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3D DWT-DCT and Logistic MAP Based Robust Watermarking for Medical Volume Data

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Abstract: Applying digital watermarking technique for the security protection of medical information systems is a hotspot of research in recent years. In this paper, we present a robust watermarking algorithm for medical volume data using 3D DWT-DCT and Logistic Map. After applying Logistic Map to enhance the security of watermarking, the visual feature vector of medical volume data is obtained using 3D DWT-DCT. Combining the feature vector, the third party concept and Hash function, a zero-watermarking scheme can be achieved. The proposed algorithm can mitigate the illogicality between robustness and invisibility. The experiment results show that the proposed algorithm is robust to common and geometrical attacks.

Keywords: 3D DWT-DCT, Digital watermarking, Logistic Map, Zero-watermarking.

1. INTRODUCTION

Along with the rapid development of computer science and multimedia technology, the digital society gradually formed. Especially in the medical field, large amount of medical information exists as digital multimedia, such as text, video, voice and so on. It is convenient and fast for hospitals to store and transmit the patient's personal information through the Internet. However, when the medical information is stored and transmitted on the Internet, it is extremely crucial to protect the patient's privacy [1-3]. Traditional digital watermarking technology is used in the copyright protection of digital media. Utilizing watermark's properties of invisibility and robustness, patient information, doctor diagnosis and Electronic Patient Records can be used as watermarking hidden in the CT, MRI (Magnetic Resonance Imaging) and other medical images [4]. Medical image digital watermarking is often divided into three categories [5].

1) RONI (Region of non-interest)-based medical image watermarking. The watermarking information is embedded in the RONI of the medical images [6, 7]. However, the capacity of hidden information is limited, as most of the RONI area of the medical image is the black background.
2) Reversible watermarking. When using reversible watermarking, once the embedded content is read, the watermarking can be removed from the image allowing retrieval of the original image [8]. Unfortunately, most of the reversible watermarking is fragile.
3) Classical watermarking. In this method, watermarking is often embedded in the least significant bit (LSB) [9], or in the low or middle frequency coefficients in the frequency domain (DCT, DFT or DWT) [10]. However, it is necessary to control the amount of the embedded watermarking to avoid the doctors making the wrong diagnosis. In addition, the classical watermarking has low robustness especially against common and geometric attacks.

More and more medical volume data appear along with the development of medical technology. Medical volume data contain more information, which can help the doctors understand the patient's pathological information accurately so it is important, to research the digital watermarking of medical volume data.

In this paper, we propose a robust watermarking algorithm for medical volume data using the Logistic Map. Applying 3D DWT-DCT to acquire the visual feature vector of medical volume data, Zero-watermarking [11, 12] can be realized. We can scramble the watermarking using Logistic Map, which can enhance the security of watermarking. Combined with the third part concept and Hash function, we can embed and extract the watermarking of high quality. Meanwhile, the watermarking algorithm has good robustness to common and geometric attacks, which can protect the personal information of patients well.

2. THE FUNDAMENTAL THEORY

2.1. Logistic Map

A chaotic system has a noise like behavior while it is exactly deterministic, so we can reproduce it if we have its parameters and initial values. These signals are extremely

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original medical volume data. To facilitate the operation, we assume M1=M2, M=N.

3.1. Extracting the Feature Vector of Medical Volume Data Using 3D DWT-DCT

Applying 3D DWT-DCT, the feature vector of the medical volume data can be obtained. Feature vector of the medical volume data is a group of symbol sequence which represents the visual feature of the medical image. Firstly, 3D-DWT is applied to the original medical volume data to obtain the approximated sub-band LLL1. Then, DCT of the whole LLL1 is computed and the DWT-DCT coefficient is obtained. We choose 8 low-frequency 3D DWT-DCT coefficients (F(1,1,1), F(1,2,1),F(1,1,2),… F(1,2,4)) to compose the coefficient sequence of the volume data, the value of the low-frequency coefficients may change under some attacks. However, the signs of the coefficients remain unchanged, as shown in Table **1**. The different attacked images are shown in Fig. (**4a**-**4h**). If the coefficient is positive or zero value, it is denoted as “1”; otherwise, it is denoted as “0”. Thus, we can obtain the sign sequence of low-frequency coefficients as shown in Table **1**. We can see that the sign sequence remains unchanged after common and geometrical attacks.

