Humanoid Robots Lab
Introductory Meeting

Prof. Dr. Maren Bennewitz
Benedikt Kreis
16th April 2024

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

Humanoid Robots Lab

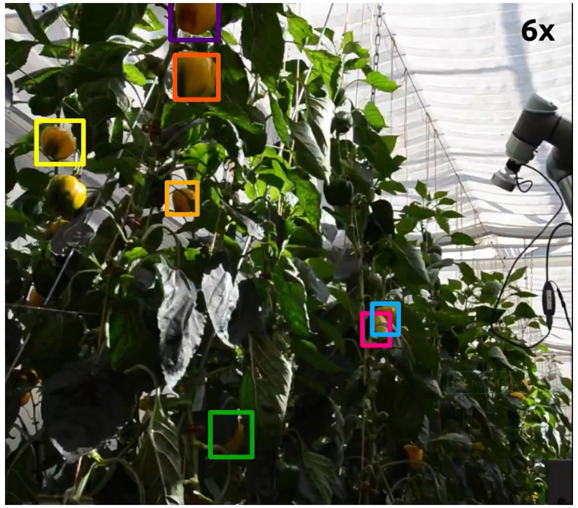
Group leader

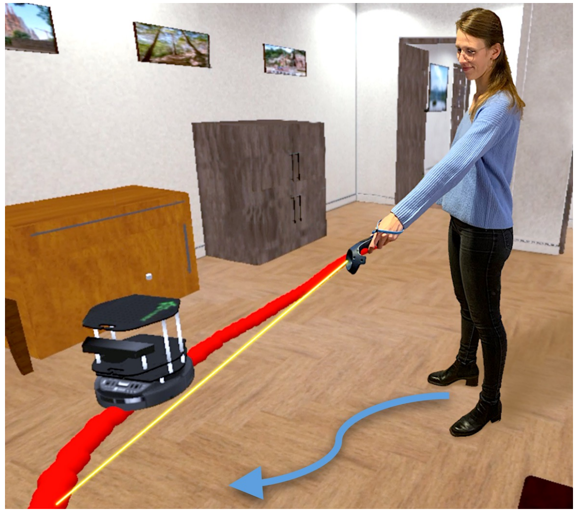
Prof. Dr. Maren Bennewitz

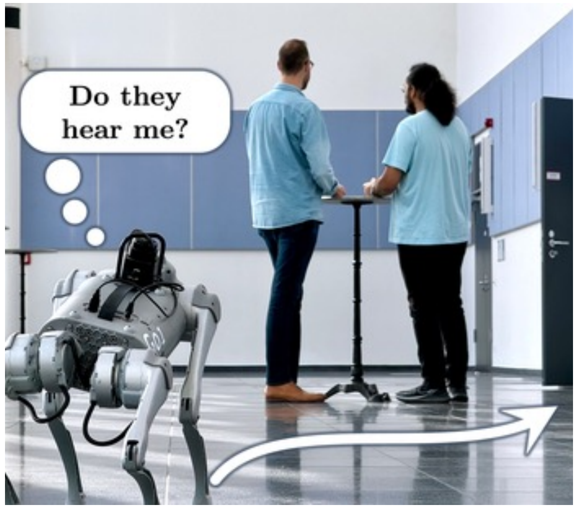
Our research topics:

- 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** (Thursday, 04.07.2024)
  - **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

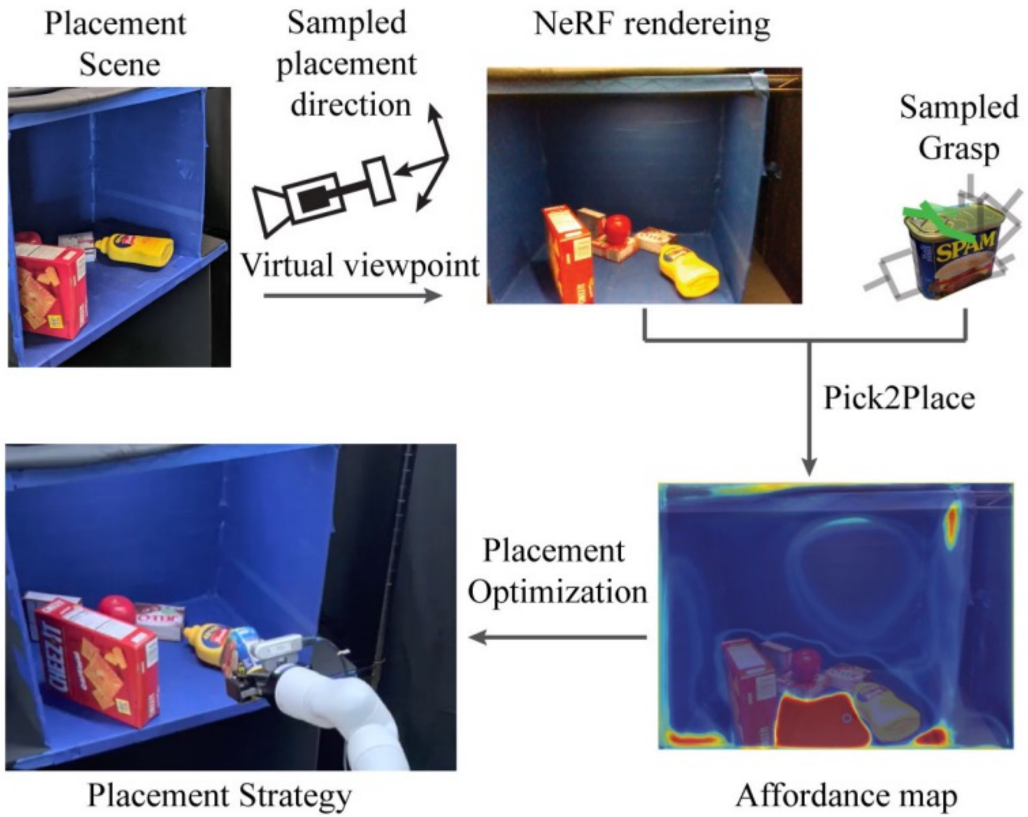
Seminar Papers
(Only MA-INF 4213 Seminar)

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.



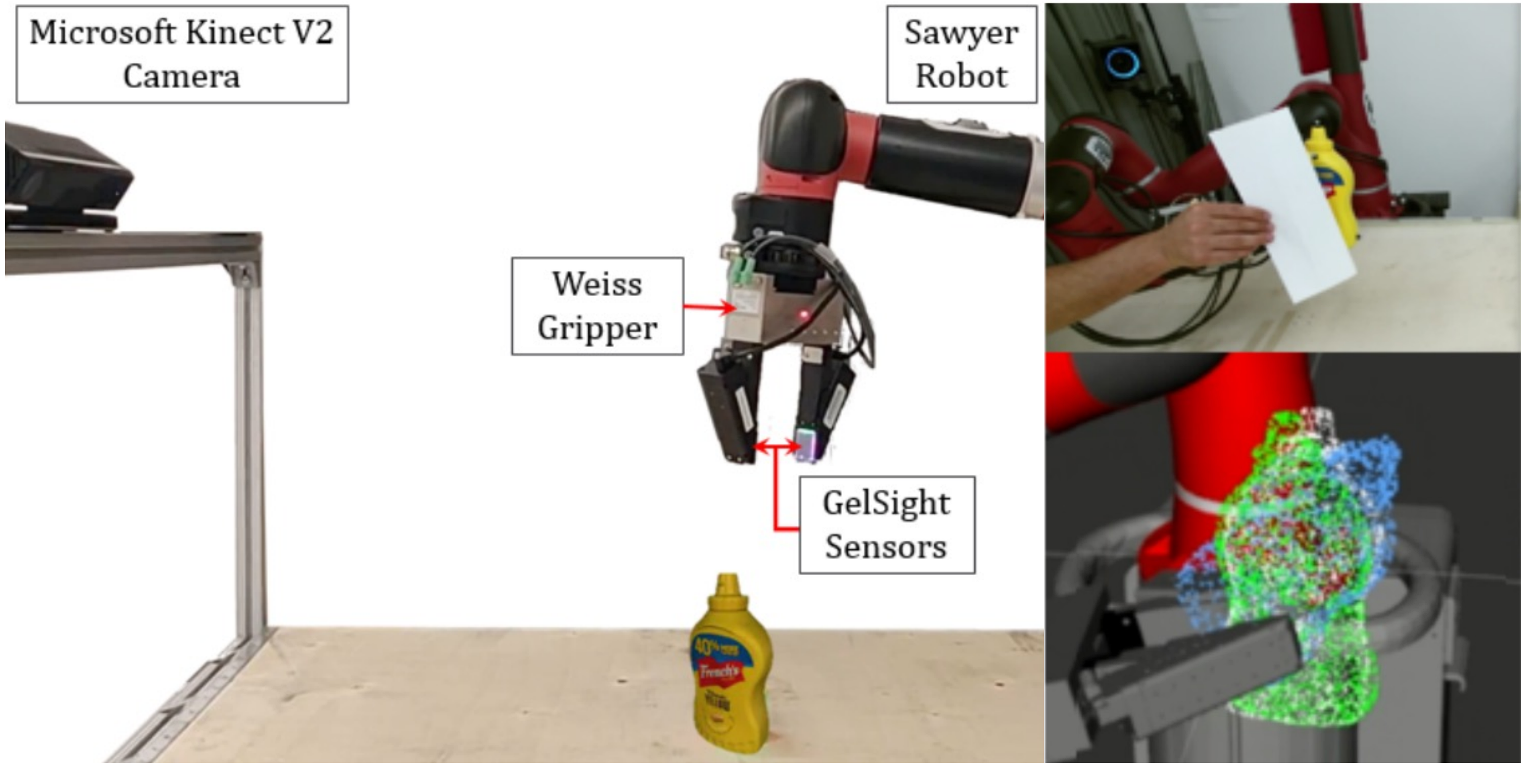
VisuoTactile 6D Pose Estimation of an In-Hand Object using Vision and Tactile Sensor Data

