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Editorial: Biologically inspired Artificial Intelligent systems: state and perspectives

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Editorial on the Research Topic
Biologically inspired Artificial Intelligent systems: state and perspectives

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We hear about Artificial Intelligence (AI) everywhere, as it is the major technological breakthrough of our time. Most of us are both drawn to it and fearful of it—attracted by the potential for everyday benefits, yet primarily concerned about the risk of losing control over our decisions and actions. We should approach the technological innovations we are facing with the same attention to technological details as we give to their social and ethical implications.

Starting from the basics, the term "Artificial Intelligence" can be somewhat misleading. A marked distinction between "natural" and "artificial" intelligence could be considered inappropriate: the difference lies rather in the data processing strategies and architectures implemented by the biological and by non-living systems. To date, we have seen non-living systems performing computation, but it is rare to witness them exhibiting intelligence in the way we understand it. Defining intelligence itself is indeed an even greater intellectual challenge. In 1921 a Symposium has been organized (Colvin and Freeman, 1921) about "Intelligence and its measurements". It consists of a group of 14 psychologists who addressed three questions posed by the editors of the *Journal of Educational Psychology*: 1) What is intelligence? 2) How can it best be measured by group tests? 3) What are the most crucial next steps in research? There was a great disagreement concerning the concept of intelligence, resulting in 14 different definitions. We suppose that we are not far from that situation of the last century.

Whatever we define it as, intelligence certainly always needs a support to run. In living beings, it is even more than a support—it is a body (Pfeifer et al., 2007). The way in which the body shapes our intelligence is deep and complex, and it is often not considered enough in the designing of data processing devices. It has nothing to do with the interplay between the software and the hardware with which AI programs currently run on the market. It counts on a self-organized complex system mutually interacting at different scales, composed of a redundant, adaptive, and fault-tolerant architecture. The difference between the effective implementation of these two realms (silicon-based and biological neuronal systems) marks the gap between data processing concepts and strategies, as well as the difference in their corresponding energy demands, which evolution has managed to minimize so effectively.

This collection of research articles highlights, on one hand, a detailed overview of the strategies supporting AI algorithms (Xu et al.); on the other hand, it illustrates the opportunities presented by neuromorphic hardware that can at least partially mimic the behavior of biological units, such as synapses (Maldonado et al.).

An insight is presented here as a common thread across different papers, focusing on the role and use of stochasticity in improving system performance, as well as the advantages brought by its non-linearity. The latter is another biologically inspired feature (Borghi et al., 2024) whose significance in data processing tasks is explored in various ways (Cipollini et al.).

Non-linearity is involved in biological systems at the level of dendritic trees (Häusser et al., 2000) as in spatial distribution of ionic channels and synapses (Mäki-Marttunen and Mäki-Marttunen, 2022), and it does not find a correspondence in the perceptron (Rosenblatt, 1958), the reference model of neuron used in AI algorithms, where the weights associated to the inputs are input-independent. The model of Receptron (Paroli et al., 2023) proposed here, accounts for the non-linearity of the system response to inputs (Martini et al.). It is implemented in a neuromorphic device used for the specific computational task of classifying Boolean functions. Furthermore, the training processes used by AI algorithms on artificial neural networks, primarily based on back-propagation, are not comparable to the reprogrammability and adaptability of these neuromorphic devices, which closely mimic biological neural networks.

Altogether, this Research Topic provides a general overview of current AI architectures, especially those used in image processing, along with examples of neuromorphic hardware units, both at synaptic and ensemble of neuronal network levels. It highlights opportunities for the development of neuromorphic data processing devices and architectures that leverage the non-linearity, stochasticity, and self-adaptability of physical systems.

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