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A path planning algorithm for industrial robots

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Abstract

Instead of using the tedious process of robot teaching, an off-line path planning algorithm has been developed for industrial robots to improve their accuracy and efficiency. Collision avoidance is the primary concept to achieve such goal. By use of the distance maps, the inspection of obstacle collision is completed and transformed to the configuration space in terms of the robot joint angles. On this configuration map, the relation between the obstacles and the robot arms is obvious. By checking the interference conditions, the collision points are indicated with marks and collected into the database. The path planning is obtained based on the assigned marked number of the passable region via wave expansion method. Depth-first search method is another approach to obtain minimum sequences to pass through. The proposed algorithm is experimented on a 6-DOF industrial robot. From the simulation results, not only the algorithm can achieve the goal of collision avoidance, but also save the manipulation steps. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Path planning; Collision avoidance; Configuration space

1. Introduction

Many researches have been investigated on the path planning for various objectives such as minimum time, minimum energy, and obstacle avoidance. Regarding obstacle avoidance, distance maps is to divide the space by grids with equal distance (Latombe, 1991; Jarvis 1993). On the intersection of grids are the nodes, which is marked with numbers for collision inspection. Configuration space method proposed by Lozano-Perez (1983, 1987) is able to represent the robot manipulation geometry via the joint space. For an n degree-of-freedom robot, there is n dimensional vector to define the manipulation. The free space approach is to search the obstacles with encircled boundaries, which form various shapes of cones. Then, the centerlines of the generalized cones are the path planned to move along (Brooks, 1983a,b). Visibility graph algorithm connects each apex of the obstacle so as to obtain the passable area, in which the likely desired paths are generated (Oomen, Iyengar, Rao, & Kashyap, 1987). A method is

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developed by means of the hierarchical tree structure, which utilizes, in general, the quadtree to segment the workspace into numerous areas represented by nodes (Samet, 1990). The nodes are categorized into the obstacle nodes and free nodes, which denote the obstructive area and passable area, respectively. The free nodes are connected to form a tree structure that provides the method of path planning.

In this paper, a robot path planning algorithm for industrial automation such as the welding of automobile and the cleaning and surveillance of power plant is studied (Lei, 1999). Instead of using the robot teaching method, searching a suitable path by mathematical analysis is feasible and may gain better solution. The environment of those applications is usually known in advance; in other words, the obstacles are already defined in the working space. Via inspecting the obstacle on the built distance maps and using both the wave expansion and hierarchical depth-first search tree methods in the configuration space, the path planning is achieved. An industrial robot, ABB IRB1400, is selected as an example to be investigated with simulation on the Deneb software (Deneb Robotics, 1996). The proposed algorithm shows the ability to avoid obstacles and to obtain an optimal path with fewer manipulation steps.

2. Collision inspection

Before the investigation of collision inspection, the geometric analysis on the robot structure is necessary. The shape of the first three links is assumed to be cylinder with radius r_1, r_2, r_3 and corresponding link length l_1, l_2, l_3. The last three joints of the wrist of most of the industrial robots have limited manipulation range. For example, the fifth joint of ABB IRB-1400 industrial robot holds insignificant confined workspace because of short link length and small joint working range, and the rest two joints have no influence. In fact, the radius r_3 of the third link is intended to expand to include the workspace of the fifth link. Therefore, the analysis and design of the path planning only considers the first three joints with joint variables (q_1, q_2, q_3) of the elbow (Jarvis, 1986).

Distance maps method is used to transform the continuous workspace into the three 2D maps with equal distance of grids and nodes on the intersection of two perpendicular grids (del Pobil, Serena, & Liovet, 1992). The distance between the two nearest parallel grids is defined as the unit distance. The

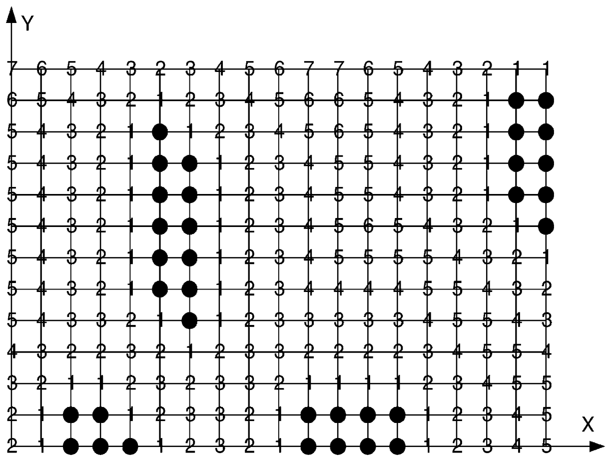

Fig. 1. Marked numbers on the nodes of a 2D distance maps.