CS 6751: Introduction to Mobile Manipulation

Project Module Proposal:
Motion Planning for the KUKA Youbot

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1 Description

The main goal of this project module is the development of a complete motion planning package for the mobile manipulator. The role of this package in the context of the whole project will be to output trajectories that drive the system from its current state to the desired feasible and optimal state extracted through the *Pose Selection* module. Upon receiving the command from the *Executive* module, the motion planner will be taking as input the known map as well as perception and localization data and will determine and output collision free and constraint aware trajectories. These trajectories will be nominal and may be later refined during execution by the *Control* module to comply with the mode specifications broadcasted by the *Executive*.

2 Approach

The motion planning computation can be separated into two main trajectory generation subproblems: i) the mobile base navigation and ii) the arm motion. At this stage these two problems could be considered as decoupled. First the motion of the base will be planned and then the arm motion will be planned given the target base configuration. The planning framework could be designed in a hierarchical fashion involving a global planner (mobile base) and a local planner (arm) as in [1]. Since the robot will be operating in a dynamic environment, interacting with humans, emphasis should be given on safety. In order for this to happen, a sufficiently high replan rate should be chosen so that planning takes place based on a high-fidelity update of the workspace, essentially allowing the robot to react to any unexpected events.

3 Planning Algorithms

Over the last years the motion planning community is focusing on developing algorithms inspired by the Rapidly Exploring Random Trees (RRT) paradigm [2]. This family of algorithms is based on sampling and is able to rapidly generate feasible paths even in cluttered workspaces with minimal tuning. Their main disadvantage is that the paths are usually jerky and non-smooth and are usually refined using a path smoothening function. Overall, their reliability and efficiency makes them a good starting point for our application both for the mobile base and for the arm [1]. As far as the mobile base is concerned the goal is to find a collision free trajectory connecting the initial configuration with the goal. For the arm motion, the specification for the motion generation may be more complex, incorporating end-effector pose constraints or even avoiding regions of the task-space. This can be carried out by considering recent works on task constraint representation and task-constrained manipulation planning such as [3] and [4]. Another interesting RRT alternative that will be considered is [5], providing optimality guarantees, leading to smoother paths.

4 Further Research

Further research may be focused on guaranteeing safety for humans by generating plans that are inherently safety-aware, i.g. by planning in a subspace of the configuration space that, based on the current belief about the environment, is safe. This can be done by employing Reachability Analysis techniques presented in [6], based on the concept of [7]. Besides, to facilitate the interaction with human partners we may consider metrics for generating legible motion, i.e., motion that conveys the robot intent in a way that feels as natural as possible for humans as in [8].

[1] In the context of our project, the path refinement could be handled externally by the *Control/Trajectory Optimization* module.

5 Development Tasks

In the area of manipulation planning there seem to exist many different planning frameworks available through ROS. My main concern will be to test them and compare their performance so that we come up with a design that suits the requirements of the project we have considered. Subsequently, I am planning on enriching the considered framework with extra components leading to increased safety guarantees and robot motion legibility.

References

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