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DIGITAL IMAGE WATERMARKING USING ADVANCED DWT-HD-SVD TECHNIQUE

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Abstract - Abstract – Digital image watermarking plays a crucial role in verifying the authenticity and protecting the ownership of digital images. This paper introduces a robust and efficient watermarking technique that combines Discrete Wavelet Transform (DWT), Hybrid Decomposition (HD), and Singular Value Decomposition (SVD). The proposed method is designed to improve both the imperceptibility and resilience of the watermarked images against a range of attacks. Experimental results demonstrate the effectiveness of the approach through key performance metrics, including Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM), and Normalized Correlation (NC), highlighting its potential for secure image authentication applications.

I. INTRODUCTION

In the digital age, the rapid proliferation of multimedia content has made copyright protection and data authentication crucial challenges. Digital image watermarking has emerged as an effective solution for protecting ownership and ensuring the integrity of digital images. A robust watermarking system must strike a balance between imperceptibility—ensuring that the watermark does not degrade image quality—and robustness—ensuring that the watermark can withstand various intentional or unintentional attacks. This paper presents an advanced digital image watermarking technique that integrates Discrete Wavelet Transform (DWT), Hybrid Decomposition (HD), and Singular Value Decomposition (SVD) to enhance both imperceptibility and robustness. The proposed method exploits the multi-resolution analysis capability of DWT, the decomposition efficiency of HD, and the stability of SVD to embed the watermark in a more secure and reliable manner.

II. OBJECTIVES AND SCOPE

A. Objectives

The main goal of this project is to develop a secure and invisible digital image watermarking system that protects image ownership and authenticity. By combining DWT, Hybrid Decomposition, and SVD, the aim is to build a strong framework that offers both reliability and robustness. The project focuses on designing algorithms for embedding and extracting watermarks with minimal impact on image quality, while ensuring high resistance to attacks like compression, noise, filtering, and geometric changes. The system is evaluated using metrics such as PSNR, SSIM, and Normalized Correlation to confirm its effectiveness in practical scenarios.

B. Scope

This project focuses on implementing an invisible watermarking technique for grayscale images using a hybrid of DWT, HD, and SVD. The embedded watermark is intentionally designed to be imperceptible while maintaining the overall image quality. Although the current system is limited to grayscale images, the approach can be adapted for color images and video in future developments. The project evaluates the method's resilience against common image processing attacks but does not include cryptographic measures or real-time capabilities. It lays a foundation for further enhancements in digital content protection.

III. LITERATURE REVIEW

Digital image watermarking has been a widely researched topic in the field of multimedia security for over two decades. Various techniques have been proposed, each aiming to strike the right balance between robustness, imperceptibility, and capacity. Among the most influential and effective approaches are transform domain techniques such as Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), and Singular Value Decomposition (SVD). These techniques often outperform spatial domain methods because they distribute the watermark information presented in a manner that is less prone to common misconceptions image processing operations.

A. DWT-Based Techniques

Discrete Wavelet Transform (DWT) is widely used in image watermarking due to its ability to represent images at multiple resolutions. It divides the image into frequency sub-bands, enabling watermark embedding in areas that are less visible but more robust to attacks. Its strength lies in time-frequency localization, which helps maintain both visual quality and durability.

B. SVD in Watermarking

Singular Value Decomposition (SVD) is valued for its stability and energy concentration. Minor changes to an image's singular values usually don't degrade visual quality, making SVD a reliable choice for embedding. It allows watermarks to remain intact even after image alterations like noise or compression.

C. Hybrid Techniques

To address the limitations of individual methods, researchers have combined DWT and SVD. This hybrid approach leverages DWT's ability to isolate frequency components and SVD's robustness, resulting in better imperceptibility and resistance to tampering than using either technique alone.

D. Emerging Trends and Techniques

Recent work has extended hybrid models by incorporating advanced techniques like Hybrid Decomposition (HD), which improves flexibility in selecting embedding regions. Other studies include multi-transform models like DWT-DCT-SVD or optimization-driven methods using Genetic Algorithms or Whale Optimization Algorithm (WOA). For instance, a GBT-DWT-SVD framework enhanced by WOA showed notable improvements in image quality (PSNR) and robustness under complex attacks.

