Patient Record data hiding in Medical Images using M-ary Modulation

Ritu Agrawal[1*] and Manisha Sharma[2]
[1]Chhattisgarh Swami Vivekananda Technical University, Bhilai, India
[2]Department of Electronics and Telecommunications, Bhilai Institute of Technology, Durg, Chhattisgarh, India
ritube_03@yahoo.co.in

Abstract

Telemedicine is a general practice among remote areas. There is a chance of modifying in medical images intentionally or accidently if transmitted through open network. The medical practitioner has to verify region of interest (ROI), the diagnosis area of the received medical images before rendering any decision report. In this paper, a medical image watermarking scheme using DCT domain is discussed. The decision area (ROI) is to be separated using Fuzzy c- means and embed watermark in region of non- interest (RONI) using M-ary modulation. The effectiveness of the system is experimentally proved for different MRI medical images using different quality measures as PSNR, MSE, NRMSE, MAE and NCC and revealed that the proposed scheme produced a preferable quality of watermarked medical images.

Keywords: Data hiding, Digital Watermarking, Region of interest, Electronic patient record and M-ary modulation.

Introduction

In information technology, internet is the most revolutionary development. There are many applications of internet in our daily life, but the most important application is in a health care environment where electronic patient record (EPR) is transmitted to health care providers of different institutional. Typically, EPR contains the patient health information either in the form of graph, text or images. By transferring all the patient information separately requires excess bandwidth, memory utilization and cost, and also there is a chance that the patient information is hacked by another unknown user[1]. Hence, in order to surmount the problem of memory utilization and to protect the medical information from an illegal manipulation, medical image watermarking is used. Medical image watermarking (MIW) is a process of embedding patient information in the medical image before it is made available publicly.

Medical image watermarking is a subset of digital watermarking and should be carried out in such a manner that the requirements of data hiding i.e. (imperceptibility property) the degradation in image quality is not perceptual to common people, also cannot be eliminated by commonly used image processing tools (robustness)[2]. It is also expected that the good watermarking algorithm must be capable of embedding as much as information in the host image without affecting the imperceptibility and robustness property. However, imperceptibility, robustness and payload properties have a certain level of limitations and might conflict with each other. Thus a proper coupling is required to achieve an optimized solution between these three parameters.
A watermarking scheme using M-ary modulation is proposed in this paper. Medical image contains two regions ROI and RONI

and both the regions should be separated according to the situation. ROI is extracted using Fuzzy C-means segmentation method and electronic patient record as watermark is embedded in RONI using M-ary modulation in the mid-band DCT coefficient. The choice of using this modulation technique before embedding is to enhance the protection and confidentiality of medical data.

The social organization of the paper is formed as follows: Section 2 presents survey work on watermarking technique in the area of the medical field. M-ary modulation is analyzed in section 3. Experiments and results are dessert in section 5. Finally, a conclusion has been analyzed in section 6.

Literature Review

MIW is a patient information embedding method in the medical image for diagnosis and should be robust in nature. D. Anand et.al proposed digital watermarking of medical image with patient information such as patients details, history and measured physiological signals. Before watermarking information is first encrypted to ensure inaccessibility of information to unauthorized person[1]. H.M. Chao et.al proposed Electronic Patient Record (EPR) data hiding in a mark image to provide confidentiality, integrity and authenticity to EPR data. The EPR data can be a diagnostic report, ECG signals or a digital signature of a doctor or a hospital logo. The doctor's digital signature and the hospital logo is used for authentication of EPR data. In order to achieve confidentiality, EPR data can be decrypted[3]. R. Acharya et.al., proposed DCT based medical watermarking technique and is adapted for interleaving patient information with medical images. The text information of a patient is first encrypted using logarithmic function and afterwards interleaved with medical images to ensure greater

