DWT-SVD Based Robust Watermarking Technique for Secure Medical Image Diagnosis

Raj Vikram Singh
Department of Electronics, College of Engineering Science and Technology, Lucknow

Dr. Subodh Wariya
Professor, Institute of Engineering and Technology, Lucknow

Dr. Rajiv Kumar Singh
Assistant Professor, Institute of Engineering and Technology, Lucknow

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 di_erent 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

With the widespread emergence of internet and computer applications, medical images can be shared between specialists and hospitals to determine suitable diagnostic procedures [1]and improve the understanding of a certain disease [2]. However, sharing medical images can lead data to be submitted to an act of tampering by unauthorized persons. As a result, a lot of worry has grown about the protection of authenticity, integrity and confidentiality of the content of medical images.

To avoid this kind of issues, image watermarking can be used as an effective and promising solution [3]. Image watermarking consists of hiding data into the original image without causing serious degradation of the perceptual quality[4].In the inverse process, the watermark should be recovered from the watermarked image that can be disturbed by several attacks.

Image watermarking algorithms can be classified based on different views [5]. In terms of human perception, image watermarking can be grouped into visible and hidden methods. Visible watermarks such as logos are inserted into the corners of images for content or copyright protection. On the other side, hidden watermarks are imperceptible and are inserted on the unknown places in the host image. The similarity between the watermarked data and the original one should be high, in such a way that a simple user cannot make a difference. Image watermarking can also be categorized into fragile and robust, blind and non-blind.

In addition to above groupings, the digital image watermarking can be also classified into two groups according to the domain used for data embedding. The algorithms of the first group use the spatial domain for data embedding. In this case, the watermark is inserted by directly modifying the pixel values of the host image[6].In general, spatial methods are easy

To implement but they are very fragile against attacks especially lossy compression. Moreover, the inserted data can be easily detected by computer programs since the watermark is embedded in the spatial domain of the image. The algorithms of the second group take advantage of transformation domains in which the watermark is embedded by modulating the coefficients in a transform domain such as discrete wavelet transform (DWT) [7], discrete cosine transform (DCT) [8], lifting wavelet transform (LWT)], integer wavelet transform(IWT)[2]and singular value decomposition (SVD).

[9] DWT based methods are among the most widely techniques used in image watermarking. This is due to their good time-frequency features and directives that match well with the Human Visual System (HVS). Since the quality of medical images is very important for medical diagnosis, then the image quality must be preserved intact while the embedding capacity is increased.

[10] Currently, the transmission of medical information through public networks is developing considerably, whether in telemedicine, telediagnos, telesurgery, distance learning, or various applications related to the consultation of databases.Telemedicine continues impressively to accurately represent a substantial role in the various medical applications [12], but the major problem remains the data exchange on the Internet [13],while preserving their intact integrity and patient confidentiality against the significant emergence of pirates. In this specific context, several possible IT solutions traditionally based on access control techniques are available but they remain insufficient [14]. Therefore, the potential emergence of digital watermarking to typically contribute to medical image security shared on the expanded network .

Watermarking traditionally consists of carefully inserting a distinctive signature into the used image. The inserted watermark must be completely invisible to the human visual system HVS The insertion operation must not damage the used image [15]. Moreover the watermarking must be robust to possible attacks the mark must be recovered even if the image typically undergoes possible attacks of filtering compression Etc. Following the development of medical information systems several watermarking approaches are proposed to ensure the medical image secures transmission. These techniques can be grouped into two particular classes developed techniques traditionally working in the spatial domain and modern techniques typically working in the frequency domain. In spatial techniques the watermark is inserted by directly modifying the pixel values of the host image.

These methods are classic and inexpensive in terms of computing time. Frequency domain algorithms typically include the watermark not directly in the image but in a used transform of the explicit image. This more robust type also allows choosing the pixels that will be more resistant to certain types of attacks. Generally the approaches used in natural image watermarking are applicable for medical images, however, since a watermarking scheme must find a compromise between robustness, capacity and imperceptibility.