E. Summary of Research Gap

While hybrid methods have shown promise, many still struggle to maintain robustness without affecting image quality. Notably, there is limited work integrating DWT, HD, and SVD into a single system. This gap forms the basis of the current study, which aims to explore and validate the combined benefits of all three techniques. 0

IV. SYSTEM ARCHITECTURE

The architecture of the proposed digital image watermarking system is designed to systematically embed and extract a watermark using a hybrid approach that leverages the strengths of Discrete Wavelet Transform (dwt), hybrid decomposition (hd), and singular value decomposition (svd). The system is divided into two main phases: Watermark Embedding and Watermark Extraction.

1. Watermark Embedding Process:

This step entails embedding a watermark into the host. The image was manipulated in a way that the alterations were undetectable. To human eyes but resilient enough to withstand standard conditions image alterations. The steps are as follows:

Step 1: Preprocessing

The host image and the watermark (usually a binary or grayscale logo) are resized and normalized to match the required dimensions.

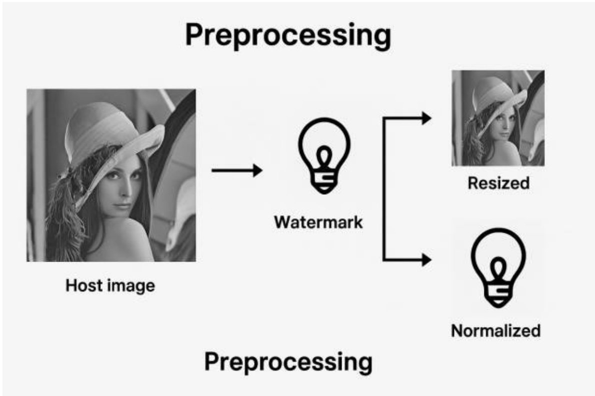

Fig 1: Preprocessing Host Images

Step 2: Apply DWT

The host image is broken down into four frequency subbands: LL (approximation), LH, HL, and HH (detail components). The LL sub-band, which holds the most significant image information, is selected for further processing.

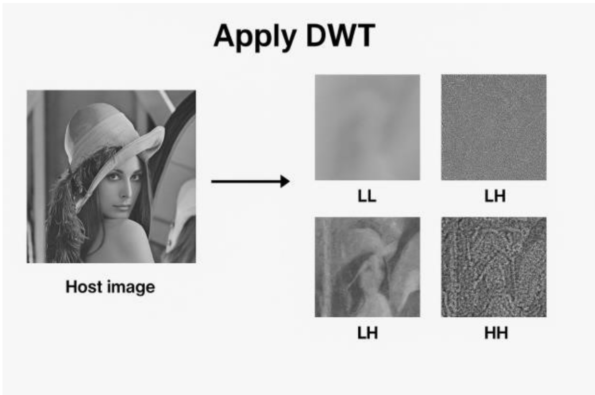

Fig 2: Apply DWT

Step 3: Hybrid Decomposition (HD)

The ll sub-band is broken down using a specially designed algorithm. Hybrid decomposition technique that integrates supplementary. Transformation or segmentation techniques. This enhances the embedding flexibility and increases the robustness of the watermark.

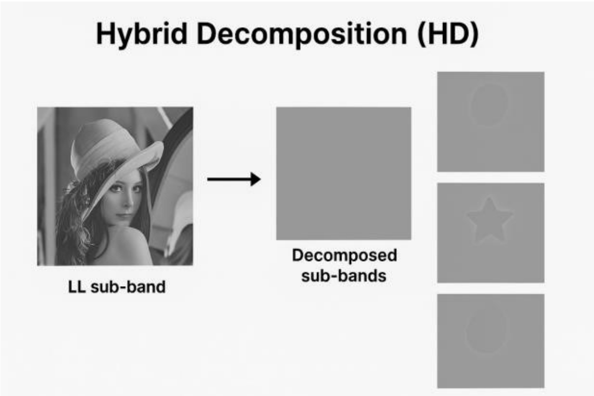

Fig 3 : Apply Hybrid Decomposition

Step 4: Apply SVD

SVD is utilized to the decomposed sub-band. The watermark is incorporated into the singular values by adjusting them slightly according to a scaling factor.

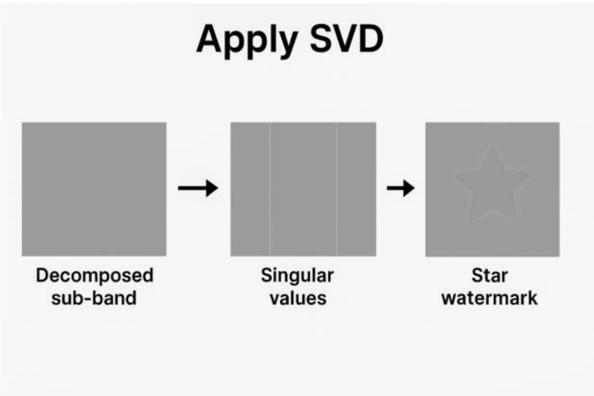

Fig 4: Apply SVD

Step 5: Reconstruction

The modified singular values are combined using inverse SVD, followed by inverse HD and inverse DWT to reconstruct the final watermarked image.

