World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:2, No:2, 2008

EPR Hiding in Medical Images for Telemedicine

K. A. Navas, S. Archana Thampy, and M. Sasikumar

***Abstract*—**Medical image data hiding has strict constrains such as high imperceptibility, high capacity and high robustness. Achieving these three requirements simultaneously is highly cumbersome. Some works have been reported in the literature on data hiding, watermarking and stegnography which are suitable for telemedicine applications. None is reliable in all aspects. Electronic Patient Report (EPR) data hiding for telemedicine demand it blind and reversible. This paper proposes a novel approach to blind reversible data hiding based on integer wavelet transform. Experimental results shows that this scheme outperforms the prior arts in terms of zero BER (Bit Error Rate), higher PSNR (Peak Signal to Noise Ratio), and large EPR data embedding capacity with WPSNR (Weighted Peak Signal to Noise Ratio) around 53 dB, compared with the existing reversible data hiding schemes.

***Keywords*—**Biomedical imaging, Data security, Data communication, Teleconferencing.

I. Introduction

EXCHANGE between clinics through open networks is a very common practice today. The motivation is to have the complete medical information of a patient available in one consistent application rather than over several information systems and this avoids the detachment of the patient data from the image. It saves storage space in hospital information system. The confidentiality of the medical reports is very critical and thus it is essential to efficiently hide the data during transmission. Medical image data hiding is the process of hiding a set of patient data into a diagnosis image imperceptibly such that it does not perceptually distort the image and such that the hidden data can be accurately recovered at the receiver end. In EPR data hiding both the hidden data and cover medium need to be recovered without error [1].

In blind reversible data hiding, it is often desired to retrieve the embedded patient data without reference (original) image and embedded media can be reversed to the original cover media without any distortion after the hidden data are retrieved. This method is proposed as a promising technique for sensitive images like medical images [8]. The major requirements of data hiding are imperceptibility, capacity and robustness. The property of imperceptibility restricts that the overall statistics of the cover image should not reveal that the data is embedded. Robustness refers to resistance to distortion introduced during either normal use or deliberate attempt to disable or remove the data present. Image data hiding capacity is an estimate of how much information can be hidden within a digital image.

In this paper, a novel blind reversible data hiding for the application of telemedicine using integer wavelet transform is proposed. The algorithm organizes wavelet coefficients to generate wavelet blocks, and applies a novel method to classify these wavelet blocks based on human visual system (HVS). The EPR data are inserted based on the result of classification. The portions of an image which contains the significant information for diagnosis are called Region of Interest (ROI) and must be stored without distortion. This concept is implemented in the newly proposed method. It is desirable to embed data outside ROI to give better protection.

The rest of the paper is organized as follows. Literature Review is included in section 2. Section 3 explains ROI in medical images. The Integer Wavelet Transform (IWT) is introduced in section 4. Section 5 summarizes the proposed data embedding and extraction algorithms. Experimental results on gray-scale medical images are presented in section 6 and conclusions are drawn in section 7.

II. Literature Review

Reversible data hiding in medical images has been a very active research subject in the last few years. The patient data will be large and the recent algorithms developed aiming at large embedding capacity. One method by Xuanwen et al [2], which utilizes compressed binary bit-plane to embed EPR data and another method of blind reversible data hiding by Rodriguez et al [3], which utilizes image moment theory.

In the first method, there is 8 bit-planes for gray scale images with pixel values ranging from 0 to 255. In order to obtain the sufficient embedding capacity, each binary bit-plane is compressed losslessly and data is embedded into saved space. In reverse direction, the embedded data is extracted and the compressed image is decompressed. The original image is recovered because the compression was lossless. The algorithm has the limitations that when data is embedded in the higher bit-plane level, the distortion becomes large and the data embedding in spatial domain results in less

K .A. Navas is with Electronics and Communication Engineering Dept of College of Engineering, Trivandrum, India (phone: 9447154654; e-mail: kanavas@rediffmail.com).

S. Archana Thampy is a PG student in Electronics and Communication Engineering Department of College of Engineering, Trivandrum, India.

M. Sasikumar is with Electronics and Communication Engineering Department of Marian Engineering College, Trivandrum, India.

robustness.

