

On the transition of particle image velocimetry into the digital age – Recounting 20 years of digital PIV

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Early 1989 the first image sequences of single exposed particle images were acquired for a low speed thermal plume in water and for the first time demonstrated the double-frame, single-exposure PIV recording and processing concept, that was to become the most common implementation of PIV up until today. The presentation provides a historical perspective of the development of digital PIV in the presence of the then already well established photographic PIV methods. Initially the implementation of the two techniques seemed to cater to different areas of application, but a steady improvement of the theoretical background during the 1990's clarified that the two techniques are merely different implementations of the same measurement principle.

In the early 1990's digital PIV was limited to the study of low speed water flows below 1 m/s at rather low spatial resolutions but nonetheless allowed time-resolved measurements through the analysis of continuous video image sequences [1]. The access to the time-evolving vorticity field and other quantities derived from the velocity maps gave researchers a powerful tool, for example, in the visualization and understanding of vortex dynamics and also has helped in the validation of numerical results obtained with direct numerical simulation (DNS).

Technological advances in subsequent years, both on the imaging as well as computational side, were key in bringing digital PIV to a much wider range of applications. In a first step digital processing of photographic PIV recordings became possible with the emergence of slide scanners which eventually replaced the optical interrogation methods. Soon thereafter new camera technology based on interline-transfer CCD sensors allowed the capture of two separate images on the microsecond scale and for the first time provided reliable digital PIV measurements of high speed flows in aerodynamics. From 1996 onward a wide variety of projects conducted by DLR made extensive use of digital PIV, turning the technique into one of the most important flow diagnostics tools in aerodynamics. At the same time these projects, oftentimes funded by the EU, were instrumental in promoting the acceptance of the technique for industrial research.

A steady increase in sensor resolution nowadays provides a spatial resolution that rivals that of high-resolution 35 mm photographic film. Extensions of the technique led to the development of stereo PIV, multiple plane PIV and tomographic PIV yielding three-component as well as volume resolved velocity data. The recent availability of high frame-rate cameras now also allows for time-resolved PIV measurements of aerodynamic flows. In parallel the increase of computational capabilities by several orders of magnitude over the past two decades can now provide high-resolution PIV velocity maps exceeding video frame rates.

[1] Willert C, Gharib M (1991) *Digital particle image velocimetry*. Exp. Fluids **10**:181-193