A Denoising Method for Ultrasound Images

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Abstract. Compared with other medical image diagnosis, ultrasound diagnosis has the advantages of simplicity and safety. Therefore ultrasound diagnosis has become one of the important methods of medical clinical diagnosis. However, when structural size of human tissue is near to wavelengths of incident ultrasound, ultrasound beam is scattered, and scattered echoes with different phases influence with each other to generate Speckle-Noise, which brings great difficulties to the post-processing of ultrasound image. Aiming at medical ultrasound image of rheumatoid arthritis, one improved algorithm is proposed, and the denoising effect of different filters is compared according to the evaluation index.

Keywords: Ultrasound Image , Image Denoising , Medical image

1. INTRODUCTION

Medical ultrasound diagnosis technology began in 1950s. In the medical field, many medical treatments or medical research processes need to process and analyze human tissue images obtained by medical imaging systems. However, due to problems of related imaging equipment, it is easy to cause the original image to be unclear with many interference noise points[1]. It can receive the reflected waves of ultrasound echoes, and then observe and analyze internal tissue structure, organ morphology and functional changes of the human body based on acoustic and optical characteristics of the reflected waves. Therefore, the denoising preprocessing could improve the target definition of interested part in a targeted manner, which can more effectively and accurately assist doctor in determining location of disease or details of patient. Ultrasound will not cause radiation and damages to human during detection process, and it is a safe detection technology. Along with rapid developments of modern information technology and auxiliary application of computers, medical ultrasound imaging technology has been effectively improved, and application of ultrasound equipment in clinical diagnosis has become more and more extensive. With the rapid development of modern information technique and computer-assisted applications, medical ultrasound imaging technology has been effectively improved, and the application of ultrasound equipment in clinical diagnosis has become more and more extensive. Along with general improvement of people health standard, people have become concerned about medical diagnosis. Safety, universality, and real-time have put forward higher requirements, and non-destructive testing technology based on ultrasound images plays an irreplaceable role.

During the ultrasound imaging process, the ultrasound device emits ultrasound waves, which are reflected back to the receiving end of the device after interaction of tissues and organs to complete imaging process. However, due to interference theory, when multiple frequencies and vibration directions are the same, sound waves with a constant phase difference are superimposed in space, which will increase in some areas, weaken or even cancel out in some areas[2]. It is precisely because of interference characteristics of ultrasound pulses that speckle noise is generated in ultrasound imaging. Speckle niose is main resource of noise from ultrasound image systems[3]. Speckle noise can cause damage to detailed information of medical ultrasound images, blur edge information, and severely reduce the image quality, thus affecting clinical diagnosis.

The current algorithms for removing speckle noise are mainly divided into three categories[4]. The first category is the spatial domain local statistical filtering algorithm. This algorithm is mainly account of statistic relationships between center pixels and surround pixel. The larger the window sizes, the smoother it is. In some images with complex structures, it is difficult to find a balance before smoothing and preserving details[5]. The second is an anisotropic diffusion filter algorithm.

The monotonic decreasing function of image gradient is mainly used to express the diffusion coefficient, and since the gradient in the noisy image has great instability, it will decrease with the increase of the smoothness of the image, so the denoising effect is not ideal. The third is a filtering algorithm based on multi-scale transformation (wavelet). The basis of two-dimensional wavelet transform is isotropic and cannot express the edge information well[6]. This makes traditional wavelet transform behave when processing two-dimensional images.

2. PRINCIPLE OF NOISE

2.1. Ultrasound Image Noise

The principle of speckle noise generation Ultrasound is a mechanical wave generated by mechanical vibration of an object. In medicine, ultrasonic waves with a frequency in the range of 2.5 to 10MHz are generally used, and the most common is the ultrasonic wave with a frequency in the range of 2.5 to 5MHz. Since human body has a very complex structure, various organs and tissues, they will have a certain impedance and attenuation effect on ultrasonic waves passing through the human tissue, which will cause the interference phenomenon between the received ultrasonic beams, which will be in image formed bright and dark spots envelope signal collected by ultrasound imaging system consisted two parts, one kind of part is reflection signal of meaningful internal tissues, and the other part is noise signal. Among them, the noise signal could be divided to multiplying noise . multiplying signal is related to principle of ultrasound signal imaging, and the main source is random scattered signal. The envelope signal initially obtained by the ultrasound imaging system is, and its general model is:

