3D PTV for Indoor Airflow Study

Ecole doctorale Sciences Pour l'Ingénieur

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Introduction

Recently, much progress has been made to bring 3D-PTV outside the laboratory to apply in real-world settings; however, there are many challenges yet to be overcome. The limited measuring volume of the 3D-PTV system is one important challenge, which needs to be extended to cover all the measuring volume [1]. In buildings and in large areas such as conference halls, clean rooms, inside the plane cabin, large-scale 3D-PTV could play a significant role in order to predict the trajectory and velocity of the air and airborne pollutants.

- Why large scale PTV is crucial?

1. Energy: saving energy
2. Environmental efficiency: thermal comfort, predicting airborne pollutants

Conference hall

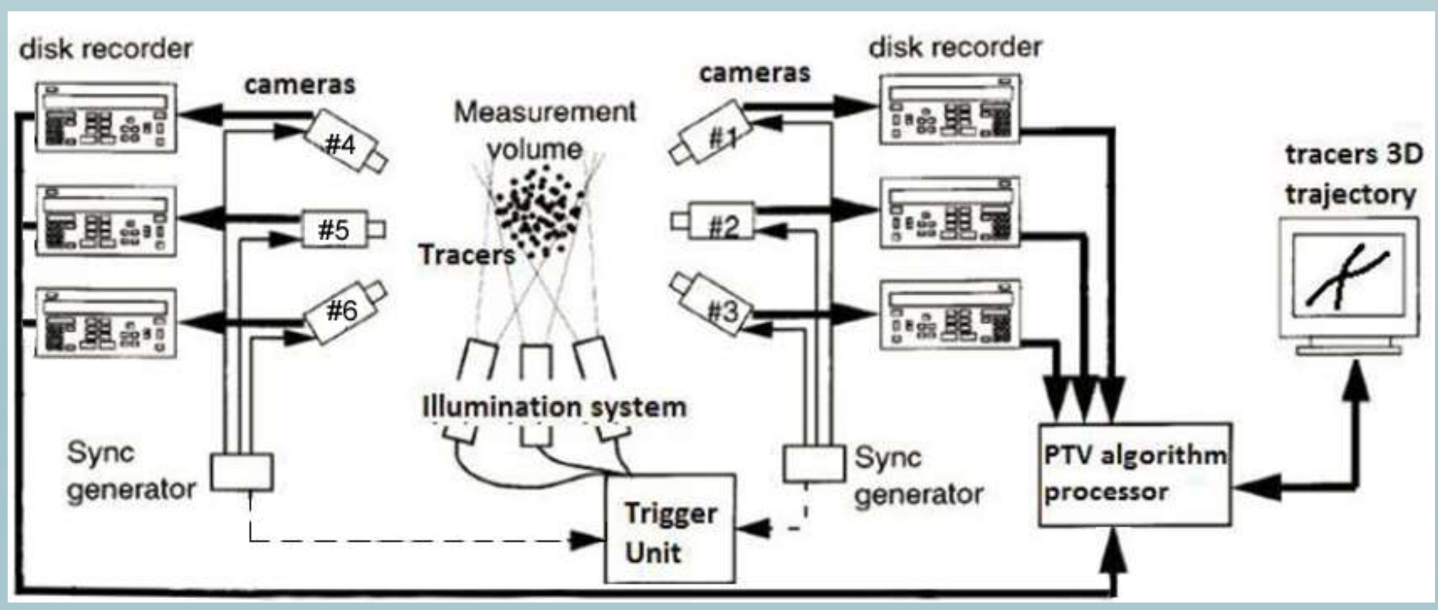
Clean room

Inside a plane cabin

Inside the home

Methods

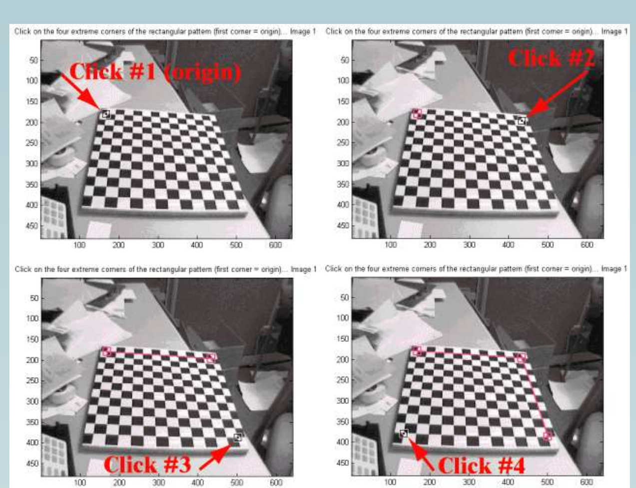
- Two 3D-PTV systems are being considered.
- Each system is composed of at least 3 cameras
- The cameras should be time synchronous