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

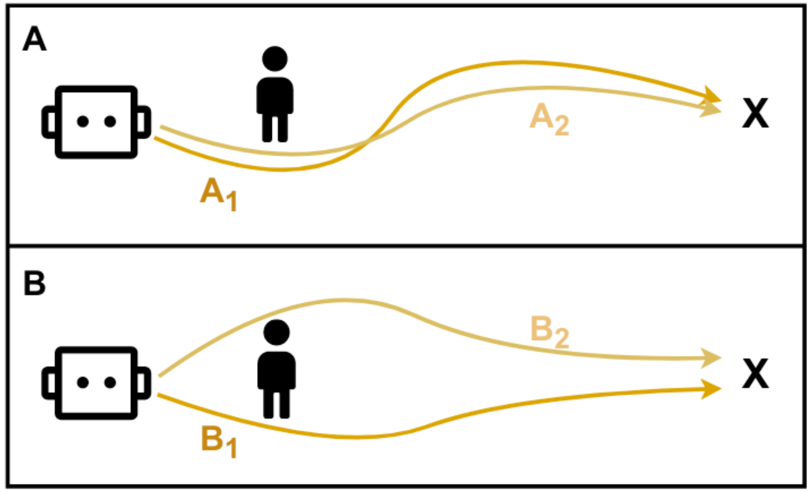
VARIQuery: VAE Segment-based Active Learning for Query Selection in Preference-based RL

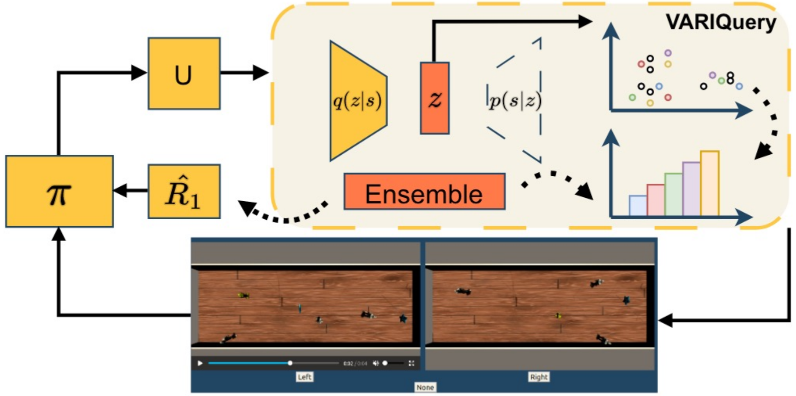
Marta et al.

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.

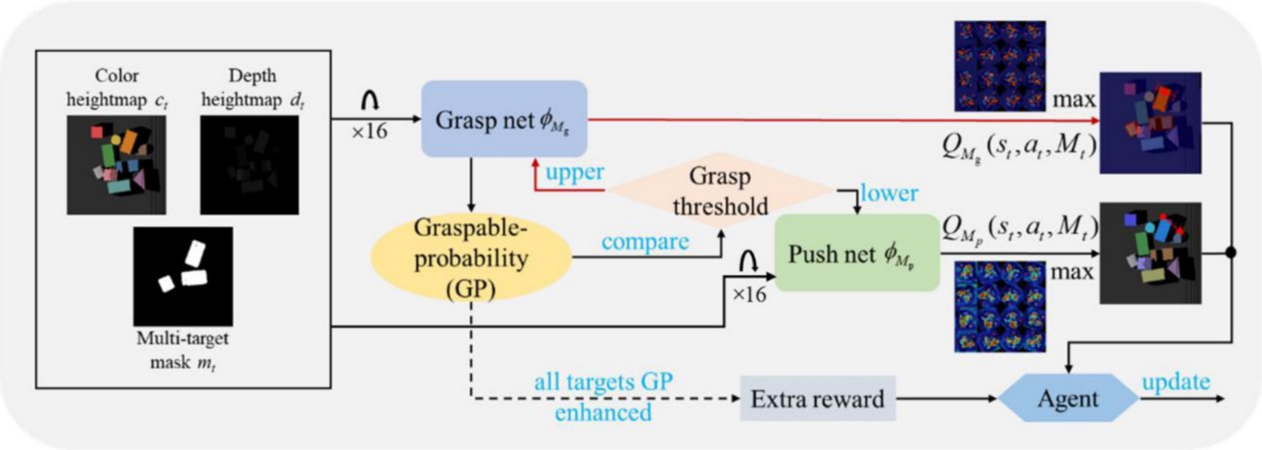




Efficient push-grasping for multiple target objects in clutter environments

Wu et al.
Front. Neurorobot. 2023
Supervisor: Nils Dengler

- **Goal:** Efficient robotic push-grasping method for cluttered environments with multiple targets.
- **Problem:** grasping multiple targets in clutter, requires an approach to minimize the total number of actions while successfully retrieving all desired objects.
- **Approach:** Reinforcement learning-based method that incorporates the states of all targets to plan actions that expand the grasping space efficiently.



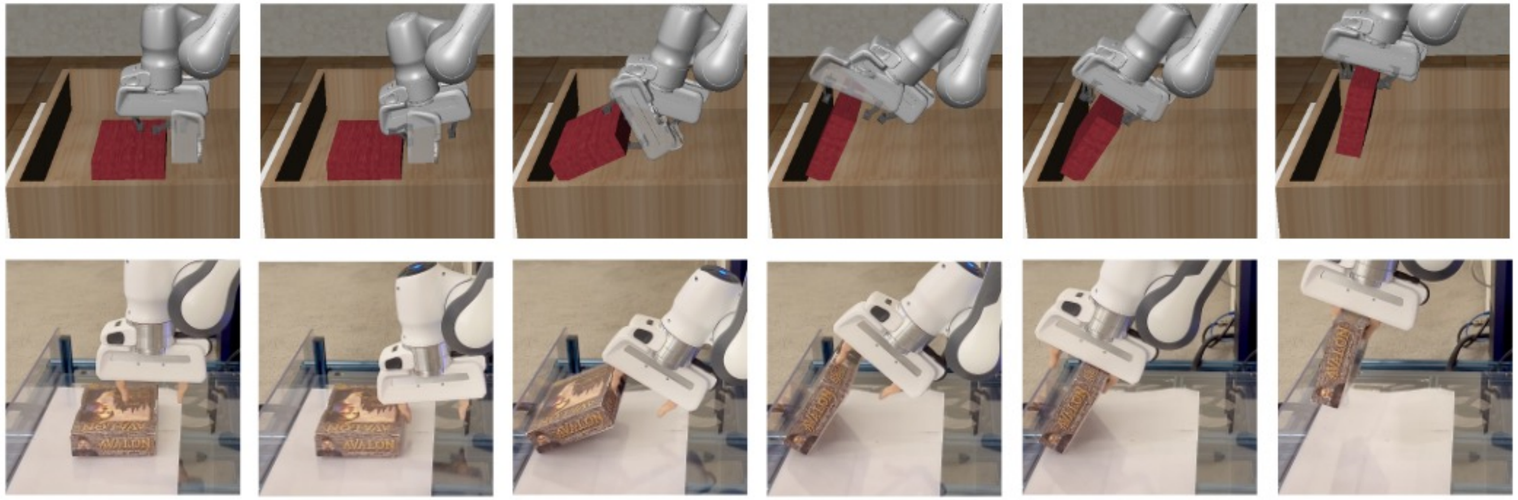
Learning to Grasp the Ungraspable with Emergent Extrinsic Dexterity

Zhou et al.

