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AN EFFECTIVE DENOISING METHOD FOR MEDICAL ULTRASOUND IMAGE

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ABSTRACT

In the present work, the denoising problem of medical ultrasound images is researched to ensure the denoising effectiveness. In the ultrasound imaging process, as the organ and tissue will scattering echo signal when the ultrasonic wave arrived, multiplicative speckle noise will form in ultrasound images, and causing damage on image quality. The traditional wiener filtering method can't effectively remove multiplicative noise and reserve image detail information, and then cause ultrasound image denoising efficiency is not high. In order to solve this problem, this paper put forward the alpha ultrasound image denoising method. Though analysis and wavelet decomposition of ultrasound image, it is found that the ultrasound image signal has significant non-Gaussianity, and two-dimensional wavelet coefficients obey the alpha distribution, according to alpha distribution characteristics, adopt estimator using minimum average absolute error criterion to remove multiplicative noise in ultrasound images. Simulation experiments results show that the present method can remove multiplicative noise in ultrasound images on the basis of maximize the retention of the image detail characteristics, and can ensure the higher effectiveness of the ultrasound image denoising.

Keywords: *Ultrasound Images; Multiplicative Noise Spots, Wavelet Decomposition*

1. INTRODUCTION

Ultrasonic detection technology is a method provides the basis for discovery and diagnostics for diseases by measuring physiological tissue morphology and data which is applied to the human body detection. In actual clinical diagnostic applications, ultrasound imaging technology is collectively known as one of the four imaging technologies the field of modern medicine with X-ray, CT, and MRI, and it is a convenient, painless, intuitive, non-invasive important means of imaging techniques for medical analysis and diagnosis[1]. Ultrasound image analysis of ultrasound-based diagnostic techniques become critical support for the clinical diagnosis and telemedicine technology because of its many advantages such as fast, wide range and timely diagnosis in the process of obtaining organic image, as well as disease diagnosis without danger and suffering, and it has important application status[2]. The clinical diagnosis applications have high demands on the quality of ultrasound images. In order to provide ultrasound images as important diagnostic evidence for medical diagnosis, the search for more effective ways to remove noise in ultrasound images become a key issue.

In the actual ultrasonic imaging process, as the ultrasonic transmitted from the emission source of the signal scattering inevitably when propagating to the deep tissues of the body organs, and the echo signals affect the imaging of ultrasound image, so multiplicative speckle noise formed in ultrasound images, interfering the detail features of the ultrasound image, thereby affecting the accuracy of medical diagnosis. Traditional de-noising method cannot effectively remove multiplicative speckle noise and ensure the detail features, result in lower accuracy of ultrasound image-based medical diagnosis.

In order to improve the effectiveness of medical ultrasound image denoising, the alpha ultrasound image denoising method is proposed. Taking into account the effect of multiplicative speckle noise in the image detail features, directly rigid filtering of the image is avoided. Though analysis and wavelet decomposition of ultrasound image, it is found that the ultrasound image signal has significant non-Gaussianity, and two-dimensional wavelet coefficients obey the alpha distribution, so it is able to take advantage of image decomposition to transform and separation multiplicative speckle noise and detail features. According to alpha distribution characteristics, estimator using minimum average absolute error criterion can

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remove multiplicative noise in ultrasound images and can maximize the retention of the image detail characteristics, improving the effectiveness of the ultrasound image denoising, and ensuring the accuracy of medical diagnosis.

2. ANALYSIS OF THE PRINCIPLE OF EFFECTIVE DENOISING MEDICAL ULTRASOUND IMAGES

2.1 Denoising Principle Of Medical Ultrasound Image

When carrying out data measurement and morphological analysis with ultrasound image for the medical diagnosis, high demands on the quality of ultrasound images were putted forward. Inevitably there will be noise formation in the imaging process which will interference image quality, therefore, how to effectively remove noise interference in ultrasonic image, and to improve the diagnostic accuracy become research difficulties.

The clinical medical diagnosis system based on ultrasound images consists of ultrasonic image, image denoising, image analysis and diagnosis as the main modules, specific principle diagram as shown in Figure 1.

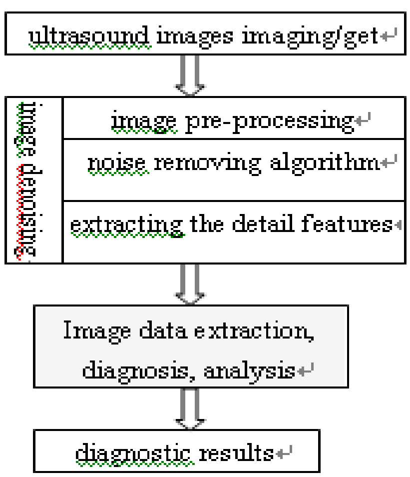

Fig1 Principle Diagram Of The Clinical Medical Diagnosis System Based On Ultrasound Images

It can be seen from principle diagram shown in Fig1 that noise removing module is an important part of the system and it directly affects the accuracy of the diagnosis.

