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On calibrating large-scale volumetric flow measurement experiments

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Performing 3D measurements in extended volumes comes along with several experimental challenges, especially when aiming for highly resolved results. Most of these are connected to achieving a sub-pixel-accurate volumetric camera calibration, which is imperative for methods like Shake-The-Box (STB) [1]. We report about an experiment to measure the flowfield in a typical classroom within a volume of 55 m^3, populated by sitting heated mannequins and seeded by Helium-filled soap bubbles, illuminated by arrays of pulsed LEDs and recorded by eight 65 MPx-cameras, installed above the transparent ceiling (Fig 1). The 28 mm wide-angle lenses show strong distortion on the large sensor. The camera system was calibrated using a large translated dot pattern target in two parallel planes.

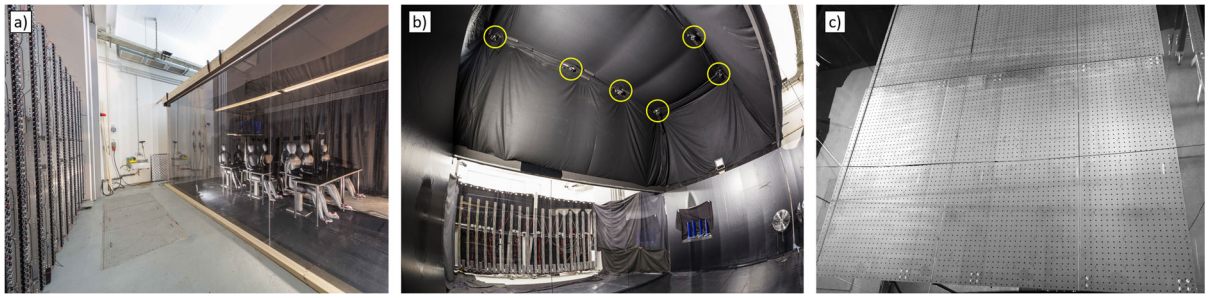

Fig. 1 a) Photograph of LED array (left) and simulated classroom (right); b) view from inside the transparent classroom showing 6 (of 8) cameras on the ceiling and again the LED array; c) Stitched upper calibration image of a single camera.

Using a simple perspective camera model, reprojection errors for the calibration markers of over 50 pixels are registered in the corners of the image (Fig. 2a). Several measures are employed to reduce these initial errors. A two-plane camera model with second-order correction terms reduces maximum errors to around 10 pixels (Fig. 2b). From these error maps, a shift field for the camera model is constructed, allowing to describe arbitrary distortions (Fig. 2c). The corrected cameras are used to perform preliminary particle tracking using STB. The tracked particles are reprojected on the cameras and the shift field is iteratively updated (Fig. 2d). Even with perfectly calibrated cameras, successful triangulation would not be possible with the standard approach of epipolar lines. Only when approximating the imaged curve of the mapped lines-of-sight by piecewise linear segments, a reliable triangulation was achieved [2]. The final distribution will detail on all necessary steps to achieve tracking of large amounts of particles (several millions) in large-scale scenarios.

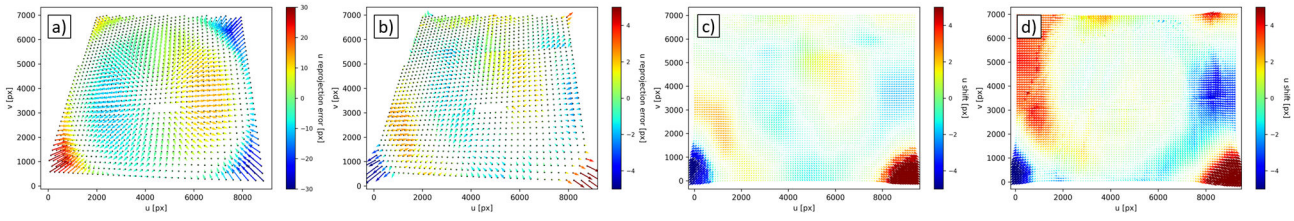

Fig. 2: a) reprojection error of one plane of calibration markers for a) perspective camera and b) two-plane-camera with 2nd order terms. Correction shift map calibrated from (b) and after iterative updates from triangulation and tracking (d)

References

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