CONNECTING BRAIN TISSUE TO ROBOTS: DEVELOPMENT OF A HYBRID SYSTEM FOR STUDYING OF NEURAL PLASTICITY

M. Kositsky, A. Karniel, K.M. Fleming, V. Sanguineti, S.T. Alford, F.A. Mussa-Ivaldi
Department of Physiology
Northwestern University Medical School, Chicago, IL

The declared goal of early pioneers of computer science was to create a machine capable of imitating the human brain. Many researchers have adopted the reference to biology as a source of inspiration for creating artificial devices, particularly in the last two decades. More recently, a new perspective has emerged: the perspective of including biological elements within hybrid integrated systems. The idea of using "neurobiology as a technology" is rooted on the simple observation that the nervous systems of the simplest organisms still outperform the most advanced digital computers. In addition, there have been important advances in the techniques for delivering stimulations to brain tissue and for recording the activity of large neuronal populations. These advances allow us to think of neural nets not just as simulations of biological properties as possible operational descriptions of neural tissue.

At the moment, the major obstacle toward the development of systems that incorporate neural elements is our own ignorance of how the brain tissue operates. But this limit should not prevent us from moving along this direction as, the creation of systems in which biological neurons interact with computers and artificial machines provides us with new tools for investigating the neurobiological underpinnings of computation.

We have developed one such hybrid system establishing a bi-directional communication between the brainstem of a lamprey and a small mobile robot. The neural tissue is maintained alive and in working conditions by immersing it in a constantly refrigerated and oxygenated Ringer's solution. The mobile robot acts as an artificial body that delivers sensory information to the neural tissue and receives command signals from it. The sensory information encodes the intensity of light generated by a fixed source. The closed-loop interaction between brain and robot generates autonomous behaviors whose features are strictly related to the structure and operation of the neural preparation. The comparison between the behaviors generated by this system and the behaviors generated by a model of its neural component is a tool for investigating the role of synaptic plasticity in sensory motor learning.

In particular, we are interested in exploring the possibility of inducing controlled long-lasting changes in synaptic efficacy so as to effectively "program" a desired response of the robot to the light. If neural tissue can be considered as a biological computer and if we have an understanding of the mechanisms of neural plasticity, this goal should be within reach. Our ability to establish bi-directional communications with neural tissue and to control the mechanisms of synaptic plasticity would have a great impact on the development of new powerful prosthetic devices and, at the same time, would provide us with a deeper insight on the processing of information within the central nervous system.