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A COMBINED APPROACH OF DWT-DCT FOR BLIND MEDICAL IMAGE WATERMARKING

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Abstract

With the rapid advancement of digital technologies, the sharing and distribution of medical images have become widespread, posing serious security challenges. To protect sensitive medical data from unauthorized access and tampering, watermarking has emerged as a crucial security measure. In addition, the concept of watermarking has become vital in preserving the integrity and authenticity of these images. Traditional watermarking techniques faced limitations in terms of robustness and visibility, especially for medical imaging, where image quality is paramount. To overcome these challenges, this work introduces an innovative blind medical image watermarking technique that combines the Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT). The proposed method ensures robust and imperceptible watermark embedding and retrieval while maintaining the visual quality of medical images. The significance of robust and imperceptible medical image watermarking cannot be overstated. As medical institutions increasingly adopt digital practices like telemedicine and electronic health records, the risk of data breaches, tampering, and unethical practices also rises. An efficient watermarking technique is crucial to protect patient privacy, maintain trust in medical institutions, and ensure the authenticity of medical data. The combined DWT-DCT approach presented in this paper offers a promising solution by enabling secure watermark embedding and retrieval, ensuring tamper detection and authentication.

1. Introduction

Blind medical image watermarking is a specialized and vital application of digital watermarking techniques within the healthcare industry. It specifically addresses the need to embed hidden, secure, and tamper-resistant information within medical images such as X-rays, MRI scans, CT scans, and ultrasounds. The primary objective of blind medical image watermarking is to ensure the integrity, authenticity, and confidentiality of patient data and diagnostic images at all stages of their lifecycle, from acquisition and storage to transmission and analysis. This technology involves the insertion of digital watermarks into medical images without compromising their diagnostic value. These watermarks typically contain essential patient information, including the patient's name, medical record number, date, and institution, as well as additional metadata for authentication and tracking purposes. Advanced algorithms and techniques are employed to embed the watermark in such a way that it remains invisible to the human eye and resilient to common image processing operations and attacks. In telemedical applications, the verification of authenticity and copyright for medical images play a major role. Telemedicine-based medical image diagnosis is carried out with different techniques such as X-ray, ultrasound scanning, etc. Verification in the medical field is an important application for ensuring the authenticity of patient data in the time of transition of medical image. Data hiding is used to conceal a piece of information secretly in the medical image such as the electronic patient report [1]. Recently, digital watermarking has become an important approach for protecting the legitimacy and copyright of medical images. The digital watermarking approach exhibits technologies and methods

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that embed data into the host such as digital data, audio, video, and image without modifying its quality [2]. Generally, digital watermarking techniques are used for authentication, broadcast monitoring, database indexing, and medical imaging. The watermarking methods use fragile, semi-fragile, blind, and robust watermarks to provide authentication and copyright protection. Watermarking schemes are classified into Region of interest (ROI) lossless watermarking scheme, zero watermarking scheme, and reversible watermarking scheme [3]. ROI is the important area where important diagnosis data is presented in the medical images. In a reversible watermarking scheme, the authentication of a specific image is extracted from its watermarked image very accurately [4].

2. Literature Survey

In digital images, watermarking secret data is embedded into the host image for ownership authentication. There are different watermarking schemes to insert the data into the host image. The easiest form of watermarking is the alteration of the least significant bit (LSB) of the host image, which is called a fragile watermark [5,6,7]. Generally, the technique is used for patient information and to identity verification. Moreover, the medical image watermarking algorithm can be categorized into the authentication and integrity control (AIC) algorithm, data-hiding algorithm, and a combination of data-hiding algorithm as well as AIC [8,9]. The AIC algorithm aims to ensure the integrity and identity of the source image [10]. There are different applications of digital watermarking, such as content and image authentication, fingerprinting, tamper-proofing, digital rights management, and copyright protection, etc. The better way of performing watermarking is by ensuring that the image quality is not degraded and not affected by any attacks.

To achieve content authentication and tamper localization in secured telemedicine, Swaraja, K et al. [11] developed a framework with blind dual medical image watermarking. This method was used to prevent the alteration of content. In the medical image, the region of non-interest (RONI) blocks were used to hide the dual watermarks for authentication and recognition. This framework demonstrated its superior capabilities and outperformed the other related optimized hybrid algorithms. This method retrieved the original region of interest (ROI) without any loss of information. Liu, X et al. [12] developed a reversible water marking technique to safeguard the integrity and authenticity of medical images. The region of interest (ROI) watermarking entailed the risk of spatial image segmenting. The ROI method had failed in the recovery of tampered areas. In this method, recursive dither modulation (RDM) is used to avoid diagnostic biases. Singular value decomposition and slantlet transform combined with RDM are used to protect image authenticity. This method outperformed all the other techniques for medical image protection.

