Humanoid Robots Lab
Introductory Meeting

Prof. Dr. Maren Bennewitz
Benedikt Kreis
9th October 2024

Course No.:
BA-INF 051 Projektgruppe
MA-INF 4213 Seminar
MA-INF 4214 Lab

Humanoid Robots Lab

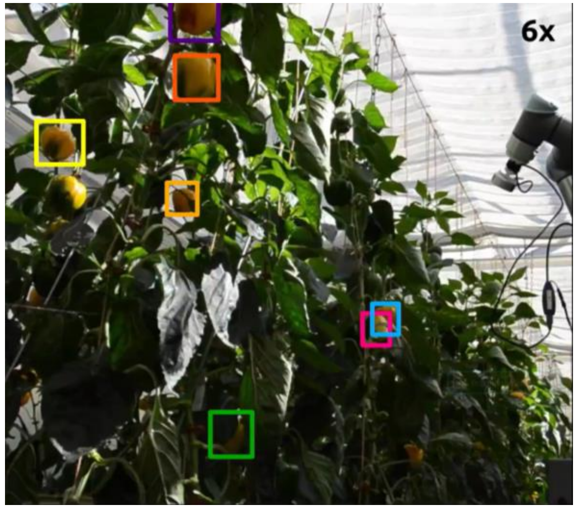
HRL

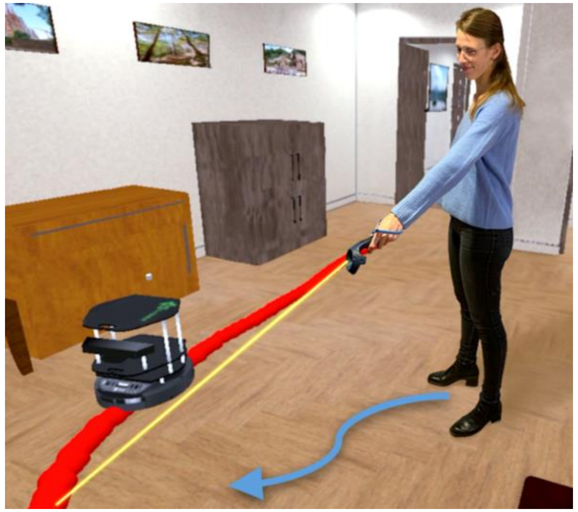
Group leader
Prof. Dr. Maren Bennewitz

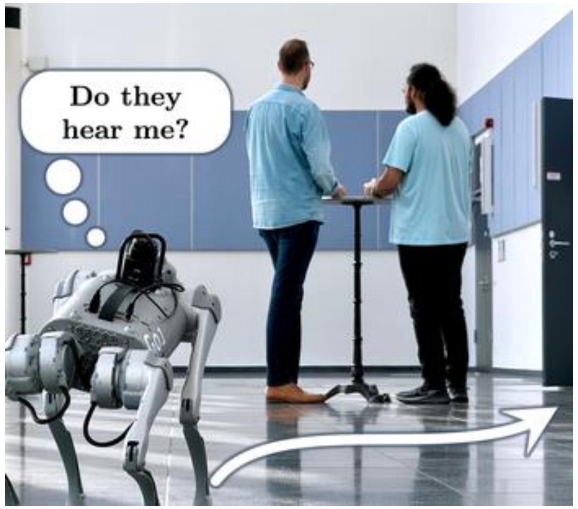
Our research topics:

- Robotics & autonomous systems
- Active perception
- Intelligent manipulation
- Human-robot interaction
- Machine learning

HRL Research Projects







Courses

	Bachelor PG			Master	Master
	Lab	+	Seminar	Lab	Seminar
ECTS points	6	+	3	9	4
Workload	180 h	+	90 h	270 h	120 h

- **Seminar:** Presentation and discussion of relevant scientific work
- **Lab:** Programming robots in simulation and on real hardware
- **Project Group:** Lab (70%) + Seminar (30%)

Course Deliverables

	Bachelor PG			Master	Master
	Lab	+	Seminar	Lab	Seminar
Presentation	X		X	X	X
Lab report	X			X	
Paper summary					X

Seminar

Seminar Overview

- **Presentation and discussion** of relevant scientific work (conference/journal papers)
- Aspects to cover:
  - Contribution of the work?
  - Technique/Methodology used?
  - Strengths & Weaknesses of the approach?
- Presentation: 20 minutes + 5 minutes Q&A
- Paper summary (M.Sc. only): **Written summary and discussion** of the work (7 pages not counting figures, LaTeX template provided on web page)

Seminar Timeline

- **Prepare** during the semester
  - Understand the paper
  - Write paper summary (M.Sc. only)
  - Prepare your presentation
- **Seminar Day** (Wednesday, 22.01.2025)
  - **Everybody must be present**
  - It's a full day event! (depending on the number of participants)

Seminar Grade

- B.Sc. Students:
  - Presentation: 100%

- M.Sc. Students:
  - Presentation: 70%
  - Paper summary and discussion: 30%

Seminar Papers
(Only BA-INF 051 Projektgruppe)

B.Sc. Students:
Paper will be assigned to you by your supervisor

Seminar Papers
(Only MA-INF 4213 Seminar)

M.Sc. Students:
You can choose from the following selection

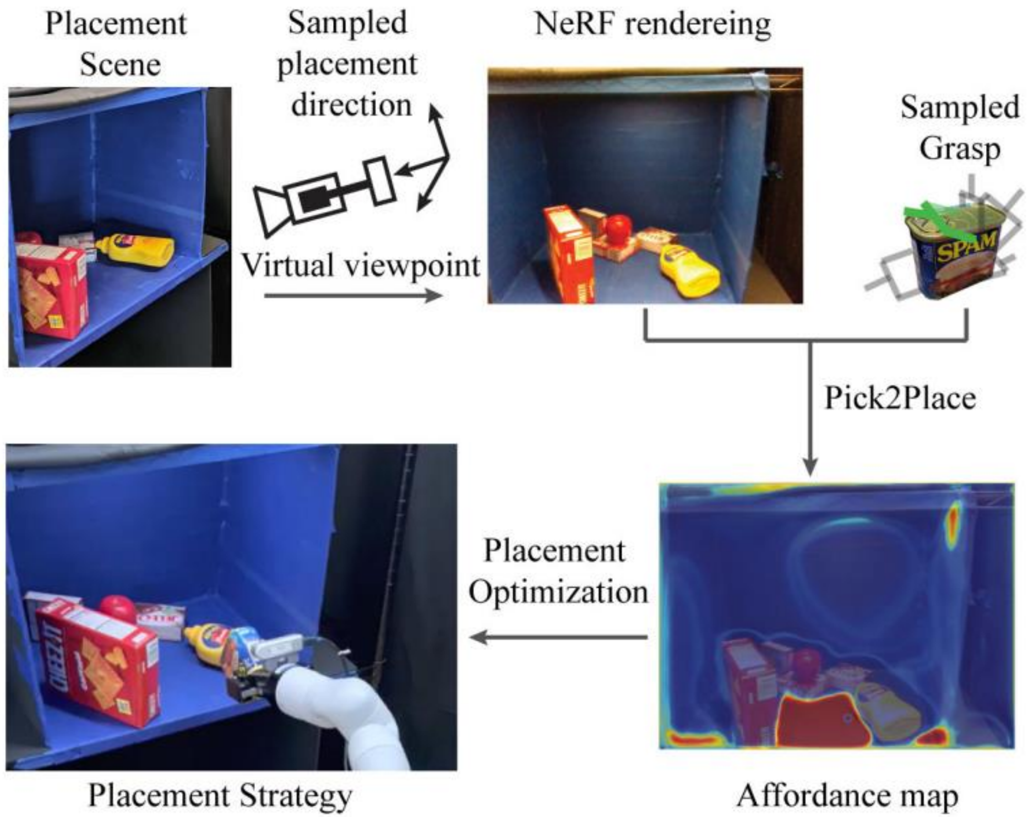
Pick2Place: Task-aware 6DoF Grasp Estimation via Object-Centric Perspective Affordance

He et al.

