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Mitigating the Effects of Mobility on Low-Cost Chemical Sensors

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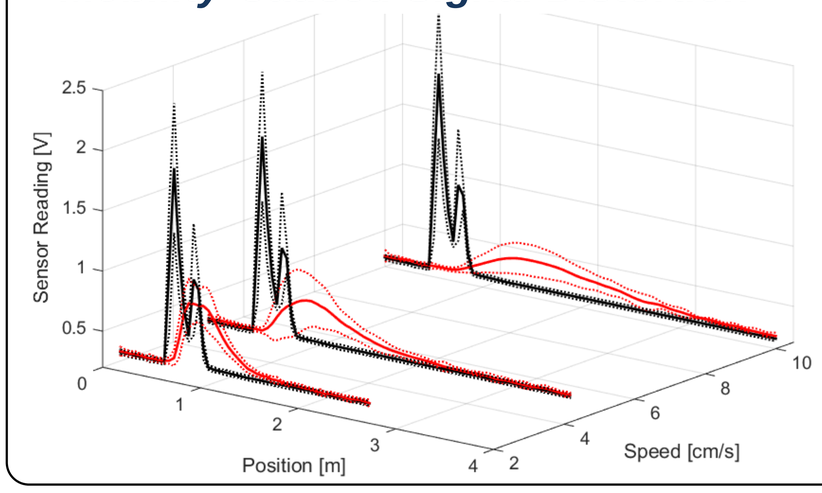
Mobility-Caused Signal Distortion



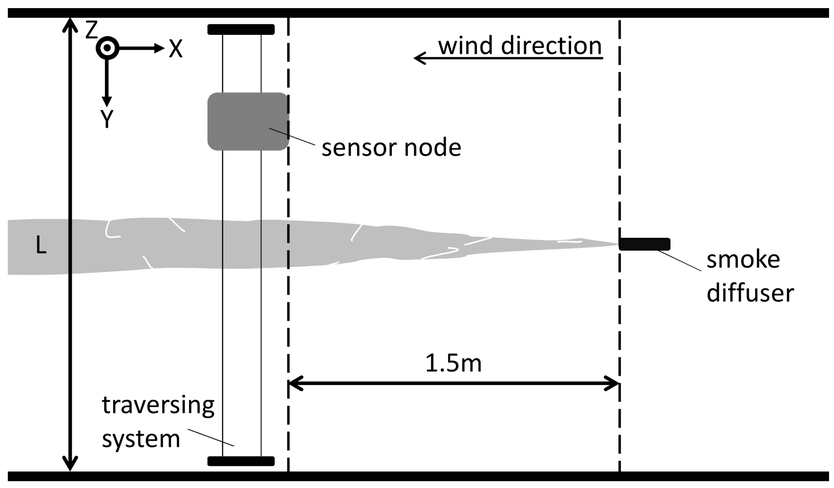
Average measured signal of electrochemical sensor over 10 dynamic runs at different movement speeds versus ground-truth.

- Chemical sensors typically have long response times to stimuli, which can range from a few seconds to multiple minutes.
- While for static deployments, this issue can be largely neglected, for mobile platforms it can induce significant distortion of the measured signal with respect to the underlying concentration levels.

Mobility & slow sensor dynamics induce a
distortion akin to motion blurring in photography

Experimental Set-up

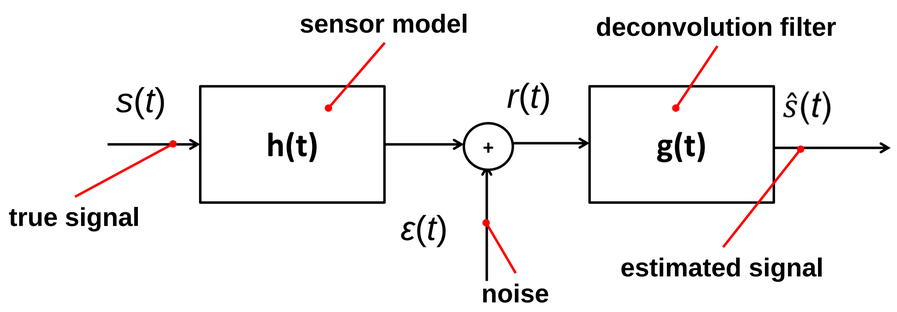
- We investigate this problem through **wind tunnel experiments:**
  - ❖ Evaluate sensing system, not only the sensor!
  - ❖ Possibility to control both sensing node mobility & air flow
  - ❖ Reduce variations of uncontrolled environmental parameters
- Sensing module attached to a **traversing system** (i.e. a cartesian coordinate robot).
- **Smoke machine** used for creating a detectable chemical plume.
- Fast response **photo-ionization detector** (PID) measurement system used as ground-truth.



