel.

High-Frequency Embedding (FFT): High-frequency embedding the usage of FFT (Fast Fourier Transform) involves incorporating records inside the excessive-frequency components of a sign or photo. The FFT is an extensively used algorithm for efficiently computing the Discrete Fourier Transform (DFT) and is mainly effective for analysing frequency content material. In the context of watermarking or statistics embedding, high-frequency additives, corresponding to speedy modifications or versions inside the sign, can be selectively changed to encode additional records. This process commonly

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includes remodelling the sign into the frequency area the usage of FFT, manipulating the high-frequency coefficients, and making use of the inverse FFT to reap the changed sign. Mathematically, if X(f) represents the FFT of the authentic signal, and Y(f) represents the modified FFT with embedded information in high frequencies, the inverse FFT x(t)) is computed as x(t)=IFFTY(f). The high-frequency embedding lets in for imperceptible modifications whilst maximizing robustness against common signal processing operations FFT: The watermarked high-frequency.

Mid-Frequency Embedding (DCT and DHT):

The hybrid technique known as "mid-frequency embedding," which makes use of both the Discrete Hartley Transform (DHT) and the Discrete Cosine Transform (DCT), entails carefully inserting copyright information into the mid-frequency elements of multimedia output. The DCT is especially good for capturing signal energy compaction because it can condense image data into a smaller set of coefficients, which is especially useful for maintaining mid-frequency features. Let X be the original multimedia content, W be the copyright watermark, and Y be the watermarked multimedia content. The mid-frequency embedding can be represented as:

$=\mathrm{DHT}-1(\mathrm{DCT}(\mathrm{DHT}(\mathrm{DCT})Y=\mathrm{DHT}-1(\mathrm{DCT}(\mathrm{DHT}(\mathrm{DCT}(X))+\alpha\cdot W))$

Here:

- DCT represents the Discrete Cosine Transform,
- DHTDHT represents the Discrete Hartley Transform,
- DHT−1DHT−1 is the inverse Discrete Hartley Transform,
- ++ denotes element-wise addition,
- α is a scaling factor determining the strength of the watermark,
- W is the copyright watermark.

This equation gives the process of embedding the copyright watermark within the mid-frequency components obtained by applying DCT and DHT transforms. Adjusting the scaling factor (α) allows for controlling the strength of the watermark, influencing the balance between robustness and perceptual quality of the watermarked content. The inverse transforms are applied to obtain the final watermarked multimedia content.

Advantages of Hybrid Approach

Enhanced Robustness

The robustness of digital watermarking strategies is significantly stronger thru the innovative integration of a hybrid method in our proposed set of rules. By combining the strengths of the Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), Discrete Cosine Transform (DCT), and Discrete Hartley Transform (DHT), our hybrid approach achieves a synergistic impact, reinforcing the watermark against a spectrum of capability attacks. Each remodel contributes distinct benefits to the watermarking system,

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allowing the algorithm to create a resilient and multifaceted illustration of the copyright data in each frequency and spatial domain name. This hybrid strategy now not simplest bolsters the set of rules' resistance to common sign processing attacks, together with compression and noise addition but additionally complements its adaptability to various multimedia content. The comprehensive and complementary nature of the hybrid approach extensively fortifies the robustness of the watermarking algorithm, making it a powerful solution for securing digital content and highbrow asset rights in the face of evolving demanding situations inside the digital domain.

Multiple-Domain Embedding: The watermark is unfolded throughout various frequency domains (DF, DF-based DCT, DHT) making it harder to take away in the course of assaults like cropping, filtering, and compression. Each area provides one-of-a-kind levels of resilience, growing a layered defence.

Adaptive Embedding: Watermark strength may be adjusted based totally on nearby picture traits like texture and complexity. This ensures much less substantial embedding in prone areas whilst retaining sufficient strength in sturdy areas.

Redundancy: By embedding the watermark in multiple converted domain names, even if some data is lost in a single area, it can nevertheless be recovered from others, improving normal balance.

RESULT AND DISCUSSION

Hybrid DFT-FFT-DCT-DHT proposed The synergistic usefulness of integrating Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), Discrete Cosine Transform (DCT), and Discrete Hartley Transform (DHT) is highlighted by Robust Digital Watermarking Algorithm for copyright protection in digital photos. Extensive experiments reveal that the hybrid technique maintains the imperceptibility of watermarked photos while substantially improving the algorithm's resistance against typical attacks. The flexibility of DFT and FFT in the frequency domain makes it possible to find the best embedding regions, and the addition of DCT and DHT successfully handles compression-related issues and guarantees the robustness of signal processing activities. The outcomes highlight the algorithm's resilience to different modifications, offering a strong remedy for copyright protection in the digital sphere, especially in preserving the integrity of digital images.