$$y^{pre}(i,j) = h^{pre}(i,j)q^{pre}(i,j) + k^{pre}(i,j) \quad (1)$$

The proportion of adding noises are small, and the model after ignoring it is:

$$y(i,j) = h(i,j)q(i,j) \quad (2)$$

Perform logarithmic compression processing on the envelopeal sign collected by ultrasound image system to obtain the additive model:

$$\log(y^{pre}(i,j)) = \log(h^{pre}(i,j)) + \log(k^{pre}(i,j)) \quad (3)$$

The signal $\log(y^{pre}(i,j))$ obtained at this time is usual medical ultrasound image. the wavelet transform is one linear transforms, the model of formula (3) is added after the discreted wavelet transform:

$$L^j_{l,k}(y) = L^j_{l,k}(h) + L^j_{l,k}(k) \quad (4)$$

$L^j_{l,k}(y)$、$L^j_{l,k}(h)$ $L^j_{l,k}(k)$ respectively represented wavelet coefficient of point noisy. The superscript j is decompositions level in the wavelet transform, the subscript (l,k) was coordinate in the wavelet domain. The maximum numbers of layers of a wavelet decompositions. For convenience, (4) is simplified as:

$$E^j_{l,k} = T^j_{l,k} + V^j_{l,k} \quad (5)$$

In the experiment, the wavelet shrinkage method uses the Bayesian maximum posterior estimation method. wavelet coefficient of the no-noise signals obey generalized Laplace distribut, which wavelet coefficiention of the speckle-noise observes the Gaussian distribution.

$$V_G(g) = \frac{v}{2s\Gamma(\frac{1}{v})}\exp(-\left|\frac{g}{s}\right|^v) \quad (6)$$

Among them, $\Gamma(ex) = \int_0^\infty x^{b-1}\exp(-x)dx$ is the gamma function and s is the scale parameter. When the shape parameter v is 1, formula of (6) will become Laplace distribution, which is one special model for generalized Laplace distributions.

wavelet coefficient $N^j_{1,k}$ in speckle noise obeys the zero mean Gaussian distribution:

$$E_N(n) = \frac{}{\sqrt{2\pi}\sigma_N}\exp(-\frac{n^2}{2\sigma^2{}_N}) \quad (7)$$

3. ULTRASOUND IMAGEG

3.1. Synovial Thickening Ultrasound Image

The thickness of a normal healthy synovial membrane is about 6mm~8mm. lesion three is tight synovial thickening. One thickened area of the synovium extends from triangular region round joint to middle of the phalanx and until the end of the phalanx. The thickness of synovial membrane exceeds 8 mm. Figure 1 to Figure 4 are the ultrasound image performance from grade 0 to grade 3 respectively.

