Karlsruhe Institute of Technology

Intuitive Robots Lab (IRL)
Prof. Dr.-Ing. Rudolf Lioutikov

Project Type

- [x] Master Thesis
- [ ] Bachelor Thesis
- [ ] Research Project

Supervisors

Xinkai Jiang
xinkai.jiang@kit.edu
Yue Yang
yygx@cs.unc.edu

Difficulty

Algorithmic

Math

Application

Requirements

- [x] Python
- [x] PyTorch & Tensorflow

Robotic Skill Transitions Reimagined: Safer, Smarter, and Human-Aware Manipulation

Description

In long-horizon robotic manipulation tasks, safety is often considered at the level of individual skills [1]. However, transitions between skills can introduce critical safety risks that are commonly overlooked.
Examples:

- A robot finishes a cutting task while holding a knife, then moves toward a human to start a new task.
- It completes pouring hot coffee and immediately transitions to placing the cup elsewhere in a hazardous way (e.g., move too fast).

These transitional phases, though brief, pose significant safety threats due to abrupt changes in context, object state, or surroundings.

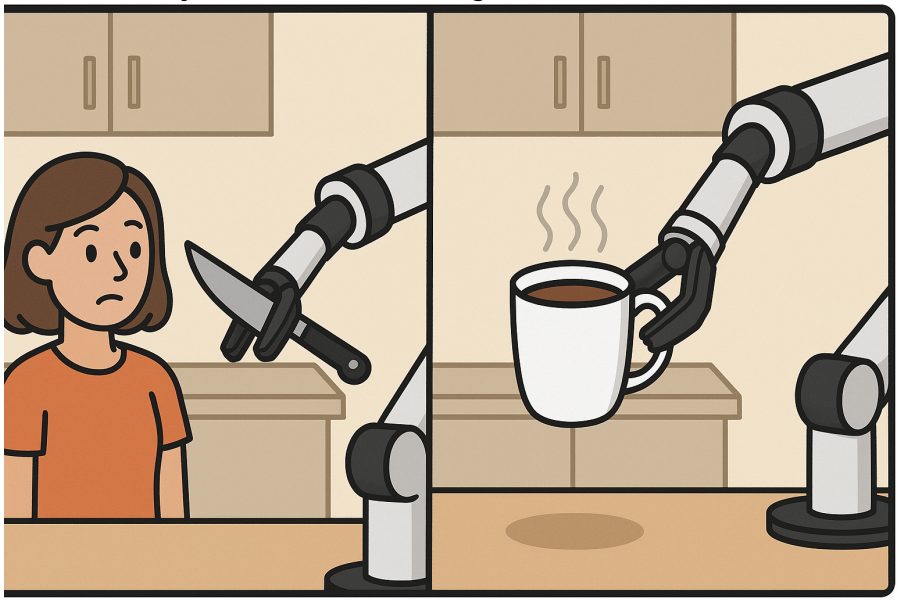

Figure 1: Two possible examples where robot may behave dangerously.

Tasks

The tasks in this project will involve:

- Data Preparation & Preprocessing: Use existing datasets or collect our own demonstrations. Collect transition states.
- Symbolic Skills Preparation: Prepare pre-trained visumotor skill policies via imitation learning.
- VLM/LLM framework: Prompt engineering to use VLM/LLM for labeling.
- Neural Control Barrier Function (CBF) Training: Train CBF neural network [2] and combine it with the motion planner to avoid safety issue during transition.
- System Evaluation: Integrate all subsystem and evaluate its performance both on simulation environment and real robot.

References

[1] Azal Ahmad Khan, Michael Andrev, Muhammad Ali Murtaza, Sergio Aguilera, Rui Zhang, Jie Ding, Seth Hutchinson, and Ali Anwar. Safety aware task planning via large language models in robotics. *arXiv preprint arXiv:2503.15707*, 2025.

[2] Yue Yang, Letian Chen, Zulfiqar Zaidi, Sanne van Waveren, Arjun Krishna, and Matthew Gombolay. Enhancing safety in learning from demonstration algorithms via control barrier function shielding. In *Proceedings of the 2024 ACM/IEEE International Conference on Human-Robot Interaction*, pages 820–829, 2024.