Zeng, C et al. [13] proposed a multi-watermarking algorithm on KAZE DCT for medical images. The features of the medical images were extracted with KAZE DCT and the sequent features of medical images were obtained with perceptual hashing. The multi-watermark images were encrypted by chaotic mapping. This method resulted in effective extraction of watermarks. This method could witheld both geometric and common attacks. Patel, N et al. [14] developed a DCT DWT hybrid ROI image compression for the application of telemedicine. This method recreated the medical image rapidly and eliminated the unwanted medical data with a compression algorithm. This method increased the data processing speed. The highest PSNR and lowest MSE were obtained using this technique. The best visual image was presented with this DCT compression method. It had bit rates higher than those obtained using wavelet compression algorithms.

Hu, K et al. [15] developed the zero watermarking algorithm used in medical field. The developed zero watermarking algorithm generated bi-dimensional empirical mode decomposition (BEMD) to detect the tampering regions. The images were divided into a number of residues and intrinsic mode functions

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(IMF). The singular value decomposition was used to extract feature matrices from the first IMF. Arnold transform was used in encrypting the watermark image to add security. The exclusive or operation was used to create feature images. These feature images were used to detect tampering and authenticate copyright. This algorithm created natural images and performed better than other algorithms in fighting various cyber-attacks. Nazari, M and Mehrabian, M. [16] developed a blind watermarking technique with integer wavelet transform (IWT) and least significant bit (LSB) for secured transmission of medical images. In this method, chaotic sequences were used to determine the host blocks locations and to encrypt watermark. A robust security level was achieved with the chaotic sequences. The ROI and the RONI were two divided parts of the image. The ROI data was not embedded due to high sensitivity. This method achieved 75 dB of PSNR value and provided highest imperceptibility. The embedded watermark's size was increased.

Gong, C et al. [17] illustrated a zero-watermarking algorithm on chaotic map and Harris SURF DCT for medical images. The established algorithm was used to exhibit the corners of the image. The descriptor matrix was created through the description of extracted corners in the SURF algorithm. The watermark was encrypted with the logistic map algorithm. The developed method obtained the water mark without any changes in the medical image. This algorithm performed better in defending geometric attacks. Dhall, S. and Gupta, S. [18] proposed a highly secured multilayer watermarking mechanism for the purpose of medical applications. The proposed method was used to secure the medical images and the transcript of patient. The original medical image was embedded with electronic patient records (EPR) to obtain the watermarked image. The quantum encrypted and compressed EPR was embedded into the lifting wavelet transform (LWT) medical image. The image stenography technique was used to change the structure of the watermarked medical image and it also avoids the images from attacks. Hash algorithm with biometric detection was used for authentication. This method presented a highly secured health care system. This method consumed more time than other conventional methods due to multilayer security. While some studies have developed effective watermarking techniques using methods such as blind dual watermarking, reversible watermarking, and zero watermarking, none of these studies have explored the possibility of combining these techniques to improve overall performance. Additionally, the studies mentioned have primarily focused on protecting the integrity and authenticity of medical images; however, there may be a need to also consider the protection of patient privacy and sensitive information.

3. Proposed System Design

Activity diagrams are graphical representations of Workflows of stepwise activities and actions with support for choice, iteration, and concurrency. In the Unified Modeling Language, activity diagrams can be used to describe the business and operational step-by-step workflows of components in a system. An activity diagram shows the overall flow of control.

