Webinar Q&A Report:

Decoding Turbulent Chemical Plumes with Improved Signal Processing and Machine Learning

Q: What are the basics for developing air pollutant sensors especially for undergrads?

[J. Burgués] The first thing is to understand which gas sensing technology is the right one for your application. There is not a single sensor that can serve all applications. For example, optical infrared sensors are very good for measuring CO_2 or CH_4, but these sensors will not be too useful to measure odors. Characteristics such as sensitivity, selectivity, response time, stability and power consumption are important factors to take into account. There are some good introductory textbooks, like the one by Gründler in 2007.

Q: Can insects' olfactory system be tuned to detect other odors of importance to humans?

[J. Burgués] Genetic engineering has been recently used to knockout the expression of some key genes governing the selective olfactory system of the hawkmoth (Fandino et al., PNAS 2019). Therefore, I wouldn´t be surprised if in the long-term it is possible to apply the same techniques to tune the selectivity of the insect's olfactory receptor to satisfy our own needs.

Q: Can you share the full citation for the Decker 2011 study that apparently indicates 10kHz odor fluctuations?

[J. Burgués] Dekker, T., & Cardé, R. T. (2011). Moment-to-moment flight manoeuvres of the female yellow fever mosquito (Aedes aegypti L.) in response to plumes of carbon dioxide and human skin odour. Journal of Experimental Biology, 214(20), 3480-3494.

The statement of the 10 kHz fluctuations contains a typo. It should be 10 Hz fluctuations as it can be observed in the figure by Decker shown on that slide.

Q: What are the highest odor plume frequencies that you actually measure with the PID in your plumes (regardless of the stated 330Hz response)?

[J. Burgués] In the plumes we can artificially produce in the lab, we have measured signals with significant spectral content up to 50-60 Hz.

Q: Can we apply these sensors to measure concentration in liquid plumes in liquid ambient fluid?

[J. Burgués] Unfortunately, these sensors will be damaged if they are directly exposed to a liquid sample. In this case, one possibility would be to design a special sampling system that retrieves the vapor from the liquid and sends it to the sensors in the gas chamber. However, the simplest solution is probably to use some kind of electrochemical sensor or biosensor that can operate in liquid environments.

Q: Have there been any tests into how the sensor sensitivity compares to that of live insects when tracking pheromone plumes?

[J. Burgués] The group of Dominique Martinez has worked extensively on comparing different plume tracking strategies either using MOX sensors or the antenna of a moth on board of mobile robots. However, they mostly focused on the impact of the response time rather than the sensitivity. Since the experiments were performed in small arenas with strong gas concentrations, it is difficult to make any statement about the sensitivity. Here are the relevant publications:

Martinez D, Rochel O, Hugues E. A biomimetic robot for tracking specific odors in turbulent plumes. Autonomous Robots. 2006 Jun 1;20(3):185-95.

Martinez D, Arhidi L, Demondion E, Masson JB, Lucas P. Using insect electroantennogram sensors on autonomous robots for olfactory searches. JoVE (Journal of Visualized Experiments). 2014 Aug 4(90):e51704.

Q: How sensitive are the parameters of the inverse filter to the plume characteristics?

[J. Burgués] The filters have been optimized for the type of plumes that we can artificially generate in the lab or in other indoor scenarios. We expect that the optimum cut-off frequency of the filter will change if the system is operated in a different type of plume, e.g., outdoors. Therefore, for maximum performance the system will need to be recalibrated under the conditions of the target scenario.

Q: How computationally complex is the execution of the inverse filter?

[J. Burgués] The filters have been designed using Finite Impulse Response (FIR) technique, which allows for an efficient real-time execution even with low-cost computers (e.g. Arduino-type). Using the FIR technique, the execution of the filter only requires multiplying the signal values by the coefficients of the filter and adding up the results.

Q: Is the miniPID capable of measuring absolute concentration?

[C. Rand] More often than not, the miniPID is used to measure the concentration of an odor relative to clean air. However, the PID can be calibrated to a specific odorant by pre-calibrated cylinders of your odor or by mixing pure odor with clean air using a mass flow controller. Alternatively, if your odorant is not readily available in pure or calibrated cylinders, then you can use an odorant with the same ionization potential as your odor of interest.

Q: Is the miniPID required for operation of the fast MOX sensors?

[J. Burgués] No, the miniPID is only used during calibration process. Afterwards, the MOX sensors can be used alone with the help of an external pump that brings the air sample into the sensor chamber (i.e. replacing the internal pump of the miniPID).

Q: Can the miniPID differentiate between odorants and their concentrations? In other words, can you measure a mixture of different odors?

[C. Rand] The miniPID functions by ionizing inbound molecules and will do so for any odorant with an ionization potential less than 10.6eV, which makes it non-specific. The output of the sensor is therefore a measure of total ionizables present and will not measure individual odor concentrations within a plume.

Q: What is the filling time of the sensing chamber that hosts the MOX sensors?

[J. Burgués] According to our CFD simulations, the time required to fill the miniaturized chamber (volume of 1.3 mL) using the miniPID's pump (1.1 L/min) is only 75 ms. This ensures that the chamber does not introduce any low-pass effect into the measurements.

Q: Are multiple MOX sensors required for operation of the system?

[J. Burgués] No, the system can work with a single sensor. Several sensors (minimum of two) are needed only for blind deconvolution approach.

Q: Is it possible to string multiple PID units together in the field?

[C. Rand] This is a common question when doing environmental monitoring or plume tracking where the need for multiple points of measurement are needed. In short, yes this is possible. The miniPID is an analog OUT device so the ability to string multiple units relies on the data acquisition system employed in the trials and the distance between sensors. You can string the PID outputs into an A to D converter to feed the signals into your software and monitor all sensors at once.

Q: How do you calibrate your device?

[C. Rand] At our shop we use calibrated tanks of propylene. The reason for this is it ionizes well, is readily available and is relatively inexpensive. These tanks come in 1000ppm, 100ppm, 10ppm and 1pmm and we combine these with a tank of zero clean air to generate additional concentrations to calibrate the device. The PID will saturate around 500ppm, so to get the top data point we run a mixture of 1000ppm and clean air in equal parts. To calibrate, we deliver these varying concentrations of propylene and record the voltage output of the miniPID to generate a calibration profile at all 3 pump speeds and ensure it is linear throughout the range which is then provided with every unit.

Q: Which models of MOX sensors are compatible with this system?

[J. Burgués] The system has been designed for TGS 26xx sensors from Figaro manufacturer, but it can be adapted for other sensors with a similar form factor (TO-39 housing or similar).

If you have additional questions for Aurora Scientific or Dr. Javier Burgués regarding content from their webinar or wish to receive additional information about plume tracking experimentation please contact them by email.

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