LaVision

We count on Photons

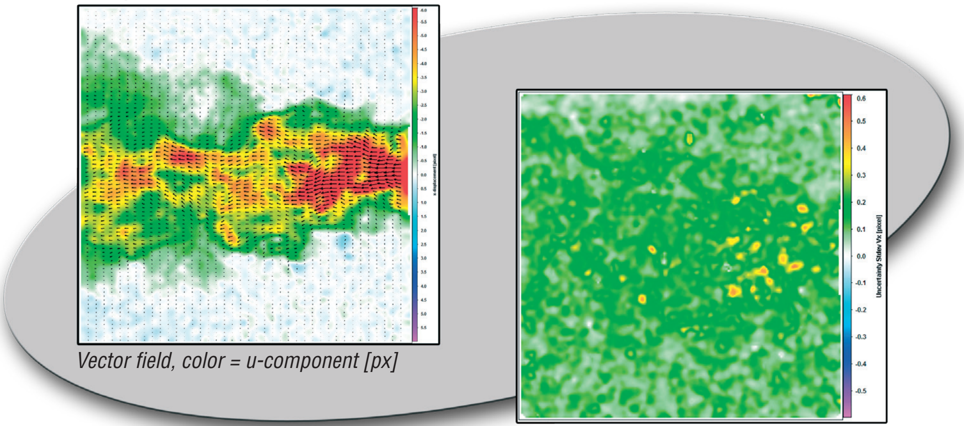
PIV Uncertainty

Instantaneous local uncertainties added to PIV results in DaVis

Particle Image Velocimetry (PIV) is a well-established measurement technique in fluid mechanics and has been continuously developed and refined over the last 30 years. As with any measurement technique it is necessary to estimate the associated errors (‘uncertainties’) for individual computed velocity vectors and by extension, derived quantities.

Both systematic and random error sources are minimized by recent developments in processing algorithms but can be further reduced by optimizing the experimental setup. For example, calibration misalignment is eliminated with LaVision’s self-calibration routine and sub-pixel displacement measurement accuracy is maximized by sophisticated sub-pixel interpolators and correlation peak-finding routines. However, quantifying the remaining measurement uncertainties for all experimental and processing parameters – seeding density, out-of-plane-motion, interrogation window size, etc. – has remained a significant challenge.

Example: PIV Challenge 2003, case A-50

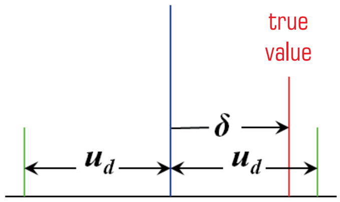


Vector field, color = u-component [px]

Uncertainty of u (10 x enhanced scaling)

Definition of uncertainty

In general, an uncertainty value u_d defines a range around the measured value *V*. The true value lies within V±u_d with some probability level of e.g. 68% (1-sigma) or 95% (2-sigma) assuming a Gaussian-shaped normal distribution.



Recently, PIV uncertainty quantification has been the subject of broader attention and has resulted in a dedicated symposium in Las Vegas (2011) as well as special sessions at several fluid dynamics conferences.

As part of an international collaboration [1,2], LaVision has now implemented an uncertainty quantification method based on correlation statistics [3]. This technique is able to provide an uncertainty value for individual instantaneous velocity vectors for planar 2D- and Stereo-PIV. The method is universal and works for all processing parameter settings in DaVis and comprehensively captures error sources included in recorded PIV images.

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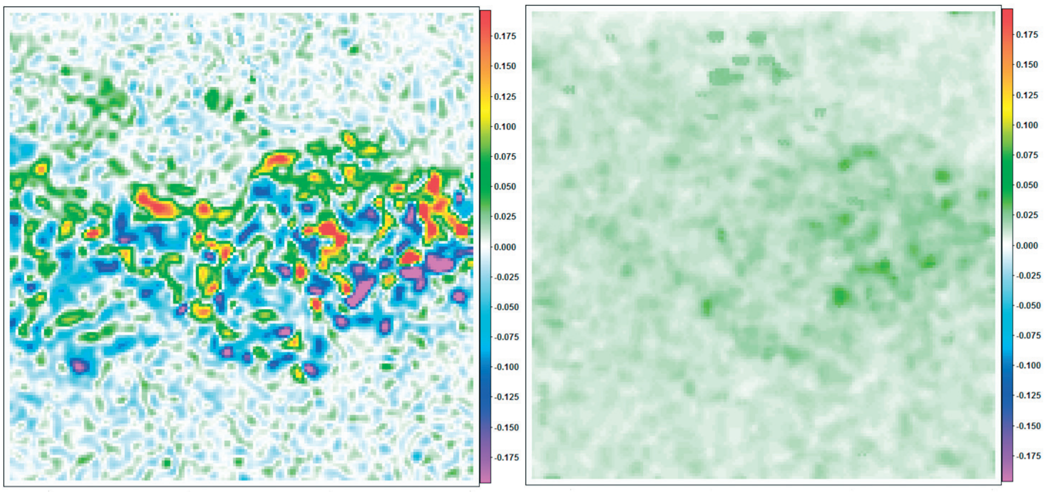
Correlation statistics method

The basis of this method of uncertainty quantification utilizes the differences between the two interrogation windows which have been mapped back onto each other by the computed displacement vector field. In the idealized case of an exact measurement all corresponding particle images match perfectly onto each other producing a symmetric correlation peak. In real measurement situations such paired images do not match exactly, and the positional disparity is reflected in a non-symmetric correlation peak. From a statistical analysis of how each pixel contributes to the cross-correlation peak shape the uncertainty of the displacement vector is derived. Details can be found in [3]. The method computes PIV uncertainties independently for the u and v components, and for w in case of Stereo-PIV. The uncertainty for derived values – avg, stdev, TKE, vorticity, Reynolds-stresses etc. – is quantified using the appropriate uncertainty propagation techniques .

PIV Challenge 2003, case A-50



Vorticity field (left, in units of %) and corresponding uncertainty (same scaling)

[1] Neal DR, Sciacchitano A, Smith BL and Scarano F (2014), Collaborative framework for PIV uncertainty quantification: the experimental database, 17th Int Symp Appl Laser Tech Fluid Mech, Lisbon, Portugal.
[2] Sciacchitano A, Neal DR, Smith BL, Warner SO, Vlachos PP, Wieneke B and Scarano F (2014), Collaborative framework for PIV uncertainty quantification: comparative assessment of methods, 17th Int Symp Appl Laser Tech Fluid Mech, Lisbon, Portugal.
[3] Wieneke B (2014), Generic a-posteriori uncertainty quantification for PIV vector fields by correlation statistics, 17th Int Symp Appl Laser Tech Fluid Mech, Lisbon, Portugal.

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