

An Algorithm for Medical Imaging Compression That Is Oriented to ROI-Characteristics Protection

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Abstract

In order to protect the ROI (region of interest) characteristics while greatly improving medical imaging compression ratio, we are proposing an algorithm for medical imaging compression that is oriented to ROI-characteristics protection. Firstly, an improved ROI segmentation algorithm is put forward based on the analysis of the ROI segmentation. Then, after the ROI segmented, the ROI edge is extracted and encoded with Freeman chain coding. Finally, the ROI is compressed by lossless compression with shearlet; the ROB (region of background) is compressed by the method of high ratio lossy compression combining with Wavelet and Fractal. Simulation results show that the ROI is segmented precisely. It holds edge integrity and has high quality reconstruction processed by the presented method, helping protect ROI characteristics while greatly improving the compression ratio.

Keywords

Medical Imaging Compression, ROI Characteristics Protecting, Segmentation, Chain Coding, Shearlet

1. Introduction

The new health care reform in China is causing an increase in the demand for PACS (picture archiving and communication systems). Medical equipment of digital imaging has been producing massive medical imaging in hospitals. This poses a serious challenge to the limited transmission bandwidth and storage capacity of PACS. So there is an urgent need for efficient medical imaging compression algorithm.

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JPEG2000 is the basic method in current medical imaging compression for PACS. The most important thing it did was to support the ROI compression. For example, [1] used a bit-plane lifting algorithm. The quantized ROI wavelet coefficient was coded by SPIHT coding according to bit-planes, improving the quality of the ROI reconstruction quality. After [2] improved [1], the wavelet coefficient was advanced based on the different interest level of ROI, reaching the balance between reconstruction quality and compression ratio. Both [1] and [2] acted on the regular rectangular space domain, but imaging segmentation region was often irregular. So [3] proposed the plane fitting method, which was simple and easy. And [4] aimed at the different importance of ROI and ROB. ROI and ROB were processed by different methods. The handling targeted had increased compression ratio as well as the PSNR. Nevertheless, these methods did not protect the ROI characteristics. The worst had inaccurate segmentation; the edges were not protected; the reconstruction quality was low; and most of the algorithm was carried out with near-lossless or lossless compression. Therefore, these methods cannot meet the need for high-speed transmission and mass storage of explosive growth of medical imaging [1]-[4].

To solve the above problem, first of all, ROI should be accurately segmented. For this purpose, an improved ROI segmentation algorithm is proposed based on ITTI visual attention model and wavelet analysis. Secondly, to protect the edge of the ROI, freeman chain coding is used to encode ROI edge obtained at the last step of ROI segmentation. Thirdly, in order to improve the compression ratio while maintaining imaging reconstruction quality, ROI and ROB are compressed with different processes; ROI is compressed lossless with shearlet to maintain the integrity of the ROI; and ROB is compressed combining wavelet and fractal method to improve compression ratio. Finally, edge-coded information and ROI and ROB coded information are reconstructed to gain the whole recovery image.

2. ROI Segmentation Analysis and Improvement

There are many ways to segment ROI. The main ways include feature point segmentation, human interaction segmentation, and segmentation based on visual attention mechanism. Among them, feature point segmentation method is applied only to the imaging having a certain type of characteristic. Although human interaction segmentation method has a better result, it is strongly influenced by subjective factors. Besides, its efficiency is low, not good for PACS as a large library.

2.1. Fundamental of Segmentation Based on Visual Attention Mechanism

ITTI, proposed by Laurent ITTI on the basis of feature integration theory, is currently the most widely used visual attention model. Firstly, ITTI model structures multi-scale image pyramid by Gaussian filtering method. Then finding the significant point through a series of treatment containing the Center-Surround algorithm, normalization, iterative portfolio, RSM (returns suppression mechanism) and WTA (Winner take all) network. Finally it gets ROI by salient points grown [5] [6].

But the multi-scale image pyramid structured by Gaussian filter method is not consistent with the image processing model constructed by the mechanism of human visual attention. Moreover, there is a huge amount of calculation to be done to structure the multi-scale image pyramid with Gaussian filtering method, which is time-consuming.

2.2. Improved ROI Segmentation Algorithm

Wavelet transform is a tool for time-frequency analysis. Multy-resolution feature is its most impeccable property, and wavelet multi-resolution feature is consistent with the human visual system. Therefore it matches the human visual attention mechanism. Comparison of Wavelet and Gaussian image pyramid is shown in figure [1].