CoRL 2022

Supervisor: Nils Dengler

- **Goal:** Building a system for the "Occluded Grasping" task as an example of the combination of RL and extrinsic dexterity that works on a physical robot.
- **Problem:** The desired grasp intersects with the table and moving the gripper in free space cannot solve this task.
- **Approach:** The robot has to interact with the object to make the pose reachable.



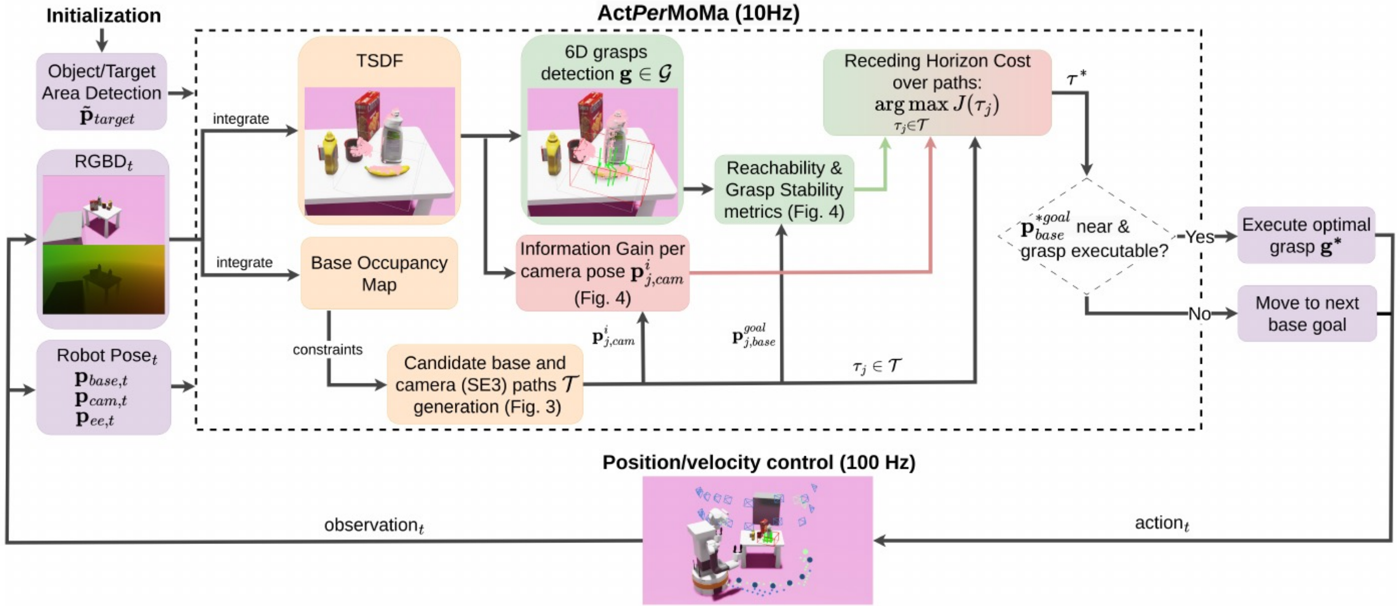
Active-Perceptive Motion Generation for Mobile Manipulation

Jauhri et al.

ICRA 2024

Supervisor: Rohit Menon

- **Goal:** Generate motions that are informative towards manipulation tasks such as grasping in unknown scenes.
- **Problem:** Occlusions in cluttered environments and complexity of objects reduces visual grasp detection capability.
- **Approach:**
  - Sample paths
  - Compute path-wise utilities
  - Ensure trade-off between utilities
  - Receding horizon based path selection



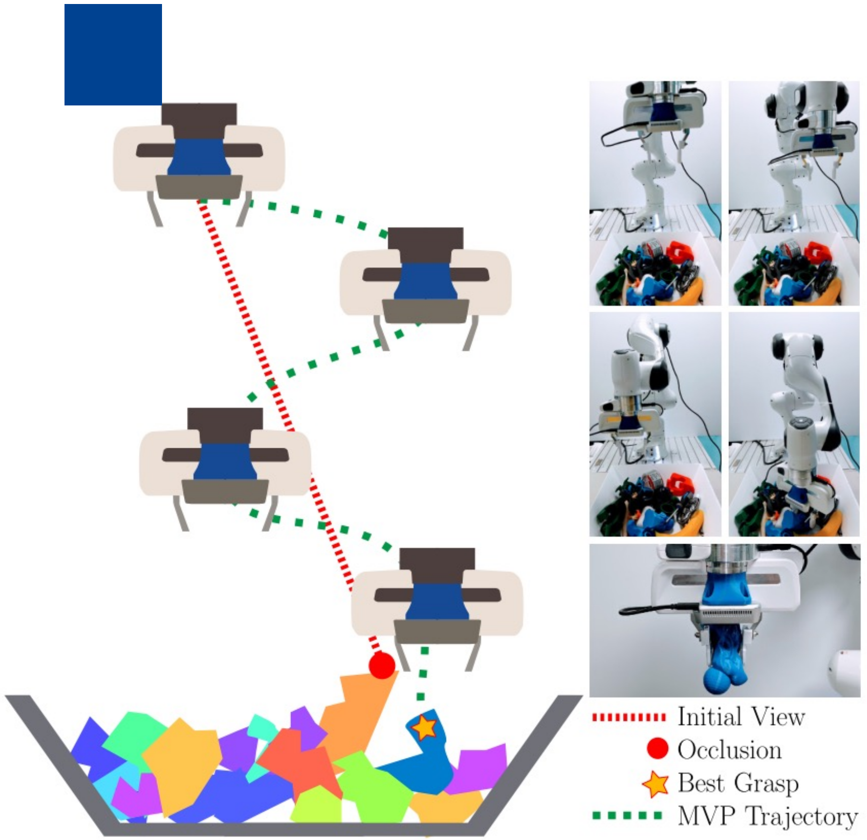
Multi-View Picking: Next-best-view Reaching for Improved Grasping in Clutter

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.



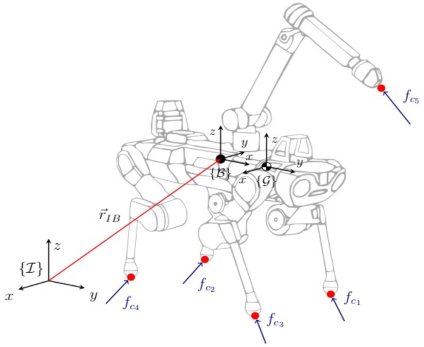
A Unified MPC Framework for Whole-Body Dynamic Locomotion and Manipulation

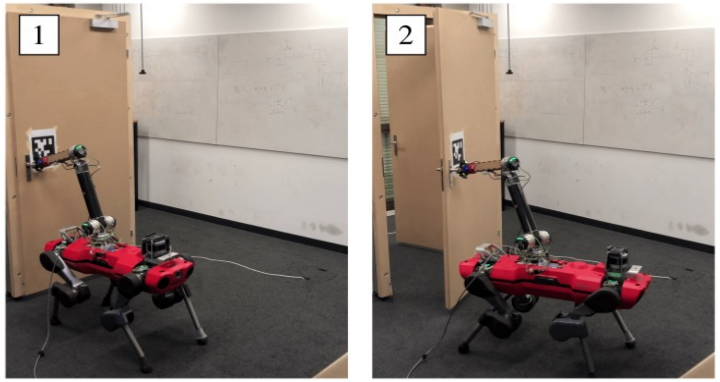
Sleiman et al.

