CPS: Medium: Towards Neural-controlled Artificial Legs using High-Performance Embedded Computers

PI: He (Helen) Huang
Co-PI: Qing Yang, Yan Sun
Award number: #0931820

This project aims to develop a novel CPS that senses signals from two physical systems—a human neuromuscular control system and a mechanical prosthesis—to drive a cyber virtual reality (VR) system for the purpose of evaluating a neural-machine interface (NMI) for artificial legs. Novel cyber techniques are proposed to tackle three fundamental challenges in this CPS system: (1) inherent computation complexity for accurately identifying user's intended movements, (2) decreased system robustness over long-term use due to unexpected disturbances in the sensor interface, and (3) real-time 3D rendering of a virtual avatar and environment on the cyber system. A neuromuscular-mechanical fusion algorithm is developed to decipher user intent. A trust management module is included to improve the robustness of NMI by reducing the effects of sensor disturbances on the system performance. The decisions of recognized user intent are then fed into the virtual reality cyber system to drive real-time motion of an avatar emulating exactly intended movements of the user. The algorithms for intent recognition, trust evaluation, and 3D VR rendering are specifically tailored to multi-core GPUs for real time implementation. A prototype of proposed CPS has been developed and tested on patients with transfemoral amputations. The results have shown that fusion of neuromuscular control and mechanical information improves the accuracy for user intent classification, compared to the interface based on either neuromuscular or mechanical information alone. The trust management module can detect many types of sensor disturbances and decrease their influences on system performance. Additionally, we find orders of magnitude speedup of GPUs over general purpose PCs, making the real-time application possible. Our prototype implementation demonstrates the feasibility of using neuromuscular-mechanical fusion to drive virtual reality in real time, which can be an effective evaluation and training tool for leg amputees to neurally control their artificial legs.