UNCERTAINTY ANALYSIS FOR PIV MEASUREMENTS

The uncertainty of a measurement is the interval in which the actual error is present. For Particle Image Velocimetry (PIV), the error depends on the PIV algorithm being employed, user inputs, flow characteristics, and experiment setup. Since these factors vary in time and space, they lead to PIV capturing inconsistent errors throughout the flow field.

Charonko & Vlachos found PIV uncertainty is correlated with image quality. [1] Local image quality contains many possible sources of error in an experiment including the PIV algorithm (interrogation window size, pixel displacement, image pre-processing, etc.). The primary measure of local image quality is the Primary Peak Ratio (PPR). The PPR is the ratio between the primary peak in the correlation map and the second highest peak; uncertainty is inversely correlated to the PPR.

TSI's uncertainty algorithm was validated by creating synthetic PIV images from a Direct Numerical Simulation (DNS) of a fully-developed turbulent channel flow. The synthetic images included light sheet thickness variations and the flow was three-dimensional with strong out-of-plane velocities. Insight 4G™ software was used to calculate velocity vectors that were then compared with the DNS baseline. Figure 1 shows that the uncertainties from our algorithm correctly predict the actual errors at two confidence intervals.
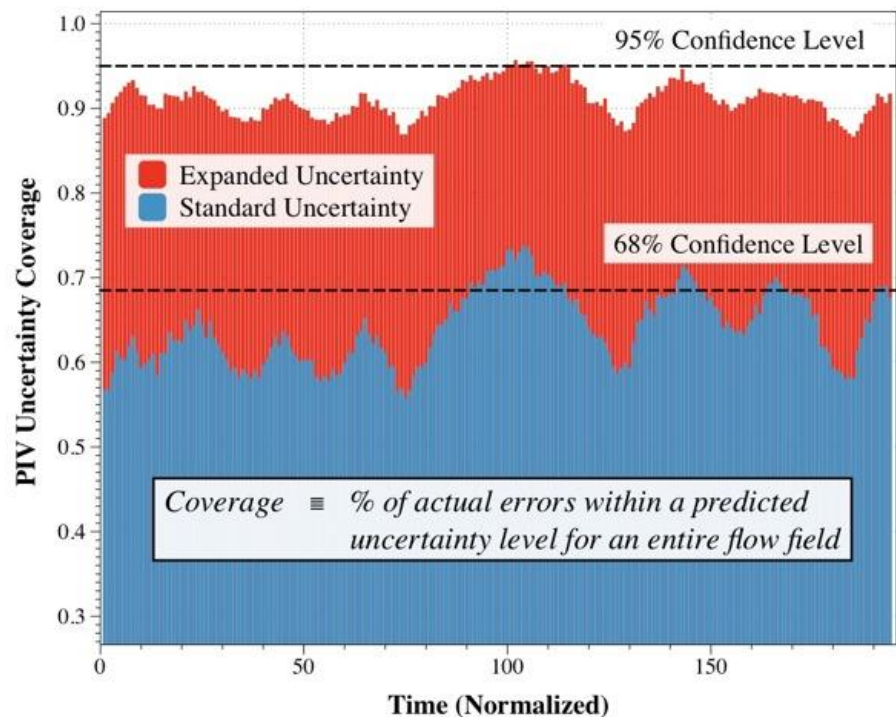

Figure 1: Expanded and standard uncertainty coverage of a turbulent channel flow with known errors.

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[1]Charonko, & Vlachos, P. (2013). Estimation of Uncertainty Bounds for Individual Particle Image Velocimetry Measurements from Cross-Correlation Peak Ratio. Measurement of Science, 24.

Calculating Uncertainty with Insight 4G™ Software

The magnitude of uncertainty can be calculated with the following equation:

$$|unc|^2 = \left(M \exp\left(-\frac{1}{2}\left(\frac{PPR-1}{s}\right)^2\right)\right)^2 + \left(A * PPR^\beta\right)^2 + (C)\^2$$

M, s, A, β, c are fitting coefficients for Insight 4G™ software. The results will be measures of uncertainty based upon the multiple sources of error in PIV image processing.

