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# A Robust Zero-watermarking Algorithm Against Geometric Attacks with Perceptual Hashing

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Abstract
Taking into account the information security problem in medical image, the paper put forward a new robust zero-watermarking algorithm with three-dimensional (3D) discrete Fourier transform (DFT) and perceptual hashing. The medical volume data was made by 3D DFT. The zero-watermarking algorithm selected the real part of 3D DFT coefficients (4*4*4) to generate the watermarking extraction key sequence (64-bit). Meanwhile, it employed Legendre chaotic neural network scrambling to achieve the two-encryption, and boosted the robustness of the algorithm, so that it can better resist conventional attacks and geometric attacks. The zero-watermarking algorithm can solve the contradiction between the watermarking imperceptibility and robustness. The experimental results show that the proposed algorithm has superduper robustness.
Keywords: ZERO-WATERMARKING ALGORITHM, 3D DFT, PERCEPTUAL HASHING.

## 1. Introduction

Today, the digital information system plays a more and more important role in the medical industry. The digitizing system not only provides convenience for the transmission and storage of medical information, but also promotes the diagnosis mode of remote medical system. At the same time, it also brings a lot of risk, which is widely concerned by people. Currently, illegal users steal patient information, tampering with electronic cases, illegal copies of medical data and patient privacy information dissemination and other issues frequently arise [1]. Therefore, these questions have caused the medical image copyright attribution and the information security question, has brought the serious negative influence to the doctor-patient relationship.

Digital watermarking as a new security measure is widely used in digital art and safety certification, copyright protection and other applications [2]. As the theory of digital watermarking technology matures, many people are beginning to apply theory to practice. Compared with general digital images, the medical image has an important role in the diagnostic process. It makes particularly demanding quality requirements. Medical image watermarking embedding has some unique requirements [3-4]. (1) No distortion, not even minor changes in the law are allowed, its potential risk will lead to medical staff misunderstanding the medical image. (2) The security of the embedded watermarking information stringent requirements, especially some special patient records is a national and corporate secret, and definitely did not leaked; the watermarking cannot be illegal extraction. (3) As the watermarking information should be extracted out completely and accurately when you need to extract it, which put forward the watermarking robustness requirements [5-6]. Medical image digital watermarking technology provides a good solution to this problem. It will be specific meaning identification information embedded in the carrier image, which can realize the authenticity and integrality authentication, electronic medical records of medical image hiding and copyright protection [7]. When using digital watermarking technology for medical image protection, a key problem is how to reduce or avoid the distortion caused by the original image watermarking embedding. In view of this situation, people put forward the concept of zero- watermarking [8-9].

With the emergence and development of computer tomography (CT), magnetic resonance imaging (MRI) and ultrasound and other medical imaging techniques, doctors are more and more get the body surface and internal tissues and organs of two-dimensional (2D) CT image sequence [10-11]. Because of the limitations of human visual perception system, 2D CT images can only become the auxiliary means of the diagnosis and research of medical workers who have experience. In clinic, the performance of CT, MRI and other testing equipment is not fully utilized. Because the two dimensional data is not easy to be accepted by the human brain. And the information processing is difficult. With the development of computer graphics and medical image 3D visualization technology, more and more medical workers pay attention to the research of 3D medical volume data, which can provide the diagnostic information directly and accurately.

Taking into account the information security problem in medical field, this paper takes medical volume data as the research object, uses the zero-watermarking technique, and proposes a robust watermarking algorithm based on 3D DFT and perceptual hashing. Its core idea: according to the information redundancy and human perception characteristics, in the premise of not affecting the quality of the original medical volume data, the specific privacy information is embedded into the protected medical volume data so as to achieve copyright certification. In order to further enhance the security of watermarking information, the algorithm employs chaotic neural network scrambling technology to achieve the two-encryption, and enhance the robustness of the watermarking, so that it can better resist conventional attacks and geometric attacks.

