Redesign of a 3D PTV system with ANDOR's Neo sCMOS

Application Note

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Aachen, Germany, (March 2013)

Abstract

Imaging measurement methods for flow analysis are very well known in many fields of application. The particle image velocimetry (PIV) is at present one of the most powerfull available methods, that are used for application in fluids. Never the less PIV cannot satisfy all requirements of actual research topics, due to its limited spatial resolution even in stereoscopic arrangements. The investigation of threedimensional room airflow structures in large enclosures is only one example, where PIV is not yet suitable for. Therefore a three-dimensional particle tracking velocimetry (3D PTV) system is redesigned to investigate large flow patterns with a high spatial and temporal resolution.

Introduction

The insvestigation of airflow structures and patterns in ventilated rooms and buidlings is important to get detailed information about formation and transport processes in large scale airflows. These processes impact on ventilation effectiveness and are responsible for the distribution pollutants, which are a important part indoor air quality determination. In addition to that the interaction of turbulent fluctuations can increase the local air velocity to a level, which is out of the range of comfort. The 3D PTV is an established method for volumetric flow analysis, but nowadays PTV systems take only a small part in experimental investigations, due to the powerful PIV systems, that are available on the market. But in fact previous experiments approved the ability of 3D PTV for large scale volumetric analysis of flow structures and opened up a new field of application for particle tracking velocimetry [1]. The main issues in large scale volumetric applications are illumination and detection of tracer particles. Therefore the Neo sCMOS cameras DC152 QFR-FI from Andor Technology were chosen for image acquisition as they enable rapid frame rates with high resolution images and a 16 bit danymic range.

Experimental Setup

The test facility 'Aachener Modellraum'(AMOR) with ongoing measurements is a generic mock-up for investigations on indoor airflow and passenger cabins at RWTH Aachen University [2]. 'AMOR'has a depth of 5 m, a height of 3m and a width of 4 m. For optical access of the inner volume equal spaced acryl glass windows with an refraction index of 1:49 and a width of 0.1 m are embedded in the wall construction.

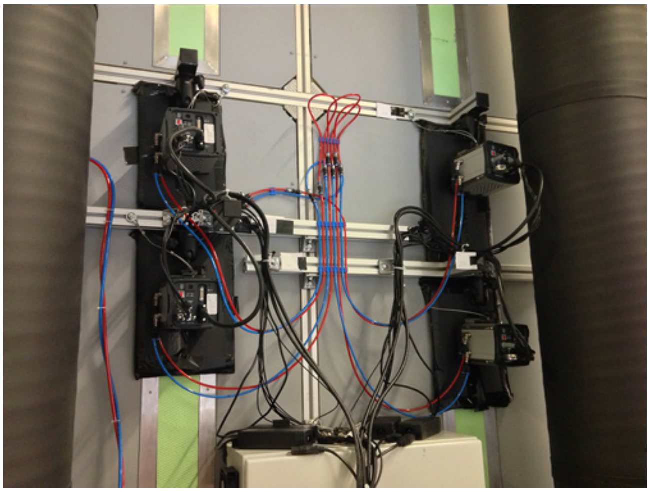


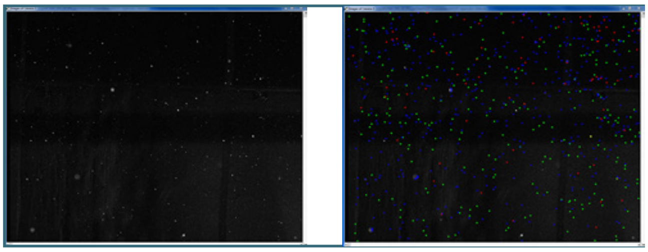
Figure 1: Four camera system with water cooling connectors in a 3D PTV setup

