TECHNISCHE UNIVERSITÄT MÜNCHEN
LEHRSTUHL FÜR INFORMATIONSTECHNISCHE REGELUNG
ORDINARIA: UNIV.-PROF. DR.-ING. SANDRA HIRCHE

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S T U D E N T T H E S I S

Neuromechanical modeling for physical Human-Exoskeleton-Interaction

Problem description:

In order to provide a safe and seamless physical Human-Exoskeleton-Interaction (pHEI), a precise dynamical model of the interacting human is essential. Particularly the joint stiffness, also referred to as impedance, is an important neuromechanical parameter to describe human behavior in previously unknown or unstable environments [1]. It is assumed that during the early stages of learning an internal dynamics model, the central nervous system modulates joint stiffness similar to an impedance controller to stabilize the interaction and increase task accuracy [2]. Currently, joint impedance estimation is primarily performed by utilizing a force-controlled manipulandum and subsequently observing the kinematics and joint torques in presence of perturbation. However, it is still an open research question how to perform joint impedance estimation by means of wearable exoskeletons. In particular the unknown interaction dynamics between the exoskeleton and human inhibit the use of simple estimation techniques. Therefore, the deployment of probabilistic learning techniques, which provide formal guarantees, such as Gaussian Processes [3], is a promising approach. Additionally, a more profound understanding of the sources of uncertainty in the interaction dynamics and their influence on the impedance estimation error, could help increase the fidelity of the neuromechanical model.
The goal of this work is the analysis of the uncertainties inherent in models of pHEI and the consequent deployment of learning techniques to estimate the joint impedance using data generated by an elbow-exoskeleton. Different learning strategies should be compared and particular focus should be given to ones that ensure robustness and safety by providing upper bounds on the model error.

Tasks:

- Literature research on human-robot-interaction and probabilistic regression techniques
- Numerical and/or analytical sensitivity analysis of model parameter uncertainties
- Learning and evaluation of a neuromechanical model with error bounds

Bibliography:

[1] E. Burdet, R. Osu, D. Franklin, T. Milner, and M. Kawato. The central nervous system stabilizes unstable dynamics by learning optimal impedance. *Nature*, 414:446–449, 2001.
[2] D. Mitrovic, S. Klanke, R. Osu, M. Kawato, and S. Vijayakumar. A computational model of limb impedance control based on principles of internal model uncertainty. *PLoS ONE*, 5(10), 2010.
[3] C E Rasmussen and C K I Williams. *Gaussian Processes for Machine Learning*. MIT Press, 2006.

Supervisor:	M. Sc. Samuel Tesfazgi
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(S. Hirche)
Univ.-Professor