Multipurpose and Intelligent Watermarking Scheme for Medical Data

Yinan Zhuo, Dong Ni, Siping Chen, Baiying Lei*,and Tianfu Wang*
Department of Biomedical Engineering, School of Medicine, Shenzhen University,
National-Regional Key Technology Engineering Laboratory for Medical Ultrasound,
Guangdong Key Laboratory for Biomedical Measurements and Ultrasound Imaging, Shenzhen, China

Haijun Lei
College of Computer Science and Software Engineering
Shenzhen University
Shenzhen, China
{leiby, tfwang}@szu.edu.cn

***Abstract*—In this paper, a new multipurpose watermarking scheme is proposed to provide protection and authentication of medical data. To achieve both purposes, integer discrete wavelet transform (IDWT) decomposition is first performed, and then robust watermark (e.g. logo data) is embedded in the low frequency IDWT sub-band for copyright protection, while fragile watermark (e.g. the diagnosis information) is inserted in the high frequency IDWT sub-band for tampering detection. A tradeoff between conflicting watermark requirements such as robustness, capacity and imperceptibility is achieved by particle swarm optimization (PSO) training technique. Experimental results validate the effectiveness and efficiency of the proposed algorithm. The achieved fragileness and robustness confirmed that the proposed scheme has capability of rightful ownership protection and authentication simultaneously.**

***Keywords*-Image Watermarking; Particle Swarm Optimization; Multipurpose; Spread Spectrum

I. INTRODUCTION

Currently, medical image has been widely used in industrial, military, medical, entertainment, navigation applications and even genetics [1, 2], but most of them are stored and exchanged without any security concern, and hence it is important to provide intellectual property protection, authentication, and integrity privacy measure for medical images after the transmission phase and legal access. In fact, a promising, efficient and feasible direction to resolve this issue is to watermark these data [3-9] with lossless or minimal distortion. As medical data has similar properties of natural images, natural image watermarking approaches can be explored to prevent the increasing popular medical data from being used illegally as well.

There are three most important properties in a watermarking scheme, that is, robustness, imperceptibility and capacity. The balance of these constraints is required depending on the applications [3, 4, 6, 10]. In the literature, most watermarking algorithms [11] have focused on 3D mesh model or depth image based rendering (DIBR) image [12, 13] either for authentication [11] or protection. The existing watermarking methods have the common disadvantage of causing distortions to the original medical data after the watermark extraction. Consequently, it is highly unsuitable for the important medical data application scenarios. The main reason is that any data disturbance is unacceptable. In view of this, reversible (lossless) watermarking methods have been widely investigated recently [14] to recover the data completely. To the best of our knowledge, the above mentioned watermarking method achieves one purpose only, there is no multipurpose schemes for watermarking medical data. In view of this, a multipurpose watermarking scheme for medical image is investigated.

Singular value decomposition (SVD) [15, 16] technique has demonstrated to provide an efficient way to obtain the algebraic features from 2-D matrix [17]. There are no distortions for small perturbation of original host signal due to favorable properties, which enhance the robustness against attacks. Therefore, content protection of medical data by robust watermarking is based on SVD. Besides, integer discrete wavelet transform (IDWT) is incorporated with SVD to insert the watermark for robustness boosting. Meanwhile, authentication of medical data is implemented by fragile watermarking by inserting the diagnosis information in the high frequency part. The insertion in high frequency part improves the fragileness without degradation of the image invisibility. Artificial intelligence based particle swarm optimization (PSO) [10, 18] approach has been widely used in pattern recognition and image processing field with demonstrated good features [19]. To strike good balance among fidelity, robustness and capacity, optimal value of multipurpose watermarking is obtained by PSO algorithm.

The primal aim of this work is to develop a multipurpose watermarking approach to secretly insert watermark image into host images. Security issue is resolved by the AES encryption based approach. To sum up, the contribution and novelty of this paper method are as below:

1)Provide both rightful ownership protection and authentication for medical data;
2)Robustness against attacks with the merits of SVD and low frequency coefficient in IDWT.

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3)Fragileness for content authentication.
4)High level security by AES encryption of watermark before embedding;
5)Flexibility and effectiveness for watermarking application.

II. PROPOSED METHOD

A. Watermarking Method

Figure 1 provides the overview of the watermark embedding algorithm. Since watermark extraction algorithm is just the inverse of watermark embedding process, watermark extraction diagram is not provided here. The improved spread spectrum method is utilized for watermarking insertion and extraction due to its simple idea, effectiveness and good performance. In short, the basic steps of embedding and extraction of medical data are given in Table 1 and 2, respectively.