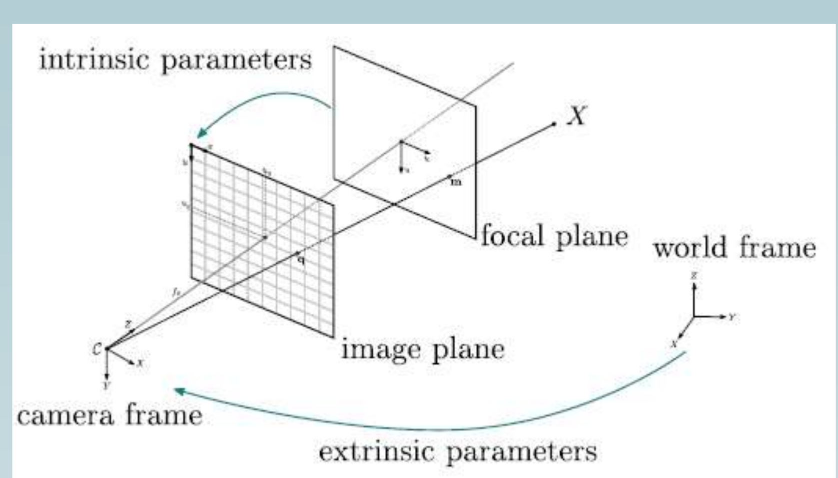
Schematic representation of the experimental setup

The main procedures performed are as follows:

- Multiple Camera Calibration: separately calculating intrinsic and extrinsic parameters using the pinhole camera model [2]
- The calibration method proposed by Zhang [3] and implemented in Matlab by Bouguet [4] in a Camera Calibration Toolbox.

