A Study of DWT-SVD Based Multiple Watermarking Scheme for Medical Images

Natarajan Mohananthini and Govindarajan Yamuna
(Corresponding author: Natarajan Mohananthini)

Department of Electrical Engineering, Annamalai University
Annamalainagar, Tamilnadu 608 002, India
(Email: mohananthini@yahoo.co.in)
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Abstract

Medical images may contain sensitive information and additional security measures are essential to preserve the patient's privacy. The multiple watermarking is projected to increase the security of medical images and to preserve the privacy of patients. In this paper a multiple medical image watermarking scheme based on discrete wavelet transform (DWT) and singular value decomposition (SVD) is presented. In the proposed method, three watermarks are embedded into different channel (R, G and B) of color images such as the first watermark is patient identification, the second watermark is patient diagnosis information and the third watermark is doctor signature image. From the experimental results, the proposed method is robust to common image processing attacks and good performance in terms of imperceptibility on different types of medical images.

Keywords: Discrete wavelet transform, medical images, multiple watermarking, singular value decomposition

1 Introduction

Digital image watermarking is the process of embedding information into digital image such that the information can later be extracted for a variety of purposes [24]. Now-a-days medical image watermarking is a popular research area and the important applications of watermarking. The uses of advanced electronic and digital equipments in health care services are increased in the electronic and digital data such as, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), X-ray images and Ultrasonic image.

The medical information records are focused, which for a complex set of clinical examinations, diagnosis observations and other findings information in its Electronic Patient Records (EPR) [6]. The three mandatory security characteristics are confidentiality, availability and integrity. Confidentiality means that only the authorized users have access to the information. Availability means the ability of an information system to be used in the normal scheduled conditions of access. Integrity means the information has not been modified by non-authorized user.

In medical image watermarking, the medical images are embedded with hidden information that may be used to assert ownership, increase the security, and verify the numerical integrity of medical images [2]. Zheng et al. [27] reviewed the algorithms for rotation, scaling and translation (RST) invariant image watermarking. There are mainly two categories of RST invariant image watermarking algorithms. One is to rectify the RST transformed image before conducting watermark detection. Another is to embed and detect watermark in an RST invariant or semi-invariant domain. In order to help readers understand, their first introduced the fundamental theories and techniques used in the existing RST invariant image watermarking algorithms and then discussed in detail the work principles, embedding process, and detection process of the typical RST invariant image watermarking algorithms.

Coatrieux et al. [1] focused on the complementary role of watermarking with respect to medical information security (integrity, authenticity) and management. Their reviewed sample cases where watermarking has been deployed and concluded that watermarking has found a niche role in healthcare systems, as an instrument for protection of medical information, for secure sharing and handling of medical images.

2 A Brief Literature Survey

A brief literature survey of image watermarking and some recent researches is presented here. Yamuna and Sivakumar [26] proposed a novel watermarking scheme for copyright protection in digital images. The watermarking is performed in wavelet domain using bi-orthogonal wavelet transform and their approach is non-blind, it requires original image for extracting the watermark. The experimental results demonstrate that the watermark with their proposed algorithm satisfied imperceptibility. The watermarking algorithm is based on Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) in [13]. A new audio signal framing, DWT matrix formation and embedding methods are proposed and successfully implemented to improve the quality of watermarked audio. The significance of their features makes the system robust to common signal processing operations.

Mehta et al. [11] studied the performance of three different watermarking algorithms (DWT, SVD and DWT-SVD based watermarking algorithms). They have created two different watermarks one is QR Code watermark image, which is capable of carrying large information in small space and other one is a normal text image watermark. Experimental results show that DWT based method is suitable for medical applications where embedding time and imperceptibility are prime concerns while SVD based methods are suitable for medical applications where robustness and capacity are the main concerns. Khan et al. [9] presented a hybrid digital image watermarking based on Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD). To embed the watermark in high band that facilities to add more information, gives more invisibility and robustness against some attacks. Sleit et al. [20] presented a semi-blind hybrid watermarking technique based on singular value decomposition (SVD) and discrete wavelet transformation (DWT). Their proposed technique decomposes the host image using DWT and combines the singular values (SVs) of the watermark and the selected sub-bands. Experimental results show that their proposed technique is able to resist a variety of attacks.

Navas et al. [18] proposed a method of non-blind transform domain watermarking based on DWT-DCT-SVD. The DCT coefficients of the DWT coefficients are used to embed the watermarking information. Their method of watermarking is found to be robust and the visual watermark is recoverable without only reasonable amount of distortion even in the case of attacks. Thus their method can be used to embed copyright information in the form of a visual watermark or simple text. Experiments conducted on four types of medical images proved that their modifications are visually imperceptible while it has a good robustness against some common attacks such as compression, filtering, and noise.