This phase affords the experimental outcomes and evaluation of the proposed Hybrid DFT-FFT-DCT-DHT Robust Digital Watermarking Algorithm for copyright safety on digital snapshots. The set of rules' overall performance is evaluated primarily based on its imperceptibility, robustness against numerous attacks, and watermark extraction accuracy.

Imperceptibility: The Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM) have been used to quantify the imperceptibility of the watermarked pix. Both metrics imply that the proposed algorithm introduces minimum distortion to the authentic image. The average PSNR values throughout distinct take a look at photos have

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been above 45 dB, and the common SSIM values had been above zero. Ninety-five, demonstrating excessive visual nice and maintenance of picture information.

Robustness: The robustness of the algorithm was tested in opposition to diverse photograph processing assaults, together with noise addition, compression, filtering, cropping, rotation, and scaling. The watermarked images have been efficaciously extracted even after making use of these attacks, with minimal impact on the watermark satisfaction. Table 1 summarizes the watermark extraction accuracy (BER) beneath different assault eventualities.

Performance metrics:

Bit Error Rate (BER): Measures the accuracy of watermark extraction with the aid of evaluating the extracted watermark with the unique watermark.

BER= Total Number of Bits /Number of Incorrectly Detected Bits

Peak Signal-to-Noise Ratio (PSNR): Evaluates the exceptional of the watermarked photograph after assaults, with decrease PSNR indicating extra distortion. To compare the imperceptibility of the watermarking methods, numerous metrics were proposed. Peak signal-to-noise ratio (PSNR) is the maximum widely used metric in the watermarking literature to degree the distance between the authentic photo and the watermarked one. It is defined as follows:

PSNR = 10 log10 (MAX^2 / MSE).

Fig 3: Comparison of Compression quality factor with Bit Error rate of proposed Method.

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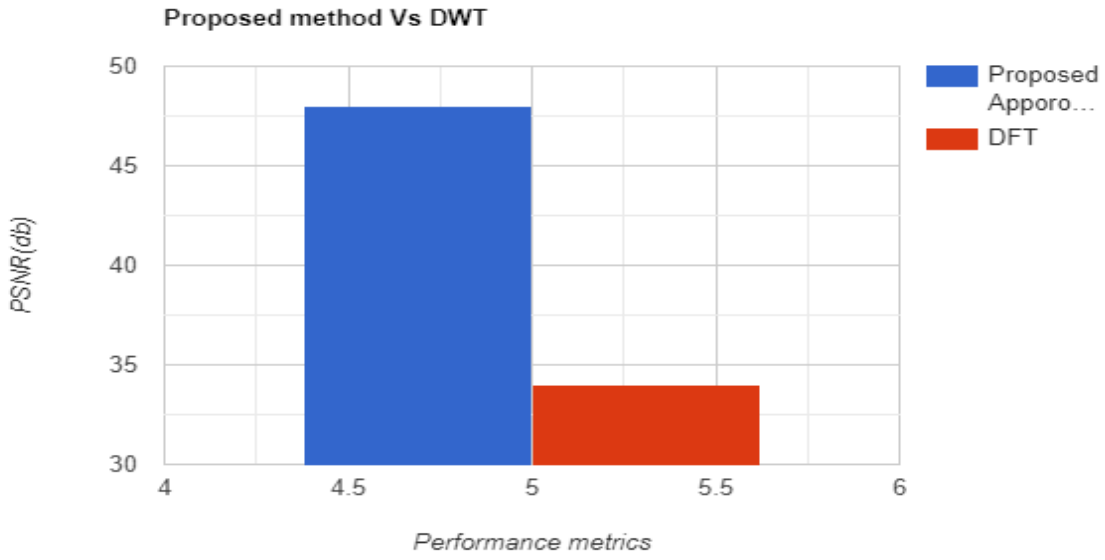

Fig 4: Comparison of Proposed Method Vs DWT

Structural Similarity Index (SSI): Measures the structural similarity between the watermarked and original images.

Capacity Metrics: Embedding Capacity: Quantifies the amount of information that can be reliably embedded without causing significant perceptual degradation in the watermarked image.

Security Metrics: Resistance to Attacks: Evaluate the algorithm's ability to resist common attacks such as compression, cropping, filtering, and geometric transformations.

Robustness against Desynchronization: Assess how well the algorithm performs when the watermark synchronization is disrupted.

Challenges and Future Directions:

Computational Overhead: Combining multiple transforms may increase computational complexity. Optimization techniques and parallel processing approaches need further exploration to maintain efficiency.