As can be seen from **Figure 1**, the wavelet image pyramid is visible to human eyes because of the strong contrast. However, Gaussian image pyramid is round, look vague. And the Gaussian running time is 0.155 s while wavelet is only 0.048 s. Efficiency is improved by 30.97%. Therefore, this paper uses wavelet instead of Gaussian to split ROI. Its frame is shown in **Figure 2**. Comparison of ITTI and Improved algorithm ROI segmentation is shown in figure [3].

From **Figure 3** we can find that ITTI model has the problem of over-segmentation. It is not enough to protect edge feature. A lot of important information is lost. But the improved ROI segmentation algorithm in this article is more accurate on segmentation as ITTI segmentation accuracy is just 74.6% and improved algorithm's is

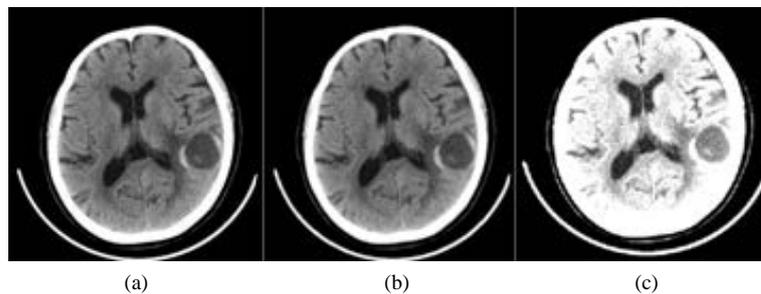


Figure 1. Comparison of Wavelet and Gaussian image pyramid. (a) Source image; (b) Wavelet image pyramid; (c) Gaussian image pyramid.

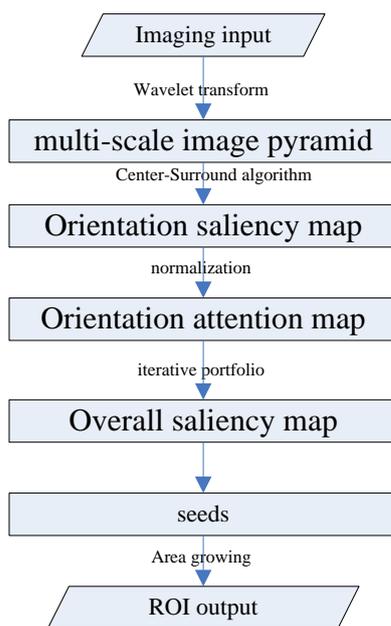


Figure 2. Improved algorithm framework of ROI segmentation.

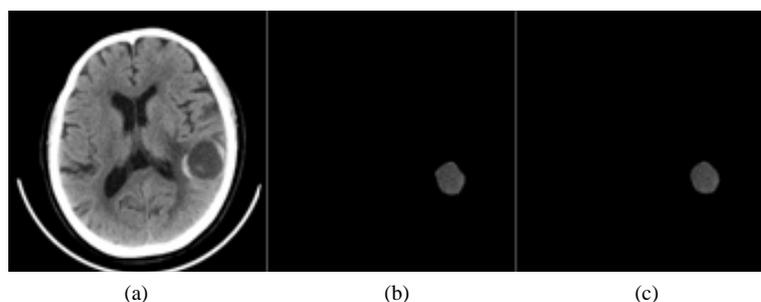


Figure 3. Comparison of ITTI and Improved algorithm ROI segmentation. (a) Source image; (b) ITTI segmentation; (c) Improved algorithm segmentation.

80.8%. It has more desired result.

3. Freeman Edge Protection Based on Former ROI Segmentation

ROI edge feature has a very high value of health diagnostic, but the edge can be severely damaged in the case of a high compression ratio. The damage interferes with the physician’s follow-up mission diagnosis and treatment. In order to protect the ROI edge, the article suggests firstly obtaining ROI edge, then encoding it. This coded

information is transmitted as a component of the compressed information. Finally the code stream has two parts including edge information and transform compressed information of ROI and ROB. Decoder integrated the two parts to get imaging with well protected edge.