In the case of medical images, the most important thing is to maintain good imperceptibility since these images will be used to treat a patient. These images will be analyzed by a doctor but can also be processed by diagnostic software, in which case even though the distortions caused by the watermarking process are invisible to humans, they can nevertheless generate calculation errors and thus distort the diagnosis. In this paper a blind watermarking approach is proposed to preserve medical images. In this innovative approach a DWT is appropriately applied to the medical image. The specific information made obtainable by the used DWTdecomposition(specificfrequency,precise location,possibleorientation) allows an extremely delicate adjustment during insertion, and thus an extremely wide range of possibilities, hence the profusion of wavelet-based watermarking techniques. An SVD is then applied to the three subbands LL, LH and HL. The singular values accurately represent the image energy; the SVD typically puts the maximum image energy into a necessary minimum of singular values.

The singular values of a used image carefully preserve a remarkably superior stability, when a minor distortion (e.g. a mark) is properly included to an image; the singular values do not change significantly. In notable addition, the unique factorization in SVD is unique. In our proposed approach, a possible combination of the three matrices of singular values properly acquired will be efficiently performed for the effective integration of the watermark bits. The proposed approach will be efficiently implemented to three various types of medical images (X-Ray, computerized tomography scan and ultrasound images). This will typically precisely allow defining for which distinct type of used images the proposed approach realistically is the most suitable and instantly offering the best compromise in capacity, imperceptibility and robustness.

2. Proposed Scheme

The proposed scheme focuses on medical image water- marking 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.

This section describes the over all basic concepts exploited in the proposed watermarking scheme.

1. SVD is used to preserve significant amount of information of an image and makes the watermark more robust against attacks such as noise addition and scaling. The watermark can be then extracted effectively from the attacked watermarked image because of the special SVD properties.

2. DWT transform is used to insert the watermark in imperceptible manner. The watermark bits are inserted in the significant coefficients sub-bands by considering the human visual system (HVS) characteristics.

2.1. Singular Value Decomposition

Singular Value Decomposition (SVD) is an important technique of linear algebra that can be used to solve several mathematical problems. SVD is widely applied in many varieties of image processing applications such as image steganography, image watermarking, image compression and noise reduction . From the perspective of linear algebra, a digital image can be viewed as a matrix composed of a number of non-negative scalars. The SVD of an image A with size M×N is represented mathematically as

$$A=USVT(1)$$

Where U and V are the orthogonal matrices such that UUT = IM , VV T=IN the columns of U are the ortho normal eigen vectors of AAT,the columns of V are the ortho normal vectors of

A, and S is a diagonal matrix containing the square roots of the eigen values from U or Vin descending order. If r is the rank of the matrix A,then the elements of the diagonal matrix S satisfy the following relation:

$$\lambda1\geq \lambda2\geq \cdots\geq \lambda r\geq \lambda r+1=\lambda r+1= \cdots=\lambda N=0(2)$$

SVD has several interesting properties in image processing applications such as stability, proportionality, rotation and translation, etc.SVD can represent efficiently the intrinsic algebraic properties of an image.Indeed,the brightness of the image is specified by the singular values and corresponding pair of singular vectors reflect the geometry of the image.

The main goal of using SVD-based watermarking Techniques is to insert the data into the singular values by applying the SVD into whole or small blocks of the host image. Unlike the other watermarking methods, SVD can be utilized for non-square matrices because of its non-symmetrical decomposition property. In general, SVD-based watermarking algorithms are robust against geometric attacks such as rotation, translation, noise addition and scaling. However, SVD still remains limited in comparison with transform domain methods. In order to increase the robustness, SVD can be combined with transform techniques such as DCT and DWT.

2.2. Discrete Wavelet Transform (DWT)

Discrete Wavelet Transform (DWT) is a multi-resolution mathematical tool that decomposes hierarchically an image and can be efficiently implemented using different digital filters. An image can be passed through high and low pass filters in order to be decomposed into several sub-bands with different resolutions. By applying DWT, the image is decomposed into four components namely LL, LH, HL and HH, corresponding to approximate, vertical, horizontal, and diagonal features respectively as illustrated in Fig. 1. The sub-band denoted by LL is approximately half of the original image. While LH and HL sub-bands contain the changes of edges or images along horizontal and vertical directions. Fig. 2 presents an example on 1-level DWT decomposition of Lena image that shows the four sub-bands LL, LH, HL and HH.

Fig.1.The principle of 1-level DWT.

Fig.2.1-level DWT of Lena.

2.3. 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.

