Machine Learning Methods for Force Myography Based Torque Estimation in Human Knee and Ankle Joints

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Background. Optimization and personalization of assistive wearable robots (exoskeletons) require a good understanding of human motor control. Myography-based methods, including electromyography (EMG) and force myography (FMG), offer immense potential in capturing information about muscle states, thereby enabling the integration of biofeedback into exoskeleton control [1]. Accurate joint torque estimation can provide insight into the human state for exoskeleton control and human motor performance evaluation. Multiple sensor signals have been applied in joint torque estimation. Previous research has successfully estimated joint kinematics and muscle forces based on EMG signals [2], while joint torque estimation using FMG is still rare [3]. However, information on muscle activity based on force instead of electrical potential might enhance the potential of assistive exoskeletons and increase their usability.

Idea. The project aims to compare and optimize machine learning based data-driven methods for estimating joint torque in real-life tasks using FMG signals. The primary objective of this research is to determine the best model and its input configuration to accurately estimate the human joint torque from FMG signals combined with other kinematic information and compare the performance to EMG-based estimation. This includes the design, implementation and optimization of multiple models and varying input configurations. The corresponding data for training and validation is currently collected in a user study focusing on the ankle and knee joint motion during cyclic and non-cyclic real-life tasks, such as walking and sit-to-stand transition.

Requirements. This project requires a basic understanding of the human musculoskeletal system and data analysis methods, as well as previous experience in Python with either *tensorflow* or *pytorch*. Prior knowledge of biomechanics, motion analysis using Vicon (Nexus), OpenSim and MATLAB is advantageous.

[1] Z. S. Mahdian, H. Wang, M. I. M. Refai, G. Durandau, M. Sartori, and M. K. MacLean, “Tapping Into Skeletal Muscle Biomechanics for Design and Control of Lower Limb Exoskeletons: A Narrative Review,” *Journal of Applied Biomechanics*, 2023.

[2] K. L. Scherpereel, D. D. Molinaro, M. K. Shepherd, O. T. Inan, and A. J. Young, “Improving Biological Joint Moment Estimation During Real-World Tasks With EMG and Instrumented Insoles,” *IEEE Transactions on Biomedical Engineering*, 2024.

[3] C. Marquardt, A. Schulz, M. Dezman, G. Kurz, T. Stein, and T. Asfour, “Force Myography Based Torque Estimation in Human Knee and Ankle Joints,” *IEEE International Conference on Robotics and Automation (ICRA)*, 2025, accepted.

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