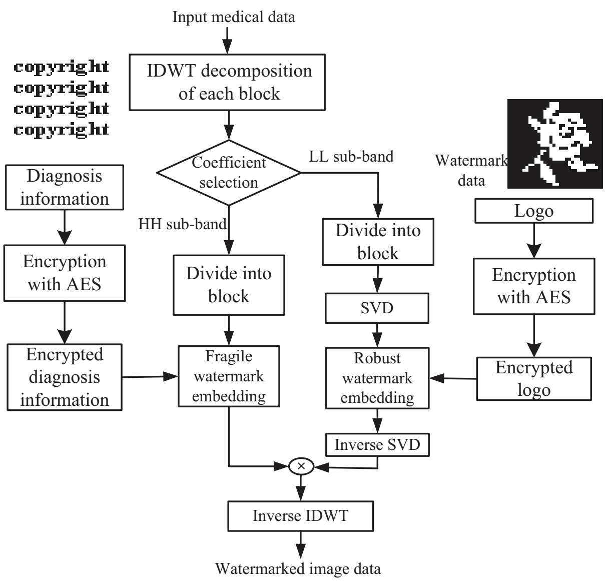

Figure 1. Flowchart of watermark embedding

Let w_{ij} be the watermark bit embedded into block I_{ij}^k and $w_{ij} \in \{0,1\}$, λ^k is the scaling factors (SFs) or watermark strength of the embedded signal at each block k, which will be optimized in the PSO training. In our method, the recent developed watermarking method, improved spread spectrum [17] is explored. Therefore, all the merits of the improved spread spectrum method enjoy here. The watermark strength selection can tradeoff watermarking fidelity and robustness, and thus this algorithm is very flexible.

B. Performance Improvement Using PSO

As known to all, watermarking requirements are mutually contradictory. Therefore, tradeoff needs to be achieved when developing a new watermarking system. Actually, PSO approach can obtain this goal by finding optimal points in the

TABLE I. WATERMARK EMBEDDING PROCEDURE OF OUR ALGORITHM

Input:	**A host medical data I with size of M×N, watermarks** $w = [w_{1,1}, \ldots, w_{ij}, 1 \le i \le m, 1 \le j \le n]$ **, block size k and key K.**
Output:	**The watermarked image** I^* **.**
Step 1	Apply the watermark pre-processing to the obtained 2D medical image from acquired medical data.
Step 2	AES encryption of the watermark w to get shuffled watermark b to be secure.
Step 3	IDWT decomposition of the processed image to the low frequency IDWT coefficients (LL) and high frequency band (HH). Sub-band LL and HH are divided into nonoverlapping blocks with size of k.
Step 4	For LL sub-band, SVD is performed; robust watermark is embedded in the first singular values using the improved spread spectrum method: $I_r^{k*} = I_r^k + \lambda_r^k b_r^k$
Step 5	HH sub-band is utilized to insert the fragile watermark with the improved spread spectrum method: $I_f^{k*} = I_f^k + \lambda_f^k b_f^k$
Step 6	Inverse SVD is applied to the updated singular values to get back the updated LL sub-band signal.
Step 7	Reconstruct watermarked host signal I^* with inverse IDWT.

TABLE II. WATERMARK EXTRACTION PROCEDURE OF OUR ALGORITHM

Input:	**Watermarked medical data** I^* **with size of M×N, key K**
Output:	**The watermark images** w'_{ij}
Step 1	IDWT decomposition of the watermarked data I^* to obtain the low and high frequency of IDWT coefficients (LL') and (HH').
Step 2	For LL' sub-band, SVD is applied, robust watermark is extracted using $b_r^k = (I''^k_r - I'^k_r) / \lambda^k$
Step 3	For HH sub-band, fragile watermark is detected using $b_f^k = (I''^k_f - I'^k_f) / \lambda^k$
Step 4	Robust and fragile images are descrambled with the same key to get the recovered watermark image w'_{ij} .
Step 5	Recover the IDWT wavelet coefficients.
Step 6	Return the recovered watermark and image

watermark. SFs of watermarks are the most important parameters in our scheme since they affect the watermarking performance most. It is obvious that larger SFs cause high robustness, but degrade the imperceptibility. Therefore, optimizations of these parameters can tradeoff robustness and imperceptibility. To achieve this goal, the popular intelligent heuristic PSO algorithm is explored. Basically, PSO algorithm includes initialization, crossover, mutation and update procedures. The objective function should be first designed to optimize the watermarking performance.

