Robots that can smell: motivation and problems

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ABSTRACT

Out of all the components of a mobile robot, its sensorial system is undoubtedly among the most critical ones when operating in real environments. Till now, these sensorial systems mostly rely on range sensors (laser scanner, sonar, active triangulation) and cameras, while electronic noses have barely been employed despite they can provide a complementary sensory information, vital for some applications, as it happens for humans.

This paper analyzes the motivation of providing a robot with smelling capabilities and also singles out some of the hurdles that are preventing smell to achieve the importance of other sensing modalities in robotics. Although we address these subjects from a wide perspective, we are particularly interested in indoor social robots, a field in which we provide our own research experience regarding three important robot olfaction problems: sensor modeling, gas distribution mapping and odor classification. We present some illustrative examples aimed at gaining a better insight into the challenges and real possibilities that olfaction offers to robots.

WHY DO WE NEED A ROBOT THAT SMELLS?

Broadly speaking, we envisage two types of scenarios where smelling becomes important for a mobile robot:

- Obviously, to carry out specific odor-oriented tasks, typically to detect hazardous substances: a mobile platform with an artificial nose can continuously sample the air, and decide its actions based on this information in a closed-loop manner. This makes robots ideal for locating gas leaks, explosives, drugs, and other dangerous stuff—since robots can go to places where it would be unsafe to send a human or a dog.
- To complement other sensing capabilities (typically vision) and to reason about the sensed information. When we face a cup with a dark liquid on it we can assert that it is coffee not only because of what we see but also because of what we smell. When we perceive the scent of food being cooked we immediately associate it to that particular human activity and infer that somebody must be in the kitchen. When we detect an abnormal butane odor we do not look for the gas leak in the living room, instead we go to the kitchen where we do not inspect everything in there but only those appliances and items that use butane gas (heater, oven, ...). All these examples illustrate an intelligent and complex mechanism of perceiving and acting in the environment, which makes use of sensorial data fusion and high-level world knowledge, especially semantic information.

MOBILE OLFACTION SPECIFIC PROBLEMS

Besides the inherent complexity of artificial olfaction, new difficulties emerge when performing olfaction with a mobile robot. Next we review these problems.

- The first and most relevant issue is that gas measures are strongly affected by environmental factors: temperature, humidity, and very specially airflows (including the one created by the own robot movement) [1]. In real uncontrolled environments where a robot operates, all these factors affect the dispersion of gases in an unpredictable way. As a side effect, this prevents us deriving a ground truth, which in turn hinders the validation and comparison between different approaches.
- Another problem relates to the own nature of the gas sensors: in most cases, point-measurement samples (typically, the sensor surface is smaller than $1cm^2$). To overcome this limitation robotic e-noses use to incorporate a fan (or a pump) to sniff air from an area around it, and then inject the airstream onto the sensor surface.
- Odor is ephemeral and thus any gas map of the environment. Any measurement provided by an e-nose captures an instantaneous reality that does not last long. Thus, we are facing an “olfactory world” which is highly changeable.
- Most gas sensors employed in robotics has long response times [2]. Among the most popular ones, because its price, simplicity and sensitivity are MOX sensors. Figure 1 shows the response of such a sensor when exposed to a pulse excitation signal.

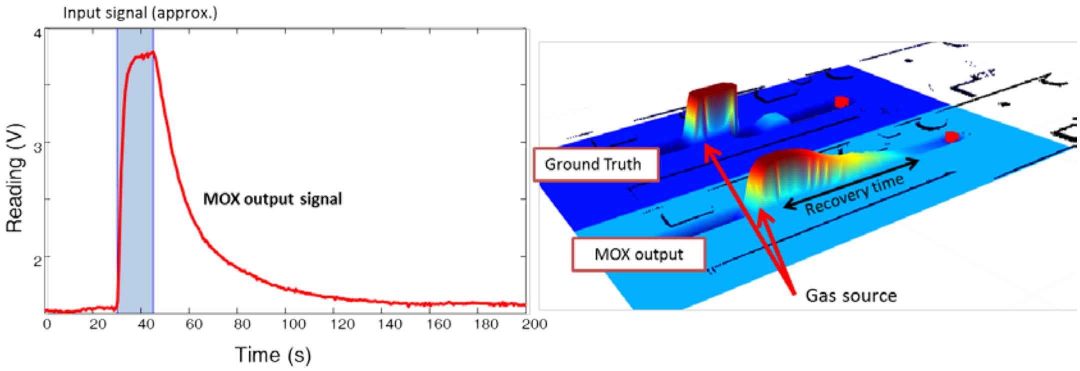

Figure 1: Illustration of the slow response of MOX gas sensors in time (left) and space (right). Such slow response means that the sensor needs to be exposed about 10s. to get the steady value, and to wait more than a minute until taking a new measure.

ADVANTAGES OF MOBILE OLFACTION

We have mentioned robotic olfaction specific-problems but, having the olfactory sensor o nboard the robot also brings some important advantages, including:

- Help from other sensors: vision, laser scanner, …
- A great deal of onboard computation available.
- Robot motion can also work to enable a better sensing, for example, validating measurements from a different position or finding a the possible odor source.
- Robot intelligence, for example making use of world semantic knowledge to infer or corroborate possible explanations (as in the examples above).

SOME ILLUSTRATIVE EXAMPLES

The rest of the paper is devoted to illustrate some of the above-mentioned issues in real examples of gas concentration mapping [3, 4] and for a robot equipped with an arm which combines vision (RGB-D camera) and an e-nose to accomplish a complex task.

References

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