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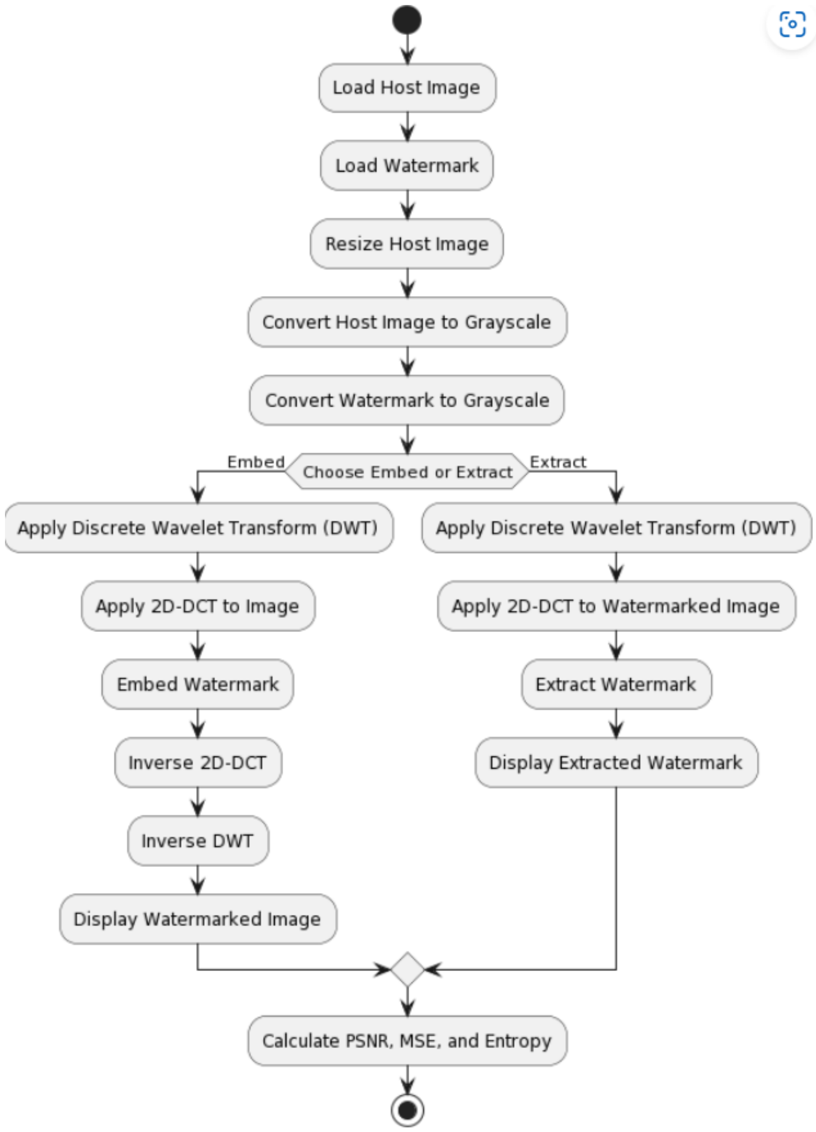

Figure 1. Proposed system design.

3.1 DWT

The Discrete Wavelet Transform (DWT) is a mathematical technique used for signal and image processing, including applications in data compression, feature extraction, and denoising. DWT operates by decomposing a signal or image into different frequency components at multiple scales. Here's a detailed explanation of the operation of the DWT:

Preparation of Data: DWT begins with a one-dimensional or two-dimensional signal or image as input data. The input signal or image typically has a finite length or size.

Filtering and Down-Sampling (Decomposition): In the decomposition step, the DWT applies a pair of filters known as the low-pass filter (LPF) and the high-pass filter (HPF) to the input data as shown in Figure 4.3. The LPF extracts the low-frequency components from the data, while the HPF extracts the high-frequency components. Low-frequency components often represent the coarse details or approximations of the original data, while high-frequency components represent the fine details or noise. After filtering, the data is downsampled by a factor of 2 in both dimensions. Down-sampling reduces the data size by discarding every alternate sample, effectively reducing the resolution by half.

ISSN: 0975-3583,0976-2833 VOL14, ISSUE 10, 2023

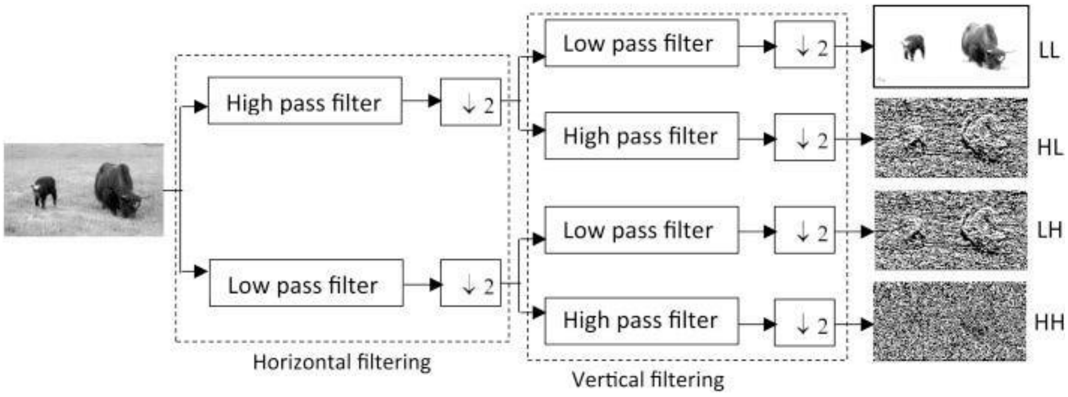

Figure 2. DWT decomposition.

Scaling and Wavelet Coefficients: The output of the DWT decomposition consists of two sets of data: the approximation coefficients (LL) and the detail coefficients (LH, HL, HH). The LL coefficients represent the lower-scale approximation of the original data, containing the low-frequency information. The LH, HL, and HH coefficients represent the detail information at different scales. LH contains information about low-frequency variations in the vertical direction, HL contains information about low-frequency variations in the horizontal direction, and HH contains high-frequency detail information.

