Real-Time Motion Planning and Safe Navigation in Dynamic Multi-Robot Environments

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CMU-CS-06-181

December 15, 2006

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Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

This research was sponsored in part by United States Grants Nos. DABT63-99-1-0013, F30602-98-2-0135, F30602-97-2-0250, and NBCH-1040007. It was also supported by Rockwell Scientific Co., LLC under subcontract No. B4U528968 and prime contract No. W911W6-04-C-0058 with the US Army. The views and conclusions contained herein are those of the author, and do not necessarily reflect the position or policy of the sponsoring institutions, and no official endorsement should be inferred.

Keywords: Robotics, Robot Navigation, Motion Planning, Path Planning, Multi-Robot Systems, Robotic Soccer

Abstract

All mobile robots share the need to navigate, creating the problem of motion planning. In multi-robot domains with agents acting in parallel, highly complex and unpredictable dynamics can arise. This leads to the need for navigation calculations to be carried out within tight time constraints, so that they can be applied before the dynamics of the environment make the calculated answer obsolete. At the same time, we want the robots to navigate robustly and operate safely without collisions. While motion planning has been used for high level robot navigation, or limited to semi-static or single-robot domains, it has often been dismissed for the real-time low-level control of agents due to the limited computational time and the unpredictable dynamics. Many robots now rely on local reactive methods for immediate control of the robot, but if the reason for avoiding motion planning is execution speed, the answer is to find planners that can meet this requirement. Recent advances in traditional path planning algorithms may offer hope in resolving this type of scalability, if they can be adapted to deal with the specific problems and constraints mobile robots face. Also, in order to maintain safety, new scalable methods for maintaining collision avoidance among multiple robots are needed in order to free motion planners from the "curse of dimensionality" when considering the safety of multiple robots with realistic physical dynamics constraints. This thesis contributes the pairing of real-time motion planning which builds on existing modern path planners, and a novel cooperative dynamics safety algorithm for high speed navigation of multiple agents in dynamic domains. It also explores near real-time kinematically limited motion planning for more complex environments. The thesis algorithms have been fully implemented and tested with success on multiple real robot platforms.

Acknowledgements

First, I would like to thank my parents for supporting and guiding me as a student and as a son. I would like to thank my advisor, Manuela Veloso for her support of my research since 1998, picking up where my undergraduate education left off. Through much of my time at Carnegie Mellon, I would like to thank Scott Lenser, for always lending an ear for a problem research related or otherwise. The lab hasn't been the same since you left. I am indebted as well to all the members of our RoboCup teams past and present, for coming together to define a collective domain for pushing research which is much greater than the sum of its parts. Particular members who have helped me since I began my work include Mike Bowling, Brett Browning, Tucker Balch, Jennifer Lin, Dinesh Govindaraju, Mike Licitra, and Stefan Zickler. Without your work the teams never would have made it. I would like to thank other fellow lab members for our other collaborations, as well as the willingness to listen to me while I stood in front of a whiteboard to expound on a problem. Douglas Vail, Sonia Chernova, and Colin McMillen have best helped fill that role.

I am also indebted to particular research groups for supporting various aspects of my work. I would like to thank Masahiro Fujita for supporting an internship at Sony Corporation which allowed to explore planning on the QRIO platform. I would like to thank Tadashi Naruse, all his students (in particular Shinya Hibino) of Aichi Prefectural University for keeping our RoboCup project alive with their offer of joint collaboration and hosting me for RoboCup 2005. Most recently, I would like the thank the members of the ACO project from Rockwell Scientific for supporting my research work on complex kinematic planners.

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