ICRA 2023

Supervisor: Benedikt Kreis

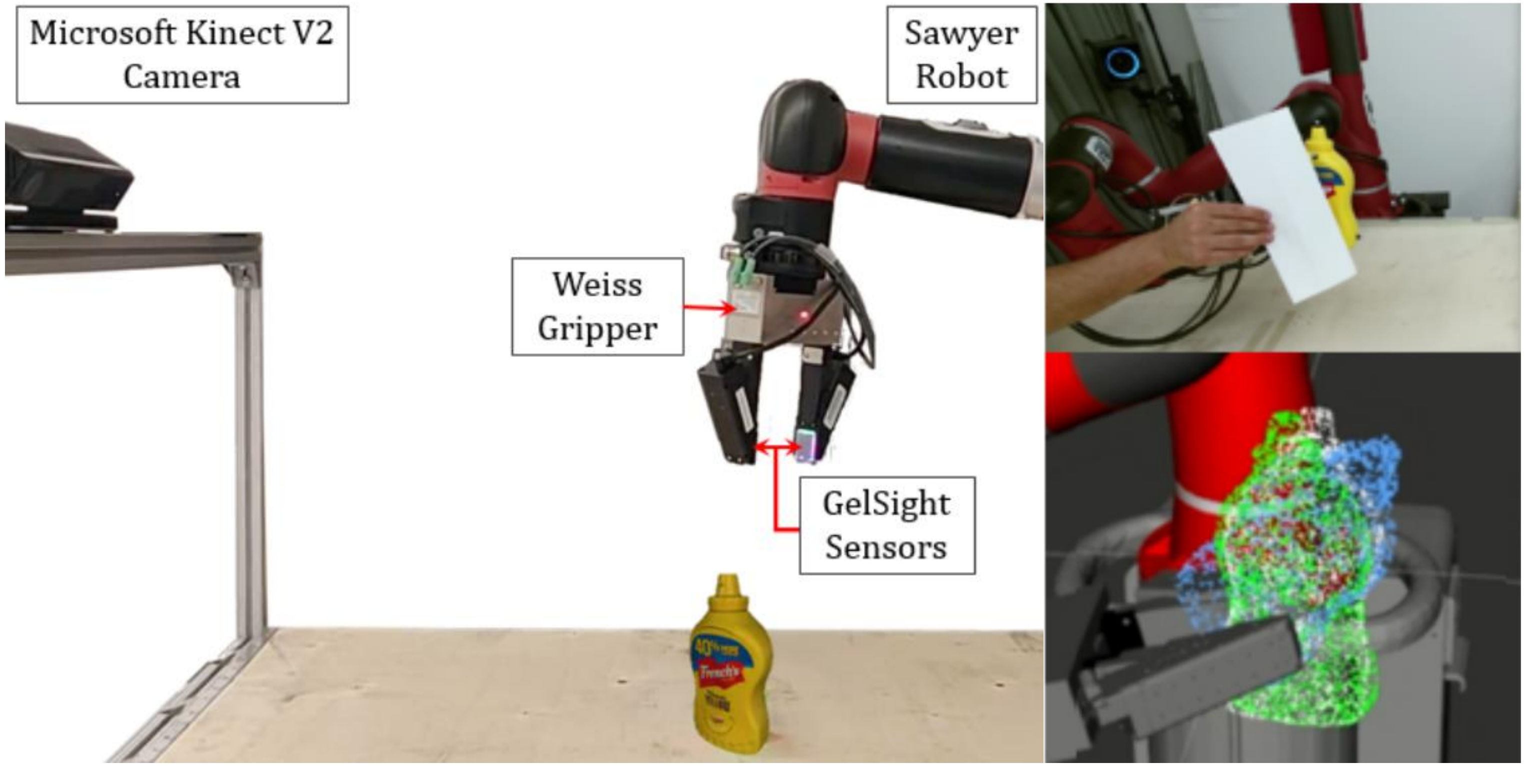
- **Goal:** Grasp objects in a way that they can be placed.
- **Problem:** The objects have to be inserted into a shelf.
- **Approach:** Use NeRF to sample placement view points and place them according to an affordance map.



VisuoTactile 6D Pose Estimation of an In-Hand Object using Vision and Tactile Sensor Data

Dikhale et al.
RA-L 2022
Supervisor: Benedikt Kreis

- **Goal:** In-hand 6D object pose estimation.
- **Problem:** Occlusions and sensor data fusion.
- **Approach:** Combine vision and tactile sensor information.

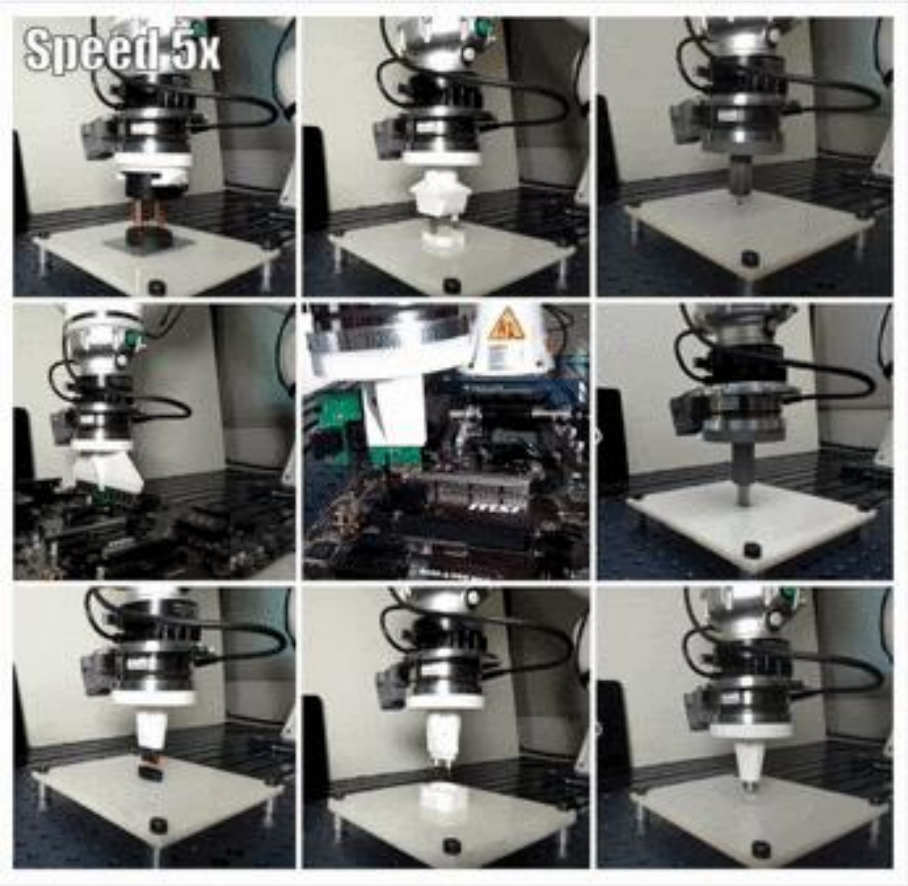


white: ground truth, green: paper approach, blue: baseline

Offline Meta-Reinforcement Learning for Industrial Insertion

Zhao et al.
ICRA 2022
Supervisor: Ahmed Shokry

- **Goal:** Train an RL agent that can assemble a variety of parts.
- **Problem:** Different tool shapes require different assembly behaviors.
- **Approach:** Use offline-Meta Reinforcement learning to train an agent that can quickly adapt its behavior to different tools.



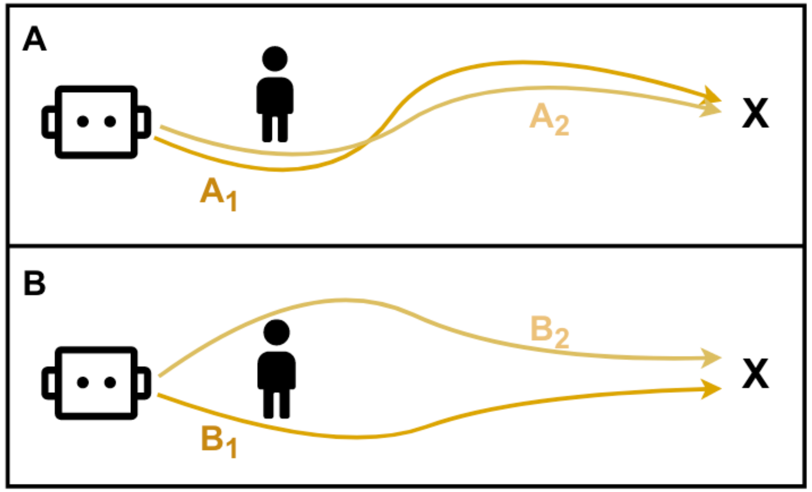
VARIQuery: VAE Segment-based Active Learning for Query Selection in Preference-based RL

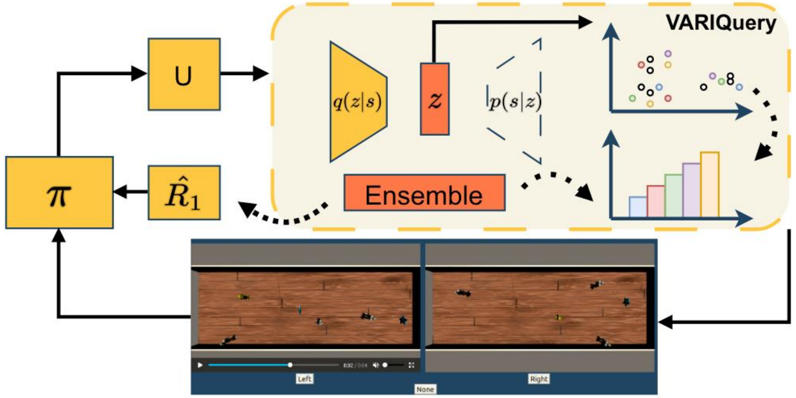
Marta et al.

IROS 2023

Supervisor: Jorge de Heuvel

- **Goal:** Enhance the efficiency of human-in-the-loop reinforcement learning (RL) for robotics by improving the query selection process in preference-based learning.
- **Problem:** Optimizing the information gain from query, while keeping the number of queries presented to the human low to minimize effort.
- **Approach:** A novel query selection mechanism using variational autoencoder (VAE) representations to generate diverse queries, integrating active learning principles to reduce human effort and improve the sample efficiency of preference-based RL.





