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## Facile sensors replacement in optical gas sensors array

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### Abstract

Sensors are the less durable parts in any chemical sensor system, then the replacement of sensors maintaining hardware and data processing is a necessity in real applications. Though sensors replacement requires a perfect reproducibility of the sensors fabrication. Among the different sensor technologies, those based on optical transduction may offer a straightforward methodology to release the requirement of identical sensor manufacturing. In particular it will be shown here that the use of image sensor provides a surprising parallel with natural olfaction. An important consequence is that the data processing is independent from the geometric arrangement of the sensitive layer. This feature leads to a simple sensor layer replacement and to a prompt arrangement of different sensor systems, even remotely located, into a single data processing system.

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### 1. Introduction

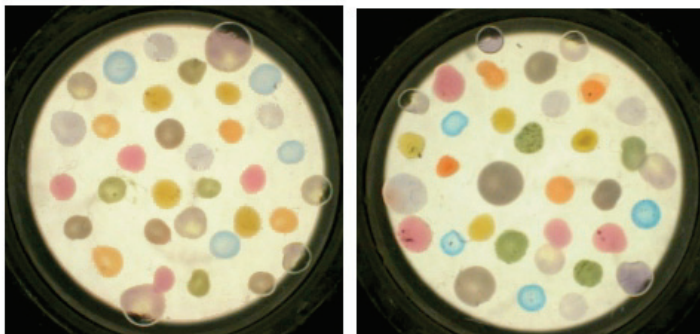
In biology, the association between Olfactory Receptor Neurons (ORN) and glomeruli (GLO) is driven by the genetic signature of the receptor [1], namely there is an intrinsic ORN gene that makes them converging to the relevant glomerulus independently from the spatial positions. This strategy is highly efficient also in case of ORN replacement. Indeed, olfactory neurons find the proper glomerulus with a very low error rate. In order to exploit the same strategy of ORN-GLO association in the artificial olfaction, a system based on an array of optical sensors has been considered. Optical sensor arrays are collections of dyes layered on a transparent substrate. The color of the dyes is intrinsically related to the molecular structure, and then it is an intrinsic property of the indicator. Hence, since image detectors measure the color of individual pixels, it is possible to cluster the pixels according to their color. This is equivalent to cluster in homogeneous classes the portions of dyes imaged in each pixel [2].

In this work, the application of the above mentioned ORN-GLO association has allowed the replacement of sensitive layers maintaining the same responses to chemical stimuli.

## 2. Experimental details

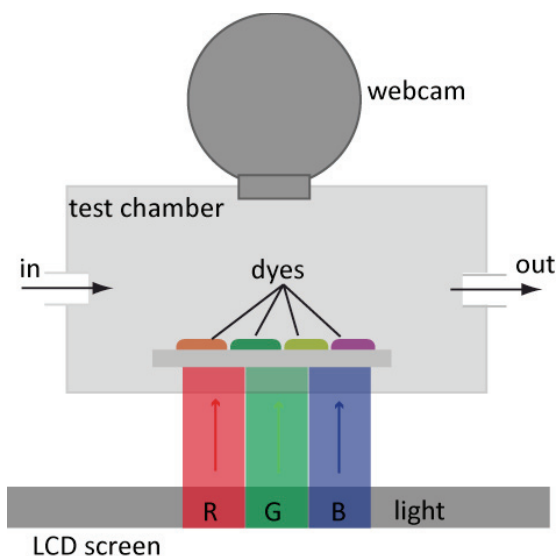
Two sensing layers (figure 1), composed by the same eight chemical indicators (porphyrinoids with different metals and Nile-blue) but with different geometric arrangement have been prepared. Chemical indicators have been spotted in a polymeric solution as elsewhere described [2].

The optical properties of the sensor arrays are interrogated with the Computer Screen Photo-assisted Technique (CSPT), a combination of computer screen and digital camera yet exploited for chemical sensing purposes [3].



**Fig. 1:** Picture of the sensing layers taken with the CSPT arrangement under white light illumination.

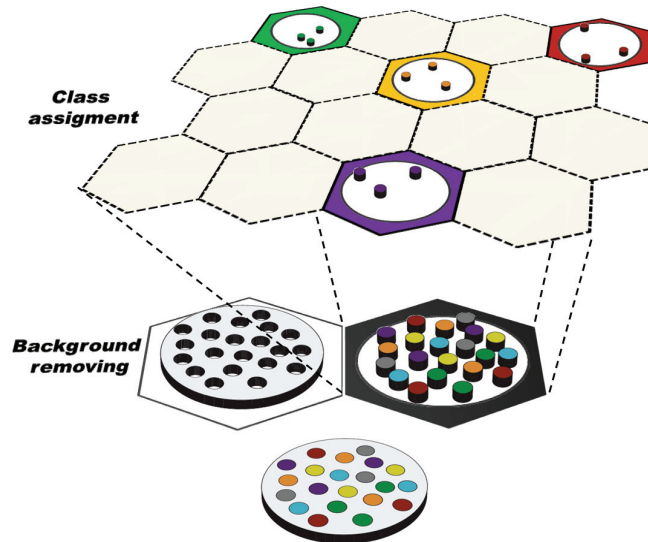
Sensing layers were illuminated with a LCD computer monitor (Philips 1704S) and imaged with a digital camera (Philips SPC900NC). A sketch of the experimental set-up is shown in fig. 2. In order to evaluate the intrinsic optical properties, the sensing layers were exposed to dry air and illuminated with a sequence of 50 colours. The optical characteristics of each pixel (called fingerprint) were obtained summing the transmitted radiation measured in the three camera filters. The response of the sensing layers during the gas exposure was measured shining the layers with a sequence of the three pure RGB colours. The tested gases were two amines (triethylamine, trimethylamine) and two alcohols (ethanol and butanol) dosed at three different concentrations.



