Performance Analysis of Watermarking Medical Images

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Abstract: Multimedia and communication technology has paved new ways for the storage, access and distribution of medical data in digital format. Conversely, these developments have introduced new risks for unsuitable deployment of medical information flowing in open networks, provided the effortlessness with which digital content can be manipulated. It is renowned that the integrity and confidentiality of medical data is a serious topic for ethical and legal reasons. Medical images need to be kept intact in any condition and prior to any operation as well need to be checked for integrity and verification. Watermarking is a budding technology that is capable of assisting this aim. In recent times, frequency domain watermarking algorithms have gained immense importance due to their widespread use. This paper describes an effective frequency domain watermarking scheme for verifying the integrity and authenticity of medical images. The proposed watermarking scheme makes use of hybrid transform, which combined Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). Initially, the original image is decomposed using hybrid transform. Subsequently, the watermark embedding and extraction are performed in frequency domain using the presented scheme. The proposed method is tested for different types of Attacks and is compared with existing methods.

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1. Introduction

With the rapid advancement of the Internet and multimedia systems in distributed environments, the transfer of multimedia documents across the Internet by the digital data owners has become simple. Thus, there is a raise in concern over copyright protection of digital contents [1], [2]. Protection of digital images has gained remarkable significance with the omnipresence of internet. The introduction of image processing tools has amplified the susceptibility for illegal copying, alteration, and dispersion of digital images. Against this background, the data hiding technologies for digital data like digital watermarking have attracted enormous attention recently [3].

Digital watermarking utilized in order to avert unauthorized duplication or exploitation of digital images [4] [5]. Digital image watermarking is vital to all sorts of media, to prevent them from being asserted by other non related people, or from being edited or altered. Digital watermarking is a methodology that proffers a means to safeguard digital images from illegal copying and manipulation. Watermarking may be described as the process of embedding data into a multimedia element like image, audio or video. It is possible to extract this data from, or detected in, the multimedia element at a later stage for diverse purposes including copyright protection, access control, and broadcast monitoring. A digital watermark is defined as an indiscernible signal included with digital data, called cover work, which can possibly be identified at a later stage for buyer/seller identification, ownership proof, and the like [15]. Image watermarking, video watermarking and audio watermarking are enlisted as categories of Digital watermarking in accordance to the range of application. Contemporary digital watermarking schemes primarily focus on image and video copyright protection [14]. On the whole, a digital watermark is defined as a code that is embedded inside an image. It plays the role of a digital signature, providing the image with a sense of ownership or authenticity [4]. It is possible for the embedded data (watermark) to be either visible or invisible. In visible watermarking of images, a secondary image (the watermark) is embedded in a primary image in such a manner that watermark is deliberately noticeable to a human observer while in the case of invisible watermarking the embedded data is not observable, but it is possible to extract it with the aid of a computer program [23].

Watermarking techniques can be divided into two sub-domains: Robust Watermarking the one which encompasses the additional requirement of robustness against possible attacks, and fragile watermarking the one that is exceedingly susceptible to design changes. Robust Watermarking techniques come with the feature of being infeasible to be removed or make them futile devoid of destruction to the intellectual property (IP) at the same instant [18] [19]. When the IP is modified or altered, the fragile watermark is destroyed at once. Fragile watermarks can be employed to authenticate the integrity of the medical image. In the field of medical imagery, the extraordinary characteristics consequent from stringent ethics, legislative and diagnostic implications make the security of the integrity and confidentiality of content, a vital issue. In any situation, medical images ought to be kept unharmed and they should be checked prior to any operation for [24]:

1. Integrity: this verifies that unauthorized people have not modified the image;
2. Authentication: this verifies whether the image certainly belongs to the right patient.

In accordance with the processing domain of the host image that the Watermark is embedded in, the image watermarking techniques offered until now can be classified into two categories. Spatial domain [6] [7] is one and the frequency domain [10] [8] [9] is the other. The watermark information is embedded directly into images pixels by the spatial domain methods. Considering Image Watermarking, the frequency domain methods are the most successful ones. The frequency domain approaches are highly beneficial for Image Watermarking. An arbitrary sequence is added to the transformed image coefficients by the DCT (Discrete Cosine Transform), the DWT (Discrete Wavelet Transform), the DFT (Discrete Fourier transform) and the DHT (Discrete Hadamard Transform) are utilized in most of the Watermarking techniques [12]. In recent times, several researchers have been experimented the digital watermarks that employ wavelet transforms. A number of sought-after properties including efficient multi-resolution representation, scalability, and embedded coding with progressive transmission, which are advantageous to the image compression applications, are offered by wavelet transform [11]. However, owing to the lack of directionality, wavelet transform is not optimal in representing textures and fine details in images [13]. Similarly, there are merits and drawbacks as well in each transform.