Deep Koopman Operator with Control for Nonlinear Systems

Shi et al.

RA-L 2022

Supervisor: Murad Dawood

- **Goal:** Using deep learning to obtain a linear representation for a robotic arm.
- **Problem:** Robotic arms have non-linear models representing a challenge when developing the controller.
- **Approach:** Linearizing non-linear systems using Koopman operators.

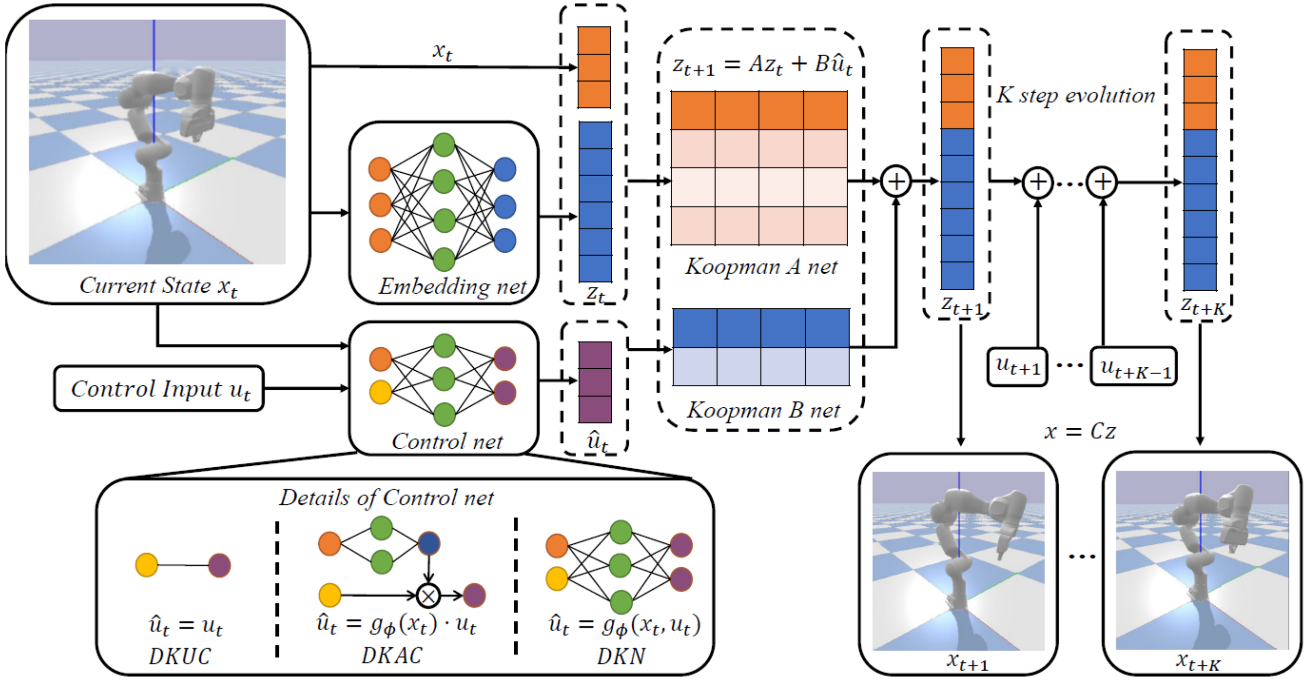


Fig. 2: The overview of neural network framework for K-steps predictions

Mechanical Search on Shelves with Efficient Stacking and Destacking of Objects

Huang et al.

ISRR 2022

Supervisor: Nils Dengler

- **Goal:** Find Objects in an occluded shelf.
- **Problem:** Occlusions and stacked objects can restrict the view inside the shelf and complicate the retrieval.
- **Approach:** Use Monte Carlo Tree Search to stack and un-stack objects and reveal hidden areas and object.

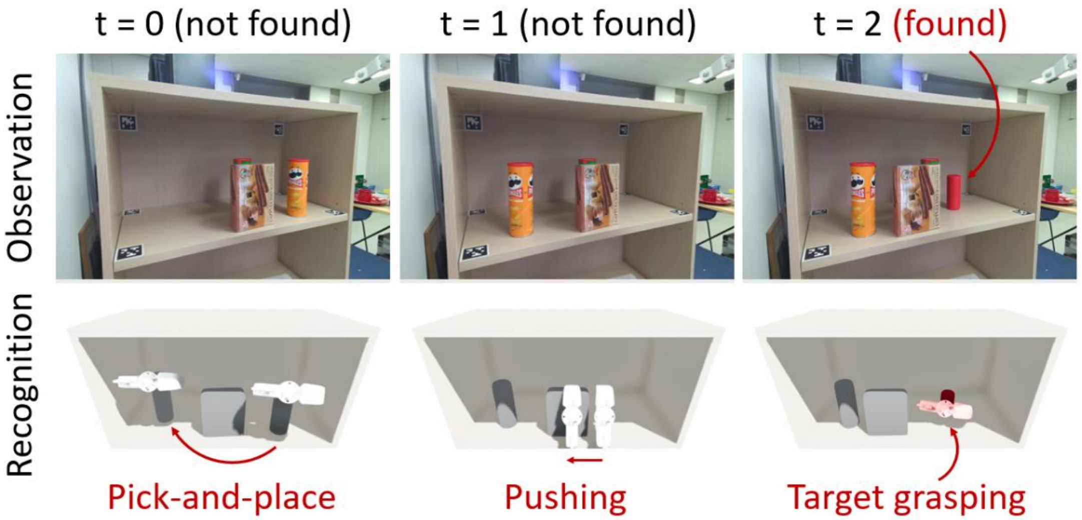
Leveraging 3D Reconstruction for Mechanical Search on Cluttered Shelves

Kim et al.

CoRL 2023

Supervisor: Nils Dengler

- **Goal:** Find Objects in an occluded shelf.
- **Problem:** Occlusions can restrict the view inside the shelf and complicate the retrieval.
- **Approach:** Use pushing and pick-and-place actions to rearrange occluding objects, making the desired target object both visible and graspable.



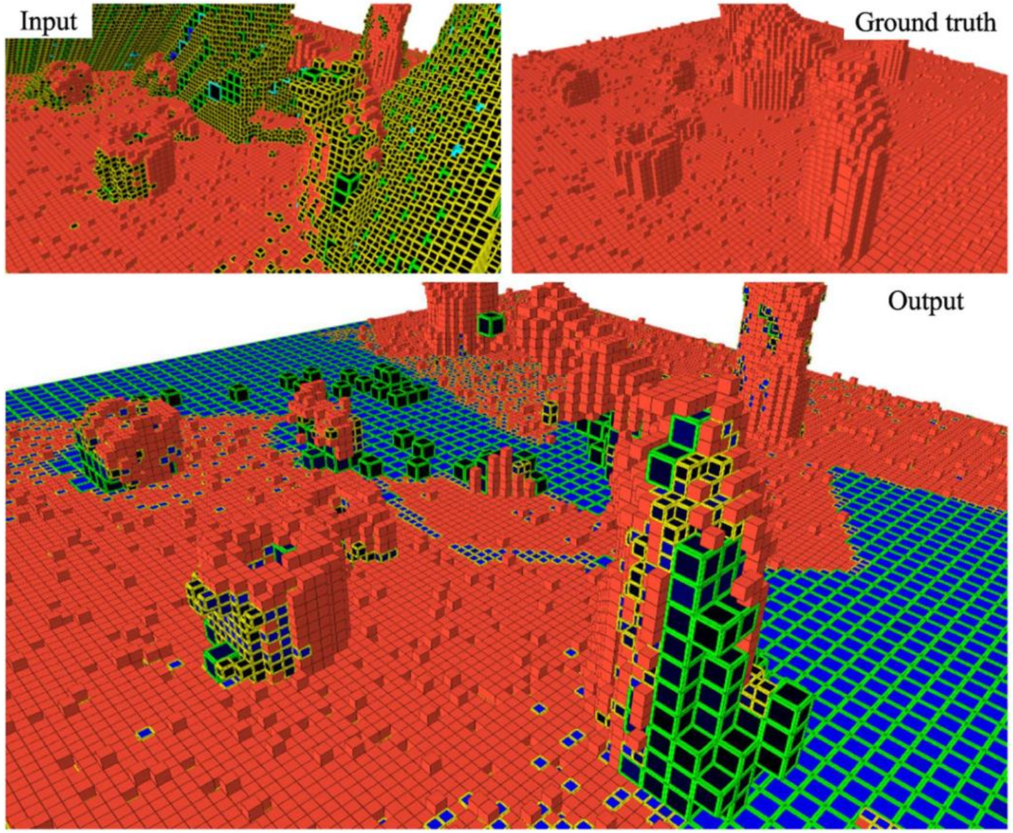
A Sparse Octree-Based CNN for Probabilistic Occupancy Prediction Applied to Next Best View Planning

Monica et al.

