3P5-11

Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 529-530
3-5 December, 2014

Motion Compensated Speckle Tracking in vivo via Particle Filtering

パーティクルフィルタを用いた生体内組織における動き補正スペックル追跡法

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1. Introduction

There is a great demand for micro movement tracking throughout ROI (Region of Interest) such as small lesions in vivo, which is usually submerged in global movement caused by inner impact such as contraction and diastolic of pulsation and respiration, or by external impact. Micro movement throughout ROI expresses a wealth of local physiological features including viscoelasticity, mass and structure of pathological tissue [1)], which are necessary for diagnostic imaging as well as surgery operation.

Time consuming is a main obstacle existing in conventional motion compensation technique that based on correlation between base frame and reference frame [2)] especially when RF signal is used [3)]. Although the size of each subregion area both in base frame and reference frames is dynamically adjusted in order to decrease the computational cost [4)], it is still time-consuming because of its traversal searching in subregions of reference frames. Furthermore, compensation vectors are greatly affected by local minimum due to the range limitation of searching area, which might cause decreasing of compensation precision.

As a representative of filtering technique that estimates target state using measurement information, particle filtering is getting prevailing because of its robust tracking performance especially in non-linear cases and non-Gaussian noise environment [5)]. A motion compensated speckle tracking method using particle filtering is introduced.

2. Methods

Discrete $(k = 1, 2, \cdots)$ nonlinear system can be described as

$$\begin{cases} \boldsymbol{x}_k = f(\boldsymbol{x}_{k-1} + \boldsymbol{\omega}_k) \\ \boldsymbol{z}_k = h(\boldsymbol{x}_k + \boldsymbol{r}_k) \end{cases} \quad (1)$$

where $\boldsymbol{x}_k, \boldsymbol{\omega}_k, \boldsymbol{r}_k \in \Re^n$ are state, process noise, and measurement noise vector respectively. f refers to the state transition function whose rationality needs to be verified after obtaining measurement vector $z_k \in \Re^n$ in observation function h. Particle filtering uses a set of particles which represents random selected speckle samples to estimate the posterior distribution. **Fig. 1** shows the processing flow of the proposed method.

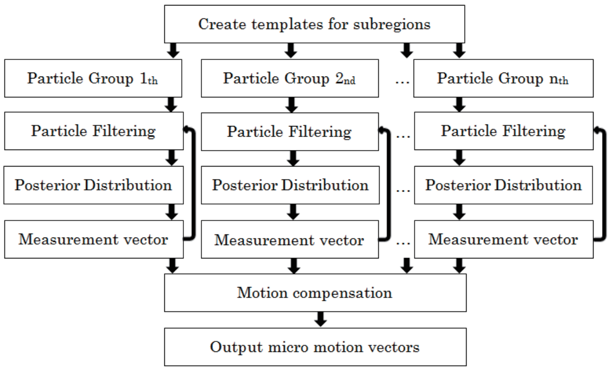

Fig. 1 Processing of speckle tracking

Schematic diagram with 9 subregions in base frame is shown in **Fig. 2**. Particle groups with the same number of subregions are created separately. Particles corresponding with each subregion distribute around each central area of subregion first within own radius range. However, particle groups work individually, which means no interference between each other group. An approximate distribution for each group can be obtained after correlating with measurement. Then particles are resampled and predicted for next iteration. Thus, after several iterations, a renewed distribution will be obtained which is approach to the optimal one.

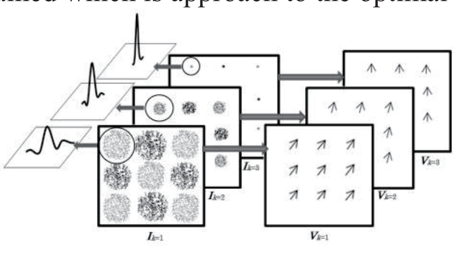

Fig. 2 Schematic diagram of iteration

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3. Simulation results

This method is prospected to be competent in tracking the micro motion throughout small ROI in vivo superposed with global movement. Speckle with both global and local micro movement for simulation is made by means of PSF (Point Spread Function). Observation area is set to be 40 mm*40 mm, and ROI area is assumed to be a circle in the center observation area with a radius of 10 mm. 64 groups of particle is created corresponding to subregion number in base frame. Each group uses 50 particles which are completely independent with other groups.

1. Convergence variety

Normalized standard deviation between estimated motion and ground truth motion is evaluated. Convergence changing graphs of 10 iterations along with 5, 15, 50 and 100 particles in each group are shown in **Fig. 3** respectively. As the number of particle increases, samplings will approach to the optimal distribution. However, few particles iterating for suitable times can save computation cost in the premise of no affect on precise of tracking.

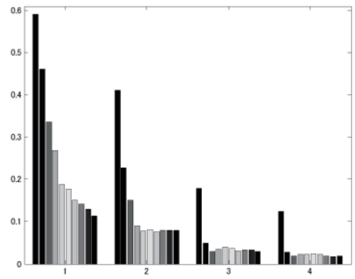

Fig. 3 Normalized standard deviation changing

2. Motion compensated speckle tracking

Global motion is set to be downward with the range of 1 mm. The ROI, circled by dotted line in **Fig. 4** (b), dilates from the center with the range of 0.06 mm. Results of global motion superposed with mirco motion and the motion compensated mirco dilatational motion throughout ROI are shown in Fig. 4 respectively.

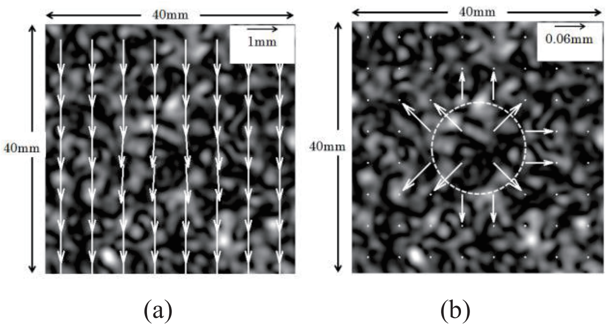

Fig. 4 Speckle tracking (a) mirco motion superposed global motion, (b) mirco dilatational motion

3. Computation cost

Computation cost of conventional method [4] and the proposed method in this paper is shown in **Fig. 5** respectively. Thereinto, the right bar is the result of the proposed method with 3 times of iteration and using 50 particles for each group. Both of them use SAD (Sum of Absolute Differences) method which is low time consumption [3].

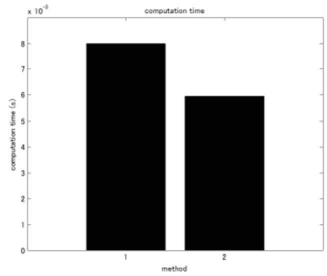

Fig. 5 Computation cost comparison

Comparing with conventional method, the proposed method saves 25.6% calculation cost. Although dynamic window was used in conventional method in order to reduce calculation, it is still based on traversal searching within subregions. The computation cost of the proposed method is greatly decreased by using particle filtering to estimate posterior probability distribution in each iteration step by random samples.

4. Conclusions

Simulation results show the effectiveness of the proposed speckle tracking method on both precision and computation cost. It is demonstrated that the tracking method is capable of visualizing micro motion throughout small ROI in vivo, which is superposed with global movement. This method is also prospected to be able to extend to three dimensional tracking by extending the dimension of state variables of particle filtering.

Acknowledgment

This paper is funded by China Scholarship Council.

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