WATERMARKING MEDICAL IMAGES BY REVERSIBLE SCHEME AND EMBEDDING IN REGION OF NON-INTEREST

Truong Hoang Vinh
Ho Chi Minh City Open University

(Received: 02/07/2013; Revised: 18/07/2013; Accepted: 30/08/2013)

ABSTRACT

Medical images can be divided into two regions such as region of interest (ROI) and region of non-interest (RONI). We define ROI is the region that contains information of the patient's state. Many watermarking schemes have been proposed since 2000 by reversible methods: lossless compression, histogram extension, spread-spectrum method. In this paper, we present a novel method for watermarking medical images. We use the RONI region of medical image as the region of embedding by geometric coding and insert the watermarking signal by the reversible watermarking scheme. We evaluate our method on MRI and CT medical images.

Keywords: ROI, RONI, reversible scheme, medical image, geometric coding transform

Introduction

The definition of e-health has been appeared since the development of Internet and technology. A doctor or specialist in medical images can view the test result of the patients even they are not in the consulting-room. Medical images acquired from machine can be sent to many specialists to diagnose and they can hold a consultant in a real-time mode in a distance. For the reason of private policy, the information of patient must be protected. And the process of telemedicine must be operating in security. In this context, watermarking is suitable among of many methods for protecting multimedia content such as cryptography and compression. Watermarking is the art of hiding information data in multimedia content without altering the original. A watermarking scheme must satisfy three main constraints: capacity, quality and security. If we embed a large amount of information in the host, the watermarked image obtained will be low quality and security. Opposite of normal image, medical images contained important information for the diagnostic and this data cannot be altered by visual vision. The meaningful region of medical images can be classified as region of interest (ROI) [1]. We have to preserve this region. The exclude region can be named as region of non-interest (RONI). The first ROI coding of compression medical images has been introduced by Jacob *et al*., [3]. Today, medical systems prefer the RONI region and use lossy compression in order to reduce the size of image directly from the machine [4]. Many methods based on ROI and RONI extraction have been published in recent year. In [5], T.M.P *et al*., proposed a scheme using lifting wavelet to extract ROI region. Malay et al use payload embedding for encoding lossless medical image [6]. In this work, we focused on RONI region as the host for embedding signal watermarking. The geometric coding transform has been proposed since 1996 in [14]. The systems watermarking can be classified according to application point of view [12]: robust watermarking (RB) and fragile watermarking (FW). RB is mainly used for protection images and FW is mainly used for content authentication. Reversible watermarking is a subset of fragile watermarking. It has an additional advantage of recovering the image which is the same as the original image pixel by pixel, after the image is authenticated. Many different reversible watermarking techniques [3] had been proposed. But all of these used to remove bits from block of the image and by lossless compressing these bits providing the space for the watermark to be embedded in the same block. Tian proposed an algorithm [16, 17] using difference expansion and using Haar wavelet transform. In this paper, firstly we determined the ROI and RONI region by the geometric coding. We used RONI as the region for embedding signal watermarking by the reversible watermarking scheme based on difference expansion [15]. Our method can be resumed in the Figure 1.

Figure 1. Scheme watermarking proposed

This rest of this paper is organized as follow. Section II describes how to decide the ROI region. Section III presents a method for embedding signal watermarking in the RONI region. Section IV gives us the experimental results of the implementation. Finally, section V discusses the conclusion and the future work of this paper.

Determine roi of medical images

The ROI of medical images must be determined by the specialist. The differential image is the RONI. We define the couple *{(u,v)}* is the point in the ROI. We must calculate the set of points on the boundary of the transformed ROI *{(u,v)}* [1]. Firstly, the radiologist expert selects the set $\{(x_b, y_b)\}$ in the original image. We have:

$$\{T(x_b, y_b)\} = \{(u'_b, v'_b)\} = BT' \qquad (1)$$

To perform (1), we have the following function as defined below:

$$u_b = gif\,(u'_b) \quad if\ y_{b+1} \geq y_b$$
$$u_b = gif\,(u'_b - 1)\ if\ y_{b+1} < y_b$$
$$v_b = gif\,(v'_b) \quad if\ x_{b+1} \geq y_b$$
$$v_b = gif\,(v'_b - 1) \quad if\ x_{b+1} < y_b$$

Where *gif* is the greatest integer function. We have the inverse matrix $G=T'$. We can check if the point $\{(u,v)\} \varepsilon RONI$.

$$\text{RONI} = \{(x, y): x,y\ \varepsilon\ R^+,\ (x_{min} < x < x_{max}) \cap (y_{min} < y < y_{max})\}$$

Where x_{min} and x_{max} are the minimum and maximum integer value of x_b, and y_{min} & y_{max} are the minimum and maximum integer value of y_b.

