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Tissue Flow Detection Using Fuzzy Logic Method in Color Flow Imaging

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Abstract

Tissue/flow detection is critical for high quality 2-D color flow image. The traditional tissue/flow detection method is based on one or several thresholds which are used for parameters after autocorrelation. Generally a lot of parameters: flow magnitude, variance and velocity are applied for tissue/flow detection. But this method may not distinguish tissue/flow because of moving tissue or noise. So in this paper, fuzzy logic method with multi-level range based on in vivo carotid I/Q data was proposed with three parameters: echo amplitude, flow magnitude and Flow variance for tissue/flow detection and then decision look-up-table (LUT) was designed for real time display. Experiment results shows that fuzzy logic method was improved for tissue flow detection significantly and can get high quality 2-D color flow image.

Keywords: *tissue/flow detection, echo amplitude, flow magnitude, flow variance, fuzzy logic*

1. Introduction

Color flow imaging has been well applied in clinical diagnosis. The Ultrasound signal consists of the Doppler signal by blood and the clutter signal from slow muscular tissue such as vessel walls and slowly moving tissue. So the clutter filter can be used to separate the signals from blood and tissue in Ultrasound Doppler blood flow measurements [1]. After clutter filtering and autocorrelation, tissue/flow detection is the critical in color flow imaging. With high effective tissue/flow detection, high quality 2-D color flow image is applied for clinical diagnosis. Traditional method and fuzzy logic method were applied in color flow imaging system [2].

Traditional method makes several thresholds which are used for some parameters such as the magnitude and velocity of the received signals, etc. For example, flow magnitude and velocity with values larger than the thresholds are assumed to be flow, whereas to be tissue. But this method cannot work well where signal are received from moving tissue or heavy noise. And Echo amplitude is not applied with traditional method which includes more information of tissue/flow. Therefore, fuzzy logic method with multi-level range was proposed with three parameters: echo amplitude, flow magnitude and flow variance in this paper. And in order to simplify the fuzzy logic method, 2-bit decision criterion was set up. Finally decision look-up-table (LUT) was designed for fast tissue/flow detection.

In this paper, in the first I/Q data were filtered with 3-order polynomial regression filter whose advantage is the same length before and after filtering, provided more abundant signal data to get the high quality blood flow images [3]. And then flow data such as flow magnitude, variance and velocity were acquired after Modified autocorrelation. In the next tissue/flow detection based on fuzzy logic method was applied and LUT was acquired. Finally 2-D color flow images were displayed after color mapping. The flow of 2-D color flow imaging in this paper are shown in Figure 1.

This paper is organized as follows. In Section 2, the technical details about autocorrelation technique, calculating of parameters and fuzzy logic method are discussed. And then vivo I/Q signal experiment and results are presented in Section 3. Finally discussion and conclusion will be drawn from this study in Section 4.

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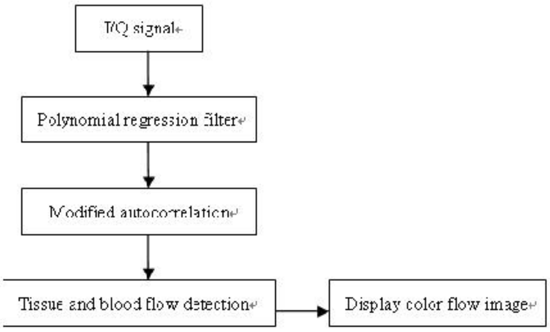

Figure 1. The Flow of 2-D Color Flow Imaging

2. Materials and Method

2.1. Modified Autocorrelation Technique

Autocorrelation algorithm proposed by Kaisai is autocorrelation of signal in the time domain [4]. Signal discrete form of the autocorrelation function $R(n)$ is defined as:

$$R(n) = \frac{1}{M-1} \sum_{k=-K}^{K} \sum_{m=0}^{M-2} S^{*}(n+k,m)S(n+k,m+1) \quad (1)$$

Where S is the input signal, * is complex conjugate, M is the length of autocorrelation signal in the time domain.

