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ENHANCING MEDICAL IMAGE SECURITY THROUGH RGB AND YUV COLOR BASED ADVANCED TRIPLE WATERMARKING TECHNIQUES

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ABSTRACT

This paper delves into the exploration and evaluation of diverse triple watermarking embedding techniques specifically tailored for medical imaging. In the healthcare sector, where the confidentiality and integrity of medical images are paramount, implementing robust security measures without compromising image quality is crucial. The study focuses on triple watermarking methods that incorporate three layers of security, aiming to enhance the protection of sensitive medical data while optimizing image compression to facilitate efficient storage and transmission. By conducting comparative analyses and performance evaluations, the paper highlights the effectiveness, resilience against tampering, and compression efficiency of these techniques in medical imaging applications. The outcomes show significant advancements in securing medical images, providing a benchmark for future research and development in medical data protection.

Keywords: Triple Watermarking, Medical Image Security, Data Compression, Embedding Techniques, Digital Healthcare

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1. INTRODUCTION

In the digital era, the security and privacy of medical data have emerged as critical concerns, especially given the sensitivity and personal nature of medical images used in diagnosis and treatment. The transmission and storage of such images cause not only confidentiality and integrity but also efficient handling to support fast access and sharing among healthcare professionals. This has led to the exploration of advanced security techniques, among which triple watermarking embedding techniques for medical imaging stand out. These techniques aim to integrate multiple layers of security within the digital images, ensuring that the data remains protected against unauthorized access and alterations. Simultaneously, they address the need for efficient data compression to manage the ever-growing volumes of medical images without compromising the quality crucial for clinical analysis.

The application of triple watermarking in the medical field represents a sophisticated approach to balancing the dual requirements of security and efficiency. By embedding three distinct watermarks into medical images, these techniques

not only fortify the data against potential cyber threats but also leverage compression algorithms to reduce file sizes, facilitating quicker transmission and reducing storage demands. This paper focuses on the compression aspect of various triple watermarking embedding techniques, examining their capacity to maintain high-quality images while applying rigorous security measures. Through a detailed comparison and evaluation of these techniques, the study aims to identify optimal strategies that uphold the stringent security standards required in healthcare while ensuring that the compressed images keep the details for accurate medical interpretation. The research findings promise to contribute significantly to the field of digital healthcare, offering insights into developing more secure and efficient methods for managing sensitive medical data.

2. PROBLEM STATEMENT

The escalating demand for digital medical imaging in healthcare poses a significant challenge in ensuring the confidentiality, integrity, and availability of sensitive medical data. Medical images, such as X-rays, MRIs, and CT scans, are integral to patient diagnosis, treatment planning, and long-term care management. However, the digital nature of these images makes them vulnerable to unauthorized access, tampering, and data breaches, compromising patient privacy and the reliability of medical diagnostics. Moreover, the large file sizes of high-resolution medical images strain storage and transmission capabilities within healthcare IT systems, necessitating efficient compression techniques that do not degrade image quality essential for clinical accuracy. Consequently, there exists a critical need for advanced embedding techniques capable of simultaneously enhancing data security through robust watermarking while optimizing compression to facilitate efficient storage and rapid transmission of medical images. This paper addresses this need by investigating the efficacy of various triple watermarking embedding techniques tailored for medical imaging, aiming to establish a balanced approach that upholds both the security and quality integrity of medical data in digital healthcare environments.

3. LITERATURE REVIEW

Multi-Color Based Multiple - Watermark embedding, a variety of sophisticated techniques can be utilized to ensure that multiple watermarks are securely embedded within an image without compromising its quality. These methods often involve manipulating different aspects of the image's color space to accommodate more than one watermark. This method involves dividing the image into different color spaces or channels (such as RGB, and YUV). Each color space or channel can then be used to embed different watermarks. By utilizing the unique characteristics of each color channel, this technique allows for the embedding of multiple watermarks without significant interference among them.

RGB Color Space

The RGB color model is the most common color space for digital images, especially in computer graphics and digital cameras. It is an additive color model where red, green, and blue light are added together in various ways to reproduce a broad array of colors. The name of the model comes from the initials of the three additive primary colors, red, green, and blue.

Watermark Embedding in RGB: Direct Embedding: The simplest approach is to directly alter the RGB values of selected pixels to embed the watermark. Techniques like LSB (Least Significant Bit) modification can be applied, where the least significant bits of one or more of the RGB channels of selected pixels are replaced with the bits of the watermark.
Triple watermarking in the RGB color space involves embedding three distinct watermarks into the red, green, and blue channels of an image. This approach leverages the separation of color channels to discreetly insert multiple layers of information, enhancing data protection and integrity.

