Abstract  A fuzzy robot motion planning approach is proposed in unknown environments for three-degree industrial robots. The proposed planning system is composed of several separate fuzzy units, which control individually each manipulator joint. Each unit combines a repelling influence, which is related to the nearby obstacle, with the attracting influence produced by the final manipulator configuration, to generate actuating command for each link. Effectiveness of the proposed approach is verified through simulation.

Keywords  robot, motion planning, fuzzy control

1 Introduction

The problem of motion planning for robot manipulator 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 at no point in the motion does the manipulator collide with any obstacle in its workspace. It can roughly be divided into two categories: global and local. The global techniques assume that a complete model of the robot’s environment is available. Most of the research in global techniques has focused on off-line planning in static environments. Local approaches, on the other hand, use only a small fraction of the world model to generate robot control. This comes as the obvious disadvantage that they cannot produce optimal solutions. Local approaches are easily trapped at local minima. However, the key advantage of local techniques over global ones lies in their low computational complexity, which is particularly important when the world model is updated frequently based on sensor information. Our approach is a real-time sensor-based local planner.

There are several robot motion planning methods such as artificial potential field method, configuration space method, and method based on the fuzzy logic. The artificial potential field method needs the accurate information of the obstacles, so it cannot be applied for moving objects or inaccurate information. The configuration space method maps the obstacles into the C-space. The computation burden is huge. It would fail to meet the real-time requirements for robot motion planning [1−4].

Fuzzy logic method simulates the human being’s thinking, and analyses fuzzy information. Fuzzy control rules are concluded by fuzzy math method. It has a good real-time ability. It is not necessary to know the exact model of the object to be controlled. It can meet the real-time requirements for robot motion planning. Gerk and Hoyer applied the fuzzy method in multi-robot motion planning [5]. Their method needs to program off-line beforehand, and cannot be used for unknown environments. Zavlangas applied the fuzzy method in the motion planning for a 3-DOF robots [6]. It deals with the SCARA robot model, which has two rotation joints and one translation joint. The application with this model is limited.

For a typical 6-DOF industrial robot, the first three links constitute its major linkage responsible for proper positioning of the arm end-effector. The remaining three degrees of freedom are responsible mainly for the orientation of the end-effector.

In this paper, a fuzzy robot motion planning approach is proposed for 3-DOF industrial robots operating among unknown obstacles of arbitrary shape. Infrared sensors are used to describe the distances from the robot to the surrounding obstacles. In our method, fuzzy method controls each manipulator joint. Effectiveness of the proposed approach is verified through simulations. This approach can meet the real-time requirements for robot motion planning in unknown environments.
2 Fuzzy motion planning strategy

This technique is based on separate fuzzy-based obstacle avoidance units, each unit controlling one individual link. Each unit has two principal inputs: the distance between the link and the nearest obstacle and the difference between the current link configuration and the target configuration, the inputs and outputs of each unit are shown in Fig. 1.

The distance between the surface and the obstacles is given by the infrared sensor array, which covers the robot arm. These distances are defined as $d_{1\text{left}}, d_{1\text{right}}, d_{1\up}, d_{1\down}, d_{2\text{left}}, d_{2\right}, d_{2\up}, d_{2\down}$, where the subscript 1 indicates upper arm and 2 indicates lower one. The $d_{1\up}$ shown in Fig. 2 represents the distance detected by the infrared sensor array covering the up surface of the upper arm. To guarantee a collision free motion, we choose the minimum distance in $S$ area. If no obstacle is found, it is assumed that the distance to the obstacle is the maximum detecting distance of the sensor.

2.1 Fuzzy controller of joint 1

The moving of joint 1 will possibly cause the collision of the left or right surface of the arm, so the inputs include $d_{1\text{left}}$.

Each fuzzy unit has two principal inputs:
1. The difference between the current link configuration $\Delta \theta_i$ and the target configuration $\theta_i\text{.target}$ ($i=1, 2, 3$);
2. The distance between the link and the nearest obstacle.

The inputs of each unit do not include these distances, but only these may collide when the joint moves, as shown in Fig. 1. The output variable of each unit is the motor command $\tau_i$.

![Fig. 1 Inputs and outputs of the fuzzy controller](image1)

![Fig. 2 Distance between the obstacle and the up facet of the robot arm](image2)

![Fig. 3 Fuzzy membership functions](image3)