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Guest editorial: Special issue on brain inspired models of cognitive memory

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Editorial

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Current memory technologies have experienced significant progress in terms of storage capacity, operation speed, integration capability, etc. However, their functions are highly constrained in storing and transferring data in space and time, prompting the need for improvement. In contrast to physical memories, the biological counterpart – cognitive memory – has versatile functions. For instance, human memory stores data associatively such that different modalities of data could be retrieved simultaneously; it can learn different concepts, categorize and store them in an organized manner; it can process and store data concurrently and in a distributed fashion; it can restore content even if some part is damaged; it can perceive the stimulus and predict the next event; it can adapt to the environment and perform selective storage. Functions such as adaptation, learning, perception, self-organization and prediction make human memory have distinct cognitive features. However, the mechanisms how human memory cognitively operates and the ways how to utilize the bio-inspired mechanisms to practical applications are rarely known, yet urgently demanded.

The scope of the questions on cognitive memory transcends several interdisciplinary boundaries and combines efforts in both hardware and software engineering. Increasing efforts towards cognitive memory have been made from researchers belonging to the various communities of computational intelligence, machine learning, cognitive modelling, as well as researchers in hardware (circuit level) implementation of cognitive systems and those working at materials level research, such as memristors and phase change materials. Hence, we felt that a special issue that discusses new ideas on the modelling of memory, latest results on the development of cognitively inspired memory devices, and approaches to create a bridge between hardware and system level research is very timely.

This Special Issue presents six original articles covering brain-inspired learning rules for different cognitive tasks, and hardware implementations of the brain-inspired mechanisms. All the papers have went through a rigorous review process.

The first paper, entitled *A brain-inspired spiking neural network model with temporal encoding and learning*, presents a biologically plausible architecture of spiking neurons for various recognition tasks. The whole system consistently operates in a temporal framework where precise spiking time is used for information processing. Both neural coding and learning are included in the system. A biologically plausible supervised synaptic learning rule is used for synaptic adaptation. This paper demonstrates a viable way of using spiking neurons to perform recognition tasks.

The second paper, entitled *Delay learning architectures for Memory and Classification*, presents a new supervised learning algorithm for spiking neurons by modifying axonal delays rather than synaptic weights. Through tuning spike delays of presynaptic neurons, the postsynaptic neuron could have a desired response of firing or keeping salient, with synchronous/asynchronous post-synaptic currents causing large/low postsynaptic potential. Various properties of this delay learning algorithm are investigated through a binary classification task. In addition, this paper also presents that the delay learning algorithm could benefit VLSI implementation with requiring only one tunable parameter.

The third paper, entitled *Reinforcement Learning and Dopamine at the striatum: A Modeling Perspective*, presents a review on various models of reinforcement learning with an emphasis on the cellular models of reinforcement learning. In particular, this paper emphasizes biochemical models of reinforcement learning, and some possible directions are also pointed out.

The fourth paper, entitled *SELP: A General-Purpose Framework for Learning the Norms from Saliencies in Spatiotemporal Data*, presents a general-purpose data-driven biologically plausible deep (or hierarchical) learning framework that gives rise to a smart memory system. The framework can learn the norms or invariances as a hierarchy of features from space- and time-varying data in an unsupervised and online manner from saliencies or surprises in the data. Given streaming data, this framework learns norms using four functions – detect salient event, explain the salient event, learn from its explanation and predict the future events.

The fifth paper, entitled *Learning to Predict Eye Fixations for Semantic Contents Using Multi-layer Sparse Network*, presents a new saliency model based on the deep learning framework and demonstrates its capability in semantic saliency computation. This model attempts to utilize hierarchies of features learned directly from natural images and naturally integrate these features to tackle the problem of object/social saliency. The performance of this model indicates that it is possible to learn semantic-related features with a hierarchical architecture in an unsupervised manner and link them with saliency by a simple linear classifier.

The sixth paper, entitled *A*0.7 V *Low-Power Fully Programmable Gaussian Function Generator for Brain-Inspired Gaussian Correlation*

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Associative Memory, proposes a brain-inspired spiking Gaussian correlation associative memory system architecture. The proposed Gaussian function generator (GFG) provides several advantages including full programmability and low power consumption. The proposed system is useful for hardware implementation of large scale associate memory with network-level reconfigurability.

We would like to thank all authors for their contributions, and the reviewers for their valuable efforts in reviewing these articles and giving a lot of constructive comments for the authors to improve their work. We are also grateful to the Neurocomputing editorial board for providing us a great support in publishing this special issue.

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