## 2. DFT

Fourier transform is a very important algorithm in the field of digital signal process, which is also the most basic method of signal analysis [12-13]. It analyzes the signal from the time domain to the frequency domain. Frequency domain response the intensity of gray level changes of images. And that is the change speed of the image gray, which is the gradient of the image. In the frequency domain, the greater the frequency shows that the original signal has the faster the speed of change, , the smaller the frequency shows that the original signal has the gently the speed of change. When the frequency is 0, it indicates that there is no change in the direct-current signal. As a result, the size of the frequency response signal changes speed. Portion of the high frequency component signal interpretation mutation. In some cases, it refers to the edge information of the image. While the low frequency component determines the overall of the signal. It refers to the change of the image of the flat part, that is, the image contour information. In other words, Fourier transform provides another perspective to observe the image.

### 2.1. One-dimensional DFT

One-dimensional DFT is defined as follows.

If $f(x)$ satisfies Dirichlet conditions: finite number of discontinuities; finite number of poles; absolutely integrable. Where $f(x)$ is a function of $x$ .Then, its transform formulas are as shown in formula (1) and formula (2).

$$F(u) = \sum_{x=0}^{N-1} f(x) e^{-j2\pi ux/N}, u = 0,1,\cdots N-1. \quad (1)$$

$$f(x) = \frac{1}{N} \sum_{u=0}^{N-1} F(u) e^{j2\pi ux/N}, x = 0,1,\cdots N-1 \quad (2)$$

Where, $x$ is the time-domain variable; $u$ is the frequency domain variable.

**2.2 2D DFT**

Set $f(x,y)$ is a 2D function of discrete space, and the image size is $M \times N$, the 2D DFT's positive change formula is as shown in formula (3).

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) e^{-j2\pi ux/M} e^{-j2\pi yv/N}$$
$$u = 0,1,\cdots M-1; v = 0,1,\cdots N-1 \quad (3)$$

Its inverse transformation formula is as shown in formula (4).

$$f(x,y) = \frac{1}{MN} \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} F(u,v) e^{j2\pi ux/M} e^{j2\pi yv/N}$$
$$x = 0,1,\cdots M-1; y = 0,1,\cdots N-1 \quad (4)$$

Where $f(x,y)$'s 2D DFT coefficient is $F(u,v)$.

In the analysis of the frequency characteristics of the image signal, for an image, the direct-current component represents the average gray level, the low frequency components represent a large area of background and slow change, the high frequency part represent the details .

**2.3 3D DFT**

The principle is that the original strong correlation signal is concentrated in a particular region by the time domain signal into a frequency domain signal, thus eliminating the data spatial redundancy to achieve compression purpose. 3D DFT formulas are as shown in formula (5) and formula (6).

$$F(u,v,w) = \sum_{x=0}^{L-1}\sum_{y=0}^{M-1}\sum_{z=0}^{N-1} f(x,y,x) e^{-j2\pi xu/L}$$
$$* e^{-j2\pi yv/M} e^{-j2\pi zw/N} \quad (5)$$
$$u = 0,1,\cdots L-1; v = 0,1\cdots M-1; w = 0,1\cdots, N-1$$

$$f(x,y,z) = \frac{1}{LMN} \sum_{u=0}^{L-1}\sum_{u=0}^{M-1}\sum_{w=0}^{N-1} F(u,v,w) e^{j2\pi xu/L}$$
$$* e^{j2\pi yv/M} e^{j2\pi zw/N} \quad (6)$$
$$x = 0,1,\cdots L-1; y = 0,1\cdots M-1; z = 0,1\cdots, N-1$$

Where $f(x,y,z)$ represents volume data value in the $(x,y,z)$. $F(u,v,w)$ denotes the 3D DFT coefficient.

**3. Legendre chaotic neural network.**

A new Legendre chaotic neural network is applied for watermarking image scrambling [14-15]. Its model is as shown in Fig. 1.

