Chapter 11
Hybrid DCT–DWT–SVD Watermarking: A Comparative Performance Analysis

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ABSTRACT

In this chapter, we present the performance of a composite watermarking algorithm that utilizes DCT, DWT, and SVD, building upon previously existing systems for robust digital image watermarking. The proposed DCT-DWT-SVD-based hybrid method uses the energy compaction, resolution in the multi-scale domain, and stability properties of SVD to enhance the imperceptibility and robustness of the embedded watermark. In this work, the watermark insertion process operates in two steps: first, by extracting the DWT of the cover image and then applying the DCT transform to the obtained sub-bands and modifying the singular values using SVD. Comprehensive experiments are conducted on various image corruptions, including noise, cropping, compression, and geometric transformations. We then

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employ PSNR, NC, and SSIM to quantify the trade-offs and performance of the compared models. Experimental results demonstrate that the hybrid DCT-DWT-SVD outperforms traditional single-transform methods and dual-transform methods in terms of robustness and perceptual quality.

I. INTRODUCTION

Hybrid DCT-DWT-SVD-based watermarking algorithms have proved an important breakthrough in multimedia security, integrating various starts from Discrete Cosine Transform, DWT and SVD to provide a robust, invisible and highly robust mark embedding technique in digital images, audio or video content (Kumar, 2024). Complex hybrid methods like these are necessary due to the increasing levels of vulnerability in the age of digital piracy, copyright infringement, and the rapid spread of multimedia content across different communication channels. All techniques – DCT, DWT and SVD – provide their specific benefit when utilized separately: DCT is energy compact and represents image features in the frequency domain, thus is robust to compression attacks (Zhang et al., 2025), the DWT is good for multiresolution analysis, capturing both spatial and frequency characteristics and allowing selective embedding in sub bands less visible to humans (Reza et al., 2025); on the other hand, the SVD has an advantageous stability and algebraic properties making it more robust to manipulation attacks and noise using singular values that are less sensitive to both host signal's systematic and random disturbances (Reza et al., 2025). Nevertheless, the hybridization of these methods has proven to create synergistic effects by combining the strengths of each technique while also compensating for their limitations. The general embedding scheme involves first dividing the cover image into sub-bands using DWT, then transforming one of the sub-bands , most commonly HH (high-high), using DCT to spread the watermark signal across different frequency ranges. Finally, SVD is utilized on the transformed coefficients to embed the watermark by modifying the singular values. This combined framework yields a watermark that is not only imperceptible since modifications are made in less visually significant regions—but also highly robust against a wide spectrum of intentional and unintentional attacks, including compression, noise, filtering, cropping, rotation, scaling, and other geometric or signal processing operations (Alshoura & Alawida, 2025). In comparative performance evaluation, hybrid DCT-DWT-SVD watermarking exhibits overall better performance in terms of several key metrics, including PSNR, NC, and SSIM, compared to single-domain and dual-domain digital watermarking techniques. For example, when attacked by image manipulations commonly used in the image processing field, such as JPEG compression, AGN, etc., the embedded watermark in hybrid schemes can maintain better quality and recognizability when