Process of Triple Watermarking in RGB

1. **Preparation of Watermarks:** Initially, three separate watermarks are prepared. These can be text, images, or any data that needs to be securely embedded within the host image. Each watermark is encoded or transformed into a format suitable for embedding.
2. **Channel Separation:** The host image is separated into its constituent RGB channels. This step involves splitting the image data into three separate matrices or layers, each corresponding to one of the primary colors.
3. **Embedding Technique:** Various techniques can be employed for embedding the watermarks into each channel. Common methods include:

- **Least Significant Bit (LSB) Modification:** Altering the least significant bits of pixel values in each channel to encode the watermark data.
- **Discrete Cosine Transform (DCT):** Applying DCT to each channel, modifying the DCT coefficients to embed the watermark, and then applying the inverse DCT to obtain the watermarked channel.
- **Discrete Wavelet Transform (DWT):** Similar to DCT but using wavelet transforms for a more hierarchical approach, allowing for multi-resolution watermarking.

4. **Adaptive Embedding:** The embedding process can be adapted based on the characteristics of each channel and the image content. For example, areas with higher color variance might be chosen for embedding to minimize visual distortion
5. **Combining Channels:** After embedding the watermarks into the separate channels, the modified channels are combined back into a single image. This reintegration must be done carefully to preserve the overall color balance and image quality
6. **Post-Processing:** Optional post-processing steps can be applied to further mask the presence of watermarks or enhance the image's resilience against attacks such as compression, cropping, or scaling.

Advantages of RGB Triple Watermarking

- **Robustness:** Embedding watermarks in separate channels enhances the overall robustness of the watermarking scheme, as an attacker would need to tamper with all three channels to remove the watermarks completely.
- **Capacity:** This method allows for a higher capacity of embedded data since three separate pieces of information can be securely inserted.
- **Flexibility:** Different embedding techniques can be used for each channel, depending on the requirements for robustness, invisibility, and capacity.

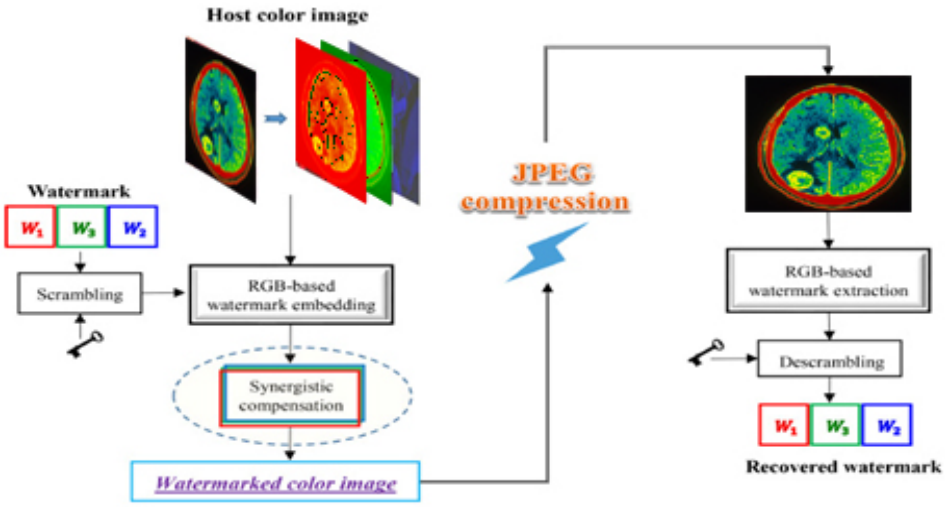

Figure 1 RGB Color Watermarking

Challenges

- **Complexity:** The process involves multiple steps and requires careful handling to ensure that the image quality is not adversely affected.
- **Detection and Extraction:** The extraction of watermarks requires the original image or knowledge of the embedding technique, which can be challenging in a non-cooperative scenario.

YUV Color Space

The YUV color model represents images in terms of one luminance component (Y') and two chrominance components (U and V). The Y' component represents the brightness level (luminance), and U and V represent the color information (chrominance). This separation is useful for processing and compression because human vision is more sensitive to variations in brightness than to color.