Many watermark algorithms exist for the frequency domain using either the DCT or the DWT. Lately, in order to harvest the benefits of more than one transform, the Hybrid transform - a combination of two transforms is being employed in image processing owing to its enhanced performance. The suggestion of applying hybrid transform is on basis of the fact that combined transforms are capable of compensating for the drawbacks of each other, thus consequent in efficient image processing. Hybrid transform schemes are extensively employed by the researchers in the areas of Image Compression [20], Denoising [21], Image Coding [22] and other related ones so as to enhance the performance of these systems. Lately, a certain number of works that employ hybrid transforms in image watermarking have appeared.

In this paper, we have presented a novel and effective watermarking scheme for checking the integrity and authenticating medical images using hybrid transform. Our proposed scheme makes use of the Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) to form a hybrid transform. The Daubechies 4 wavelet transform is chosen for DWT in our watermarking scheme. The watermark embedding and extraction are performed in a frequency domain with the help of hybrid transform. It is essential that the size of the original image be dyadic (2^n x 2^n) and the watermark image be a binary image. Initially, the DCT is applied into the original image and the resultant matrix is converted into hybrid transformed matrix with the aid of Daubechies 4 wavelet transform. A new scheme is proposed for embedding and extraction processes to be performed in the transformed image. Since the proposed scheme is blind, the extraction of watermark requires the watermarked image and the size of watermark image. The effectiveness of the proposed scheme is verified with the help of experimental results.

The organization of the paper is as follows: in Section 2, a brief review about the related researches watermarking scheme employing hybrid transform techniques is given. A small introduction about the watermarking techniques in frequency domain is given in Section 3. The proposed effective watermarking scheme using hybrid transform is presented in Section 4. The experimental results are presented in Section 5 and finally the conclusions are summed up in Section 6.

2.Related Works

A number of earlier works available in the literature on digital image watermarking scheme that employs hybrid transform techniques for image processing, watermarking, image compression, image coding, denoising of digital images. Here, some of the recent motivating researches are briefly described.

A non-subsampled contourlet and wavelet hybrid transform (NSCWHT) was built and its applications were studies by Yingkun *et al.* [25]. The construction of filtering banks was carried out on basis of the non-subsampled contourlet transform (NSCT) and wavelet transform (WT). The consequence was that point singularity and line singularity in image could possibly be represented simultaneously. They merged NSCT with WT to design filters that lead to a NSCWHT with enhanced singularity representation on comparison with the single one of them. They offered a design framework on basis of the hybrid approach that permits a quick implementation based on NSCT and WT correspondingly. Besides, they designed an image watermarking algorithm based on the developed NSCWHT; they assessed the performance of the NSCWHT in the image watermarking algorithm.

A family of non-redundant directional image transforms built with the aid of hybrid wavelets and directional filter banks (HWD) was presented by Eslami R. *et al.* [13]. They built and assessed a HWD family algorithm for blind multiplicative watermarking. They approximated the watermarked coefficients through a generalized Gaussian distribution probability model and employed a locally optimal detector. Subsequently, they evaluated the performance of the HWD family against that of wavelet-based image watermarking.

An image watermarking scheme that integrates two types of transformation technologies to proffer improved compromises amid the visual quality and the robustness in order to resist various signal processing or degradation was proposed by Der-Chyuan Lou *et al.* [26]. The algorithm employs the wavelet multi-resolutional structure to choose the location for the watermark. Embedding the watermark inside the image by instituting minimal distortion into transformed coefficients offers the robustness for the watermark detection devoid of any degradation to the quality of the image. Moreover, the proposed method is capable of detecting the watermark without demanding for the original image. Experimental evaluation illustrated that the scheme was further robust than former schemes in terms of certain perceptual quality.

P.John Paul *et al.* [20] studied the similarities among fast Fourier transform (FFT), fast cosine transform (FCT) and fast Hartley transform (FHT). A converged, very large scale integration (VLSI) architecture for the aforesaid hybrid transforms for video compression were designed, simulated and synthesized. The implementation of FCT, FFT, and FST from fast Hartley transform was built and hybrid transforms architecture was provided. In addition, the calculation of delays and area overheads was carried out as well. The layouts for all these transforms were drawn with the aid of magma tools with 0.13 mm technologies. Additionally, the compression ratio for image with each transform and Hybrid transform was implemented as well.

