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Neuromorphic computing with memristive devices and arrays

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Memristive devices[1] have become a promising candidate for unconventional computing[2]. In this talk, I will present some of our recent work on unconventional computing experimentally implemented by using memristive devices or crossbar arrays.

Using traditional non-volatile memristors with 64 stable analog resistance levels, we have built a dot-product engine based on a 128 x 64 1T1R crossbar array[3]. Accurate image compression and filtering have been demonstrated with such analog computing accelerator[3]. In addition, we have demonstrated efficient and self-adaptive *in-situ* learning in a two-layer neural networks using such memristive arrays[4], which is expected to significantly improve the speed and energy efficiency of deep neural networks.

Using our newly developed diffusive memristors[5] with diffusion dynamics that is critical for neuromorphic functions, we have developed artificial synapses[6] and neurons[7] to more faithfully emulate their bio-counterparts and more efficiently perform spiking neural network functions. We have further integrated these artificial synapses and neurons into a small neural network, with which pattern classification and unsupervised learning have been demonstrated[7].

1 Yang, J. J. *et al.* Memristive switching mechanism for metal/oxide/metal nanodevices. *Nature Nanotechnology* **3**, 429 (2008).
2 Yang, J. J., Strukov, D. B. & Stewart, D. R. Memristive devices for computing. *Nature Nanotechnology* **8**, 13 (2013).
3 Li, C. *et al.* Analogue signal and image processing with large memristor crossbars. *Nature Electronics* **1**, 52 (2018).
4 Li, C. *et al.* Efficient and self-adaptive in-situ learning in multilayer memristive neural networks. *Nature communications*, under revision (2018).
5 Midya, R. *et al.* Anatomy of Ag/Hafnia-Based Selectors with 1E10 Nonlinearity. *Advanced Materials* **29**, 1604457 (2017).
6 Wang, Z. *et al.* Memristors with diffusive dynamics as synaptic emulators for neuromorphic computing. *Nature Materials* **16**, 101-108 (2017).
7 Wang, Z. *et al.* Fully memristive neural networks for pattern classification with unsupervised learning. *Nature Electronics* **1**, 137 (2018).