# Probe Capture for Quantitative Flow Visualization in Large-scale Wind Tunnel Measurements

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### Motivation

Wind tunnel measurements play an important role in the testing, optimization and certification process of aero-dynamic shapes. Routine measurements generally include the aerodynamic forces only. Albeit the characteristics of the flow field around the model would be of great interest, quantitative volumetric flow measurements are generally to complex. Probe Capture (ProCap) is a novel approach capable of measuring time-averaged quantities (e.g. pressure, temperature, velocity etc.) in large-scale test sections. While the accuracy is comparable to a scanning traverse system [1], its real benefit lies in its simplicity, its short setup and measurement time and its capability to provide a visual feedback of the measurement in real-time.

### Experimental Setup and Measurement Procedure

A hand-held probe (cf. Fig. 1) with a flow sensor at the tip and fitted with retro-reflective markers is guided to the region of interest. An optical motion capture system (Qualisys AB, cf. Fig. 2) is used to determine the position and orientation of the probe while the data is collected. The used motion capture system is capable of tracking a large number of markers with a latency of a few milliseconds and a spatial accuracy below 1 mm for a working distance of 2-3 m. The data signal of the probe is sampled time-synchronously to the tracking with a capture rate of 100 Hz.

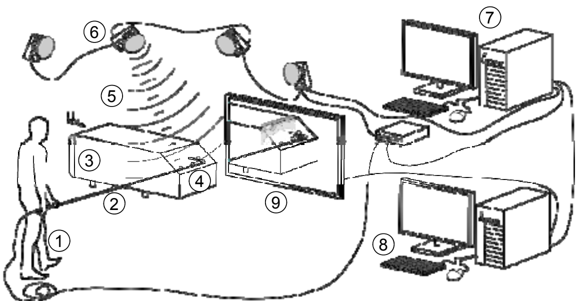


**Fig. 1:** Schematic diagram of the experimental setup

Using different probe types (cf. Fig. 2), the volumetric distribution of virtually any flow quantity (e.g. pressure, velocity vector etc.) can be measured.

### Data Processing

The flow field is reconstructed in real-time. This not only informs the operator about the flow field to reduce measurement time but also increases the accuracy of the method as the operator can concentrate on regions with interesting flow structures.

For visualizing the flow field in real-time the measured data has to be interpolated onto a regular grid. Normalized convolution [2] is a local approximation method that allows for efficiently interpolating non-uniformly distributed data onto a regular grid. Furthermore, normalized convolution can be easily adjusted to meet physical constraints (e.g. mass conservation, boundary conditions).

**Fig 2:** a) Motion capture system in the test section of the wind tunnel, b) Pitot-static probe. c) Tuft probe.

### Real-Time Flow Visualization Feedback

Fig. 3 illustrates the capabilities of ProCap on the tip vortex of a wing. With the help of the visual feedback, regions con-taining interesting flow structures are quickly identified and the probe can be directed accordingly. Measurement data is collected until the real-time feedback has converged.

To improve the quality of the measurement, ProCap currently contains several real-time feedback elements (cf. Fig. 4).

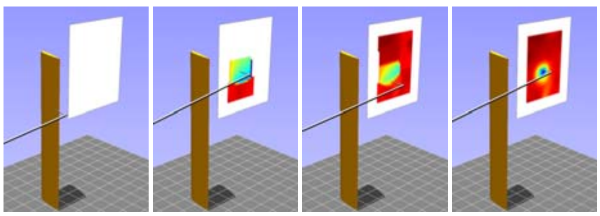

**Fig 3:** Snapshots of the RT-Feedback in chronological order

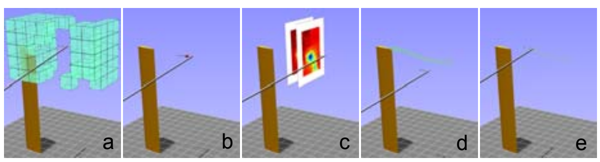

**Fig. 4:** Real-time flow visualization capabilities of ProCap: a) Voxel eraser, b) Visualization of the latest measured data, c) Contour- and Vector-Planes, d) Streamlines, e) Virtual Smoke-Probe

### References

[1] A. Landolt, B. Kraeutler, T. Roesgen, *13th Int. Conference on Wind Engineering,* 2011

[2] H. Knutsson and C.-F. Westin, *Proceedings of IEEE CVPR '93*, pp. 515–523, 1993