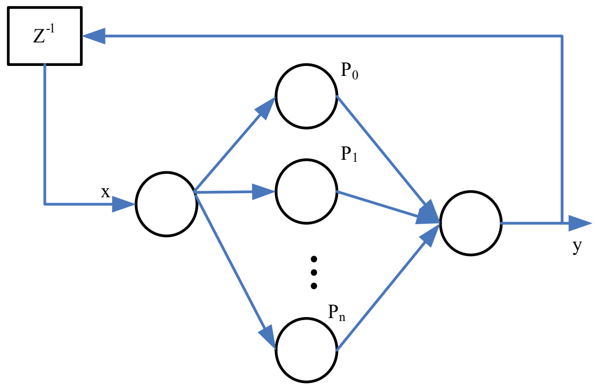



**Figure 1**. Network model

The activation function of hidden-layer first neuron is as shown in formula (7).

$$p_0(x) = 1 \quad (7)$$

The activation function of hidden-layer second neuron is as shown in formula (8).

$$p_1(x) = x \quad (8)$$

The activation function of hidden-layer n-th neuron is as shown in formula (9).

$$P_n(x) = \frac{1}{2^n n!} * \frac{d^n}{dx^n} (x^2 - 1)^n$$
$$n = 1,2,3,\cdots \quad (9)$$

$P_n(x)$ is called n-orthogonal Legendre polynomials. Its value range in $[-1,1]$.

The weights of the network are obtained by BP algorithm [15].

**4. Perceptual hashing algorithm**

Perceptual hashing algorithm concept was proposed shortly. It has been taken seriously in the research of multimedia information security, retrieval and authentication, and has achieved some results [16]. Perceptual hashing provides effective support for the content and copyright protection of the image, which can be used to assist the digital watermarking technology [17]. Advantages of perceptual hashing are that no matter you change the image 's height or width, brightness or color, will not change the hash value, that image of a fingerprint, the most critical is the operation quickly. In this paper, a perceptual hashing based on the three-dimensional Fourier transform is used to construct zero-watermarking. The algorithm flow is as shown in Fig. 2.