In general, ultrasound image denoising principle process used for medical diagnostic is roughly as follows:

1）Preprocessing of obtained ultrasound images. Preliminary ensure the quality of ultrasound images through simple image pre-processing operations.

2）Removal of multiplicative speckle noise in ultrasound images. Remove noise in ultrasound images through the filter, and the Equation for the denoising is:

$$B=\frac{\Gamma\left(f-\bar{f},f-\hat{f}\right)}{\sqrt{\Gamma\left(f-\bar{f},f-\hat{f}\right)\cdot\Gamma\left(\hat{f}-\bar{f},f-\hat{f}\right)}} \qquad (1)$$

$$\Gamma(f-\bar{f},f-\hat{f}) = \sum_{x=1}^{m}\sum_{y=1}^{n}[f(x,y)\bar{f}(x,y)-\bar{f}(x,y)\hat{f}(x,y)] \qquad (2)$$

Where: f indicates the original ultrasound images, $\bar{f}$ indicates the coaxial symmetric image of the ultrasound images , $\hat{f}$ indicates rotation axis symmetrical image, B indicates the ultrasound image obtained by denoising through the filter , $\Gamma(\cdot)$ indicates the used filter, wherein the function of the Wiener filter $\Gamma(\cdot)$ is specifically expressed as shown in Equation (2). As can be seen, in the Wiener filter multiplicative speckle noise $\bar{f}\cdot\hat{f}$ in the ultrasound image is removed, but at the same time the detail information $f\cdot\bar{f}$ and $f\cdot\hat{f}$ are damaged.

3）Extracting the detail features $S(f)$ from the de-noised ultrasound image, and using the extracted image data to complete the medical diagnostic.

2.2 Drawbacks Analysis And Methods Put Forward

The calculation Equation for the effectiveness of the ultrasound image denoising is as follow:

$$L=\frac{H\{S(f)\}\cdot\sum_{i=1}^{k}P(\bar{f}\cdot\hat{f})H\{P(\bar{f}\cdot\hat{f})\}}{\sum[P(f_z)\,|\,f]} \qquad (3)$$

Accuracy calculation Equation of medical diagnosis based on ultrasound images is as follow:

$$Z=\frac{L\cdot H\{S(f)\}P(f\cdot\bar{f}+f\cdot\hat{f})}{W(Z_r)+W_c} \qquad (4)$$

Where: L indicates the effectiveness of the ultrasound image denoising, it is proportional to the removed image noise $P(\bar{f}\cdot\hat{f})$ and the reserved image details feature amoun $H\{S(f)\}$,Z indicates the accuracy of medical diagnosis based on

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ultrasonic imaging, it is proportional to the noise removal effectiveness.

Because in the ultrasound imaging process, affected by the scattered waves produced after the ultrasonic reach organ, multiplicative speckle noises will formed in ultrasound images, these noises not only affect the quality of ultrasonic image, but also interfere the image details, and they are embedded in the image detail and extremely difficult to remove. The traditional Wiener filtering method only remove part of the speckle noise $\overline{f} \cdot \hat{f}$ through Wiener filter, but also damaged the detail information of the image, as shown in Equation (2). It caused ultrasound image noise removal amount $P(\overline{f} \cdot \hat{f})$ is not high, and reduced the image detail characteristic quantity $H\{S(f)\}$. It can be found by the proportional relationship shows in the Equation (3) that the noise removal efficiency is comparatively low. It can be also found by the proportion relationship shows in the Equation (4) that this directly caused the medical diagnosis accuracy is not high enough to meet the requirements of clinical medical diagnosis.

To sum up, in order to improve the ultrasonic image denoising effectiveness, Alfa ultrasound image denoising method is proposed. The method not only can effectively remove multiplicative speckle noise, but also can effectively retain the image details. At first, analysis and wavelet decomposition of the ultrasonic image were carried out, and it was founded that ultrasound image signal has obvious non Gauss characteristics and the two dimensional wavelet coefficients obey Alfa distribution. Then according to the Alfa distribution characteristics, the estimator using minimum mean absolute error criterion is adopted to remove ultrasound image noises, in order to improve the denoising efficiency and diagnosis accuracy.