security[4]. H.K. Lee et. al. proposed DWT based watermarking technique to prevents illegal forgery. Patient details as a watermark is embedded in RONI, which produces a diagnosis accurately[5]. Mingyan Li. et. al. proposed medical image watermarking using IA-W watermarking in order to locate the origin of an unauthorized release of medical images in multicast environment[6]. K.A. Navas et. al. proposed invertible EPR data hiding technique using integer wavelet transform (IWT) for CT brain images. In order to provide additional security to medical images encrypted EPR information is embedded in RONI and ROI is chosen arbitrarily as a rectangular shape[7]. R.C. Raul et. al. proposed a spatial domain medical image watermarking technique in order to enhance the confidentiality and integrity of DICOM images[8]. X. Guo et. al proposed a ROI lossless medical image watermarking scheme using Difference Expanson method where watermark is embed in RONI and ROI as a polygon chosen manually[9]. M. Kundu et. al. proposed a Lossless ROI, blind and fragile medical image watermarking technique with good imperceptibility and high payload capacity. The ROI is manually chosen as a polygon as generally in all the cases ROI is irregular in shape. In order to enhance the security of watermarking scheme encrypt the patient information before embedding in RONI region[10]. Sunita V. Dhavale et. al. proposed secure transmission of medical images by using both Discrete Cosine Transform (DCT) and Least Significant Bit (LSB) substitution along with new (CDCS) for embedding of patient information in order to increase hiding capacity and provide better perceptual quality of stago images. By using this scheme if there is slight modification of stago images either in embedding region or in ROI can be easily detected at the receiver end[11]. D. Bouslimi et. al. proposed spatial domain technique where watermarking and encryption system using Quantization Index Modulation (QIM) and a cipher algorithm is applicable for medical images. This system gives access to two distinct messages in the spatial domain and are used for verifying the image reliability even though it is encrypted[12].

M-ary Modulation

The smallest information entity in digital communication is called as symbols but there are two different symbols logic 0 or logic 1 in case of binary signaling. In case of M-ary (M>2) signaling more than two different symbols are there[2]. Consider M possible signals in case of M-ary signaling scheme as $s1(t), s2(t) \dots sm(t)$ and these signals can be transmitted for each signalling and for a particular duration of time Ts. Generally, for all applications the possible number of symbols can be represented as is $M = 2^n$ where n is an integer. Data transmission in case of pass-band can be generated by varying the amplitude, phase, frequency of a sinusoidal carrier in M discrete steps thus ASK, PSK and FSK digital modulation schemes obtained[13-15]. Different bandwidth efficiency at the expense of power efficiency can be achieved using M-ary modulation schemes[16].

M- PSK: Consider M-PSK modulation where signals can be defined as

$$S(t) \{ A\cos(2\pi f_c t + \theta_i + \theta^{'}), 0 \le t \le T \ 0 \ else \ where \quad (1)$$

Where: $\theta_{i = \frac{2\pi}{M}} i \qquad (2)$

for i = 0, 1, ..., M − 1 where A is a constant and f_c is a carrier frequency. The initial phase angle is represented by $\theta^{'}$ and symbol duration is represented by T. When, expanding equation (1) we get,

$$A\cos\theta_i \cos(2\pi f_c\, t + \theta') - A\sin\theta_i \sin(2\pi f_c t + \theta') \qquad (3)$$

Signal power can be represented as $P = \frac{A^2}{2}$ so A = $\sqrt{2P}$

Thus equation (3) can be written as

$$S(t) = \sqrt{PT\cos\theta_i \sqrt{\frac{2}{T}}\cos(2\pi f_c\ t + \theta')} - \sqrt{PT\sin\theta_i \sqrt{\frac{2}{T}}\sin(2\pi f_c\ t + \theta')}$$

$$S(t) = \sqrt{E\cos\theta_i \sqrt{\frac{2}{T}}\cos(2\pi f_c\ t + \theta')} - \sqrt{E\sin\theta_i \sqrt{\frac{2}{T}}\sin(2\pi f_c\ t + \theta')} \quad (4)$$

