Internship in ESA's Advanced Concepts Team
On
Olfactory system as a blueprint for novel neural architectures for spacecraft autonomy

European Space Research and Technology Centre
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Topic description

Biology has been a major source of inspiration for artificial intelligence and hence for advanced spacecraft autonomy. A prominent example is the convolutional neural network architecture - nowadays the standard model for image recognition tasks - which was inspired by the visual neural system of mammals and initiated the ongoing deep learning revolution in 2012. However, despite this success, other senses have been mostly overlooked in the pursuit of novel neural network architectures and learning paradigms.

One such biosensor modality is olfaction. In general, olfactory systems are highly plastic, show high robustness towards noise and generalise well to unseen stimuli. Similar to vision systems, olfactory systems are composed of stereotypical motifs that can be utilised as a blueprint for exploring novel neural network architectures for machine learning applications. For instance, olfaction combines concepts from biology such as Hebbian learning, random projections, neuromodulation of plasticity and lateral competition between neurons in a clear and approachable setting.

In recent work, the olfactory system of insects has been investigating for solving machine learning problems like digit classification [1,2] as well as odour localization tasks on the planetary surface [3]. In this internship, we will greatly extend these studies by identifying interesting architectural and functional concepts observed in olfactory systems and applying those concepts to a variety of benchmark tasks that are relevant for the space sector, such as image classification and optimal control.

Candidate's task

The internship will have two main goals:

1. Identification of the essential aspects of olfactory systems and their implementation in a pyTorch model. This will allow the flexible application of the model to a variety of machine learning benchmarks and will benefit from modern optimisation techniques.
2. We will investigate possible extensions of the pyTorch olfaction model by combining it with other neural network architectures or by applying modern optimisation techniques, e.g., evolutionary optimisation, end-to-end learning using gradient descent or meta-learning strategies. This will enable us to find a network architecture and learning rules that are biologically plausible and perform well on relevant machine learning benchmarks.

The result of this study will drive forward the search for computational architectures that are energy efficient, performant and potentially realisable on emerging hardware platforms, such as neuromorphic processors. Moreover, this work will contribute to the search for novel computing paradigms that might re-envision how we realise artificial intelligence onboard spacecraft.

Joining the ACT

Creativity and out-of-the-box thinking are essential in the ACT. Therefore, the team is constantly striving to be a diverse, inclusive and equitable workplace bringing together people from various backgrounds. We strongly encourage people from under-represented groups to apply to be part of our team as diversity is central to our mission and core values.

In order to make our hiring as fair as possible, we also ask applicants to not include photos in their CVs.

References

[1] C. B. Delahunt & J. Nathan Kutz, Putting a bug in ML: The moth olfactory network learns to read MNIST (2018).

[2] R. Huerta & T. Nowotny, Fast and robust learning by reinforcement signals: explorations in the insect brain (2009).

[3] de Croon, G. C., O'connor, L. M., Nicol, C., & Izzo, D. Evolutionary robotics approach to odor source localization. Neurocomputing (2013).