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ROI Recovery for Medical Images using FRT-based Watermarking Technique

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***Abstract*—The recent evolutions in technology and globalization impacted a lot in the field of medicine. This evolved in communicating medical images among medical practitioners, patients and analysts through wired or remote networks for having better diagnosis medically. To accomplish this diagnosis as the best, the Region of Interest (ROI) of medical image is focused a lot by practitioners. This ROI may get affected by intruders during transmission of images. The receiver must recuperate the ROI of image when it gets tampered by an intruder. The data of ROI is hidden into RONI (Region of Non-Interest) of medical image in order to recuperate the ROI of medical image when it gets interfered or disturbed. More data has to be concealed in the RONI of the image when the size of the ROI is large. This paper proposes a watermarking scheme based on Finite Ridgelet Transform (FRT) which supports high embedding capacity. This proposed method recuperates ROI when it gets tampered by an intruder during transmission of medical image by concealing data of whole ROI in RONI.**

***Index Terms*— Telemedicine, Watermarking, FRT, ROI, RONI.**

I. INTRODUCTION

Based on the applications they are used for, watermarking techniques are categorized as semi-fragile, fragile, and robust. Approaches for semi-fragile watermarking can tolerate accidental attacks, but not malicious ones. Fragile watermarking techniques can locate and identify tampering, guaranteeing the authenticity and integrity of digital media. The robust watermarking approaches for copyright protection and ownership verification can withstand even the most intense image processing attacks [1-4].

Watermarking techniques for medical images are classified into three categories based on their application, they are: integrity and authenticity control approaches, data-hiding techniques, and combinations of both. The major objective of the integrity and authentication control technique is to warranty the authenticity and integrity of the medical image origin. Using this way, the suitable source can be originated; areas with tampers can be located along with recovery [5]. The key motive of the data concealing technique is to sphere a high level of imperceptibility while masking noteworthy volumes of data in the cover image [6]. The third category, which integrates both, makes certain the e-medical care system fulfills with all stipulations.

In medical imaging, the two regions are typically the significant area for analysis (ROI) and the unimportant area (RONI). A little alteration in the ROI's composition could result in a mistaken diagnosis and perhaps the patient's death. Recovering the ROI is therefore essential. Medical photos can be severely protected using digital

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watermarking's support for authentication, copyright protection, integrity management, data concealing, and tamper detection applications [7, 8].
The following Section II summarizes previous research, followed by the Section III in the elaboration of the proposed plan. Section IV examines the experimental findings and Section V concludes.

