AN OPTIMIZED MEDICAL IMAGES WATERMARKING TECHNIQUE UTILIZING A CONSTANT RATIO OF FREQUENCY DOMAIN

BY

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ABSTRACT

A medical image is a visual representation of the shape or function of internal body organs or tissues used in clinical analysis or medical diagnosis. Watermarking techniques are used to protect copyright and provide evidence of any attempt to unlawfully manipulate the content of medical images. The watermarking technique was used to mask the data within the medical image without affecting the original visual quality. The challenge is producing an optimal watermarked image for different types of medical images where each with unique characteristics. Currently, there is no watermarking technique that can find the optimal action to use without affecting the visual quality and can resist image attacks. This research aims to investigate the characteristics of the frequency watermarking technique that affect the process of producing an optimal watermarked medical image. In the proposed optimal watermarking technique, watermark data will embed in a constant ratio of the original medical images frequency domain to increase the resistibility of the watermarked medical image to image attacks. The first step in developing an optimal watermarking technique in this research is to construct a theoretical framework and conceptual design model to understand the underlying characteristics of the watermarking technique process. Based on the proposed theoretical framework and conceptual design model, this research then investigates the role of the optimized frequency technique to achieve optimal performance for the watermarking technique. This research conducted an implementation experiment and simulation for the optimized frequency watermarking algorithm. Also, it analysed the effect of using the optimized frequency domain on the performance of the watermarking technique. Finally, the results of the optimized frequency watermarking algorithm are compared to the results of published watermarking algorithms. The proposed watermarking technique used optimization algorithm with frequency technique and Schur decomposition to produce watermarked images able to trade-off between the performance evaluation terms. The imperceptibility performance is high and has the robustness of the JPEG compression, salt and pepper noise, Gaussian noise, and rotation attack image attacks. Where the average PSNR values is 75.44 dB and NCC values for rotation attack is 0.91 and PEG compression is 0.99.

خلاصة البحث

الصورة الطبية هي تمثيل مرئي لشكل أو وظيفة أعضاء أو أنسجة الجسم الداخلية المستخدمة في التحليل السريري أو التشخيص الطبي. تُستعمل تقنية العلامة المائية لحماية حقوق الطبع والنشر وتقديم دليل على أي محاولة للتلاعب بشكل غير قانوني بمحتوى الصور الطبية. حيث تم استعمال تقنية العلامة المائية لإخفاء البيانات داخل الصورة الطبية دون التأثير على الجودة البصرية الأصلية. يتمثل التحدي في إنتاج صورة مثالية ذات علامة مائية لأنواع مختلفة من الصور الطبية حيث لكل منها خصائص فريدة. ولا يوجد تقنية للعلامات المائية يمكنها العثور على الإجراء الأمثل لعملية تضمين البيانات دون التأثير على الجودة المرئية وإعطاء القدرة على مقاومة الهجمات التي تستهدف الصور. تهدف هذه الدراسة إلى التحقيق في خصائص تقنية العلامة المائية التي تؤثر على عملية إنتاج صورة طبية ذات علامة مائية مثالية. في تقنية العلامة المائية المثلى المقترحة، سيتم تضمين بيانات العلامة المائية في نسبة ثابتة من مجال تردد الصور الطبية الأصلية لزيادة مقاومة الصورة الطبية ذات العلامة المائية لهجمات الصور. خطوتنا الأولى في تطوير تقنية العلامة المائية المثلى هي بناء إطار نظري ونموذج تصميم مفاهيمي لفهم الخصائص الأساسية لعملية تقنية العلامة المائية. بناءً على الإطار النظري المقترح ونموذج التصميم المفاهيمي ، يتم بعد ذلك دراسة دور تقنية هجينة المجال الترددي والأسلوب الإرشادي لتحقيق الأداء الأمثل لتقنية العلامة المائية. أجرينا تجربة تنفيذية ومحاكاة لخوارزمية العلامة المائية الهجينة. كما قمنا بتحليل تأثير استخدام مجال التردد الأمثل على أداء تقنية العلامة المائية. أخيرًا، تم مقارنة نتائج خوارزمية العلامة المائية للتردد المُحسَّن بنتائج خوارزميات العلامات المائية المنشورة. استعملت تقنية العلامة المائية المقترحة خوارزمية التحسين مع تقنية التردد وتحلل شور لإنتاج صور ذات علامة مائية قادرة على المفاضلة بين شروط تقييم الأداء. وتبين أن أداء عدم الإدراك مرتفع ولديه

قوة مقاومة هجمات الصور: ضغط JPEG وتشويش الملح والفلفل، والتشويش الغاوسي، وهجوم الدوران. حيث يبلغ متوسط قيم PSNR 75.44 ديسيبل وقيم NCC لهجوم الدوران 0.91 وضغط PEG هو0.99.