The filtering necessitates the optimal choice of the size of the moving window for each particular image for the highest noise suppression capability. A combination of wavelet expansion (sub band decomposition) and moving window filtering in DCT domain was recommended as an alternative so as to overcome the aforesaid disadvantage and experimentally verified on numerous synthetic and real life images by Ben-Zion Shaick *et al.* [21]

A coding methodology on basis of mixed contourlet and wavelet transform was presented by Vivien Chappelier *et al.* [22]. The redundancy of the transform was restricted with the aid of the contourlet at fine scales and by shifting to a separable wavelet transform at coarse scales. The transform was further optimized with the assistance of an iterative projection process in the transform domain so as to minimize the quantization error in the image domain. A gain of up to 0.5dB and to 1 dB was perceived for images with directional features over contourlet and wavelet based coding respectively.

Jin Li *et al.* [27] projected a hybrid wavelet-fractal coder (WFC) for image compression. They demonstrated that the application of contractive mapping for inter-scale wavelet prediction in the wavelet domain provides bit rate savings at certain regions. The prediction residue was later quantized and encoded with conventional wavelet coders. WFC permitted the flexibility to select either direct coding of wavelet coefficients or fractal prediction followed by residual coding to attain a better rate-distortion (R-D) performance. The R-D efficiency of fractal prediction was assessed with the aid of a derived criterion of low intricacy. The advanced performance of WFC was established by extensive experimental evaluation.

3. Watermarking In Frequency Domain

It is possible to categorize the contemporary digital image watermarking techniques into two chief classes: spatial-domain and frequency-domain watermarking techniques [28]. With the comparison of spatial domain techniques [29], frequency-domain watermarking techniques proved to be more efficient with regard to achieve the imperceptibility and robustness requirements of digital watermarking algorithms [30]. Discrete Wavelet Transform (DWT), the Discrete Cosine Transform (DCT) and Discrete Fourier Transform (DFT) are some of the generally utilized frequency-domain transforms. Nevertheless, DWT [31] has been employed in digital image watermarking often owing to its excellent spatial localization and multi-resolution characteristics that are identical to the theoretical models of the human visual system [32]. Further performance enhancements in DWT-based digital image watermarking algorithms could be achieved with the combination of DWT with DCT [33].

A. Discrete Cosine Transform

The Discrete Cosine Transform is a renowned coding technique employed in image and video compression algorithms. It is capable of carrying out decorrelation of the input signal in a data-independent manner [16]. The DCT is a methodology for the transformation of a signal into elementary frequency components. The sequences of n real numbers $x_1, \cdots, x_n$ are converted into the sequence of n complex numbers $f_1, \cdots, f_n$ by the DCT [35] in accordance with the following formula:

$$f_j = \sum_{k=0}^{n-1} x_k \cos\left[\frac{\pi}{n} j\left(k+\frac{1}{2}\right)\right]$$

B. Discrete Wavelet Transform

Wavelets can be described as functions defined over a finite interval and having an average value of zero. The fundamental idea of the wavelet transform is to denote any arbitrary function as a superposition of a set of such wavelets or basis functions [16]. These wavelets are acquired from a single mother wavelet through multiplicative scaling and translational shifts. The large number of known wavelet families and functions provides a rich space in a variety of applications. Biorthogonal, Coiflet, Haar, Symmlet, Daubechies wavelets [34] and the like, are some of the wavelet families.

1) Daubechies-4 Wavelet Transform

Daubechies [17] created a set of most elegant ortho-normal wavelet basis function. These wavelets are efficiently supported in the time-domain and possess superior frequency domain decay. This denotes the motivation behind our choice of Daubechies wavelet transform. Daubechies-4 wavelet, the one that consists of only 4 coefficients, is considered to be the simplest member of the Daubechies family. The coefficients are

$$h_0 = \frac{1+\sqrt{3}}{4\sqrt{2}}, h_1 = \frac{3+\sqrt{3}}{4\sqrt{2}}, h_2 = \frac{3-\sqrt{3}}{4\sqrt{2}}, h_3 = \frac{1-\sqrt{3}}{4\sqrt{2}}$$

The Daubechies D4 wavelet transform has four wavelet and scaling function coefficients.