3.1. Edge Obtaining Based on Former ROI Segmentation

Traditional way of obtaining edge often uses operator of edge detection, but the detector operators are too sensitive to noise (e.g. Prewitt operator and Sobel operator) although they have certain smoothing effect and they have removed part of the pseudo-edge to leave out the real edge. At the same time, the positioning accuracy is not high. Robert operator is not ideal for the imaging with familiar Gaussian noise. The processed edge will be disconnected. In this paper, we get ROI through significant point growing. So obtaining processing can be finished by just preserving the pixels that does not meet region growing criteria. It is convenient and advanced. In this paper, we discuss growing with the 8 neighborhoods, setting the threshold value T as 80, and preserving the pixels t in the storage E [8].

3.2. Freeman Chain Coding

Freeman chain coding is a lossless compression algorithm of image edge. It could use only a small amount of data to store much information. But its criterion is difficult to meet because the criterion is sensitive to noise. However, because of the adequate application of wavelet and its filter characteristic, this paper can use Freeman chain coding to encode edge [9]. The seed was randomly selected from E , using Freeman4 direction chain coding, the Freeman4 direction of the order and Freeman4 Chain code definitions as shown in **Figure 4(a)** and **Figure 4(b)** below.

4. The Principle of Compression Algorithms in This Paper

4.1. Compression of ROI

Shearlet was born as a new tool to overcome the limitations of wavelet. Although it has not distributed three high frequency detail sub-image and a low frequency profile sub-image, its image information can be concentrated on the sub-picture containing the larger coefficient. According to this good sparse features, ROI was compressed based on shearlet in this paper [10]. Furthermore, we found Huffman suitable for the statistical characteristics of ROI significant transform coefficients. So we select shearlet and Huffman to compress ROI to protect the ROI characteristics and improve its reconstruction quality. This article introduces the following steps in the algorithm of ROI the specific compression:

Step 1. Shearlet transform.

Four levels of shearlet are transformed on ROI. Each level generates 10 directional sub-image.

Step 2. Quantization.

Threshold of 10 direction transform coefficients, calculates the average value, using the coefficients sum of maximum average value to approximate source image, which is the initial step of compression and de-noising.

Step 3. Entropy coding.

Huffman entropy coding of the selected coefficient [11].

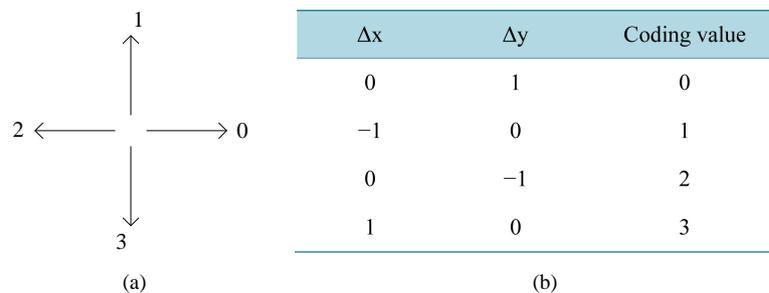


Figure 4. Freeman4 direction chain code. (a) Freeman4 direction of the order; (b) Freeman4 Chain code definitions.

4.2. Compression of ROB

Aiming at these problems that the wavelet compression ratio is not high and the Fractal needs long encoding time. Wavelet and Fractal were combined to compress ROB with high compression ratio and within only a little time. So we just encode low frequency sub-image while eliminating the high-frequency sub-images directly with fractal because imaging energy is always concentrated on those areas after Wavelet transform. The following are the algorithm steps of the ROB specific compression:

Step 1. Four levels of wavelet are transformed on ROB to produce 12 high-frequency sub-image and a low-frequency sub-image. For the wavelet base in this step, a D9/7 wavelet is chosen on the basis of the confirmed experiment [12];

Step 2. High frequency sub-image information is filtered out. The low-frequency sub-image is reconstructed. Fractal encodes the reconstructed image [13] [14].