Top view of experimental set-up inside wind tunnel (not to scale). Depending on experimental configuration, the value of L was either 2 m or 4 m. The PID was attached in close vicinity to tested sensor.

Signal Reconstruction through Deconvolution

- A typical signal processing approach for reducing the effect of motion-blurring is through **deconvolution**.



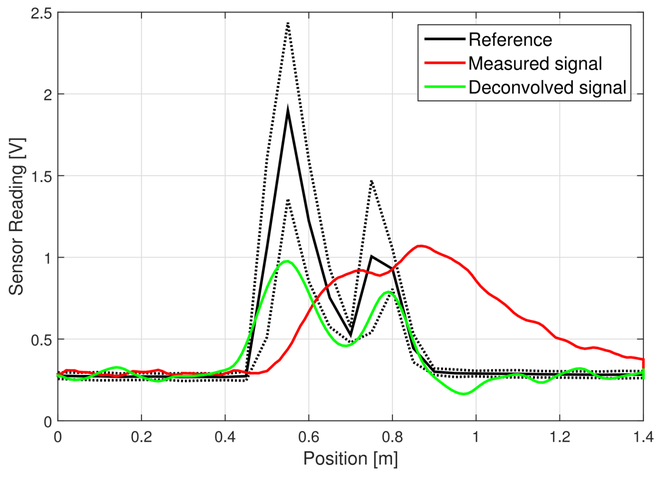
A deconvolution procedure convolves a distorted signal with a filter *g*(*t*), in order to obtain an estimation of the original signal.

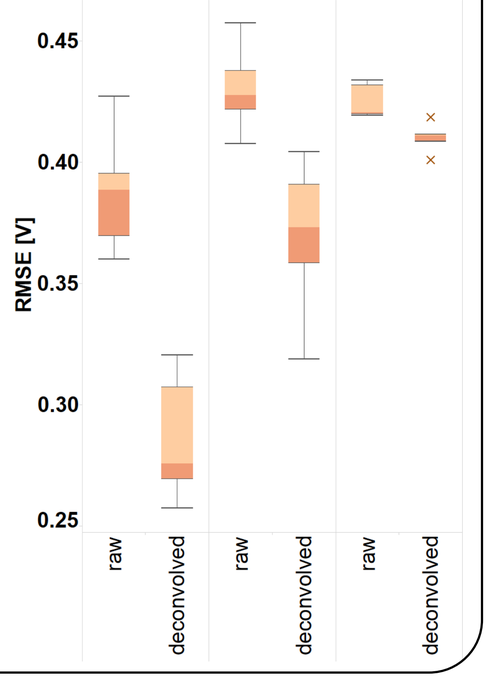
We use the **Wiener filter** $G(\omega)$ for performing the deconvolution...

$$G(\omega) = \frac{H^*(\omega)}{|H(\omega)|^2 + 1/SNR(\omega)}$$

… and assume a second order over-damped **sensor model** $H(\omega)$.