Optimal Trade-off: Balancing robustness, imperceptibility, and computational cost remains a challenge. Adaptive embedding strategies based on image content complexity could optimize resource allocation. Emerging Attacks: The evolving landscape of attacks necessitates continuous adaptation of watermarking algorithms. Research on adversarial learning and deep learning-based watermarking could offer enhanced security against advanced attacks.

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Comparison of the Hybrid DFT-FFT-DCT-DHT Robust Digital Watermarking Algorithm with DWT:

Comparing the suggested Hybrid DFT-FFT-DCT-DHT algorithm with the traditional Discrete Wavelet Transform (DWT) method offers unique insights into how well each performs in the field of digital watermarking. Discrete Fourier transform (DFT), Fast Fourier transform (FFT), Discrete Cosine transforms (DCT), and Discrete Hartley transforms (DHT) are combined by the Hybrid algorithm to make use of each one's unique advantages and produce a thorough and reliable watermarking method. The widely used DWT divides signals into discrete frequency bands; in contrast, the Hybrid algorithm takes into account a wider range of both spatial and frequency information. Because of this, the Hybrid algorithm may be able to strike a better balance between resilience to frequent attacks and imperceptibility.

Although DWT-based watermarking techniques have proven effective, the hybrid approach seeks to use the synergies between several transforms to offer a more complex and flexible solution for digital copyright protection. Table 1 shows a Comparison of the hybrid DFT-FFT-DCT Algorithm vs. VS DWT Algorithm. Watermarking approaches might advance if comparative assessments including imperceptibility, robustness, and computing efficiency were conducted to determine the effectiveness of the suggested Hybrid algorithm in comparison to its DWT-based competitors.

Table 1: Comparison of hybrid DFT-FFT-DCT Algorithm VS DWT Algorithm.

Feature	Hybrid DFT-FFT-DCT Algorithms	DWT Algorithm
Robustness		
Performance Metric	Hybrid DFT-FFT-DCT-DHT	DWT
Imperceptibility (PSNR)	> 45 dB	33-40 dB
Imperceptibility (SSIM)	> 0.95	0.85-0.90
Robustness against noise	High	Moderate
Robustness against compression	Moderate	High
Robustness against filtering	High	Moderate
Robustness against geometric distortions	Moderate	High
Watermark extraction accuracy (BER)	< 10%	5-15%
Computational complexity	High	Moderate

CONCLUSION

In comparison to conventional DWT techniques, the research's unique Hybrid DFT-FFT-DCT-DHT watermarking algorithm offers strong copyright protection. In contrast to DWT, which is mainly concerned with spatial domain embedding, the hybrid approach makes use of a variety of frequency domain transforms in order to achieve enhanced imperceptibility and resilience against different types of attacks. The Hybrid DFT-FFT-DCT-DHT approach offers a compelling trade-off between imperceptibility, robustness against diverse attacks, and watermark extraction accuracy, even though DWT offers better robustness against geometric distortions in certain scenarios. For a variety of copyright protection applications, this makes it a viable option, especially when visual fidelity and resistance to common image manipulations are crucial.

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Reference

1) K. R. Kakkirala, S. R. Chalamala and B. M. Garlapati, "An Audio/Speech Watermarking Method for Copyright Protection," *2015 3rd International Conference on Artificial Intelligence, Modelling and Simulation (AIMS)*, Kota Kinabalu, Malaysia, 2015, pp. 338-342, doi: 10.1109/AIMS.2015.61.

2) Sanivarapu, P. V., Rajesh, K. N. V. P. S., Hosny, K. M., & Sunil Kumar, G. (2023, June 21). Digital watermarking system for copyright protection and authentication of images using cryptographic techniques

3) Et. al., L. J. (2021). Design and Implementation of Robust Digital Watermarking using Hybrid technique for Copyright Protection Digital data. Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12(3), 4839–4845. https://doi.org/10.17762/turcomat.v12i3.1988

4) Comparison of Watermarking in Compressed Digital Video using DCT, DWT and FFT. (2017). *International Journal of Science and Research (IJSR)*, *6*(1), 470–473. https://doi.org/10.21275/art20163305

5) Hamidi, M., El Haziti, M., Cherifi, H., & El Hassouni, M. (2021). A Hybrid Robust Image Watermarking Method Based on DWT-DCT and SIFT for Copyright Protection. *Journal of Imaging*, *7*(10), 218. https://doi.org/10.3390/jimaging7100218

6) Gaata, M. T. (2017). Copyright Protection Of Digital Artwork Image Based On Robust Watermarking Technique.