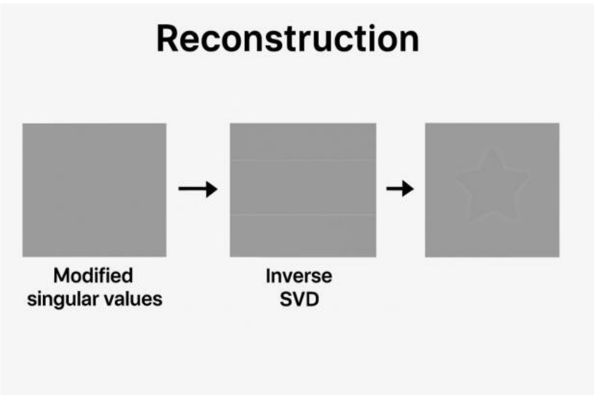

Fig 5: Recostruction

2. Watermark Extraction Process

The watermark extraction process is essentially the reverse of embedding:

Step 1: DWT of Watermarked Image

Break down the watermarked image using dwt to extract the ll sub-band.

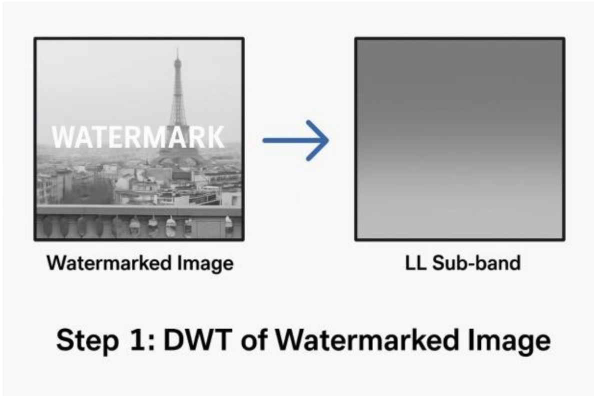

Fig 6: DWT of Watermarked Image

Step 2: Apply HD

Use the same hybrid decomposition technique used for embedding the ll sub-band.

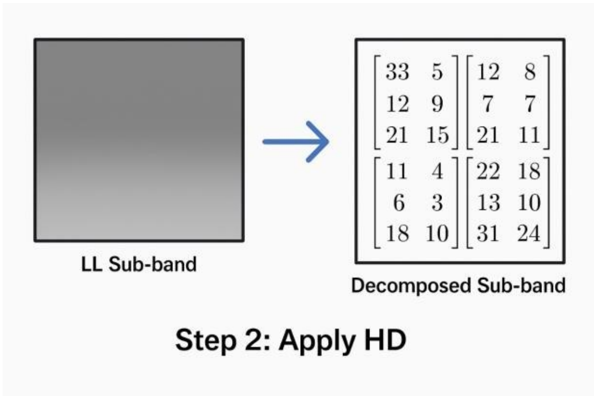

Fig 7: Apply HD

Step 3: Apply SVD

Perform SVD on the decomposed LL sub-band and extract the watermark using the singular values.

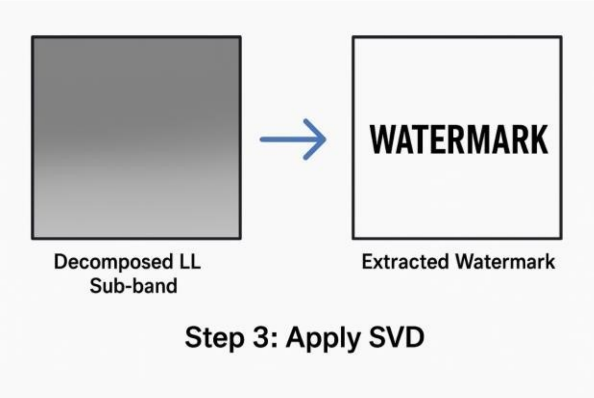

Fig 8: Apply SVD

Step 4: Post-processing

The extracted watermark is resized and binarized (if required) for comparison with the original watermark.