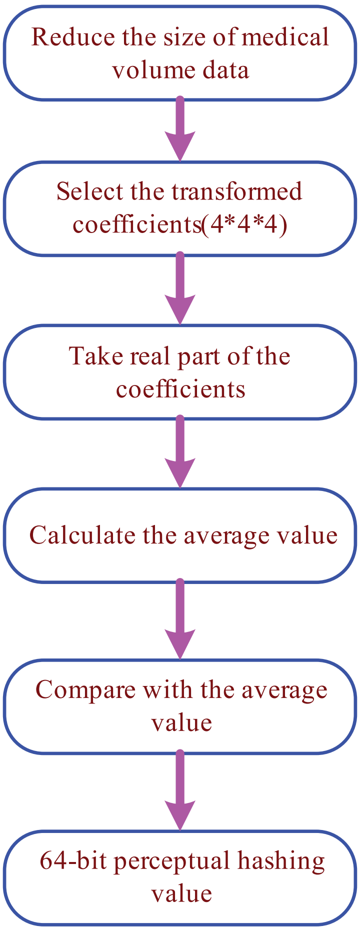



**Figure 2**. Perceptual hashing algorithm flow

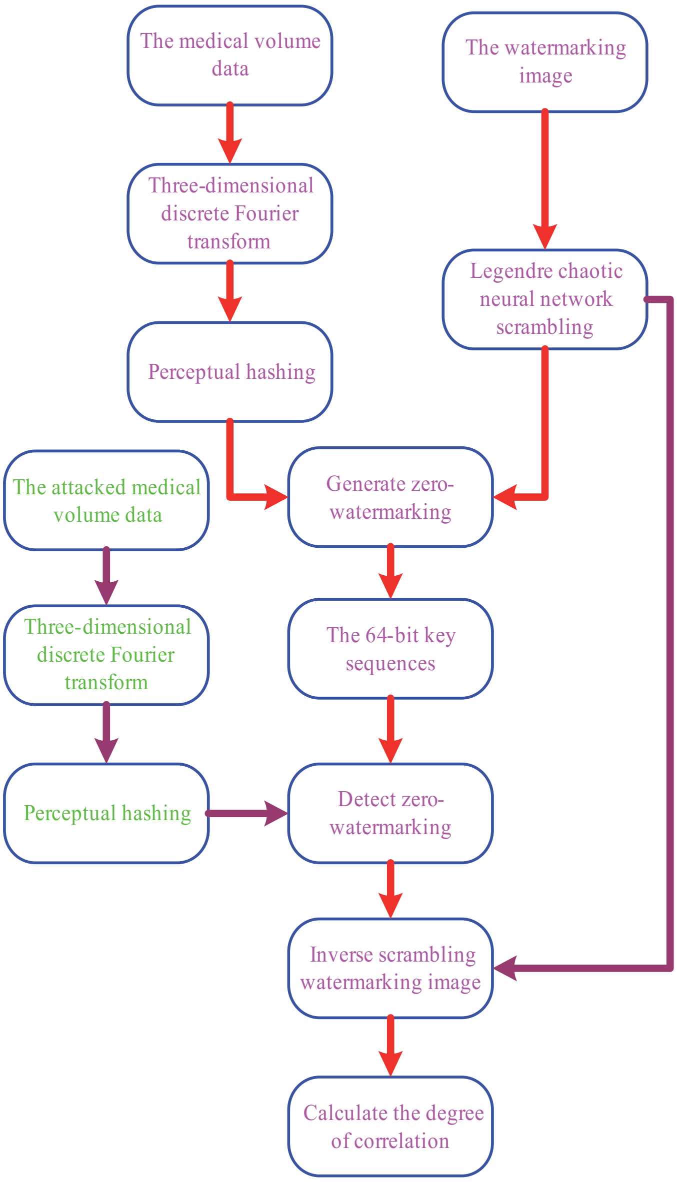



**Figure 3**. The algorithm implementation flow

**5. Zero-watermarking algorithm**

The proposed and development of zero- watermarking provides a better way to realize medical image digital watermarking. To this end, a new zero-watermarking algorithm is proposed, which is used to protect medical volume data. The zero-watermarking algorithm implementation flow is given in Fig. 3.

**6. Experiments**

The zero-watermarking algorithm is implemented in Matlab.R2010a. The original medical volume data came from Matlab.R2010a's own MRI.mat. In order to verify the robustness and security of the zero-watermarking algorithm, a series of experimental tests are carried out in this paper.

(1) No attack.

Under the condition of no attack ,the medical volume data without attack is as shown in Fig.4 (a). Its slice is as given in the Fig.4 (b). The extracted watermarking image is displayed in the Fig.4 (c).

(2)JPEG attack

JPEG compression is the most popular standard of static image compression. So, the basic requirements of the watermarking algorithm have good robustness against JPEG attack. The compression quality factor is 7%. The corresponding experimental results are as shown in the Fig.5. Experimental results indicate that the algorithm holds fine robustness against anti-JPEG attack.

(3) Scaling attack

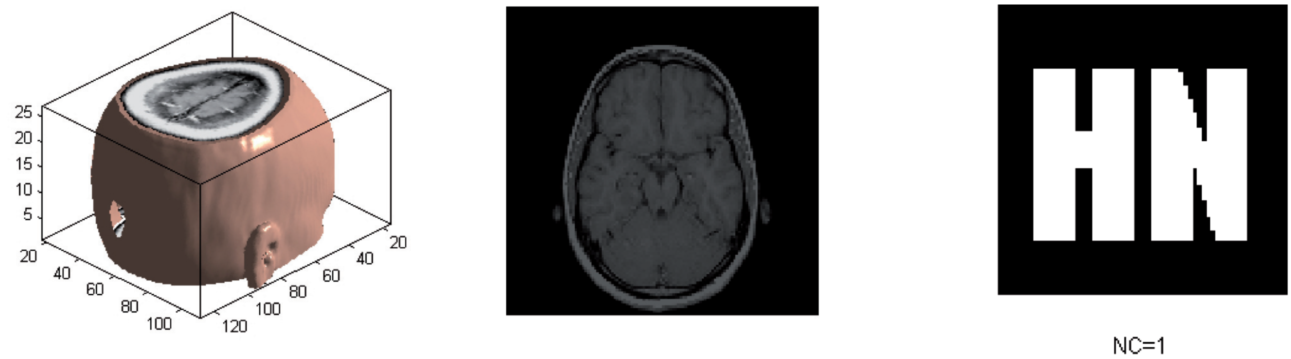
Most of the current watermarking algorithms can resist scaling attacks. But this scaling factor is limited in the interval [0.5, 2]. And the algorithm can resist any size scaling attack. When scaling factor is 3, the Fig.6 provides the corresponding experimental results. It can be seen that the experimental results obtained in the paper are very good ability against scaling attack.

