A Fast Method for Speckle Tracking

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Abstract – Speckle tracking method has been studied for velocity vector imaging in medical ultrasound for many years. However, the method is slow as compared to the conventional color Doppler imaging due to a larger amount of computation needed. In this study, a method is developed to reduce the amount of computation. Instead of using an entire rectangular block in a 2D kernel (full kernel) to calculate the sum of absolute difference between image frames, only data in two diagonal lines, two bisectors, or a combination of the diagonal and bisector lines (see Fig. 1(b), (c), and (d)), are used. Both simulation and experiment were conducted to verify the proposed method. 11 frames of images are reconstructed with the delay-and-sum (D&S) and the high-frame-rate (HFR) imaging methods of a single plane wave transmission. In the simulation, two point scatterers, located at depths of 10 and 70 mm with velocities of 0.5 and 1.0 m/s respectively, are placed in the imaging area. Ten velocities are estimated by speckle tracking using both the full kernel and the crosses. The average errors of velocities measured are 7.3% for D&S and 5.5% for HFR imaging methods with diagonal lines, 2.5% for D&S and 4.0% for HFR imaging methods with bisectors, 3.6% for D&S and 3.2% for HFR imaging methods when both diagonal and bisector lines are used, and 2.6% for D&S and 2.5% for HFR imaging methods based on the full kernel. In the experiment, two small glass beads (point scatterers), located at depths of around 10 and 70 mm with velocities of 0 and a fixed value respectively, were placed in a water tank. The average measurement errors are 15.5% for D&S and 11.4% for HFR imaging methods with diagonal lines, 10.7% for D&S and 12.5% for HFR imaging methods with bisectors, 13.2% for D&S and 9.3% for HFR imaging methods when both diagonal and bisector lines are used, and 10.3% for D&S and 8.7% for HFR imaging methods with the full kernel. These results were obtained with a kernel area of 1.8 x 1.8 mm (or 100 x 100=10000 pixels for the full kernel and 4 x 100=400 pixels for a combination of diagonal and bisector lines). In this condition, the computation time is 18.5 times smaller with the combined diagonal and bisector lines than that with the full kernel (excluding the fixed image reading time). As the size of the kernel is increased, there will be more reduction in computation time with the new method. The new speckle tracking method can achieve similar accuracies in velocity estimations while significantly reducing the computation time.

Keywords - fast speckle tracking, cross, high frame rate imaging

I. INTRODUCTION

The speckle tracking method has been applied for tracking tissue motion in ultrasound images for decades. It has the advantage of angle independent property compared to the tissue Doppler imaging. In 1987, Trahey et al. utilized the cross correlation to calculate block similarity between two consecutive images to detect the blood flow [1]. However, the correlation based two-dimensional (2D) speckle tracking method encountered the difficulty of long computation time. The large computation burden for speckle tracking proposed based on correlation in [1] was alleviated by using the sum of absolute difference (SAD) to search the match block [2]. The SAD algorithm was firstly proposed by Barnea in 1972 to boost the speed of the digital image registration [3]. The sum of squared difference (SSD) was also adopted as a block matching criterion during tracking speckle pattern by Yeung et al. [4]. In addition to utilizing the SSD for the speckle tracking, Yeung et al. also used multilevel method, which was similar to the digital image compression technique, to reduce the computation time, and used motion model-based block matching method to optimize the displacement estimation error. However, this method proposed by Yeung et al. increases the complexity of block matching and meanwhile has lower accuracy of the speckle tracking than the method using SSD only. Another block matching algorithm based on the spatial intensity distribution was proposed by Jung et al. in 2005 [5]. However, this method still uses the SAD to find match block, and additionally, it also requires unknown times of iterations for the block matching with different margins of intensity difference. Jiang and Hall treated the block matching during the speckle tracking as an optimization problem of the cost function to improve the displacement estimation accuracy [6]. However, this method requires a small kernel which makes the speckle tracking susceptible to noise and speckle decorrelation. In short, the existing methods of speckle tracking still face the challenge of improving computation efficiency or otherwise, complex procedures if the computation time is decreased. Recently, the high frame rate (HFR) imaging method is used to track small tissue motions using speckle tracking [7-9]. However, a high image frame rate requires a high image resolution to track small displacement, resulting in large kernels.

To speed up the computation and reduce the complexity for the speckle tracking technique, this paper proposes a fast speckle tracking method. The new method uses three simplified versions of block matching strategies during the speckle tracking. Instead of manipulating all data in a 2D kernel during SAD calculation, the new block matching strategies only manipulate data in a cross or two crosses: two diagonal lines, two bisectors and the combination of two diagonal lines and two bisectors (see Fig. 1). The simplified block matching strategies reduce data manipulation from N² times to be 2N
(Figs. 1(b) and 1(c)) or 4N (Fig. 1(d)) during the speckle tracking. Therefore, the new method reduces the computation time when tracking moving speckles in two consecutive images, and moreover, the time reduction becomes more when larger kernel is used (for example, when N=100 in this study). There are two cases that large kernel size (N) is required: higher accuracy for the speckle tracking and the speckle tracking used in high frame rate (HFR) imaging. Both simulation and experiment are conducted to verify this method of simplifying block similarity calculation during speckle tracking. The images used for the speckle tracking are reconstructed with the HFR and delay and sum (D&S) imaging methods. Dynamic focusing is applied in reception for the D&S imaging method.