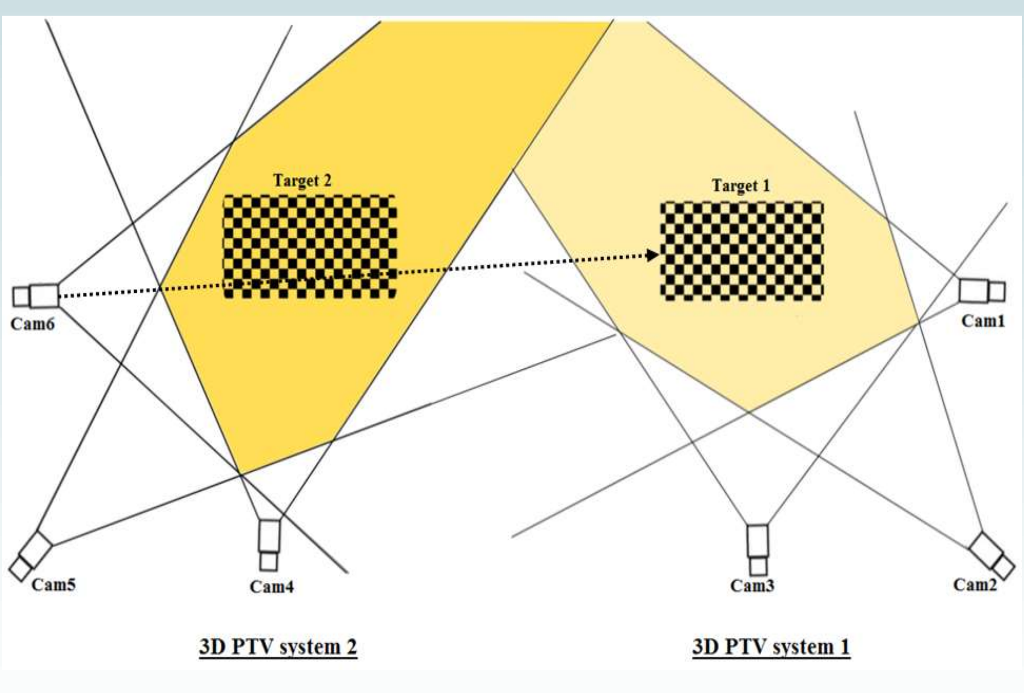


Calibration toolbox



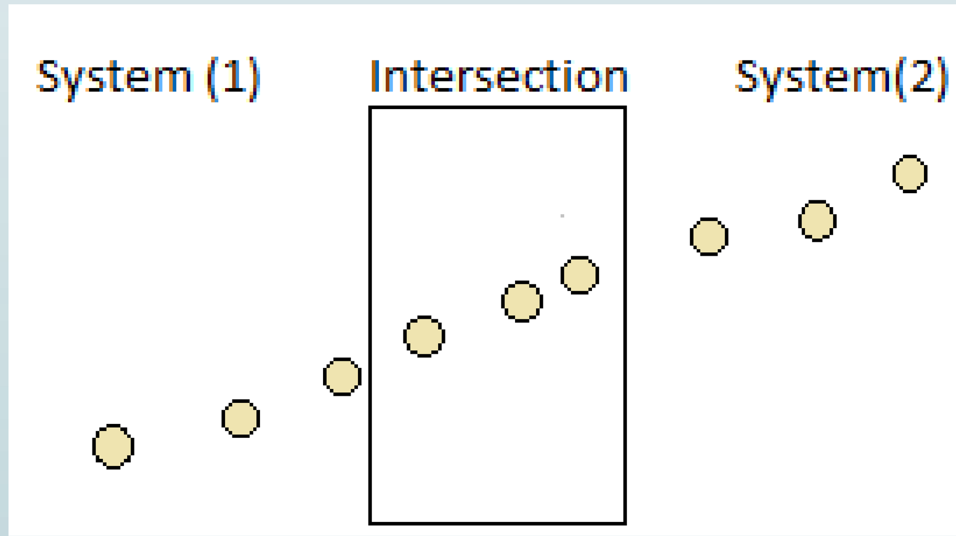
Pinhole camera model

- At least one camera should have a view over the calibration target of the other system.



Results

- Transforming camera i coordinates system XX_C into the calibration target coordinate system XX:
  $XX_{Ci}{}^{n} = R_i{}^{n}.XX^{n} + T_i{}^{n}$
- If camera i of system n sees the calibration target of system m, then the relationship between $XX_{Ci}{}^{n}$ and XX^{m} can be written as:
  $XX_{ci}{}^{n} = R_i{}^{m}.XX^{m} + T_i{}^{m}$
- The relationship between XX^m and XX^n can be deduced as:
  $XX^{n} = [R_i{}^{n}]^{-1}[R_i{}^{m}.\ XX^{m} + T_i{}^{m} - T_i{}^{n}]$



A non-zero intersection in the 3D fields observed by the two adjacent 3D-PTV systems should be assumed to establish a link between the trajectories.

- Two 3D coordinates of the two 3D-PTV systems are considered to be "similar", meaning that they correspond to the same particle, if the Euclidean distance between the 3D coordinates, noted below as A and B, is lower or equal than a threshold value s:

$$\|A - B\|_2 = \sqrt{(x_A - x_B)^2 + (y_A - y_B)^2 + (z_A - z_B)^2} \leq s$$

- ❖ s can be also specified through a physical parameter, such as the average particle diameter or according to the experiment accuracy.

- If the similarity criterion is valid for at least three consecutive instants, then the algorithm proceeds to link the trajectories related to those particles, $XX^{(1)}$ and $XX^{(2)}$. The algorithm, therefore, performs a comparison of the 3D coordinates particle by particle and at each time step.

	$XX^{(1)'}$	$XX^{(2)'}$
t_1	OK	-
t_2	OK	-
t_3	OK	-
t_4	OK ≈	≈ OK
t_5	OK ≈	≈ OK
t_6	OK ≈	≈ OK
t_7	-	OK
t_8	-	OK
t_9	-	OK

Conclusions and Future Studies

- A method is proposed by using multiple 3D-PTV systems applicable for large enclosures such as conference rooms. Several 3D-PTV systems located next to each other are utilized to cover the entire volume measured.
- The calibration of the cameras is described to define a common 3D coordinate system for the particle trajectories.
- An algorithm for linking the particle trajectories is developed based on a similarity criterion.
- The performance of this algorithm will be investigated using the experimental data of two 3D-PTV systems.
- In order to reduce the computational time, a parallelized programming method will be utilized by the aid of FPGAs as a future study.

Bibliography

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