APPROVAL PAGE

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Maryam Jasim Abdullah

Signature .... Date 21/07/2022 ....

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LIST OF ABBREVIATIONS

DICOM	Digital Imaging and Communications in Medicine
EPR	Electronic Patient Record
PSNR	Peak Signal-to-Noise Ratio
NCC	Normalized Cross-Correlation
SSIM	Structural Similarity Index Measure
BER	Bit Error Rate
BE	Bit Error
CT	Computed Tomography
MR	Magnetic Resonance
US	Ultrasound
SPECT	Single Photon Emission Computed Tomography
PET	Positron Emission Tomography
ECG	Electrocardiogram
EEG	Electroencephalography
EMG	Electromyography
EOG	Electrooculography
OCT	Optical coherence tomography
DWT	Discrete wavelet transform
LL	Low Low
LH	Low High
HL	High Low
HH	High High
PSO	Particle Swarm Optimization
ROI	Region of Interest
RONI	Regions Of Non-Interest
IWT	Integer Wavelet Transform
DCT	Discrete Cosine Transform
SLT	Slantlet Transform
FCT	fast Curvelet Transform
LWT	Lifting Wavelet Transform
DOST	Discrete Orthogonal Stockwell Transform
FRWPT	Fractional Wave Packet Transform
RDWT	Redundant Discrete Wavelet Transform
SWT	Stationary Wavelet Transform
IDWT	Integer-to-integer discrete wavelet transform
FWHT	Fast Walsh-Hadamard transform
IEO	Input-Environment-Output
MSE	Mean Square Error
FV	Fitness Values
WE_Position	Weight Position
Gbest	Global Best

Pbest	Particle Best

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE RESEARCH

Digital imaging and communications in medicine (DICOM) is a standard for managing and communicating information about medical imaging and data related to the electronic patient record (EPR) (Singh et al., 2015). A DICOM consists of a head that contains patient information and pixel data that represents the visual presentation of the patient's body (Laouamer et al., 2016). There are chances that the content of the DICOM header may be lost, attacked, or disturbed (Singh et al., 2015). The medical field takes advantage of the internet to provide instant telemedicine diagnoses (Laouamer et al., 2016). Internet services have provided easy access to the content of DICOM to modify, copy, distribute or destroy the content of digital products illegally (Bhinder et al., 2018).

To overcome the illegal use of digital products during transmission for share or storage, there have been techniques required to save and secure digital product data (Lendale et al., 2018). These techniques are encryption, steganography, and watermarking (Vinothini et al., 2019). Encryption technology is used to convert digital product data into codes, and these codes prevent unauthorized uses during the conversion or storage of the digital product (Poonam & Arora, 2018). Steganography is a process of hiding a secret message in the host digital product, where the host digital product is less important than the secret message (Pan et al., 2018). Watermarking technology is the process of hiding information in a host digital product in a way that cannot be noticed by humans and without affecting the quality of the host digital product (Singh, 2016).

Watermarking techniques are used to protect copyrights and provide evidence of any attempt to manipulate medical images unlawfully (Liu et al., 2019). Watermark technology is used to mask the data inside the image without affecting the original visual quality (Zear et al., 2016). The embed process is hiding the data within the image, while the extract process retrieves the hidden data from the image (Shen, Tang, Xu, Chen, & Lei, 2021).

As shown in Figure 1.1, watermark technology embeds the watermark data into the original image, known as the host or cover image, to create a watermarked image (Ayad & Khalil, 2018). Spatial domain or frequency was used to include the watermarked data in the medical cover image (Wang & Yang, 2020).

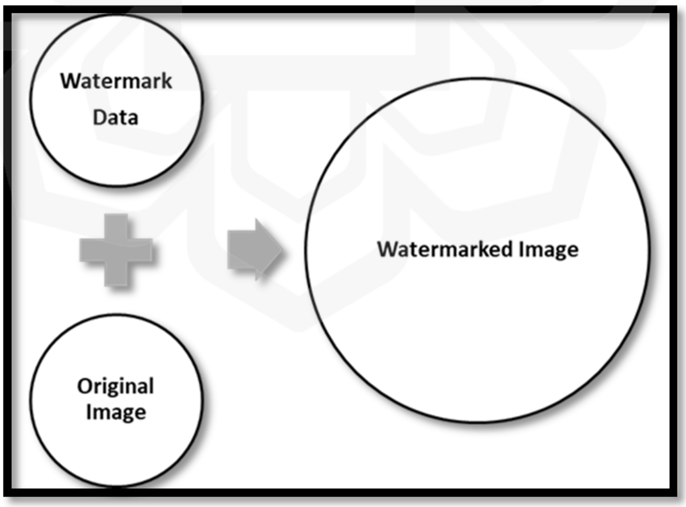

Figure 1.1 Hides the Watermark Data within the Original Image to Generate the Watermarked Image

In the case of the spatial domain, the watermark data is directly embedded in the host image pixel value, while in the frequency domain, the watermark data is embedded in the frequency coefficients resulting from transferring the host image pixel value (Wang & Yang, 2020).

