NEUROSCIENCE 2012

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Control/Tracking Number: 2012-S-5454-SfN
Activity: Scientific Abstract
Current Date/Time: 5/9/2012 4:20:41 AM

Online optimization of multisite electrical spinal cord stimulation increases consistency of stepping and limb control in spinal rats

AUTHOR BLOCK: *E. MARTIN MORAUD[1,2], N. WENGER[3], J. DIGIOVANNA[2], P. MUSIENKO[3], M. MORARI[1], G. COURTINE[3], S. MICERA[2,4];
[1]Neuroprosthesis Control Group, Automatic Control Laboratory, ETH Zurich, Zurich, Switzerland; [2]Translational Neural Engin. Lab, Ctr. for Neuroprosthetics, Ecole Polytechnique Federale de Lausanne (EPFL), Lausanne, Switzerland; [3]Ctr. for Neuroprosthetics and Brain Mind Institute, Sch. of Life Sciences, EPFL, Lausanne, Switzerland; [4]The BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy

Abstract:
Epidural electrical stimulation of lumbosacral circuits is capable of restoring coordinated locomotion in rats with complete spinal cord injury (SCI). Most recent experimental setups employed multiple electrodes implanted on the dorsal aspect of lumbosacral segments to deliver constant (tonic) electrical stimulations that were manually tuned based on empirical observations. Each electrode and stimulation parameter modulates specific aspects of gait. Consequently, manual tuning of multiple electrodes is time-consuming and necessarily sub-optimal to facilitate locomotion. Here, we investigated the capacity to optimize multisite epidural stimulation online with the aim to promote more natural, consistent stepping patterns in rats with complete SCI. We designed a real-time control system that could adapt the frequency of stimulation for each electrode independently. The controller exploited an input-output model that incorporated bilateral biomechanical states. Compared to uncontrolled conditions, real-time control of multisite stimulations promoted highly consistent foot trajectories that resembled those underlying locomotion of intact rats. The controller converged to optimal stimulation parameters within less than 20 gait-cycles. These results pave the way towards the design of fully operative spinal neuroprosthetic systems to promote near-optimal locomotor states during training, and thus improve use-dependent plasticity of neuronal systems and motor recovery with neurorehabilitation after SCI.
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Presentation Preference (Complete): Poster Only
Linking Group (Complete): MauveBlack
Nanosymposium Information (Complete):
Theme and Topic (Complete): D.10.b. Spinal cord injury: Recovery
Keyword (Complete): Epidural Electrical stimulation ; Multisite control
Support (Complete):
Support: Yes
Grant/Other Support: : The European Community's Seventh Framework Programme (CP-IP 258654)
Grant/Other Support: : the European Research Council (ERC 261247)

Grant/Other Support: : International Paraplegic Foundation

Special Requests (Complete):

Religious Conflict?: No Religious Conflict
Additional Conflict?: No

Status: Finalized