A POD-based spatial resolution enhancement method for real-time event-based imaging velocimetry

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Event-Based Imaging Velocimetry (EBIV) introduces a novel paradigm in flow diagnostics by replacing conventional frame-based image acquisition with asynchronous, high-frequency event data, enabling reduced latency and lower data rates for real-time applications [1].
We propose a real-time method to estimate high-resolution (HR) flow fields from low-resolution (LR) EBIV data, based on POD-driven spatial refinement [2]. In the offline phase, EBIV recordings are processed using both fast single-pass (LR) and accurate multi-frame, multi-pass (HR) cross-correlation. POD is applied to extract spatial modes and temporal coefficients. Online, new LR measurements are projected onto downsampled HR modes to estimate coefficients, which are then used to reconstruct the HR field. A Kalman filter refines the coefficients using a dynamic model learned from training data, enhancing temporal consistency and robustness. The methodology has been tested on two flow configurations: a turbulent channel flow in air at 5 kHz and a submerged water jet in water at 200 Hz [3]. Results demonstrate the method's capability to deliver fast and accurate high-resolution estimations, making it suitable for real-time flow analysis in complex unsteady environments. Figure 1 compares the real-time LR velocity field (a), the reference HR field (b), and the estimated HR field (c) for the water jet flow case. The LR field is obtained using a 32×32 single-pass processing, while the HR reference is derived from a multi-pass processing with a 32×32 interrogation window and 75% overlap, resulting in an effective vector spacing of 8 pixels—four times finer than the LR case.

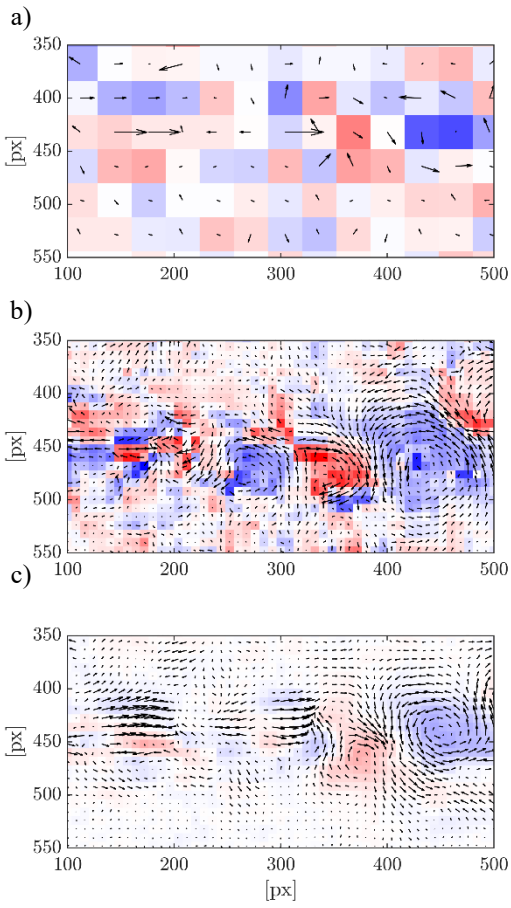

Figure 1. Vorticity (colormap) and velocity vectors in the upper region of the jet centerline. (a) Low-resolution (LR) field obtained from single-pass processing; (b) high-resolution (HR) reference field from offline multi-pass processing; (c) estimated HR field from the proposed real-time method.

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