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A computational approach to neurogenesis and synaptogenesis using biologically plausible neurons with learning

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Traditional rate-based neural networks and the newer spiking neural networks have been shown to be very effective for some tasks, but they have problems with long term learning and "catastrophic forgetting." Once a network is trained to perform some task, it is difficult to adapt it to new applications. To do this properly, one can mimic processes that occur in the human brain: neurogenesis and synaptogenesis, or the birth and death of both neurons and synapses. To be effective, however, this must be accomplished while maintaining the current memories. In this paper we will describe a new computational approach that uses neurogenesis and synaptogenesis to continually learn. Neurons and synapses can be added and removed from the simulation while it runs. The learning is accomplished using a variant of the spike time dependent plasticity method, which we have recently developed [Ankur and Long, IEEE Paper, IJCNN, June, 2009]. This Hebbian learning algorithm uses a combination of homeostasis of synapse weights, spike timing, and stochastic forgetting to achieve stable and efficient learning. The approach is not only adaptable, but it is also scalable to very large systems (billions of neurons). We will demonstrate the approach on a character recognition example, where the system learns several characters and then to learn more it automatically adds more neurons and synapses. Also, it has the capability to remove synapses which have very low strength, thus saving memory. There are several issues when implementing neurogenesis and synaptogenesis in a spiking code. Though they may seem different, they are actually a coupled phenomenon. When several synapses die, it may lead to a neuron which has no synapses and thus require its removal. Conversely, a neurons death may require updating of synaptic information of all neurons it was connected to. These issues and efficient ways to address them will be discussed. The neuron model that we use is the Hodgkin-Huxley model with four coupled, nonlinear ordinary differential equations. We will compare this approach to the simpler leaky integrate and fire approach also. The algorithms have been implemented in C++ and are fast, efficient, and scalable.