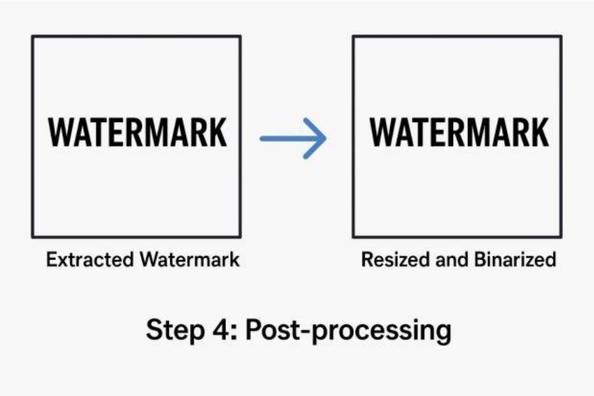

Fig 9: Apply Post-processing

V. PROPOSED METHODOLOGY

This section presents a robust and imperceptible digital image watermarking technique that integrates Discrete Wavelet Transform (DWT), Hybrid Decomposition (HD), and Singular Value Decomposition (SVD). The primary objective is to embed a watermark in such a way that the visual quality of the host image is preserved while the embedded watermark remains resilient to a wide range of image processing attacks.

The proposed methodology is divided into two main stages: Watermark Embedding and Watermark Extraction.

A. Watermark Embedding Algorithm

The watermark embedding process involves incorporating a watermark into a host image with minimal perceptual distortion. The detailed steps are as follows:

1) Input Preparation

- Load the host image in grayscale format.
- Load the watermark image (binary or grayscale) and resize it to match the dimensions of the transform domain used during embedding.

2) Discrete Wavelet Transform (DWT)

- Apply a single-level 2D DWT to the host image, resulting in four sub-bands:
- LL (Approximation)
- HL (Horizontal details)
- LH (Vertical details)
- HH (Diagonal details)
- The LL sub-band is selected for embedding, as it retains the most significant visual information and offers higher robustness against common attacks.

3) Hybrid Decomposition (HD)

- Further decompose the LL sub-band using a hybrid approach, which may combine techniques such as:
- Discrete Cosine Transform (DCT)
- Image segmentation
- Other transformation methods
- This step helps localize stable embedding regions, enhancing precision and robustness.

4) Singular Value Decomposition (SVD)

- Perform SVD on the decomposed LL-HD component:
- LL_{HD} = U \cdot S \cdot V^T
- Modify the singular value matrix (S) by embedding the watermark into its singular values using a predefined scaling factor \alpha:
- S’ = S + \alpha \cdot

5) Reconstruction

- Reconstruct the modified LL-HD sub-band using the original U, modified S’, and V matrices.
- Apply inverse HD followed by inverse DWT to obtain the final watermarked image.

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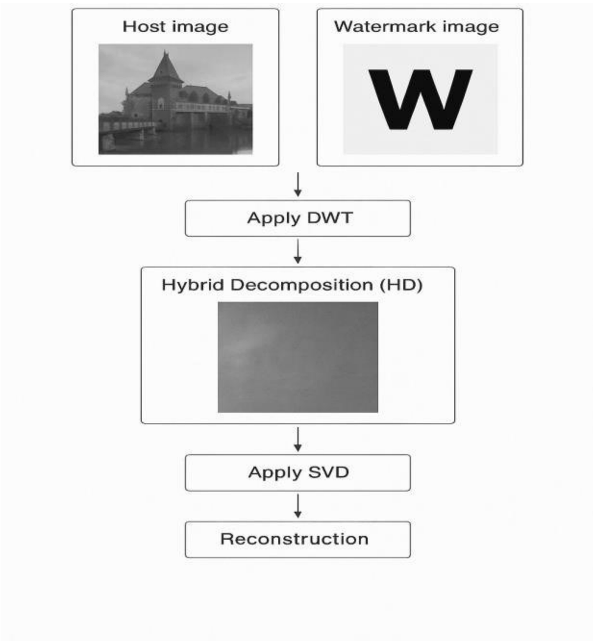


Fig 10: Representation of Watermark Embedding Algorithm Process

B. Watermark Extraction Algorithm

To retrieve the embedded watermark, the extraction process reverses the embedding steps:

1) Input Watermarked Image

• Load the watermarked image, which may have undergone processing or attacks.

