Neuromorphic Atomic Switch Networks

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Abstract The self-organization of dynamical structures in natural systems is associated with an intrinsic capacity for computation, where the spontaneous emergence of complex behavior occurs through the collective interaction of nonlinear elements. Explorations that reside at the interface of complexity, nonlinear dynamics, neuroscience and engineering undoubtedly provide a vast arena for fundamental and applied research. We have set out to develop purpose-built dynamical systems as physical platforms for modeling cortical dynamics and implementing emerging paradigms in neuromorphic computing[1]. By leveraging the advantages of structural control with those of self-organization through a nanoarchitectonic approach[2], massively interconnected networks containing functional atomic switch elements at a density of ~10^8 synthetic synapses/cm^2 have been produced[3,4]. These atomic switch networks (ASN) have structural characteristics similar to synaptically rich connectivity matrix of the neocortex, emulate a diversity of complex behaviors similar to those found in biological neural networks[3], and provide a means to explore the dynamical systems approach to a new paradigm in computation known as reservoir computing (RC)[4,5]. The ability to generate synthetic device architectures comprising functional nonlinear elements such as atomic switches and other memristive systems will continue to foster an expansion of inquiry into the dynamics of complex networks, allowing for new capabilities and opportunities. Based on their ability to integrate, segregate, store and respond to external stimulus, the use of ASNs as nonlinear reservoirs capable of task performance in the RC paradigm has been shown through simulation and experimental implementation of multiple benchmark tasks known as (1) waveform generation, (2) parity-n (3) NARMA-10 and (4) the T-maze. The functional diversity demonstrated to date has strong implications for using the ASN as a universal approximator of dynamical systems, not only as a physical device for information processing and computation but also as a scalable experimental platform for investigating theoretical constructs of complexity and neuroscience.

References

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