

Vector Spin Capsule Neurons - Towards a Spintronic Vector Deep Learning Framework

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Spintronics has the potential to revolutionize computing and storage [1] for the beyond CMOS era. Spintronic and multiferroic phenomenon with spin transfer torque, all spin currents, spin based threshold operations and Rashba-spin-orbit effects provide a rich platform that allows complex signal processing [2]. Recently, a major breakthrough has been reached with the application of deep-learning [3] methods for artificial intelligence. However, the computing for AI and deep learning is increasingly dependent on scaling of Teraoperations/second and Teraoperations/watt. For the complete advancement of AI to its potential a breakthrough is required in computing hardware itself [4,5].

Vector capsule networks [6,7] are an important evolutionary step towards vector deep neural networks where the vector nature of image information is comprehended in the neural network to overcome the “bag of features” problems in traditional scalar neural networks. Vector networks capture both the features of an object and its orientation to decide classification. Spin provides a natural fit for such a representation due to the vector nature of spin currents where the orientation is captured in the orientation of Spin and strength is captured in the magnitude of the spin current [8].

We describe the generalization of vectorial spin neurons with scalar, vector and tensor weights. We also describe the nature of vector neurons with scalar, vector and tensor weights. We show examples of neuron non-linear vector-valued sigmoid functions that allow back propagation. We also describe a physical method for implementing such vector spin devices [9].

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