Normalized cross correlation coefficient (NC) is regarded as an effective way to measure the robustness in the literature [17]. The mean structural similarity index measure (MSSIM) is also considered as good metrics for evaluation of the perceptual similarity [20]. Therefore, both NC and MSSIM are adopted in the fitness function. The capacity represented as bit message per pixel (BPP) is also included into the objective function. Accordingly, the fitness function is finally designed as:

$$\text{fitness}=\max(\alpha \times MSSIM + \beta \times \frac{1}{H}\sum_{i=1}^{H} \mu_i \times NC_i + \gamma \times BPP), \quad (1)$$

where H is the total number of attacks, weighting factors , and are introduced to reduce the significant difference between the metrics of system performance. The metrics are selected to ensure successfully convergence to a saturated value using PSO as well. Furthermore, there is a need to choose the number of particles and iterations carefully. If too many particles are chosen, more places are searched to find the global optimal solution easily. However, it will increase the computation time and may result in memory allocation problems.

III. EXPERIMENTAL RESULTS

In our experiment, medical data rendered from the top directions of the pelvis, brain, and skeleton are utilized to evaluate the proposed algorithm, which are shown in Figure 2 (noted that the images shown here are resized). A 64×64 robust watermark and a 64×64 fragile watermark are employed in our scheme as shown in Figure 3, respectively. The maximum generation is 80 and population size is 30. The weighting factors are also set based on numerous experimental results and validated empirically to be closely related to balance robustness and imperceptibility, that is, $\alpha = \beta = \gamma = 1/3$. As to the watermarking performance, the objective value (Obj), peak signal noise ratio (PSNR), MMSIM and average NC value of all attacks (NC) of three host medical data for both the robust and fragile watermarking are conducted for performance evaluation.

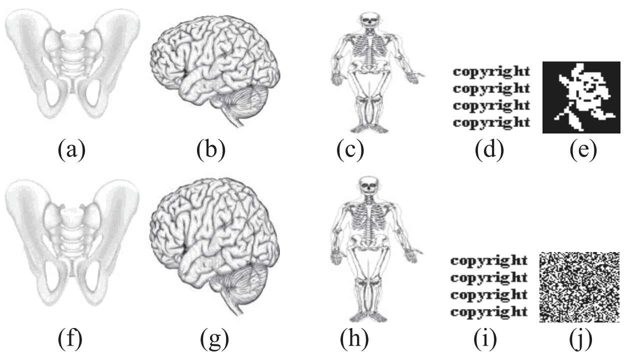

Figure 2. Cover objects and watermarks.(a)Pelvis; (b) Brain; (c)Skeleton; (d)Robust watermark; (e) Fragile watermark; (f)-(h)Watermarked cover objects;(i-j) Extracted watermarks.

The overall performance is shown in Table 3. It can be seen that Brain, Pelvis and Skeleton images share similar performance in both robust and fragile watermarking results. Overall, the experimental results of robust watermarking are higher than the fragile watermarking result, which validate the proposed method not only has multipurpose function, but also the robustness of robust algorithm is higher than fragile algorithm. The high PSNR, MSSIM and NC results show that the proposed method achieves good balance of robustness and fidelity.

The following attacks are applied to test the robustness of the watermarking performance: a) histogram equalization (NCH); b) 10% of signal is cropped randomly (NCC); c)3×3 Gaussian low pass filtering is applied (NCL);d) Image size is enlarged to 2 and then reduced to the original size (NCS); e) 3×3 median filtering is added (NCM); f) JPEG compression with quality factor 80 (NCJ); g) 5% Gaussian noise is added (NCN); h) rotate 10◦(NCR). Figure 3 shows NC results after these attacks. It can be seen that robust watermarking algorithm achieves very high NC results, whereas NC results for fragile watermarking are quite low, which demonstrate the successful implementation of multipurpose approach. Obviously, the proposed robust watermarking scheme can robustly resist common image processing problems with the proposed IDWT-SVD method, whereas fragile watermarking in the IDWT high frequency can be used for content authentication.

