Cross-correlation or tracking - comparison and discussion

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The determination of velocity fields in 2D with particle image velocimetry using correlation based evaluation methods is state of the art since many years. Correlation works very robustly even for low signal to noise ratios. However, for the evaluation of a single vector, several particle images are required thus limiting the spatial resolution [2, 3]. Due to the improvements in image recording, particle manufacturing and laser technology even for single particles, reliable velocity measurements can be done. Especially for volumetric techniques, where the seeding is sparse, PTV offers great potential to increase the spatial resolution dramatically. In this paper, different techniques will be discussed to reliably detect particle images and determine their center accurately. Since the data is not available on a structured grid, gradient estimation becomes more complex. However, three different methods are tested and show good results, thus particle tracking might become more attractive for many fluid dynamic applications.

One of the biggest advantages of PIV is the representation of the velocity vector field on a regular grid. The gradient estimation is straightforward for each coordinate direction using neighboring data points. For unstructured grids the data is often interpolated on a regular grid. However, all interpolation methods cause data smoothing since more data points (at least 8 in 3D) are used. This decreases random errors but might smooth large gradients. Hence, the resolution for PTV would decrease drastically. Furthermore, the grid spacing should be large enough to match the Nyquist criterion also in regions of sparse seeding (vortex cores, recirculation regions etc.) thus lowering the overall resolution. A comprehensive comparison of different gradient estimation methods was recently presented by Correa et al. [1]. Three different averaging schemes were tested and a comparison of these PTV gradient estimation methods with a typical PIV method was performed using the Lamb-Oseen vortex model. As can be seen on the 2D vorticity distributions in Figure 1 on top, the resolution for PIV is rather low and underestimates the gradients. Since in PTV the vector positions are randomly distributed in space the resolution can be greatly enhanced for stationary flows. For the data presented in Figure 1 a very high uncertainty of 0.1 pixel was assumed for the displacement estimation to test the robustness of the different weighting schemes. In the lower part of the figure the larger scatter for the PTV gradient estimation methods can be clearly seen. In contrast to image rendering, the inverse distance weighting gives a larger scatter since the relative error for gradients in the close neighborhood is significantly stronger. Using the median averaging provides very good results and proves to be a suitable method to determine gradients on unstructured grids.

Fig. 1 Vorticity distribution PIV evaluation and PTV gradient estimation using mean, median and inverse distance averaging (top) and radial distribution (bottom).

The paper discussed particle image detection methods and the gradient estimation in greater detail and provides guidelines when to apply PTV or PIV.