

Nonholonomic Motion Planning for Mobile Manipulators

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Abstract—A nonholonomic motion planner for mobile manipulators moving in cluttered environments is presented. The approach is based on a discontinuous feedback law under the influence of a special potential field. Convergence is shown via Lyapunov's direct method. Utilizing redundancy, the methodology allows the system to perform secondary, configuration dependent, objectives such as singularity avoidance. It introduces an efficient feedback scheme for real time navigation of nonholonomic systems.

I. Introduction

One of the most severe restrictions to a wider application of robotic manipulators are their limited workspace. To answer the need for increased workspace, mobile manipulators were constructed. The first mobile manipulators operated in space but nowadays their application is spreading to terrestrial and aquatic environments.

Mobile manipulators are systems composed of a robotic arm mounted on a mobile base. This combination gives rise in a new class of robots with remarkable properties. Such systems inherit the dexterity of a robot manipulator and the increased workspace of a mobile robot. Moreover, the merging also results in new properties not encountered in any of the component subsystems, which should be investigated and exploited.

Among the unique properties possessed by such a system, redundancy is one of the most important. Redundancy is created by the increased number of degrees of freedom. This property enables one to use the redundant degrees of freedom to accomplish secondary tasks. Towards redundancy resolution, several methodologies have been presented.

Mobile manipulators have been studied during the last decade and significant work appears in literature [1],[2]. Several papers are related to motion planning for such systems: Desai and Kumar [3] have formu-

lated the problem as an optimal control problem. Pin et. al [4] performed local optimization at velocity level to achieve redundancy resolution using their FSP method. Ferrier et. al [5] minimized the total position error using a linearized model. Huang et. al [6] decoupled the motion of the vehicle from that of the manipulator and optimized each one using different criteria.

In this paper the system is kinematically steered between two arbitrary configurations amongst obstacles. Obstacle avoidance, therefore, naturally arises as a secondary objective which is to be achieved by utilization of the system's redundancy. Another important secondary objective could be the avoidance of the manipulator singular configurations.

Due to the kinematic constraints imposed on its base, the mobile manipulator is a nonholonomic system. This complicates considerably the motion planning problem, since no continuous static feedback motion planning scheme can be applied. The motion planning strategy has to be either open-loop, time varying or discontinuous.

Motion planning for nonholonomic systems has traditionally been divided into two stages: path planning and trajectory planning. Path planning consists of defining an admissible continuous sequence of configurations linking the initial position with the goal. Motion planning deals with the time parameterization of the obtained path. In this framework, a motion planning strategy is inevitably open-loop. Alternative methodologies include non smooth feedback and time varying schemes though they usually focus on tracking an existing holonomic path.

Particularly for mobile manipulators, the issue has generally been treated within the framework of optimal control. Optimal control is a powerful tool which is able to incorporate state constraints. It is notoriously known though for its computational requirements that render it impractical in real time applications.

Our approach is based on the use of fast feedback.

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