RA-L 2024

Supervisor: Rohit Menon

- **Goal:** Predict 3D Occupancy for Next Best View (NBV) Planning.
- **Problem:** Octrees are resource intensive. Prediction of unobserved space at scale is memory and time consuming.
- **Approach:**
  - Develop OCLe-CNN sparse network with Multi-scale loss function.
  - Predict occupancy probability with multi-scale nodes.
  - Perform NBV using the predicted values.



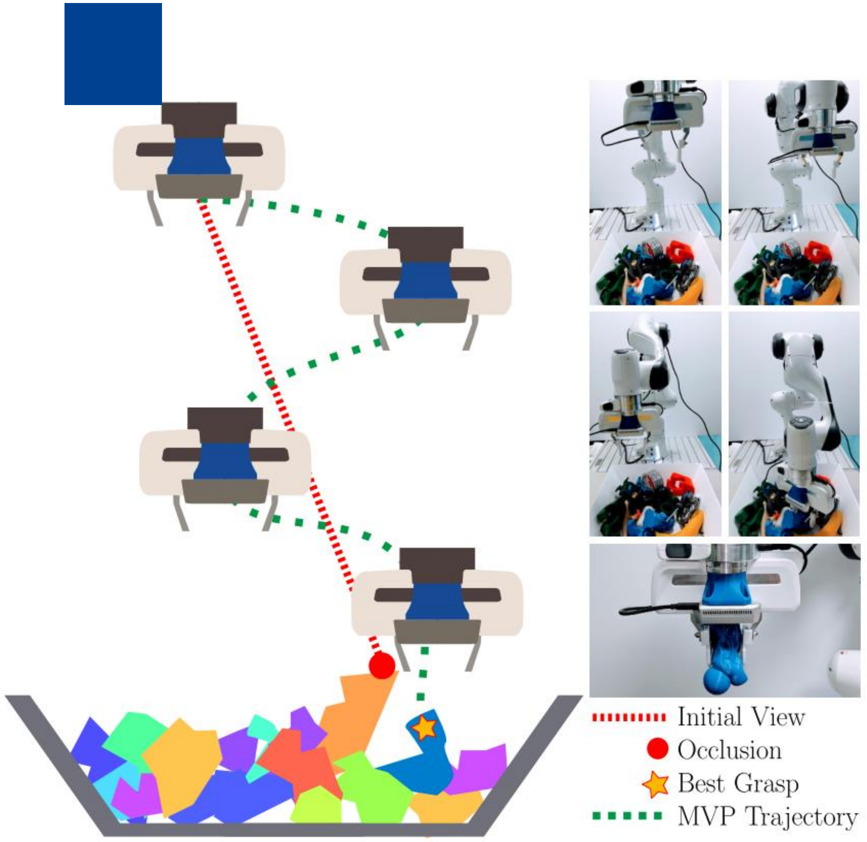
Multi-View Picking: Next-best-view Reaching for Improved Grasping in Clutter

Douglas et al.

ICRA 2019

Supervisor: Rohit Menon

- **Goal:** Improve grasping in cluttered environments.
- **Problem:** Occlusions in cluttered environments and complexity of objects reduces visual grasp detection capability.
- **Approach:**
  - Select next best informative viewpoint based on quality of grasp estimate in real time to reduce grasp pose uncertainty.
  - Use the act of reaching towards a grasp as a method of data collection for grasping.



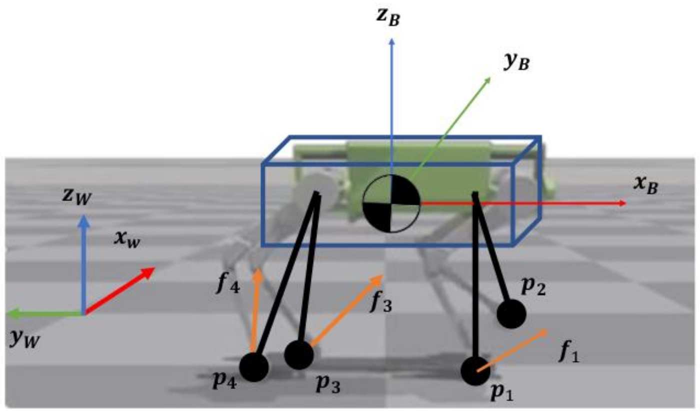
GLiDE: Generalizable Quadrupedal Locomotion in Diverse Environments with a Centroidal Model

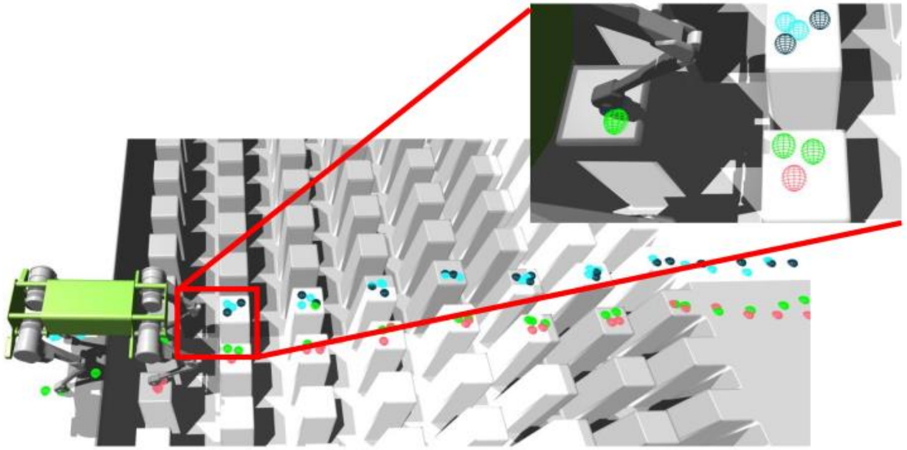
Zhaoming Xie, et al.

WAFR 2022

Supervisor: Shahram Khorshidi

- **Goal:** How to utilize a simple centroidal model in training RL agent and achieve versatile locomotion.
- **Problem:** Model-free RL for legged locomotion commonly relies on a physics simulator that can accurately predict the behaviors of every degree of freedom of the robot, can we instead rely on simplified models and achieve similar performance?
- **Approach:** Using centroidal model instead of whole body dynamics to train the RL agent.

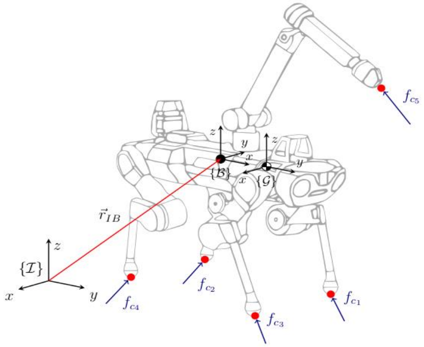


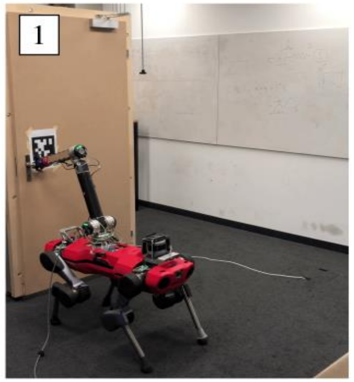


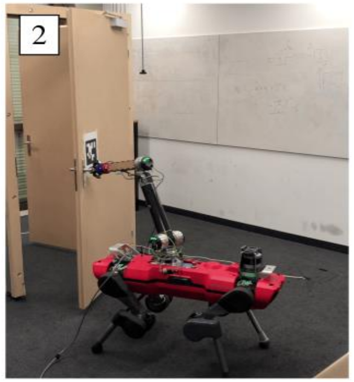
A Unified MPC Framework for Whole-Body Dynamic Locomotion and Manipulation

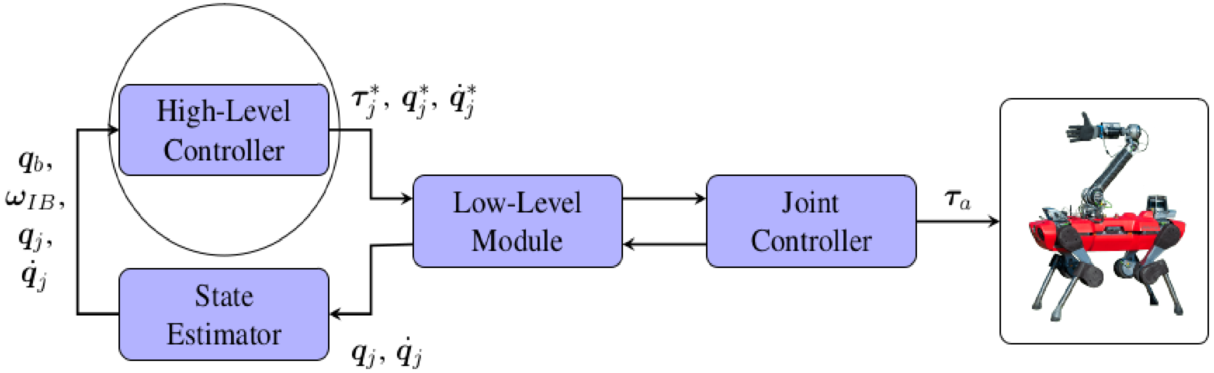
Sleiman et al.
RA-L 2021
Supervisor: Shahram Khorshidi

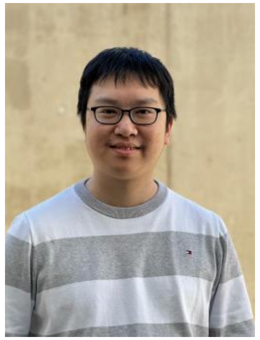
- **Goal:** Whole-body planning framework that unifies dynamic locomotion and manipulation tasks.
- **Problem:** Hybrid nature of generic multi-limbed mobile manipulation and legged locomotion can be model as a switched system.
- **Approach:** Formulating a single multi-contact optimal control problem by augmenting the robot's centroidal dynamics with the manipulated-object dynamics.