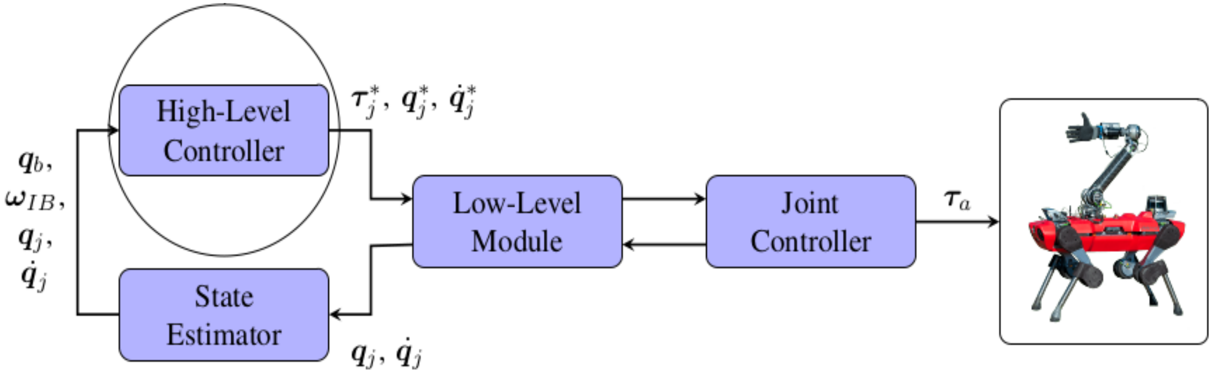
RA-L 2021

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.







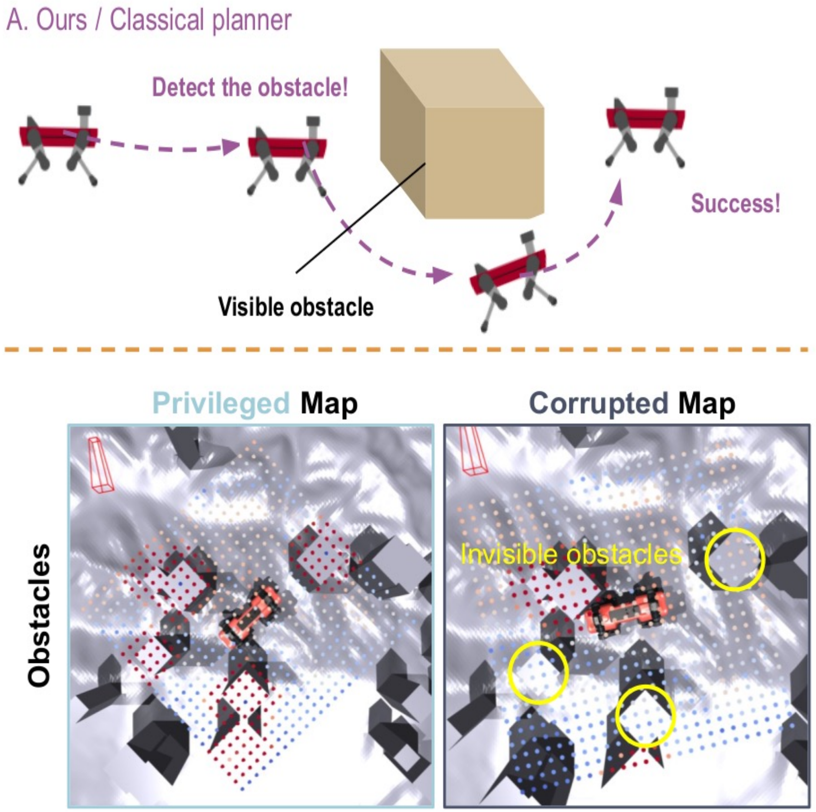
Resilient Legged Local Navigation: Learning to Traverse with Compromised Perception End-to- End

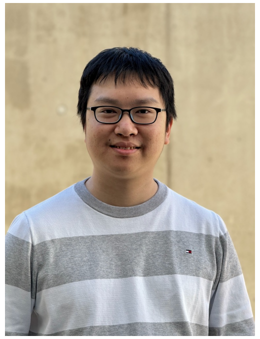
Chong et al.

ICRA 2024

Supervisor: Shahram Khorshidi

- **Goal:** Autonomous robots navigation in unknown environments under compromised exteroceptive sensing, or perception failures
- **Problem:** Perception failures often occur when harsh environments lead to degraded sensing, or when the perception algorithm misinterprets the scene due to limited.
- **Approach:** Modeling perception failures as invisible obstacles and pits, and train a reinforcement learning (RL) based local navigation policy to guide the legged robot.

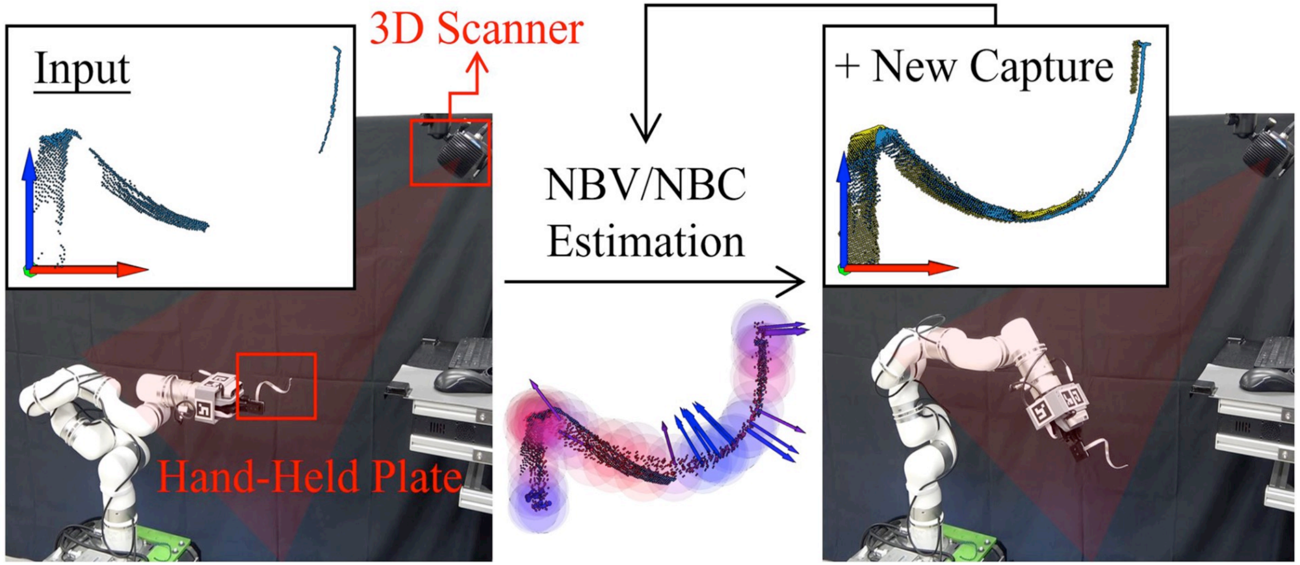


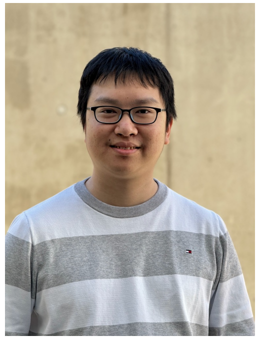


NBV/NBC Planning Considering Confidence Obtained From Shape Completion Learning

Liu et al.
RA-L 2024
Supervisor: Sicong Pan

- **Goal:** Reconstructing object's 3D model with a small number of consequent views.
- **Problem:** Metal plates have shiny and flat surfaces, leading to noisy point cloud data and low guidance in the surface normal for completion.
- **Approach:** Using a point cloud completion network to find the next best view (NBV) or the next best robot configuration (NBC) via confidence estimation.