2) DWT Decomposition

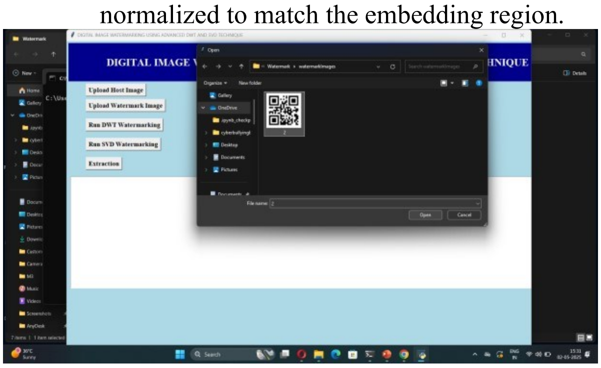
• Apply DWT to decompose the image and extract the LL sub-band.

3) Hybrid Decomposition

• Apply the same HD technique as used in the embedding phase on the LL sub-band.

4) SVD Decomposition

• The watermark image, typically a small grayscale logo (e.g., 64×64 pixels), was resized and normalized to match the embedding region.



- Perform SVD on the HD-processed LL sub-band:
- LL_{HD}’ = U’ \cdot S’ \cdot V’^T

5) Watermark Recovery

• Recover the watermark \hat{W} using: • \hat{W} = \frac{S’ - S}{\alpha} where S is the original singular value matrix (assumed known or stored securely), and \alpha is the scaling factor used during embedding.

6) Post-processing

- Resize or binarize the extracted watermark if required.
- Compare it with the original watermark using similarity metrics like PSNR, NC (Normalized Correlation), or BER (Bit Error Rate).

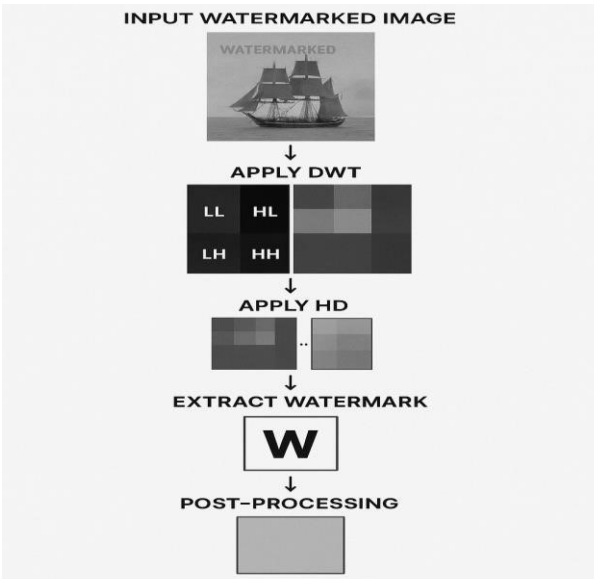


Fig 11: Representation Of Watermark Extraction Algorithm

Process

C. Advantages of the Proposed Method

- Robustness: The combination of DWT, HD, and SVD ensures high resilience against various signal processing attacks including JPEG compression, Gaussian noise, filtering, and geometric distortions.
- Imperceptibility: Embedding in singular values (which carry minimal perceptual significance) maintains the host image's visual quality.
- Scalability: The proposed framework can be seamlessly extended to color images and video watermarking with minimal algorithmic adjustments.

VI. IMPLEMENTATION AND RESULTS

The watermarking system was implemented using MATLAB, which provides robust tools for image processing and matrix operations. The choice of MATLAB was driven by its simplicity in handling large matrices, image transforms, and visualization, all of which are essential for developing and testing the watermarking algorithm.

Step-by-Step Implementation Process

1. Image Input and Preprocessing
   - A grayscale image of size 512×512 pixels was selected as the host image.

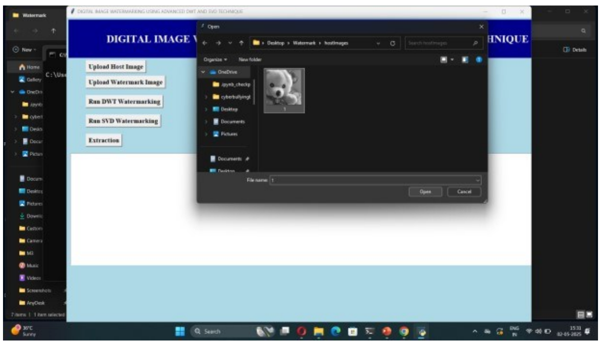


Fig 12: Selecting Host Image

Fig 13: Selecting Watermark Image

2. Transformation using DWT
   - A single-level 2D Discrete Wavelet Transform was applied to the host image using the 'haar' wavelet.
   - This led to the formation of four distinct subbands: ll, lh, hl, and hh.. The LL subband,being the most stable and informative, was selected for watermark embedding.