In the second method, searches for the suitable pixels to embed information using the spiral scan starting from the centroid of the image. Then obtain a block with its center at the position of the selected pixel. If the bit to be embedded is 1, change the luminance value of the central pixel by adding the gray-scale level mean of the block with luminance of the block. If the bit to be embedded is 0, change the luminance value of the central pixel by subtracting the luminance of the block from the gray-scale level mean of the block. In the extraction procedure, marked pixels are located the using the spiral scan starting in the centroid of the image. If the luminance value of the central pixel is greater than the gray scale level mean of the block, then the embedded bit is identified as 1, otherwise as 0. The algorithm has the limitations that some parts of the recovered data are illegible because some bits are lost in the extraction process (i.e., BER not equal to zero) which would affect the recovered data if the embedded data contains numeric values. ROI which is diagnostically important area in medical images cannot be implemented in this embedding method and the data embedding in spatial domain results in less robustness.

Some of the important requirements in medical field are to recover the EPR with zero BER, to have the cover image without any distortion .Another requirement is that the ROI should be protected [4].

III. ROI Mapping

In the proposed technique EPR is embedded into Region of Background (ROB) excluding ROI. Though actual ROI may be irregularly shaped multiple areas, in this work it is manually selected as a rectangle. To select the ROI as a rectangle it is specified using the co-ordinates of two diagonal vertices of the rectangle and the data is embedded outside the selected ROI region to avoid erroneous diagnosis. The ROI is usually selected in the spatial domain. In spatial domain data hiding techniques, the pixels in ROB parts can be modified directly. However in wavelet domain, each wavelet coefficient corresponds to a 2×2 area of the original image.

IV. Integer Wavelet Transform

Transform domain embedding techniques offer a higher degree of robustness to common image processing operations, compared to spatial domain ones. In most of the cases, the wavelet transform produces floating point coefficients, and although this allows perfect reconstruction of the original image in theory. The use of finite-precision arithmetic, together with quantization, results in a lossy scheme. Integer wavelet transform allows to construct lossless wavelet transform which is important for reversible data hiding.

In IWT, integer to integer transformation results in better computational efficiency and lesser transmission time [5]. All calculations are done in place and hence in the computer the memory space can be saved. Number of floating point operations to calculate smooth and detail parts is reduced in IWT and hence more efficient. Although various wavelet families can be applied to reversible embedding scheme, through experimental comparison CDF (Cohen-Daubechies Feauveau) was found to be better than other wavelet families in terms of embedding capacity and visual quality of embedding images. CDF format is also adopted by JPEG2000 standard.

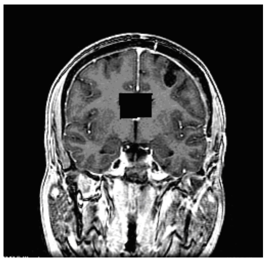

Fig. 1 ROI marked image

V. Proposed Algorithm

The proposed blind reversible data hiding scheme uses the integer wavelet transform to obtain the wavelet coefficients and embed EPR data into the first level high frequency sub bands of the image namely HL and LH. The ROI of the image is excluded from embedding the data.

A. Data Embedding

1. Transform the original medical image using integer wavelet transform.
2. Select two adjacent pixels in a row as a single block in the horizontal and vertical sub bands of level 1.
3. Identify the highest pixel value from the block and divide the value by 2.
4. If the smallest pixel value in the block is greater than the value obtained from step 3, the block is selected for data embedding.
5. Then the first nibble of the data to be embedded is compared with the difference of the pixel values in the selected block.
6. If the first nibble of the data and difference of the pixel values are not same, adjust the pixel value to make them equal.
7. Thus data is embedded in the HL and LH sub bands in level 1 excluding ROI.
8. Apply the inverse integer wavelet transform to obtain the embedded image.

B. Data and Image Recovery

1. Transform the embedded image using integer wavelet transform.
2. Do steps 2 and 3 of the data embedding process.
3. If the smallest pixel value in the block is greater than the value obtained from step 2, the block contains the embedded data.
4. Obtain the difference of the pixel values in the selected block. This gives the embedded data.

5. Apply the inverse integer wavelet transform to recover the original image.

C. Encryption and Decryption of EPR Data

The EPR is first encrypted for extra security using the equation

$$T_e = t^r - d \quad (1)$$

where t is the input text, T_e is the encrypted text, r and d are constants. r can have a value in the range 1.000 to 1.143 and d can be between 0.0 and 10.0. The first level of security lies in this encryption process [8].

The extracted encrypted text is decrypted using the relation

$$D_e = \left(T_e + d\right)^{\frac{1}{r}} \quad (2)$$

where D_e is the decrypted text.