Scaling function,

$$a[i] = h_0 s[2i] + h_1 s[2i+1] + h_2 s[2i+2] + h_3 s[2i+3]$$

Wavelet function,

$$c[i] = g_0 s[2i] + g_1 s[2i+1] + g_2 s[2i+2] + g_3 s[2i+3]$$

C. Hybrid Transform

A number of watermarking algorithms that utilize either the DCT or the DWT exist in frequency domain. Major benefits of the hybrid DWT-DCT transform algorithm include the following:

Combined transforms recompense for the disadvantages of each other.

- Produce an effective image watermarking.
- Enhanced Peak Signal to Noise Ratio (PSNR).

4. Effective Watermarking Scheme Using Hybrid Transform (Dct-Dwt)

There are numerous important requirements needed into the medical image watermarking which should not affect the quality of the medical image. In the medical field, the qualities of the biomedical images are crucial, treated strictly and the image shall not be altered in any way. Digital watermarking in medical images is very important to prevent modification of medical images by any parties. Because of the importance of the security issues in the management of medical information, we have presented a novel and effective watermarking scheme for checking the integrity and authenticating medical images using hybrid transform. Our proposed scheme makes use of the Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) to form a hybrid transform. For DWT, the Daubechies 4 wavelet transform is chosen in our watermarking scheme. The novel watermark embedding and extraction are performed in a frequency domain with the help of hybrid transform. The following subsections portray the steps involved in the watermark embedding and extraction processes.

A. Watermark Embedding

The embedding of watermark image into the original image is detailed in this subsection. It is essential that the size of the original medical image be dyadic (2^n x 2^n) and the watermark image be a binary image. Our watermark embedding process is performed in a frequency domain with the help of hybrid transform. Initially, the DCT is applied into the original image and the resultant transformed image is converted into the hybrid transformed image with the aid of Daubechies 4 wavelet transform. Subsequently, the extraction process proceeds as, the LSB (Least Significant Bit) value of every two bytes of the hybrid transformed image is computed and followed by the XOR operation is performed for those LSB values. The resultant XOR value is compared with each pixel value of the binary watermark image to obtain a modified embedded transformed image. Then, the watermark embedded transformed matrix is mapped back to its original position. Subsequently, inverse Daubechies 4 wavelet transform and inverse DCT are applied respectively to obtain the watermarked image. Fig 1 depicts the block diagram of the watermark embedding process.

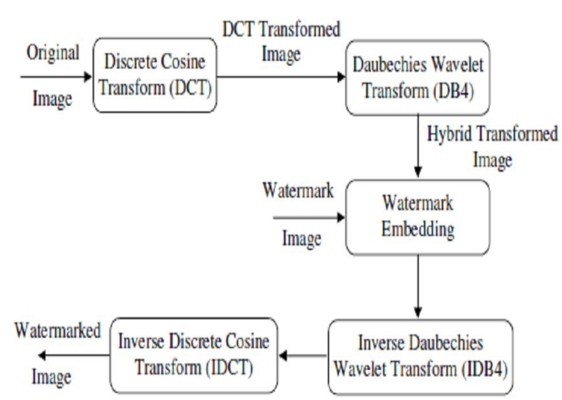

Figure 1 Block diagram of Watermark Embedding

Watermark Embedding Steps

Input: Original Image (I), Binary Watermark Image (W)

Output: Watermarked Image (W_I)

Let I be an original grayscale medical image of size nxn be represented as:

$$I = \left\{ x_{ij} \mid 0 \le i < n,\ 0 \le j < n \right\}\ ;\quad x_{ij} \in \{0,1,\cdots,N\}$$

Apply the DCT into the original image I and generate a resultant transformed matrix T_I.

$$T_I = \left\{ x'_{ij} \mid 0 \le i < n,\ 0 \le j < n \right\}$$

$$T_I = \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{bmatrix}$$

Subsequently, the resultant matrix is altered by means of the daubechies 4 wavelet transform in order to get the hybrid transformed image.

$$HT_I = \left\{ x''_{ij} \mid 0 \le i < n,\ 0 \le j \le n \right\}$$

Then, the LSB value of every two bytes of the hybrid transformed matrix HT_I is taken out and stored it in an intermediate vector I_V. In order to find the LSB value of every two bytes, the pixel values must be in whole number so that the whole number and the mantissa part are separated out.

