Learning and adaptivity in organic neuromorphic systems

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The process of neural network training can be slow and energy-expensive due to the transfer of weight data between digital memory and processor chips. Neuromorphic systems can accelerate neural networks by performing multiply-accumulate operations in parallel using non-volatile analogue memory. However, the backpropagation training algorithm in multi-layer (deep) neural networks requires information - and thus storage - on the partial derivatives of the weight values, preventing easy implementation in hardware.

In this talk I will highlight a novel hardware implementation of the well-established backpropagation algorithm that progressively updates each layer using *in situ* stochastic gradient descent, thus avoiding this storage requirement. We experimentally demonstrate the *in situ* error calculation and the proposed progressive backpropagation method using a multi-layer hardware implemented neural network based on organic EC-RAM, and confirm identical learning characteristics and classification performance compared to conventional backpropagation in software. I demonstrate how we can use on-chip learning in trainable biosensors and smart autonomous robotics and highlight a manufacturing route towards large-scale integration of organic neuromorphic arrays that are necessary for advanced intelligent computing systems.

Next to that, organic electronic materials have the potential to operate at the interface with biology. This can pave the way for novel architectures with bio-inspired features, offering promising solutions for the manipulation and the processing of biological signals and potential applications ranging from brain-computer-interfaces to bioinformatics and neurotransmitter-mediated adaptive sensing. I will highlight our recent efforts for such hybrid biological memory devices and artificial neurons.