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Positioning Control for Articulated Robots using Artificial Potential Field Technique

Hirokazu Tanaka

School of Information Science,
Japan Advanced Institute of Science and Technology

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In recent years, Robotics is studied, not only in the industrial domain but also non-industrial, for the usage as manipulating robots working in assembly lines and as remote agents working in dangerous places. It takes a long time to teach robots in order to manufacture goods on an assembly line, and motions are planned by computers in many cases, for efficient calculation for generating simulated robot motion. It also takes a long time to generate simulated motion for robots with many degrees of freedom (DOF). In this paper we propose a new approach in positioning control for articulated robots operating in known static environments.

We shall start with defining a certain preprocessing of the configuration space (C-space), after which many difficult path planning problems can be solved in time of the order of a fraction of a second. And the preprocessing itself does not take very long, too. During the preprocessing stage random configurations of the robot (nodes) are generated in the free C-space. The generated configuration is tested for collision with obstacles and self-collision. And keep it only if it passes these tests. Then interconnect it into a graph using Delaunay graph technique; it has an advantage of requiring less time to generate the graph. This step is repeated until a prespecified number N of nodes has been computed. Also the initial configuration is given in this preprocessing.

The problem of path planning for articulated robots can be defined as that of finding a continuous motion that will take a manipulator from a given initial configuration to a desired final configuration, subject to the constraint that during the motion the robot does not collide with any obstacle in its workspace. In ordinary methods, there are several more constraints to determine final configuration, such as to compute all angles from an appointed trajectory, to move the elbow to an appointed point or to keep the elbow

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lowest possible position; this pose has an advantage of requiring less power to hold the pose. According to existing C-space methods, the problem of planning a path from a given initial node to a desired goal node is solved by searching the graph consist of edges connecting those nodes. But, having only one goal configuration may not be a good idea for flexibility and efficiency. An articulated robot is called (kinematically) "redundant" if it possesses more degrees of freedom than are necessary for performing the specified tasks. Redundancy of an articulated robot is, therefore, determined according to the particular task to be performed. For example, in the two-dimensional space, a planar revolute robot with three joints is redundant for achieving any end-effector position. For another expression, in the two-dimensional space, a planar revolute robot with four joints and the tasks involving both position and orientation of the end-effector, if we consider the last revolute joint of the robot as the end-effector position, then these tasks can be replaced by a planar revolute robot with three joints only achieving end-effector position, which means there is no constraints to determine final configuration except end-effector position. This suggests that more goal configurations should be available for performing specified end-effector position.

After the preprocessing, we find all possible combinations of angles which satisfy the desired end-effector position. Then we interconnect them into a graph using Delaunay graph technique. In the previous procedure the connected components of the resulting graph are computed by a straightforward breadth-first search algorithm. But in this study the idea of artificial potential field technique is used.

An artificial potential is a mathematical description of the potential energy within the C-space of a manipulator. Regions in the C-space that are to be avoided are modelled by repulsive potentials (energy peaks), and the region to which the end effector is to move is modelled by an attractive potential (energy valley). The addition of repulsive and attractive potentials provides the desired C-space energy topology. Thus, for each point in the C-space of the manipulator there is a modelled value of potential energy and an associated gradient or force. This force causes the end-effector of the manipulator to move through its environment in a manner which is directly responsive to the modelled potential energy function of that environment. Previous use of artificial potentials has demonstrated the need for an obstacle avoidance potential that closely models the obstacle, yet does not generate local minima in the C-space of the manipulator. But in this study, the problem is solved by using a graph and strategy of wave front.

The path planning algorithm connects any configuration nodes to the goal configuration whose path is thus the shortest in the number of nodes. This algorithm behaves like a parallel breadth-first search of the graph, and constructs trees rooted at each goal configuration. When the initial configuration is once connected, the algorithm will terminate and exhibit all nodes included in the path to the goal configuration. The algorithm fails if it cannot connect to the initial configuration in the graph, or if the initial configuration and any of the goal configurations lie in two different connected components of the graph. The resulting path can also be improved using any standard smoothing algorithm.

We present a new methodology for exacting robot motion planning and control. It guarantees collision-free motion and convergence to the destination from almost all initial free configurations. Simulation results of three links of an arm are given to illustrate the proposed control scheme. We have implemented the above-described method by a program written in C language and implemented it on a workstation. And experimental results are presented and discussed.