$$HT_I = [P_1\ \ P_2\ \ P_3\ \cdots\ P_N]$$

$$I_v = LSB[P_i, \mathrm{P}_{i+1}]\ ;\quad 1 \le \mathrm{i} \le \mathrm{N}$$

Then, the XOR operation is performed for the resulted LSB values of every two bytes in the I_V.

$$C = XOR[\mathrm{I}_{v(i,i+1)}]$$

If the XOR value is equal to the every pixel of the binary watermark image W, then embed the summation of XOR values and the mantissa part to obtain the watermarked image W_I. If the value is not equal, then any of the LSB value is adjusted to get the same value as the pixel value of the watermark image W.

$$Watermarked\ \ \text{image}, \mathrm{W_I} = \begin{cases} C + M_P & ;\ if\ \ C == W_{(i)} \\ I_v = LSB(P_{i+1}, P'_{i+1} \\ C = XOR[I_{v(i,i+1)}) & ;\ \ otherwise \\ C + M_p \end{cases}$$

Then, the watermark embedded transformed matrix is mapped back to its original position. Subsequently, inverse Daubechies 4 wavelet transform and inverse DCT are applied respectively to obtain the watermarked image W_I.

B. Watermark Extraction

This section explains the process utilized in our proposed scheme for the extraction of binary watermark image from the watermarked image. As our watermarking scheme is blind, it requires the watermarked image and size of watermark image for extraction. To begin with, the DCT is applied into the watermarked image as a result of the DCT transformed image. Then, the Daubechies 4 wavelet transform is applied into the transformed matrix to attain the hybrid transformed image. Subsequently, the XOR operation is performed for LSB (Least Significant Bit) values of every two bytes present in the hybrid transformed image. Eventually, the binary watermark image is extracted with the help of hybrid transformed image by utilizing the size of the watermark image. Fig 2 shows the block diagram of the watermark extraction process.

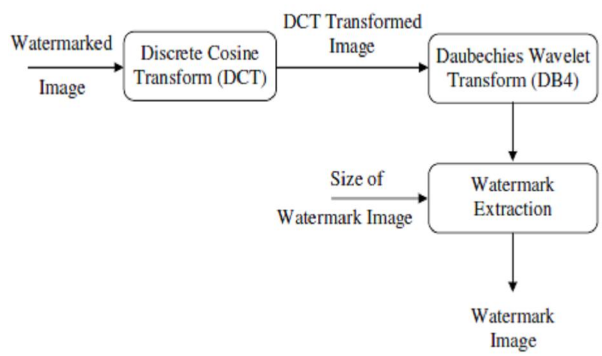

Figure. 2 Block diagram of Watermark extraction

Watermark Extraction Steps

Input: Watermarked Image (W_I), Size of watermark image ($|W|$)

Output: Watermark Image (W)

Initially, the DCT is applied into the watermarked image W_I which produces the resulted transformed matrix TW_I.

$$HT_M = \left\{ y'_{ij} \mid 0 \le i < n,\ 0 \le j < n \right\}$$

Subsequently, the LSB of every two pixel values of the hybrid transformed matrix HT_M is taken out and stored it in a vector V_I.

$$V_I = LSB[HT_{M(i,i+1)}]$$

Eventually, the XOR values are computed from the stored values and placed it in a matrix with the size of the watermark image in order to extract the binary watermark image W.

$$W = XOR(V_{I(i,i+1)})$$

$$TW_I = \left\{ y_{i_j} \mid 0 \le i < n,\ 0 \le j < n \right\}$$

Then, the Daubechies 4 wavelet transform is applied into the transformed matrix TW_I and resulted as a hybrid transformed matrix HT_M .

5. Experimental Results

The experimental results of the proposed effective watermarking scheme for checking the integrity and authenticating medical images using hybrid transform (DCT-DWT). The proposed watermarking scheme is programmed in Matlab (Matlab7.4) and tested with different sizes of medical images of 150 sets. The technique discussed in the paper effectively embedded the watermark image into the original image and extracted it back from the watermarked image. The watermarked images possess superior Peak Signal to Noise Ratio (PSNR) and visual quality. The watermark and watermarked images of different original CT (Computed tomography) medical images are shown in Fig. 3, 4, 5, 6 and 7 along with the PSNR values.

Performance measures

The performance of the Watermarking images can be measured in terms of perceptibility. Below are three methods that can be used for measuring the performance for three medical images.

