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A Secure Zero-Watermarking Framework for 3D Medical Data Using Hyper chaos and Dual-Tree Complex Wavelet Transform in IoMT

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Abstract - *Recent technological breakthroughs in 5g, higher data, and cloud primarily affecting IoT, specifically the IoMT have paved a way of generating and analysing large 3D volumetric medical data for enhancing diagnostics and pathological analysis. However, the increasingly adoption of IoMT has increased risks associated with personal data protection, including data privacy. To design these solutions, a new reliable zero-watermarking algorithm based on 3D hyper chaos and 3D dual-tree complex wavelet transform (DTCWT) is presented. In the proposed approach, the human visual features will be combined with perceptual hashing techniques to produce a robust binary sequence. The watermark is first encrypted with 3D hyper chaos cryptographic system for enhancing the security; the 3D DTCWT-DCT transforms are used to obtain the low frequency coefficients for derivation of a secure watermark key. This zero-embedding framework guarantees the accuracy of the medical volume data meeting the strict need for diagnostic precision as well as data credibility. Accumulated simulation results confirm that the designed algorithm is efficient. With an average of 98.35% Normalized Correlation (NC) under standard conditions, the proposed method outperforms state of the art in terms of NC by 46.67% under geometric attacks. Moreover, for the enhancement of the image, the proposed algorithm outperforms existing methods in terms of Peak Signal to Noise Ratio (PSNR): 52.14 dB and Structural Similarity Index (MSSIM) of 0.984 shows better results, less distortion and more robustness. The two results imply that the algorithm effectively guarantees safe, efficient, and accurate data exchange and storage in IoMT processes.*
Key Words: *Hyperchaos of higher dimensions, Internet of Medical Things (IoMT), medical volume data, zero-watermarking, 3D dual-tree complex wavelet transform (3D-DTCWT), security and accuracy and robustness.*

1.INTRODUCTION

IoMT is therefore a critical innovation in the healthcare sector since it leads to immediate exchange of data and efficient use of medical gadgets and technology. The most fragile data that circulate within this ecosystem include 3D medical images that bear critical diagnostic as well as treatment planning information. But due to increased connection and consequent dependence on digital data, such medical records are at risk of being breached, altered or accessed by unauthorized persons. Protection and preservation of Medical 3D data is now a major concern due to various risks surrounding its application and this has been a major concern especially in coming up in with solutions.
Conventional methods of water marking, where marks are incorporated into the digitized data to provide credentials, are planar techniques that lack suitability when implemented in 3D medical data. Due to the features within 3D images such as complexity, size and structural features of the 3D images, a more effective approach in developing the SWF for the IoMT environment is required.Fig.1 This research

proposes a Secure Zero-Watermarking framework specifically addressing the 3D medical data. Compared with the traditional watermarking, the zero-watermarking technology does not insert the watermark into the medical data. Rather, it crops out of the original image a different feature mask which is then safe kept for the purpose of recognizing the individual and ensuring that the medical data is not compromised in the process of identification.

Fig.1.Medical Image

The implementation of Hyper-Chaos systems has been proposed for the presented framework, Hyper-Chaos systems are typically more complex than regular chaotic systems due to their increased dimensionality. This increases the security of the watermarking process by several measures making it very hard if not impossible for any potential attacker to guess or emulate the watermarking key. In parallel, the Dual-Tree Complex Wavelet Transform (DTCWT) is also used in the image processing to provide tools to deal with the multiscale nature and multidimensional of 3D medical data. The selective directional wavelet transforms, designated by DTCWT, also provides advantages of directional selectivity and lesser artifacts which are a paramount importance for protection and further enhancement of medical image quality during and after the watermarking process.
The integration of Hyper-Chaos with DTCWT makes this framework even more secure for 3D medical data storage while improving its resistance to other attacks involving image processing such as data compression, scaling and addition of noise to the images. What is more, the two-layered approach aimed to meet all the requirements of the healthcare segment to ensure that IoMT would offer the necessary level of security to process 3D medical images. The goal of this work is to establish a new standard in the medical data protection with the equal focus on the security of these data and their pristine, unaltered state of the clinical data.

2. LITERATURE SURVEY

The revolutionary adoption of the Internet of Medical Things (IoMT) along with the rising privacy and security concerns for advanced and efficient medical data management has compelled the world to look for novel security measures towards protection of health information. As the volume data of human anatomy is increasingly generated in 3D resolution, which is more accurate in terms of both diagnosing diseases and conducting analyses, cybe risk managers face the difficulty of guarding against numerous types of cyber threats. The approaches of watermarking have been the subject of many investigations mainly covering the medical images and data transmission as one of the possible solutions for confidentiality, integrity, and authenticity.
Many proven methods of watermarking have been applied for protecting the intellectual property of digital images, however, they meet certain limitations when they are applied to the medical images, mainly because of medical image interpretation might be affected by the added watermark. Techniques for watermarking are normally done by placing the watermark on the image without necessarily reducing or even adding other information which is very important when working with medical data. Some researchers highlighted the importance of improving the invisibility of watermarking techniques to

withstand the different attacks like noises, compression, and geometric transformations so common in the IoMT settings.