Multiple Decomposition Levels: The DWT process can be recursively applied to the LL coefficients (approximation coefficients) to obtain further decomposition levels. Each level provides a different level of detail, with LL coefficients becoming lower-resolution approximations at each level.

End of Decomposition: The decomposition process continues until the desired level of detail or the maximum decomposition level is reached.

Reconstruction (Inverse DWT): The original signal or image can be reconstructed from the DWT coefficients as shown in Figure 4.4. This is done by applying the inverse DWT, which involves up-sampling (increasing the resolution) and applying the inverse of the filters used during decomposition.

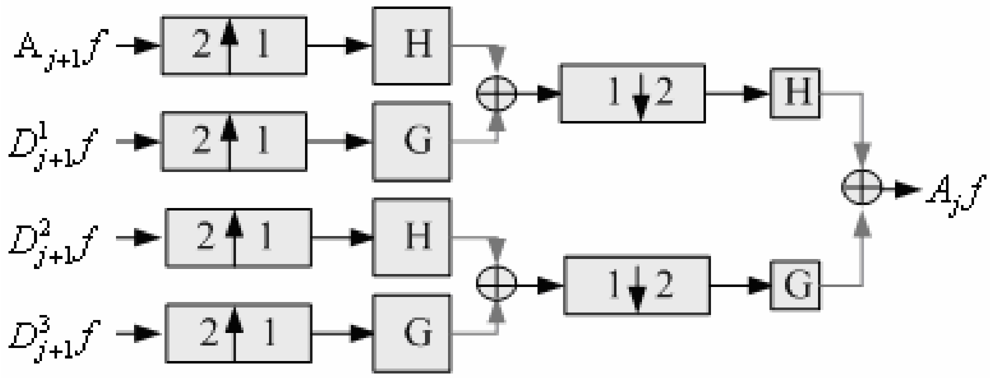

Figure 3. DWT reconstruction.

4. Results and description

The given figure represents the watermarking embedding performance. In (a), we observe a medical image of the brain, which serves as the host image for the watermarking process. This work aims to embed a unique watermark into this medical image while preserving its diagnostic information. In (b), we see the original watermark, which is essentially a distinct identifier or piece of data that needs to be

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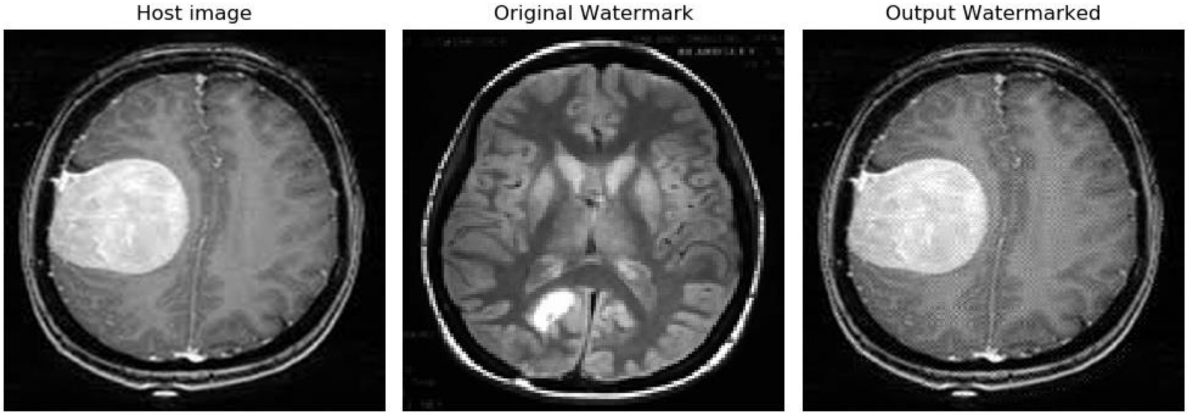
incorporated into the host image. The effectiveness of the watermarking technique used in this work becomes evident in (c), where we witness the output watermarked image. This output image showcases the successful integration of the watermark into the brain medical image, demonstrating the robustness and reliability of the watermarking method employed in this study.



(a) (b) (c)

Figure 4: Watermarking embedding performance. (a) brain medical image. (b) original watermark. (c) output watermarked image

5. Conclusion

In conclusion, the combined approach of DWT-DCT for blind medical image watermarking presented in this study addresses critical security concerns in the sharing and distribution of medical images. The technique offers a robust and imperceptible means of embedding and retrieving watermarks while preserving the visual quality of these sensitive images. As the healthcare industry continues to embrace digitalization and telemedicine, the need for secure and trustworthy medical data management becomes increasingly paramount. This innovative watermarking method contributes significantly to safeguarding patient privacy, maintaining the integrity of medical records, and ensuring the authenticity of medical images.

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