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# Accelerated block-based 2D motion estimation for pre-processing in elastography

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## Abstract

In intravascular ultrasound, we investigate vessel motion due to pulsating blood flow. Relatively large lateral displacements are observed. To incorporate these, we propose an initially 2D displacement estimation based on an accelerated block matching algorithm for preprocessing. In this paper, an accelerated algorithm based on the Successive Elimination Algorithm is described. Furthermore, we evaluated the algorithm based on intravascular ultrasound data. The proposed algorithm is compared to an exhaustive search. The results show a reduction in search time and identical motion field.

## 1 Introduction

Plaque detection has become a hot topic in the medical diagnostic field. In intravascular ultrasound (IVUS) elastography, we make use of the fact that the elastic properties of a plaque are different from the surrounding tissue. Soft material will strain more in comparison to hard material when a deforming pressure is applied [1]. The pressure change is provided by the pulsation. Because the vessel wall deformation has a significant lateral component partially due to catheter motion, two-dimensional modeling has been necessary, although it slows down the RF-data processing. We present a method to speed up the processing of IVUS elastography data, by making an initial 2D displacement estimation for preprocessing on the radio-frequency data. This method has been based on an accelerated block matching algorithm presented for motion estimation in image processing [2].

### 1.1 Block matching based motion estimation

Block matching is a common motion estimation approach. It involves dividing a frame, called the reference frame, into a series of search blocks and for each block finding the position of the best matching block in the next frame, the motion frame, via some criterion. Typically this search is restricted to a limited region around the position of the block in the reference frame.

The performance achieved by block motion estimation depends on the search space. Examining every possible point in the search space leads to best performance at the expense of speed. Most fast algo-

rithms reduce the computational effort by eliminating search positions or by reducing the number of image pixels for which the error criterion is calculated and thus decrease the number of matching evaluations that require intensive computations. Some of these algorithms are suboptimal in that they trade estimation accuracy for speed. In the next section, a method based on the Successive Elimination Algorithm (SEA) is presented [2]. This method accelerates the motion estimation without compromising the optimal solution.

### 1.2 Block matching acceleration

The SEA generates error limits. Only if a candidate block lies within these limits, the error is computed. This leads to a faster algorithm, because that constrains the search process within the search window to a limited number of positions while preserving the optimal solution for the motion vector  $\mathbf{d}$  mentioned below. To generate the limits, an inequality relation is established.

The grey value block of size  $B_1 \times B_2$  of the reference frame with width  $W$  and Height  $H$  centered at  $\mathbf{z} \in \Omega = \{0, \dots, W-1\} \times \{0, \dots, H-1\}$  at time  $t$  is denoted as  $b_t^{\mathbf{z}}$ . The grey value block of the motion frame centered at  $\mathbf{z} + \mathbf{d}$  with the motion vector  $\mathbf{d}$  is denoted as  $b_t^{\mathbf{z} + \mathbf{d}}$ . Using the Cauchy-Schwarz and the triangle inequality it follows:

(1)

$$\frac{1}{B_1 \cdot B_2} (\|b_t^{\mathbf{z}}\|_1 - \|b_t^{\mathbf{z} + \mathbf{d}}\|_1)^2 \leq \|b_t^{\mathbf{z}} - b_t^{\mathbf{z} + \mathbf{d}}\|_2^2 =: SSE(\mathbf{z}, \mathbf{d}).$$

The left hand side in (1) represents the sum-norm of the reference and the current candidate block. Assuming positive grey values, the summation on the right

hand side represents the sum of square error (SSE) evaluated for motion vector  $\mathbf{d}$ .

To further eliminate search positions the left hand side in (1) is multiplied by a tightening factor  $\mu$  that weighs the difference between the sum norms of the reference and the candidate block. For  $\mu > 1$  there is no guarantee that the vector found minimizes the mean square error. The tightening factor increases the computational speed but on the other hand the estimation accuracy is impaired.

## 2 Methods

We made use of a clinical study involving seven patients, who were subjected to IVUS in the range of 30-40 MHz. The data had been collected in the coronary artery. Motion vectors  $\mathbf{d}$  were computed using a frame of  $H = 1024$  and  $W = 256$  for  $B_1 = 50$  and  $B_2 = 10$ . We applied phase-sensitive 2D motion estimation to intravascular ultrasound images. The grid of calculation positions was kept coarse as the vector fields were assumed smooth and they will be used only for initialization of the precise estimation. With our clinical intravascular ultrasound data, 2D motion vector fields could be computed for regions close to the vessel wall.

## 3 Results and Discussion

The computation time for the accelerated block-based method is approximately 85% of the computation time for full search. This poor improvement has been attributed to the high noise level in our data. As the minimization of the SSE criterion is still guaranteed, the error is the same as for full search. The experiments revealed that the number of matching operations is decreased by using (1). However, this number is still very large compared to the number of matching operations leading to a new minimum value. Therefore, a tightening factor was introduced.

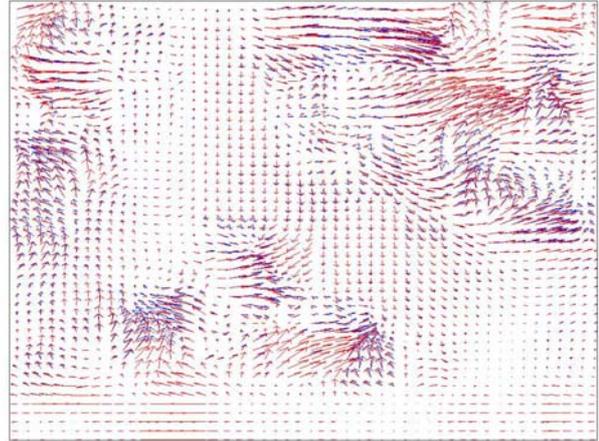
The results after tightening the inequality are listed in Table 1.

$\mu$	COMPUTATIONAL TIME	ERROR
1	85 %	0
2	73 %	0.0008
5	58 %	0.0812
10	42 %	0.1376
30	26 %	0.2214
100	11 %	0.2777

**Tab.1:** Results for tightened inequality

Compared to an exhaustive search block-matcher, the accelerated algorithm with a tightening factor  $\mu = 100$  shows an improvement in speed by a factor

of 10. The decrease in computational time is clouded by the loss of estimation accuracy. This is supported by the mean square error of the motion vector. Figure 1 shows a motion vector field. Blue arrows demonstrate the vector field computed on the exhaustive block matching method. Red arrows represent the motion vector field calculated on the method of tightening the inequality by a factor of 100.



**Fig.1:** An example of a motion field. Each arrow represents a computed motion vector  $\mathbf{d}$ . The computation time sped up by a factor 10 with an MSE of 0.28.

## 3.1 Conclusions

The computation times of the strain images of intravascular ultrasound images can be improved considerably by analyzing 2D motion in a pre-processing step based on accelerated block matching. Even with the acceleration, however, the computation times are too long to allow for an affordable real-time solution in clinical elastography.

## 4 Literature

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