Based on the above, we can draw a conclusion that the sign sequence of 3D DWT-DCT low-frequency coefficients can represent the main visual characteristics of the medical volume data and it is robust to common and geometrical attacks.

To prove that the sign sequence of 3D DWT-DCT for volume data is an important visual feature, we choose some different medical volume data which are shown in Fig. (**5a**-**5f**) and use 3D DWT-DCT transform. The coefficients and sign sequences of low frequency are different and the NC value between the different sign sequence is very small, and it is less than 0.5. It is shown in Table **2**.

3.2. Scrambling the Watermarking

The steps of generating the scrambled watermarking are as follows:

Step1: Generate the chaotic sequence.

The chaotic sequence X(j) was generated by the initial value, x_0, which is regarded as the private key. Each value of X(j) is between 0 and 1. The original watermarking cannot be recovered without the private key.

Step2: Obtain the scrambled watermarking.

Table 1. Changes of the 3D DWT-DCT low-frequency coefficients with respect to different attacks.

Image Processing	F(1,1,1)	F(1,2,1)	F(1,1,2)	F(1,2,2)	F(1,1,3)	F(1,2,3)	F(1,1,4)	F(1,2,4)	Sequence of Signs	NC
Original image	14.25	0.52	1.73	-0.29	-2.27	-0.13	0.98	0.11	11100011	1.0
Gaussian noise(3%)	22.12	0.41	1.89	-0.18	-2.22	-0.09	1.23	0.08	11100011	1.0
JPEG (4%)	15.19	0.47	1.79	-0.27	-2.14	-0.13	1.11	0.10	11100011	1.0
Median filter [3x3]	14.34	0.53	1.72	-0.30	-2.27	-0.13	1.02	0.12	11100011	1.0
Rotation 20°	14.25	1.78	1.73	-0.31	-2.27	-0.29	0.98	0.23	11100011	1.0
MRI scaling (×2)	28.55	1.05	3.47	-0.58	-4.56	-0.26	1.96	0.22	11100011	1.0
MRI scaling (×0.5)	7.14	0.26	0.87	-0.15	-1.14	-0.07	0.49	0.06	11100011	1.0
Translation 10%	13.74	0.51	1.56	-0.29	-2.00	-0.12	1.02	0.10	11100011	1.0
Crop (8% from Z)	14.11	0.49	1.14	-0.30	-1.93	-0.08	0.95	0.10	11100011	1.0

Table 2. The NC values between feature vectors of different medical volume data using 3D DWT-DCT.(choose 8 bit)

Volume Data	F (1,1,1)	F (1,2,1)	F (1,1,2)	F (1,2,2)	F (1,1,3)	F (1,2,3)	F (1,1,4)	F (1,2,4)	Sign Sequence	NC
Fig. 5 (a)	14.24	0.52	1.70	-0.29	-2.21	-0.13	0.85	0.09	11100011	1.00
Fig. 5 (b)	20.30	-1.54	-1.89	1.01	-6.04	1.11	3.54	-0.39	10010110	-0.25
Fig. 5 (c)	32.54	-25.57	14.71	32.24	30.31	15.78	1.35	14.10	10111111	-0.42
Fig. 5 (d)	53.45	-28.34	0.59	-2.00	-4.82	2.45	3.54	-2.11	10100110	0.25
Fig. 5 (e)	54.9	0.21	0.475	-0.19	1.88	0.18	-0.79	-0.33	11101100	-0.06
Fig. 5 (f)	14.72	0.002	-10.44	0.06	-3.77	0.01	6.92	-0.39	11010110	-0.06

*the unit of transform coefficients is 1.0e+003.

watermarking can be extracted with NC=0.95 shown in Fig. (**11c**). The extracted watermarking is almost the same to the original one. From Table 5, we can see that the watermarking can still be extracted even when the parameter of Median Filter is [7×7], repeat times are 10. Thus, we can conclude that the proposed algorithm is robust to Median Filter attacks.

