

Dataset: Odour sensing in turbulent plumes with high-speed e-nose and PLIF ground truth

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Summary: Real-world gas sensing requires resolving turbulent odour plumes with rapid concentration fluctuations, yet compact metal-oxide (MOx) sensors strongly low-pass filter these dynamics. Here we present a benchmark dataset combining planar-laser-induced-fluorescence (PLIF) measurements of an acetone plume with synchronised kilohertz-rate recordings from an electronic nose. The measurements enable direct comparison between turbulent plume dynamics and sensor response and thus enable the validation of algorithmic approaches for high-speed olfactory sensing in turbulent environments.

Keywords: turbulence, odour plumes, electronic nose, metal-oxide sensors, PLIF, fast sensing

Introduction

Artificial olfaction in real-world environments requires operation in turbulent flow fields, where odour is transported as intermittent and filamentous plumes with rapid concentration fluctuations rather than smooth gradients [1]. These temporal features carry information relevant to source localisation, plume inference, and—consequently—odour guided navigation [2]. However, commercially available metal-oxide (MOx) gas sensors strongly low-pass filter the underlying gas signal due to their thermal and surface-kinetic dynamics [3]. Progress in reconstructing fast odour dynamics from the sensors is in principle possible [4], but has been limited by the lack of benchmark datasets that jointly capture realistic plume structure and synchronised sensor response.

To address this, we developed a multimodal dataset that combines non-invasive planar laser-induced fluorescence [5] (PLIF) measurements of an acetone tracer plume with co-located, kilohertz-rate recordings from a custom eight-channel MEMS MOx electronic nose [4] in a laboratory wind tunnel. The contribution is intended as a reusable benchmark for studying sensor dynamics and evaluating reconstruction algorithms under controlled but realistic turbulent conditions.

Dataset design

The dataset was acquired in a low-speed turbulent wind tunnel using acetone as a tracer (see Fig. 1a). Two modalities were measured simultaneously. First, PLIF provided quantitative, two-dimensional concentration fields at high spatial resolution (see Fig. 1b). Second, a custom eight-channel MEMS MOx electronic nose recorded sensor resistances, heater temperatures, and environmental variables on a shared

time base at kilohertz rate (see Fig. 1c). The e-nose comprised eight MOx sensors with closed-loop heater control and on-board data logging.

Experiments were performed at three nominal flow velocities (10 cm/s, 15 cm/s, 20 cm/s) and at three sensor positions (see Fig. 1b). Each condition was repeated, yielding a set of experiments that sample distinct plume statistics and sensor exposures. The PLIF measurements were spatially averaged over regions corresponding to the physical sensor housings, and temporally aligned to the e-nose recordings using shared trigger pulses and shape-preserving interpolation.

The released data products consist of: (i) processed PLIF image sequences in HDF5 format, containing concentration fields and calibration information, and (ii) synchronised CSV files containing e-nose measurements together with spatially and temporally aligned PLIF-derived concentration traces for the sensor regions. This structure is designed to support both image-based plume analysis and direct time-series modelling.

Technical validation

A central requirement for the dataset is that both modalities are quantitatively reliable and meaningfully aligned. The PLIF measurements achieved adequate signal quality for this purpose, where time-averaged signal-to-noise ratio exceeded 30, while instantaneous values frequently exceeded 100. The e-nose operated stably throughout the measurements due to closed-loop heater control, maintaining hotplate temperatures near 400 °C with sub-degree variation.

Crucially, the synchronised optical and sensor measurements exhibit clear correspondence despite the expected low-pass behaviour of MOx sensing. Distinct turbulent events, including

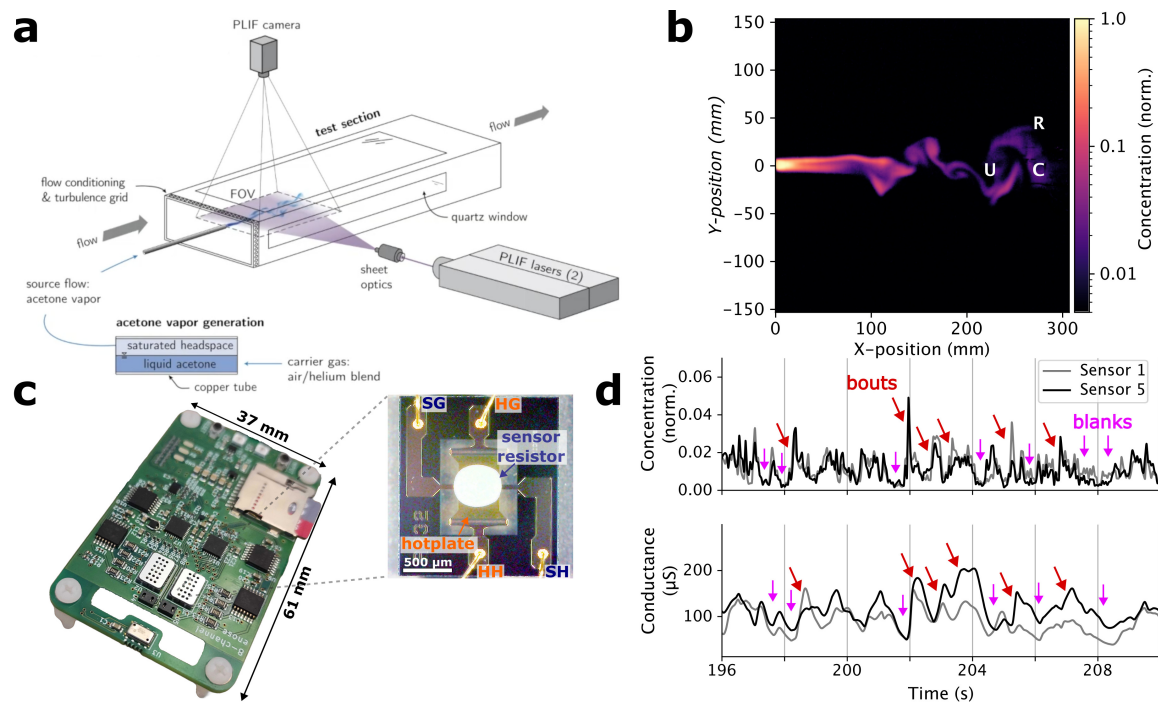


Fig. 1: Benchmark dataset for turbulent odour sensing. **a** PLIF setup in a turbulent wind tunnel (adapted from [6]). **b** Example PLIF image of the acetone plume with sensor locations. **c** Custom eight-channel MEMS MOx electronic nose (adapted from [4]). **d** Representative temporally aligned PLIF concentration and MOx sensor signals, illustrating that salient plume features remain visible in the sensor response.

bouts and blanks, are clearly visible in both modalities (see Fig. 1d). This confirms that the dataset captures shared plume structure across the optical and sensor domains.

Relevance and outlook

This dataset provides a benchmark for studying how turbulent odour fields are transformed by compact MOx sensors. The resource is directly relevant for deconvolution [7], system identification, transfer-function modelling, and data-driven reconstruction of gas concentration signals from sensor measurements. More broadly, it supports work in olfactory robotics [8], environmental monitoring, and neuromorphic sensing [9], where realistic turbulent statistics are essential but difficult to access experimentally. By combining non-invasive optical ground truth with synchronised high-speed gas sensing, the dataset fills an important methodological gap and offers a practical basis for comparing algorithms under shared experimental conditions.

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