Structural Similarity Index Measure (SSIM)

This SSIM is defined as:

$$SSIM(x, y) = (2\mu x\ \mu y + c1)\ (2\mu x\ \mu y + c2)\ /((\mu x^2 + \mu y^2 + c1)\ (\sigma x^2 + \sigma y^2 + c2)$$

Peak signal to noise ratio (PSNR)

In the case of watermarking, PSNR indicates the quality of the watermarked image. Higher the PSNR, higher will be the quality. Quality of the watermarked image should be higher to the quality. Quality of the watermarked image should be higher to make the secret data invisible to attackers. PSNR can be calculated by the equation:

$$PSNR = 10\log 10 \frac{\sqrt{\text{MaxB}}}{\text{MSE}}$$

Mean Square Error (MSE)

MSE is one of the simplest functions to measure the perceptual distance between watermarked and un watermarked images. This is defined as:

$$MSE = \frac{1}{pq}\left(\sum_{n=1}^{q}\sum_{m=1}^{p} f(m,n) - f^*(m,n)^2\right)$$

Where pq is the size of two images f and f*. Which is average term by term difference between the original image, f and the watermarked image, f^{*}

Table 1: Showing the corresponding PSNR and SSIM VALUES of the figures.

Table 2: Comparison of proposed method with existing method

Table:3 Comparison of PSNR with other methods

MI: Medical Image

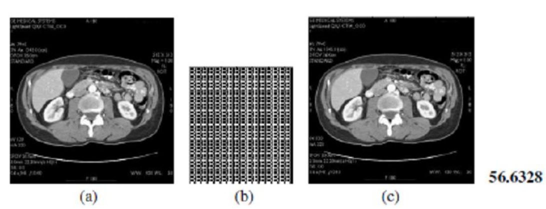

Fig. 3 (a) Original Image (b) Watermark Image (c) Watermarked Image with PSNR (dB) value

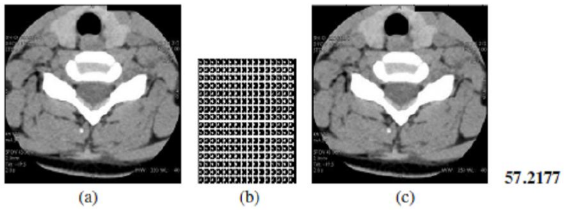

Fig. 4 (a) Original Image (b) Watermark Image (c) Watermarked Image with PSNR (dB) value

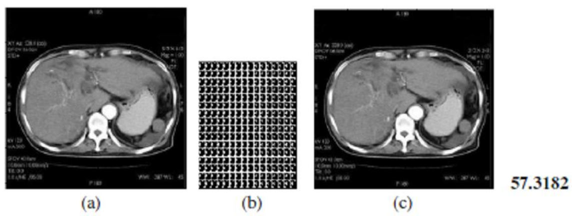

Fig. 5 (a) Original Image (b) Watermark Image (c) Watermarked Image with PSNR (dB) value

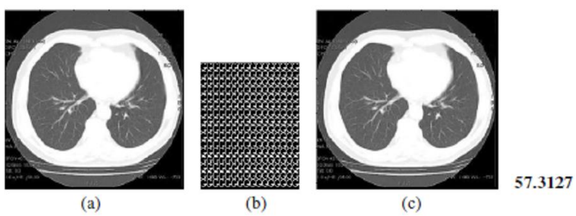

Fig. 6 (a) Original Image (b) Watermark Image (c) Watermarked Image with PSNR (dB) value

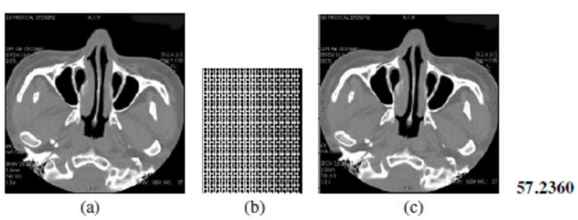

Fig. 7 (a) Original Image (b) Watermark Image (c) Watermarked Image with PSNR (dB) value

6. Conclusion

In this paper, an effective watermarking scheme is presented for the integrity and authenticity verification of medical images. The proposed frequency domain watermarking scheme made use of hybrid transform, in which Discrete Cosine Transform is combined with Daubechies 4 wavelet transform. The watermark embedding and extraction are done in the frequency domain using the presented watermarking scheme. As the proposed watermarking scheme is blind, the watermark can be extracted without the need for the original image or any of its characteristics. The proposed watermarking scheme has been experimented with different CT images and the experimental results revealed the efficiency of the proposed watermarking scheme.

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