II. Literature Review

For x-ray medical images Rajitha Bakthula et al. [9] introduced a watermarking method. This method segments the x-ray image into regions of significant and insignificant (ROI and RONI). RONI is masked with ROI pixel's LSBs. Tamper detection based on the pixel is braced by this method. This method lacks robustness over the data which is concealed, lacks recovery of region of significant when tampered and doesn't support varying types of images.
To brace genuineness and integrity Liu et al. [10] introduced a watermarking method, which uses SVD, SLT and RDM. In the whole image the watermark is concealed. Promises robustness to the data which is concealed and ensures apt genuineness besides detecting tampering and recovery.
An adaptive watermarking method with an aim in support of the authentication of the content, protection of copyright and localization of tamper was introduced by Shaozhang Xiao et al. [11]. ROI is embedded with ROIs authentication data. RONI is concealed with authentication data and noticeable watermark. This method promises high robustness and the best visual quality of the image. By embedding data in ROI, ROI gets distorted and lacks in the recovery of ROI when being tampered.
Using DWT SVD hybrid transformation Hansan S. Alshanbari [12] introduced a watermarking method. To withstand ownership attack PC based insertion is used by this method. In RONI of image, compacted version of ROI and its respective hash code is masked. This procedure guarantees robustness to the concealed data, localization of tamper and recovery of ROI. One pitfall to this method is, due the presence of embedded data ROI gets distorted.
For medical images like X-Ray and MRI Jessie Ooi et al. [13] introduced a watermarking method. ROI of medical image is compacted by using JPEG followed by concealing into RONI of medical image using LSB procedure. When ROI is tampered, this method ensures high imperceptibility and recovery of ROI. This method doesn't guarantee robustness to concealed data.
Using the PSBFO optimization technique and DWT-Schur hybrid transformation Swaraja K et al. [14] introduced a watermarking method. For concealing compacted version of the image's ROI into appropriate blocks of RONI visual and entropy concepts are used. When ROI of the image gets tampered this method proves to guarantee ROI's recuperation and robustness to the concealed data. High imperceptibility is not guaranteed.
Dhivya et al. [15] projected a watermarking procedure stranded on IWT and chaotic map. This method proves to be 100% in locating and detecting tampered blocks within ROI. Also, this method recovers effected blocks of ROI with zero MSE.
A watermarking technique was suggested by Muzamil Hussan et al. [16] to identify and pinpoint the tampering and restore the medical image. Four 4x4 blocks are randomly chosen to create the watermark using chaotic mapping. The watermark is divided into four sub-blocks so that it can be restored even if three of the four sub-blocks are altered. For the purpose of assessing this method's effectiveness, several collage attacks are used.
For the purpose of preserving the information integrity of the medical images, Qingdan Li et al. [17] suggested a recovery strategy centered on the compression of block and permutation ordered binary (POB) number system. This mode compresses medical image ROI by using JPEG-LS. ROI of medical image is compressed by the low-plane and high-plane. To generate the authentication bits, POB is employed. This technique endures several attacks likely insertion of text, cropping content and exchange of content.
Watermarking technique with an aim for multipurpose functionality was proposed by Rishi Sinhal et al. [18] to provide detection of tamper, localization of tampers, and with 100% reversibility of ROI recovery. This technique integrated robust watermark into medical images using SLT. Hash keys are created by using SHA-256 and to compress recovery data of ROI, LZW algorithm is used. Exploiting an LSB method in few selected RONI locations hides ROI and hash key recovery data.

III. Proposed Method

A. Finite Ridgelet Transform (FRT)

Donoho [19] designed the Continuous Ridgelet Transform and proved to be useful over wavelets. Differentiation of information from edges of images was not done by standard wavelet transforms [20]. The Ridgelet Transform characterizes an image with line singularities whereas wavelet transform represents an image as point singularities. When FRT is executed to an NxN-pixel image, the consequence is a 2Nx2N-pixel image with ridgelet coefficients. In applications of watermarking host picture's Ridgelet coefficients are attuned rendering to the bits of watermark. To enhance the embedding capability of watermarking technique FRT is introduced in watermarking.

B. Embedding Algorithm

Medical image which is to be communicated over telemedicine from one physician to another physician is the input to this embedding algorithm. Before sending to the remotely located physician the input medical image is applied with this embedding algorithm. The embedding algorithm includes the following steps:

Step 1: Within the ROI convert pixels to binary form and generate recovery data of ROI by concatenation. R represents recovery data.

Step 2: To calculate the ROI hash value, hashing method SHA-1 is used. H1 represents the measured hash value.

Step 3: To make watermark concatenate R and H1. W represents the created watermark.

Step 4: Segment RONI into four regions as shown in Figure 1.

Step 5: For each component P, in RONI,

Step 5.1: Using FRT, generate ridgelet coefficients

Step 5.2: Hide one watermark bit in each ridgelet coefficient

Step 5.3: Employ inverse FRT

Thus, the remote physician is sent with the resultant watermarked image.

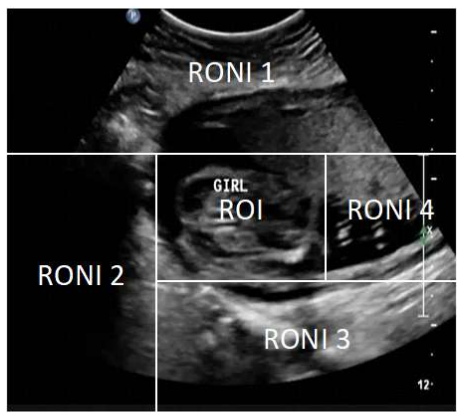


Figure 1. Segmentation of RONI into four regions

C. Extraction Algorithm

The remote physician, who receives the medical image, applies this extraction algorithm before performing the diagnosis. The extraction algorithm includes the following steps:

Step 1: Calculate the ROI hash value using the SHA-1 hashing method. H2 represents the calculated hash value.