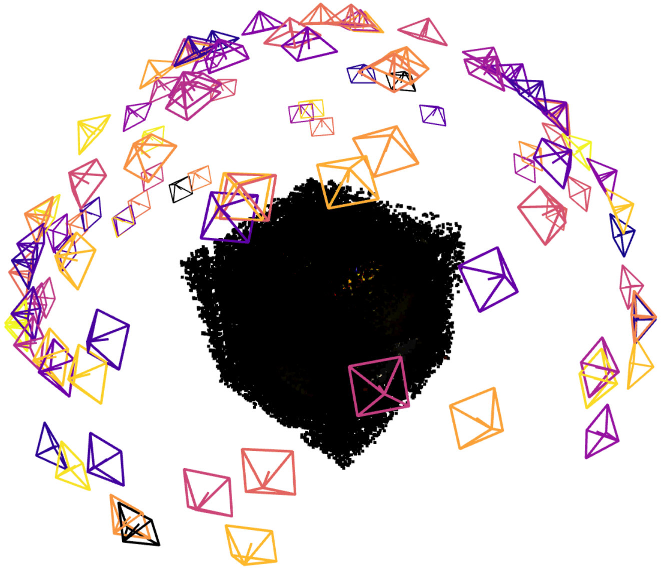


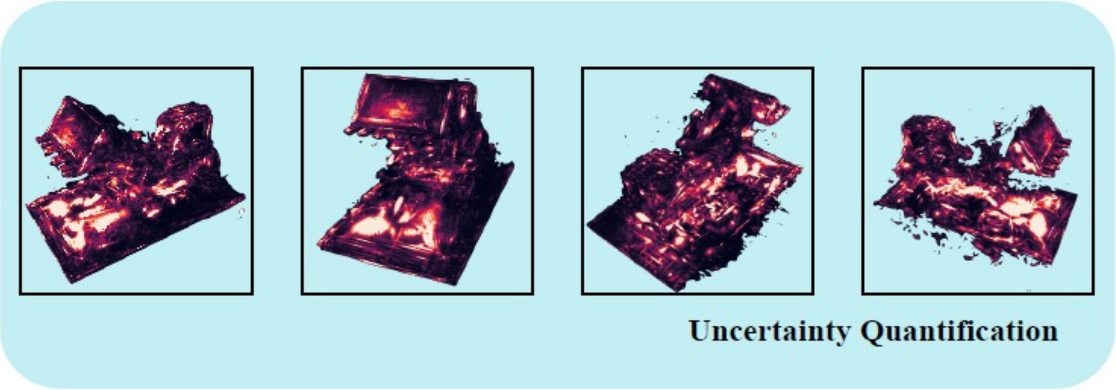


FisherRF: Active View Selection and Uncertainty Quantification for Radiance Fields using Fisher Information

Jiang et al.
ArXiv 2023
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.





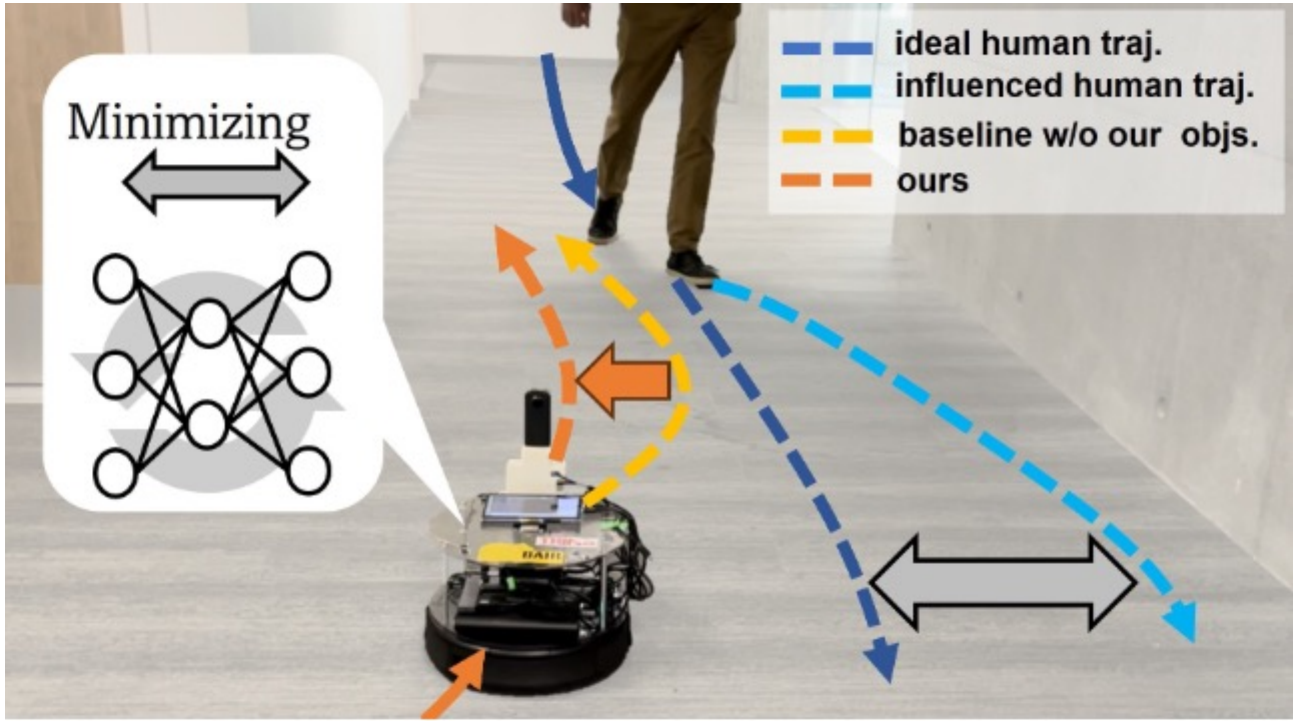
SACSoN: Scalable Autonomous Control for Social Navigation

Hirose et al.

RA-L 2024

Supervisor: Subham Agrawal

- **Goal:** Develop training policies for socially unobtrusive behavior.
- **Problem:** Humans navigate by relying on complex non-verbal cues and basic social etiquette. This is difficult for robot using traditional modeling techniques.
- **Approach:** Using a vision based system to autonomously collect interaction data and using model based method to learn socially compliant visual navigation policy.



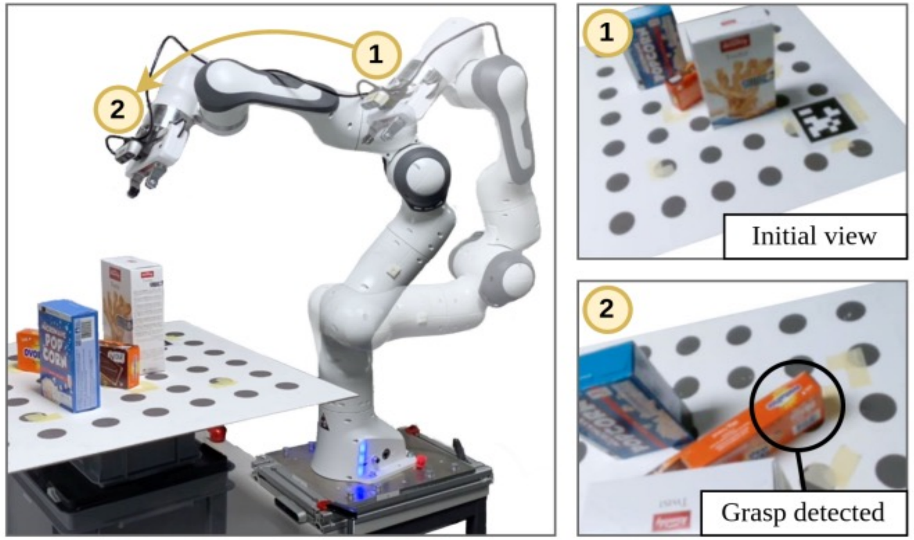
Closed-Loop Next-Best-View Planning for Target-Driven Grasping

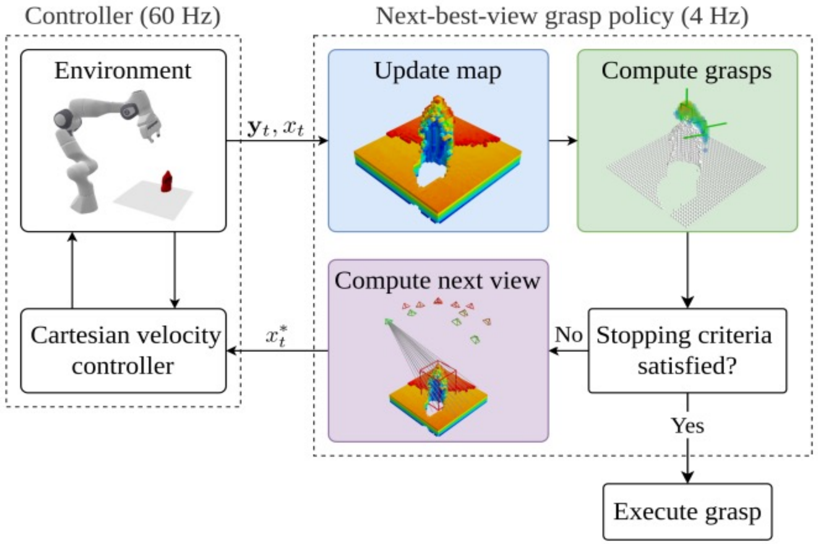
Breyer et al.

