Adaptive MLOS-SMART improved accuracy tomographic PIV

Callum Atkinson1,2, Nicolas Buchmann1, Michel Stanislas2, Julio Soria1

1: Laboratory for Turbulence Research in Aerospace and Combustion, Department of Mechanical and Aerospace Engineering, Monash University, Melbourne, Australia, Callum.Atkinson@eng.monash.edu.au
2: Laboratoire de Mecanique de Lille, Ecole Centrale de Lille, Lille, France

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To improve the accuracy of tomographic particle image Velocimetry (Tomo-PIV) an adaptive reconstruction method is implemented based on the accelerated MLOS-SMART reconstruction technique. Adaptive MLOS-SMART (AMLOS-SMART) attempts to reduce the presence of ghost particles and reconstruction noise by iteratively adapting reconstructed intensity fields based on an estimate of the velocity field, retaining only those particles that are present across consecutive exposures. Non-coherent intensity peaks are removed from the solution, which reduces the influence of ghost particles and their associated contamination of the velocity field. This paper describes the working principles of this method, with a performance assessment based on the use of simulated images, including the influence of image noise and calibration error.

1. AMLOS-SMART method

The AMLOS-SMART approach involves dividing the measurement domain into a series of sub-volumes. Multiplied line of sight (MLOS) estimation of all possible particle locations is performed and projected images are calculated for each camera, based on the estimated particle locations. The ratio of the recorded and projected images is then used to establish a correction for the intensity at each particle location using a simultaneous multiplicative algebraic reconstruction technique (SMART) as outlined in Atkinson and Soria (2009).

The accuracy of this reconstruction is improved in a manner analogous to that described by Novara et al. (2010). The average displacement of each particle in a sub-volume is determined by cross-correlation of sub-volume A with an associated sub-volume B, reconstructed from a subsequent image. The displacement of this sub-volume is then validated and smoothed before being used to adapt the intensity of each potential particle, based on whether or not a corresponding shifted particle is found in the opposite exposure. Two methods for adapting intensity are used based on a direct search or an intensity averaging.

The performance of this technique is evaluated using simulated particle fields and images where the effect of seeding density, calibration error and image noise are considered. Results are compared with those of the standard 5 MART iterations and 10 or 40 MLOS-SMART iterations. The effect of these methods is illustrated in Fig. 1, where the reconstruction coefficient $Q$ represents the correlation between the reconstructed and simulated particle intensity fields.

Fig 1. Effect of iterations and adaptive steps on the standard and adaptive reconstruction methods. Simulated volume of 1000x1x200 pixels, 4 cameras at angles of -30, -10, +10, +30 deg, seeding density of 0.2 ppp. Adaptive correction is applied every 10 or every 40 MLOS-SMART iterations.

Conclusions

A method to adapt the efficient MLOS-SMART technique for improved reconstruction accuracy has been presented, which should be able to reconstruct a volume of 1000x1000x200 pixels in under 2 hours per volume object compared to 10 hours for similarly corrected MART based reconstruction. AMLOS-SMART has been evaluated using simulated particle fields and camera images. Results indicate for seeding densities > 0.1 ppp AMLOS-SMART provides significant improvement in the reconstruction quality and a reduction in random velocity errors of up to 0.7 pixels, even in the presence of calibration error and image noise. At standard seeding densities (0.05 ppp) AMLOS-SMART was shown to maintain a random velocity error of 0.2 pixels despite calibration errors up to 1 pixel. The same benefits were not seen for standard seeding densities in the presence of image noise, indicating that careful image preprocessing is still needed to ensure accurate velocity measurements.

References
