Examples

March 17, 2015

This document illustrates some results obtained with `PIVlab` from two different example experiments. In *experiment A*, a relatively inexpensive setup consisting of a 5W CW Nd:YAG DPSS laser (Snoc electronics co., LTD, Guangdong, China; laser sheet thickness $\approx$ 1.5 mm) and a A504k high speed camera (Basler AG, Ahrensburg, Germany) was used. The flow around a transparent flapping wing was mapped during the downstroke (see Figures 1 and 2). The measurements were performed in water that was seeded with polyamide particles with a diameter of 57 μm. The flow velocity was set to 0.4 m/s and the wing (span = 0.12 m) was flapping sinusoidally with 1 Hz (Reynolds number $\approx$ $2.4 \cdot 10^4$, Strouhal number = 0.3).

PIV images were captured with 500 Hz (Δt = 2 ms) and the exposure time was set to 1.5 ms. The A504k camera delivers 8-bit images with a resolution of $1024 \cdot 1024$ pixels. In `PIVlab`, the images were analysed with the DFT technique in 4 passes using an interrogation area of 48·48 pixels in the first pass, 32·32 pixels in the second pass and 24·24 pixels in the last two passes (each pass with 50% overlap between the neighbouring interrogation areas).

The flapping wing generated highly three-dimensional flow patterns and strong velocity gradients. Additionally, the lighting was problematic in this experiment due to a relatively low laser power and a limited light sensitivity of the camera. The resulting velocity measurements are nevertheless of very good quality. Only a few vectors needed to be interpolated (1.2% of all vectors, shown in orange).

In *experiment B*, a 120 mJ pulsed Dual-Nd:YAG-Laser (Pegasus, New Wave Research, Inc., Fremont, California; laser sheet thickness $\approx$ 2 mm) was used together with the required synchronizer (ILA GmbH, Jülich, Germany) and an ultima APX-RS high speed camera (Photron Inc., San Diego, California). The wake of a rainbow trout (*Oncorhynchus mykiss*, body length = 0.3 m) that was trained to swim in a water tunnel at 0.45 m/s was recorded (Reynolds number $\approx 1.4 \cdot 10^5$). The identical particles as in *experiment A* were used for seeding.

Images were captured with 400 Hz (Δt = 2.5 ms), at 8-bit and with a resolution of $1024 \cdot 1024$ pixels. The images were analysed with the DFT technique in 4 passes using an interrogation area of 64·64 pixels in the first pass, 32·32 pixels in the second pass, 16·16 pixels in the third pass and 12·12 pixels in the last pass (each pass with 50% overlap between the neighbouring interrogation areas). Due to the exceptional light sensitivity of the ultima APX-RS camera and the very short high power laser pulses, the quality of the analyses is even better than in *experiment A* (see Figures 3 and 4). The size of the final interrogation area can be reduced, which increases the spatial resolution (about

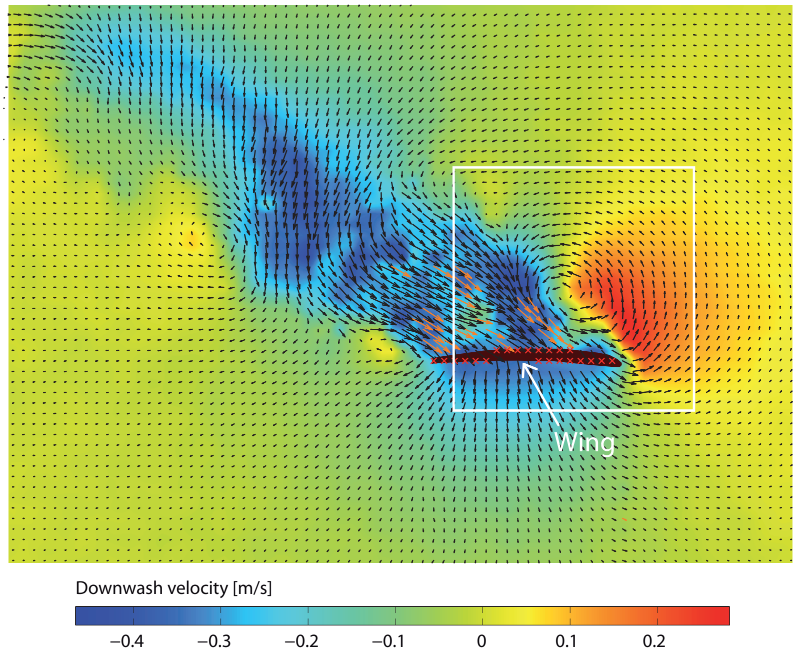

Figure 1: *Experiment A*: Analysis of a flapping wing at mid-downstroke and mid-span. The wing translates from left to right. The flow has separated from the wing. Colours show the downwash velocity.

4 times more vectors per image). At the same time, the amount of erroneous velocity estimates decreases to 0.3%.

