21th International Symposium on Flow Visualization
June 21-25, 2025, Tokyo, Japan

Large scale 3D particle tracking for the study of airborne transmission of pathogens in realistic class room settings

Stephan Weiss[1], Andreas Schröder[1,2*], Daniel Schanz[1], J. Lemarechal[1], J. Bosbach[1] and T. Strübing[1]

[1] Institute of Aerodynamics and Flow Technology, German Aerospace Center (DLR), 37073 Göttingen, Germany
[2] Brandenburgisch Technische Universität (BTU), Cottbus-Senftenberg, Germany
*Corresponding author: andreas.schroeder@dlr.de

Keywords: Lagrangian particle tracking, aerosol transport in mixed convection, room ventilation

Due technological advances in the development of high-speed cameras, illumination technologies and image processing algorithms dense Lagrangian particle tracking (LPT) is nowadays a reliable tool to probe velocity fields with high spatial and temporal resolution [1]. In many cases, the spatial resolution of state-of-the-art LPT measurements allow resolving the smallest relevant scales in turbulent flows and proper data assimilation techniques are used to calculate Eulerian flow fields (pressure, velocity and acceleration) from the Lagrangian tracks e.g. FlowFit [2]. Lagrangian properties themselves are of utter interest, whenever material transport or mixing is investigated.

We conduct LPT measurements in order to study the spread of airborne pathogens in a realistic class room setting within mixed turbulent convection. The setting consists of a 6 m long, 4 m wide and 2.8 m high cubicle of ~70 m³ with heated dummies, desks and chairs placed in various configurations. The room is seeded with neutrally buoyant helium-filled soap bubbles (HFSB) of about 600 µm in diameter, i.e. small enough to follow the flow passively in order to investigate the main features of airborne pathogen transport and dispersion quantitatively. For illumination we used 2648 pulsed high-power LEDs, which were combined into arrays and installed along the long sidewall of our measurement volume for homogeneous illumination of the entire domain. We image particles with eight high-resolution cameras (Emergent, HZ-65000-G-M, 9344px x 7000 px) from different angles through the transparent ceiling. Since the field of view of a single camera is smaller than the measurement volume, each set of four cameras captures images in one of two overlapping sub-volumes, slightly larger than half the entire measurement volume of ~55 m³. Measurements were conducted with a frame rate between 34 and 70 Hz depending on the flow dynamics of specific ventilation configurations. Particle location, velocity and accelerations along several millions of particle trajectories per time-step are determined via the Shake-The-Box (STB) [3] particle tracking algorithm. With this setup, we can study particle transport from each of one (infected) person to each other (susceptible) person represented by the dummies.

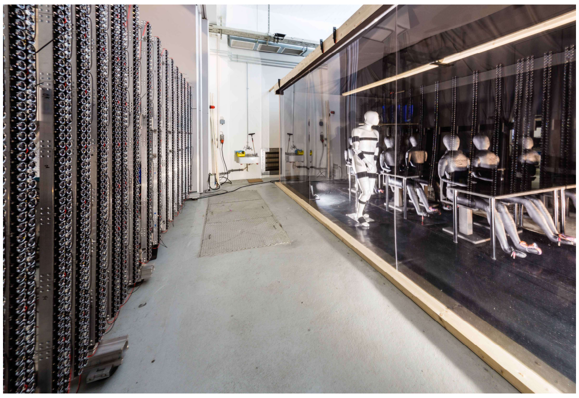

Figure 1: Research seminar room with transparent walls and ceiling at DLR Göttingen for investigations of mixed turbulent convection flows using several seated and one upright and traversable thermal dummies. 3D Lagrangian Particle Tracking with Shake-The-Box will be used to track millions of submillimeter Helium-Filled-Soap-Bubbles (HFSB) illuminated by a large pulsed LED array.

References

1. Schröder A. and Schanz D**.** *3D Lagrangian Particle Tracking in Fluid Mechanics*. Ann. Rev. Fluid Mech., Vol 55, pp 511-540, 2023. https://doi.org/10.1146/annurev-fluid-031822-041721
2. Godbersen P., Gesemann S., Schanz D. and Schröder A., *FlowFit3: Efficient data assimilation of LPT measurements*, 21th International Symp. on Appl. of Laser and Imaging Tech. to Fluid Mechanics Lisbon, Portugal, July 8-11, 2024
3. Schanz D., Gesemann S. and Schröder A. *Shake-The-Box: Lagrangian particle tracking at high particle image densities.* Exp Fluids 57, 70 (2016). https://doi.org/10.1007/s00348-016-2157-1