Manipulation Algorithms Project Proposal
Trajectory Retiming for Manipulation Planning

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1 Problem

This project is to design a motion planner that accounts for kinodynamic constraints and moving obstacles. The project aims to circumvent the curse of dimensionality in the kinodynamic configuration-space, $\mathbb{C}_d$, for search-based planners through adaptation of Bobrow's trajectory retiming algorithm [1].

2 Approach

2.1 Kinodynamic Constraints

Since planning in the kinematic configuration-space, $\mathbb{C}$, and consequently retiming the trajectory for dynamics is not a complete approach, the project will leverage previous work that allows us to efficiently assess whether a given path in $\mathbb{C}$ can be traversed with respect to the kinodynamic constraints [2]. By propogating the velocity intervals (the set of valid velocities) for a given waypoint in $\mathbb{C}$, the proposed planner is able to ensure that a valid retiming exists for a plan, that respects the kinodynamic constraints.

2.2 Moving Obstacles

Dealing with moving obstacles may create inadmissible islands to retimings below the maximum-velocity curve of Bobrow's algorithm [3]. Literature survey currently does not turn up any method to path around these regions in the phase-plane, so the possible approaches the project will explore are:

- Graph-based search in the phase-plane using the velocity field over the phase plane as defining the motion primitives.
- Integrating the SIPP framework [4] with Bobrow's algorithm providing a way to compute the *safe* time-intervals of the states in traversals.
- Designing the switching point strategy for object collisions.

3 Motivation

4 Deliverables

Progress	Deliverables	When
50%	1. Implement and test numerically robust Bobrow's Algorithm. 2. Visualize collision regions in the Phase-plane with moving obstacles. 3. Develop augmented $\mathbb{C}$-space planner with velocity interval propogation.	Oct-30
75%	Develop and implement a scheme mentioned in Section 2.2.	Nov-14
100%	1. Develop naive approach using *VIP* and simple collision checking. 2. Create test scenarios. 3. Compare naive approach with approach from Section 2.2. 4. Analysis of planner variants.	Nov-28
125%	Try other approaches enumerated in Section 2.2.	Time permitting

References

1. James E Bobrow, Steven Dubowsky, and JS Gibson. Time-optimal control of robotic manipulators along specified paths. *The International Journal of Robotics Research*, 4(3):3–17, 1985.

2. Quang-Cuong Pham, Stéphane Caron, and Yoshihiko Nakamura. Kinodynamic planning in the configuration space via velocity interval propagation. In *Proceedings of Robotics: Science and Systems*, Berlin, Germany, June 2013.

3. Kang Shin and N McKay. Minimum-time control of robotic manipulators with geometric path constraints. *Automatic Control, IEEE Transactions on*, 30(6):531–541, 1985.

4. Mike Phillips and Maxim Likhachev. Sipp: Safe interval path planning for dynamic environments. In *Robotics and Automation (ICRA), 2011 IEEE International Conference on*, pages 5628–5635. IEEE, 2011.