Uniting Biology and Maths to Understand the Human Brain

Professor William W. Lytton
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The biomimetic MI is programmed as a multi-scale simulation. In this version of the model, there are three basic layers in the network that can be grossly mapped onto layers of cortices: a motor layer that controls muscle excitations, a somatosensory layer that coordinates between the two other layers, and the proprioceptive layer that controls limb masses, i.e., the size of the virtual muscles as they contract and relax. These three layers are also divided into the various virtual muscles that control the extension and flexion of shoulder and elbow. Left to its own devices – that is, untrained – the virtual arm simply flails around without purpose, causing the same to happen with its robotic alter ego. With training, however, things are much different.

Programming the virtual arm to pick up an object on a table is accomplished by rewarding the arm for getting closer to the object or punishing it for getting further away. Of course, rewarding or punishing a computer program is obviously analogous to the human experience. In practice, what Professor Lytton’s team does is to provide the virtual arm with feedback on how far it is from the target, on a variety of cognitive tasks. However, this is a different kind of feedback, for it is based on the virtual arm’s performance, rather than on experimental data from the real arm.

Professor Lytton and his colleagues at the Neurosimulation Laboratory of the State University of New York in Brooklyn are using computer simulation to investigate brain function and disease. Their research has far-ranging implications in addressing human illness.

The extraordinary success of artificial neural networks and computer learning in seemingly simulating the human mind – for example, computer playing chess and actually defeating human opponents – are not the things that are really difficult. They are also, of course, largely not the things that actually defeat us. The challenge for computer scientists is to figure out how the brain works, to determine how the brain controls the various levels of control, and to understand the principles that underlie the brain’s ability to function as an algorithm.

Professor Lytton’s interest in the brain’s motor cortex is precisely due to this being one of the areas – along with the cerebellum, thalamus, basal ganglia, red nucleus, anterior cord, etc. – that is responsible for the coordinated control of muscles to affect alterations in the environment. To attempt to understand how all of that works, what else would he do but build a cybernetic arm?

Driving an Arm with Multiscale Simulation!

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The purpose of this multiscale model is to incorporate multiple levels of biologic function into a computer model. Here we have cellular dynamics, immediate network interactions, learning, and interactions between arm and brain. In the long run, the ideal would be to include many more parts in the model – cortex, cerebellum, thalamus, basal ganglia, red nucleus, anterior cord and other relevant areas, some modelled in detail, others only at a high scale. Once you can fashion a multiscale model of complex brain pathways, you can start to program the information processing of mind. Just like the virtual computer simulator presents as a disease of the mind. It may, therefore, offer insight into the classical duality of mind and brain. 'He and his team are examining the relationships among brain oscillations – popularly called brain waves – and information flow in the brain, their current, weak proxy for the information processing of mind. Just like the virtual computer arm modelling the function of the human arm, they hope to create more complex models for the more complex functions of the brain. In other words, they want to create functional cybernetic androids – brain region by brain region – so they can study biological human beings. Or is it the other way around?

What's Next in This Research?

There is a great deal of technical work that Professor Lytton and his colleagues are doing to make massive multiscale simulations and their analysis possible on modern supercomputers. At the same time, they are working to incorporate new streams of data coming in and their analysis possible on modern supercomputers.