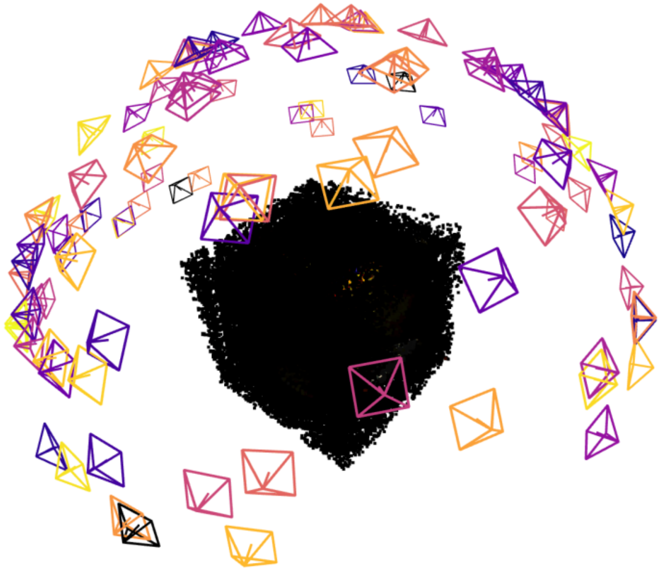


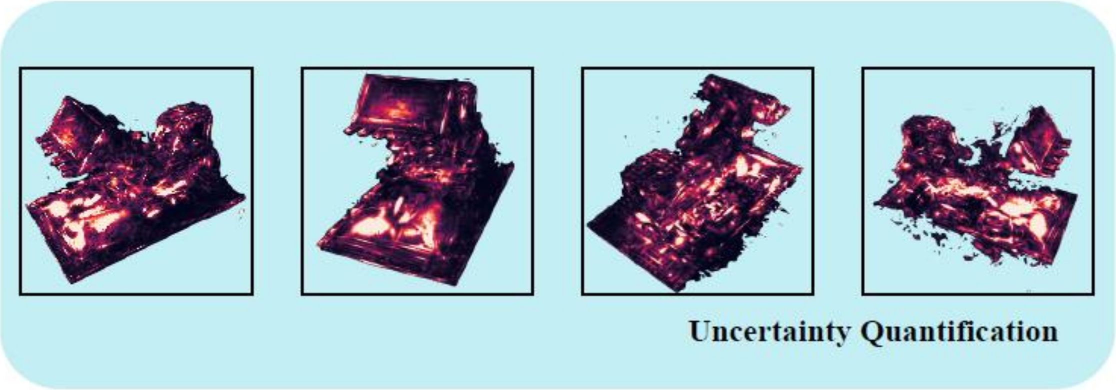


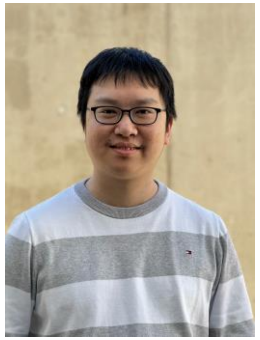
FisherRF: Active View Selection and Uncertainty Quantification for Radiance Fields using Fisher Information

Jiang et al.
ECCV 2024
Supervisor: Sicong Pan

- **Goal:** Active view selection and uncertainty quantification within the domain of radiance fields (3D Gaussian splatting).
- **Problem:** Existing methods depend on model architecture or are based on assumptions regarding density distributions that are not applicable.
- **Approach:** Leveraging Fisher information (Hessian of the log-likelihood function) to quantify observed information.







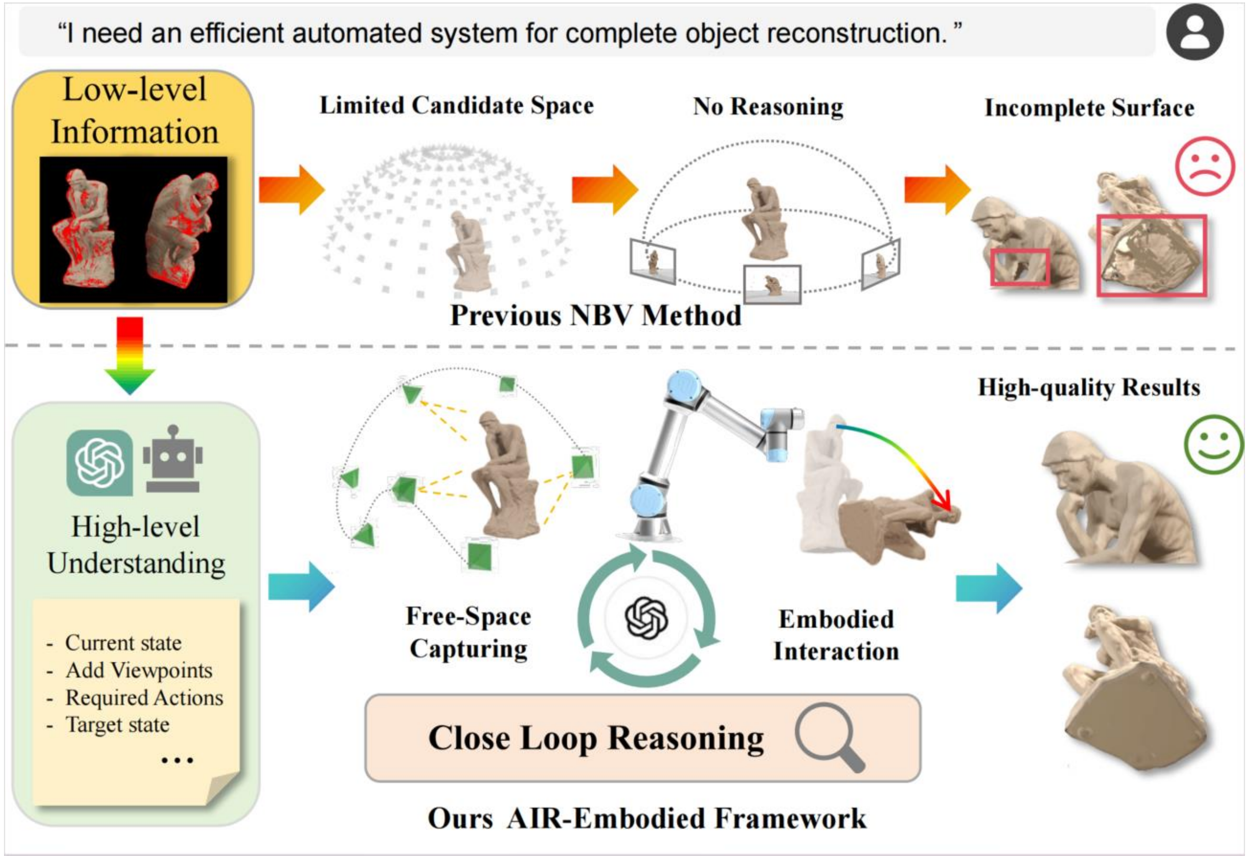
AIR-Embodied: An Efficient Active 3DGS-based Inter-action and Reconstruction Framework with Embodied LLM

Qi et al.

arXiv preprint 2024

Supervisor: Sicong Pan

- **Goal:** Reconstructing a complete 3D model of an object with bottom surfaces.
- **Problem:** Existing methods are often limited by predefined criteria and fail to enough surface details.
- **Approach:** Using uncertainty of 3D GS with LLM for close-loop viewpoint and action planning.