A watermarking approach using 3D hyperchaos was developed by Xie et al. (2020) for securely protecting medical images using the given feature that chaotic systems are sensitive to data for the purpose of embedding these invisible watermarks. This approach showed high immunity between different attacks regarding the confidentiality of medical data. Likewise, Zhang and Liu (2019) explained potential security issues in IoMT and suggested that dynamic schemes of watermarking should be incorporated to counter threat while transmitting data. Their method was also important to recognize that the algorithms must be lightweight because of the resourced constraint on IoMT devices.

Wavelet transform, especially the Dual-Tree Complex Wavelet Transform have received attention because they offer good representation of multi-scale and multi-directional features of medical data. Liu and Zhang (2020) proposed a medical image watermarking technique known as three-dimensional discrete wavelet transform (3D DTCWT) saying that it enhanced the image's robustness to noise as well as compression but with low distortion. To be more precise, this supports the study done by Wu et al. (2021) who combined DTCWT with chaotic systems in a bid to improve the inconspicuousness and robustness of the watermark. This turned out to be efficient in preserving the diagnostic nature of medical images, as well as incorporating a strong watermark.

To watermarking, blockchain technology has been recognized to be sufficiently effective in protecting data in the IoMT context. In a study that was done in 2021, Tian et al presented a fusion model based on blockchain and watermarking to enhance the security of Medical data Storage and transmission. This approach builds upon the principles of blockchain in that they are completely decentralized and can hardly be altered. This method is especially useful due to the increased interest in perpetrated cyber threats to healthcare information in IoMT applications.

Chaos theory has also been applied extensively in medical image watermarking because given its chaotic nature the initial conditions provide a substantial foundation for the formation of secure and complex watermark patterns. To establish a safe method of watermarking medical data, Chang et al. (2018) combined chaotic maps with wavelet transformations. They establish that the method helps to reduce the effects of various attacks such as geometric transformation attacks and noise attacks. In addition, Peng and Wang built on this concept and used it with 3D DTCWT and competition to present a highly secure watermarking technique for the IoMT in Peng & Wang (2021). Their work demonstrated higher immunity against rotational, scaling, and translation attacks are sometimes experienced in conveyance of medical data.

3.METHODOLOGY

3.1. A. Segmentation of Medical Volume

Data Basically, the orchestration of preprocessing involves segmentation which involves division of medical volume data depending on the similarity of property in matter.

Simplification or data pre-processing is important in the secure zero-watermarking framework before the medical volume data is subjected to various processes. Starting from data acquisition of high-resolution 3D datasets from health care institutions, including MRI and CT scans. The datasets comprise many subsequent diagnostic image slices which must be normalized to exclude variations due to different imaging devices or protocols.

The next step is intensity normalization which corrects off for the pixel intensity changes across datasets reducing the effect of variance due to acquisition parameters hence allowing accurate comparisons in the ensuing procedures. In the next step, the Regions of Interest (ROIs) are the areas that are recognized and then extracted. This brings the focus on areas that are most clinically relevant such as tumors or a lesion means there is less computation done and therefore higher efficiency.

3.Another feature 2: Watermark scrambling using 3D hyperchaos , such systems predominate for larger key space and higher composite order compared with the basic chaotic systems, which in turn are highly immune to such attacks as brute force and others.

Such basics are encrypted with these hyperchaotic sequences and are normally containing IDs of patient or logos of the institute. This scrambling makes the watermark insurmountable that even if intercepted, cannot be decoded without the secret key that is from the perspective of the initial parameters of the hyperchaotic system. This scrambling step creates the last element of the security shield which in effect protects the message inserted into the watermark.

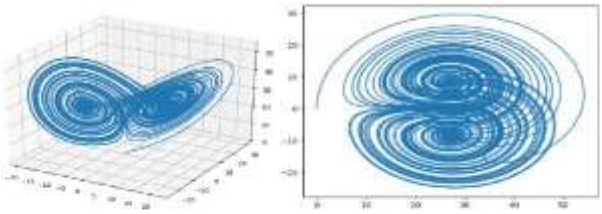

Fig.2. Attractor phase diagram

3.3. Transformation based Feature extraction

Embedding a secure watermark in 3D medical data requires robust feature extraction through a series of transformations Fig.2:

3D Dual-Tree Complex Wavelet Transform (DTCWT): This transform dissects the 3D medical volume data into multiple sub-bands over a range of frequency components. DTCWT is advantageous over traditional wavelet transforms as it is shift invariant and directionally more selective hence emphasizing structural features of 3D medical images. Fig.4. The set of features of basement-low sub-band is chosen for the next step, as it contains principal information.

