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# An ensemble of adaptive classifiers for improving faulty and drifting sensor performance

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## Abstract

Gas sensor arrays can be very sensitive to the properties of individual sensors, then even the fault of one of the array element can greatly jeopardize the array performance. Sensor replacement easily achieves the pristine conditions but non reproducibility between sensors of the same series may also require a new calibration. In this paper, a processing strategy aimed at counteracting the necessity of new calibration is introduced. It is based on an ensemble of adaptive classifiers each built with single sensors data. The array prediction is then obtained by a majority voting decision rule based on the outputs of the ensemble of models. The classifier has been tested with an experiment aimed at detecting gases with a drifting gas sensors array. The classifier performance has been compared with a standard classifier.

"Keywords: Gas sensor; adaptive classifier; drift counteraction; fault tollerance."

## 1. Introduction

The use of sensor systems in real scenarios suffers of limitations that may drastically reduce the potential applications [1, 2]. Sensor drift is surely one of the more frequent of such impairments [3]. Another recurrent problem is the fault of one of the array elements and the management of the replacement procedure. Non reproducibility among sensors nominally equal makes impossible to transfer the old calibration to the new sensor array, and then a re-calibration procedure is necessary to recover the pristine performance [4]. This procedure is time consuming and it requires an additional data analysis step to adapt the new database to the classification model trained with old data. For classification purposes the problem can be alleviated by using properly designed classifiers. Herewith, a solution based on an ensemble of adaptive classifiers is presented when a non-selective gas array sensors is considered.

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## 2. Algorithm

The schematic representation of the algorithm is illustrated in figure 1. During the training, a pool of templates for each sensor classification model is generated avoiding the class templates overlapping. This property is crucial for an effective adaptive strategy of the templates. The class assignment of the single model is based on a minimum distance criterion, while the predictions of the classifiers are used for the final class assignment by means of a majority-voting strategy [5]. This approach avoids that the malfunctions of one of the sensors hinders the discrimination power of the overall array. In test, the presentation of every new data generates an update of the templates of the single sensor models in order to follow the evolution of the drift and to maintain at the same time also the class distances. This algorithm exploits the redundant information of the sensors composing the array to maintain the classification rate also in presence of sensor faults.
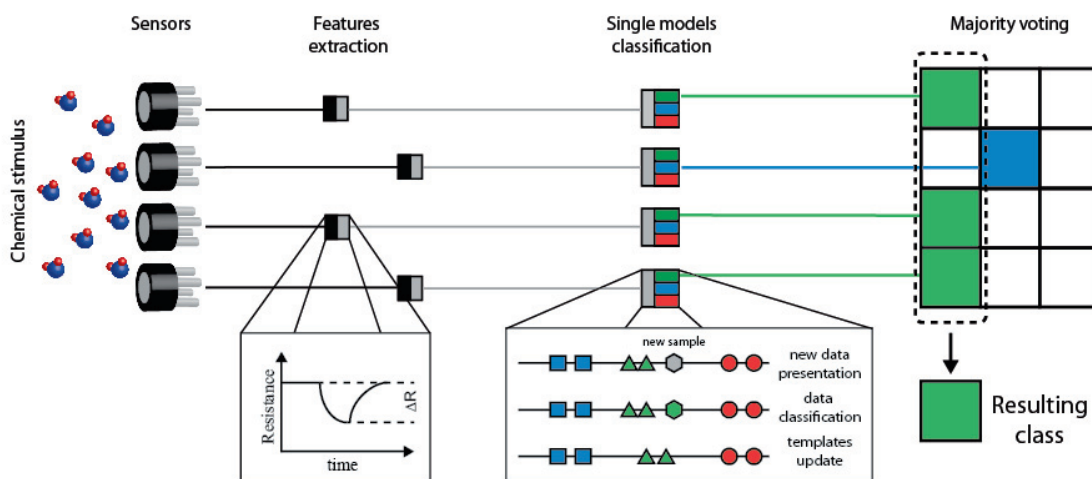


Fig. 1*: Architecture of the classification model. The left box shows the sensor feature (ΔR) that is considered as the measure descriptor; the right box shows the adaptation strategy used by the classifiers.

