Aix*Marseille université

Collège doctoral

Project title:
Development of hybrid approaches of data analysis and automatic classification augmented by physical knowledge: application to the design of smart microsensors, versatile, for selective measurement of VOC emissions.

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Project description:

The increasing demands of government and industry in terms of exhaust emissions have motivated the scientific community to focus its research on the development of sensors more and more sensitive and versatile. As the variety of pollutants is large and the levels of adverse health effects may be very low, it has become imperative to design detection systems that are both highly sensitive and highly selective. Today, only on-site sampling and laboratory analysis can meet these requirements that remain expensive and not compatible with real-time monitoring. The development of highly sensitive, reliable, portable and low-cost detection systems is still limited because it is not selective enough.
Aix Marseille University (AMU) is particularly involved in this research through the Institute Materials, Microelectronics and Nanosciences of Provence (IM2NP), with the installation of equipment for manufacturing and testing prototypes of gas sensors, in close collaboration with local and national industrial partners. The Microsensors and Instrumentation team of the IM2NP has been interested for many years in the development of microsensors for the monitoring of indoor and outdoor air quality [1-3]. It has recently developed and patented (No. FR 13 59494) a generic transducer serving as a base for gas microsensors consisting of this transducer and a heated sensitive layer, allowing the detection of different gases. This transducer allowed the realization of several prototypes of sensors for the measurement of concentrations of carbon monoxide or ozone, or volatile organic compounds (VOCs) (mixture BETEX: benzene, toluene, ethylbenzene, xylene) [4-5].
For these prototypes, the technological solution used involves a sensitive layer of tungsten oxide whose IM2NP masters the manufacturing with very accurate characteristics. Indeed, the gas microsensors based on semiconductor oxides (SnO_2, WO_3, ZnO ...) are of interest because they are very sensitive. Their operation is based on the variation of conductivity of the semiconductor layer during the adsorption of the gas. Their compatibility with the collective fabrication techniques of microelectronics allows a low-cost production.
However, it is important to specify that the results obtained with these prototypes were carried out under a controlled laboratory atmosphere, comprising the gas to be detected diluted in dry air. Nevertheless, tungsten oxide, like all semiconductor oxides, does not make it possible to obtain a very selective response to a given gas. In the case of the detection of pollutants in a real atmosphere, which is therefore very complex, the sensitive surfaces of the sensors are simultaneously subjected to all the gases present, and a cumulative overall response is obtained, characterizing all the compounds, and not each of the gases present within the mixture. This usually does not identify and accurately quantify the intended constituent.

This project aims to develop software solutions to improve the selectivity of the VOC sensor previously realized, in order to be able to discriminate benzene from toluene, taking into account also the most frequent interferents (water stream, CO_2, CO, ozone, nitrogen oxides). The influence of sensor aging on its sensitivity, selectivity and repeatability of measurements will also be modeled and integrated into the software.

Solutions can be provided through advanced data analysis and classification, sensitivity analysis, and trend analysis techniques combined with physical knowledge of the gas and sensor environment [7-14]. The Laboratory of Computer Science and Systems (LIS) works from years on statistical and multivariate analysis of data associated with the physical knowledge of systems and the environment, applied mainly in the field of fault diagnosis and prognosis [7-14] with various applications, ranging from microelectronics [10] to large-scale systems ([9],[13],[14]). The research will focus on the development of hybrid methods, where the statistical tools for feature extraction and classification will be applied initially on data from the IM2NP test benches. Then, the research issues related to the isolability of the characteristics and their trend will be addressed as follows:

- The first research issue that will be addressed in this PhD work concerns the identification of the variables carrying the characteristics of the different gases to be detected. Statistical methods such as Empirical Modes Decomposition [14] and techniques for extracting statistical attributes [9], methods of frequency analysis and time-frequency analysis such as Wavelet decomposition [13] will be particularly investigated.
- The second research problem is related to the identical signatures of several gases; it will be treated by integrating into the algorithms, the physical knowledge specific to the environment and to each gas. For the integration of physical knowledge, parameter estimation and on-line parameter updating techniques will be the first line of research to increase the size of the gases signature-matrix and thus improve their isolability.
- The last issue concerns the time-evolution of the characteristics, which is very much in demand by the industrialists for safety reasons. It will be treated by trend modeling and online updating methods [7-9]. Geometric trend modeling techniques, based on Euclidean distance, continuous Markov models, and adaptive differential models will be the research that will be explored in this thesis work.

The ultimate aim being the development of the quickly marketable sensors in the industrial environment, special attention will be given to the development of efficient algorithms but also easily implementable in embedded microcontrollers or FPGA modules.

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