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Speckle Reduction of Ultrasound Elastography with Bilateral Filter

Xiaoming Zhou*[1], Wen Liu[1], Dong.C. Liu[2]
[1]Computer College of Sichuan University
[2]School of Computer Science, Sichuan University
Chengdu 610065, China, +86-28-85125269-100
*Corresponding author, e-mail: softzhou621@163.com

Abstract

Ultrasound elastography has been well applied in early tumor diagnosis for obtaining tissue stiffness information. Elastograpyy may provide useful clinical information for the tissue characterization. But ultrasonic wave interference will produce speckle in both phase and envelope. So in conventional ultrasound elastography, there are noise artifacts which produce some misdiagnosis. In this paper, we investigate bilateral filter de-noising method to reduce the speckle. Because the bilateral filter de-noising method can greatly smooth the speckle at the same time protect the lesion edge well, it has been well proved good impact in B-mode. But in ultrasound elastography, the bilateral filter hasn't been used. So we use the bilateral filter to reduce artifacts to prove the performance of this method. In the experiment, because of the bilateral filter de-noising method, the noise artifacts will be reduced largely. We use SNRe and CNRe to verify the performance of the bilateral filter and finally this method proved a significant improvement to SNRe and CNRe.

Keywords*: ultrasound elastography, bilateral filter, SNRe, CNRe*

1. Introduction

In the past, the palpation was the only primary technique to estimate the stiffness of tissue especially breast. But palpation has large uncertainty and limitations in diagnosis. The ultrasound elastogtaphy have proposed by Ophir et al [1]. in 1991 which is a new technique to provide doctors more clinic information.

As we know, high quality displacement estimation is a major step. So the iterative phase zero method is used for displacement estimation [2].However, there are noise artifacts in the ultrasound elastography. So a lot of de-noising methods are used to reduce the artifact including compounding, filters and wavelet transform. And the bilateral filter de-noising method is shown to largely use in image processing and it has been applied in B-mode [3]. Because the bilateral filter de-noising method can greatly smooth the speckle at the same time protect the lesion edge well, we use the bilateral filter de-noising method in this paper.

2. Research Method

The bilateral filter is noise smoothing and edge-preserving filter. The intensity value of pixel is replaced by a weighted average of intensity values from near pixels and the weight is based on Gaussian distribution. The bilateral filter function is defined as:

$$BF[X]_p = \frac{1}{W_p}\sum_{q\in S} G_{\sigma_S}(\|p-q\|)G_{\sigma_r}(|X_p - X_q|)X_q \tag{1}$$

$$W_p = \sum_{q\in S} G_{\sigma_s}(\|p-q\|)G_{\sigma_r}\left(\left|X_p - X_q\right|\right), G_\sigma\left(x\right) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{x^2}{2\sigma^2}\right) \tag{2}$$

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Where S is the p-centric set of local pixel, q is the element of . And $\| p-q \|$ is the geometric distance between q and p as the center point in the set. $\left| X_P - X_q \right|$ is the light distance between q and p as the center point in the set.

As we know, the iterative phase zero method is a useful method to estimate the displacement. And the two preconditions: one is motions are only ultrasound scan line direction and the second is rigid motion exists [4]. But in fact, it is impossible. In modified phase-zero method, we perform two-dimensional cross correlation calculation which is shown below [5]:

$$\tau_{x,0} = 0, \tau_{x,y} = \tau_{x,y-1}; -\frac{1}{\varpi_0}\arg\left(e^{jw0\tau_{x,y-1}} \cdot \int_{-n/2}^{n/2}\left(\int_{\tau_{x,y-1}-Tw/2}^{\tau_{x,y-1}+Tw/2} yl\left(x,t\right)\cdot y2^*\left(x,t-\tau_{x,y-1}\right)dt\right)dx\right) \quad (3)$$

Where the variable $\tau_{x,y}$ means the displacement of the x^{th} scan at the y^{th} position along scan line direction. The number n is the horizontal window size, and Tw stands for the axial window size. Variables $y1$ and $y2$ are baseband complex signals of the previous and the current frame respectively.

3. Results and Analysis

We use the Model 049 Elasticity QA phantom, CRIS Virginia, USA, to obtain our pre- and post-compression RF data from a commercial ultrasound system scanner, the Saset iMago c21.And the RF data consists of 512 samples with 40MHz sampling frequency and the central frequency as 7.5MHz.

Experiment has three primary steps: firstly using modified phase-zero method on I/Q signal to estimate the delay and linear interpolation is used in correlation calculation with shift. The sample window for displacement calculation is 2mm with 75% overlap and the iteration number is 1; the second step is filtered with a seven point Savitzky-Golay digital differentiation filter to get the elastograms of the tissue and the final step is applying 7*7 widows bilateral filter to strain image.

To test performance of the bilateral filtering method, we use SNRe to test the speckle reduction:

$SNR_e = \frac{\mu}{\sigma}$, where μ and σ are the luminance mean and the standard deviation respectively of the luminance inside a 19*19 window excluding the structure and wire targets. We use 3 windows to compute the SNR and estimate the mean from 3 groups of SNRe.

We use the CNRe to estimation the contrast enhancement in strain image [6]:

$CNR_e = \frac{2(\mu_{sb} - \mu_{st})^2}{\sigma_{sb}^2 + \sigma_{st}^2}$, where μ_{st} and μ_{sb} denote the mean strain of the target and the background, σ_{st} and σ_{sb} represent the standard deviation of the strain in the target and the background respectively.

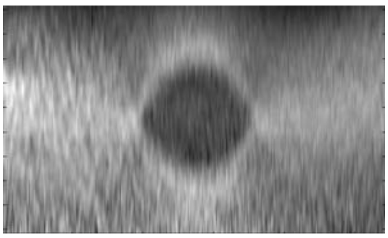

Figure 1(a). Conventional Strain Image

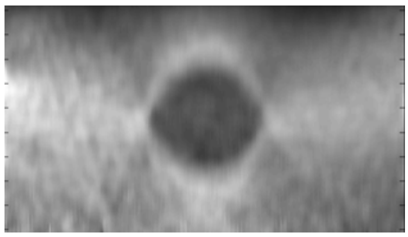

Figure 1(b). The Strain Image used the Bilateral Filter

In Figure1, we found that the strain image with bilateral filter is useful to reduce the speckle. And we we found that the SNRe and CNRe with the bilateral filter de-noising method are 39.7196 and 3.218; the SNRe and CNRe of conventional strain image are 17.772 and 2.4758. So SNRe and CNRe with the bilateral filter de-noising method have been improved 222.8% and 129.9% respectively. So the bilateral filter de-noising method is useful in strain elastography.

4. Conclusion

In this paper, we proposed bilateral filter de-noising method to reduce the artifacts in strain image and preserved the edge of lesion inclusion. Firstly, we apply the modified phase-zero method to get the strain image and the second step is the bilateral filter de-noising method to reduce the speckle. In the experiment, with the bilateral filter de-noising method the noise artifacts has been reduced largely and application of this method proved a significant improvement to SNRe and CNRe.

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