Step 2: Segment the RONI of the watermarked medical image into four parts.

Step 3: For each component P, in RONI,

Step 3.1: Using FRT, generate ridgelet coefficients

Step 3.2: Extract one watermark bit from each ridgelet coefficient,

Step 4: By concatenating the extracted bits the watermark is obtained.

Step 5: Divide the watermark into two portions: hash recovery data

Step 6: If the extracted hash ties the recalculated hash, then close the algorithm

Step 7: Otherwise, using recovery data replace the ROI

For apt medical diagnosis the re-established medical image is used.

IV. EXPERIMENTAL RESULTS

The experiment was performed using MATLAB R2015a. On a personal PC running Windows 10 with 8 GB of RAM and an i5-8th generation processor, experiments were directed. Medical images with varying sizes and types (MRI, Ultrasound and CT) were engaged during experimentation. The proposed method performance is assessed pertaining to imperceptibility, ROI recovery and robustness which is disclosed in the following sections.

TABLE I. DETAILS OF MEDICAL IMAGES WITH VARYING SIZES AND TYPES USED IN THE EXPERIMENTATION

Image Modality	Image Size	ROI Size	Watermark Size	PSNR
MRI	512 × 512	150 × 180	216256	52.48
Ultrasound	758 × 600	210 × 230	386656	55.19
CT	630 × 630	160 × 180	230656	54.27

A. Imperceptibility

To investigate the recitation of the proposed method, experimentation over three hundred images was done. Few images, which includes MRI of the brain, CT of liver and Ultrasound of the uterus which are used during the test were disclosed in Figure 2. These images are of 8-bit grey scale. After applying the embedding algorithm over these images, the resulting watermarked images are shown in Figure 3. Table I discloses the features of the cover medical images as well as the PSNR value attained. The PSNR is above 50 dB with all medical images. Thus, the proposed method ensures the imperceptibility necessity in full.

(a) (b) (c)

Figure 2. Cover images: (a) MRI of brain (b) Ultrasound of uterus (c) CT of liver

(a) (b) (c)

Figure 3. Watermarked images: (a) MRI of brain (b) Ultrasound of uterus (c) CT of liver

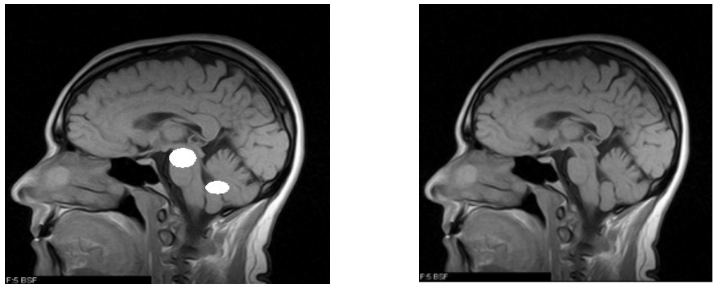
B. Tamper Detection and Recovery

To investigate the strength of the proposed method of locating and recovering the tampers, watermarked medical images are tampered. The proposed method was able to locate and recover ROI when being tampered. Locating and recovering abilities of the proposed method are disclosed in Figures 4-6. These figures upon evaluation pins that these recovered images are with worthy visual quality.

