Real-time particle image velocimetry using event-based imaging

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key-words: on-line processing, experiment, turbulence measurement, flow control

Abstract:
In the context of active flow control the continuously increasing speed of both imaging and computing hardware are enabling real-time particle image velocimetry (RT-PIV) processing scenarios such as outlined in Fig. 1a ([4, 2]). The basic idea is to extract flow relevant information from real-time processed PIV data to determine flow-controlling parameters with minimal inference time (latency). The proposed contribution describes the implementation of a PIV system based event-based vision (EBV) camera technology and is capable of processing incoming imagery at high frame rates approaching 1 kHz. Unlike conventional cameras, EBV cameras only detect and report intensity changes in the observed scene, providing an asynchronous data stream of contrast change events. With its reduced data rate and potentially rapid data processing capability, EBV is a strong candidate for this purpose [1]. To date, the real-time capability of EBV has not been fully exploited with the exception of the 3d particle tracking velocimetry (PTV) implementations by [3] that reconstructed the (time-averaged) 3d flow field in real-time. However, their setup can only simultaneously track a small number of particles of O(50-100). The present work aims at acquiring and processing imagery containing O(1000) particles necessitating approaches differing from conventional PTV.

While not making direct use of the asynchronous nature of the data provided by the EBV camera, the generation of pseudo-frames from the event stream was found to be considerably more efficient than trying to continuously extract (and track) clusters over time. The pseudo-frames can then be processed using conventional PIV algorithms, which are easily parallelized in comparison to PTV schemes. Compared to RT-PIV implementations using framing cameras, the latency of real-time EBIV (RT-EBIV) is reduced by at least one framing interval: the second pseudo-frame is immediately available at the end of the time-slicing period (see Fig. 1b).

Initial implementations of RT-EBIV operate by accumulating pseudo-image pairs at a defined framing intervals followed by a single-pass PIV algorithm with subsequent validation to provide velocity field data. A bench-top validation on a rotating disc and a turbulent water flow in a small tank is shown in Fig. 2 and demonstrated a velocity field processing speed of several hundred Hz. For higher pseudo-image rates the incoming data stream must be down-sampled, which however, does not affect the overall latency. The proposed contribution will compare the performance with a RT-PIV implementation based on a streaming CMOS camera and showcases an application to a turbulent boundary layer using the profile-PIV technique.

References

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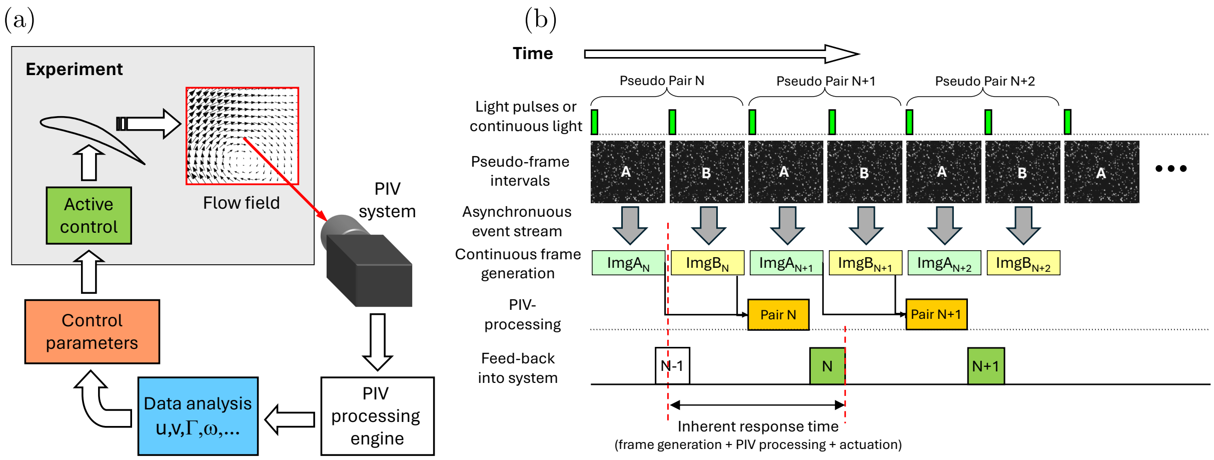

Figure 1: (a): possible implementation of active flow-control based on real-time flow field data (from [4]); (b): data stream for pseudo-frame-based, real-time event-based imaging velocimetry (EBIV). Contrary to framing cameras the pseudo-frames are available immediately after the end of framing period, thereby reducing system latency.

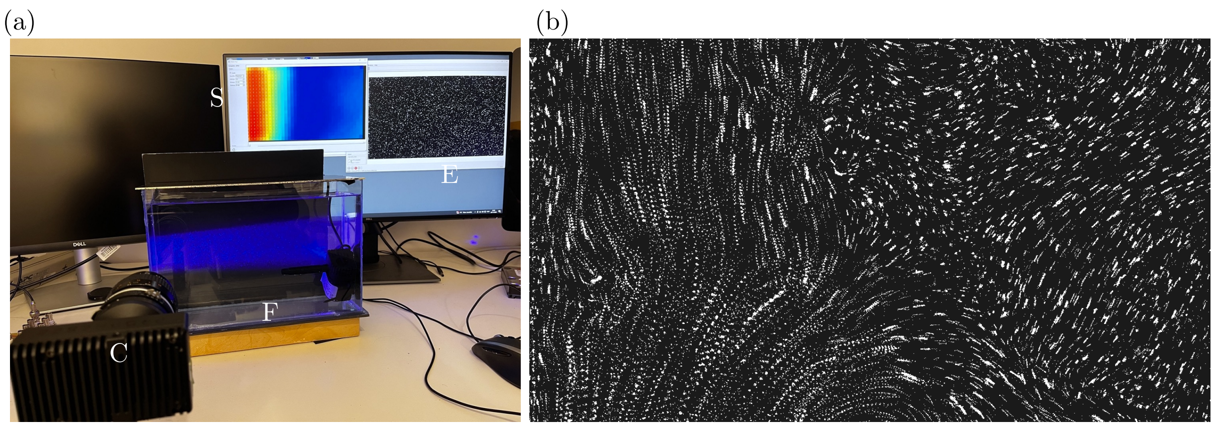

Figure 2: (a): benchtop demonstration of the implemented RT-EBIV configuration on a turbulent water flow (F) using a Prophesee EVK2 camera (C) and a low-cost pulse-modulated blue laser. Computer screen displays raw event imagery (E) and continuously updated flow statistics (S). (b): pseudo-frame obtained of the water flow at a laser pulsing frequency of 800 Hz capturing 8 pulses (10 ms).