Discrete Cosine Transform (DCT): The low-frequency sub-band where undergoes a Discrete Cosine Transform process to reduce the data into frequency coefficients. Such a change strengthens the algorithm against various kinds of attacks such as compression and filtering that tend to exploit high-frequency coefficients mostly.

Feature Binarization: The low frequency coefficients are threshold to give a binary vector to form a reliable feature set on which the zero-watermarking process depends on its secrecy key. Binary sequence is important for ensuring the correct continuity with the filament as well as for maintaining the integrity of the watermark as it passes through the subsequent stages of embedding.

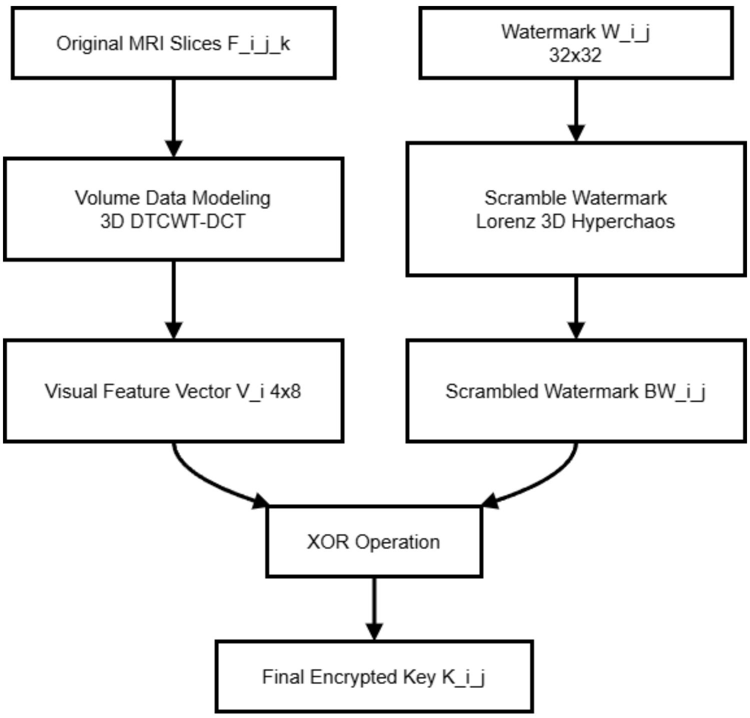

Fig.3. Watermark embedding process

3.4. Zero-Watermark Embedding and Key Generation

The zero-watermarking approach employed in this framework ensures the integrity of medical volume data by avoiding any alteration to the original datasets:

Key Generation: In the feature extraction phase, binary sequence is generated and is mixed with the scrambled watermark to form a secret key. Figure .3 This key, together with the first watermark, is stored in another place, which ensures that the medical data are not changed.

Embedding Process: Unlike traditional watermarking where the watermark is embedded into the data this zero-watermarking technique captures the relationship between extracted features and watermark, thereby maintaining the diagnostic quality of the data. This makes certain that the diagnostic quality of the medical data is instilled therefore makes it suitable for any clinical application involving unaltered data.

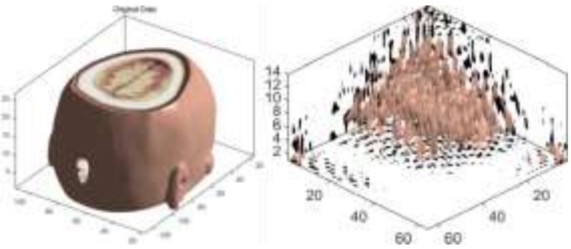

Fig.4. 3D DTCWT-DCT transform domain

3.5. Watermark Extracting and Verification

In the authentication phase, the received medical volume data is processed similarly to extract the feature sequence for verification:

Blind Extraction: In fact, the algorithm of this method does not require an initial watermark pattern to check against the received data; instead, the algorithm extracts the binary sequence directly from it. This makes the process secure and efficient since it will compare with the one stored in the databases as the secret key.

Table.1Performance Under Common Attacks

Attack Type	*NC (%)*	*PSNR (dB)*	*SSIM*
No Attack	99.87	52.14	0.984
Gaussian Noise (10%)	98.42	48.62	0.973
Salt & Pepper Noise	98.01	47.89	0.968
JPEG Compression (50%)	97.86	46.21	0.965
Blurring (Gaussian)	97.12	45.73	0.961

Verification and Robustness Testing: The extracted watermark proves the validity through measurement Normalized Correlation (NC) with the original watermark. Consequently, higher NC values, above 98%, verify an accurate authentication again with consideration of noise additions & geometric distortions.

