On the stabilization and spatial resolution of iterative PIV interrogation

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Keywords: PIV processing

The stability and spatial resolution of iterative PIV interrogation methods was investigated from a fundamental standpoint. It has been shown that the iterative process is intrinsically unstable due to sign reversal in the frequency response of the cross-correlation operator (Nogueira et al 1999, Scarano, 2004) and the results may diverge unless the image processing is interrupted at an early stage.

To compensate for this unstable behavior filtering is applied, which can be done in several ways and in several places in the iterative process. In the study three different filtering approaches are studied: predictor filtering, corrector filtering and image weighting. In case of predictor filtering a two linear and one non-linear filter is used. The linear filters are a moving average filter (*pz∞*) and a less strong filter (*pz1e-2*) that is obtained by using a one-parameter filter approach (Schrijer and Scarano, 2006). The non-linear filter is a second order least squares fit (regression) to the predictor field (*regr*). For corrector filtering a moving average filter is used (*cz∞*). Finally for image weighting the LFC function introduced by Nogueira et al (1999) is used (*LFC*). These methods are compared to the non-filtered approach referred to as local predictor (*Local*).

First the filtering approaches are investigated theoretically on stability and spatial resolution. This is followed by a numerical assessment by means of synthetic images where two displacement fields are considered: a one-dimensional shearing motion and a two-dimensional vortex-like flow field. In both displacement fields the wavelength was varied. In Figure 1 the spatial modulation is given for the two-dimensional displacement at the 4th iteration.

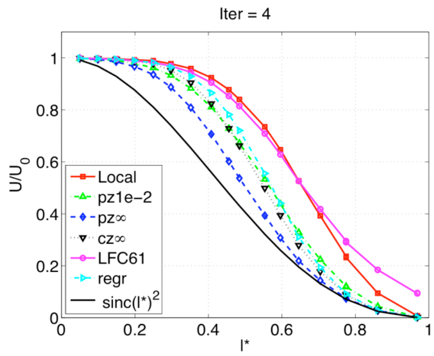

Fig. 1 - Spatial response of cross-correlation analysis for a 2D sinusoidal displacement

The figure shows that the *LFC* method shows the best spatial response, similar to the local method. The most modulation is observed from the moving average predictor filter. The rest of the approaches are found to give intermediate results. The displacement rms values are presented in Figure 2 where it can be seen that the local method is unstable since the curve diverges. The rest of the methods show a stable behavior. The rms values are found to be the lowest for the *LFC* mehod, directly followed by the regression, corrector and linear filtered predictor approaches.

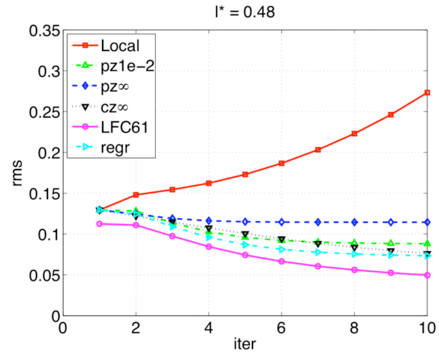

Fig. 2 - rms values of cross-correlation analysis for a 2D sinusoidal displacement

Finally the filtering approaches were applied to an experimental dataset of 200 images of a water-flow over a backward facing step. From the spatial distribution of the average velocity magnitude followed that the moving average predictor filter showed the most modulation effects compared to the rest of the filtering approaches, which yield similar results. The rms values of the vertical velocity component depicted in Figure 3 show that the filtering approaches result in similar rms values, except for the moving average predictor filter, which attenuates the rms values. In case of the local (non-filtered) predictor was found that the rms values increased due to instabilities in the process.

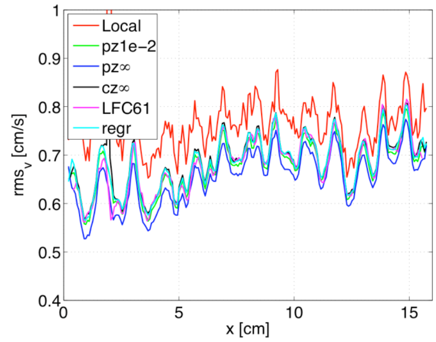

Fig. 3 - rms of the vertical velocity component at the line y = 3 cm

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