The set of point $(x,y)=G(u,v)$ obtained which is the region that consist points of ROI region. To support completely in finding the boundary of ROI, we also use the spline for interpolation [9]. A B-spline function can be characterized by a Spline expansion as in [10].

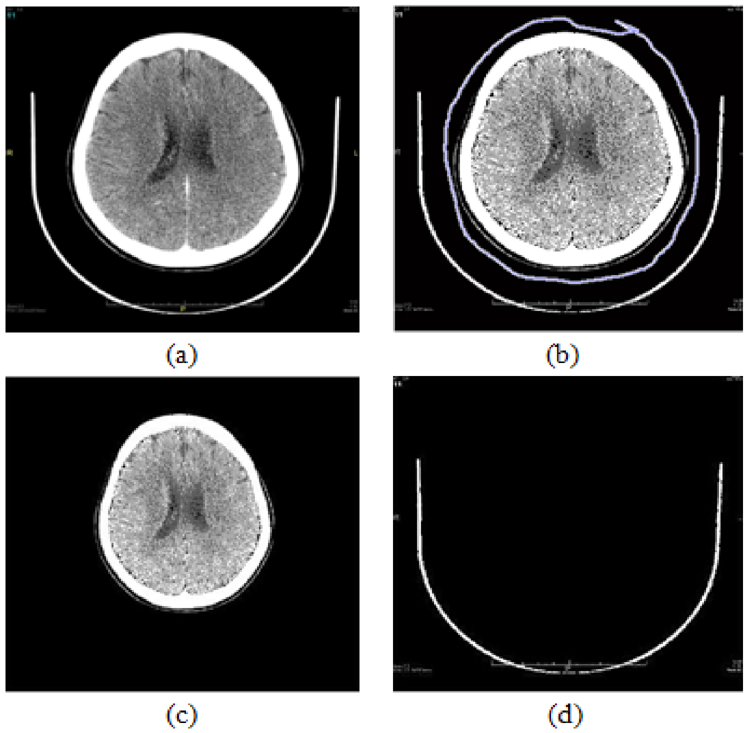
$$s_n = \sum_{k=-\infty}^{\infty} c[k]\beta^n (x-k) \qquad (3)$$

Where $c[k]$ are the B-spline coefficients. To obtain $f(x,y)$ for any (x,y) = G (u,v), we have:

$$f(x,y) = \sum \sum c[i,j]\, \beta^{\delta} (x-i)\, \beta^{\delta} (y-j) \qquad (4)$$

Where $c[i,j]$ is the interpolation coefficients in 2D, x and y are any real values. After determining the ROI region, the specialists have to approve the process. We implement this first stage (see Figure 1.1) and Figure 2 gives an example of the process.

Figure 2. ROI coding of Brain's MRI image: (a) Original image; (b) ROI region determined by geometric coding transform; (c) ROI; (d) RONI



Riversible watermarking by difference expansion

We have the RONI region extracted by geometric coding in section II. Now we use it as the host for embedding the signal watermarking. The amount of information that we wanted to be added in the host is the payload may be larger in some cases. This method use the difference expansion technique discovers extra storage by using the redundancy data in the RONI which is unuseful for the diagnostics [15]. For a pair value (x, y) in a grayscale image, x,y ε Z,$0 \le x,y \le 255$, an average value l and the difference h are defined as: $l = \frac{[x+y]}{2}$; $h=x-y$, (5) where the symbol $\lfloor\cdot\rfloor$ is the floor function meaning "the greatest integer less than or equal to". We can infer from (5):

$$x=l+\left\lfloor\frac{h+1}{2}\right\rfloor, y=l-\left\lfloor\frac{h}{2}\right\rfloor$$

We also have

$$0 \le l+\left\lfloor\frac{h+1}{2}\right\rfloor \le 255,\ 0 \le l-\left\lfloor\frac{h}{2}\right\rfloor \le 255 \qquad (6)$$

Which is equivalent to

$$|h| \le min\,(2(255 - l),2l+1) \qquad (7)$$

The least significant bit (LSB) of the difference number h will be selected embedding area

$$h = \left\lfloor\frac{h}{2}\right\rfloor.2 + LSB(h) \qquad (8)$$

with $LSB(h)=0$ or 1, to prevent any overflow and underflow problems, we insert in changeable difference numbers.