TABLE III. EXPERIMENTAL RESULTS

Target	Image	Obj	PSNR	MSSIM	NC
Robust	Brain	0.8898	67.01	0.9789	1
	Pelvis	0.8900	66.10	0.9785	1
	Skeleton	0.8895	67.12	0.9787	1
Fragile	Brain	0.6318	23.34	0.8897	0.9954
	Pelvis	0.6347	23.57	0.8898	0.9970
	Skeleton	0.6373	22.51	0.8894	0.9957

As to the capacity performance, PSNR vs. BPP for robust and fragile watermarks are shown in Figure 4 and Figure 5, respectively. PSNR with SVD transform outperform method without SVD transform as illustrated in the Figure s. It can be also seen that the robust watermarking can achieve higher PSNR compared to fragile watermarking with the same BPP. With the increase of the BPP, the imperceptibility in terms of PSNR is satisfied. Generally, the wavelet transform method outperforms the pure SVD method.

Figure 6 plots the objective values and SFs obtained by PSO after 80 generations. It is observed that both objective value and SFs approach to constants (representing the optimal value) after several generation, which demonstrate the successful implementation of PSO algorithm to achieve tradeoff between the contradictory requirements.

IV. CONCLUSIONS

In this paper, a multipurpose and intelligent watermarking scheme for image data copyright protection and authentication is proposed. Heuristic PSO algorithm is adopted to optimize SFs to achieve the balance among robustness, imperceptibility and capacity. The proposed method inserts robust watermarks into the original host data by modifying the singular values of the low frequency blocks. Fragile watermark is inserted in the IDWT high frequency part. Furthermore, PSO is employed to find the optimal SFs with the unique designed objective function. Experiments demonstrate good performance of copyright protection and content authentication of the proposed algorithm. The proposed algorithm can give the inspiration and direction of the protection and authentication measure for the 3D medical data too.

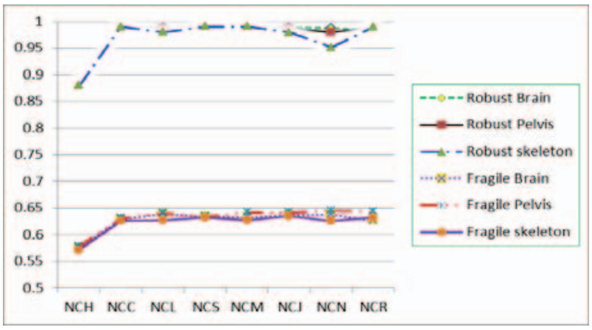

Figure 3. NC results after malicious attacks

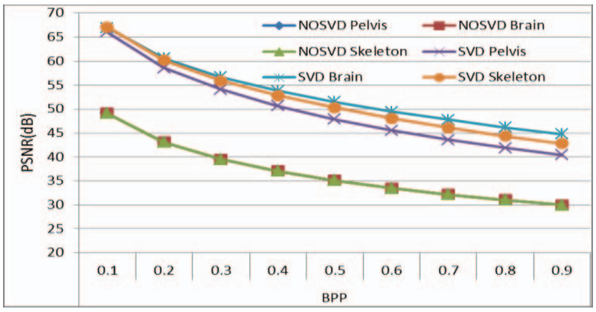

Figure 4. PSNR vs. BPP results of robust watermarking

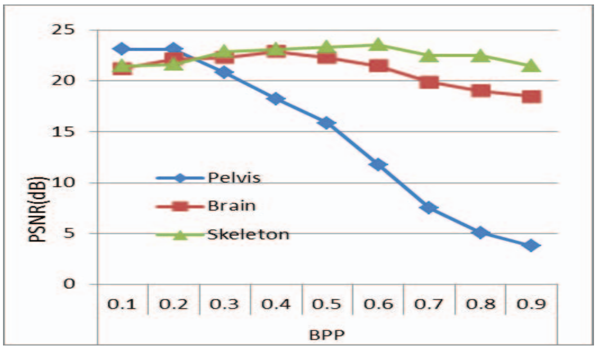

Figure 5. PSNR vs. BPP results of fragile watermarking

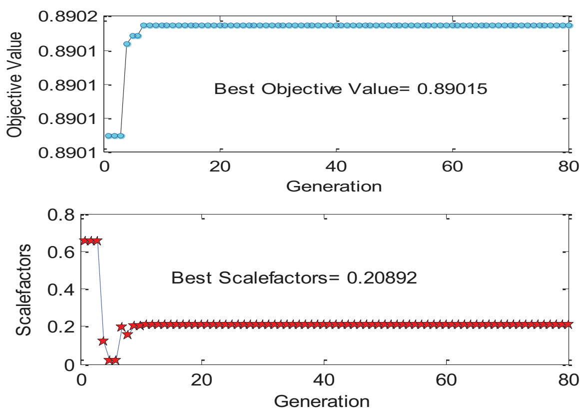

Figure 6. PSO optimization results of objective values and SFs

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