Evolutionary Camera Pose Estimation of a Multi-Camera Setup for Computed Tomography

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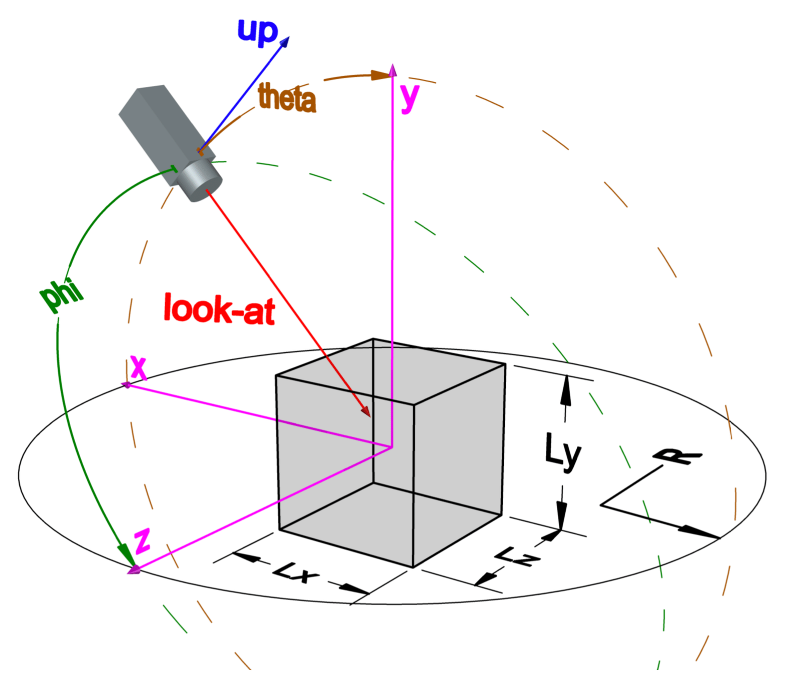
Introduction

To achieve high quality tomographic reconstructions a well calibrated measurement setup is needed.

- Our computed tomography (CT) setup is composed of an array of CCD cameras
- A calibration procedure for the estimation of a cameras extrinsic parameters was developed using a genetic algorithm and a ray-tracer.
- A 3D target was designed, manufactured and tested in phantom studies as well as in a computed tomography of chemiluminescence (CTC) experiment

Camera Calibration - Optimization Procedure



The extrinsic camera parameters (orientation and location) are encoded as genes in a chromosome by 7 real valued variables:

$$c = (\theta, \phi, R, Lx, Ly, Lz, \alpha)$$

Where α is the rotation about the look-at-vector axis.

A population of chromosomes undergoes an evolutionary process by means of selection, crossover and application of genetic operators such as mutation.

Fitness of a chromosome is measured by ray-tracing a numerical replica of the 3D target and evaluation of the L_1-norm between ray-traced image and camera image.

Camera reference image

Rendered initial view (left) and calibrated view (right) superimposed on the reference image

Error Study Using the Numerical Target

A numerical test of the calibration accuracy was conducted:

- Two tests, each with 7 cameras arranged in a half circle. One set with $\theta = 90°$ (planar) and the second with $\theta = 60°$ (inclined).
- 25 runs were carried out per case to obtain some statistics.

Calibration errors for the planar cameras

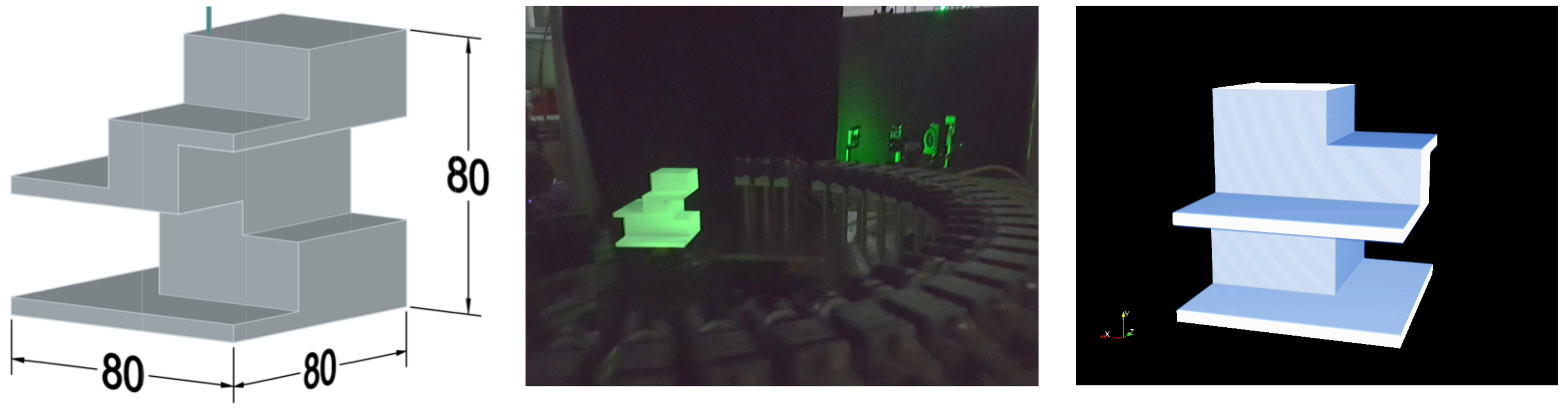
cam	ε_{loc} [mm]	ε_{x-rot} $[10^{-2}°]$	ε_{y-rot} $[10^{-2}°]$	ε_{z-rot} $[10^{-2}°]$
1	0.1115	0.1409	-0.0653	0.1563
2	0.3293	-0.6960	0.0762	0.1223
3	0.5610	-6.6090	0.2566	4.6972
4	0.2071	-0.7724	1.2652	-0.1753
5	0.1873	0.5474	-1.3476	-0.0385
6	0.3159	-1.5687	2.6161	-0.8555
7	0.1675	0.6832	1.1192	0.0607