The medical image is partitioned into pair of pixel values. A pair consists of two neighboring pixel values or any of two pixels with a small difference number.

We define here the suits of five disjoint sets of difference numbers [15]: EZ, NZ, EN, CNE, and NC:

EZ: expandable zeros, for all expandable h $\varepsilon \{0,-1\}$

NZ: not expandable zeros, for all non-expandable h $\varepsilon \{0,-1\}$

EN: expandable nonzero, for all non-expandable h $\varepsilon \{0,-1\}$

CNE: changeable, but not expandable, for all changeable $h \not\varepsilon \{0,-1\}$

NC: not changeable, for all non-changeable $h \not\varepsilon \{0,-1\}$

We collect original LSV values of difference numbers in EN2 which is the subset of EN (we always have: EN = EN2 ∪ EN1 with the location of map *L*, which is the bit streams compressed, the original LSB values C and a payload *P*, we insert them together into one binary bit stream B.

$$B = L \cup C \cup P \qquad (9)$$

After all bits in B are embedded, we apply the inverse integer transform (6) to obtain the embedded image. The bit stream B has a bit length of (|L|+|C|+|P|). Assume the total number of 1 and -2 in EN2 and CNE is *N*, as each expanded pair give one extra bit, the total capacity will be (|C|+N+|EZ|+|EN1|). B is fully marked if we have this condition

$$|L|+|C|+|P| \leq |C|+N+|EZ|+|EN1| \qquad (10)$$

All the rest of this technique have been presented in [15].

Experimental results

To evaluate the watermarked image, we use the PSNR index which is defined via the mean squared error. Given a noise-free M×N monochrome image *I* and its noisy approximation *I'*, MSE is defined as

$$MSE=\frac{1}{MxN}\sum_{i=0}^{M-1}\sum_{i=0}^{N-1}\|I(i,j)-I'(i,j)\|^2 \qquad (11)$$

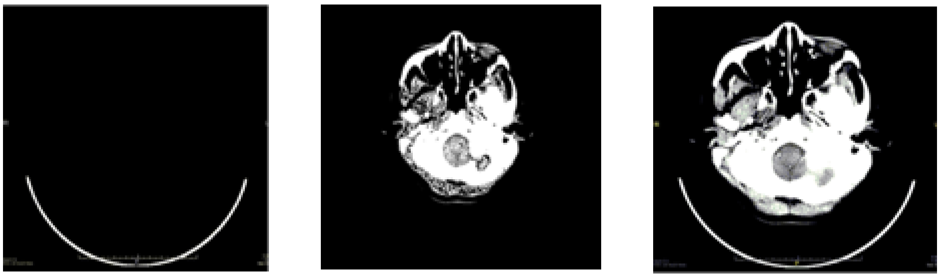
$$PSNR = 10log_{10}\frac{d^2}{MSE} \qquad (12)$$

A good quality image has a value PSNR in range [25, 40] dB.

Table 1. Experimental result – Payload and PSNR of a few grey-level images, 512×512, 8 bits per pixel, 8 bits per pixel with n = 20

Image	Payload size (bits)	Bit rate (bpp)	PSNR (dB)
X1	128962	0.3190	47.83
X2	128369	0.3175	49.54
X3	190307	0.4707	54.03
X4	189942	0.4699	54.06
X5	190376	0.4788	54.05

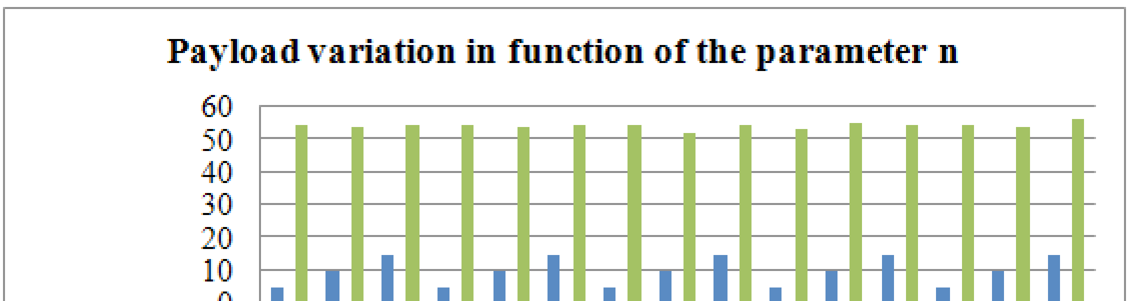
Fig 3. Illustration of algorithms on image X4 watermarked image with Payload 0.4699 bpp and PSNR = 54.06 dB. (a) RONI region embedded with high paypload; (b) ROI region; (c) watermarked image



(a) (b) (c)

We implemented the algorithms in MatLab code and tested with 5 CT and MRI of head's image. The RONI region which extracted in Section II will be embedded by difference expansion to obtain pre-embedded image. After that, we combined pre-embedded image and ROI region to acquire the watermarked image. This section showed a few results are given tested for grey-level images, 512×512, 8 bits per pixel. The payload results here with a maximal parameter n=20 as proposed in [15].