VI. Experimental Results

The experiments were carried out in 512 x 512 gray scale medical images (e.g. MRI3.gif). For most of images, the distribution of high frequency (HL, LH and HH) sub band coefficients of integer wavelet transform obeys Laplacian-like distribution. Most of the high frequency integer wavelet transform coefficients are very small in magnitude. Since, the coefficients in these three sub bands consist 75% of all IWT coefficients, by processing these coefficients, the highest embedding capacity can be achieved [9]. In the proposed method a maximum of 3400 characters could be embedded and recovered without any distortion.

The robustness of the data to various medical image-processing operations was evaluated using BER. The BER is evaluated by varying the strength of each degradation process. In the proposed method the BER was observed to be zero.

The embedded image is perceptually identical to the original under normal observation. In order to determine the degradation in the embedded image with respect to the host image, metrics namely, PSNR, WPSNR are used to measure the distortion produced after embedding process [10].

The quality assessment of an image after embedding is done to measure the amount of distortion due to data hiding. PSNR penalizes the visibility of noise in an image. It is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Values over 36 dB in PSNR are acceptable in terms of degradation, which means no significant degradation is observed by human eye [2]. The proposed method has a higher PSNR of 44 dB. Higher is the PSNR, the smaller is the difference between the original and embedded image.

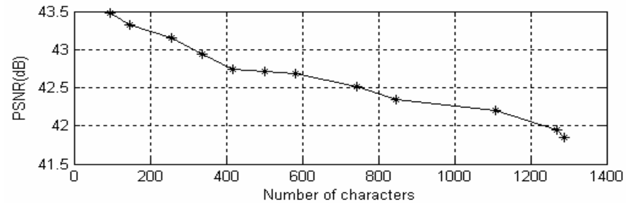

Fig. 2 Variation of Capacity vs. PSNR

Weighted Peak Signal-to-Noise Ratio is given by the expression:

$$WPSNR = 10\log_{10}\left(\frac{255^2}{NVF \times MSE}\right) \quad (4)$$

An alternative approach based on a model which tries to predict human observer’s responses is WPSNR. The WPSNR uses an additional parameter in PSNR called the Noise Visibility Function (NVF) which is a texture masking function. NVF uses a Gaussian model to estimate how much texture exists in any area of an image [7]. The WPSNR uses the value of NVF as a weighting factor. For flat regions, the NVF is close to 1 and for edge or textured regions NVF is more close to 0. The form of NVF is expressed as:

$$NVF = NORM\left\{\frac{1}{1+\delta^2 block}\right\} \quad (5)$$

where δ is the luminance variance for the 8×8 blocks and is the normalization function. The proposed method has a higher WPSNR of 53 dB which states that the embedded image is less distorted.

For evaluating WPSNR, error (difference between cover image and embedded image) in different modalities is scaled by the corresponding NVF values evaluated at each pixel. It can be seen that CT images provide the highest value of imperceptibility for the given number of embedded characters compared to images in other modalities. This is due to the high contrast between adjacent regions in CT images.

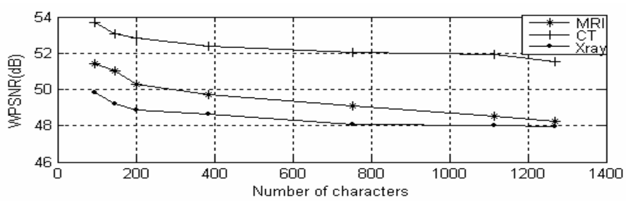

Fig. 3 Variation of Capacity vs. WPSNR in different modalities

As a result of transmission of the data embedded image through the channel, channel noise could get added to the embedded image which could affect the accuracy of recovery of data at the receiver end [6]. Various types of noises usually degrade medical images during transmission and the overall noise can be modeled as Gaussian as per central limit theorem. To study the effect of channel noise, AWGN noise was generated, added to the embedded image to get the image distorted due to the noise. The data was recovered from this image and the BER determined.

BER versus Attack strength graph is used to find out the robustness of the data against various attacks. The BER between the original and extracted data increases with increase in the variance of Gaussian noise is shown:

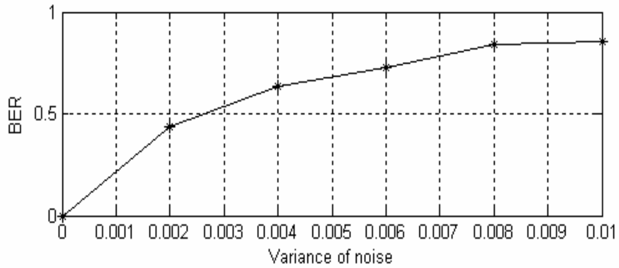

Fig. 4 Bit Error Rate vs. Variance of Noise

VII. Conclusion

In this paper, a novel blind and reversible data hiding technique in ROI images using integer wavelet transform is proposed. The method allows the simultaneous storage and transmission of EPR and the medical image and lossless retrieval of the EPR at the receiver without the original image. Encryption of EPR is done to provide additional security. The proposed scheme also has large capacity, which is important for EPR data hiding. The obtained result shows higher value of PSNR, WPSNR and zero BER. Thus the capacity and visual quality is superior compared to the existing blind reversible data hiding methods.