Calibration errors for the inclined cameras

cam	ε_{loc} [mm]	ε_{x-rot} $[10^{-2}°]$	ε_{y-rot} $[10^{-2}°]$	ε_{z-rot} $[10^{-2}°]$
1	0.4055	-0.9858	1.7274	-0.6111
2	0.6161	-3.0382	-2.8156	1.8501
3	0.4826	-1.3804	-1.8737	0.8298
4	0.2865	-1.1062	-0.0407	-0.5665
5	0.3577	-0.9471	-1.5949	1.2145
6	1.5749	3.7147	-13.2241	6.5970
7	0.5310	-1.7956	4.5259	-2.8453

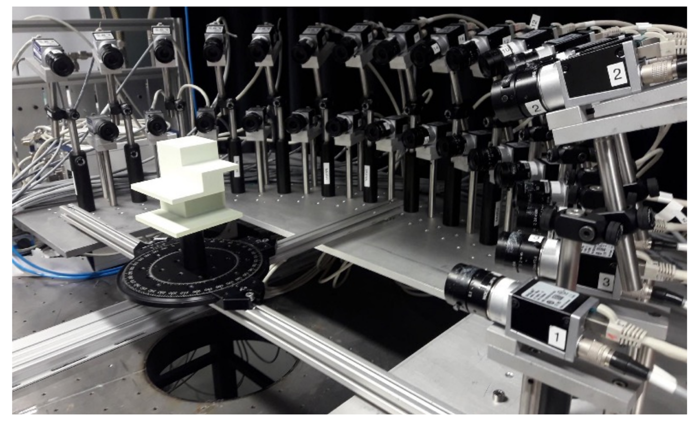
Manufacturing and Design of the 3D Target

- The target was manufactured from a solid block of aluminum and was coated with luminescent spray-paint.
- The target is modeled using cubic voxels in a ray-tracing algorithm and can be rendered from different views.

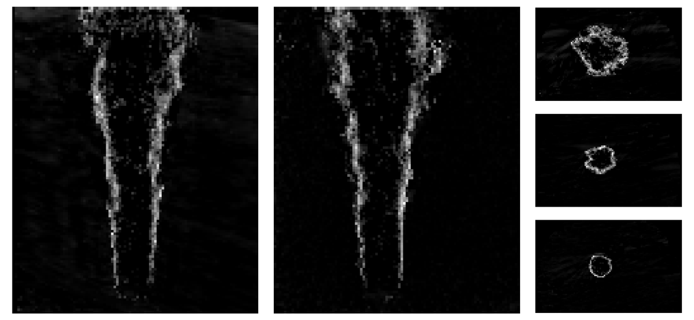


Dimensions of the target in mm (left). Image of a CTC setup (middle). Rendered movie (right)

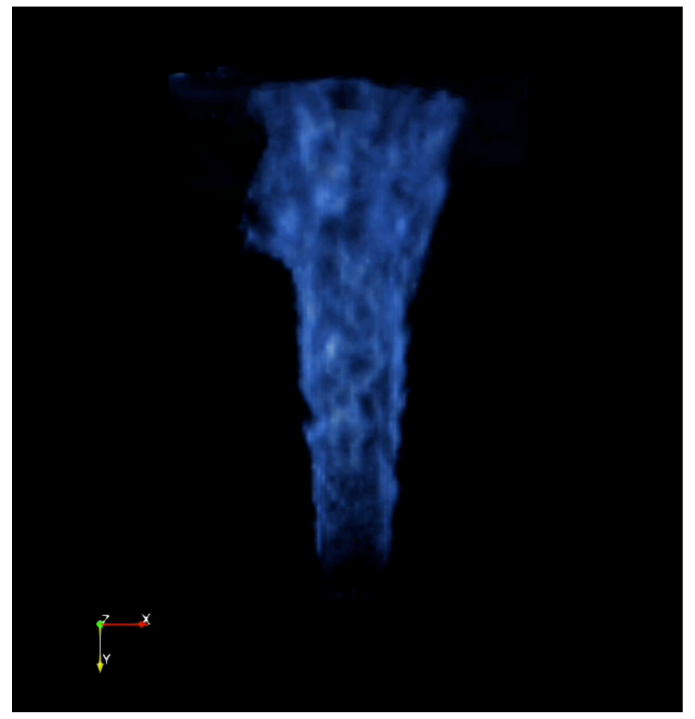
Calibration in a CTC Experiment



- The calibration was tested in a reconstruction of the Cambridge-Sandia stratified flame SwB1 [1] with CTC [2].
- The CTC setup [3] consisted of 30 Basler acA645-100 gm GigE cameras.
- Half of the cameras were arranged planar in a half circle around the burner, the other half had an inclined view



Vertical (left) and horizontal slices (right) of different heights above the burner of the reconstructed 3D field.



Volume rendered reconstructed 3D field.

Conclusions

- We demonstrated the accuracy of our calibration method numerically and experimentally.
- The calibration algorithm was later transferred to C/CUDA and runs on a GPU server, which allows a calibration in less than 60 sec for a single camera.
- Further investigations on an optimal target shape are underway.

References

1) M.S. Sweeney et al., Combust. Flame , vol. 159, pp. 2896 - 2029, 2012.
2) J. Floyd, P. Geipel, A. M. Kempf, Combust. Flame., vol. 158, pp. 376–391, 2011.
3) K. Mohri et al., Appl. Opt. vol. 56, 7385-7395, 2017.