3. RESEARCH AND REALIZATION OF ALFA ULTRASOUND IMAGE DENOISING METHOD

3.1 Wavelet Decomposition And Two Dimensional Wavelet Coefficient Extraction Of Ultrasound Image

Because in the ultrasound imaging process there are outside interference noise produced by affecting of light and other effects in external environment, the image processing operation of obtained ultrasonic image is needed for initial remove of influence of the external environment on the ultrasound image quality. Then the ultrasound image multiplicative speckle noise removal operation is carried out, due to the direct use of filter cannot effectively remove multiplicative speckle noise and easy to loss image detail characteristics and effect ultrasonic image denoising effectiveness, to effectively remove the influence of multiplicative speckle noise, conduct wavelet analysis of ultrasound images taking advantages of the characteristics of wavelet transform, and extract the two-dimensional wavelet coefficients, in order to avoid the problem of low effectiveness of direct filtering denoising.

Extract wavelet analysis of ultrasound images obtained after pretreatment, set ultrasound image obtained after the preprocessing is expressed as X , the Equations for the wavelet transform analysis is as follows:

$$f(X) = \frac{1}{2\pi |C|^{\frac{1}{2}}} \exp\left[\frac{(X-\mu)^T C (X-\mu)}{2}\right] \quad (5)$$

$$C = \begin{bmatrix} E[X-\mu]^2 & E[(X-\mu)(\overline{X}-\mu)] \\ E[\overline{X}-\mu] & E[\overline{X}-\mu]^2 \end{bmatrix} \quad (6)$$

Where: $f(X)$ indicates the results of the wavelet transform of the ultrasound image X, $\overline{X}$ indicates transpose matrix representation of the ultrasound image, μ indicates mean vector of the ultrasound image, and its algebraic representation is:

$$\begin{aligned}\mu &= [E(X_1), E(X_2), ..., E(X_n)] \\ &= [\mu_{X1}, \mu_{X2}, ..., \mu_{Xn}]^T\end{aligned} \quad (7)$$

The mean vector of the ultrasound images is an n-dimensional image vector function. The two-dimensional random function of ultrasound images is expressed as:

$$f_X(x_1, x_2) = \frac{1}{2\pi |C|^{\frac{1}{2}}} e^{[-\frac{1}{2|C|}\sum_{i=1}^{x_1}\sum_{j=1}^{x_2}|C|_{ij}(x-\mu_{x1})(x-\mu_{x2})]} \quad (8)$$

Where: $f_X(x_1, x_2)$ indicates the two-dimensional random function of the ultrasound image, x_1, x_2 indicates the two-dimensional coefficient of the ultrasound image. Extract the two-dimensional wavelet coefficients from two-dimensional random function of the ultrasound images, specifically extraction Equation of the two-dimensional wavelet coefficients is:

$$\Phi_X(x_1, x_2) = \exp(\sum_{i=1}^{n} X_i \mu_{X_i} - \sum_{i=1}^{n}\sum_{j=1}^{n} \mu_{X_i}\mu_{X_j}) \quad (9)$$

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Where: $\Phi_X(x_1, x_2)$ indicates extracted two-dimensional wavelet coefficients, which contains multiplicative speckle noise of ultrasound images and ultrasound image detail features information and their associates, Therefore, it can be taken advantage of the two-dimensional wavelet coefficients as the breakthrough point multiplicative speckle noise removal, effectively removing the multiplicative speckle noise on the basis of maximize the retention of the detailed features of the ultrasound image.

3.2 Algorithm Of Alpha Ultrasound Image Denoising

It can be know by the analysis of extracted two-dimensional wavelet coefficients, two-dimensional wavelet coefficients extracted by wavelet analysis of ultrasound images obey the alpha distribution, the characteristic function of the alpha distribution can be expressed as:

$$\varphi(u) = \exp\{ju - \Phi_X(x_1, x_2)[1 + \beta \operatorname{sgn}(u)]\} \quad (10)$$

Where: $\varphi(u)$ indicates the characteristic function of the alpha distribution, sgn function represents third-order units function using u as coefficient, its concrete form is:

$$\operatorname{sgn}(u) = \begin{cases} 1 & u > 0 \\ 0 & u = 0 \\ -1 & u < 0 \end{cases} \quad (11)$$

Based on the extracted two-dimensional wavelet coefficients and its characteristic function of the alpha distribution, the estimator using minimum mean absolute error criterion is adopted to construct noise remover, and the ultrasound images are inputted into alpha noise remover to remove multiplicative speckle noises in ultrasound images. The Equation for the estimator using minimum mean absolute error criterion are shown as follows:

$$E[X] = \begin{cases} C(p, \varphi(u))\gamma^{p/a} & 0 < p < a \\ 0 & p \ge a \end{cases} \quad (12)$$

$$C(p,a) = \frac{2^{p+1}\Gamma(\varphi(u)\frac{p+1}{2})\Gamma(-\frac{p}{a})}{a\sqrt{\pi}\Gamma(-p\varphi(u)/2)} \quad (13)$$