IROS 2022

Supervisor: Tobias Zaenker

- **Goal:** Grasp object in cluttered environments.
- **Problem:** Predicting good grasp with only one view of object unreliable.
- **Approach:** Create TSDF map from camera mounted on arm and Plan views to improve reconstruction until stable grasp is found.





Semantic Trajectory Planning for Long-Distant Unmanned Aerial Vehicle Navigation in Urban Environments

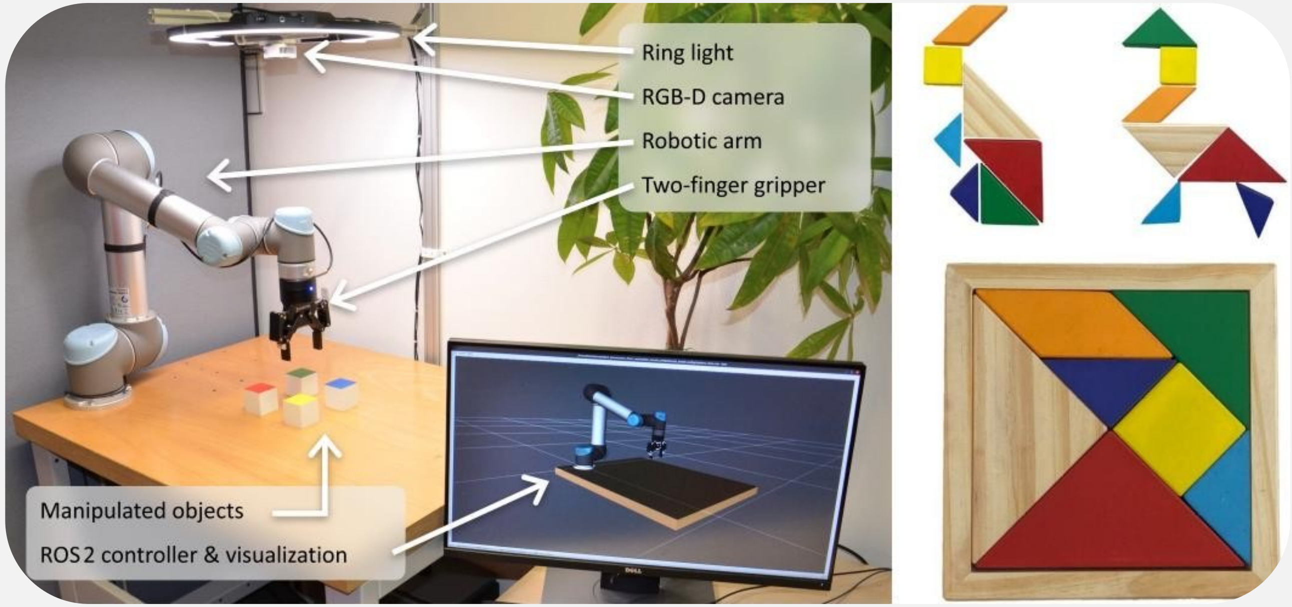
Ryll et al.
IROS 2020
Supervisor: Tobias Zaenker

- **Goal:** Autonomously navigate MAV to map urban environment.
- **Problem:** Limited perception range, size, weight, power constraints of MAV.
- **Approach:**
  - Utilize semantic segmentation of RGB camera
  - Infer sparse road graph from top-view projection
  - Use graph to plan exploration trajectories

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

Available Lab Projects

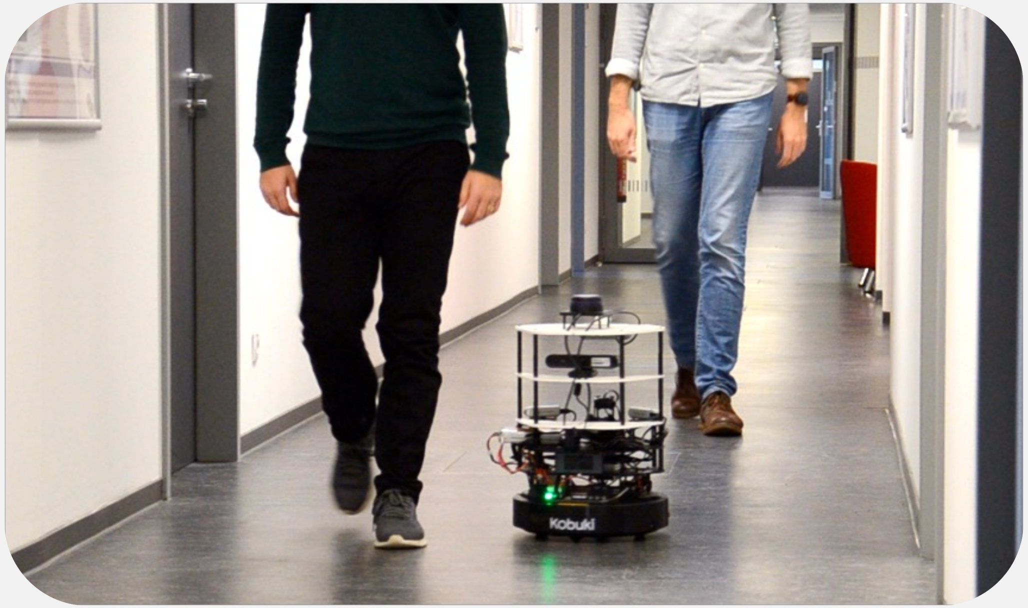
TANGRAM PUZZLES (B.Sc./M.Sc.)



Goal: Generate and assemble tangram puzzles

Challenge: Puzzle generation, object detection, successful assembly sequence generation and execution

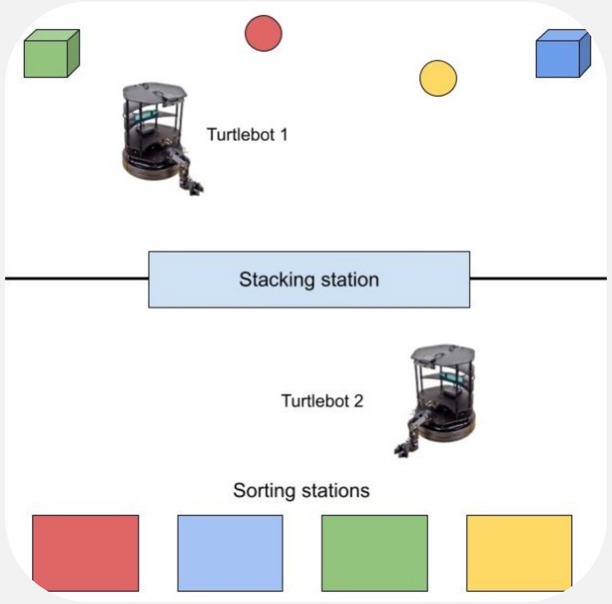
LEARNING-BASED NAVIGATION (M.Sc.)



Goal: Train a RL agent to navigate among dynamic obstacles

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

COLLABORATIVE ROBOTS (B.Sc./M.Sc.)