## 3. Experimental Details and Results.

In order to evaluate the proposed algorithm, an array of 8 commercial semiconductor gas sensors was routinely exposed to three volatile compounds (acetaldehyde, ethylene and toluene) each at a fixed concentration. For each sensor the difference of resistance after and before the injection of the gas has been measured and used as feature. The collected data were arranged in chronological order obtaining 300 samples equally distributed for the three classes. The first 60 measures where use to train the model and the remaining samples to test the calibrated model. Principal Component Analysis (PCA) is enough to highlight the different time behavior of the signals to the three classes (see Fig. 2). Scores plot shows that the trajectories of ethylene and acetaldehyde are almost orthogonal among them while toluene signals in this particular projection remain rather stable.
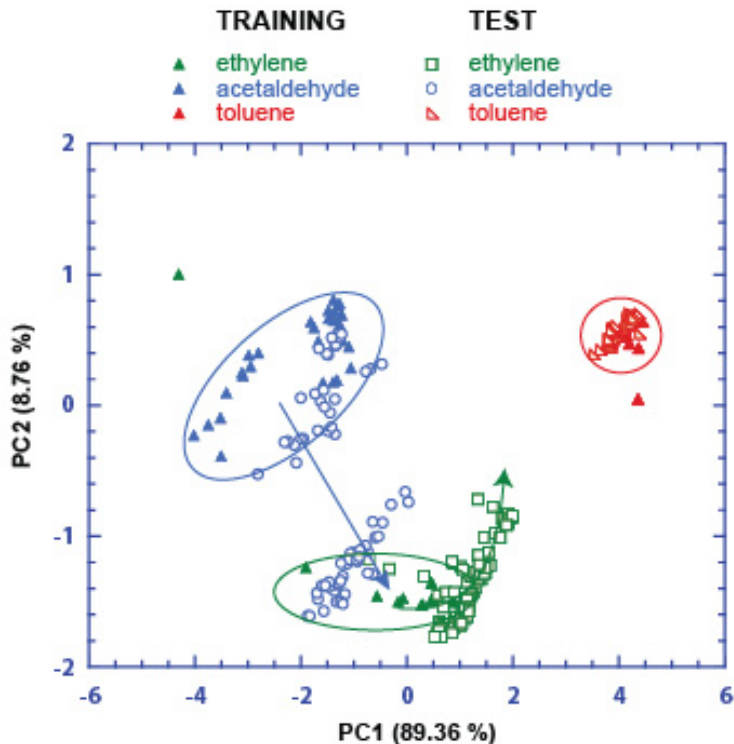
Fig. 2: PCA Scores plot of the first two principal components of the experimental dataset.

The performance of the ensemble of classifiers was compared with those obtained with k-NN (k=1) classification model and with the proposed algorithm without adaptation. This last model has been considered to put in evidence the contribution of the majority voting to the identification rate. Results show that the ensemble of adaptive models can maintain the complete classification during the whole test (see Fig. 3). It is also interesting to note that non-adaptive majority voting outperforms the k-NN.

This suggests that k-NN is more sensitive to the behavior of individual sensors, and then the drift of a subset of sensors affects the overall classification.

## 4. Conclusion

In this work a classification model based on a majority voting applied to an ensemble of adaptive classifiers for an array of non-selective gas sensors has been introduced and validated with an experimental dataset. The complete classification achieved by the here presented algorithm indicates that the combined approach of a majority voting decision rule and an adaptation of the single sensors can effectively de-sensitize the classification from the drift of individual sensors improving the sensor system performance in real scenarios.
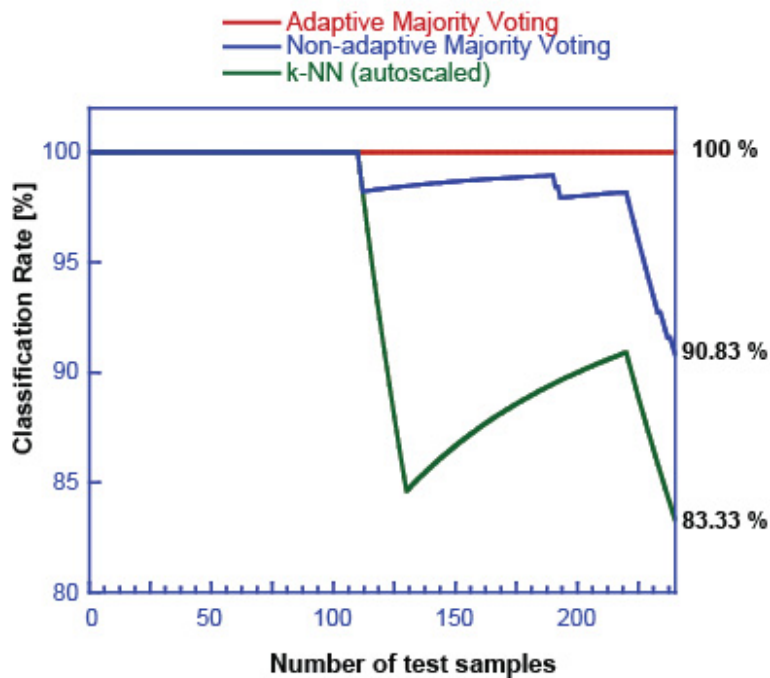
Fig. 3: Evolution of the performance in the testing phase for the three considered models.

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