Biologically inspired computation for chemical sensing

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INTRODUCTION

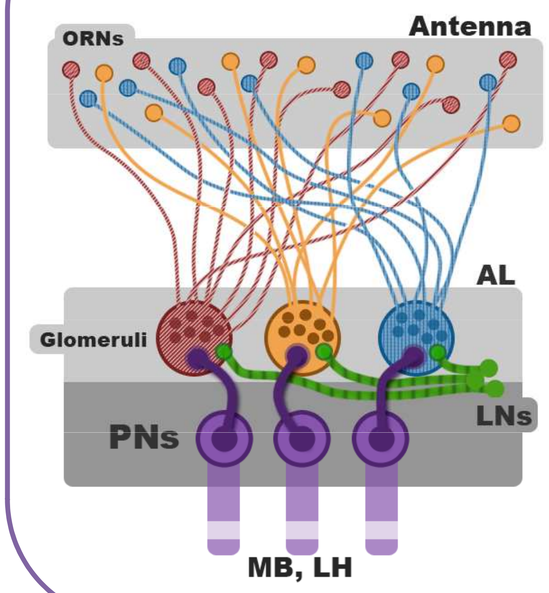
Biological olfaction outperforms chemical instrumentation in specificity, response time, detection limit, coding capacity, time stability, robustness, size, power consumption, and portability. This outstanding performance is due to the unique architecture of the olfactory pathway, which combines a high degree of redundancy, an efficient combinatorial coding along with unmatched chemical information processing mechanisms. These exceptional features of biological olfaction have not yet been successfully captured by Artificial Olfaction, which combines non-specific chemical sensors with intelligent data processing.

OBJECTIVE

In this work we present the new findings related to NEUROCHEM project (FP7/Bio-ICT Grant no. 216916) that have considerably increased the understanding of the olfactory system and helped to develop novel computing architectures and models for chemical sensing.

RESULTS

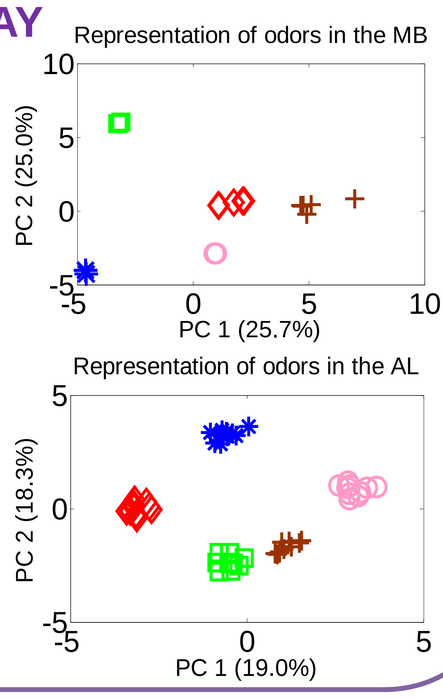
COMPUTATIONAL MODEL OF THE BIOLOGICAL OLFACTORY PATHWAY



Olfactory Receptor Neurons (ORN) belonging to the same class converge onto the same glomerulus. Local Neurons (LN) laterally interconnect Projection Neurons (PN) shaping their activity through inhibitory interactions. PNs integrate the activity of a glomerulus and transduce it to higher brain centers such as the Mushroom Body (MB)

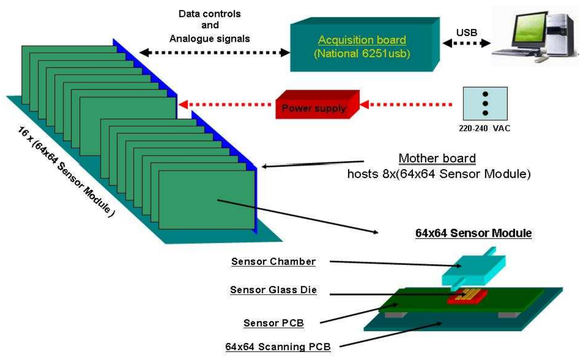
The representations of odours at the Mushroom Body become more similar to other representations of the same odour and at the same time more dissimilar to representations of different odours than representations at the Antennal Lobe.