The performance of the watermark technique is measured in terms of three evaluating terms: imperceptibility, robustness, and embedding capacity (Swaraja, 2018). Imperceptibility is the calculation of the similarity between the original and watermarked medical image (Kumar & Jha, 2019). Embedding capacity is the size of the watermark data included in the original medical image (Zhong & Shih, 2018). The robustness measure the ability of the watermarked image to resist the image attacks such as resizing, rotation, cropping, JPEG compression, sharpening, averaging, salt and pepper noise, Gaussian noise, and histogram equalization (Venkateswarlu et al., 2018). The Author (Voloshynovskiy, Pereira, Pun, Eggers, & Su, 2001) mentioned the goals of image attacks on the watermarked image:

- Try to remove watermark data from the host image.
- Destroy the watermark data.
- Or change the content of watermark data.

The robustness of the watermarked image is calculated after the extraction process (Singh et al., 2015). The extraction process is to separate the watermark data from the cover image (Priya et al., 2017).

The watermarked image generated by the watermarking techniques used in the frequency domain of the medical cover image, to include the watermark data, is more robust than the techniques used in the spatial domain (Ustubioglu et al., 2019). Incorporating watermark data using the host image's frequency domain leads to imperceptibility and robustness performance (Agrwal et al., 2016). While, the spatial domain is classified as fragile because of its lack of resistance to the JEPG compression attack (Das et al., 2017). As shown in Table 1.1, the fragile watermarking technique is useful for tampering localization and tampered area recovery (Ansari et al., 2017) because the embedded watermark data damage if the watermarked image is exposed to any kind of manipulation (Ouazzane et al., 2017). While the robustness watermarking technique is useful for images' copyright protection and ownership verification (Loan et al., 2018) because the embedded watermark data can resist any kind of modification caused by image attacks (Prathiwi et al., 2015; Soualmi et al., 2019).

Table 1.1 Comparison between Embedding in the Spatial and Frequency Domain

Spatial Domain	Frequency Domain
Robust watermarking technique.	Fragile watermarking technique.
Watermark data resist image attacks.	Watermark data damage from any kind of manipulation.
Used for copyright protection and ownership verification.	Used for tampering localization and tampered area recovery.

Single value and Schur decomposition technology are used to watermark the image to improve performance (Marjuni & Nurhayati, 2021). The advantage of using the Schur decomposition is more robust to image attacks (Mohan et al., 2011) and requires less computing time in comparison with using Singular Value Decomposition (SVD) (Kahlessenane et al., 2021; Marjuni & Nurhayati, 2021).

There is an inverse relationship between performance evaluating terms imperceptibility and robustness performance, as well as imperceptibility and embedding capacity (Guo et al., 2017). Optimization algorithms are used to trade-offs between the performance evaluation terms of the watermarking technique (Pourhadi & Mahdavi-Nasab, 2020).

This chapter is organized as follows: Section 1.2 explains how the performance quality of the watermarking technique is measured. Section 1.3 defines the DICOM and their modalities. Section 1.4 describes the techniques used for the proposed watermarking technique for medical images. Section 1.5 illustrates the problems of the watermarking technique for medical images. Section 1.6 is the aim of the research proposal. Following this, Section 1.7 and 1.8 present the research questions and research significance, respectively. Section 1.9 illustrates the research scope. The research contributions discuss in Section 1.10 and the definition of research terms are in Section 1.11. Finally, the organization of the thesis outlines in Section 1.12.

1.2 PERFORMANCE EVALUATION TERMS

This section discusses the performance evaluation terms of the watermarking technique. The performance of the watermarking technique was analyzed by computing the level of imperceptibility, robustness, and embedding capacity (Swaraja, 2018).

A. Imperceptibility

Imperceptibility is computing the similarity between the original medical image and the watermarked medical image (Khedr & Elsoud, 2019; Kumar & Jha, 2019). Medical image data is used in disease diagnosis (Mashalkar & Shirgan, 2017). For this reason, the watermarked medical image has to be similar to the original medical