Dhaliwal et al. [3] presented a comparative study of single watermarking to multiple watermarking over a color image. Li et al. [10] proposed a novel multiple watermarking algorithm which embedded two watermarks into original image in different frequency by using bandelet transform. Experimental results demonstrate that their watermarking algorithm based on bandelet transform has a good performance both in invisibility and robustness. Radharani et al. [19] presented the concept of multiple watermarking is used to hide both copyright and authentication information into a color image. Experimental results indicate that their proposed watermarking scheme is highly robust and does not degrade the original signal. A watermarking technique is proposed in [14], to directly embed multiple watermarks into a single color image. The watermark embedding process the multiple watermarks are embedded into original image and the extraction processes recover the watermarks from the watermarked image. The experimental results have shown their scheme has preferable performance of imperceptibility. A digital image multiple successive watermarking scheme based on wavelet transform is proposed in [15]. In their method, the PSNR and image quality are degraded with every one new watermark embedded into image, and the watermarked images are tested for non-geometric attacks such as less robustness of salt and pepper noise and Gaussian noise and more robustness of median filtering, sharpening, smoothing and JPEG compression.

Successive and segmented watermarking techniques are proposed in [17]. The embedding and extraction process using multi-resolution analysis of wavelet transform for color images. The successive watermarking technique, the watermarks are embedded one after the other and the segmented watermarking technique, one watermark is embedded into odd-numbered rows and another watermark is embedded into even-numbered rows. Their segmented watermarking vividly shows better visual quality on watermarked image when compared with successive watermarking. The different embedding methods of single and multiple watermarking are compared using discrete wavelet transform in [16]. The different embedding methods are additive, multiplicative and hybrid watermarking with importance on its robustness versus the imperceptibility of the watermark. The objective quality metrics are demonstrated that, their additive embedding method achieves superior performance against watermark attacks on multiple watermarking technique.

Woo et al. [25] proposed a multiple digital image watermarking method which is suitable for privacy control and tamper detection in medical images. The annotation watermark can be detected in a blind manner, that is the original un-watermark image is not required to detect the annotated watermark. The effectiveness of the fragile part in tamper detection has been proved some general image manipulation attacks. Giakoumaki et al. [5] presented the perspectives of digital watermarking in health information systems, and proposes a wavelet-based multiple watermarking schemes that address the issues of medical data protection, archiving, and retrieval, as well as of origin and data authentication. The experimental results demonstrate the efficiency and transparency of their watermarking scheme, which conforms to the strict limitations that apply to regions of diagnostic significance.

Giakoumaki et al. [4] discussed the perspectives of digital watermarking in a range of medical data management and distribution. Their scheme imperceptibly embeds in medical images multiple watermarks conveying patient's personal and examination data, keywords for information retrieval, the physician's digital signature for authentication, and a reference message for data integrity control. Experimental results indicate the efficiency and transparency of their scheme, which conforms to the strict requirements that apply to regions of diagnostic significance. Kallel et al. [8] applied a multiple watermarking technique in the wavelet field to preserve the traceability and the record of the medical image diagnosis.

Rathi et al. [21] focused on the study of medical image watermarking methods for protecting and authenticating medical data. The medical images can be transferred securely by embedding watermarks in Region of Non Interest (RONI) allowing verification of the legitimate changes at the receiving end without affecting Region of Interest (ROI). The experimental results show the satisfactory performance of their system to authenticate the medical images preserving ROI. Irany et al. [7] proposed a high capacity reversible multiple watermarking scheme for medical images based on integer-to-integer wavelet transform and histogram shifting. The novelty of their proposed scheme is that it uses a scalable location map and incorporates efficient stopping conditions on both wavelet levels and different frequency sub bands of each level to achieve high capacity payload embedding, high perceptual quality, and multiple watermarking capabilities.

Memon et al. [12] proposed a multiple watermarking scheme, embeds robust watermark in region of non interest (RONI) for achieving security and confidentiality, while integrity control is achieved by inserting fragile watermark in region of interest ROI. ROI in the medical image is important from diagnosis point of view so it must be preserved. The image visual quality as well as tamper localization has been evaluated. Sujatha et al. [22] proposed an innovative watermarking scheme, in which low frequency subband of wavelet domain and the rescaled version of original image are utilized in the watermark generation process. A watermark hiding scheme for copyright protection of sensitive images is proposed in [23].

In analysis of various literatures the medical image watermarking is found to be imperceptibility, robust, high security and verify the integrity of medical images. In this paper a study of discrete wavelet transform and singular value decomposition based multiple watermarking schemes for medical images. The multiple information's are embedded into the medical image for patient's privacy.

In the extraction process multiple information are recovered from the watermarked image. Experimental results demonstrate that, the proposed method achieves high security, imperceptibility and robustness against attacks for three different types of medical images.

3 Proposed Scheme

The proposed scheme focuses on medical image watermarking methods for protecting and authenticating the medical image. Medical images information related to the patient's health condition is stored separately either in digital documents or images. The embedded information of medical images is exchanged from hospitals to required area. Also, as this exchange of medical embedded information done through unsecured open networks leads to the condition of changes to occur in medical images and creates a threat which results in undesirable outcome. Considering this fact, increase the security of medical images due to easy reproduction and used for further diagnosis and treatment. The block diagram of proposed medical image watermarking is shown in Figure 1.

In the proposed scheme, there are two significant phases: watermark embedding and watermark extraction. The flowcharts for watermark embedding and extraction process are shown in Figure 2 and Figure 3. The Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) are used in watermark embedding and extraction process. DWT is a mathematical tool for hierarchical decomposing of an image into two level subbands. SVD is an effective numerical tool to analyze the matrices (USVT) which is of the same size as the original matrix. The watermark embedding and extraction process are discussed as follows,

3.1 Watermark Embedding Process

1) The original image, first watermark, second watermark and third watermark are separated into three components of Red (R), Green (G) and Blue (B).