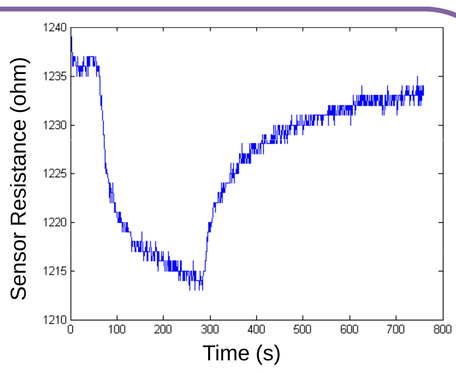
Fisher discrimination ratio for the AL representation is 1.74 and 15.64 for the MB representation.



LARGE SCALE VOLATILE SENSOR ARRAY

A large scale chemical sensor array that may be used to mimic some aspects of the biological olfactory epithelium has been developed. The array is composed of 4096 polymeric sensors. A maximum of 16 arrays can be combined in an electronic system, which scans them in parallel, allowing rapid acquisition. Up to 65536 elements can be implemented.





Single sensor response to 4ppm of ammonia. Response time (t 90%) = 90s

BIOMIMETIC PLATFORM

The developed models have been integrated in a complete olfactory pathway model and included in the IQR environment for final execution in an embedded computing platform suitable for chemical instrumentation.

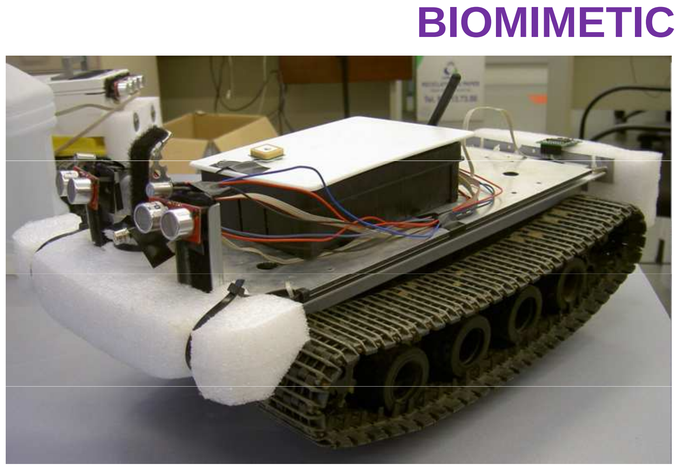
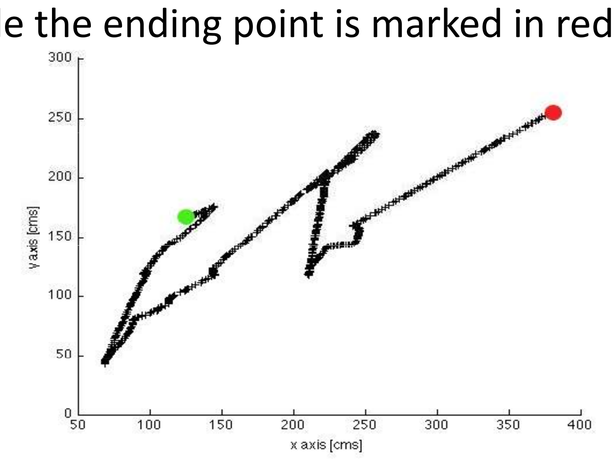


Image of the trajectory of the robot while casting. The initial point is marked in green while the ending point is marked in red



The embedded platform is capable of running the IQR neural network simulator, doing sensor read-out and even controlling a mobile robot.

CONCLUSIONS

- Novel computational models of biological olfactory pathways are presented to understand the mechanisms that underlie the chemical information processing abilities.
- The application of innovative bioinspired data processing tools and new developments in chemical sensors will overcome the limitations of traditional volatile sensing techniques.
- The developed models have been integrated and included in an embedded platform to test the performance of the models in problems where the results of traditional techniques are limited.

Neurochem Project:
FP7, Bio-ICT – FET Grant 216916
www.neurochem-project.org