4.2. Geometrical Attacks

4.2.1. Rotation Attacks

The slice rotated by 20° is shown in Fig. (**12a**), and the corresponding 3D image of volume data is shown in Fig. 12(b). The watermarking can be extracted with NC=0.87 and PSNR=12.44dB, shown in Fig. (**12c**). The watermarking can still be extracted even when the watermarked volume data rotated clockwise by 40°, shown in Table **6**. Thus, the proposed algorithm has strong robustness to rotation attacks.

4.2.2. Scaling Attacks

Fig. (**13a**) is a slice of the watermarked volume data under scaling attack. Fig. (**13b**) shows that the Volume data shrunk with a scale factor of 0.5. We can still extract the watermarking accurately with NC=1.0, shown in Fig. (**13c**). The watermarking can still be extracted even when the watermarked volume data shrunk with a scale factor of 0.2, shown in Table **7**. Thus, the proposed algorithm has strong robustness to scaling attacks.

4.2.3. Translation Attacks

The slice under translation down by 8% is shown in Fig.

(a) (b) (c)

Fig. (13). Under scaling attacks (factor 50%):; (**a**) a slice with scaling attack; (**b**) the corresponding 3D volume data; (**c**) watermarking detector.

Table 7. The NC under scaling attacks

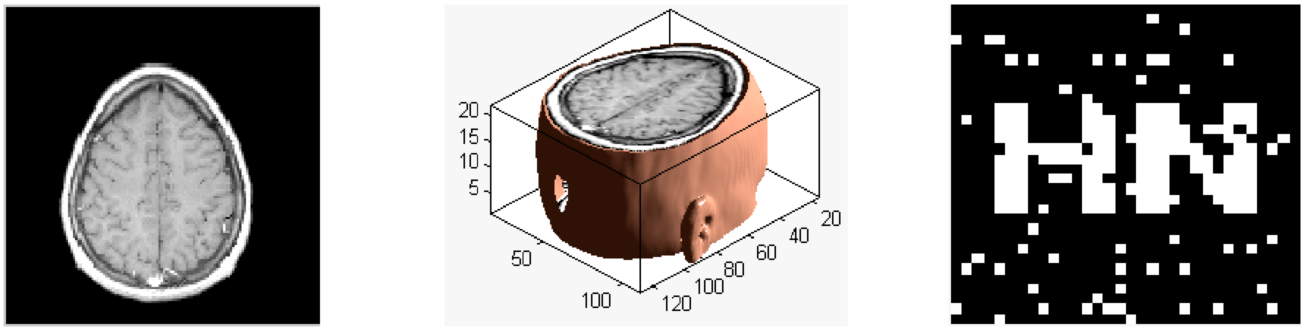
Scaling factor	**0.2**	**0.5**	**0.8**	**1.0**	**1.2**	**2.0**
NC	1.00	1.00	1.00	1.00	1.00	1.00

(a) (b) (c)

Fig. (14). Under translation attacks (down8%): (**a**) a slice with translation attack; (**b**) the corresponding 3D volume data; (**c**) watermarking detector.

Table 8. The PSNR and NC under translation attack

Down distance (%)	**2**	**4**	**6**	**8**	**10**	**12**
PSNR(dB)	15.65	12.40	11.66	11.09	10.85	10.51
NC	1.00	1.00	0.94	0.82	0.61	0.61



(a) (b) (c)

Fig. (15). Under cropping attacks; (**a**) a slice of watermarked volume data cropped by 20%; (**b**) The watermarked volume data cropped by 20% (**c**) the extracted watermarking.