5. Simulation

The overall framework of the algorithm is shown in Figure 5. To verify the effectiveness of the proposed method, it is necessary to perform a simulation experiment on the CT imaging of the DICOM standard brain lesion. The Nanjing Health Information Center provide CT imaging, the simulation environment is MATLABR2012b. PSNR and MSSIM are used to make sure the evaluation is objective. The definitions of MSN and PSNR are

$$MSN = \frac{1}{M * N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [x(i, j) - \hat{x}(i, j)]^2 \tag{1}$$

$$PSNR = 10 \lg \left(\frac{255 * 255}{MSN} \right) \tag{2}$$

In the formula, $\hat{x}(i, j)$ and $x(i, j)$ are the imaging pixel values of the reconstructed image and the original. MN is the image size. Let x and \hat{x} be structural similarity,

$$SSIM(x, \hat{x}) = [l(x, \hat{x})]^\gamma [c(x, \hat{x})]^\eta [s(x, \hat{x})]^\mu \tag{3}$$

In the formula, μ, η, γ are used to adjust the structure, contrast, and brightness weight factor. The $l(x, \hat{x})$ is brightness function, $c(x, \hat{x})$ is the contrast function, and $s(x, \hat{x})$ is the structural function. Their definitions are

$$l(x, \hat{x}) = \frac{2\mu_x \mu_{\hat{x}} + d_1}{\mu_x^2 + \mu_{\hat{x}}^2 + c_1} \tag{4}$$

$$c(x, \hat{x}) = \frac{2\sigma_x \sigma_{\hat{x}} + d_2}{\sigma_x^2 + \sigma_{\hat{x}}^2 + c_2} \tag{5}$$

$$s(x, \hat{x}) = \frac{\sigma_{x\hat{x}} + d_3}{\sigma_x \sigma_{\hat{x}} + c_3} \tag{6}$$

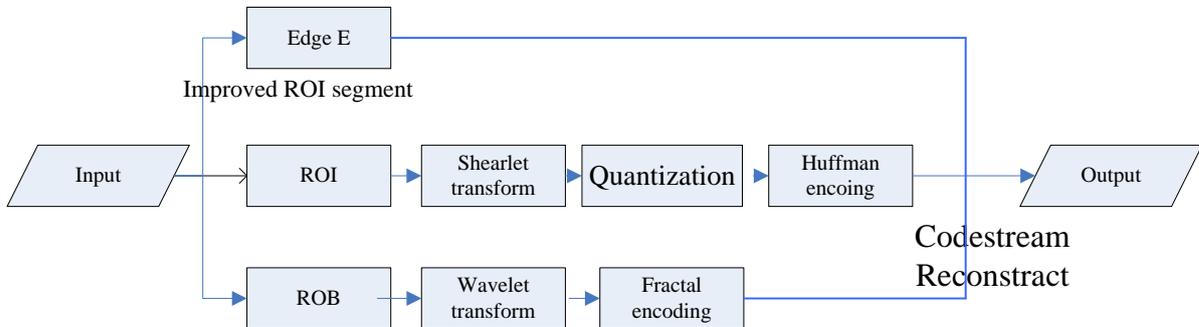


Figure 5. The overall framework of the algorithm in this paper.

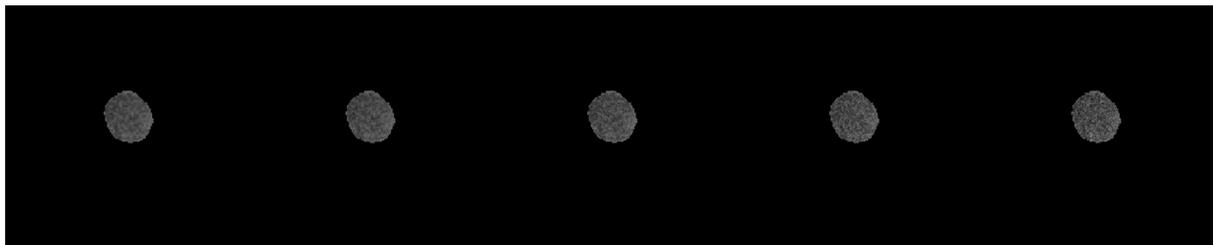
where $\sigma_{\hat{x}\hat{x}}$ is the covariance. And $\mu_x, \mu_{\hat{x}}$ are respectively the standard deviation of x, \hat{x} . The d_1, d_2, d_3 is constant. All SSIM to obtain mean values to get MSSIM is defined as

$$MSSIM(x, \hat{x}) = \frac{1}{K} \sum_{i=1}^k SSIM(x, \hat{x}) \tag{7}$$

K is the number of sub-image.