Goal: Develop a collaborative stacking and sorting system

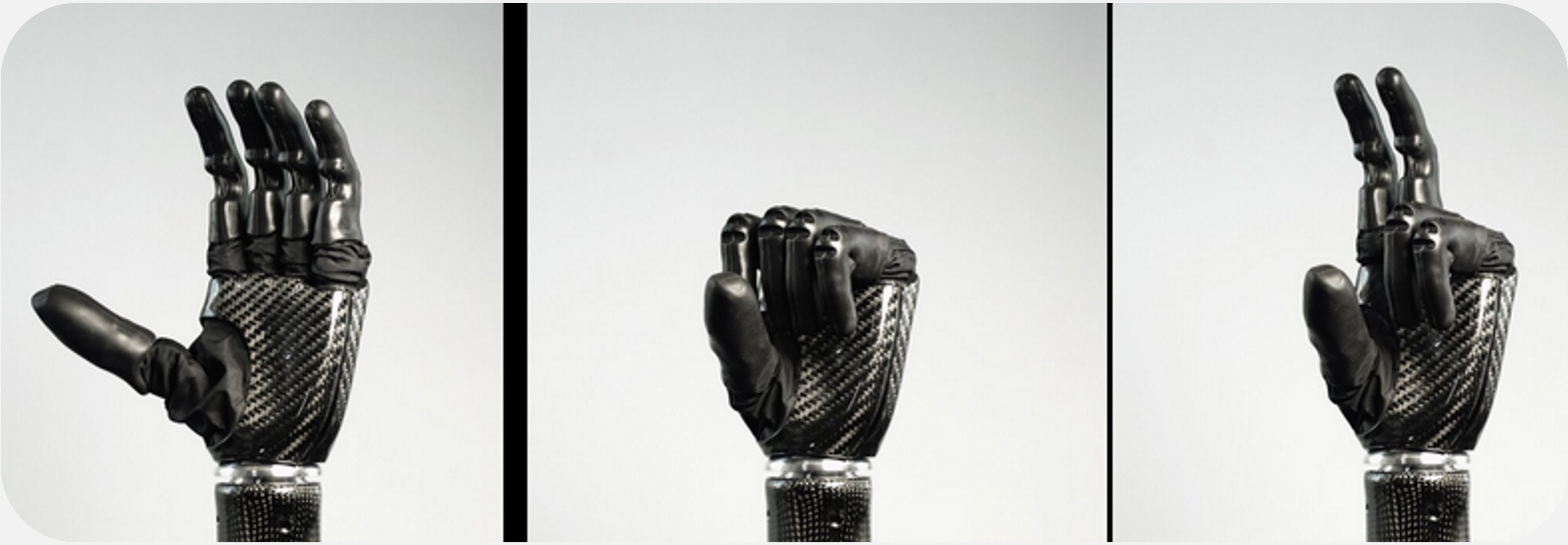
Challenge: Object detection and manipulation, navigation, robot collaboration

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

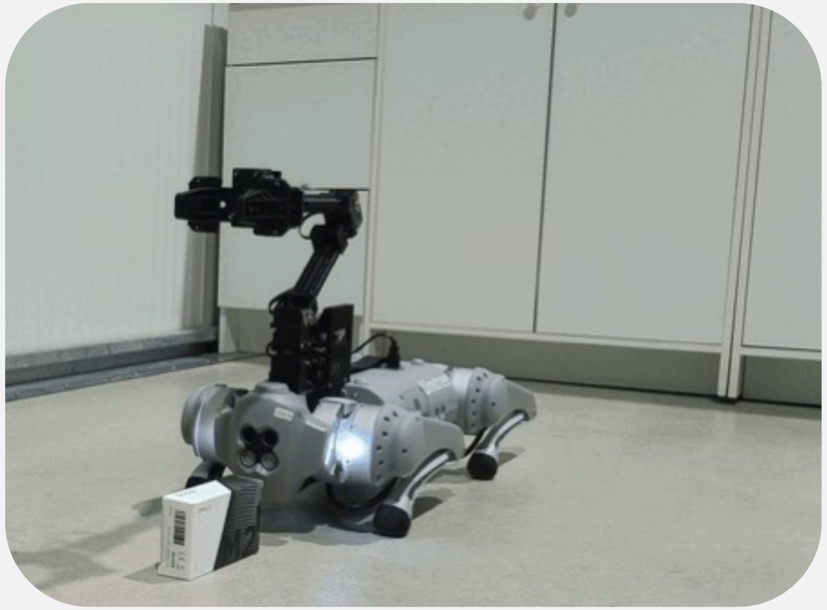
ROCK, PAPER, SCISSORS (B.Sc./M.Sc.)

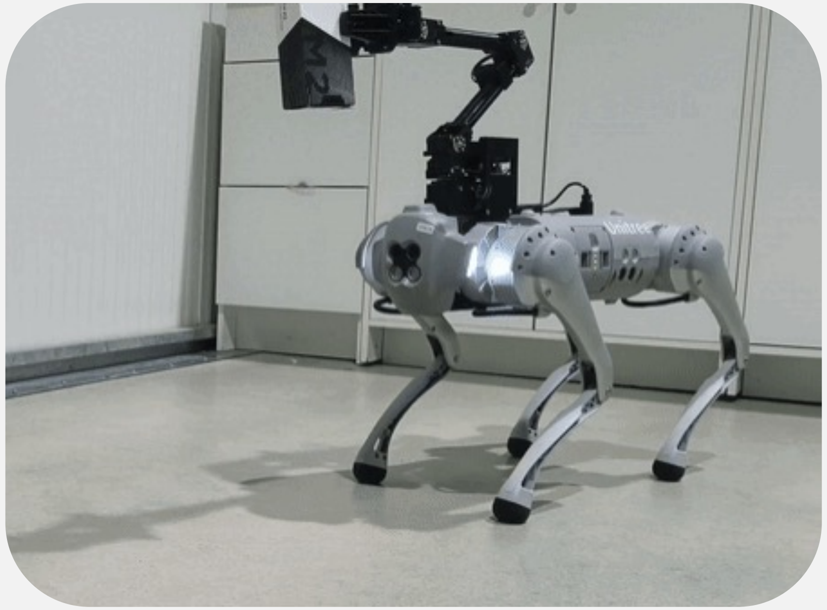


Goal: Implement the game using the 5-finger Psyonic hand

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

QUADRUPED MANIPULATION (B.Sc./M.Sc.)

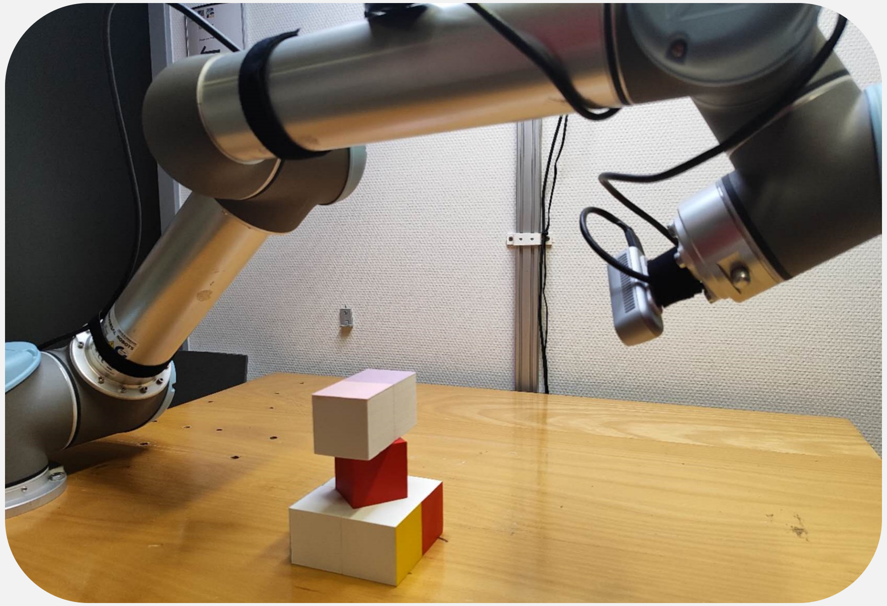


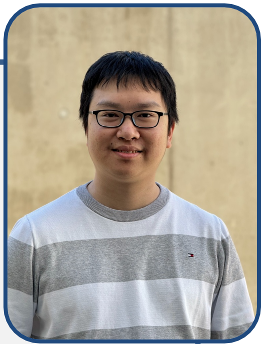


Goal: Develop an autonomous quadruped robotics system

Challenge: Mapping, navigation, obstacle avoidance, object detection and manipulation