C. Robustness

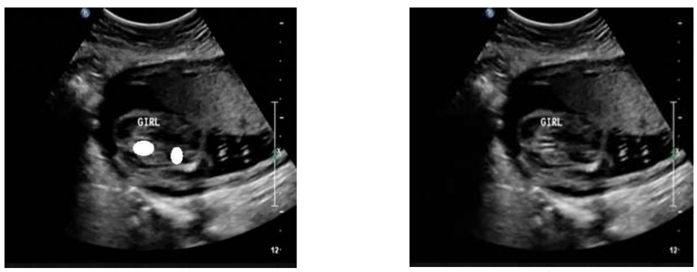
Another crucial requirement for image watermarking is robustness. To test the robustness and usefulness of the suggested technique, various noises and filters were applied to the watermarked photos. For the purpose of evaluating the robustness of the suggested approach, Salt & Pepper and Gaussian noise were introduced to the watermarked photos. Table II presents the outcomes of applying noise to watermarked photos. The suggested method is discovered to be immune to noise attacks.

Filtering, the illustrious watermarking attack; is used in evaluating the efficacy of watermarking systems. The watermarked photos were subjected to various filter masks, and the outcomes are shown in Table III. The suggested method makes disguised watermarks resistant to filtering assaults.



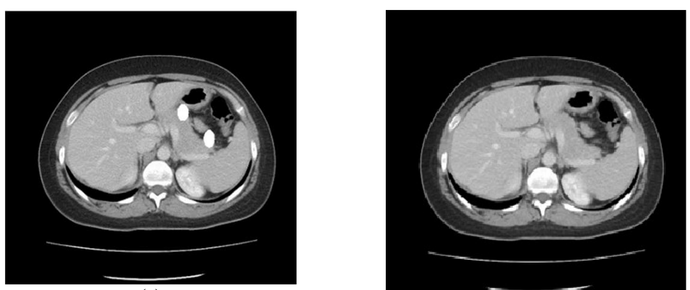
(a) (b)

Figure 4. MRI image a) Tampered b) Recovered



(a) (b)

Figure 5. Ultrasound image a) Tampered b) Recovered



(a) (b)

Figure 6. CT image a) Tampered b) Recovered

TABLE II. RECITAL OF PROPOSED SCHEME UNDER NOISE ATTACKS

Noise type	Modality of watermarked image	SSIM	NC
Salt & pepper noise	MRI	0.9993	0.9962
	Ultrasound	0.9998	0.9941
	CT	0.9996	0.9938
Gaussian noise	MRI	0.9996	0.9972
	Ultrasound	0.9997	0.9956
	CT	0.9995	0.9981

D. Comparison Analysis

Comparative analysis is disclosed in Table IV. As medical practitioners use ROI for apt diagnosis, ROI of images shouldn't get effected with concealed data. No data is hidden in ROI of medical image in the proposed method. Few existing methods don't support in the recovery of ROI of medical image. In majority of the practices addressed in the literature, the average PSNR value is less than 50 dB. On average, the proposed scheme has a PSNR of more than 50 dB.

TABLE III. UNDER FILTERING ATTACK PERFORMANCE OF THE PROPOSED SCHEME

Filtering attack	Watermarked image Modality	SSIM	NC
Low pass (3x3)	MRI	0.9985	0.9989
	Ultrasound	0.9992	0.9977
	CT	0.9988	0.9985
Median (3x3)	MRI	0.9756	0.8882
	Ultrasound	0.9694	0.8663
	CT	0.9683	0.8837

TABLE IV. PROPOSED METHOD VS EXISTING METHODS

Method	ROI is distorted	ROI is recovered	Average PSNR	Embedding Capacity (RONI)
Rajitha B [9]	No	No	<34	2 bpp
Shaozhang X [11]	Yes	No	<40	0.2 bpp
Hanan S [12]	Yes	Yes	<49	1 bpp
Jessie O [13]	No	Yes	<53	2 bpp
Swaraja K [14]	No	Yes	<34	0.0625 bpp
Dhivya R [15]	No	Yes	<50	1 bpp
Rishi [18]	Yes	Yes	<50	1bpp
Proposed method	No	Yes	>50	2 bpp

V. CONCLUSIONS

For telemedicine a high payload watermarking technique is proposed in this paper. This method supports high payload and evades ROI distortion by not embedding any data into ROI. This method recuperates the medical image ROI when being attacked likely by intruders during transmission including noise or tampered. This proposed method in this paper ensures an average PSNR value greater than 50 dB.

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