Novel Applications Enabled by Memristors

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CONSTANT ADVANCES IN SEMIconductor manufacturing have led to the ubiquitous presence of cheap and reliable computing devices in all aspects of our lives. However, further innovation exclusively based on scaling the CMOS technology feature size will not be sufficient in the coming years, as the well-known Moore's law is slowing down. While CMOS is not going to disappear, it will most likely be supported by several other innovative technologies with stronger performance in specific application scenarios. Among various novel technologies, memristors are emerging as promising devices for high-density memory arrays, neuromorphic computing, and, recently, logic and processing in memory. Recent research also revealed memristor sensitivity to gases and other chemicals. All these developments show that memristors have unexplored potential to shift the paradigm for several other applications.

This special issue consists of three articles that cover in-memory processing enabled by memristors for neural networks and encryption. In the first, Mannocci et al. discuss in-memory computing for data-intensive accelerators of machine learning with memristors. The authors experimentally demonstrate a new algorithm for principal component analysis based on power iteration and deflation executed in a 4-kbit array of resistive switching random-access memory. The results show that the classification accuracy remains close to floating point implementation, while energy efficiency improves 250× compared to commercial graphics processing units.

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In the second article, Eshraghian, Wang, and Lu present a different type of neural network—binarized spiking neural networks—where information is represented as digital spiking events. Mapping this application into memristive arrays can improve noise margins and tolerance to device variability, compared to analog bit–line current summation approaches to multiply–accumulate operations, as presented by Ma et al. The significant analog-to-digital converter overhead that mixed-signal approaches have struggled to overcome is also alleviated due to the single-bit spikes. The information is encoded in the spike time as a temporal code, in the spike frequency as a rate code, and in any number of stand-alone codes and combinations. This overcomes the standard tradeoff of precision and accuracy. The article explores the challenges facing memristor-based acceleration of neural networks and how binarized spiking neural networks may offer a good fit for these emerging systems.

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Finally, Ma et al. take a different approach using digital in-memory computing for encryption applications. Their technique relies on performing efficient in-memory Boolean operations in parallel to eliminate data movement overhead and enable faster and more energy-efficient encryption. They start by recognizing that the bottleneck in previous implementations of the Advanced Encryption Standard algorithm lies in inefficient write-back operations for intermediate data produced by the cumulative exclusive-OR computation. The article introduces an in-memory logic method for bipolar and unipolar nonvolatile devices by mapping the Boolean variables to the device resistance and electrical signals. To support the proposed method, the peripheral circuits of the nonvolatile memory array, a buddy latch structure, and a dedicated dataflow are designed. We hope you find the contents of this special issue interesting. We would like to acknowledge the reviewers and editors for serving in the submission and production process. Finally, we wish to thank the authors for submitting their excellent research.