This paper is organized as follows. Section II and III provides set-ups and results of simulation and experiments. The study is concluded in section IV.

![Figure 1](image1.png)

**Figure 1.** Three simplified block matching strategies for the fast speckle tracking. (a) indicates that all data in the 2D kernel are used for the SAD calculation. (b), (c), and (d) show respectively only data in the diagonal lines, bisectors, and both the diagonal lines and bisectors are used for the SAD calculation.

II. SIMULATION AND RESULTS

In the simulation study, two point scatterers are assumed in the imaging area (19.2 mm in width and 120 mm in depth) to mimic a virtual tissue segment (see Fig. 2(a)).

![Figure 2](image2.png)

**Figure 2.** Simulation (a) and experiment (b) settings, which are the same as those in [9]. For simulation study in (a), both point scatterers move, but have different speeds to mimic the tissue segment stretch. For experiment study as shown in (b), two glass beads are used to imitate two point scatterers. Only point scatterer 2 moves at an unknown speed but with a fixed step size of 1mm.

Fig. 2(a) also shows the moving directions and speeds of the two point scatterers. 11 consecutive transmissions of the plane wave are used to obtain 11 images for measuring speckle moving velocities. The frame rate is assumed to be 625 frames per second, meaning the time interval between two consecutive images is 0.16 ms. To simulate the noisy ultrasound images in practice, pseudo-random noise with the amplitude equal to 50% of the maximum amplitude of the echo data is added into raw echo data.

Images, reconstructed with the HFR and D&S imaging methods, are shown in Fig. 3, in which the speckles’ moving trajectories are clearly demonstrated. Images are used for speckle tracking with the four different kernels in Figs. 1(a), 1(b), 1(c), and 1(d) to calculate velocity, strain and strain rate. The 2D kernel size of 100*100 (N=100) was used during the speckle tracking. The estimation of the velocities of speckle 1 and 2 in Fig. 2(a) was obtained. The results using diagonal lines are shown in Fig. 4(b). They are compared with the results obtained with the full kernel in Fig. 4(a). The highest average errors of the velocity measured using the diagonal lines during the speckle tracking are 7.3% for the D&S and 5.5% for the HFR imaging methods, respectively, as compared with the highest average velocity measurement errors of 2.6% for D&S and 2.5% for HFR based on the full kernel. The results using bisectors are shown in Fig. 4(c) with the highest average velocity measurement errors of 2.5% for D&S and 4.0% for HFR respectively. The results using the combination of diagonal lines and bisectors are shown in Fig. 4(d), where the highest velocity measurement errors are 3.6% for D&S and 3.2% for HFR, respectively.
It is found that when the speckle tracking utilizes a full kernel, the velocity estimation have the highest accuracy. However, when the combination of diagonal lines and bisectors is used in the speckle tracking, the velocity measurement have comparable accuracy to that with the full kernel, but the computation time based on the former is about 18.5 times less. It is also worth mentioning that the HFR imaging method results in a higher measurement accuracy than D&S imaging method. Moreover, the computation time of the image reconstruction using the HFR is much less than that of the D&S imaging method with dynamic focusing in reception. If a further reduction of computation for the speckle tracking is needed, either bisectors or diagonal lines can be used. It is also found speckle tracking based on the bisectors has higher measurement accuracy than with the diagonal lines in this simulation study. This might be due to the lateral image resolution is lower than that of the axial resolution (unsymmetrical speckle patterns), and thus the bisectors contain more useful information of speckles than diagonal lines.

III. EXPERIMENT AND RESULTS

Two glass beads are used to imitate the point scatterers in experiment set-up (see Fig. 2(b)). The experiment was conducted in a water tank with an assistance of a motor controlling system to move the glass bead (point scatterer 2 in Fig. 2(b)) [9]. Since the motor moving speed is unknown, the moving speed of point scatterer 2 in Fig. 2(b) is unknown too. Therefore the relative moving speed of point scatterer 2 to the exact moving speed (V0) is calculated with the moving step size of 1 mm. 11 transmissions of plane wave are used to produce 11 ultrasound images. A homemade HFR imaging system was used to acquire echo data [10]. Pseudo-random noise was also added into the experimental echo data to produce noisy images, which are shown in Fig. 5.

The results of relative velocity measurement for the diagonal lines, the bisector lines, and the four lines are shown in Fig. 6. The average measurement errors are 15.5% for D&S and 11.4% for HFR imaging methods respectively when diagonal lines are used during speckle tracking, as compared to errors of 10.3% for D&S and 8.7% for HFR when the full kernel is used. When bisectors are used, the average errors of velocity measurement are 10.7% for D&S and 12.5% for HFR respectively. The average errors of velocity measurement are 13.2% for D&S and 9.3% for HFR respectively if both diagonal and bisector lines are used. Overall, the HFR imaging method can provide higher measurement accuracy than the D&S imaging method. The measurement accuracies using simplified kernels are comparable to that using the full kernel.
IV. CONCLUSION

Simplified kernels, using only data located in two diagonal lines, two bisectors, or a combination of the diagonal and bisector lines, for fast speckle tracking are proposed in this paper. They are aimed to reduce the computation time of speckle tracking while maintaining the accuracy of the velocity estimation. Images from simulation and experiment are used to verify the proposed method. The results show that the new kernels reduce the computation time by about 18.5 times while maintaining comparable measurement accuracy as with a full kernel. The new method is promising and could be applied in elasticity imaging, especially when HFR imaging is used.

REFERENCES