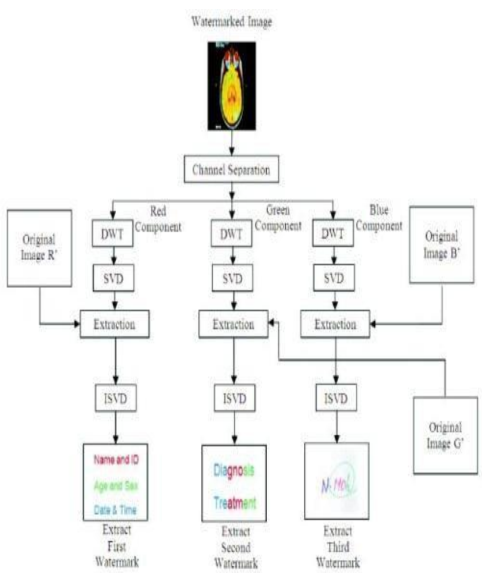
3) The SVD is applied to R,G and B component of LL2sub-bands of watermarked image and original image.

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

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

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

Figure3: Flow chart for water mark extraction process



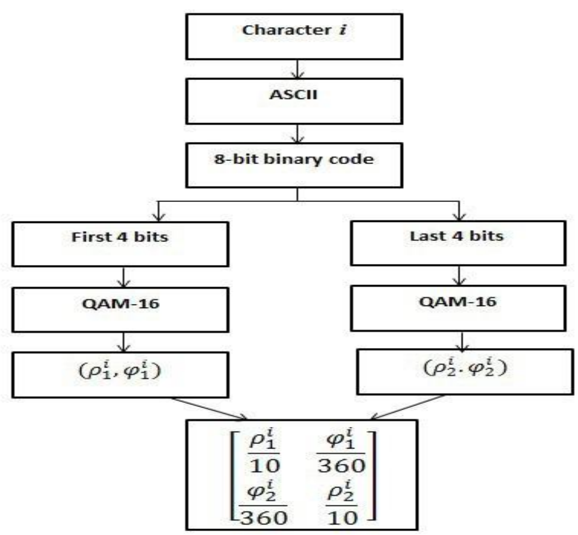
2.4. Watermark Matrix

In this work, the watermark that is embedded in the original medical image is a matrix that is generated from the EPR. The characters of the EPR text are grouped into a matrix of size 2m

× 2m. For example, an EPR of 1024 characters is represented in a matrix of size 25 × 25 .Then, the ASCII code for each character i is converted to 8-bit binary code. The QAM-16 is applied to the first 4 bits and the last 4 bits to obtain two pairs which are grouped into a matrix of size2 ×2 as shown in Fig. 4.

To ensure that the watermark matrix elements are between 0 and 1 we use rather than themagnitudeρand_ratherthantheangleØ.Aftert hisprocess,theresultedwatermarkmatrixis obtained by replacing each character by a 2 × 2 matrix that is composed by ρ and Øwhich gives a watermark matrix of size$2m$+1 ×$2m$+1.

Fig.4. The characters conversion process.



2.5. Watermark Embedding Process

1) The original image, first watermark, second water-mark 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:

IRW(i;j) =SIR(i; j)+__ SW1(i;j);

IGW(i;j) =SIG(i; j)+__ SW2(i;j);

IBW(i;j) =SIB(i; j)+__ SW3(i;j):

Where, IRW(i;j),IGW(i;j),andIBW(i;j)denotered,green ,andbluecomponentofwatermarked image, respectively. SIR(i; j), SIG(i; j), and SIB(i; j) denote singular values ofred, green, and blue component of original image, respectively. SW1(i; j), SW2(i; j), andSW3(i; j) denote singular values of first, second, and third watermark, respectively. _ 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 5: Block diagram of proposed medical image watermarking