Watermark Embedding in YUV

Luminance Channel (Y') Embedding: Embedding the watermark in the Y' channel affects the brightness of the image. This approach can be more noticeable but is suitable for watermarks that need to be more robust against color transformations. Embedding the watermark in the U or V channels alters the color information. Since human vision is less sensitive to these channels, modifications here can be less perceptible, providing a suitable compromise between visibility and robustness. This is useful for video and broadcast applications where color information can be subtly manipulated without affecting the overall quality. Multilayer watermarking involves embedding different watermarks or different components of a single watermark into separate layers or channels of the image. This approach can enhance the robustness and capacity of the watermarking system.

Multilayer YUV Watermark Embedding Process

1. **Convert RGB to YUV:** The first step is to convert the image from the RGB color space into YUV. This is necessary because the watermarking process will take advantage of the separate luminance and chrominance channels.
2. **Prepare Watermarks:** Depending on the application, you might have multiple watermarks ready to be embedded into different channels. These could be texts, images, or patterns designed to be minimally invasive.
3. **Embedding in Luminance (Y) Channel:** Embedding in the Y channel should be done with caution because changes to the luminance can be more perceptible. Techniques like spread spectrum or least significant bit (LSB) modification are commonly used but with minimal changes to maintain image quality.
4. **Embedding in Chrominance (U and V) Channels:** Since human eyes are less sensitive to color changes, the U and V channels can hide more robust or larger watermarks. Techniques like DCT (Discrete Cosine Transform) or DWT (Discrete Wavelet Transform) embedding can be used here. These methods involve transforming the channel data, changing certain coefficients, and then performing an inverse transform to get the watermarked channel.
5. **Recombination and Conversion Back to RGB:** After embedding the watermarks in the desired channels, the changed YUV components are recombined. The image is then converted back to the RGB color space for storage or transmission.
6. **Extraction Process:** The watermarks can be extracted by reversing the embedding process. This requires the original image or knowledge of the embedding algorithm and parameters. Extraction can be more challenging if the image transforms through compression or cropping.

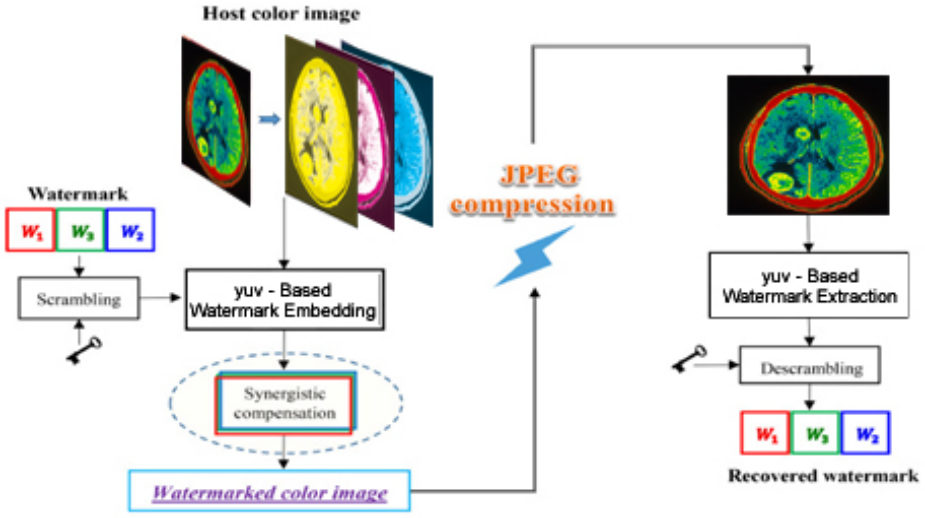

Figure 2: YUV Watermarking Process

Advanced Considerations

- **Robustness vs. Imperceptibility:** There's a trade-off between making the watermark robust against attacks (like cropping, compression, or filtering) and keeping it imperceptible to maintain image quality. Techniques and parameters must be carefully chosen based on the application's requirements.
- **Watermark Security:** Encryption of the watermark before embedding can enhance security. Only authorized parties with the decryption key can extract and recognize the watermark.

- **Adaptive Watermarking:** To further protect against detection and removal, adaptive watermarking techniques adjust the embedding strength based on the image content. For example, embedding more strongly in busy areas and less so in smooth areas.
- This deep dive into multilayer YUV watermark embedding highlights the complexity and considerations involved in designing an effective and secure digital watermarking system. The specific techniques and algorithms chosen for embedding and extraction depend on the application's needs, including the balance between robustness, imperceptibility, and capacity