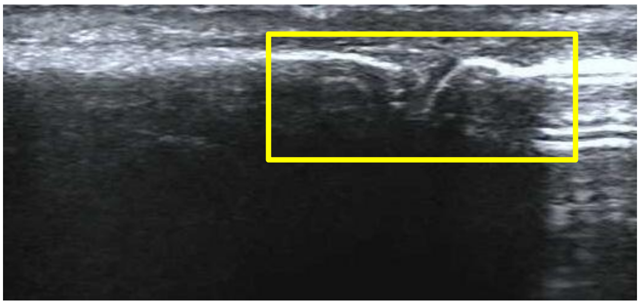

Fig. 1 Grade 0 ultrasound image with noise

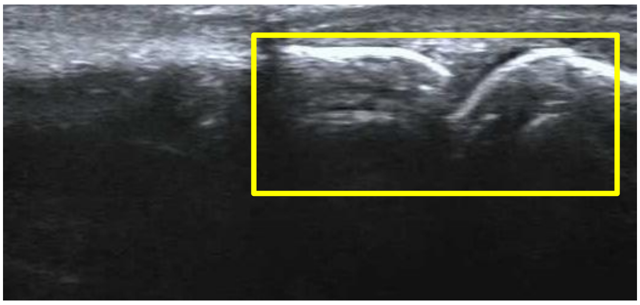

Fig. 2 Grade 1 ultrasound image with noise

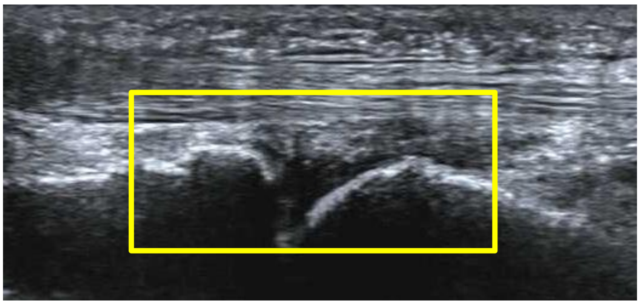

Fig. 3 Grade 2 ultrasound image with noise

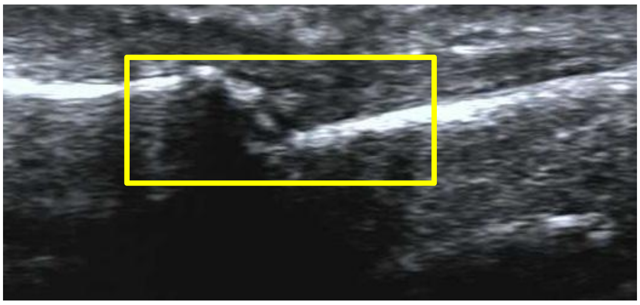

Fig. 4 Grade 3 ultrasound image with noise

3.2. Bone erosion ultrasound image

Symptoms of metacarpal and phalangeal arthritis are divided into bone erosion and synovial thickening, corresponding to three levels of symptoms, representing different levels of severity .

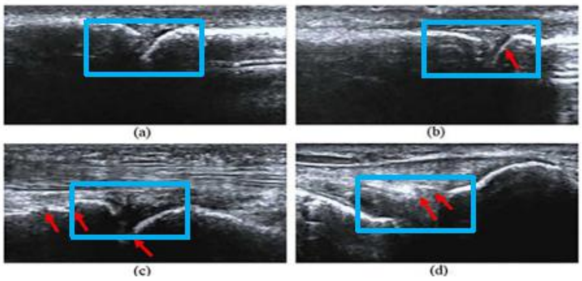

Fig. 5 Grade 0 to grade 3 bone erosion image

3.3. Algorithm performance evaluation

The indexes to evaluate performance of ultrasound image denoising methods are peak signal-to-noise ratio (PSNR), and structural similarity (SSIM), algorithm time. The peak signal to noise ratio is:

$$PSNR(X,\hat{X}) = 10\lg(\frac{255^2)}{MSE} \tag{8}$$

Whole meaning is to arrive at peak signal of noise ratio, PSNR is usually used with a project between maximum signal number background noise. In general, after image compression, output image would be different from original image with some extent. for purpose of measuring the image quality after managing, it is usually refer to psnr value to evaluate if a certain processing procedure is satisfied, and its unit is dB.

In the formula, $\hat{X}$ is one estimated value of signal X, and MSE is:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(X_{i,j} - \hat{X})^2 \tag{9}$$

$$SSIM(X,\hat{X}) = \frac{(2\mu_X\mu_{\hat{X}} + c_1)(2\sigma_{X,\hat{X}} + c_2)}{(\mu_X^2 + \mu_{\hat{X}}^2 + c_1)(\sigma_X^2 + \sigma_{\hat{X}}^2 + c_2)} \tag{10}$$

SSIM (Structural Similarity), structural similarity, is one index to evaluate similarity of two images. Among two images used by SSIM, one is an uncompressed image, and the other is a distorted image.

In the formula, μ_x , $\mu_{\hat{x}}$, σ_x , $\sigma_{\hat{x}}$ are the mean with variance of image respectively. C1 and C2 are constants. When both them are choosed as positive numbers, the score area of SSIM is [0,1], where 1 is the best outcome, which desires that the two images have same structure.