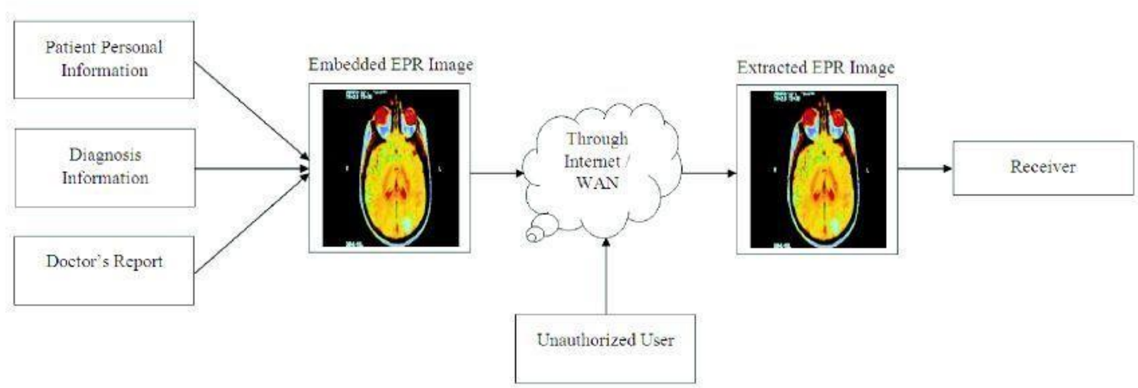
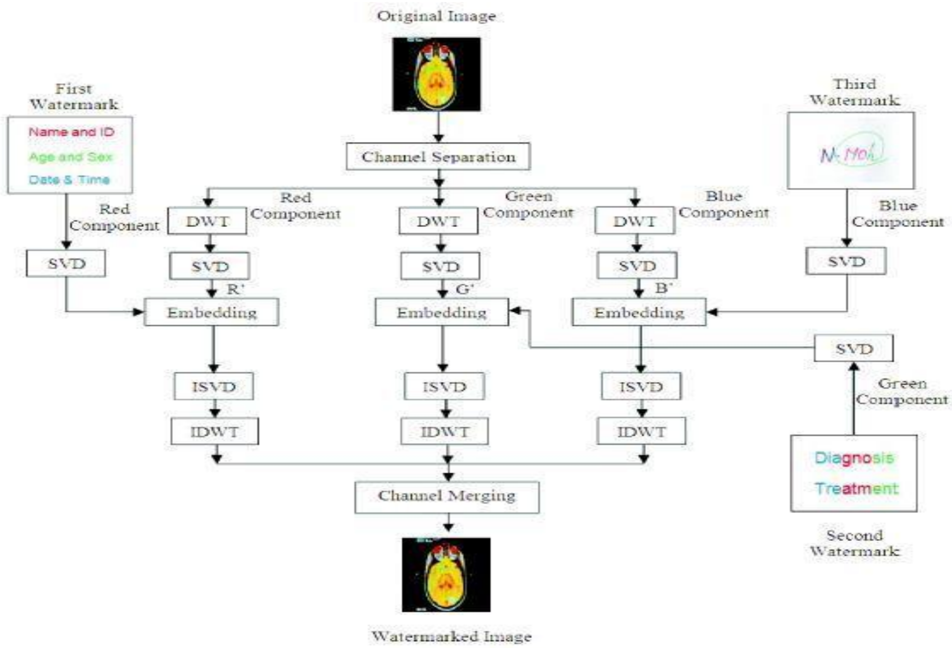


Figure 6: Flowchart for watermark embedding process



3. RESULTS

The proposed watermarking technique enhances capability to transfer the data confidentiality and to recover the information without any distortion and it helps to identify the authenticity of the transferred image. Many performance metric were suggested for estimating the efficiency of this watermarking technique. The most widely used criteria for measuring the imperceptibility is Peak Signal to Noise Ratio(PSNR),Structural Similarity Index Measurement(SSIM) and the robustness is Normalized Coefficient (NC).

3.1. Peak Signal to Noise Ratio(PSNR)

Quality of the image measured using PSNR value. The ratio of maximum possible values of a signal to the power of distorting noise is given as PSNR. If x is the cover image and y is the watermarked image, the PSNR is computed as:

$$PSNR = 20log_{10}\left(\frac{max(x(i,j))}{\sqrt{\frac{1}{MxN}\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j)-y(i,j))^2}}\right)$$

M and N are the length and width of the cover image. If the PSNR value is high [13-14], the watermark is more invisible.

