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

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M A S T E R ' S   T H E S I S
for
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**Physics-based Deep Learning with Application to Planning and Control of Soft Robots**

Problem description:

Soft robot actuators behave in a nonlinear manner and exhibit hysteresis effects due to their visco-elastic materials. Modelling these actuators can be inaccurate and create challenges for the control of soft robots. Using the expressive power of Deep Neural Networks (DNN), this work will model the actuator more accurately to represent the real robot. To this end, the differentiability from the soft robot simulator "DiffPD" [1] will be used. An additional source of inaccuracy in soft robot modelling is their forward dynamics. Hence this work will follow a similar approach to residual physics [3] in order to model the simulation-to-reality gap for DiffPD. Given the recent success of machine learning approaches for forward dynamics, a comparison will be made with one particular data-driven framework: Koopman Operators. These create an embedding in which the dynamics are globally linearized, allowing the use of efficient linear control methods. As the Finite Element Method will be used for simulation, many vertices will have similar behavior, hence the Compositional Koopman Operator [2] will allow for much more efficient computation. In their work, the vertices are manually assigned to objects that share dynamics. Scalability and automation of this procedure will be investigated in this work. Lastly both the actuator model and forward dynamics using the Compositional Koopman Operator will be tested on the planning and control of a real soft robot arm.

Tasks:

- Familiarizing with DiffPD framework
- Implement and train mapping from actuator pressures to FEM simulation control input
- Implement and train automatic object assignment for compositional Koopman
- Evaluate performance on the real soft robot arm

Bibliography:

[1] T. Du, K. Wu, P. Ma, S. Wah, A. Spielberg, D. Rus, and W. Matusik. Diffpd: Differentiable projective dynamics with contact. *arXiv:2101.05917*, 2021.
[2] Y. Li, H. He, J. Wu, D. Katabi, and A. Torralba. Learning compositional koopman operators for model-based control. In *International Conference on Learning Representations*, 2020.
[3] A. Zeng, S. Song, J. Lee, A. Rodriguez, and T. Funkhouser. Tossingbot: Learning to throw arbitrary objects with residual physics. *IEEE Transactions on Robotics*, 36(4):1307–1319, 2020.

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