where $E = PT$ is the energy contained in a symbol duration. For convenience, choose angle θ' to be zero and take $\varphi_1(t)$ $= \sqrt{\frac{2}{T}}\cos 2\pi f_c\, t$ and $\varphi_2(t) = \sqrt{\frac{2}{T}}\sin 2\pi f_c\, t$ as the orthogonal basis functions. The signal constellation diagrams for M-PSK modulation is shown in Figure-1 with M to be 16.
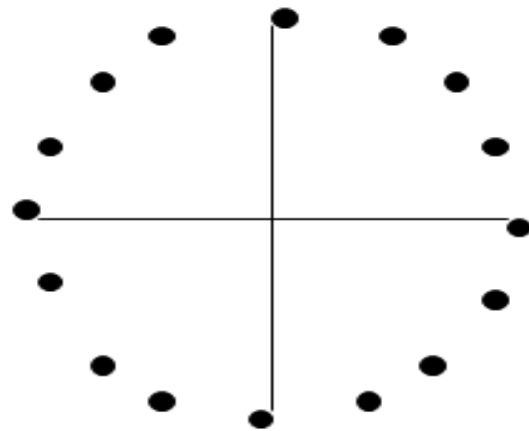

Figure-1
Constellation diagram with M=16

Proposed Scheme

In this paper EPR as a watermark is embed in mid- frequency band of DCT coefficients using M-ary modulation is discussed.

The embedding scheme involves two steps firstly, region of interest (ROI) which is a diagnosis part is to be extracted using Fuzzy C-means and secondly, electronic patient record (EPR) as a watermark is to embed in mid DCT coefficients using M-ary modulation.

ROI Extraction: ROI, diagnosis part of any medical image which contains beneficial materials and must be stored without distortion. There are several image segmentation methods followed by morphological operations to extract ROI part. The steps used to find ROI from the original image is discussed below.

Step1: Consider grey scale image as an input.

Step2: Apply fuzzy c-means algorithm to convert grey scale image into a binary image. Fuzzy clustering means grouping of data from a large set to produce a concise representation.

Step3: Apply canny edge detection to work out an automatic threshold value using an estimate of the number of light and non-edge image pixels.

Step4: Apply Morphological operation. In this procedure, the output image is obtained based on a comparison of the corresponding picture element in the input image with its neighbors. By using dilation and erosion operation, binary mask can be created and obtained a white portion image. This white portion is called ROI.

Step5: Apply subtraction operation between the original image and ROI to get RONI region.

Watermark Embedding: Electronic patient record as awatermark is to be embed in the mid- frequency band of DCT coefficients. Before embedding watermark, first modulated using M-ary modulation. In order to improve the visual imperceptibility and robustness of the proposed scheme,a watermark is embedded in the middle selected DCT coefficient[17,18].

An algorithm of watermark embedding using M-ary modulation in the mid-band DCT coefficient is illustrated in Figure-2 and the corresponding embedding steps are discussed below:

Step1: Read the host/ cover gray scale medical image of size 256x256 pixel.

Step2: The cover image transformed into 8x8 pixels for DCT computation. After dividing the image into 8x8 block size some middle frequency range DCT coefficients are selected for embedding.

Step3: Checking for X and Y coordinates of region of interest (ROI) portion. The watermark should not be embedded in that particular coordinate.

Step4: To enhance the security of the algorithm, M-ary modulation technique is applied to watermark data and this watermark data is embedded in the mid- band frequency of DCT coefficients. The watermark is 32x32 pixels and 16-PSK modulation is used.

Watermark Extraction: The extraction process is a reverse process of embedding. The extraction steps are:

Step1: Watermarked image of 256x256 pixel is to be read.

Step2: Watermarked image is transformed into 8x8 pixels and applies DCT.

Step 3: Extract the middle band coefficient of the recorded location for watermark.

Step4: Apply M-ary demodulation technique.

Step5: Watermark is recovered.

Experimental results and performance evaluation

Experiments were conducted on different MRI medical images. Medical original images are of size 256x256 pixels and the watermark size used is 32x32 pixel.

In our scheme watermark is embedded in RONI region and ROI (the diagnosis portion) should remain intact. In this paper only the watermark embedding and extraction is discussed using M-ary modulation to different MRI medical images. Electronic patient record (EPR) as a watermark with different MRI images is illustrated in Table-1. In order to evaluate the distortion between the original image and watermarked image some fixed additive white Gaussian noise (AWGN) is applied and result is analysed by evaluating some performance parameters as: Peak signal to noise ratio (PSNR), mean square error (MSE) normalized root mean square error (NRMSE) and mean absolute error (MAE).

