ADVANCED DEVELOPMENT OF METHODS FOR GLOBAL ADAPTIVITY IN PIV TECHNIQUES FOR COMPLEX FLOWS AND INTERFACES

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PIV has matured as a measurement technique enabling to describe whole field velocity from digitally recorded particle image motion. Nowadays the analysis of the PIV recordings is mostly based on the cross-correlation of small interrogation areas. Prior to starting the interrogation process, the processing parameters (primarily window size and overlap factor) are optimized in a global sense by the user itself. The user must make a compromise between process-robustness, requiring large interrogation windows, and spatial resolution, which demands the application of small windows. Once selected the fixed window size and overlap are used everywhere throughout the recording. This user-defined dependency inherits the disadvantage of applying non-optimal parameters since the recorded flow field can contain possibly spatially varying seeding density or velocity fluctuation length scales. A straightforward example is the presence of interfaces where current PIV algorithms tend to give biased displacement results due to scattering of light (reflections) and signal truncation and suffer furthermore from poor spatial resolution. At this point an algorithm has been devised incorporating signal adaptivity and flow adaptivity. The former relates the number, location and size of the interrogation areas to the amount of available signal i.e. tracers. Flow adaptivity prescribes the distribution and size of interrogation windows such that they properly sample the spatial fluctuations in the flow qualified by the spatial standard deviation in velocity. Within an iterative structure the algorithm automatically processes the digital flow recording such as to obtain the best possible results for each snapshot-couple. This is done in order to limit the user interaction. To minimize the degradation of the correlation process near interfaces a special interface treatment has furthermore been implemented. This feature not only included an extension of the adaptivity parameters and a relocation of the obtained displacement vector but also a adjusted correlation operator to exclude interfaces from the correlation operation itself. Experimental applications have demonstrated the improved robustness, consistency and enhanced resolution of the presented methodology (see Figure 1).

The above presented adaptive technique focused on the optimization of adaptivity criteria for each pair of image recordings. Academic and industrial applications however deal with large data sets in the order of 100 or even thousands of image pairs. Current research therefore aims at optimizing the processing parameters for a series of flow recordings. At this moment merely flow adaptivity is taken into account through non-isotropic window sizing. The window eccentricity is based on the eigenvalues of the Hessian tensor for the statistical mean of the processed data fields. The optimization becomes therefore an iterative and time-elaborate process. Instead, the already existing correlation methodology *ensemble correlation* has been demonstrated in literature to be robust in providing a mean flow estimate when dealing with quasi-steady phenomena. The goal now is to be able to extract information concerning the signal from the ensemble correlation function, which would allow an optimized signal-based sizing of the correlation windows. Global optimization would furthermore allow a drastic reduction in computational effort since the number of correlation windows can be limited through the adaptive sampling. Post-processing of the obtained results often restricts itself to the mean values of a statistical quantity. Though of importance, confidence levels are often omitted or erroneous through application of non-valid formulae. Recently, in collaboration with A. Di Sante, an existing statistical technique known in the econometric community as dependent circular block bootstrapping, has been brought to the attention of the PIV community. This technique had never before been applied to PIV data. Examples considering both dependent and independent data have however demonstrated the robustness, consistency and ease of the bootstrapping technique in the determination of the mean value of any statistical parameter and coherent confidence levels.

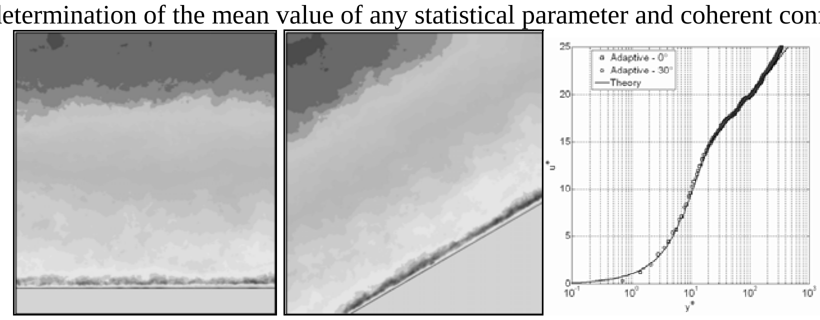

Figure 1: PIV analysis of a turbulent boundary layer over a flat plate. (Left) Turbulence intensity for original images (Middle) and for the images rotated over 30°. The TI does not increase, indicating an equal number of outliers. (Right) Plotting the u+y+-profile indicates the consistency of the adaptive method