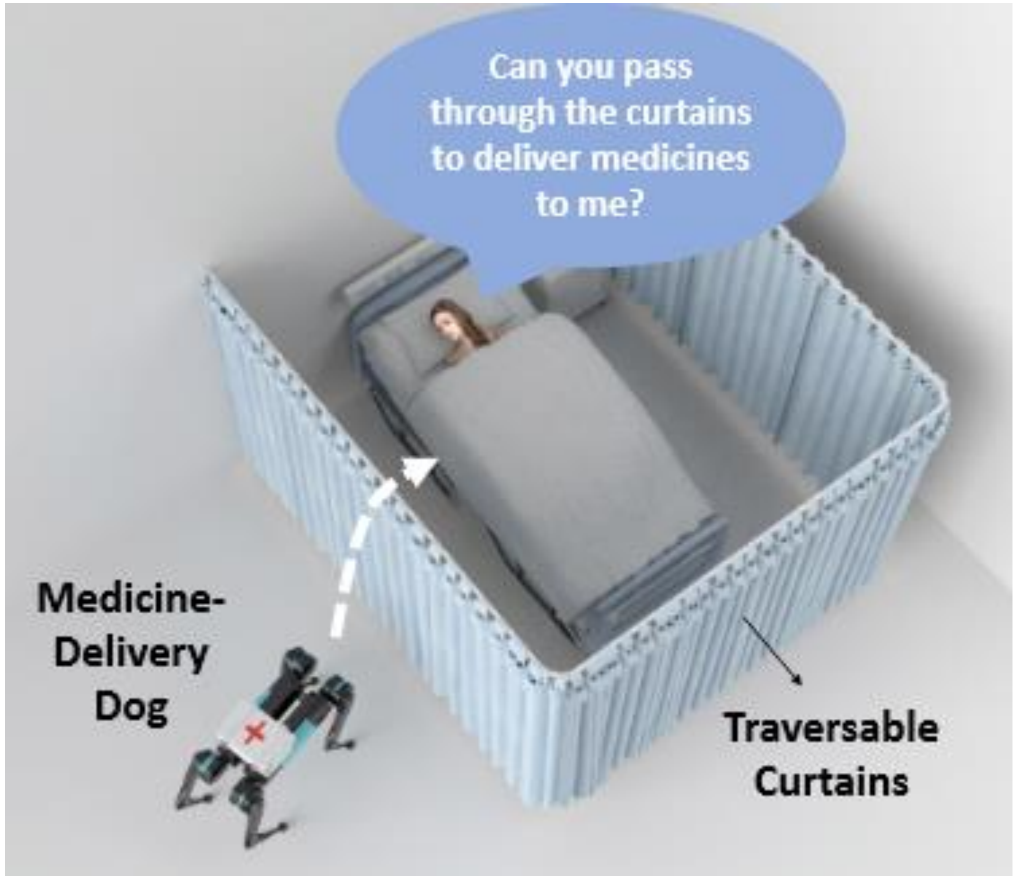
Interactive Navigation in Environments with Traversable Obstacles Using Large Language and Vision-Language Models

Zhang et al.

ICRA 2024

Supervisor: Subham Agrawal

- **Goal:** Use LLMs and VLMs to allow robots to navigate in environments with traversable obstacles (curtain, grass, etc.).
- **Problem:** Difficult and time consuming to train traversability of each and every obstacle.
- **Approach:** Using pretrained LLMs and VLMs to acquire action-aware attributes of obstacles from instructions of humans and build a costmap accordingly.

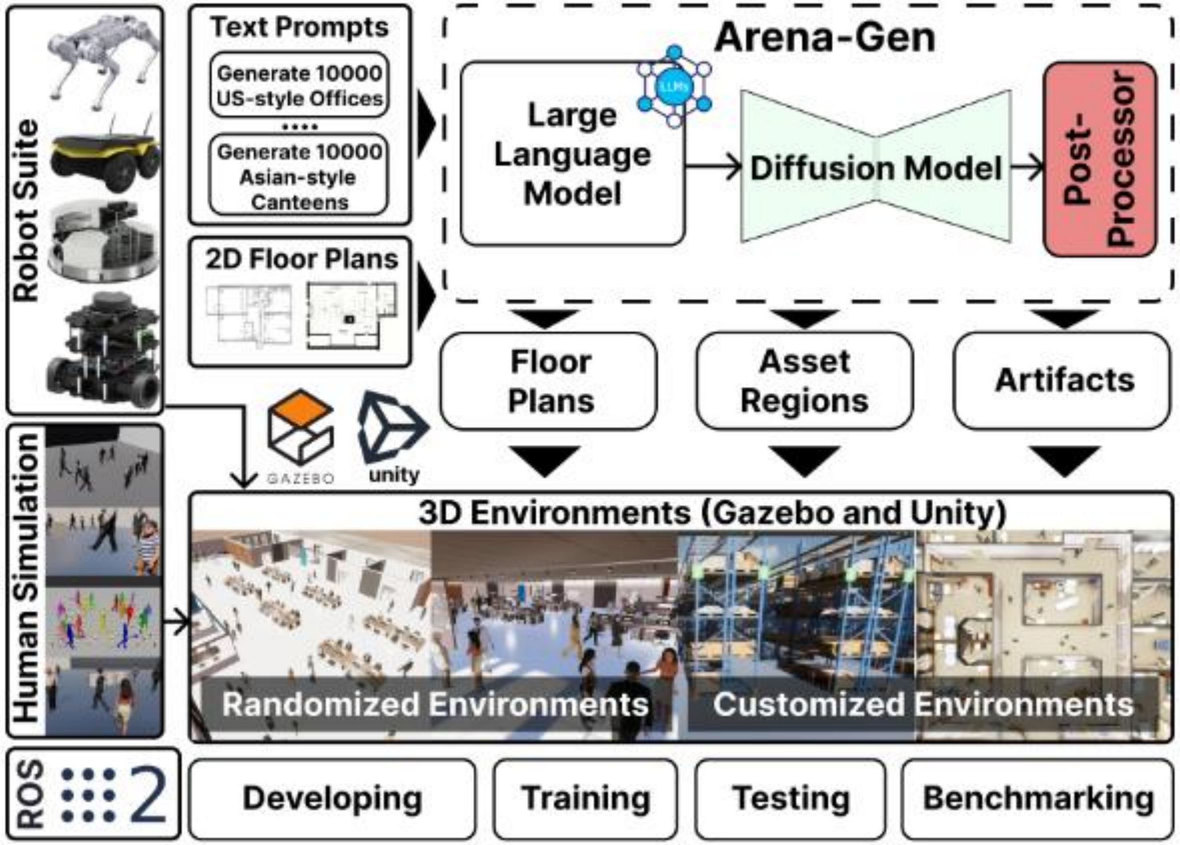


Arena 4.0: A Comprehensive ROS2 Development and Benchmarking Platform for Human-centric Navigation Using Generative-Model-based Environment Generation

Shcherbyna et al., arXiv preprint 2024

Supervisor: Subham Agrawal

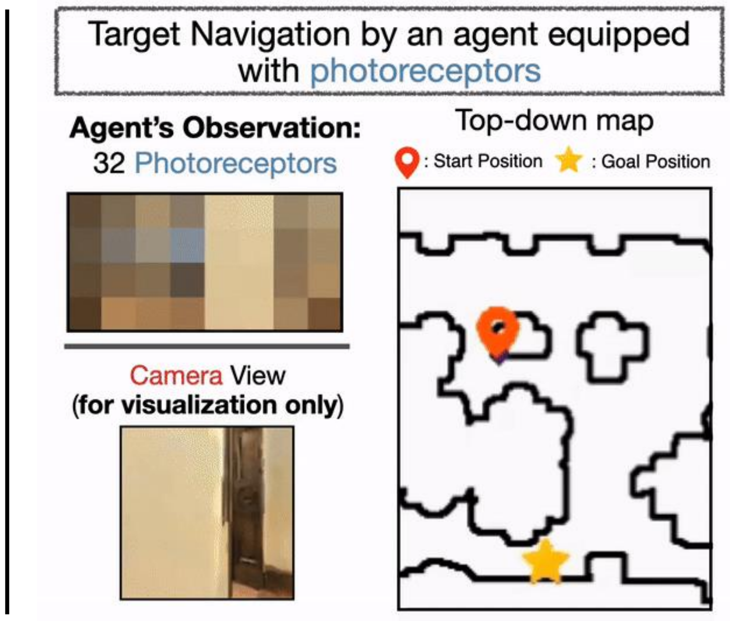
- **Goal:** a ROS2 based simulation platform for simulation and benchmarking social navigation approaches.
- **Problem:** Difficult to generate scenarios for development and benchmarking of social navigation strategies.
- **Approach:** Use generative models to dynamically generate complex, human-centric environments from text prompts and 2D floorplans.



Solving Vision Tasks with Simple Photoreceptors Instead of Cameras

Atanov et al.
ECCV 2024
Supervisor: Xuying Huang

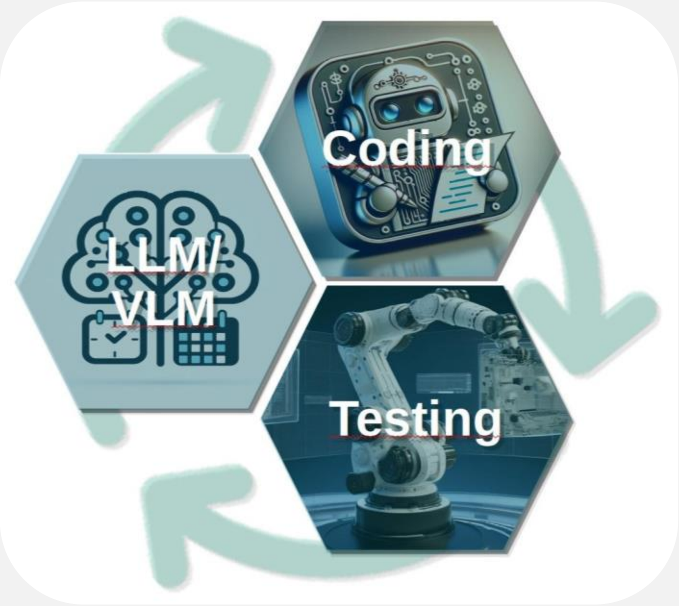
- **Goal:** Using low-resolution photoreceptors to solve vision tasks.
- **Problem:** How effective simple visual sensors are in solving vision tasks instead of relying on high-resolution camera and how their design affect the effectiveness?
- **Approach:** Propose a computational design optimization method to improve initial design and find well-performing ones.