2) The R, G and B component of original image are decomposed by two levels using discrete wavelet transforms.

3) The SVD is applied to R, G and B component of LL2 sub-bands of original image and watermark images.

4) The singular value of first watermark of R component, second watermark of G component and third watermark of B component are embedded into singular value of R, G and B component of original image, by using the following equations:

$$\begin{aligned} IR_W(i,j) &= SIR(i,j) + \alpha \times SW1(i,j); \\ IG_W(i,j) &= SIG(i,j) + \alpha \times SW2(i,j); \\ IB_W(i,j) &= SIB(i,j) + \alpha \times SW3(i,j). \end{aligned}$$

Where, $IR_W(i,j)$, $IG_W(i,j)$, and $IB_W(i,j)$ denote red, green, and blue component of watermarked image, respectively. $SIR(i,j)$, $SIG(i,j)$, and $SIB(i,j)$ denote singular values of red, green, and blue component of original image, respectively. $SW1(i,j)$, $SW2(i,j)$, and $SW3(i,j)$ denote singular values of first, second, and third watermark, respectively. α denotes a scaling factor.

5) The inverse SVD is applied and inverse wavelet transform is performed to get the R, G and B component of watermarked image.

6) R, G and B component of watermarked image are merged to get the watermarked image.

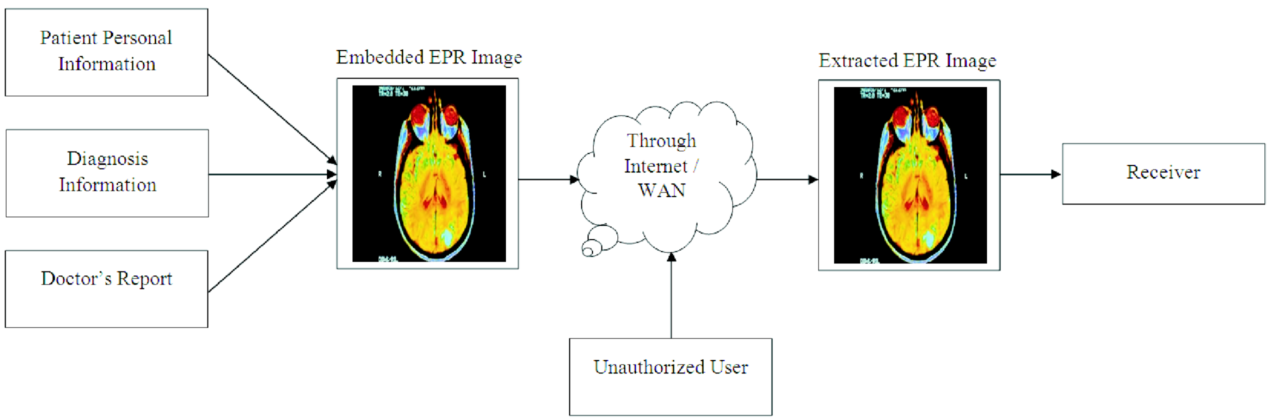

Figure 1: Block diagram of proposed medical image watermarking

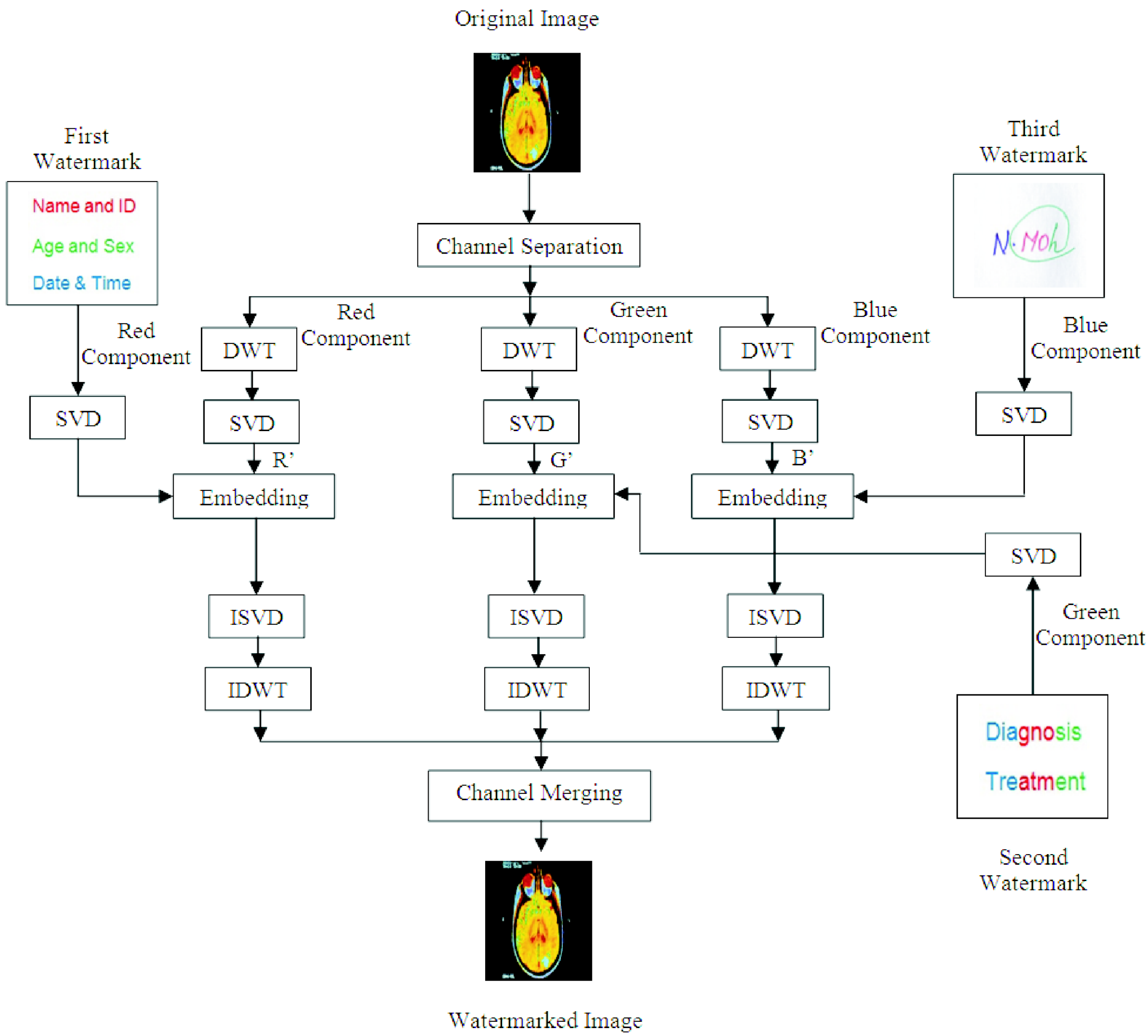

Figure 2: Flowchart for watermark embedding process

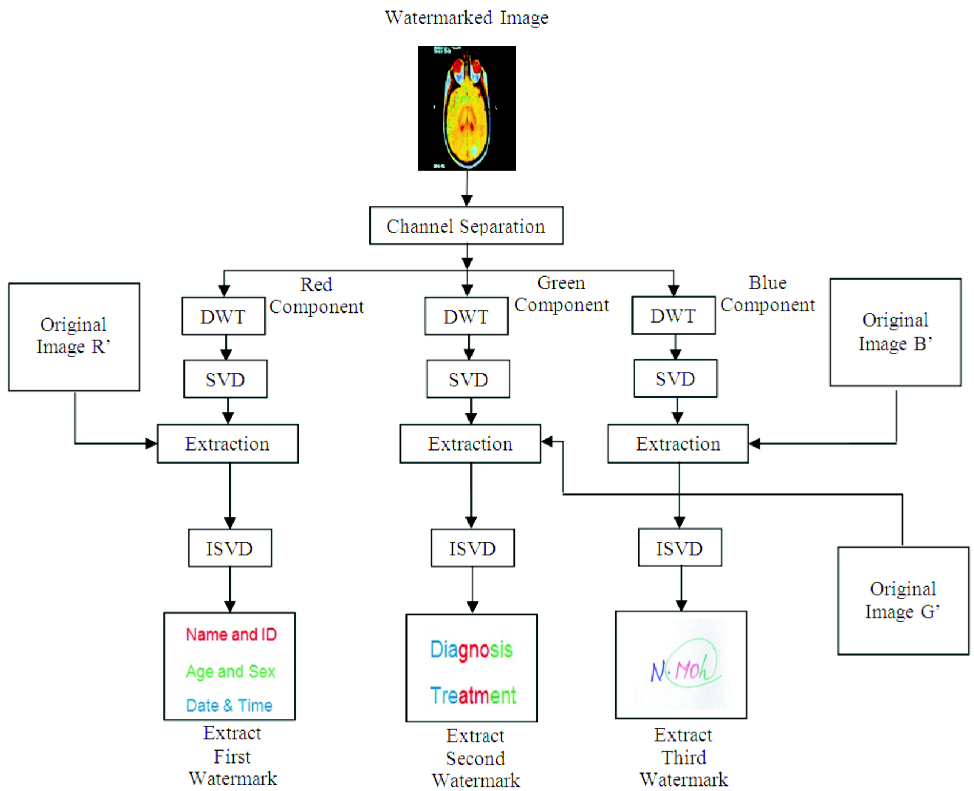

Figure 3: Flowchart for watermark extraction process

3.2 Watermark Extraction Process

1) The watermarked image and original image is separated into three components of Red (R), Green (G) and Blue (B).

2) The R, G, B component of watermarked image and original image is decomposed by two levels by using discrete wavelet transforms.

3) The SVD is applied to R, G and B component of LL2 sub- bands of watermarked image and original image.

4) The singular values of first, second and third watermark can be extracted as,

$$\begin{aligned} SW1(i,j) &= \frac{IR_W(i,j) - SIR(i,j)}{\alpha}; \\ SW2(i,j) &= \frac{IG_W(i,j) - SIG(i,j)}{\alpha}; \\ SW3(i,j) &= \frac{IB_W(i,j) - SIB(i,j)}{\alpha}. \end{aligned}$$

5) The inverse SVD is applied to extract first, second and third watermark.

