Biomorphic Circuits and Systems:

Control of Robotic and Prosthetic Limbs

by

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Abstract

The goal of this work is to advance the fields of prosthetics and robotics through the introduction of novel neuromorphic circuits and systems. Specifically, we show that rhythmic motions of lower and upper limb prostheses for patients suffering from spinal cord injury (SCI) and amputees can be controlled and modulated using silicon neurons, designed in Very Large Scale Integration (VLSI) technology, that mimic pattern generation circuits found in the human spinal cord. Furthermore, we show that synchronized patterns with arbitrarily offset phases between them, can easily be implemented using this technology. This allows locomotory gaits of any kind to be programmed *in silico* to control bipedal robotic locomotion. We argue that it is possible to use these circuits to control hand movements in prosthetic upper limbs using the same approach: the neurons' oscillatory behavior can trigger rhythmic movements that can be started or stopped at any phase, thus enabling the production of discrete movements in upper limb prosthesis.

The bold endeavor of discovering an all-encompassing solution for control of upper and lower limbs will open up new perspectives in the fields of both robotics and prosthetics. In the process of doing so, we have shown how to successfully *decode myoelectric* *signals* from able bodied subjects and a *transradial amputee*, and how the technology developed is suitable for real-time applications, particularly multi-degree-of-freedom upper limb prostheses.

The systems developed in this work have been validated on different platforms dependent on the type of prosthesis required. For lower limb prostheses, a bipedal robot with servomotors actuating its hips and knees was used to prototype walking motions generated by silicon neurons. Upper limb (finger) control was achieved on a Virtual Integration Environment (VIE), developed by JHU's Applied Physics Laboratory (JHUAPL), characterized by real-time animations of hand and finger motions based on any type of input biosignal, from non-invasive surface myoelectric signals to neural signals from the motor cortex.

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