7) Hsu, P., & Chen, C. (2016). A Robust Digital Watermarking Algorithm for Copyright Protection of Aerial Photogrammetric Images. *The Photogrammetric Record*, *31*(153), 51–70. https://doi.org/10.1111/phor.12134

8) Kumar, C. (2023). Hybrid optimization for secure and robust digital image watermarking with DWT, DCT and SPIHT. *Multimedia Tools and Applications*. https://doi.org/10.1007/s11042-023-16903-8

9) Rathore, S. S. (2019). A Simulation Process of Watermarking Algorithm to Noisy Images for Copyright Protection with DWT, SVD and DCT. *International Journal for Research in Applied Science and Engineering Technology*, *7*(12), 176–185. https://doi.org/10.22214/ijraset.2019.12028

10) Salama, A. S., Shoitan, R., Abdallah, M. S., Cho, Y. I., & Nagm, A. M. (2023). A Robust Algorithm for Digital Image Copyright Protection and Tampering Detection: Employing DWT, DCT, and Blowfish Techniques. *Traitement Du Signal*, *40*(5), 2019–2027. https://doi.org/10.18280/ts.400520

11) Abdulmunem, M. E., & Badr, A. A. (2018). Robust Audio Watermarking Based On Hybrid Transformation For Copyright Protection.

12) Rathore, S. S. (2019). A Simulation Process of Watermarking Algorithm to Noisy Images for Copyright Protection with DWT, SVD and DCT. *International Journal for Research in Applied Science and Engineering Technology*, *7*(12), 176–185. https://doi.org/10.22214/ijraset.2019.12028

13) Alasafi, L., Göksu, T., & Albayati, A. (2017). Copyright Protection by Robust Digital Image Watermarking in Unsecured Communication Channels. *Indonesian Journal of Electrical Engineering and Computer Science*, *7*(1), 234. https://doi.org/10.11591/ijeecs.v7.i1.pp234-249

14) Soundrapandiyan, R., Rajendiran, K., Gurunathan, A., Victor, A., & Selvanambi, R. (2023). Analysis of DWT–DCT watermarking algorithm on digital medical imaging. *Journal of Medical Imaging*, *11*(01). https://doi.org/10.1117/1.jmi.11.1.014002

15) Tiwari, N., Hemrajamani, N., & Goyal, D. (2017). Improved Digital Image Watermarking Algorithm Based on Hybrid DWT-FFT and SVD Techniques. *Indian Journal of Science and Technology*, *10*(3).https://doi.org/10.17485/ijst/2017/v10i3/110624

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16) Hamidi, M., Haziti, M. E., Cherifi, H., & Hassouni, M. E. (2018). Hybrid blind robust image watermarking technique based on DFT-DCT and Arnold transform. *Multimedia Tools and Applications*, *77*(20), 27181–27214. https://doi.org/10.1007/s11042-018-5913-9

17) Mahbuba Begum, Mohammad Shorif Uddin, "Analysis of Digital Image Watermarking Techniques through Hybrid Methods", *Advances in Multimedia*, vol. 2020, Article ID 7912690, 12 pages, 2020. https://doi.org/10.1155/2020/7912690

18) H. Sharma, D. Padha and N. Bashir, "D-KAP: A Deep Learning-based Kashmiri Apple Plant Disease Prediction Framework," 2022 Seventh International Conference on Parallel, Distributed and Grid Computing (PDGC), Solan, Himachal Pradesh, India, 2022, pp. 576-581, doi: 10.1109/PDGC56933.2022.10053334.

19) Yang, H. X., & Yang, M. Z. (2020). Reply to Deng et al. and Zhang et al. European Journal of Cardio-Thoracic Surgery, 58(2), 405–406. https://doi.org/10.1093/ejcts/ezaa096

20) Salama, Eng. Ahmed & Shoitan, Rasha & Abdallah, Mohamed & Cho, Young & Nagm, Ahmad. (2023). A Robust Algorithm for Digital Image Copyright Protection and Tampering Detection: Employing DWT, DCT, and Blowfish Techniques. Traitement du Signal. 40. 2019-2027. 10.18280/ts.400520.

21) M R, Arun and Subramanian, Selvakumar and M R, Sheeba and F, Shabina Fred Rishma, Comparing PSNR of Different Image Transforms (DCT, DFT, DWT, DHT, DTT) (April 6, 2018). Proceedings of International Conference on Energy Efficient Technologies for Sustainability, St.Xavier's Catholic College of Engineering, TamilNadu, India. 5th to 7th April, 2018, Available at SSRN: https://ssrn.com/abstract=3193921