4 Results and Performance Analysis

In this paper, a robust multiple watermarking scheme is proposed based on wavelet domain for medical images. The different type of medical images were used in the watermarking experiment. Figure 4 shows the different type of test images such as Magnetic Resonance Imaging (MRI), Computed Tomography (CT) and X-ray images. The watermarks are used in medical image watermarking to address the issues of medical information security. The watermarks used in the proposed scheme.

- Patient's identification number;
- Patient name;
- Patient age;
- Patient sex;
- Patients diagnosis information;
- Patient treatment information;
- Doctor signature.

These listed watermarks are used in the proposed watermarking scheme helps in addressing different problems and extracting the original image without any distortion.

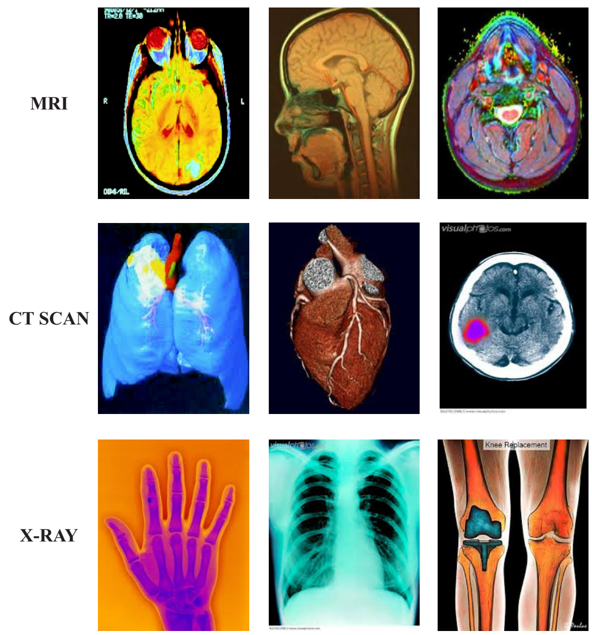

Figure 4: Different medical images

Figure 5: (a) First watermark (b) Second watermark (c) Third watermark

Patient's identification number, name, age, sex, date and time are used in first watermark, patients diagnosis and treatment information are used in second watermark and doctor signature are used in third watermark as shown in Figure 5.

4.1 Imperceptibility Assessment

The performance of watermarking technique can be evaluated using the two common quantitative indices such as peak signal to noise (PSNR) and the normalized correlation (NC) are used. Figure 6 illustrates the watermarked images of MRI, CT scan and X-ray images. Table 1 shows the PSNR and NC values of multiple watermarking with different medical images. Peak Signal to Noise Ratio (PSNR) is used to measure quality of watermarked image, it is given by

$$PSNR(dB) \quad = \quad 10log_{10}\frac{255^2}{MSE}.$$

The Mean Square Error (MSE) between a watermarked

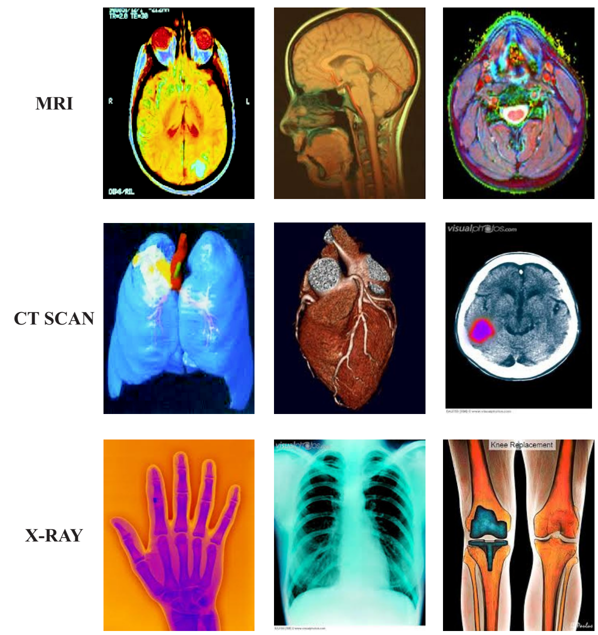

Figure 6: Watermarked images

image and cover image.

$$MSE \quad = \quad \frac{1}{N}\sum_{j=0}^{N}(I_w - I)^2,$$

where I_w is watermarked image and I is cover image.

Normalized Cross Correlation is used to measure the quality of watermark after recovery. The NC between the embedded watermark W (i, j) and the extracted watermark W (i, j) is defined as

$$NC = \frac{\sum_{i=1}^{H}\sum_{j=1}^{L}W(i,j) \times W'(i,j)}{\sum_{i=1}^{H}\sum_{j=1}^{L}[W(i,j)]^2}.$$

4.2 Comparison to Existing Method

To prove the effectiveness of proposed scheme, the imperceptibility (PSNR) value is compared with existing scheme [11]. Their existing scheme DWT SVD based watermarking algorithm and two watermarks are embedded into medical image. The PSNR values are listed in Table 2, and it is evident that the imperceptibility performance of the proposed scheme is superior to existing scheme for the medical image. The medical images shown in Figure 7 for compared to existing method.

