Functional Electrical Stimulation, Prostheses, and Brain-Computer Interfaces for Restoring Motor and Sensory Functions

Past, Present and Future funding directions from an NSF Perspective

Functional Electrical Stimulation (FES) endeavors to restore the lost functions of the nervous system by means of electrical stimulation. It is a multidisciplinary field at the interface of neuroscience, engineering, rehabilitation and physical therapy. The most developed applications of FES are pacing of the heart and cochlear neuroprostheses for restoration of hearing, but additional clinical applications include respiratory pacing of the diaphragm, the rehabilitation and restoration of locomotion and hand functions, and the restoration of bladder and bowel functions. Currently, FES for restoration of the lost locomotor functions is a rapidly developing area that is on the verge of broadening its acceptance among therapists. Evidence for this is the increasing number of various neuroprosthetic devices, some of which are already beyond the prototype stage, that have been developed recently. Existing FES treatments combined with conventional occupational and physical therapy still remain the most promising approach in rehabilitation of spinal cord injury patients and stroke patients. An overview of the FES applications will be presented to show that a number of fundamental scientific problems have to be solved before a degree of effectiveness and penetration in the common medical practice is achieved for locomotion neuroprostheses. A summary of the major clinical and fundamental directions of research needed for further improvement of FES will be discussed.

Finally, several initiatives by the National Science Foundation, which will provide funding opportunities to researchers in the area of FES and Rehabilitation Engineering, will be discussed. The National Robotic Initiative, for example, started about three years ago and is seeking innovative robotics research and applications emphasizing the realization of robots acting in direct support of and in collaboration with human partners. Several projects have already been funded which deal with exoskeletons, prosthesis, and augmenting human perception. The existing Cognitive Engineering program is concerned with improving understanding of the brain and nervous system to enable the engineering of novel systems and machines. Examples include devices that augment the senses and intelligent machines that analyze and adapt. During a recent NSF workshop regarding the Grand Challenges in Mapping the Human Brain, several potential areas of research have been highlighted that go beyond the scope of the existing Cognitive Engineering program, which will be discussed.

Alexander Leonessa's Biosketch

Dr. Alexander Leonessa obtained a Doctoral degree in Aerospace Engineering at GeorgiaTech in December 1999. His research focused on nonlinear robust control techniques for general nonlinear systems. His appointment as a faculty member at Virginia Tech started in December 2007, after two previous similar appointments at Florida Atlantic University and the University of Central Florida. His research and contribution include (i) control theory with application to autonomous vehicles guidance and navigation, (ii) nonlinear system identification with application to health monitoring, (iii) real-time embedded control with application to system design of robotic systems, and (iv) functional electrical stimulation of muscles for rehabilitation of stroke survivors and patients with spinal cord injuries. In particular, the dominant idea in his research effort is that most real-world physical systems are too complex to accurately model, hence model uncertainties must be accounted for in the control system design process using some kind of self-learning procedure. Dr. Leonessa has been involved in these areas of research for more than 15 years during which he has published more than 60 papers (all peer reviewed). In September 2014 he started a rotation at the National Science Foundation, where he is currently supervising the General and Age Related Disability Engineering (GARDE) program as well as participating to the Major Research Instrumentation program, the National Robotic Initiative, the Partnership for Innovation program, and the Integrative Strategies for Understanding Neural and Cognitive Systems program.