These two experiments show that very good results can be achieved with affordable equipment, and that the quality even improves when using more advanced material. One major challenge in DPIV is to capture enough light with the high speed camera. However, the availability and affordability of suitable components improves relatively fast, and recently it has been shown that `PIVlab` can generate high accuracy results even when used in conjunction with a simple laser pointer and an inexpensive, consumer grade high speed camera.

Acknowledgements

We would like to thank René Sonntag for training of the rainbow trout and for providing the images of *experiment B*.s

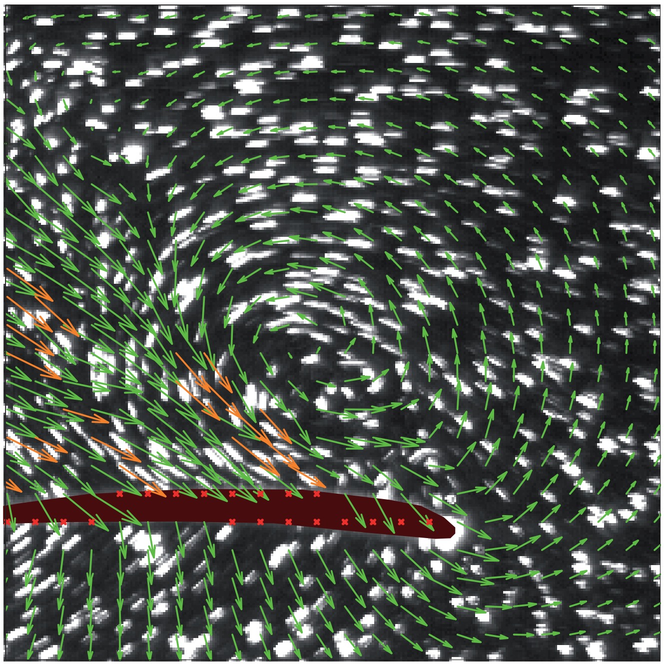

Figure 2: Magnification of the flow patterns shown in Figure 1. An excellent vector resolution is achieved although the flow is highly three-dimensional and the particles are relatively large and motion-blurred.

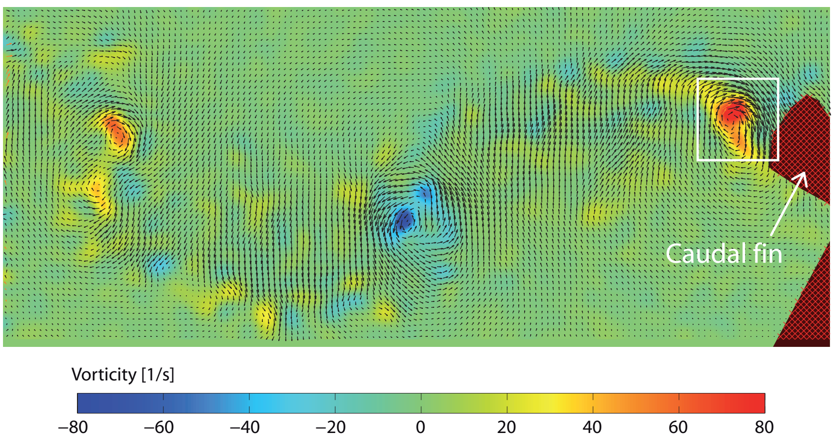

Figure 3: *Experiment B*: Analysis of the wake of a trout swimming from left to right. Top view on a cross-section through mid-span of the caudal fin. An inverse van Kármán wake is generated in the water. Colours show vorticity.

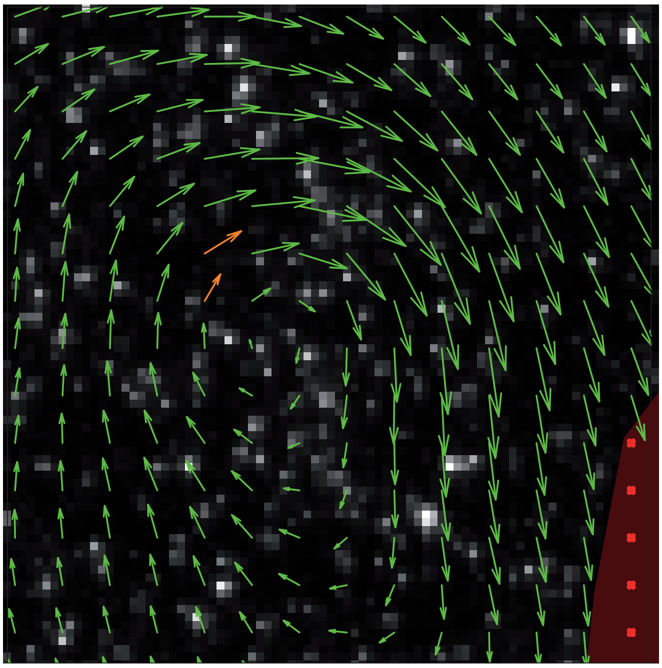

Figure 4: Magnification of the wake shown in Figure 3. A high vector resolution is achieved by the use of multiple interrogation passes and window deformation.