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Bio-inspired models of astrocyte-neuron interactions for fault tolerant neuro-control systems.

The human brain exhibits many desirable properties in the context of engineering systems. One property is fault tolerance, the ability to maintain stable function during and after periods of disease or injury. Recent work has highlighted the role of astrocytes in regulating neuronal function. In this project we aim to exploit computational models of retrograde signalling in astrocytes as a principle for developing fault tolerant electronic systems. Astrocytes can modulate synaptic transmission at tripartite synapses using indirect signalling via retrograde messengers to systematically alter synaptic transmission probability. In this study we describe results from a computational model of a spiking astrocyte-neural network (SANN). The SANN uses a novel learning rule which combines spike timing dependant plasticity (STDP) with the Bienenstock, Cooper, Munro (BCM) learning rule. Synaptic weights are altered according to input-output spike time differences where the level of potentiation is controlled by postsynaptic firing rates according to a Gaussian tuning curve. This tuning curve controls initial learning and allows the network to "open-up" to re-learn when levels of synaptic activity alter in response to faults in the network. We demonstrate how this computational model can be implemented in field-programmable gate array (FPGA) technology which allows an SANN to control a small autonomous robot in an obstacle avoidance task combined with visual target following. The SANN allows the neuro controller system to re-learn after synaptic faults are injected, thus demonstrating fault tolerance. This work opens up new approaches in the field of bio-inspired fault tolerant hardware design.

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