(4) Rotation attack

Experimental results for rotation attack with anti-clockwise degree 10 are shown in Fig.7. The degree of correlation shows that the extracted watermarking image is very clear. So the algorithm can be considered to have a good robustness against the rotation attack.

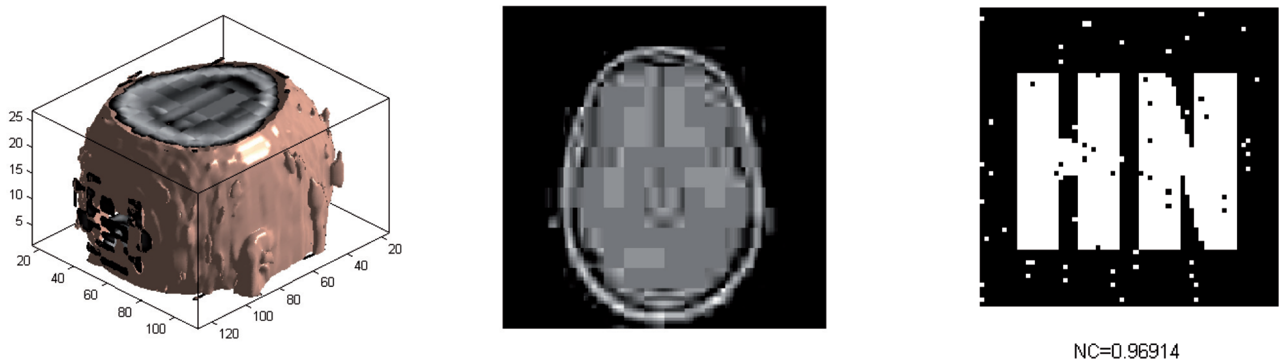
(5) Cutting attack

At present, most of the watermarking algorithms of anti geometric attacks are unable to resist cutting attack, and this algorithm can resist a lot of cutting attacks. Of course, too much of the cut will make the image lose its meaning and value, so the extent of the general cutting attack will not be too large. Fig.8 displays experimental results under cutting 6% from Y-axis direction. The extracted watermarking image is still easy to distinguish, so it can be considered that the algorithm is robust against the cutting attack.



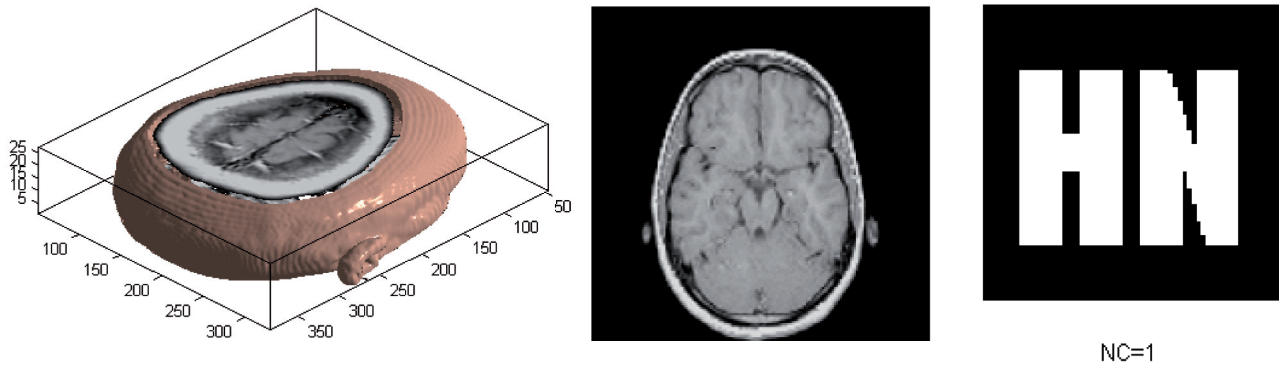

(a) (b) (c)