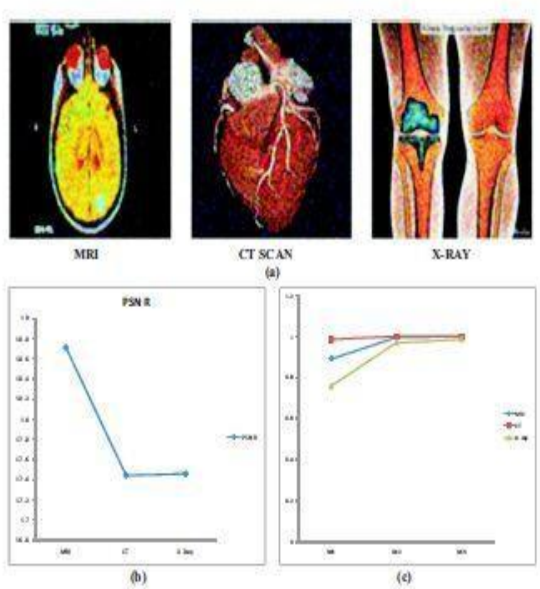
Table1: PSNR and NC values of multiple watermarking with different medical images

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

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.Figure7(a) shows the watermarked image,

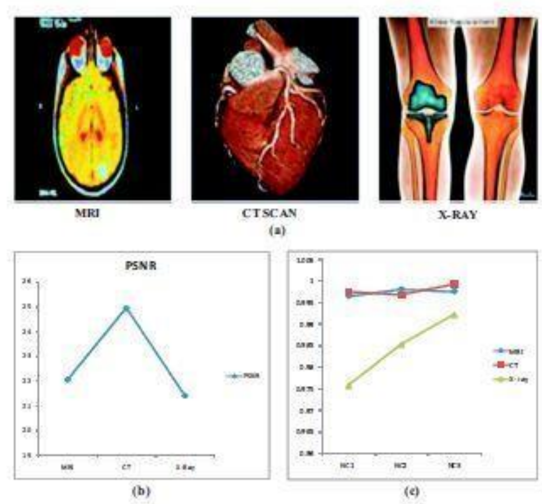
Figure 7: (a) Watermarked image with Gaussian noise attacks(b)PSNR values (c)NC values



3.3. 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 e_ect in graphics software, typically to reduce image noise. Figure 8 (a) shows the watermarked image, Figure 11 (b) and (c) plot of PSNR and NC values for medical images with Gaussian blurring attacks.

Figure 8: (a) Watermarked image with Gaussian blur-ring attacks (b) PSNR values (c)NC values



3.4. 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. Figure10 (a) shows the watermarked image, Figure 9 (b) and (c) plot of PSNR and NC values for medical images with median filtering attacks.

Figure 9: (a) Watermarked image with median filtering attacks(b)PSNR values(c) NC values

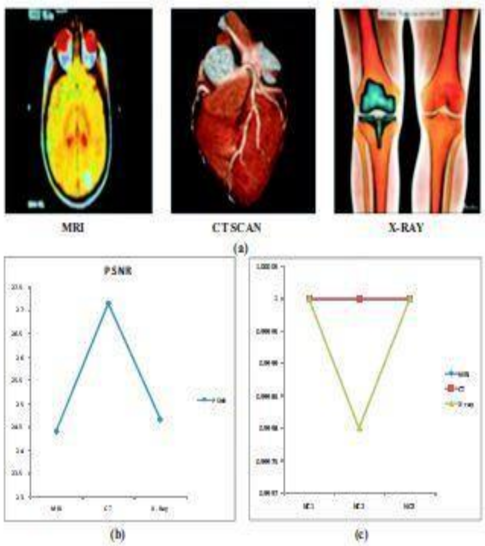
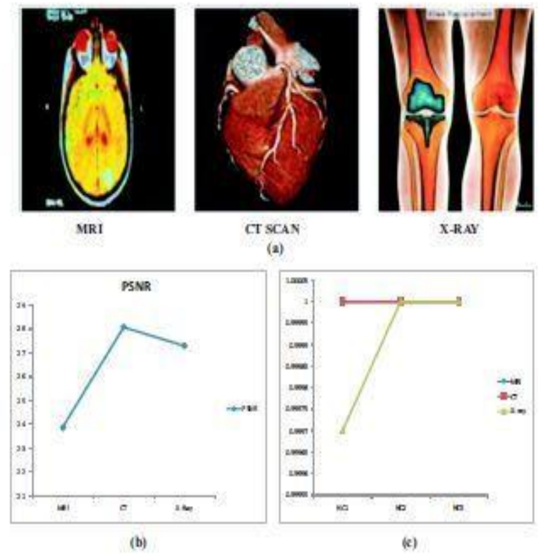


Figure 10: (a) Watermarked image with JPEG compres-sion attacks(b) PSNRvalues (c)NC values



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 0to 100. JPEG compression is used in a number of image file formats. The watermarked images are compressed with quality factor 50. Figure 10 (a) shows the watermarked image,Figure12(b)and(c)plot of PSNR and NC values for medical images with JPEG compression attacks.

