Chapter 70
Towards Odor-Sensitive Mobile Robots

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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. Until now, these sensorial systems mostly relied on range sensors (laser scanner, sonar, active triangulation) and cameras. While electronic noses have barely been employed, they can provide a complementary sensory information, vital for some applications, as with humans. This chapter analyzes the motivation of providing a robot with gas-sensing capabilities and also reviews some of the hurdles that are preventing smell from achieving the importance of other sensing modalities in robotics. The achievements made so far are reviewed to illustrate the current status on the three main fields within robotics olfaction: the classification of volatile substances, the spatial estimation of the gas dispersion from sparse measurements, and the localization of the gas source within a known environment.

INTRODUCTION

In the last decade, the number of research works published in the area of artificial olfaction has increased notably, with important advances in chemical sensor technology, bio-inspired and engineering based e-noses, and a broad range of algorithms to counteract drift and environmental cross-sensitivity, as well as to improve efficiency in the recognition of chemical volatiles. Likewise, a promising transfer from laboratories to real world applications has started, which despite the long and challenging road ahead, vows for granting this forgotten sense the importance it has in the animal kingdom (Doty, 2015).

In this regard, mobile robot olfaction (MRO), the branch of robotics that addresses the integration of gas and chemical sensors on-board mobile platforms, has also gained substantial relevance in the scientific community due to the interesting advantages a mobile robot brings when compared with the

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traditional approach based on networks of static e-noses (Tsujita, Yoshino, Ishida, & Moriizumi, 2005). First, a mobile robot usually carries only one e-nose, therefore a more sophisticated and powerful (and more expensive) model can be used, enabling the analysis of more complex compounds and the detection of faster changes in the gas concentration (Gonzalez-Jimenez, Monroy, Garcia, & Blanco, 2011; Ishida, Kobayashi, Nakamoto, & Moriizumi, 1999; Sanchez-Garrido, Monroy, & Gonzalez-Jimenez, 2014; Werle et al., 2002). The calibration phase of the sensing devices is greatly simplified because of the reduced number of e-noses, something that represents an important issue in large gas sensing networks (Esposito et al., 2016). Also, MRO systems permit sampling at higher (and adaptive) resolutions, while still providing the required accurate localization of each measurement. Finally, a mobile robot can leverage environmental information provided by other sensors on board (anemometers, cameras, laser scanners, etc.) to enhance the olfaction task, for example by detecting obstacles or changes in the environmental conditions, and to process such data in an online fashion, allowing decision making.

Three are the main fields where gas-sensitive mobile robots have been proposed: volatile chemical recognition, which deals with the problem of identifying which of a set of categories a new volatile sample belongs to, gas distribution mapping, where the objective is to obtain a truthful representation of how volatiles are dispersed in the inspected area and their respective concentrations, and gas source localization, where the robot is commanded to localize the emission sources. In this chapter, achievements made to each of these three fields are reviewed after a brief overview of the specific challenges of gas-sensitive mobile robots.

SPECIFIC CHALLENGES OF GAS-SENSITIVE MOBILE ROBOTS

The development of mobile robot olfaction systems is not a trivial problem, and despite recent achievements, the potential of gas-sensitive mobile robots has yet to be fully realized. Besides the inherent complexity of artificial olfaction, new difficulties emerge when performing olfaction with a mobile robot. In this section, a review of the main issues and technical solutions proposed so far is presented.

Chemical Sensors

While most animals, from simple bacteria to mammals, are empowered with a highly developed and sharp sense of smell, sensors for robots with capabilities close to those of animals are not yet available. One of their main drawbacks is related to the response speed. While the response time of an animal's chemoreceptor is in the order of 100ms (Beer & Ritzmann, 1993), typical gas sensors need several tens of seconds before their responses reach the steady state values (Pearce, Schiffman, Nagle, & Gardner, 2006). For illustration, Figure 1 shows the rise and recovery times of a conventional metal oxide gas sensor when exposed to a rapid excitation. As reported in (Monroy, Gonzalez-Jimenez, & Blanco, 2012) the adopted solution to palliate this negative effect has been, in most cases, to slow down the locomotion of the robot to a few cm/s, as in (Ishida, Suetsugu, Nakamoto, & Moriizumi, 1994). Yet, over the past years, different hardware and software approaches have been proposed to overcome to a certain extent this important limitation (Di Lello, Trincavelli, Bruyninckx, & De Laet, 2014; Fonollosa, Sheik, Huerta, & Marco, 2015; Gonzalez-Jimenez, Monroy, & Blanco, 2011), enabling a higher speed for the robot and consequently improving its effectiveness in real world applications.

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