Compression of RGB and YUV Multilayer Watermarking

- **Effect on Watermark Robustness:** When images or videos are compressed, especially using lossy compression algorithms, the watermark's robustness can be affected. YUV watermarking, particularly when focused on the chrominance channels, may offer better robustness against compression artifacts than RGB watermarking. This is because compression algorithms typically preserve more detail in the luminance channel and may discard fine details in the chrominance channels, where the human eye is less likely to detect changes.
- **Imperceptibility and Quality:** Embedding watermarks in the less perceptually significant parts of the YUV color space can maintain higher image quality compared to RGB watermarking. This is especially true for images and videos that will undergo significant compression, where maintaining the watermark's imperceptibility becomes challenging.
- **Adaptability to Content and Compression:** YUV watermarking can be more adaptable to different types of content and compression levels. Adaptive watermarking techniques can vary the embedding strength and strategy based on the content's characteristics in the luminance and chrominance channels, optimizing both robustness and image quality.

4. CONCLUSION

This study delves into the comparative analysis of triple watermarking embedding techniques in RGB and YUV color spaces, specifically tailored for medical imaging, to enhance security without compromising image quality. It highlights the superiority of YUV-based watermarking in achieving robustness against tampering and efficiency in compression, crucial for the vast data management needs in healthcare IT systems. The research demonstrates that embedding watermarks in the YUV color space, particularly within chrominance channels, offers a promising balance between imperceptibility and watermark robustness, ensuring medical images retain their diagnostic value. These findings underscore the potential of advanced triple watermarking techniques in safeguarding sensitive medical data, providing a benchmark for future developments in digital healthcare security.

CONFLICT OF INTERESTS

None

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REFERENCES

Al-Jubouri, H. T., & Al-Shamma, A. A. (2021). Robust and secure triple watermarking algorithm for medical images. Journal of King Saud University - Computer and Information Sciences, 33(4), 471-479. https://doi.org/10.1016/j.jksuci.2020.08.014.

Chadwick, D. W., & Sastry, R. S. R. (2006). Triple watermarking for secure medical image transmission. IEEE Transactions on Information Technology in Biomedicine, 10(1), 192-200. https://doi.org/10.1109/TITB.2005.855981.

Chauhan Neha, Waoo Akhilesh A., Patheja Pushpinder Singh, (March 2013) A Novel Attack Detection Technique to Find Attack in Watermarked Images with PSNR and RGB Intensity, International Journal of Electronics and Communication Engineering Research and Development (IJECERD), Volume 3, Number 1, 2248– 9525 (Print) 2248 –9533 (Online).

Chauhan Neha, Waoo Akhilesh A., Patheja Pushpinder Singh, (September 2012), Information Hiding Watermarking Detection Technique by PSNR and RGB Intensity, Volume 3, No. 9, September 2012 Journal of Global Research in Computer Science.

Dave, M., Khurana, S., & Singh, S. K. (2018). A novel approach for secure transmission of medical images using triple watermarking. International Journal of Computer Applications, 179(13), 30-36. https://doi.org/10.5120/ijca2018916285.

Gopi, M., Jayachandran, A., & Thandapani, K. (2018). Enhanced medical image security using multi-layer watermarking technique. International Journal of Imaging Systems and Technology, 28(1), 60-69. https://doi.org/10.1002/ima.22253.

Jain, A. K., & Singhal, N. (2020). Triple layer watermarking approach for secure medical image communication. Journal of Computational and Theoretical Nanoscience, 17(12), 5917-5924. https://doi.org/10.1166/jctn.2020.9932.

Kumar, S., Raj, S., & Sharma, A. (2022). A novel triple watermarking technique for secure transmission of medical images over the internet. Journal of Ambient Intelligence and Humanized Computing, 13(8), 6181-6190. https://doi.org/10.1007/s12652-021-03465-1.

Prasad, R. R. M., Singh, B. K., & Mathew, S. (2021). Triple watermarking technique for secure and efficient transmission of medical images. International Journal of Electrical and Computer Engineering, 11(1), 178-185. https://doi.org/10.11591/ijece.v11i1.pp178-185.

Saxena, S., & Singh, R. K. (2020). Secure transmission of medical images using triple-layer watermarking technique. Procedia Computer Science, 174, 134-141. https://doi.org/10.1016/j.procs.2020.04.019.

Sharma, P. K., Choudhary, S., & Singh, P. (2021). A robust triple watermarking scheme for secure transmission of medical images. Advances in Intelligent Systems and Computing, 1260, 211-222. https://doi.org/10.1007/978-981-16-4730-7_21.

Singh, P., Sharma, P. K., & Gupta, S. (2023). Triple watermarking technique for enhanced security of medical images. International Journal of Computational Intelligence & IoT, 1(1), 23-30.