TECHNISCHE UNIVERSITÄT MÜNCHEN
Human-centered Assistive Robotics
UNIV.-PROF. DR.-ING. DONGHEUI LEE

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MASTER'S THESIS

for

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Variable interaction control with dynamical systems

Problem description:

Dynamical systems (DS) [2, 3] has recently emerged as a powerful tool for encoding robot motions and generating reference trajectories. DS feature nice stability properties in terms of convergence to a point attractor or a limit cycle, and lend themselves well to learning from demonstrations frameworks. In addition to learning DS, recent work [5] has also aimed at combining DS with low level interaction control for providing safe and compliant interaction with the environment. However, as explained in [5], the interaction control framework is different from the classical impedance control since it does not posses the symmetrical stiffness behavior of impedance control. Recently, an approach [1] to encode such stiffness behaviors into DS has been proposed which enables the robot to track a specific reference trajectory. In this thesis, it shall be investigated how variable impedance/stiffness control can be embedded into the framework of interaction control with DS, while still retaining the passivity features of the interaction controller developped in [5] . This offers the possibility to change the apparent robot dynamics, which can be crucial for tasks involving direct human-robot interaction, as pointed out in [4].

Tasks:

- Literature research on dynamical systems and variable impedance control
- Extension of the formulation in [1] to embed varying stiffness behaviors into DS
- Identify how the proposed formulation can be combined with passive interaction control
- Test the approach in simulations and on the real robot

Bibliography:

[1] Nadia Barbara Figueroa Fernandez and Aude Billard. Modeling compositions of impedance-based primitives via dynamical systems. In *ICRA 2018*, 2018.

[2] S. Mohammad Khansari-Zadeh and Aude Billard. Learning stable nonlinear dynamical systems with gaussian mixture models. *Trans. Rob.*, 27(5):943–957, October 2011.

[3] S. Mohammad Khansari-Zadeh and Aude Billard. Learning control lyapunov function to ensure stability of dynamical system-based robot reaching motions. *Robotics and Autonomous Systems*, 62(6):752 – 765, 2014.

[4] Mahdi Khoramshahi and Aude Billard. A dynamical system approach to task-adaptation in physical humanrobot interaction. *Autonomous Robots*, 43:927–946, 2019.

[5] K. Kronander and A. Billard. Passive interaction control with dynamical systems. *IEEE Robotics and Automation Letters*, 1(1):106–113, Jan 2016.

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