MA-INF 4214 Lab
&
BA-INF 051 Projektgruppe
(Lab Part)

Available Lab Projects

LLM MEETS ROBOTICS (M.Sc.) INDUSTRY PROJECT



Goal: Sort unknown objects into bins using a robotic arm

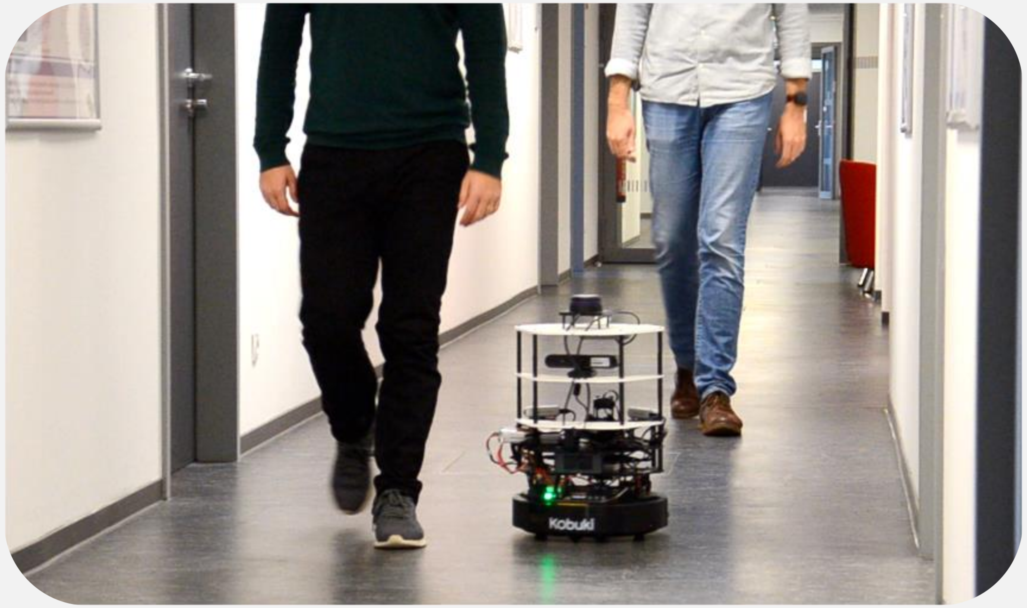
Challenge: Object detection, picking and placing, leveraging LLMs and VLMs

RL-BASED ROBOTIC SORTING (M.Sc.)

Goal: Sort cubes according to features using a robotic arm

Challenge: Reinforcement learning, object detection and localization, bin identification

LEARNING-BASED NAVIGATION (M.Sc.)



Goal: Train a RL agent to navigate among dynamic obstacles

Challenge: Learning architecture design, dynamic obstacle avoidance, sim-to-real transfer

QUADRUPED OBSTACLE COURSE (B.Sc./M.Sc.)

Goal: Navigate through an obstacle course

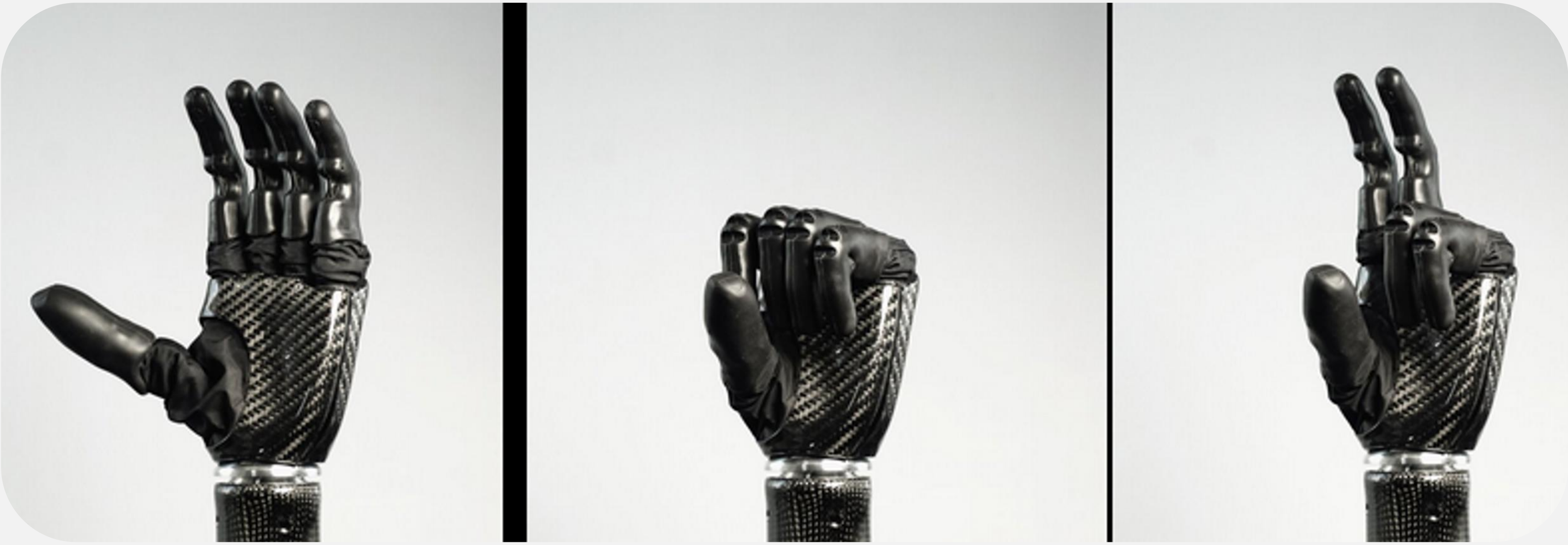
Challenge: Obstacle detection and avoidance, navigation, gait adaption to different scenarios

AUTONOMOUS RACING (M.Sc.)

Goal: Train a RL agent to autonomously drive on a race track

Challenge: Track detection, obstacle avoidance, motion planning and execution

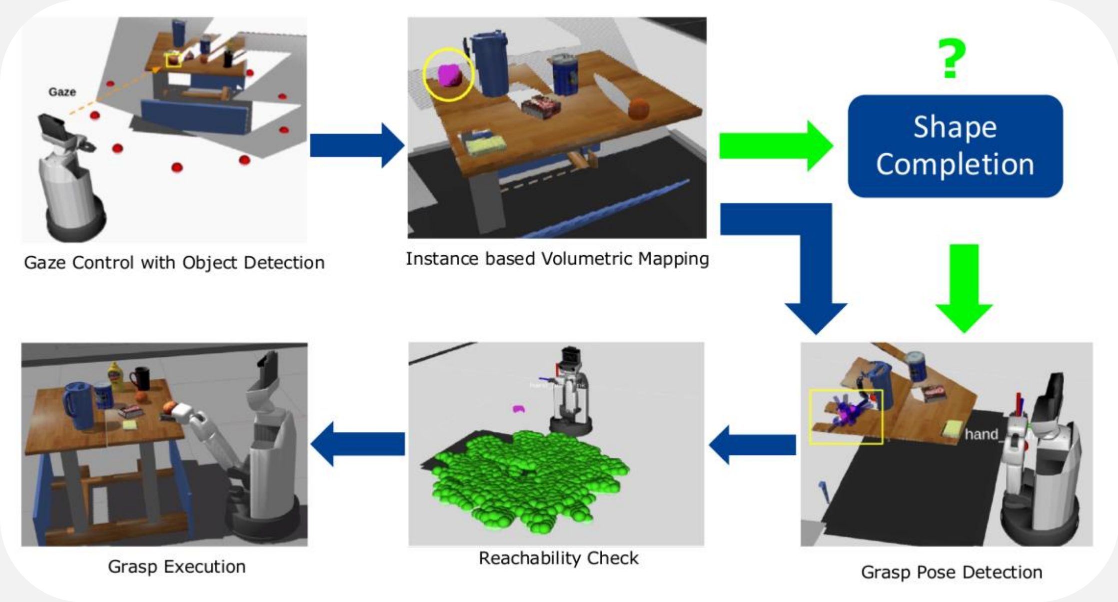
ROCK, PAPER, SCISSORS (B.Sc./M.Sc.)



Goal: Implement the game using the 5-finger Psyonic hand

Challenge: Realistic imitation of a human hand, hand gesture recognition, intuitiveness of the interface

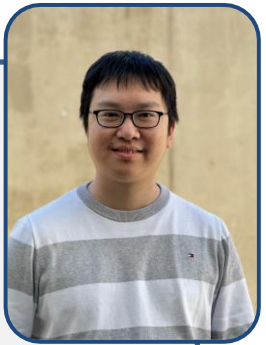
P2G MOBILE MANIPULATION (M.Sc.)

