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Abstract

A methodology to plan the trajectories of robots that move in an n-dimensional Euclidean space, have to reach a target avoiding obstacles and are constrained to move in a region of the space is described. It is shown that if the positions of the obstacles are known then a Hamiltonian function can be constructed and used to define a collision-free trajectory. It is also shown that the method can be extended to the case in which the target or the obstacles (or both) move. Results of simulations for a pair of planar robots and a three degrees-of-freedom manipulator are finally reported.

Keywords: Obstacle avoidance, Hamiltonian systems, Kinematic constraints.

1. Introduction

Robot path planning is an important topic that has been extensively studied in the past three decades. Different approaches have been proposed for solving the problem of reaching a (possibly moving) target while avoiding (possibly moving) obstacles (see e.g. [1] and references therein). Among several ideas that have been developed, we recall the workspace density [2], the harmonic potential functions [3], the navigation functions [4], the decomposition approaches [5, 6, 7], the distance function [8], the vector field histogram [9, 10], the dynamic window method [11], the rule-based approach [12], the use of the so called Particle Swarm Optimization [13]. A well-known family of techniques is that based on artificial potential fields [14], in which the point representing the configuration of the robot behaves like a charged particle moving in a force field. In particular, the point moves along the antigradient of a potential field depending on both the obstacles and the target position and generated in such a way that a repulsive potential function is associated with each obstacle, while an attractive one is generated by the goal. As a result, a (possibly local) minimum of the potential function is placed in correspondence of the goal. By using harmonic functions [15], or restricting the admissible obstacle shapes [16], uniqueness of the minimum can be guaranteed. Methods for facing other drawbacks, such as chattering in narrow passages and mislocation of the minimum, or to broaden the field of applicability of the method, are also available (see for example [17, 18, 19, 20, 21]).

Other approaches that have been widely used rely on sampling-based algorithms, in particular the probabilistic road maps (PRM) [22] and the rapidly exploring random tree (RRT) algorithm (introduced by [23]), which can efficiently solve complex high-dimensional problems. The main idea of such algorithms is to perform a search in the configuration space, applying a proper sampling