References

[1] H. Munch, U. Engelmann, A. Schroter, H.P. Meinzer, “The Integration of Medical Images with the Electronic Patient Record and their Web-Based Distribution,” in *Academic Radiology*, Vol.11, No.6, Pp.661-668, June 2004.

[2] Xuanwen Luo, Qiang Cheng, Joseph Tan, “A Lossless Data Embedding Scheme For Medical in Application of e- Diagnosis,” *Proceedings of the 25th Annual International Conference of the IEEE EMBS Cancun*, Mexico. September 17-21, 2003.

[3] Rodriguez-Colin Raul, Feregrino-Urabe Claudia, Trinidiad Blas Gershom De J. “Data Hiding Scheme for Medical Images”, *17th International Conference on Electronics*, *communications and computers* (CONIELECOMP) 2007.

[4] Smitha B, Navas. K A, “Spatial Domain-High capacity data hiding in ROI images”, *Proc. Int. Conf on Signal processing, communication and networking IEEE-ICSCN-2007*, Chennai, India, pp 528-533. 22-24 Feb 2007.

[5] Xiaoyun Wu, Junquan Hu, Zhixiong Gu, Jiwu Huang, “A Secure Semi-Fragile Watermarking for Image Authentication Based on Integer Wavelet Transform with Parameters” *Australasian Information Security Workshop*, Newcstle, Austalia, 2005.

[6] Nopporon Chotikakamthorn and Natapon Pantuwong, “Attacks on Feature–based Affine-invariant watermarking method,” *the fifth international conference on computer information technology* (CIT’05) 2005.

[7] Sviatolsav Voloshynovskiy, Shelby Pereira, Thierry Pun, Joachim J. Eggers and Jonathan K. Su, “Attacks on Digital Watermarks: Classification, Estimation-Based Attacks, and Benchmarks” *IEEE Communications Magazine* August 2001.

[8] Navas K A, Nithya S, Rakhi R, Sasikumar M, ”Lossless watermarking in JPEG2000 for EPR data hiding”, *Proc. IEEE-EIT 2007*, Chicago, USA, 17-20 June 2007, pp 697-702.

[9] S.Yousefi, H.R.Rabiee, E.Yousefi, M.Ghanbari, “Reversible Data Hiding Using Histogram Sorting and Integer Wavelet Transform” *Inaugural IEEE International Conference on Digital Ecosystems and Technologies* (IEEE DEST) 2007.

[10] M. Kutter and F. A. P. Petitcolas, “A fair benchmark for image watermarking systems,” *Electronic Imaging '99. Security and Watermarking of Multimedia Contents*, vol. 3657, Sans Jose, CA, USA, The International Society for Optical Engineering, 25-27 January 1999.

K. A Navas is an Asst. Professor in ECE Department of College of Engineering Trivandrum, Kerala, India. He obtained B Tech degree from T K M College Engineeering, Kerala in the year 1987 and M Tech degree from S J College of Engineering, Mysore, India in the year 1995. He is currently pursuing Ph D degree in Kerala University in India. He has been teaching in various engineering colleges since 1987. He is a member of faculty of Engineering and Technology of Kerala Univeristy. He has published 30 papers in national and international conferences. His research interests are in Data hiding and steganography.

Archana Thampy obtained B Tech Degree from Kerala University in 2004 . She is currently a Post graduate student in Electronics and Communication Engineering Dept of College of Engineering Trivandrum, India.

M. Sasikumar obtained BSc (Engg.) from College of Engineering Trivandrum in the year 1968 and ME from Indian Institute of Science, Bangalore, India in the year 1976 and PhD from Indian Institute of Technology, Madras, India in the year\1984. He was the Sr. Joint Director of Technical Education in Kerala, Coordinator of Swiss aided IPACT Project, member of many engineering education bodies. Currently he is head of Dept of Electronics and Communication Engineering Dept of Marian Engineering College, Thiruvananthapuram. He has authoured books and was a coordinator of many research programmes and a project consultant. He has published 70 papers in International conferences and journals. He is a senior member of Computer society of India.