Wigner 121
Scientific Symposium

Wigner Research Centre for Physics
Institute for Particle and Nuclear Physics
Department of Computational Science

Neurorehabilitation and Motor Control Research Group

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Introduction

Motor Control

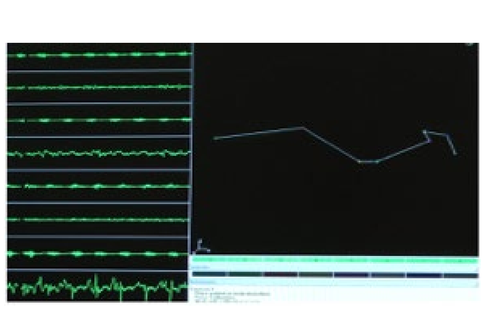
Our research group studies the biomechanical properties and control of human limb movements. We perform measurements on able-bodied people and on people with neural based motor impairments, mainly during their cyclic limb movements. We apply ultrasound based and infrared based motion capture systems synchronized with electrical muscle activity (EMG) recording systems. We process and analyze and model the recorded bioelectric signals to answer questions related to the coordinated activities of several muscles (muscle synergies) and to study geometric features of various motor tasks. One special interest is to develop body-machine interfaces. Our group collaborate with several domestic, European and American institutions, and have significant activities in teaching university courses, supervise BSc, MSc and PhD studies.

Application in Neurorehabilitation

People who lost some of their motor functions due to neural injury (e.g. spinal cord injury) are not able to control their muscle activities and generate muscle forces voluntarily. They are able to exert active muscle forces with the help of Functional Electrical Stimulation (FES). Especially FES controlled cycling movements are beneficial for these patients and prevent health problems related to their sedentary lifestyle. The therapy, developed by our group is available in the National Institute for Medical Rehabilitation regularly for inpatients and outpatients as well. There are several cycling equipment are available to use the muscle activation patterns developed by our research group. Additionally, we provide possibilities to follow up physiological effects of the application of innovative neurorehabilitation methods.

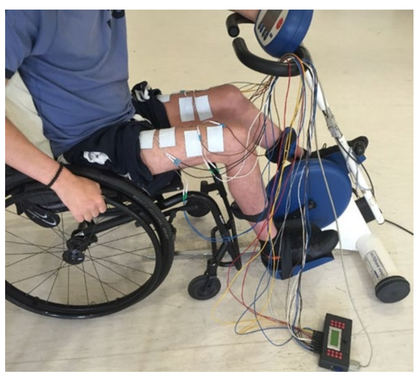
Methods

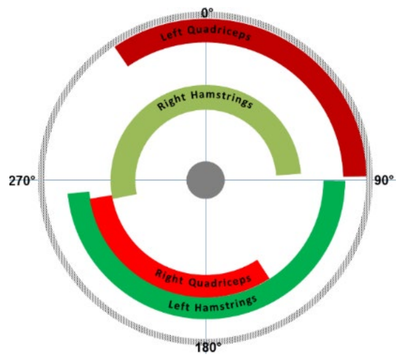
A Measurement of cyclic limb movements



Kinematics is recorded using markers placed on anatomical landmarks and muscle activities are recorded by surface electromyography (EMG) (right).
Representation of the movement of the arm, based on marker positions, and EMG signals are shown at a computer screen (left).

B Functional Electrical Stimulation (FES)

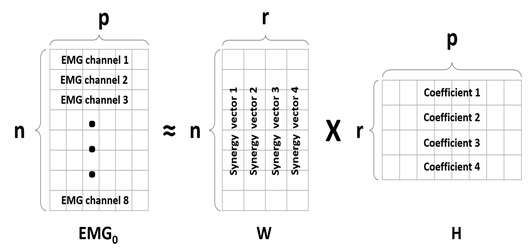




FES assisted cycling of spinal cord injured, paralyzed persons. Muscle activities are generated by electrical stimulation via surface electrodes. A stimulation pattern is represented by the circular diagram. A FES controller Transfers electrical signals to the electrodes as a function of crank angle.

C Non-negative Matrix Factorization to discern muscle synergies in human limb movements

Muscle synergies are represented by synergy vectors (W) and their time dependent activation coefficients (H).



The number of synergy vectors are less than the number of muscles. This means that less activation (control) signals are required than the number of muscles.

D Optimization of jerk in multi-joint human limb movement

Position of the limb's endpoint:

$\mathbf{p}(t) = [p_x(t), p_y(t), p_z(t)]$

Integral of squared jerk characterizes the smoothness of the movement (this should be optimized):

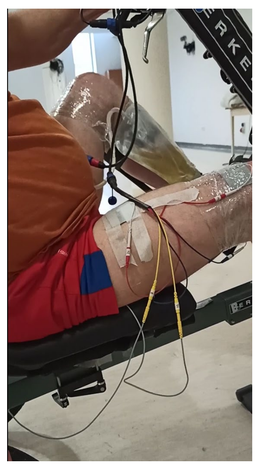
$$L = \int_0^T \mathbf{p}'''(t)^2 \, dt$$

Publications of the group

- Botzheim, L, DM Ernyey, M Mravcsik, L Varaljai, A Klauber, P Cserhati, and JLaczko. 2022.**"Changes in Active Cycling Time and Distance during FES-Assisted Cycling before and after the Pandemic Closure – A Case Study."***ARTIFICIAL ORGANS 46 (3): E178–E182.*
- Radeleczki, B, M Mravcsik, L Botzheim, and J Laczko. 2022. **"Prediction of LegMuscle Activities from Arm Muscle Activities in Arm and Leg Cycling."***ANATOMICAL RECORD. doi:10.1002/ar.25004.*
- Botzheim, L, J Laczko, D Torricelli, M Mravcsik, JL Pons, and Barroso FOliveira. 2021. **"Effects of Gravity and Kinematic Constraints on MuscleSynergies in Arm Cycling."** *JOURNAL OF NEUROPHYSIOLOGY 125 (4): 1367–1381. doi:10.1152/jn.00415.2020.*
- Mravcsik, M, L Botzheim, N Zentai, D Piovesan, and J Laczko. 2021. **"The Effectof Crank Resistance on Arm Configuration and Muscle Activation Variancesin Arm Cycling Movements."** *JOURNAL OF HUMAN KINETICS 76: 175–189.doi:10.2478/hukin-2021-0053.*
- Botzheim L, Mravcsik M, Zsenak I, Piovesan D, Laczko J (2019): **Jerk Decomposition during Bimanual Independent Arm Cranking**. IEEE 16TH INTERNATIONAL CONFERENCE ON REHABILITATION ROBOTICS (ICORR), Toronto, ON, Canada, 2019, pp. 264-269. (2019)
- Mravcsik M, Kast C, Vargas Luna JL, Aramphianlert W, Hofer C, Malik Sz, Putz M, Mayr W, Laczko J (2018): **FES driven cycling by denervated muscles.** 22nd *ANUAL CONFERENCE OF THE FUNCTIONAL ELECTRICAL STIMULATION SOCIETY. Nottwil, Switzerland, Program Book, pp. 134-136*

Results

A-B



Paraplegic, spinal cord injured "pilot" tricycling, controlled by FES, using our muscle stimulation pattern at the Lyon Cyber Days 2023 competition.

C

The cycling mode has a significant effect on the synergy vectors and the activation coefficients during arm cycling.

D

The movement size has a significant effect on the endpoint jerk during arm cycling in all cycling mode.

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