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Biologically Inspired Computation for Chemical Sensing

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Abstract

In this paper, we present how the achievements related to NEUROCHEM project (FP7, Bio-ICT, Grant number 216916) have increased the understanding of the olfactory system and helped to develop novel computing architectures and models for chemical sensing. We present the developed computational models of the olfactory pathway of vertebrates and insects to capture the mechanisms that underlie their chemical information processing abilities. To mimic the biological olfactory epithelium a large scale chemical sensor array has been developed. We also present a robot that demonstrates the chemical search task as a direct application of the computing paradigms extracted.

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Keywords: Olfactory coding; olfactory receptor neurons; biomimetic artefacts; large scale sensor array; gas sensing; odour tracking; odour source localization

1. Introduction

Biological olfaction outperforms chemical instrumentation in specificity, response time, detection limit, coding capacity, time stability, robustness, size, power consumption, and portability. This biological function provides outstanding performance 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. In this work we aim to present how the new findings related to NEUROCHEM project have considerably increased the understanding of the olfactory system and have helped to develop novel computing architectures and models for chemical sensing.

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2. Results

2.1. Olfactory pathway models

On the side of the computing architecture, we have developed new computational models of the olfactory pathway of vertebrates and insects. Neuronal olfactory circuits were simulated in biologically detailed models to understand the mechanisms underlying biological olfactory coding. These models were simplified to perform mathematical analysis and extract general computational principles that can be applied to artificial olfaction [1].

2.2. Large scale volatile sensor array

As a direct application of the computing paradigms extracted, we built biomimetic artefacts that are able to perform chemical sensing. We have developed a large scale chemical sensor device composed of 16 parallel arrays of 4096 resistive polymeric sensors to mimic the redundancy and the large number of receptors of the biological olfactory epithelium [2].

2.3. Biomimetic platform

The developed submodels 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 or even robotics.

3. Conclusions

We presented novel computational models of biological olfactory pathways to understand the mechanisms that underlie the chemical information processing abilities. In the medium term, the application of innovative bioinspired data processing tools and new developments in chemical sensors will overcome the limitations of traditional gas sensing, open new applications, and contribute to the odour tracking in plumes, a problem that animals can complete with impressive performance.

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