Enhanced particle tracking algorithm based on a modified expectation maximization algorithm

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An enhanced particle tracking algorithm is developed based on a modified expectation maximization algorithm. Particle tracking results using this method for a series of nine synthetic vortical test images are compared to results obtained using the algorithms of Baek & Lee [1] and Labonte [2]. The test cases utilized particle drop out, varying vortex sizes and shapes and other parameters to evaluate the algorithms. The appreciable improvement in the accuracy of EPTA tracking results for the test cases presented here shows the benefits of explicitly incorporating a vector field representation that is flexible yet regularized and serves as a model to both guide and constrain the process of determining particle correspondence. In particular, it is shown how two B-spline surfaces that are regularized using either a thin plate spline (TPS) or velocity-shear-dilation (VSD) model can accommodate flow gradients while attempting to maintain a degree of smoothness in the displacement field during the determination of particle-to-particle correspondence.

Nine synthetic test cases are used to benchmark the utility of the EPTA in comparison with the algorithms of Baek & Lee [1] and Labonte [2]; however, it is important to note that this comparative analysis is not meant to statistically quantify the amount by which one algorithm is 'better' than another. Providing a conclusive comparison between the many existing PTV algorithms over a range of flow conditions has yet to appear in the literature and should be the subject of future work. With this in mind, it should also be noted that accomplishing such a task will not be a simple matter because there is not unified agreement about the important aspects that should make up such a comparison.

The results presented facilitate many comparative analyses however the following four general evaluations are the most important.

1. Except for case 1.1, both the thin plate spline (TPS) and vorticity-shear-dilation (VSD) versions of the enhanced particle tracking algorithm (EPTA) outperform the methods of Baek & Lee [1] and Labonte [2]. For case 1.1, which is a single vortex with 200 particles, results for all methods are comparable. To quantify the improvement of the EPTA over the other methods, the average difference of the TER over all particle dropout scenarios is listed for each case in table 4. The most significant differences in the TER are observed for cases 3 through 9 where the combined effects of increased particle number density, greater particle displacement, and larger flow gradients make the tracking problem more difficult. Averaging TER values over all test cases, values obtained for the EPTA are higher than those of obtained for Labonte and Baek & Lee by 0.45 and 0.20 respectively.

2. Based on the results in tables 2 and 3 the differences between the TPS and VSD versions of the EPTA are not large enough to make definitive conclusions about whether one method is superior to the other.

3. As a general rule, the best tracking results are obtained when there is no particle dropout. This observation is independent of the tracking algorithm employed. As particle drop out increases the tracking problem becomes more difficult for all of the algorithms. In general, the degradation of TER values from that obtained for the 0% particle dropout case is largest for the method of Labonte [2], but is also significant for the method of Baek & Lee [1]. TER values are also degraded for the EPTA but to a lesser extent than for the other methods. Degradation of the TER for the EPTA is most evident only for the more complicated flows in cases 8 and 9 which contain 8 and 16 vortices respectively.

4. Except for the method of Labonte [2], the tracking results for all algorithms are better for the 'few to many' scenario than for the 'many to few' scenario. Over all test cases, the average difference between the TER value calculated for the 'few to many' and the 'many to few' scenarios are 0.11, 0.08, and 0.11, for the algorithm of Baek & Lee [1] and the EPTA with TPS and VSD, respectively.

At present there does not exist a practical PTV algorithm that is general enough to be used in a variety of flows without significant user intervention and/or pretesting. As such, there still exist exciting opportunities for future research in the area of PTV and the future development of the EPTA and/or algorithms that employ ideas contained within the EPTA.

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