A 3D Graphics Environment for Behavioral Neurobiology Research

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1. Introduction

Neurobiologists have conducted extensive research on animals to understand the neural basis for adaptive behaviors. Great strides have been made in understanding the roles of individual neurons and simple networks. This understanding has led to a number of hypotheses that attempt to explain how the neural architecture produces those behaviors. However, testing these neuronal models can be a very daunting task. Attempting to take measurements from numerous neurons while the animal is performing complex tasks is often difficult if not impossible.

We are currently building a 3D graphics environment that allows users to easily build the body and neural network of different organisms. Biologists can use these simulated organisms (also called animats) to test various hypotheses. Our goal is not just to build a working simulation, but also to discover the constraints on model architecture imposed by the structure of the animal, our knowledge of neural organization and mechanisms, and the physical forces at play in the environment. This knowledge will prove useful both in the construction of autonomous robots and in understanding the neural architecture of various animals.

2. System Design

An overview of the system design is shown in figure 1.

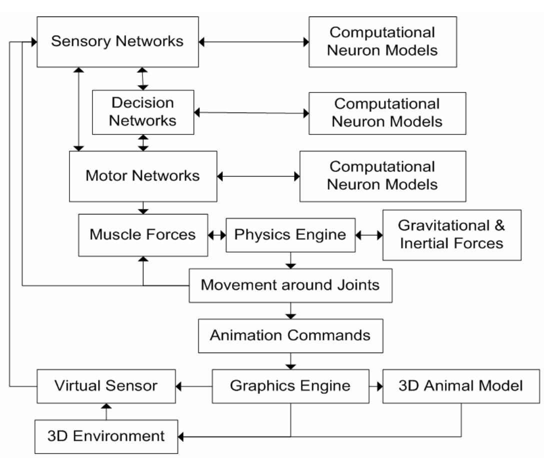

Figure 1 System overview

The system consists of three main applications, two editors and a simulator. The Editors allow the user to build animats, configure their environment, and analyze data from the simulation runs. The simulator loads in the XML based configuration files produced by the editor and performs the simulation. It will also collect any data that was requested by the editor so that it can be analyzed. The configuration file allows the editors and simulator to run separately, if needed.

The Physics Engine Editor allows the user to configure the body plan of the animats and their properties. The Neural Engine Editor allows the user to configure the neural network of the animats. Figure 2 is a snapshot of the Neural Engine Editor with a neural circuit that controls the movement of one animat leg during standing or walking.

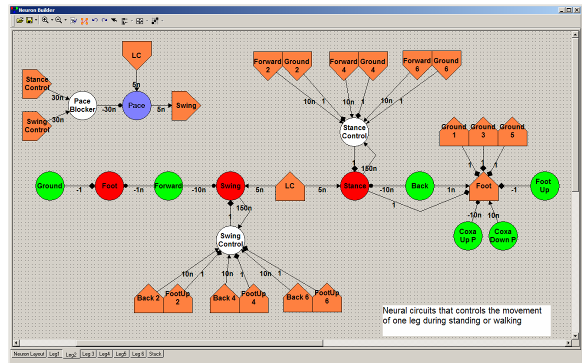

Figure 2 Neural Engine Editor

The Simulator consists of a physics engine, a neural engine, and a graphics engine. The physics engine is based on Vortex [CMLabs], a commercial software package that models accurate motion and interactive behavior for real-time applications. The neural engine is largely based on a neural network architecture proposed by Beer [Beer 1990]. One of the main benefits of this architecture is that it performs biologically realistic neural simulations using the standard electrical equivalent circuit for modeling neurons, and does so in a way that allows us to perform the calculations in real time. The graphics engine is developed with OpenGL.

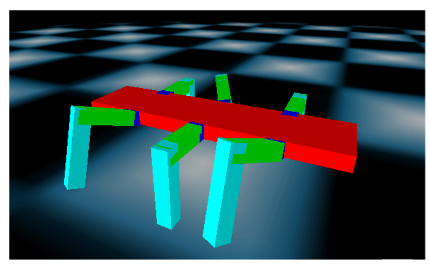

Figure 3 Insect Walking Simulation

Our current implementation is able to perform physically based animation of a multi-legged insect using a biologically inspired neural network (Figure 3). The Neural Engine Editor has also been developed. We are building neural networks that can simulate various animal behaviors, such as crayfish tail flips. We are also developing a Physics Engine Editor that will allow us to create and configure 3D animal models in a more intuitive way.

References

Beer, Randall D. 1990. *Intelligence as Adaptive Behavior: An Experiment in Computational Neuroethology*. Academic Press.

CMLabs, http://www.criticalmasslabs.com/products/vortex/

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