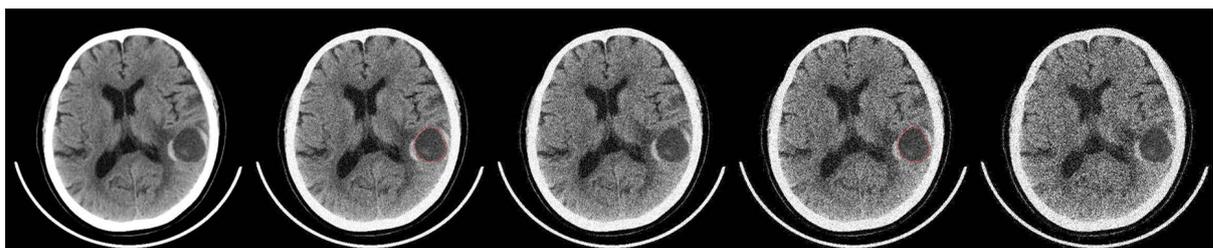
ROI and the whole image were carried out on the compression simulation. As for ROI, comparing classic wavelet with the shealet is used in this article. For the whole image, this paper compares classical JPEG2000 algorithm of PACS with proposed algorithm [15], and records the PSNR and MSSIM value. Compression effect is shown in **Figure 6** and **Figure 7**. The results are shown in **Table 1** and **Table 2**, carrying out time comparison is shown in **Table 3**.

It can be seen in **Table 1**, **Table 2** and **Table 3** that although improved algorithm average need 0.9s more carrying out time than JPEG2000, it is worth sacrifice. Because the characteristics of ROI were completely protected. When the ROI compression in low compression ratio, the PSNR value of shearlet is higher than average wavelet's 51 dB, and the MSSIM value of shearlet is as high as 1.0, ROI information is completely restored, and



Ratio = 40, psnr = 83 db; Ratio = 40, psnr = 31 db; Ratio = 60, psnr = 80 db; Ratio = 60, psnr = 30 db
 (a) (b) (c) (d) (e)

Figure 6. Results of ROI compression. (a) ROI source image; (b) Shearlet; (c) Wavelet; (d) Shearlet; (e) Wavelet.



Ratio = 40, psnr = 38 db; Ratio = 40, psnr = 32 db; Ratio = 60, psnr = 34 db; Ratio = 60, psnr = 31 db
 (a) (b) (c) (d) (e)

Figure 7. Results of the whole image compression. (a) Whole source image; (b) Improved; (c) JPEG2000; (d) Improved; (e) JPEG2000.

Table 1. ROI compression results contrast.

Ratio	PSNR/db		MSSIN	
	Wavelet shearlet		Wavelet shearlet	
20	34	87	0.99	1.00
30	31	83	0.98	1.00
40	30	81	0.95	1.00
50	30	80	0.95	0.99
60	27	76	0.91	0.99

Table 2. Whole image compression results contrast.

Ratio	PSNR/db		MSSIN	
	JPEG2000 improved		JPEG2000 improved	
20	33	41	0.991	0.998
30	32	38	0.978	0.984
40	31	34	0.973	0.982
50	31	34	0.968	0.979
60	30	31	0.949	0.973

Table 3. Time comparison of JPEG2000 and the improved algorithm/s.

Ratio	JPEG2000	Improved
20	10.29	11.24
30	10.79	11.57
40	6.25	7.09
50	6.23	7.18
60	4.14	5.17

the reconstruct quality is high. When the whole image compression under the same compression ratio, in the proposed algorithm, the values of PSNR and MSSIM are higher than those of JPEG2000 classic algorithm.

Because the **Figure 7** results of the whole image compression can be seen, the reconstructed imaging of compression algorithm in this paper is clear, especially the characteristics of the ROI. The segmentation is accurate, and the edge protection is complete.

6. Conclusion

This paper introduced wavelet to ITTI model, whose segmentation accuracy reached to 80.8%. We used the Freeman chain coding to encode the edge of ROI. This method significantly protected the edge, because of the good spare characteristic of shearlet. We also used shearlet to compress ROI. The PSNR value of shearlet was higher than average wavelet's 51 dB, and the MSSIM value of shearlet was as high as 1.0. In general, the characteristics of ROI were completely protected. Because of the application of the wavelet and its filtering properties, the algorithm in this paper has the noise robustness suitable to mass storage of medical image compression for PACS.

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