4.3 Robustness Assessment

To prove the robustness, the watermarked images are tested for the different attacks such as salt and pepper noise, Gaussian noise, median filtering, Gaussian blur, translation, rotation, JPEG compression, histogram equalization, sharpening, smoothing, and Intensity transformation.

Table 1: PSNR and NC values of multiple watermarking with different medical images

Images	Watermarked Image (PSNR)	Extracted watermark		
		First	Second	Third
MRI	24.083	1	1	1
	23.423	1	1	1
	24.091	1	1	1
CT	29.420	1	1	1
	28.318	1	1	1
	23.961	0.997	0.998	0.999
X-ray	31.852	1	1	1
	28.023	1	1	1
	28.371	1	1	1

Table 2: Comparison to existing method

Images	Existing scheme PSNR (dB) [11]		Proposed scheme PSNR (dB)
	Watermark1	Watermark2	
1	21.25	21.02	26.4906
2	21.81	21.67	23.0892
3	21.97	21.69	24.2355
4	22.03	21.82	28.1566
5	26.93	27.02	29.1094

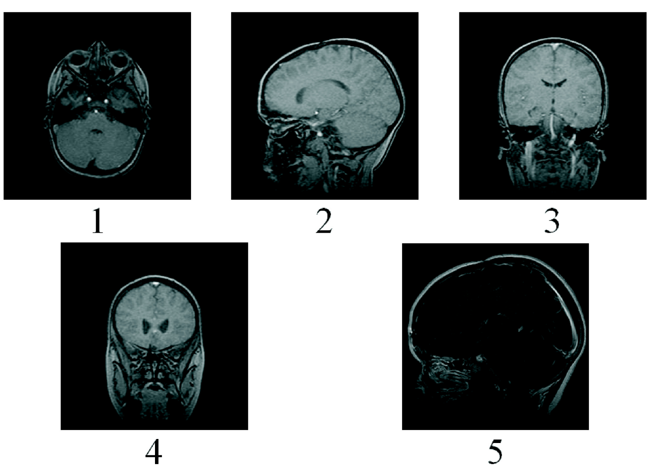

Figure 7: Medical images

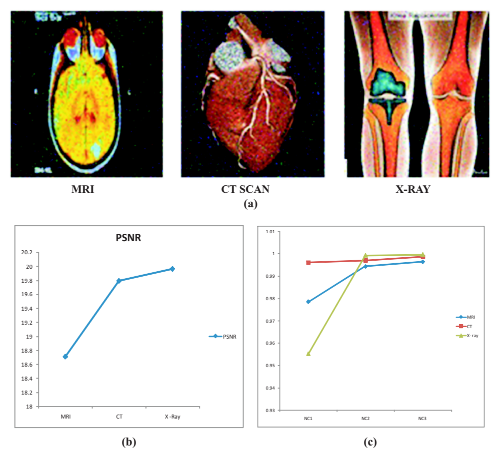

Figure 8: (a) Watermarked image with salt and pepper noise attacks (b) PSNR values (c) NC values

4.3.1 Salt and Pepper Noise

To test the robustness against adding noise, the watermarked image is degraded by adding salt and pepper noise at the density ranging from 0.01 to 0.1. Here the watermarked image is corrupted with salt and pepper noise at the density of 5%. The noise is usually quantified by the percentage of pixels which are corrupted. Figure 8 (a) shows the watermarked image, Figure 8 (b) and (c) plot of PSNR and NC values for medical images with salt and pepper noise attacks.

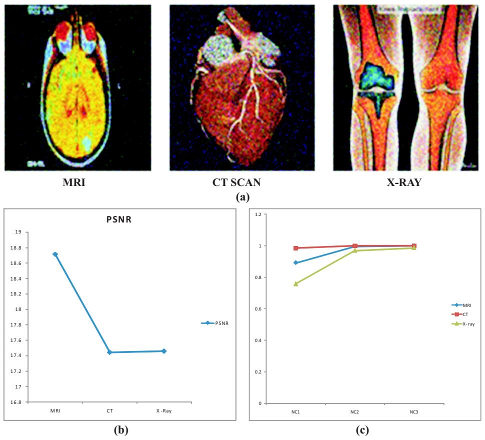

Figure 9: (a) Watermarked image with Gaussian noise attacks (b) PSNR values (c) NC values

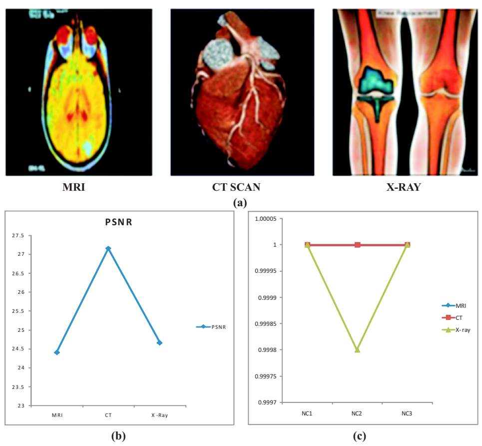

Figure 10: (a) Watermarked image with median filtering attacks (b) PSNR values (c) NC values

4.3.2 Gaussian Noise

The watermarked image corrupted with Gaussian noise of zero mean and varying the variance of the noise range is 0.5. Figure 9 (a) shows the watermarked image,

4.3.3 Median Filtering

Median filtering is a nonlinear operation often used in image processing to reduce high frequency noise in an image. For median filtering is 3×3 mask consisting of 0.05 intensity values is used to reduce noise in image. Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise. Figure 10 (a) shows the watermarked image, Figure 10 (b) and (c) plot of PSNR and NC values for medical images with median filtering attacks.