Table 9. The NC under cropping attacks

Cropping(%)	4	6	8	10	14	16	18	20	22	24
NC	1.00	0.94	0.94	0.94	0.94	0.94	0.88	0.88	0.82	0.82

(**14a**) and the corresponding 3D image of volume data is shown in Fig. (**14b**). The PSNR of the translated volume data is 11.09dB. Fig. (**14c**) show that the watermarking can still be detected, NC=0.82. Table **8** gives the PSNR and NC when the volume data has been translated by different distance. Hence, we can conclude that the algorithm is robust against translation attacks.

4.2.4. Cropping Attacks

Fig. (**15a**) is a slice of the watermarked volume data under cropping attack. The watermarked volume data has been cropped 20% from Z direction, shown in Fig. (**15b**); we can see clearly that the main information loss is at the top of volume data. We can still extract the watermarking accurately with NC=0.88, shown in Fig. (**15c**). Through the experimental data of Table **9**, we can find that the watermarking can still be extracted under cropping attack 24%. Therefore, the proposed algorithm is robust to cropping attacks.

5. CONCLUSION

In this paper, we proposed a robust watermarking algorithm for medical volume data. The watermarking is scrambled by Logistic Map to improve its security. Applying 3D DWT-DCT, the visual feature vector of medical volume data is obtained. Combining the feature vector, the third part concept and Hash function, a zero-watermarking scheme can be achieved. Experimental results show that the watermarking can still be extracted accurately without the original medical volume data, which achieves the blind extracting and protects the medical volume data adequately. Moreover, the proposed algorithm has strong robustness to common and geometrical attacks.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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REFERENCES

[1] S. Kaur, O. Farooq, R. Singhal, B. S. Ahuja, "Digital watermarking of ECG data for secure wireless communication", *In Proceedings of the 2010 IEEE International Conference on Recent Trends in Information, Telecommunication and Computing*, pp. 140-144.

[2] K. A Navas and M. Sasikumar, "Survey of medical Image watermarking algorithms", *In Proceedings of the 4th Sciences of Electronic, Technologies of Information and Telecommunications International Conference*, Tunisia, Mar. 25-29, 2007.

[3] A. Castiglione, C. D' Ambrosio, A. De Santis, A. Castiglione,and F. Palmieri, "On secure data management in Health-Care environment", *in Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), 2013 Seventh International Conference* pp. 666-671.

[4] U. R. Acharya, U. C. Niranjan, S.S. Iyengar, N. Kannathal, Lim Choo Min, "Simultaneous storage of patient information with medical images in the frequency domain," *In Computer Methods and Programs in Biomedicine*, vol.76, 2004, pp.13-19.

[5] G. Coatrieux, H. Maître, B. Sankur, Y. Rolland, R. Collorec, "Relevance of watermarking in medical imaging," *In Proc. IEEE Int.Conf. ITAB*, USA, 2000, pp.250-255.

[6] G. Coatrieux, B. Sankur, H. Maître, "Strict integrity control of biomedical images," *In Proc. Electronic Imaging, Security and Watermarking of Multimedia Contents*, SPIE, USA, 2001, pp. 229-240.

[7] A. Wakatani. "Digital watermarking for ROI medical images by using compressed signature image". In: *Proceedings of 35th Hawaii International Conference on System Sciences*, 2002, pp. 2043-2048.

[8] B. Macq, F. Dewey, "Trusted headers for medical images," *In DFG VIII-DII Watermarking Workshop*, Erlangen, Germany, 1999.

[9] X. Q. Zhou, H. K. Huang, S. L. Lou, "Authenticity and integrity of digital mammography images," *IEEE Trans. on Medical Imaging*, vol.20, no.8, pp.784-791, 2012.

[10] J. Song, G. Wang, H. Ma, Y. Wang, "A digital watermark method based on DWT and Tent Mapping," *IJACT*, vol. 4, no.18, pp.11-21, 2012.

[11] C. Dong, J. Li, X. Han, Y. Chen, “Multiple watermarks for management in medical image based on DWT”, *JDCTA*, vol. 6, no.10, pp.239-247, 2012.

[12] C. Duanmu, W. Zhang, “A new algorithm for the generation of a type of zero-watermarks which are robust to geometrical attacks,” *JDCTA*, vol. 6, no. 15, pp. 388-397, 2012.

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