4. IMPROVED ALGORITHM STEPS

4.1. Algorithm Steps

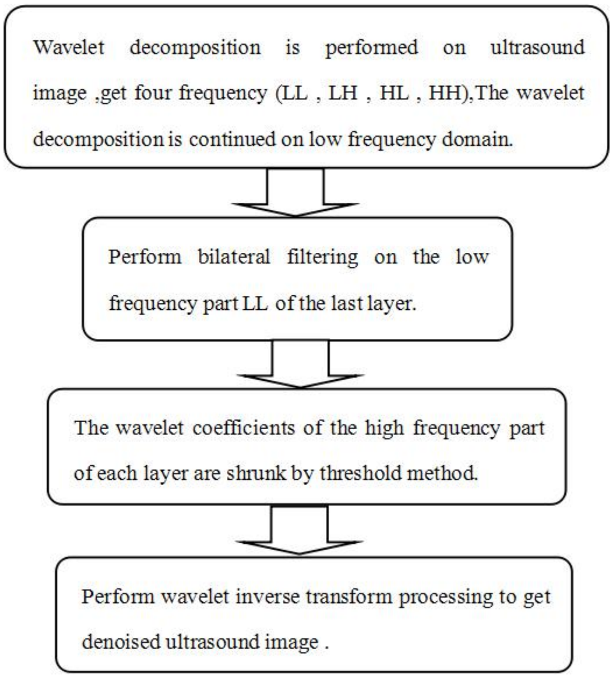

Fig. 6 Algorithm flow chart

4.2. Experiment Results

The improved algorithm is compared with other 4 denoising algorithms (Lee, Frost, bilateral filtering, wavelet soft threshold): The Figure7 shows the comparison of different denoising algorithms.

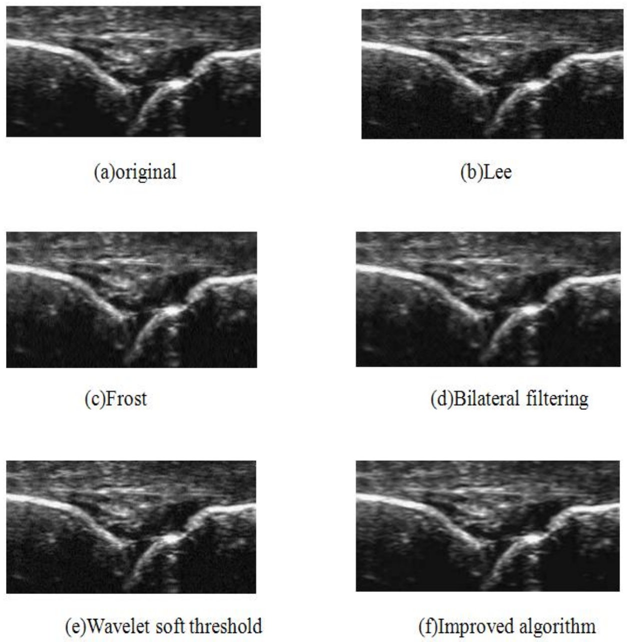

Fig. 7 Comparison of experimental results

The denoising results obtained by the algorithm in this paper show that the PSNR values of the image are the largest, which verifies that algorithm in this paper has a better denoising impact and edge detection quality for simulated images. Through the comparison of SSIM, explain the denoising result image of the algorithm in this paper.

It also has good structural similarity. Due to the algorithm steps, the improved algorithm in this paper still needs to be improved in terms of algorithm time.

Table. 1 experiment results.

Algorithm	PSNR/dB	SSIM	Run time/s
Original image	19.3685	0.4137	---
Lee	22.819	0.6951	0.95
Frost	26.339	0.7583	21.06
Bilateral filtering	20.090	0.7497	11.68
Wavelet soft threshold	22.461	0.6455	5.91
Improved algorithm	31.377	0.908	46.64

Conclusion:

Directing at problem of speckle noise in medical ultrasound image, one improved denoising algorithm has been proposed. As compared with the other four algorithms, the improved algorithm has better effect than other denoising algorithms in evaluation index of denoising effect.

However, from the point of view of the time consumed by the algorithm, the improved algorithm has no advantage in the algorithm running time, and further improvement is needed.

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