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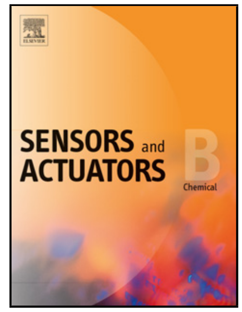

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A Cluster Analysis Approach Based on Exploiting Density Peaks for Gas Discrimination with Electronic Noses in Open Environments

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Abstract

Gas discrimination in open and uncontrolled environments based on smart low-cost electro-chemical sensor arrays (e-noses) is of great interest in several applications, such as exploration of hazardous areas, environmental monitoring, and industrial surveillance. Gas discrimination for e-noses is usually based on supervised pattern recognition techniques. However, the difficulty and high cost of obtaining extensive and representative labeled training data limits the applicability of supervised learning. Thus, to deal with the lack of information regarding target substances and unknown interferents, unsupervised gas discrimination is an advantageous solution. In this work, we present a cluster-based approach that can infer the number of different chemical compounds, and provide a probabilistic representation of the class labels for the acquired measurements in a given environment. Our approach is validated with the samples collected in indoor and outdoor environments using a mobile robot equipped with an array of commercial metal oxide sensors. Additional validation is carried out using a multi-compound data set collected with stationary sensor arrays inside a wind tunnel under various airflow conditions. The results show that accurate class separation can be achieved with a low sensitivity to the selection of the only free parameter, namely the neighborhood size, which is used for density estimation in the clustering process.

Keywords: gas discrimination; environmental monitoring; metal oxide sensors; cluster analysis; unsupervised learning.

1 Introduction

Gas discrimination using low-cost electronic noses (e-noses) is of great interest in many applications outside laboratory conditions, such as detecting hazardous gases, monitoring air pollution in urban areas, emissions from sewage facilities and animal production facilities [1-3]. In some cases, these applications entail continuous data collection in open and complex environments. One prominent example is mobile robots equipped with e-noses conducting tasks like exploration of hazardous areas and leak detection [3-5].

Traditionally, gas discrimination with e-noses has been carried out in chambers, where environmental conditions, such as humidity, temperature, airflow, and gas exposure patterns are tightly controlled. Such conditions enable the well established three-phase sampling strategy to be performed [4]. In a three phase-sampling process, the sensors are firstly exposed to a reference gas (e.g. clean air) to set a known baseline response level for the sensor array. Then, the sensors interact with injected gas samples for a period of time until a steady response state is reached. The sampling process concludes as the sensors recover to their baseline level when the gas sample is flushed away. For example, in Fig. 1a, the sensor responses show a clear three-phase profile, which is acquired with the sensors inside in a chamber after the sensors have been exposed to the gas sample for a considerable amount of time. Up to date, many studies on gas discrimination have achieved great success under the three-phase sampling strategy [6-8]. Contrary to laboratory