Quantification of the loss-of-correlation due to PIV image noise

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HIGHLIGHTS

\begin{itemize}
  \item The loss-of-correlation due to PIV image noise is estimated from the height of the auto-correlation function.
  \item A useful definition of the SNR of PIV images is the ratio of the standard deviations of the noise-free image and the image noise.
\end{itemize}

ABSTRACT

In this work, a new method is proposed to estimate the loss-of-correlation due to image noise $F_\sigma$ from the auto-correlation function of PIV images. Furthermore, a new definition of the signal-to-noise ratio $SNR$ for PIV images is suggested

$$SNR = \frac{I_0}{2\sigma_n} \sqrt{\frac{N_{ppp}}{\left(\frac{\pi}{4}D^2 - 1\right)}},$$

which results in a bijective relation between $F_\sigma$ and $SNR$: 

$$F_\sigma = \left(1 + SNR^{-2}\right)^{-1}.$$

Based on the newly defined $SNR$ it becomes possible to estimate the signal level and the noise level itself by adding additional noise with known intensity to the images. The presented method is very general because the estimation of $F_\sigma$ and $SNR$ works independently of various parameters, including the particle image intensity, the particle image density and the particle image size. The findings lead to an extension of the fundamental PIV equation 

$$I = N_{ppp} F F_F F_A$$

and enable PIV users to optimize their measurement setup with respect to the image noise and not only based on the loss-of-correlation due to in-plane motion, out-of-plane motion and displacement gradients. Furthermore, the new definition of $SNR$ allows for a characterization and comparison of PIV images. Finally, the quantification of the uncertainty contribution due to image noise is possible.

Fig. 1 Loss-of-correlation due to image noise as a function of the $SNR$. Each symbol contains a variation of $D$ and $N_{ppp}$.