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Accuracy Improvements in Particle Image Velocimetry Algorithms

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ABSTRACT

An adaptive, second-order accurate particle image velocimetry (PIV) technique is presented. The technique uses two singly pulsed images which are interrogated using a modified cross correlation algorithm. Consequently, any of the equipment commonly available for conventional PIV (such as dual head Nd:YAG lasers, interline transfer CCD cameras, etc.) can be used with this more accurate algorithm. At the heart of the algorithm is a central difference approximation to the flow velocity (accurate to order t^2) versus the forward difference approximation (accurate to order t) common in PIV. In order to use the central difference approximation, an adaptive interrogation region shifting algorithm must be used. Adaptive shifting algorithms have been gaining popularity in recent years because they allow the spatial resolution of the PIV technique to be maximized. Adaptive shifting algorithms also have the virtue of helping to eliminate velocity bias errors. Consequently, since in many cases an image shifting algorithm would be used anyway, the second order accuracy of the central difference approximation can be had for very little additional cost.

The adaptive central difference interrogation (CDI) algorithm has two main advantages over adaptive forward difference interrogation (FDI) algorithms: it is more accurate, especially at larger time delays between exposures; and can maximize the signal-to-noise ratio of the velocity measurements. The technique is shown to perform better than conventional PIV algorithms when measuring near flow boundaries and in areas of low signal-to-noise ratio by comparing measurements of flow around a single red blood cell. Also, the technique is shown to be significantly more accurate than conventional PIV algorithms as the time delay between exposures is increased by interrogating cylindrical Couette flow images acquired both experimentally as well as computationally. The results of the interrogations are shown to agree quite well with analytical predictions and confirm that the CDI algorithm is indeed second order accurate while the conventional FDI algorithm is only first order accurate.