Figure 4. Real payload variation in function of the parameter n for few medical images



	X1			X2			X3			X4			X5		
n	5	10	15	5	10	15	5	10	15	5	10	15	5	10	15
Bit rate (bpp)	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
PSNR (dB)	54.	54	54.	54.	54.	54.	54.	51.	54.	53.	55.	54.	54.	54.	56.

Conclusion

We introduced the joint of extraction ROI region of medical images and embedding signal watermarking by difference expansion. Due to the performance of the experimental results, we see that our systems (Intel Core i5, 1.9 Ghz, 8Gb RAM) took a long time for responding the results. That is the reason why the future work should be the evaluation of algorithm's complexity or the performance of lossless compression in the ROI region. In addition, we can study the problem of payload for embedding a large amount of information in RONI region.

REFERENCES

[1] Abniav K, Haranath K, "*Geometric transformation of Interest in medical Images*"IEEE International Conference on Image Processing, (2003).

[2] Jacob Strom and Pamela C. Cosman, "*Medical image compression with lossless regions of interest"*, Elsevier: Signal Processing, Vol.59, No.2,pp.155-171, (1997).

[3] Coltuc, D "*Improve Capacity Reversible Watermarking*", IEEE International Conference on Image Processing, ICIP'2007, (2007).

[4] T.M.P Rajukumar and Mrityunjaya V Latte, *"ROI based encoding of medical images: An effective scheme using lifting wavelets and SPIHT for telemedicine".* International Journal of Computer Theory and Engineering, Vol. 3, No, 3, (2011).

[5] Malay Kumar Kundu and Sudeb Das, "*Lossless ROI medical image Watermarking Technique with enhanced security and high payload embedding*". International Conference on Pattern Recognition. (2010).

[6] Aggarwal, P. and Rani, B. "*Performance Comparison of Image Compression Using Wavelets*", International Journal of Computer Science and Communication, Vol. 1, No. 2, Pp. 97-100.(2010).

[7] Assche, S.V., Rycke, D.D., Philips, W. and Lemahieu, I. "*Exploiting interframe redundancies in the lossless compression of 3D medical images*", Data Compression Conference, P. 575. (2000).

[8] M. Unser, A Aldroubi, and M. Eden, "*B-Spline signal processing : Part I-Theory*" IEEE Trans. Signal Processing, Vol 41, No 2 pp 821-833, (1993).

[9] L.L. Schumarker, "*Spline Functions :Basic Theory, New York",* (1981).

[10] Duraisamy, R., Valarmathi, L. and Ayyappan, J. "*Iteration Free Hybrid Fractal Wavelet Image Coder, International Journal of Computational Cognition*", Vol. 6, No. 4, Pp. 34-40. (2008).

[11] I. Cox, M. L. Miller, and J. A. Bloom, "*Digital Watermarking*", San Francisco, CA: Morgan Kaufmann, (2001).

[12] Michael Arnold, Martin Schmucker and Stephen D. Wolthusen, "*Techniques and Applications of Digital Watermarking and Content Protection*", published by Artech House, Boston, London. www.artechhouse.com.

[13] Eri, H., YI, J. and Charles A,B, "*Segmentation for MRC compression*", Proceedings of SPIE, The International Society for Optical Engineering, Color imaging. Conference, Vol.6493, San Jose, California, USA), (2003).

[14] Strohmer T., Binder T., Sussner M, "*How to recover smooth object boundaries in noisy medical images*" Image Processing, Proceeding, International Conference, Volume:1, 16-pp 331-334 vol.1. (1996).

[15] J. Tian, "*Reversible Watermarking by Difference Expansion*", ACM Multimedia and Security Workshop, (2002).

[16] Jun Tian, "*Reversible Data Embedding Using a Difference Expansion*", IEEE Transactions on Circuits and Systems for Video Technology, vol.13, No.8, (2003).

[17] J.Tian, "*High capacity reversible data embedding and content authentication*" , IEEE Proceedings of International Conference on Acoustics, Speech, and Signal Processing, vol. 3, pp. III–517–20, (2003).