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GUEST EDITORIAL

Nanotechnology-Enabled Unconventional Computing

by Georgios Ch. Sirakoulis and Sorin Cotofana

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SORIN COTOFANA

THE HISTORY OF COMPUTING IS inextricably bounded and heavily dependent on materials technology advances, especially nanotechnology. During the last decade, we have witnessed significant nanotechnology science discoveries from memristive and spin-orbit torque materials, carbon nanotubes to graphene, and biomaterials that have enabled several novel computing ways usually entitled under the generic term of unconventional computing. A common characteristic of these unconventional computing paradigms is their intrinsic capability to outperform, in terms of specific figures of merit, traditional von Neumann related computing architectures.

Although unconventional computing cannot be yet easily formalized, typical unconventional computing includes, but clearly is not limited to, physics of nano-computation, non-Boolean logics, novel hardware, magnetic, mechanical, neuromorphic, chemical, and quantum nanocomputing. Albeit current nanoscale CMOS technology is still considered the cornerstone for today's computing, it is evident that unconventional computing paradigms encourage rather appealing novel ways of thinking that take advantage of nanomaterial's specific operation principles and mechanisms, as well as information processing and functional properties of physical, mechanical, chemical, and living nano-systems.

In this Special Issue on Nanotechnology-Enabled Unconventional Computing, four articles aim to enlighten the principles of nanotechnology-enabled unconventional computing. In particular, it starts with a brief review on the utilization of unconventional materials for various forms of unconventional computing, continues by presenting specific unconventional computing paradigms that make use of nanomaterials like graphene and memristive for the resolution of challenging, e.g., NP-complete, problems and, concludes by describing various unconventional computing applications.

In the first article, Tsipas et al. present a feasibility investigation on unconventional memristive nanodevices with focus on the underlying physics of the different memristive materials. Four general types of memristive nanodevices have been examined, namely: 2D-material based, organic, cryogenic, and perovskites memristors. Moreover, a thorough investigation on device switching mechanisms and material selection has been conducted, and performance comparison of various fabricated devices in terms of characteristic figures of merit is presented.

Next, Cucu Laurenciu et al. introduce a generic Graphene NanoRibbon (GNR)-based synapse able to emulate Spike Timing Dependent Plasticity (STDP) and provide Post-Synaptic Potential (PSP) amplitude and temporal dynamics associated with different synaptic receptors (AMPA, NMDA, GABA). The synapse operation is validated by means of SPICE circuit simulations, and its synaptic modulation ability is showcased through reinforcement learning within a Spiking Neural Network for robotic navigation with obstacles avoidance.

Tsipas et al., in the third article, describe memristive nanocircuits for the resolution of NP-complete problems. Bio-mimetic computing based on living organisms' behavior and wave computing utilizing memristive oscillators have been explored. Moreover, distributed computing and unsupervised learning through memristive learning cellular automata is introduced. Furthermore, the realization of quantum computing through the exploitation of memristor crossbar configurations for development of nano-accelerators for quantum computing is proposed.

Finally, Niknia et al. present the implementation and corresponding designs of various multilayer perceptrons MLP accelerators. The hardware for performing network computation using conventional floating-point and fixed-point based computing and stochastic computing, as well as different schemes (parallel, serial and hybrid arrangements), are analyzed and implemented. The evaluation shows that each type of implementation has a unique advantage in hardware metric. All findings and designs presented provide a comprehensive assessment for designing nanoscale accelerators.

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