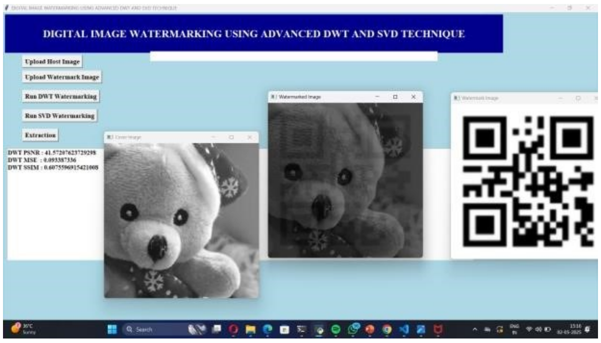


Fig 14: DWT Watermarked Image

3. Hybrid Decomposition (HD)
   - The LL sub-band was passed through an additional transformation, such as DCT or segmentation-based decomposition, to further localize the embedding process.
   - This step increased robustness by focusing on regions less affected by noise or image compression.

4. SVD-Based Watermark Embedding
   - Singular Value Decomposition (SVD) was applied to the HD-transformed image block.
   - The watermark was embedded into the singular values (S matrix) using a controlled embedding strength (α).
   - The watermarked block was then reconstructed using the inverse of SVD, HD, and DWT.

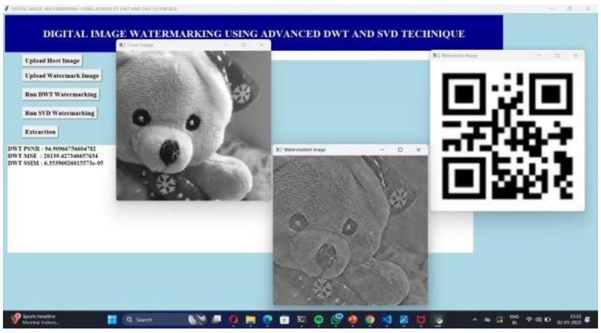


Fig 15 : SVD Watermarked Image

5. Output Generation
   - The final watermarked image was saved and displayed alongside the original for visual comparison.
   - The system also stored the singular values from the original image for use during the extraction phase.

6. Attack Simulation

- Various standard attacks were simulated to test the system's robustness, including:
- JPEG compression
- Salt and pepper noise
- Gaussian noise
- Median filtering
- Image rotation and cropping.

7. Extraction Process
   - The watermarked image (or its attacked version) was passed through the reverse process: DWT → HD → SVD.
   - The watermark was extracted from the modified singular values and compared with the original.

Results and Observation

The proposed dwt-hd-svd watermarking system was evaluated using three crucial performance metrics:

- **Psnr (peak signal-to-noise ratio)** is a metric that quantifies the level of image quality in relation to the original.
- **SSIM (structural similarity index):** quantifies the level of visual similarity between the watermarked image and the original.
- **Nc (normalized correlation):** measures the degree of similarity between the original watermark and the extracted one.

Performance Outcomes

1. Imperceptibility Results
   - The PSNR values consistently remained above 40 dB, indicating that the watermarked image maintained high visual quality.
   - The SSIM scores were very close to 1.0, showing minimal structural difference from the original image.

2. Robustness Against Attacks
   - Even after applying compression (at 50% JPEG quality), the extracted watermark maintained high fidelity, with NC > 0.90.
   - The system demonstrated robustness against noise, such as salt and pepper and Gaussian, with only slight reductions in watermark clarity.
   - For geometric attacks like rotation and cropping, the extracted watermark was still recognizable, though some performance drop in NC was noted.

3. Visual Evaluation
   - Both the original and watermarked images looked the same to the human eye.
   - The extracted watermark was clear and closely matched the original under normal and attacked conditions.

VII. CONCLUSION AND FUTURE SCOPE

This work presents a robust and imperceptible image watermarking technique that combines DWT, Hybrid Decomposition, and SVD. The method successfully embeds watermarks without noticeable changes to image quality and shows strong resistance to common attacks like compression, noise, and geometric distortions. Result confirm that the technique balances visual quality and robustness, making it suitable for practical use. Looking ahead, the approach can be extended to color images by embedding across different color channels. Integrating deep learning models could further enhance adaptability and protection against complex attacks. Future work may also explore video watermarking to support real-time content protection in areas like streaming and surveillance.

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