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MASTER THESIS

Shared and cooperative control for exoskeletons

Problem description:

Exoskeletons are expected to have a major impact in rehabilitation, specifically for individuals with motor deficits. The core of our novel control approach for exoskeletons is an advanced, efficient and adaptive strategy to distribute the control effort between the human muscles with functional electrical stimulation (FES) and the motors in the exoskeleton. In this setting, both actuators contribute to a joint task, which is considered as a mixed-initiative because an overlapping interaction is established. The summary in [1] outlines that most work in this field relies on blending mechanisms to linearly weight the control contributions, which was shown to be unsafe (even for safe individual contributions). Therefore, model predictive control (MPC) schemes [2], game theoretic approaches and passivity-based controllers [3] have been proposed for the human-machine cooperative control, nevertheless, none of them has been applied to control exoskeleton in combination with FES. In this thesis we aim to develop a cooperative control architecture, which allows an optimal distribution of available resources and properly deals with time varying dynamics. The latter enables the exoskeleton to react to fatigue or other changing human factors quickly enough. Ideally, the shared control allows online adaptation of the employed models and is robust to uncertainties present in the system, which might arise from imprecise modelling. The designed algorithm will deal with various optimality measures depending on the operational mode of the system. For example, maximizing the patients training effect in rehabilitation will require different control strategies than maximizing the success rate of a task in daily activities. Most importantly, the architecture will ensure that the user and the environment are safe for any operational mode at any point in time. This is a particularly challenging because multiple actuators (motors and muscles) injecting energy into the system are subject to unknown delay and noise. The architecture will therefore consider different theoretical concepts ensuring stability of control systems subject to uncertain actuators. The goal of this work is to develop the cooperative control concept and validate it in simulation.

Bibliography:

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- [2] R. Chipalkatty, G. Droge, and M. B. Egerstedt, Less Is More: Mixed-Initiative Model-Predictive Control With Human Inputs, *IEEE Trans. Robot.*, vol. 29, no. 3, pp. 695703, 2013.
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Supervisor: Dr.-Ing. Stefan Sosnowski, Dr. Satoshi Endo
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(S. Hirche)
Univ.-Professor