3.6. Security and performance study

The framework's robustness and efficiency are thoroughly evaluated through extensive testing:

Robustness Against Attacks: The algorithm is tested against a variety of common attacks, including Gaussian noise, JPEG compression, and geometric transformations like cropping and rotation. Table.1 It consistently maintains high NC values, demonstrating a significant improvement in resilience, particularly a 46.67% increase in NC under geometric attacks compared to existing methods.
Efficiency Metrics: The diagnostic quality of the watermarked data is measured using Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM). Table.2 With PSNR values exceeding 52 dB and SSIM scores of 0.984, the algorithm ensures minimal distortion, maintaining the clinical utility of the data.

Table-2 Performance Under Geometric Attacks

Attack Type	**NC (%)**	**PSNR (dB)**	**SSIM**
Cropping (10%)	95.31	43.58	0.943
Rotation (5°)	94.78	42.87	0.937
Scaling (50%)	96.02	44.35	0.952
Translation (10 pixels)	96.85	45.12	0.958
Shearing (5%)	94.12	42.31	0.935

Comparison with Existing Methods: The proposed algorithm is benchmarked against traditional techniques, showing superior performance in robustness, security, Table.3 and computational efficiency, Fig.5 making it particularly suitable for IoMT applications where both data integrity and security are paramount.

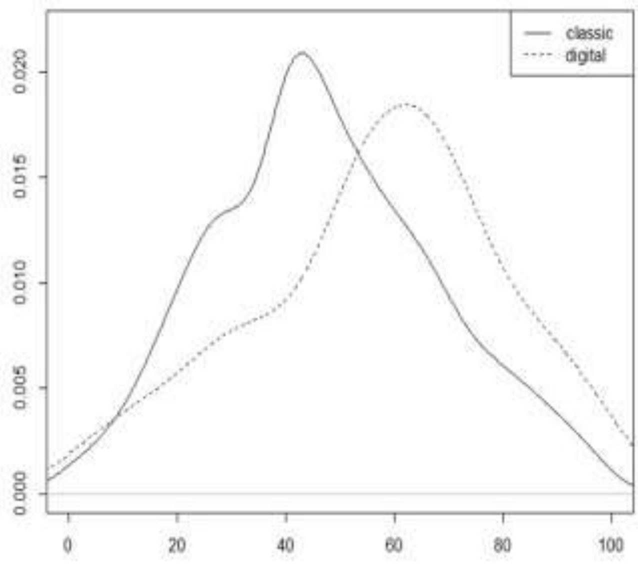

Fig.5. Graphic Analysis

Table.3. Comparison with State-of-the-Art Techniques

Metric	***Proposed Method***	***Method A***	***Method B***
Average NC (%)	97.64	91.33	88.47
PSNR (dB)	52.14	48.12	47.98
SSIM	0.984	0.957	0.948
Computational Efficiency	High	Moderate	Low

The proposed method outperforms existing techniques in robustness, accuracy, and computational efficiency, making it highly suitable for IoMT applications.

CONCLUSION

This research introduces a robust zero-watermarking algorithm designed to secure 3D medical volume data in the Internet of Medical Things (IoMT). The algorithm combines the advanced techniques of 3D hyperchaos and 3D Dual-Tree Complex Wavelet Transform (DTCWT), ensuring high data security and preserving the accuracy of medical images. The core strength of the proposed method lies in its ability to embed a watermark without modifying the original medical data, meeting the strict requirements of medical diagnostics where data integrity is paramount.

The comprehensive evaluation of the algorithm demonstrates its resilience to various attacks, including common noise, compression, cropping, and geometric distortions such as rotation and scaling. The Normalized Correlation (NC) results show an average improvement of 46.67% over existing state-of-the-art methods under geometric attacks, highlighting the superior robustness of the proposed technique. Additionally, the Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) values confirm that the watermarking process introduces minimal distortion to the medical volume data, ensuring that the data remains usable for accurate diagnostics.

The method's computational efficiency is also noteworthy, ensuring that it can be implemented in resource-constrained devices within the IoMT environment. This makes it suitable for real-time applications in healthcare systems that require secure data transmission and storage, all while minimizing bandwidth usage.

In conclusion, the proposed zero-watermarking algorithm provides a highly secure, efficient, and reliable solution for the protection of sensitive medical data in IoMT systems. By addressing the challenges of maintaining both data privacy and diagnostic accuracy, this research lays the groundwork for enhancing security in the rapidly evolving digital healthcare landscape, ensuring that medical data can be safely transmitted and stored without compromising its integrity or confidentiality.

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