But it has aliasing effects due to the noise with this autocorrelation technique. So modified autocorrelation technique by Liu is smoothing processing to remove aliasing in the spatial domain after autocorrelation [5]. Signal discrete form of the autocorrelation function $R(n)$ is defined as:

$$R(n) = \frac{1}{2k+1} \frac{1}{M-1} \sum_{k=-K}^{K} \sum_{m=0}^{M-2} S^{*}(n+k,m)S(n+k,m+1) \quad (2)$$

Where S is the input signal, * is complex conjugate, M is the length of autocorrelation signal in the time domain and K is the smoothing window dimensions in the spatial domain.

2.2 Decision Parameters

2.2.1. Echo Amplitude

Echo amplitude of sample is important decision parameter and it was computed:

$$|A(n)| = \sqrt{I(n)^2 + Q(n)^2} \quad (3)$$

Where I is the real part of I/Q signals and Q is imaginary part of I/Q signals, and if A is very large, the sample will be tissue instead of flow.

So decision rule: $A > A_t \Rightarrow$ Tissue. Where A is value of amplitude and A_t is threshold.

2.2.2. Flow magnitude

Flow magnitude R was computed:

$$|R(n)| = \sqrt{D(n)^2 + N(n)^2} \quad (4)$$

Where D and N are the real and imaginary parts of autocorrelation function $R(n)$. If R is very small, the sample will be tissue.

So decision rule: $|R| < R_{¦} \Rightarrow$ Tissue. Where R is Flow magnitude and $R_{¦}$ is threshold.

2.2.3. Flow Variance

Flow variance ¢ was computed [6].

$$¢^2 = \frac{1}{T^2}[1 - \frac{[R_i^2(n) + R_q^2(n)]^{\frac{1}{2}}}{A(0)}] \quad (5)$$

Where T is pulse repetition, $A(0)$ is echo amplitude, f_0 is center frequency of pulse and $R(n)$ is the autocorrelation function. If v is very small, the sample will be tissue.

So decision rule: $|¢| < ¢_{¦} \Rightarrow$ Tissue. Where v is the mean velocity and $¢_{¦}$ is threshold.

2.3. Fuzzy Logic Method with Multi-level Range and LUT

According to the above three decision rules, a simple decision algorithm can be drawn as follows:

If $A > A_{¦}$ then Tissue Valid

Else if $|¢| > ¢_{¦}$ and $|R| > R_{¦}$ then Flow Valid

Else Tissue Valid

But the decision algorithm cannot determinate continuous changes in the decision boundary. So to avoid this problem fuzzy logic method with multi-level range was proposed such as less than, a little bit greater than, greater than and much greater than. In order to simplify the fuzzy logic method, 2-bit decision rule was set up as follows:

Less than:	X < X*	: 0
A little bit greater than:	X* X < 1.5X*	: 1
Greater than:	1.5X* X < 2X*	: 2
Much greater than:	2X* X	: 3

The output of each decision parameter is 2-bit number and three sets output of three parameters were formed 6-bit number as the index address of tissue/flow. If three index address were D_a, $D_¢$ and D_r, respectively, the finally index address of LUT was computed as follows: $D_a 2^4 + D_¢ 2^2 + D_r$.

3. In Vivo Experiment and Results

3.1. Experiment Data

In vivo carotid I/Q data was got with the iMago c21 ultrasound machine produced by Saset Company at Chendu city. One sets of in vivo carotid I/Q data were used in experiment. Table 1 shows different parameters of I/Q data.

Table 1. Different Parameters of I/Q Data

Parameter	The I/Q data
Ensemble Size	12
The center frequency f	5.0 MHz
PRF	3076.8 Hz
Samples of a line	512
Scanning direction number	24

3.2. Experiment Thresholds of Parameters

Firstly, echo amplitude was computed. After polynomial regression filter and modified autocorrelation of I/Q data, flow magnitude and flow variance was calculated.