The experimental result in terms of PSNR, MSE, NRMSE and MAE is shown in Table-2. The distortion between the original watermark image and retrieved watermark image is evaluated in terms of PSNR and Normalised cross correlation (NCC) and is shown in Table-3.

The detailed description with formulae of PSNR, MSE, NRMSE and NCC parameters are explained as follows:

Peak Signal to Noise Ratio (PSNR): Peak signal to noise ratio is employed to access the similarity between the image before and after watermarking[19]

$$PSNR = 10 \, log_{10} \frac{\{2^d - 1\}^2}{MSE} \qquad (5)$$
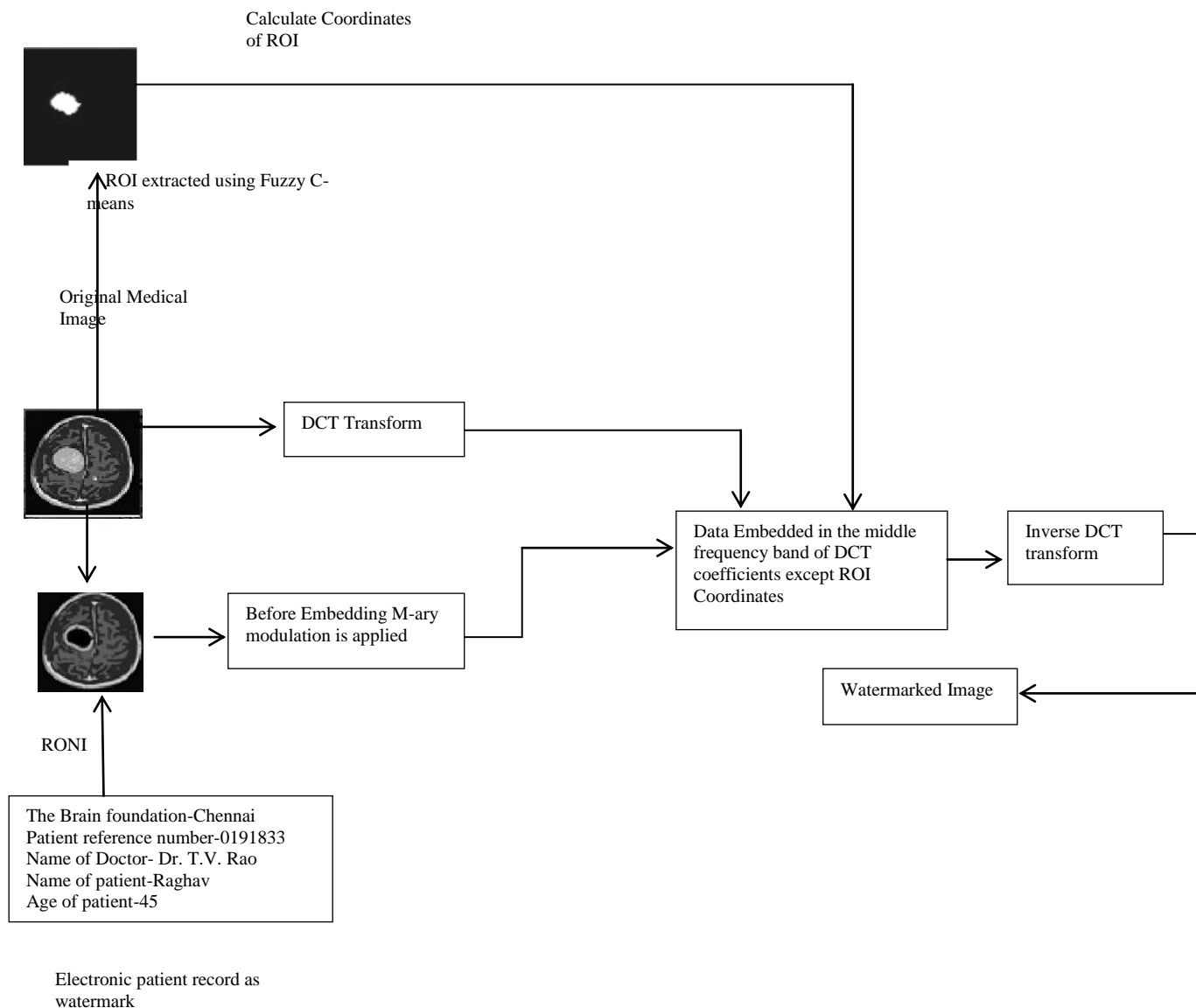
Where d is image depth.

