Neurogenesis in a High Resolution Dentate Gyrus Model

Craig M. Vineyard, James B. Aimone, and Glory R. Emmanuel

Sandia National Laboratories
Albuquerque, New Mexico, USA
cmviney@sandia.gov

Keywords: Neurogenesis, dentate gyrus, computational neural network model, spiking neuron model.

It has often been thought that adult brains are unable to produce new neurons. However, neurogenesis, or the birth of new neurons, is a naturally occurring phenomenon in a few specific brain regions. The well-studied dentate gyrus (DG) region of hippocampus in the medial temporal lobe is one such region. Nevertheless, the functional significance of neurogenesis is still unknown. Artificial neural network models of the DG not only provide a framework for investigating existing theories, but also aid in the development of new hypothesis and lead to greater neurogenesis understanding.

Consequently, we have developed a biologically realistic spiking model of DG. This model is realistic in terms of scale, connectivity, neuron properties, as well as being implemented using Izhikevich spiking neurons. While many DG models are a vast simplification consisting of between only 1,000 and 10,000 neurons, our model is a mouse sized DG comprised of 300,000 granule cells. Instead of simply assuming new neurons have full synaptic connectivity at birth; our model incorporates a temporal maturation process by which a neuron attains more synapses, which effectively alters its excitability as well. In addition to excitability, other neuron properties which our model implements in a realistic manner are spiking rate and signal conductance based upon experimental mouse/rat data. Implementing the model using Izhikevich spiking neurons allows for high biological realism at a low computational cost.

Benefits of a high resolution computational neural network model of DG such as ours include resilience to signal noise, an ability to study scaling effects, and a framework to investigate the implications of neurogenesis for memory. Models with fewer neurons are inherently much more sensitive to noise. The larger quantity of neurons incorporated in our model also addresses scale effects. For example, to replicate the sparse DG activity observed in neural recordings, smaller scale models are forced to have minimal neuron firings in effect nearly silencing their own network and lessening the ability to model and understand desired phenomena. On the other hand, a larger network increases the likelihood of being able to replicate desired neural behavior computationally.

A. Chella et al. (Eds.): Biologically Inspired Cognitive Architectures 2012, AISC 196, pp. 371–372.
springerlink.com

This ability to replicate biological functionality ultimately aids in the quest to understand the role of neurogenesis in memory function because it provides a platform to investigate, amongst others, memory resolution and pattern separation hypothesis.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energys National Nuclear Security Administration under contract DE-AC04-94AL85000.