These can either be used for illumination purposes or camera mounting. Four inner cuboids with a width of 0.4 m and a height of 0.6 m provide a thermal load up to 6000 W. Starting from the outer walls the spacing of the elements is 0.4 m, only the distance between the second an third cuboid is 0.8 m. A distance of 0.15 m between the bottom of the heat sources and the ground of 'AMOR'is representative for the geometric parameters of cabin ventilation systems. The ventilation system is a mixing ventilation setup with slot inlets of 20 mm height on the top of both sides and the outlets placed next to the ground with an height of 150 mm. The boundary conditions for the presented case are 0.8 ms inlet velocity with a thermal load of 1000 W leading to an temperature difference of 7.5 K between the heat sources and inlet. A for imaging measurement methods real quest are the inner surfaces. About 85% are covered by an aluminium sheet of 0.3 mm thickness to minimize the influence of radiative heat transfer. The measuring volume is illuminated by up to twelve LED-lightsources with about 1500 lm each. These spots are variable and allow a homogenized lighting through the depth of the interrogation volume. The usage of helium-filled soap bubbles with an average diameter of 2mm as tracer enables the detection of tracer particles even at large distances. The used camera systems consists of 4 Neo sCMOS cameras with Zeiss Distagon 25MM/F2,8 ZF2 f-mount lenses. Their water-cooling unit is connected to a refrigerated bath circulator to enable the full cooling performance of the Neo. Figure 1 shows the mounted cameras in a stereoscopic setup as they are used for 3D PTV.

The cameras are connected to two computers using 5 m Cam-Link connection cables. Each of the computers has two frame-grabbers installed. In order to prevent any bottle-neck in data handling, the acquired data is spooled to a 2 TB RAID 0 storage system, which is supported by a 20GB virtual RAM disk. Illumination and image acquisition of the 3D PTV system are synchronized by a timing device, so the external trigger of the Neo sCMOS is used. Over all the system performs a synchronized framerate of 25 Hz.

Results

The scripting option of Andor Solis is very useful for any experimental setup. It offers a huge library of 'ready-to-use'postprocessing routines. In our case we used the image operations to subtract a backround image from each acquired image to enhance the contrast of the exported images. Figure 2 shows an extract of a processed image of one camera. Figure 2(a) is an extract after image subtraction in Andor Solis, figure 2(b) shows the detected particles in the image marked with blue, green and red crosses. These point data get converted from image to object space by using the epipolar geometry as described in [3].



(a) 'Cleaned'particle image of a Neo sCMOS

(b) Particle detections with 16 Bit peak-fitting and local adaptive threshold computing

Figure 2: Particles and particles detections in an extract of an acquired image, $t_{exp} = 11:3$ ms, $T_{sens} = -30$ °C

With object space data a threedimensional tracking is performed taking additional criterias, like shape and brightness to increase the connection performance of the tracking algorithm.

Further work will focus on detection of formation processes and structures interacting with each other. Therefore several variations of acquisition parameters are used for analyses of the time-dependent effects. For the camera setup with four cameras, shown in figure 3, on one side of the test facility two different methods of analysis can be applied. With some small modifications 3D PTV and large sacle PIV maesruements as discussed in [4] can be performed to compare and validate the results of both techniques. An example how the reconstructed trajectories for a testcase look like is shown in figure 3. An image sequence of 1000 images was acquired with a framerate of 25 Hz. Only reconstructed trajectories with a length larger than 35 timesteps ($t_{track} > 1:4$s) are displayed. This selection out of a long sequence shows, that there is no clear pattern to identify which shows the transient and instable characteristics of this boundary conditions.

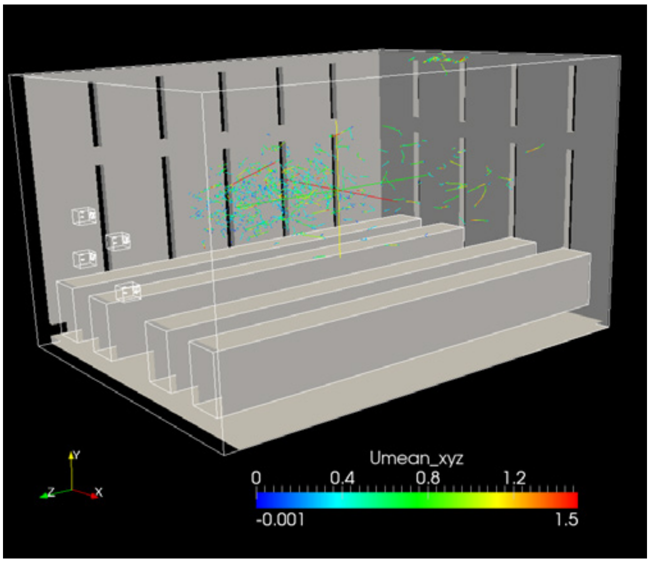


Figure 3: Trajectories with a length of more than 35 time steps out of a 1000 image sequence with 25 Hz, coloured by the mean velocity magnitude Umean_xyz

Acknowledgement

Grateful acknowledgement is made for financial support by DFG (German Research Foundation), promotional reference AOBJ 579046.

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