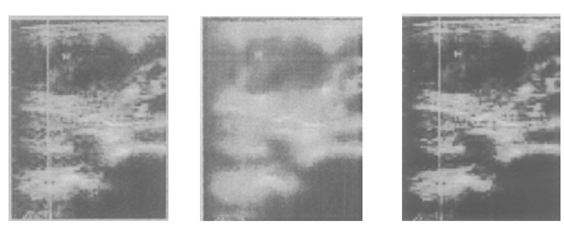
Where: $E[X]$ indicates the alpha noise remover, γ indicates balance adjusting coefficient, $C(p,a)$ indicates the estimator using minimum mean absolute error criterion, Filter function $\Gamma(\cdot)$ is selected according to the two-dimensional wavelet coefficient.

The wavelet transformations of ultrasound images are conducted and the two-dimensional wavelet coefficients are extracted. the estimator using minimum mean absolute error criterion is adopted to construct noise remover. The two-dimensional wavelet coefficients are input to the noise removing device, the multiplicative speckle noises in the ultrasound images are effectively removed, and the accuracy of medical diagnostic using ultrasound imaging is ensured.

4. SIMULATION AND RESULTS ANALYSIS

The effective ultrasound image denoising has been the difficult problem because of there will be noise affect inevitably in ultrasound imaging process, and noise interference the detail characteristics of the ultrasound image, and it is difficult to effective denoising on the basis of guarantee the image detail characteristics. This problem is affecting the accuracy of clinical diagnosis. To verify the effectiveness of the present ultrasound image noise removal method, a clinical medical diagnosis system is built using computer to test the denoising performance of ultrasound images.

Simulation experiments adopt computer-based control system, and the simulation platform is built by Labview software. Based on Visual C++ 6.0 software, ultrasound image denoising algorithm programming is completed and inputted into the system to control and implementation. In the experiment, 10 ultrasound images with noise are selected and inputted into the system platform built by traditional methods and the system platform built by alpha ultrasound image denoising method to conduct simulation experiments. In simulation experiments, not only records the final simulation denoising results but also records the data generated during the experiment one by one, in order to carry out the following analysis of the experimental. From the experimental results, a group of simulation results are chosen and compared, as shown in Fig2.



1) Original Image 2) Traditional Denoising 3)Alfa Denoising

Fig2 Comparison Of The Denoising Results

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Using experimental data recorded in the experimental process, and according to the calculation equation of denoising validity and diagnostic accuracy given by Equation (3) and Equation (4) , the average performance data in 10 simulation denoising experiments were calculated for each methods, the results are shown in Table1.

Table1: Comparison Of The Experimental Data

Denoising method	Denoising validity	Diagnostic accuracy
Traditional Wiener method	*53.4%*	*63.3%*
Present alpha method	*76.1%*	*88.7%*

Comparative analysis of the above experimental results and data shows that affected by multiplicative speckle noise generated in the ultrasonic imaging process, it is difficult to effective denoising on the basis of guarantee the image detail characteristics. Traditional Wiener filtering method only considered denoising, rigid denoising the ultrasound image with Wiener filter, can not take into account the de-noising and detail features retention, the final denoising validity of the ultrasound image is only 53.4%, and ultimately result in lower accuracy of the clinical diagnosis which only reach 63.3%. On the basis of taking into account of the characteristics of multiplicative speckle noise, in order to balance the denoising effectiveness and retention of image detail characteristics, the alpha ultrasound image denoising method is proposed, carried out analysis and wavelet decomposition of ultrasound images, extracted the transformed two- dimensional wavelet coefficients and the coefficients obey the alpha distribution, according to alpha distribution characteristics, estimator using minimum average absolute error criterion can remove multiplicative noise in ultrasound images and can maximize the retention of the image detail characteristics, improving the effectiveness of the ultrasound image denoising to 76.1%, and ensuring the accuracy of medical diagnosis to88.7%, meet the performance requirements of the clinical diagnosis.

5. CONCLUSION

The alpha ultrasound image denoising method is proposed in the present work. Though analysis and wavelet decomposition of ultrasound image, it is found that the ultrasound image signal has significant non-Gaussianity, and two-dimensional wavelet coefficients obey the alpha distribution, according to alpha distribution characteristics, adopt estimator using minimum average absolute error criterion to remove multiplicative noise in ultrasound images. Simulation experiments results show that the present method can remove multiplicative noise in ultrasound images on the basis of maximize the retention of the image detail characteristics, and can ensure the higher denoising validity and the diagnostic accuracy, and has high practical application value.

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