R Sharif Razavian[1], B Ghannadi[1], N Mehrabi[1], J McPhee[1], A Mihailidis[2,3]

[1] University of Waterloo, Systems Design Engineering; [2] Toronto Rehabilitation Institute, Intelligent Assistive Technology and Systems Lab; [3] University of Toronto, Department of Occupational Science and Occupational Therapy and Institute of Biomaterials and Biomedical Engineering

Feedback Control of Functional Electrical Stimulation Using Mathematical Models of the Human Motor Control System

Rehabilitation programs involving functional electrical stimulation (FES) have shown promising improvements in performance index of post-stroke and spinal cord injury patients. The state-of-the-art, however, has one important drawback: the application of the electrical stimulations is independent of the state of the patient---there is no feedback to the FES system.

A feedback control scheme measures the patient's posture in real-time, and uses it to modulate the stimulation intensities in order to achieve the desired goal. By including feedback control in the FES system, less time is spent on manual system tuning, as the feedback control automatically handles the error. Therefore, more time is left for the exercises. Additionally, the feedback allows for more accurate control of the motion, smaller deviation from the desired target, and more robust behavior in the presence of environment disturbances.

The human musculoskeletal system is very complex, requiring a motor controller that mimics the human nervous system. We have developed a mathematical model of the human motor control system based on muscle synergy theory, that is capable of handling the complexities of the human musculoskeletal system. This model is the first of its kind that can be used for the real-time feedback control of the FES system, to control the human arm motion.