TRAJECTORY PLANNING OF TWO COOPERATIVE MOBILE MANIPULATORS UNDER CLOSED-CHAIN AND DIFFERENTIAL CONSTRAINTS

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ABSTRACT. In this paper, we consider a new method for trajectory planning of two mobile manipulators for cooperative transportation of a rigid body. The method consists of constructing a graph on a portion of the configuration space that satisfies collision and closure constraints and searching the graph for the shortest possible path using an optimal graph search algorithm. Then, a sequence of time-optimal trajectories for movement between the consecutive points of the path is calculated. This approach allows for geometric constraints, such as joint limits and closed-chain constraints, along with differential constraints, such as nonholonomic velocity constraints and acceleration limits to be incorporated into the planning scheme. We also propose a heuristic method to keep the system from colliding with moving obstacles by adjusting a time scaling factor based on linear estimation of obstacles’ position. Simulation results illustrate the effectiveness of the proposed method.

Keywords: Cooperative mobile manipulators, Nonholonomic motion planning, Velocity adjustment, Collision avoidance, Moving obstacles

1. Introduction. Over the past few decades, various robotic systems with different structural and computational complexities ranging from simple mobile robots [1-4] to cooperative multi-robot systems, including multiple mobile robots [5-8], multiple manipulators [9-11], multi-fingered hands [12-15] and multi-legged vehicles [16,17], have been extensively studied in a variety of contexts focusing on motion planning. Among these efforts, an interesting topic that has recently attracted a considerable amount of research is the motion planning of cooperative mobile manipulators [18-31]. Despite the expanded workspace and increased capability in carrying out more complicated and dexterous tasks, the motion planning of these systems is complicated due to their high degrees of freedom and presence of several kinematic and dynamic constraints, including nonholonomic, closed chain and obstacle avoidance constraints [32,33]. Thus far, two main approaches for motion planning have been proposed: “Cartesian space method” and “joint space methods”. Cartesian space planning methods [18-20] first compute a desired trajectory for the manipulated object in Cartesian space and then, with regard to the constraints of the system, compute the corresponding desired trajectory in the joint space for each mobile manipulator system. However, since these methods need to solve the inverse kinematic problem, they may fall into singular states, which lead to increased complexity in planning the trajectory of the object. Therefore, numerous methods in the literature have been devoted to motion planning in the joint space [21-31], mainly categorized as “complete method” and “probabilistically complete methods”.

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