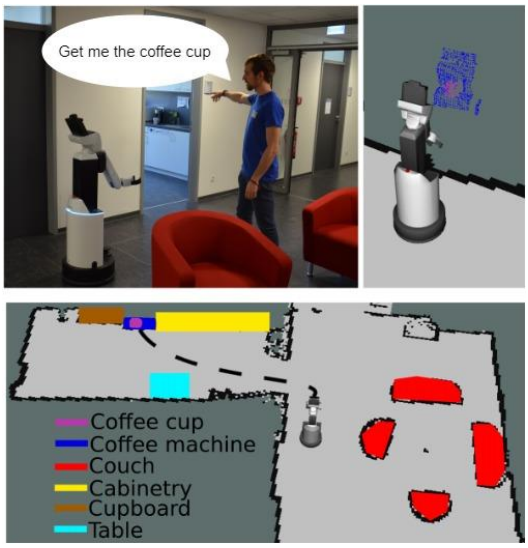
Coupled Active Perception for Mobile Manipulation in Unknown Environments

UNIVERSITÄT BONN

RHEINISCHE FRIEDRICH-WILHELMS-UNIVERSITÄT BONN

Position:	Master Thesis
Start date:	Flexible (Preferably Jan 2024)
Type:	On-site



Background:

With service robots being increasingly deployed in unstructured environments like households, users typically only specify “get me the coffee cup” or “TV remote”, while their exact location and pose is unknown. For e.g., there are a table and cupboard where the coffee cup could be located. Table has clutter and needs to be viewed from a different direction to check if it contains the cup. Cupboard has no clutter. Based on the relative distance between them, mobile manipulators (**MoMa**) need to decide whether to map table or move to the cupboard. Additionally, for e.g., if the cup is found on the cupboard shelf, MoMa has to decide whether the current perception is sufficient for reliable grasping.

Research Gap:

Current approaches assume the destination is known and require separate phases for navigation to move to the destination, for mapping to localize the cup (target pose estimation), and for manipulation to pick up the target object (cup) [1,2]. Optimal base placement considering navigation and manipulation costs have been investigated for time-efficient mobile manipulation [3]. Recent approaches have also demonstrated the effectiveness of reactive base control for on the move picking of objects [4]. However, in this case, it is assumed that approximate pose of the target object is known beforehand.

Objective:

We propose a new approach where the actively controllable cameras on the MoMa actively perceive the objects and makes an initial guess of the environment. Using this information, the MoMa decides whether to perform exhaustive search on current location, move to next location for initial mapping, or to plan the steps for grasping. We hypothesize that such a coupled active perception reduces the mapping time and also assists the system in reliable grasping.

Scope of the thesis:

- Implement a coupled active perception method for the mobile manipulator system
- Optimize MoMa for grasping success and time to complete the task
- Quantitative evaluation of coupled active perception mobile manipulation with baseline approaches in simulation and on real robotic systems

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Available Resources:

- Multiple mobile manipulator platforms with ROS framework for navigation and manipulation control and Gazebo simulation for initial testing
- Baseline approaches for mapping and picking
- Active perception approaches for semantic mapping of objects [5,6]

Bibliography:

1. S. Chitta et al. "Mobile manipulation in unstructured environments: Perception, planning, and execution." IEEE Robotics & Automation Magazine 19.2 (2012)
2. H. Brad, et al. "An autonomous mobile manipulator for assembly tasks." Autonomous Robots 28 (2010)
3. R. Fabian et al. "Combining navigation and manipulation costs for time-efficient robot placement in mobile manipulation tasks." IEEE Robotics and Automation Letters 7.4 (2022)
4. B. Ben, et al. "An Architecture for Reactive Mobile Manipulation On-The-Move ." IEEE International Conference on Robotics and Automation (ICRA) (2023)
5. N. Dengler et al. "Online object-oriented semantic mapping and map updating." European Conference on Mobile Robots (ECMR). IEEE, 2021.
6. S. Oßwald et al. “Efficient Coverage of 3D Environments with Humanoid Robots Using Inverse Reachability Maps.” IEEE-RAS International Conference on Humanoid Robots (Humanoids), 2017

Desired Student Profile:

- Enrolled in computer science or similar MSc program in and around Bonn/Cologne
- Familiarity with mobile manipulation and 3D perception
- Excellent academics and strong background in probability theory, linear algebra, and optimization.
- Programming experience with C++, Python, and ROS (Robot Operating System).
- Experience with reinforcement learning, and computer vision is a plus.
- Enthusiasm for real-world robot deployment and scientific publishing of results
- Ability to work independently as well as collaborate in a team

About the Humanoid Robots Lab:

The Humanoid Robots Lab, at the Institute for Computer Science, headed by Prof. Dr. Maren Bennewitz, has been participating in several national and international projects funded by the German Research Foundation and the European Commission. We have introduced several novel methods for 3D environment perception and exploration, footstep planning, manipulation planning, and human-aware navigation, for wheeled and biped robots. Currently, our focus is on motion planning and navigation through cluttered and dynamic scenes as well as on generating foresighted robot behavior by anticipating human behavior. Additionally, we work on active perception of crops for monitoring growth and to enable harvesting in the cluster of excellence PhenoRob.

Scan for more information

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