$$H(\omega) = \frac{A_0}{(1 + j\omega\tau_0)(1 + j\omega\tau_1)}$$

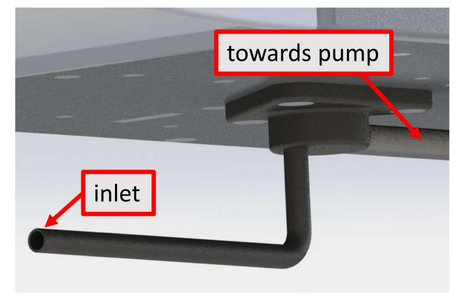




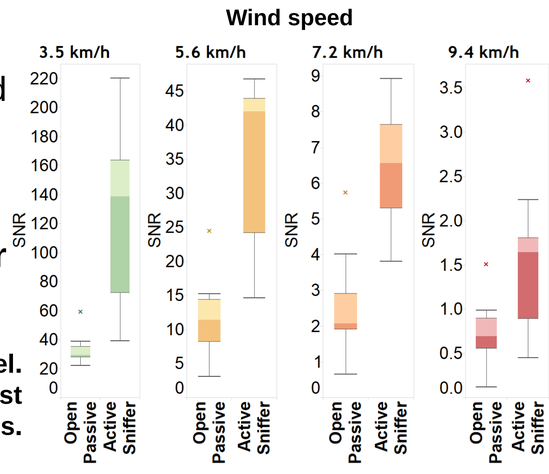
Signal deconvolution example for measurement data gathered during a run at 2.5 cm/s (top). Performance evaluation for each of the considered movement speeds in terms of root mean square error (right).

Air Sampling System Design

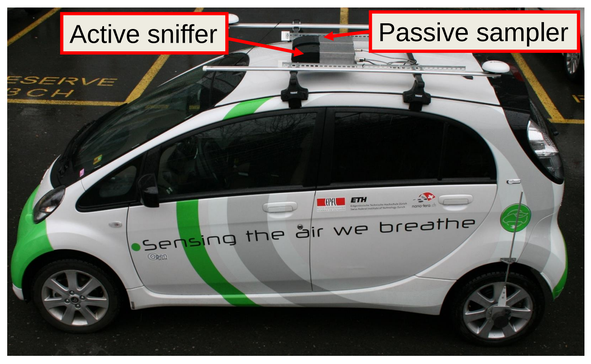
- The effectiveness of deconvolution techniques is limited by the **typical poor Signal-to-Noise Ratio (SNR)** of the measured signal.
- We studied the ability of **active sniffers** to **enhance measurement SNR**
- We investigated the performance of **different sniffer designs**, employing both fans and pumps as actuators.
- A significant improvement was obtained for one of our **pump-based design**.
- The SNR enhancement was validated through both **wind tunnel and outdoor trials**.

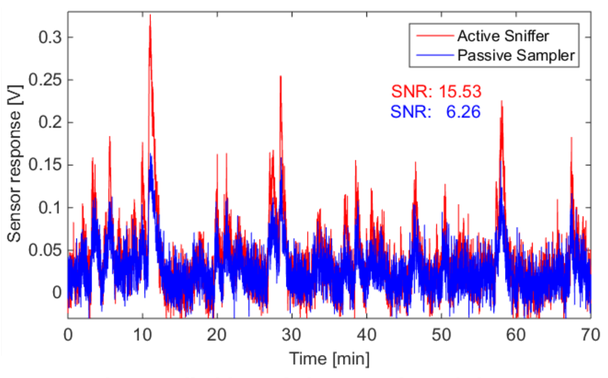


The best performing air sampling system design: a pump-based sniffer.



Evaluation of best sniffer in wind tunnel. The performance of the sniffer is robust to large wind speed variations.





Electrical car set-up used for our outdoor experiment (left) and the results of the real-world experiment (right), which confirm the benefit of using the active sniffer for enhancing the SNR of the chemical sensor measurements.

References:

A. Arfire, A. Marjovi, and A. Martinoli, "Mitigating Slow Dynamics of Low-Cost Chemical Sensors for Mobile Air Quality Monitoring Sensor Networks", in *Proceedings of the International Conference on Embedded Wireless Systems and Networks*, 2016, pp. 159–167

A. Arfire, A. Marjovi, and A. Martinoli, "Enhancing Measurement Quality through Active Sniffing in Mobile Air Quality Monitoring Sensor Networks", submitted to *the 2016 IEEE International Conference on Advanced Intelligent Mechatronics* (*AIM*).

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