**Fig. 2:** CSPT arrangement for sensing layers interrogation.

### 3. Results

Fingerprints of image pixels were clustered by a Self Organizing Map (SOM) [4]. The classification concept is illustrated in Fig. 3. Since most of the sensing layers is uncoated the largest portion of image pixels do not carry information about the sensitive spots. Two neurons SOM was used to separate dye carrying pixels (coloured) from background pixels (white coloured). The segregated pixels related to dye spots were classified by a 16 neurons SOM. All SOM models were arranged in hexagonal topology.



**Fig. 3:** Background pixels are removed through a 2-units SOM and then the remaining pixels are classified into 16 classes by a second SOM according to their optical properties.

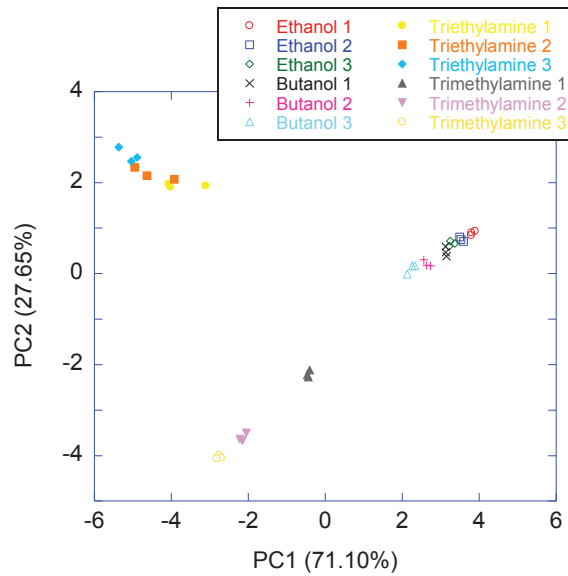
The SOM was trained with the pixels of one of the two sensing layers; the fingerprints of the pixels of the second layer were then projected onto the trained SOM. The response to gases was calculated as the mean of the signals of the pixels converging onto each SOM units. Eventually, The sensor array output is a 16 components vector.

To compare the responses of the sensor arrays, the multivariate sensor outputs have been processed by Principal Component Analysis (PCA). The plots of the first two principal components are shown, for both sensing layers, in Fig. 4 and Fig. 5.

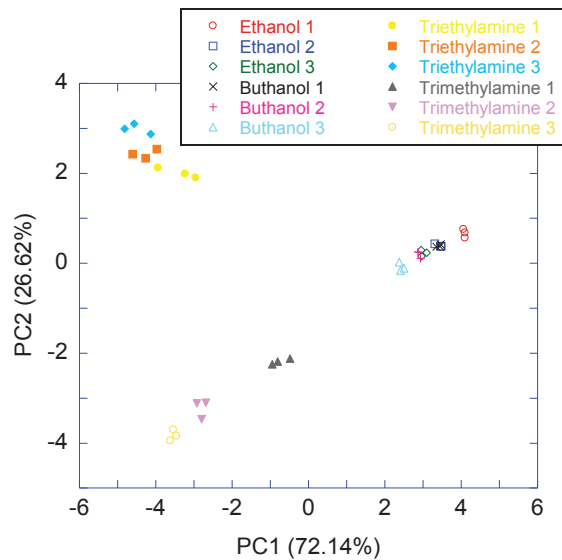
The two scores plots are qualitatively similar demonstrating that the second sensor layer is adequately processed by the SOM trained by the first sensor layer. The result is also corroborated by the fact that in both plots the same amount of variance is explained.

### 4. Conclusion

In conclusions it has been shown that the same data analysis can be applied, without the necessity of repeat the training, to another physical implementation of the sensor array. It is interesting to note that the two sensing layers utilized in the experiment here described were handheld manufactured. As a consequence, although the composition of the spots (indicator and supporting polymer) was the same, the geometry of the spot and the distribution of the indicator were quite different. Furthermore, the spots were deposited in a different geometric organization. It can be expected, that the subtle differences, found comparing Fig. 4 and Fig. 5, can be strongly reduced when automatic spotting devices are used.



**Fig 4:** Scores plot of the PCA model obtained with the data collected from the first artificial epithelium.



**Fig 5:** Score plot of the PCA of the data collected from the second artificial epithelium, using the SOM obtained for the first artificial epithelium. The plot shows a qualitative behaviour similar to the first epithelium.

## References

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