3.2.1. Thresholds of Echo Amplitude and Flow Variance

The data of echo amplitude can be preprocessed. Firstly values of echo amplitude and flow variance were compressed to 0-255 with dynamic range map. In the second, echo amplitude was divided by the average of echo amplitude for fast computing. And the range of new data and flow variance were divided into nine grades. Table 2 shows nine grades values of echo amplitude and flow variance.

Table 2. Nine Grades Values of Echo Amplitude and Flow Variance

Parameter	values
Echo amplitude	0.4, 0.5 0.6, 0.7 ,0.8, 0.9 ,1, 1.1, 1.2
Flow variance	40,60,80,104,128,139,150,200,255

From Table 2, threshold was selected according to nine grades. In this paper, the third grades values of echo amplitude and flow variance are the thresholds.

3.2.2. Threshold of Flow Magnitude

The value of flow magnitude was compressed to 0-255. Histogram method was proposed to get threshold. 2-D data of flow magnitude was reshaped to 1-D data and then histogram was acquired. Figure 2 shows the histogram of 1-D new data of flow magnitude.

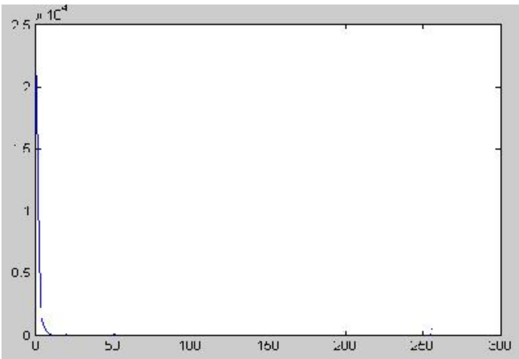

Figure 2. Histogram of 1-D New Data of Flow Magnitude

The value of tissue magnitude is close to zero. So the location of maximum value was computed and then differentiation was started from this location. If the value of differentiation is small than a given value, the boundary position of tissue and flow was confirmed. In this paper, the position is eight with this method.

3.3. Experiment Results

With our fuzzy logic method, LUT using three parameters was acquired. And three LUT were acquired with each parameter. Finally, 2-D color flow image were acquired with four LUT. Figure 3(a) shows 2-D color flow image with echo amplitude parameter; Figure 3(b) shows 2-D color flow image with flow variance parameter; Figure 3(c) shows 2-D color flow image with flow amplitude parameter and Figure 3(d) shows 2-D color flow image with fuzzy logic method.