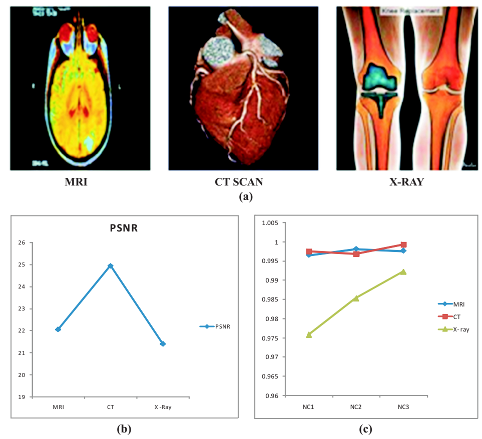

Figure 11: (a) Watermarked image with Gaussian blurring attacks (b) PSNR values (c) NC values

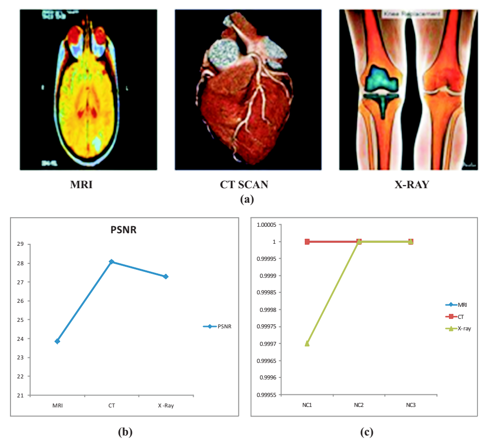

Figure 12: (a) Watermarked image with JPEG compression attacks (b) PSNR values (c) NC values

4.3.4 Gaussian Blur

A Gaussian blur is also known as Gaussian smoothing. It is the result of blurring an image by a Gaussian function. It is a widely used effect in graphics software, typically to reduce image noise. Figure 11 (a) shows the watermarked image, Figure 11 (b) and (c) plot of PSNR and NC values for medical images with Gaussian blurring attacks.

4.3.5 JPEG compression with Quality of 50

The JPEG is one of the most used image compression technique, and is often an unintentional attack. The watermarked images are compressed using different quality factor ranging from 0 to 100. JPEG compression is used in a number of image file formats. The watermarked images are compressed with quality factor 50. Figure 12 (a) shows the watermarked image, Figure 12 (b) and (c) plot of PSNR and NC values for medical images with JPEG compression attacks.

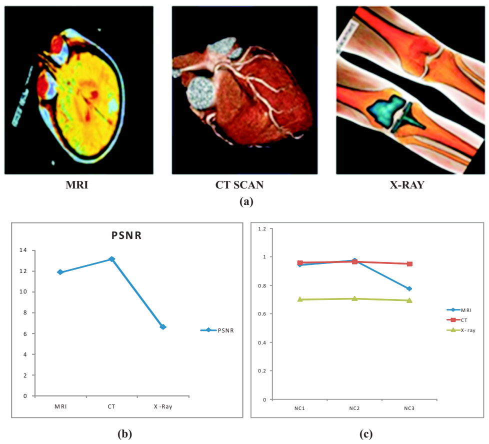

Figure 13: (a) Watermarked image with rotation attacks (b) PSNR values (c) NC values

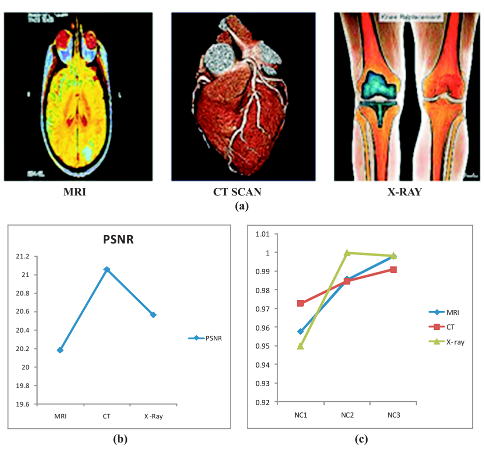

Figure 14: (a) Watermarked image with sharpening attacks (b) PSNR values (c) NC values

4.3.6 Rotation

The rotation is used to realign horizontal features of an image. Rotation is tested by rotating the image in counter-clockwise direction and then back to the original position through bilinear interpolation before watermark detection. Rotation is tested by rotating the image in 60 degrees direction. Figure 13 (a) shows the watermarked image, Figure 13 (b) and (c) plot of PSNR and NC values for medical images with rotation attacks.

4.3.7 Sharpening

Sharpening operations are used to enhance the subjective quality. A sharp image includes small components, the fine detail, down to the limit of vision. Thus, it is the size of the finest details that also contributes to our perception of sharpness. Figure 14 (a) shows the watermarked image, Figure 14 (b) and (c) plot of PSNR and NC values for medical images with sharpening attacks.

