Karlsruhe Institute of Technology


Autonome Lernende Roboter (ALR) and ZEISS InnoHub

Prof. Gerhard Neumann


## Project Type

- ☑ Master Thesis
- ☐ Bachelor Thesis
- ☑ Research Project

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## Difficulty

Algorithmic

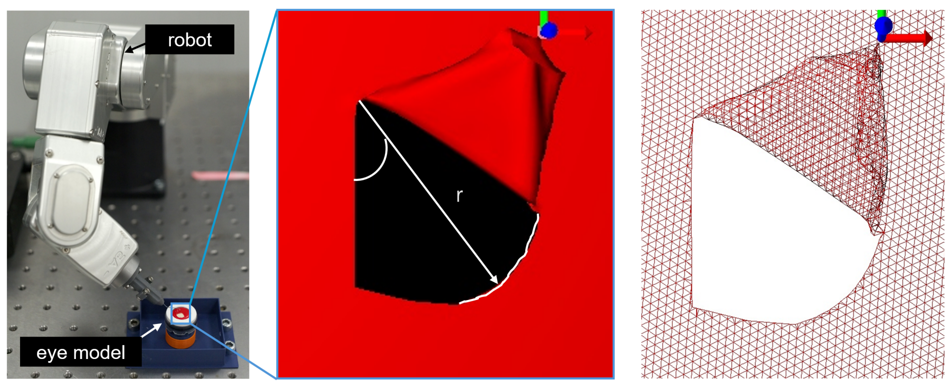
Math

Application

# RL for Soft-Material Tearing: From Paper Cutting to Cataract Surgery

## Description

This thesis explores reinforcement learning (RL) for soft-material cutting tasks, with the long-term goal of automating complex procedures such as the Continuous Curvilinear Capsulorhexis (CCC) in cataract surgery. Peter et al. [3] demonstrate that RL can learn precise tearing behavior using a FEM-based simulation in SOFA, but the high computational cost limits its scalability to more complex tasks. To address this challenge, modern simulation platforms such as Taichi, Warp, and IsaacLab have been adopted for their speed and GPU support, though they are primarily tested on simple rigid-body dynamics. Deformable simulation remains difficult due to contact, fracture, and topology changes. Recently, ScissorBot [2] introduced a Taichi-based implementation for cutting simulation that supports interactive fracture. Compared to SOFA, Taichi runs entirely on GPU, offering significant speedup and making it suitable for policy learning. However, reinforcement learning support is currently missing. This work will bridge that gap by developing an RL framework tailored for high-fidelity cutting environments, enabling scalable learning for surgical automation and soft-material manipulation.




(a) Lab setup (b) Capsulorhexis simulations

Figure 1: Examples setup from Zeiss.

## Tasks

- Explore ScissorBot and try out their Imitation Learning examples.
- Implement a simple algorithm for this task with image observation as a starting point, similar to [3].
- Develop a new RL algorithm that can work with 3D points or mesh-based observations, similar to [1].

## References


[1] Tai Hoang, Huy Le, Philipp Becker, Vien Anh Ngo, and Gerhard Neumann. Geometry-aware RL for manipulation of varying shapes and deformable objects. In *The Thirteenth International Conference on Learning Representations*, 2025.

[2] Jiangran Lyu, Yuxing Chen, Tao Du, Feng Zhu, Huiquan Liu, Yizhou Wang, and He Wang. Scissorbot: Learning generalizable scissor skill for paper cutting via simulation, imitation, and sim2real. In *8th Annual Conference on Robot Learning*.

[3] Rebekka Charlotte Peter, Steffen Peikert, Ludwig Haide, Doan Xuan Viet Pham, Tahar Chettaoui, Eleonora Tagliabue, Paul Maria Scheikl, Johannes Fauser, Matthias Hillenbrand, Gerhard Neumann, and Franziska Mathis-Ullrich. Lens capsule tearing in cataract surgery using reinforcement learning. In *2024 IEEE International Conference on Robotics and Automation (ICRA)*, pages 15501–15508, 2024.