**Figure 4**. Experimental results under no attack



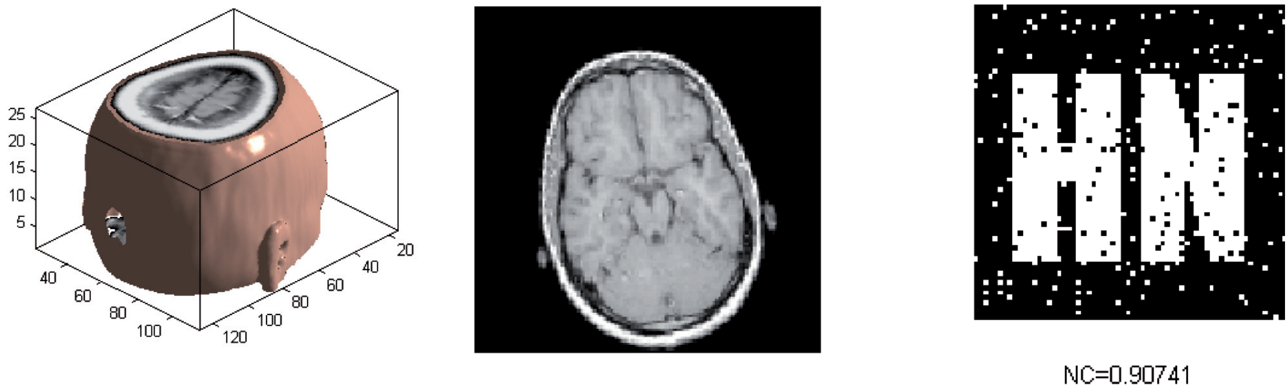

(a) (b) (c)

**Figure 5**. Experimental results under JPEG attack



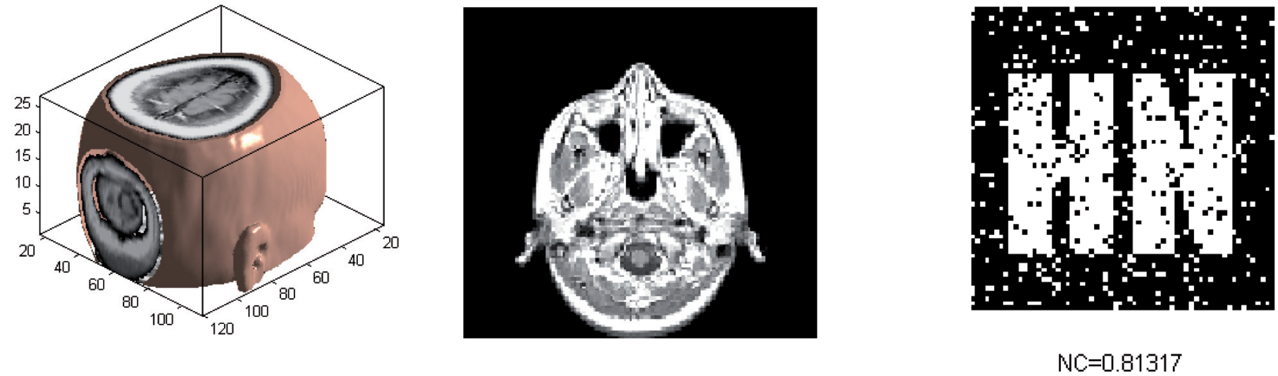

(a) (b) (c)

**Figure 6**. Experimental results under scaling attack




(a) (b) (c)

**Figure 7**. Experimental results under rotation attack




(a) (b) (c)

**Figure 8**. Experimental results under cutting attack

**Conclusions**

A new zero-watermarking algorithm is proposed, which uses 3D DFT and perceptual hashing to generate the watermarking extraction key sequence (64-bit). The algorithm can solve the contradiction between the watermarking imperceptibility and robustness, which can be extracted without the original medical volume data, thus avoiding the original medical image tampering. It had no embedding capacity limit, had very high use value. Legendre chaotic neural network can enhance security and robustness of the watermarking algorithm. Therefore, the algorithm had a better robustness and the ability to resist attacks. The experimental results show that the algorithm was better robustness and security, which can be applied to the protection of medical volume data.

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