Calculate Coordinates
of ROI

ROI extracted using Fuzzy C-means

Original Medical Image

DCT Transform

Data Embedded in the middle frequency band of DCT coefficients except ROI Coordinates

Inverse DCT transform

Before Embedding M-ary modulation is applied

Watermarked Image

RONI

The Brain foundation-Chennai
Patient reference number-0191833
Name of Doctor- Dr. T.V. Rao
Name of patient-Raghav
Age of patient-45

Electronic patient record as watermark

Figure-2
Watermark Embedding

Mean Square Error (MSE): Mean square error is the simplest part to access the perceptual distance between watermarked image and cover image[8].

$$\text{MSE} = \frac{1}{MN} \sum_{x=1}^{M} \sum_{y=1}^{N} \{f(x,y) - f'(x,y)\}^2 \qquad (6)$$

Where: M xN are pixels of an image, f(x, y) is the cover image and f'(x,y) is the watermarked image.

Normalized root mean square error (NRMSE): To evaluate the quantitative assessment of any watermarking algorithm normalized root mean square error used. It quantifies the average amount of distortion in each pixel of the image.

Mean Absolute Error (MAE): MAE quantifies the mean of the entire absolute pixel by- pixel differences in I_{ij} and I'_{ij}

Where: I_{ij} is the original image and I'_{ij} is the watermarked image[20].

Normalized cross correlation (NCC): NCC is used to calculate the closeness between the watermark and recovered watermark. Higher the value better is the watermarking algorithm[19].

Table-1
Shows watermarking algorithm without attacks for different MRI medical image

Sr.No.	Modality	Original MRI Medical Image	Watermark	Watermarked Output
1	ELBOW		The Brain foundation-Chennai Patient reference number-0191833 Name of Doctor-Dr.T.V.Rao Name of patient-Raghav Age of patient-45	
2	HEART		The Brain foundation-Chennai Patient reference number-0191833 Name of Doctor-Dr.T.V.Rao Name of patient-Raghav Age of patient-45	
3	HIPS		The Brain foundation-Chennai Patient reference number-0191833 Name of Doctor-Dr.T.V.Rao Name of patient-Raghav Age of patient-45	

Table-2
Performance metrics of the watermarking algorithm without attacks for images shown in Table-1

Sr.No.	MRI Medical image	PSNR (dB)	MSE	NRMSE	MAE
1	ELBOW	52.01	0.0051	4.47E-003	4.47E-003
2	HEART	54.15	0.0020	2.80E-003	2.80E-003
3	KNEE	49.67	0.0022	2.93E-003	2.93E-003

Table-3
Results of recovered watermark in terms of PSNR and NCC without attacks for the images shown in Table 1

Sr.No	MRI Medical image	PSNR (dB)	NCC
1	ELBOW	52.01	0.927
2	HEART	54.15	0.935
3	KNEE	49.67	0.945

Conclusion

Tele diagnosis system is getting popular nowadays in rural areas where medical service is hard to obtain. In this paper a medical image watermarking using DCT transformed is discussed and is applied to different medical modalities. Medical image watermarking is a method of embedding patient report in the medical image satisfying the watermarking requirements in terms imperceptibility and robustness. Medical image contains two parts ROI (valuable information) and RONI. ROI is extracted using fuzzy C- means method and electronic patient

record (EPR) as a watermark is to be embedding in mid-band DCT coefficients using Mary modulation. By using M-ary modulation robustness of the system is improved and achieves high values of PSNR with an average value of 51.94dB and also offered high values of normalized cross correlation (NCC) of the extracted watermark.

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