Exporting Uncertainty in Insight 4G Software

To export the calculated uncertainty levels in Insight 4G™ software, access the PIV processing window, select the "Advanced>>" tab and export either (or both) uncertainty levels, as shown in Figure 2.
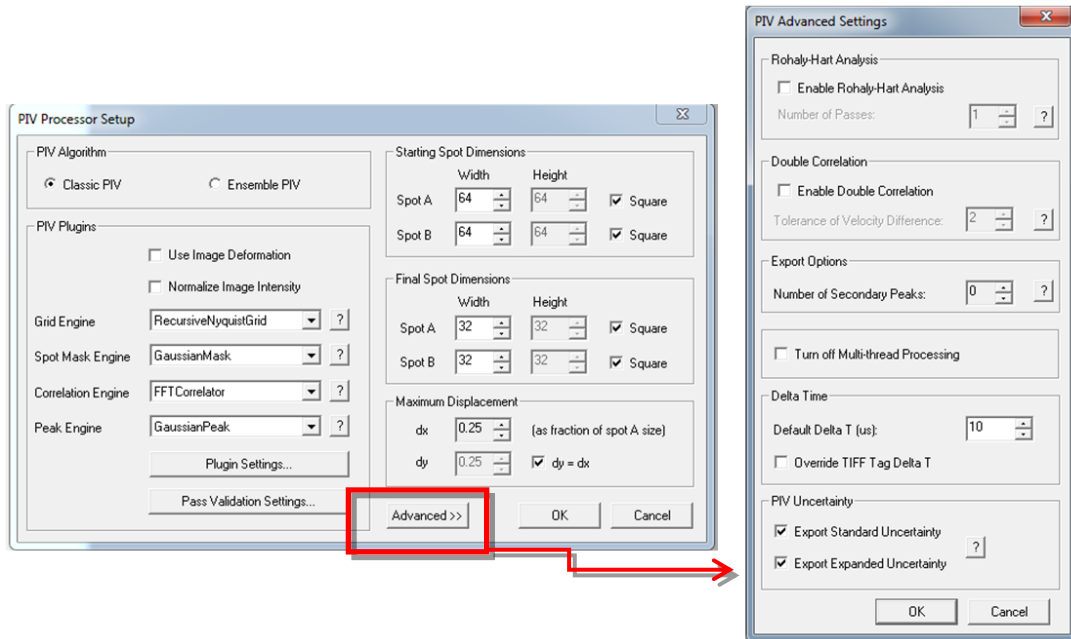

Figure 2: Exporting the standard and expanded levels of uncertainty in Insight 4G software.

Once activated, uncertainties are viewable in Tecplot® as contours. In Figure 3, instantaneous values of relative uncertainty are plotted along with time-resolved vectors of velocity.
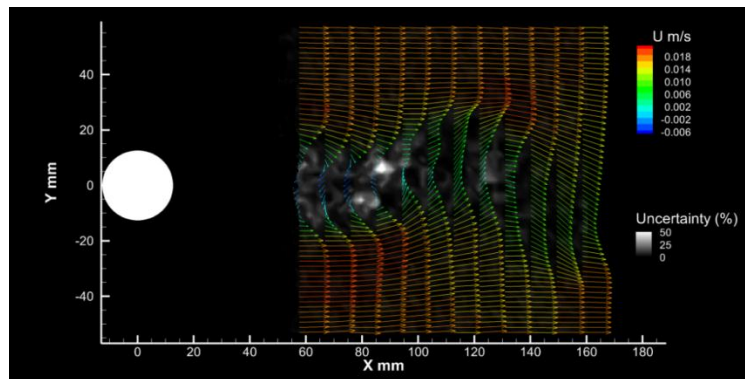

Figure 3: Contour plot of relative uncertainty of flow behind a cylinder