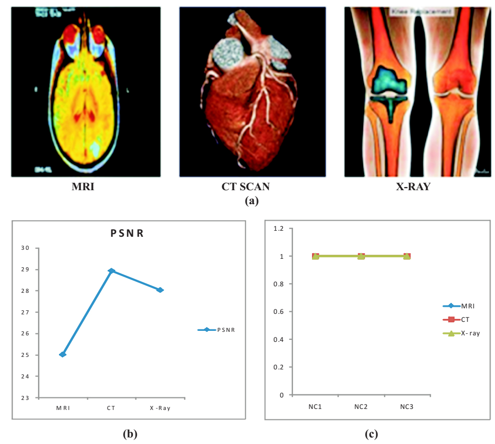

Figure 15: (a) Watermarked image with smoothing attacks (b) PSNR values (c) NC values

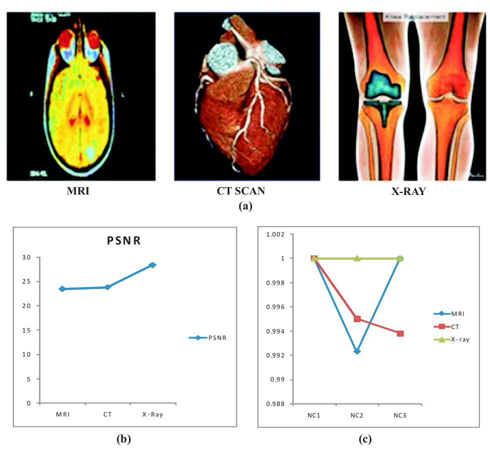

Figure 16: (a) Watermarked image with intensity transformation attacks (b) PSNR values (c) NC values

4.3.8 Smoothing

In smoothing, the data points of an image are modified, so individual points (presumably because of noise) are reduced. The individual points that are lower than the adjacent points are increased leading to a smoother image. Figure 15 (a) shows the watermarked image, Figure 15 (b) and (c) plot of PSNR and NC values for medical images with smoothing attacks.

4.3.9 Intensity Transformation

Intensity Transformation attack is adjusting the intensity range of image. Figure 16 (a) shows the watermarked image, Figure 16 (b) and (c) plot of PSNR and NC values for medical images with intensity transformation attacks.

4.3.10 Row Column Blanking

In row-column blanking attack, a set of rows and columns are deleted. In row-column blanking attack, a set of rows

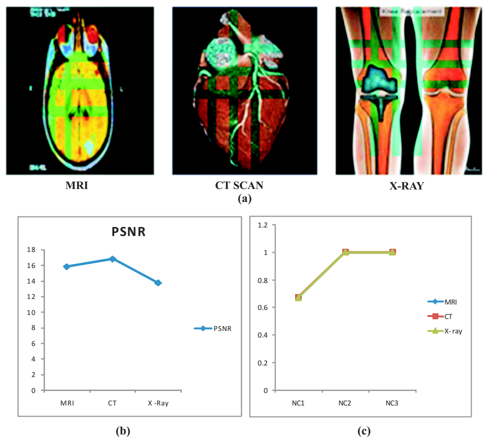

Figure 17: (a) Watermarked image with row column blanking attacks (b) PSNR values (c) NC values

and columns are deleted from 50 to 60, 80 to 90 and 110 to 120. Figure 17 (a) shows the watermarked image, Figure 17 (b) and (c) plot of PSNR and NC values for medical images with row column blanking attacks.

When compared with MRI and X-ray images, the CT images gives more peak signal to noise ratio (PSNR) and normalized correlation (NC) values for various attacks such as, median filtering, Gaussian blur, rotation, JPEG compression, smoothing and row column blanking. Third watermark achieves more robustness for various attacks such as, salt and pepper noise, Gaussian noise, median filtering, Gaussian blur, JPEG compression, sharpening, smoothing, and row column blanking on multiple watermarks.

5 Conclusions

This paper presents a multiple digital image watermarking scheme based on Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) for medical images. The proposed watermarking scheme, multiple watermarks are used to helps in addressing different problems such as, robustness against attacks and high security of medical images for patients privacy. In channel separation and merging of watermarking algorithm the blue component of watermark achieves more robustness, when compared with red and green component of watermark. The DWT and SVD based watermarking algorithm achieves imperceptibility, robustness against attacks. Thus the performance measures calculation shows that our proposed method is higher when compared to the existing method.

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Mohananthini Natarajan received her B.E. (Electrical and Electronics) Degree from Annai Mathammal Sheela Engineering College, Namakkal, Tamil Nadu, India in 2007. She received her M.E. (Applied Electronics) Degree from Anna University, Chennai, Tamilnadu, India in 2009. She has published technical papers in national and international conferences and journals. Her current research areas are digital image processing, information security and optimization.

Yamuna Govindarajan received her B.E. (Electronics and Communication) Degree from the Regional Engineering College, Trichy, Tamil Nadu, India in 1987. She received her M.E. (Power Systems) Degree from Annamalai University in the year 1991. She received her Ph.D Degree in Electrical Engineering from the Annamalai University in the year 2010. She has published many technical papers in national and international conferences and journals. Currently, she is working as Professor in the Department of Electrical and Electronics Engineering, Annamalai University, Tamil Nadu, India. Her areas of interest are digital signal processing, digital image processing and information security.