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





Goal: Find the viewpoint of the given RGB image

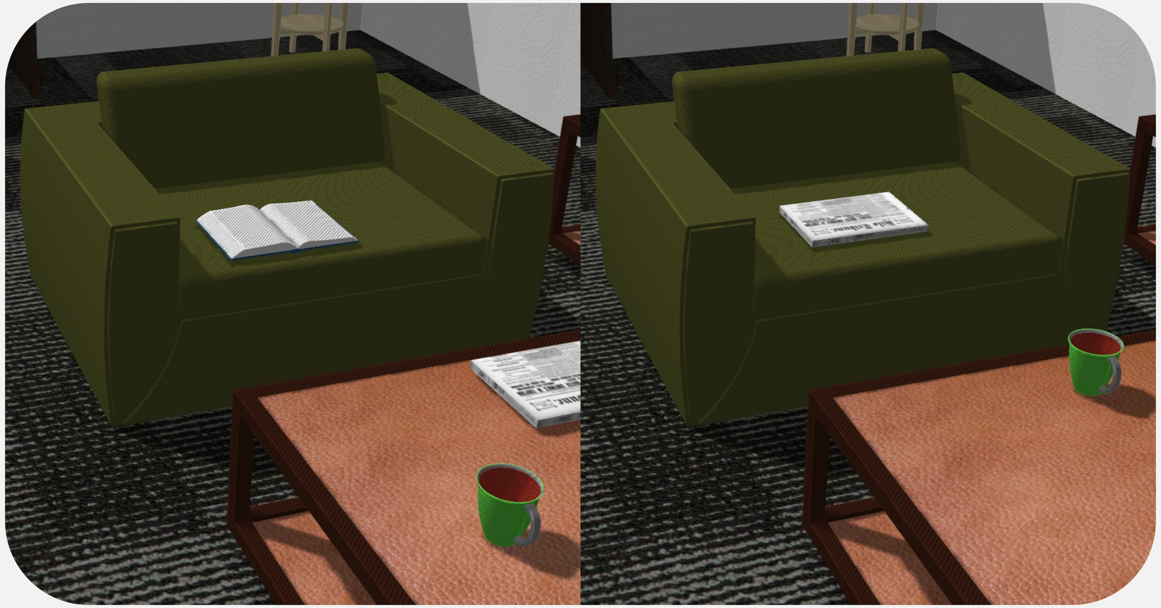
Challenge: Suitable active search method, computational complexity → speed of the search

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

WHERE IS MY STUFF? (B.Sc./M.Sc.)



Goal: Generate a map using a mobile robot

Challenge: Detect and mark objects of interest, motion planning and execution

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, 25.07.2024)
- Demonstration and written lab report at the end of the semester (Wednesday, 18.09.2024)

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, 18.09.2024)
   - **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, 21.04.

➡ Project, topic and group assignment
until Wednesday, 24.04. (notification via e-mail).

2) Registration in **BASIS until Thursday, 25.04.**

Website Registration

Humanoid Robots

hrl.uni-bonn.de/teaching/sommersemester-24/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.

10.04.2024, 10:00-11:00h (room 2.025)	**Introductory Meeting (mandatory)**
14.04.2024, Sunday	Registration deadline and topic selection on our website
21.04.2024, Tuesday	Registration deadline in BASIS
TBA	Lab presentation and deadline for lab documentation

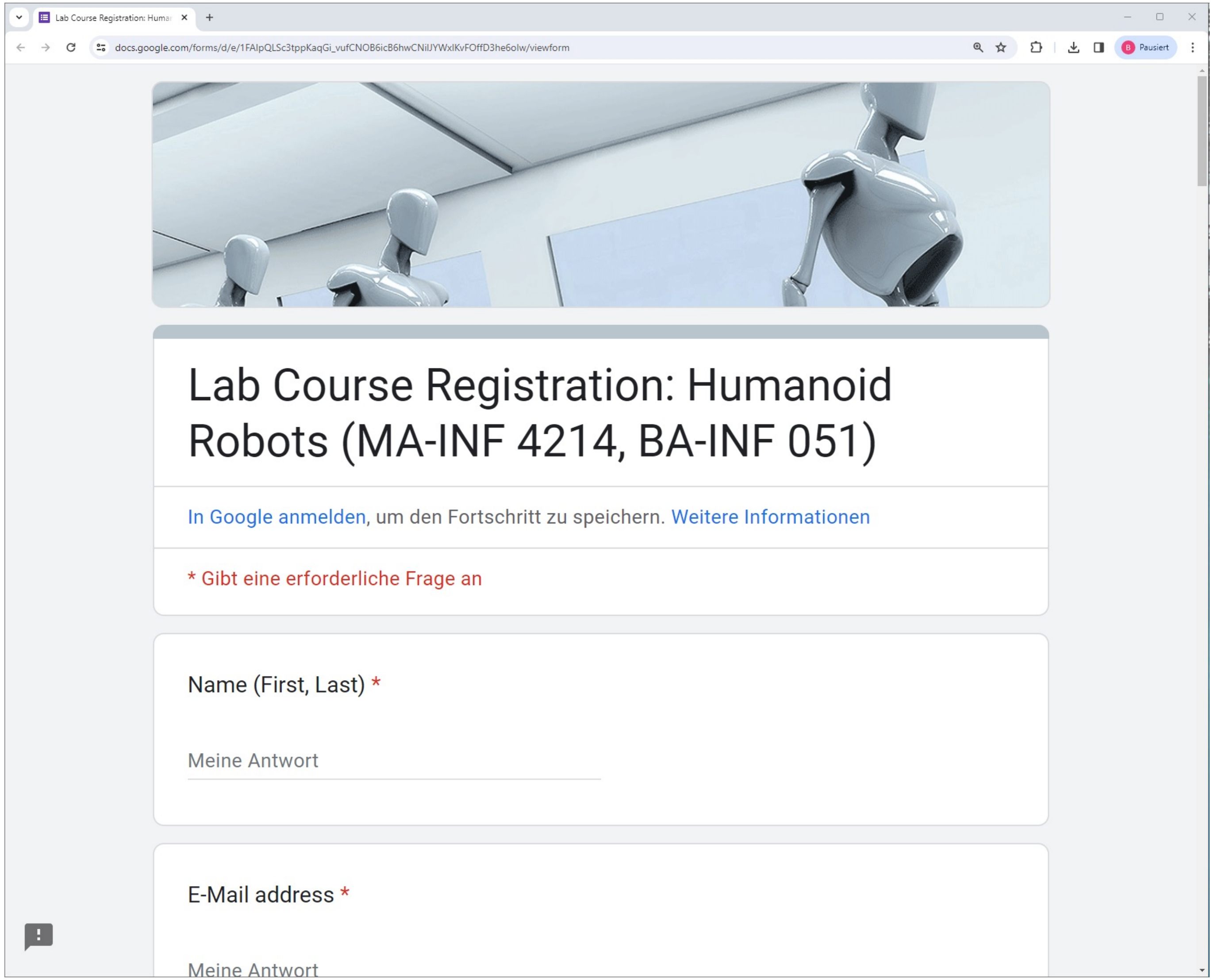
After the Introductory Meeting, each participant arranges an individual schedule with the respective supervisor.

Registration

The registration is open. Register here

Projects:

Website Registration



Schedule

Date	BSc Project Group	MSc Lab Course	MSc Seminar
Sun, Apr 21	Registration deadline		
Wed, Apr 24	Participation confirmation and topic assignment		
Thu, Apr 25	BASIS registration deadline		
	Supervised lab course during the whole semester		Individual supervision
Thu, Jul 04	Seminar presentation		• Seminar presentation • Deadline for the summary
Thu, Jul 25	Midterm lab presentation (in person)		
Wed, Sep 18	• Lab demonstration (in person) • Deadline for the lab report		

Open HiWi Position

- **Job description PDF available at**
  - hrl.uni-bonn.de/jobs
- **Contact**
  - Benedikt Kreis
  - kreis@cs.uni-bonn.de

Student Assistant (HiWi) for Robotics Research

(10 hs/week)

Job description
- ✓ Perception & object manipulation with robotic arms
- ✓ Diverse tasks related to assembling structures & solving puzzles
- ✓ Code implementation of state-of-the-art algorithms
- ✓ Hardware & software integration tasks
- ✓ Robot simulation & real world experiments
- ✓ Related project: "RePAIR" - Reconstructing the Past: Artificial Intelligence and Robotics meet Cultural Heritage

Key requirements
- ✓ Interested in robotics & autonomous systems
- ✓ Good programming skills (Python, C++, git)
- ✓ Completed bachelor degree in computer science or engineering
- ✓ Enrolled in a master program (computer science, robotics or similar)

Valuable qualifications
- ✓ Experience with ROS 1/2 & simulation (Gazebo, PyBullet, MuJoCo)
- ✓ Experience with machine learning & frameworks (Pytorch, OpenCV)
- ✓ Reliable & responsible
- ✓ Independent & flexible work attitude
- ✓ Excellent communication skills

What we offer
- ✓ Access to cool robots & premium coffee
- ✓ Flexible working hours
- ✓ Active contribution to scientific publications & co-authorship

Application
- ✓ Email to kreis@cs.uni-bonn.de
- ✓ Include **in 1 PDF**: Letter of motivation, CV & transcript of records (bachelor & ongoing master)

Scan for more information

Benedikt Kreis
kreis@cs.uni-bonn.de
Humanoid Robots Lab - University of Bonn
Friedrich-Hirzebruch-Allee 8, 53115 Bonn
Website: hrl.uni-bonn.de

Thank you!

Questions ???