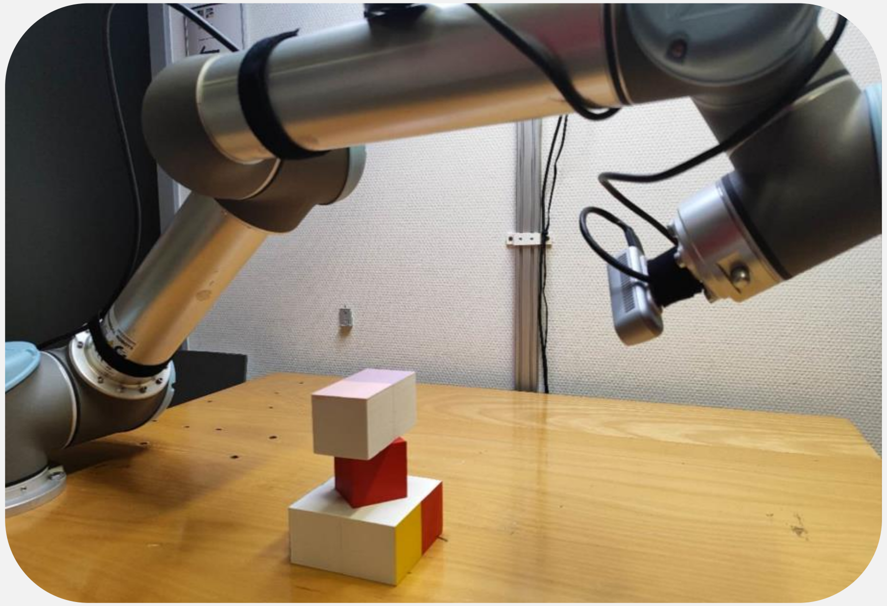


Goal: Predict shapes for NBV and grasp pose detection

Challenge: Picking and placing, navigation, shape prediction, environment perception

FIND THE VIEWPOINT! (B.Sc./M.Sc.)





Goal: Find the viewpoint of the given RGB image

Challenge: Suitable active search method, computational complexity → speed of the search

SOCIAL FORCE MODEL (B.Sc./M.Sc.)

Goal: Implement the social force model for crowd simulation

Challenge: Complex scenarios, 3D visualization, photorealistic environment, several metrics

LLM-BASED ROBOT NAVIGATION (B.Sc./M.Sc.)

Goal: Teach a robot to navigate given spoken instructions

Challenge: Spoken instructions, navigation, environment perception

Lab Overview

- Small groups of 2-3 people
- A selection of projects involving perception and action generation for different robots
- Recommended experience: C++, Python, ROS 1/2, OpenCV
- Midterm presentation (Thursday, 23.01.2025)
- Demonstration and written lab report at the end of the semester (Wednesday, 19.03.2025)

Lab Timeline

1) Project work
   - Plan how to achieve the project goal
   - Program the simulated/real robot(s)
2) Midterm presentation
   - Present your progress, problems and plans
   - Get feedback from all supervisors and peers

Bi-weekly supervisor meeting:
Talk about progress, problems and plan the next steps

3) Demonstration day (Wednesday, 19.03.2025)
   - **Everybody must be present the whole day!**
   - Show both (if available), simulation and real robot
   - Prepare a video as backup

Lab Grade

- Individual grade for each group member
- Depends on participation during the semester and the performance of the system in the final demonstration
- Lab report is a precondition!
- **Written lab report** of the work (LaTeX template provided on web page)

Registration

Next Steps

- **Two** separate registrations are necessary!

1) Registration on our web site (first-come-first-serve!)
until Sunday, 13.10.2024

➡ Project, topic and group assignment
until Wednesday, 16.10.2024 (notification via e-mail).

2) Registration in **BASIS until Sunday, 20.10.2024**

Website Registration

Humanoid Robots

hrl.uni-bonn.de/teaching/ws2425/lab-humanoid-robots

Responsible HRL Lecturers:

Prof.Dr. Maren Bennewitz

M.Sc. Benedikt Kreis

Important dates:

All interested students have to attend the Introductory Meeting. In the Introductory Meeting, we will present the projects, the schedule, the registration process, and answer your questions.

09.10.2024, Wednesday, 10:00-11:00hs, Room 1.047	**Introductory Meeting (mandatory)**
13.10.2024, Sunday	Registration deadline and topic selection on our website
20.10.2024, Sunday	Registration deadline in BASIS
23.01.2025, Thursday	Midterm lab presentation
19.03.2025, Wednesday	Lab presentation and deadline for lab documentation

After the Introductory Meeting, each participant arranges an individual schedule with the respective supervisor.

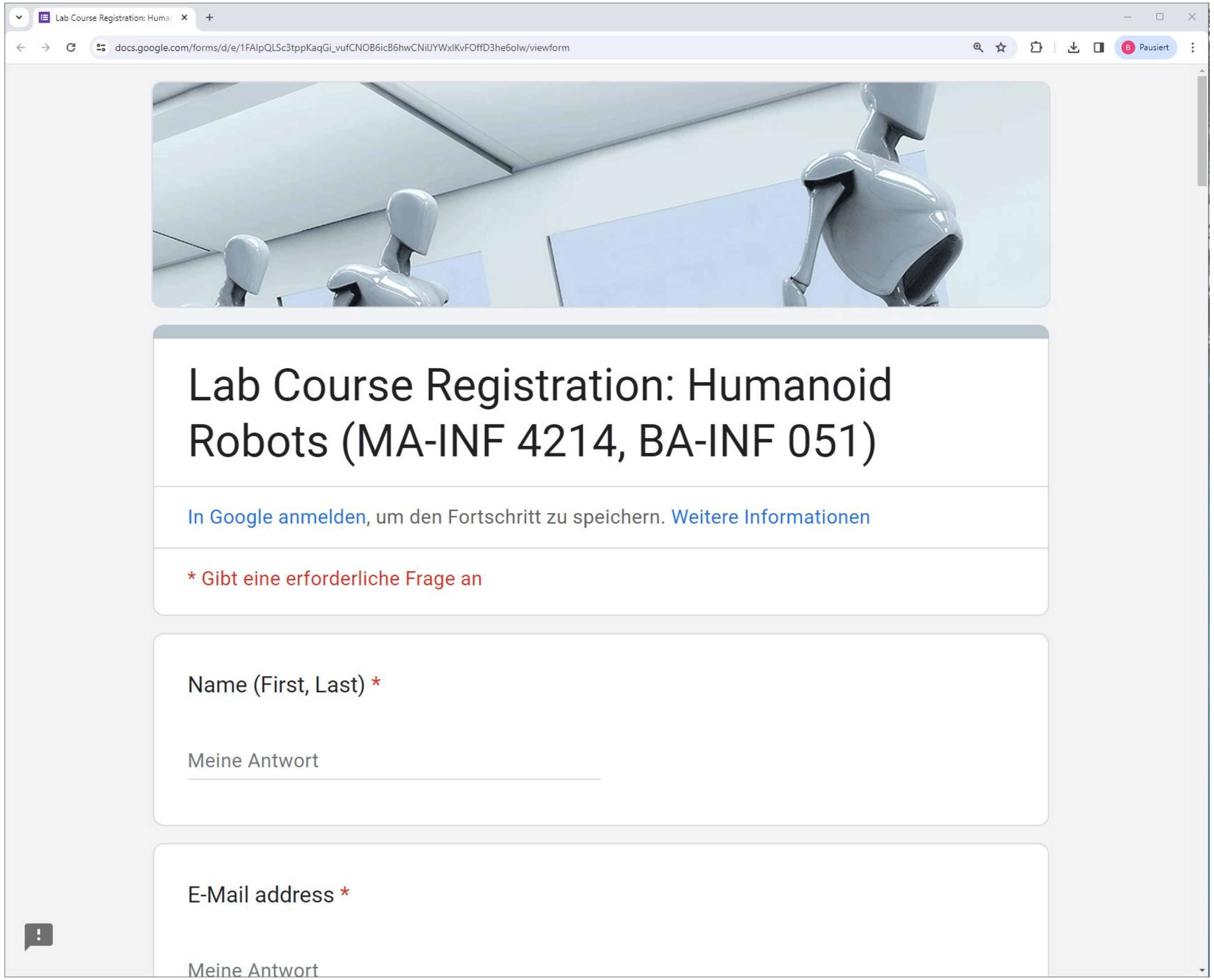
Registration

The registration is open. Register here

Report template

Please use the following template for the written summary:
Report template

Website Registration



Schedule

Date	BSc Project Group	MSc Lab Course	MSc Seminar
Sun, Oct 13	Registration deadline		
Wed, Oct 16	Participation confirmation and topic assignment		
Sun, Oct 23	BASIS registration deadline		
	Supervised lab course during the whole semester		Individual supervision
Wed, Jan 22	Seminar presentation		• Seminar presentation • Deadline for the summary
Thu, Jan 23	Midterm lab presentation (in person)		
Wed, Mar 19	• Lab demonstration (in person) • Deadline for the lab report		

Thank you!

Questions ???