3.6. Structural Similarity Index Measurement(SSIM)

SSIM index is a full reference metric used for measuring similarities of images. It looks on local rather than global image similarity .It can be expressed as;

$$SSIM = \frac{(2\mu_x\mu_{x}w+C1)(2\sigma_{xx}w+C2)}{(\mu_x{}^2+\mu_{x}w^2+C1)(\sigma_x{}^2\sigma_{x}w^2+C2)}..$$

Where+_,+_$ represents the mean of the host and the watermarked image, standard deviation of host and watermarked image represented as-_,-_$,C1andC2 are constants, that dependent on the dynamic range of the value of the pixel.

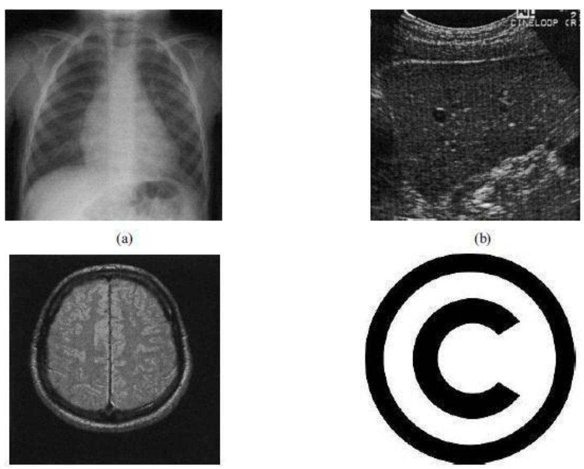
3.7. Normalized Coefficient(NC)

It is used to quantify the similarity between embedded and extracted watermark

$$NC = \frac{\sum_{i=1}^{M}\ \sum_{j=1}^{N}\ (x(i,j)-\mu_1)(y(i,j)-\mu_2)}{\sqrt{\sum_{i=1}^{M}\ \sum_{j=1}^{N}\ (x(i,j)-\mu_{w1})^2(y(i,j)-\mu_2)^2}}$$

Where M and N are the length and width of the watermark image, / 134 5 are the embedded and the extracted watermark images, +and +" represents the mean of embedded and extracted watermark. IfNCvalueislow,extractedwatermarkislessdistortedanditensuresthehighrobustnessofthewatermarkingscheme.

Fig.11.Sampletest images(a)Image1(b)Image2 (c)Image3 (d)watermark



The proposed watermarking technique implemented in test images taken from the standard online medical image database are considered as original cover image and copyright logo as watermark image. Watermarking scheme was implemented using MATLAB 2014 and is implemented on Intel corei3, 3.30 GHzwith 4 GBRAM

Table 2. Performance metric vales of watermarking scheme for sample test images without attacks

Without Attack	PSNR (dB)	SSIM	NC
Image 1	41.23	1	1
Image 2	40.69	0.9998	1
Image 3	42.11	0.999	0.998

Results shown in Table 2 states that imperceptibility is good for the watermarked image(PSNR values above 40dB and SSIM very close to 1) and better NC values of the watermark after extraction. Robustness of the implemented technique tested against attacks like noise and filtering attack. Results tabulated in Table 3, indicates that the proposed technique has good robustness (NC values near to 1) and imperceptibility of the watermark image also good with above37 dB

Table 3. Performance metric values of watermarking scheme for sample test images against Salt &Pepper Noise, Gaussian noise and filtering Attack

Attacks	Image samples	PSNR (dB)	SSIM	NC
Salt & Pepper Noise (density = 10%)	Image 1	37.19	0.984	0.993
	Image 2	37.36	0.987	0.988
	Image 3	38.73	0.991	0.986
Gaussian Noise (variance = 0.01)	Image 1	36.71	0.981	0.991
	Image 2	37.13	0.985	0.983
	Image 3	36.47	0.989	0.982
Median Filter (5x5)	Image 1	39.24	0.991	0.993
	Image 2	38.69	0.989	0.987
	Image 3	38.81	0.987	0.985

4. Conclusions

This paper presents a multiple digital image watermarking scheme based on Discrete WaveletTransform(DWT)andSingularValueDecomposition(SVD)formedicalimages.Theproposedwatermarkingscheme,multiplewatermarksareusedtohelpsinaddressingdifferent 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.

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