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Quantification of uncertainty in a stereoscopic particle image velocimetry measurement

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ABSTRACT

In Stereoscopic Particle Image Velocimetry (Stereo-PIV), the three velocity components are obtained by illuminating a planar region in the flow field and recording the region of interest using two cameras at an angle. Calibration, planar velocity estimation, and velocity reconstruction are the three essential steps involved in the process. Earlier efforts to quantify the accuracy in a Stereo-PIV measurement process have shown higher error in out of plane motion. However, a detailed analysis of the measurement uncertainty involved in a Stereo-PIV calibration-based reconstruction process has yet to be presented. This analysis provides a detailed framework to specify the uncertainty in the coefficients of the calibration mapping function and the uncertainty involved in self-calibration step for correction of the registration error. Using Taylor series expansion for uncertainty propagation the contribution of the calibration step uncertainties are combined with planar field uncertainties to predict the overall uncertainty in the reconstructed velocity components. The analysis is tested using simulated random field images and experimental vortex ring images. The results emphasize the sensitivity and interdependence of the individual uncertainties involved in each step of a Stereo-PIV measurement process.