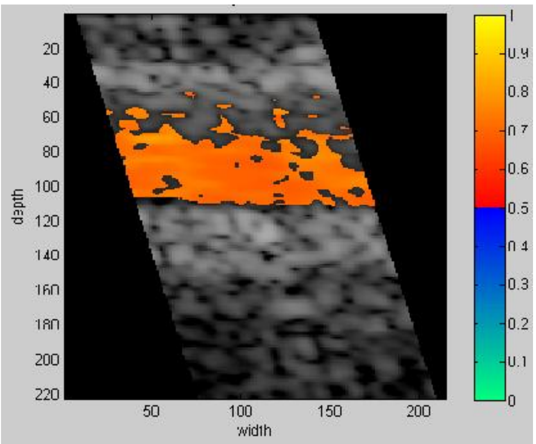

Figure 3(a). 2-D color flow image with echo amplitude

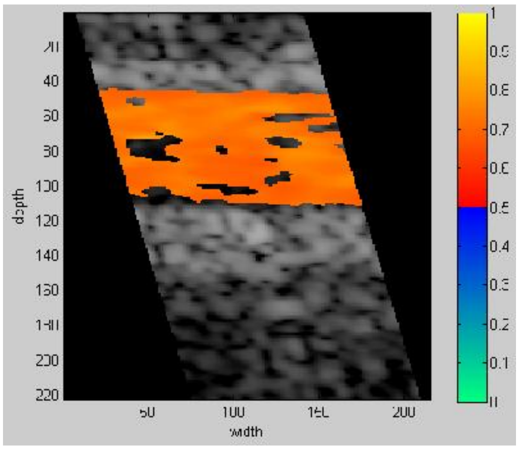

Figure 3(b). 2-D color flow image with flow variance

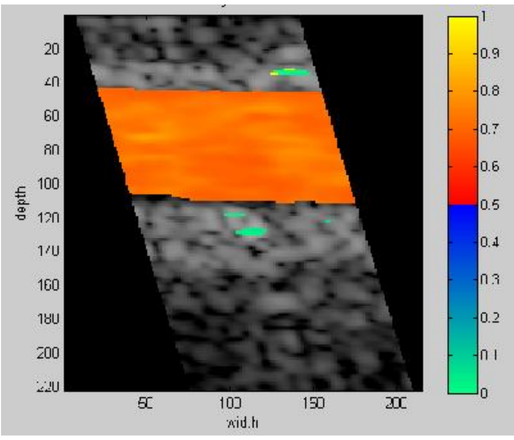

Figure 3(c). 2-D color flow image with flow amplitude

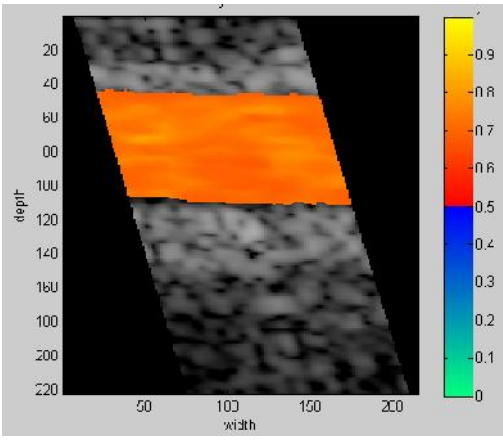

Figure 3(d). 2-D color flow image with fuzzy logic method

4. Discussion

To test performance of fuzzy logice method, flash arifacts and edge were applied to test. If less flashe arifacts in 2-D color flow image and smooth edge, the color flow image has better quality image. Figure 3(a), (b), (c) shows that 2-D color flow images with each parameter has the worse quality image and Figure 3(d) shows that the 2-D color flow image with proposed method has the best quality image because it has the least flash artifacts such as holes in the middle of color flow image and color area in tissue, smooth edge.

5. Conclusion

In this paper, fuzzy logic method with multi-level range based on in vivo carotid I/Q data was proposed with three parameters: echo amplitude, flow magnitude and Flow variance for tissue/flow detection. And decision look-up-table (LUT) was designed for real time display. With proposed method, the quality of 2-D color flow image can be enhanced significantly than traditional tissue/flow detection method. In the future, more clinical data will be tested with proposed method.

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References

[1] S Bjarum, H Torp. Clutter filter design for ultrasound color flow imaging. *IEEE Trans. Ultrason. Ferroelectr. Freq. Contr*. 2002; 49: 202-216.
[2] Q Ma, J Lazenby. Fuzzy logic tissue flow determination system. United States Patent 5857973, 1999
[3] X Lai, H Torp. *Effects of the Wall Filter on the Estimation of High Blood Velocity*. Ultrason. Symp. 1997: 1263-1267.
[4] C Kasai, K Namekawa, et al. Real-time two-dimensional blood flow imaging using an autocorrelation technique. *IEEE Trans. Sonics Ultrason*. 1985; SU-32 : 458-464.
[5] DC LIU, J KIM, M SCHARDT. *Modified autocorrelation method compared with maximum entropy method and RF cross-correlation method as mean frequency estimator for Doppler ultrasound*. Ultrasonic Symposium, 1991; 2: 1285-1290.
[6] DC Liu. Basic Functions of Color Flow Imaging. RDS-MEMO-CFM