Review of Trajectory Planning for Industrial Robots

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Abstract: More and more industrial robots need high-precision trajectory control, but the traditional PID control is difficult to achieve. The simulation diagram and pose of the collision free mechanism are drawn by using rosty software. At the same time, through the experiment of MOTOMAN-HP3 robot, using VC + + application program to call the external interface function of motocom32 software, the application program planning is realized. The linear and circular trajectory planning of industrial robot in Cartesian space is studied. Linear interpolation algorithm based on spatial parabola transformation and circular interpolation algorithm based on local coordinates are proposed. The algorithm is applied to a self-designed 5-DOF spraying robot. An evolutionary algorithm based optimal trajectory planning method for PUMA560 robot is proposed. The method is based on the elite non dominated sorting genetic algorithm (NSGA-II). The results show that the minimum angular displacement, angular velocity and angular acceleration of X3 parallel robot are 56, and the maximum angular displacement, angular velocity and angular acceleration are 89.

1. Introduction

With the continuous progress of computer technology, robot technology has become an indispensable technology in our life. Nowadays, robots have been widely used in human production and life. From the most common sweeping robot in China, the intelligent robot can automatically identify and classify in the industrial field. To the heavy intelligent robot used in the heavy industry, all have changed from the initial stage of human imagination to the existing productivity. These robots played a huge role in the application field of industrial production.

With the continuous development of artificial intelligence, many experts have studied industrial robots. For example, some domestic teams have studied the trajectory optimization of hsr-605 robot, and studied an ordinary robot with simple structure and friendly motion environment. This limitation enables us to generate trajectories in a simpler and more practical way. The coordinate system of adjacent links is established by D-H representation. On the basis of kinematic analysis, the relationship model between the angular derivative of robot axis and the trajectory accuracy of robot end effector is established by differential homogeneous transformation. In the workspace of the robot, several typical trajectories are selected. The genetic algorithm toolbox in MATLAB is used to optimize the time. An algorithm is proposed to transform the asymptotic stability controller into the orbit stability controller, and the effectiveness of the algorithm is verified by simulation. The trajectory tracking modeling and Simulation of a 6-DOF joint robot on a given curve are introduced. This paper introduces a vision system of industrial robot, which can recognize the position of object in space through a mark. Some experts have studied the trajectory planning and parameter optimization of 6-DOF mobile pendulum feeding robot. Based on cubic polynomial interpolation, the velocity, acceleration and additional acceleration of the robot are constrained. The simulation of trajectory planning is carried out in...
MATLAB. Aiming at the contour problem of articulated industrial robot arm, a practical method to realize accurate and hit-free servo is proposed. The proposed solution is an off-line trajectory construction algorithm, which solves the related industrial constraints and specifications, namely speed constraints, torque / acceleration constraints and trajectory allowance. Spline approximation method is used to eliminate hitter, and forward compensate is used to compensate dynamic time delay. The feed forward control method is used to analyze the residual vibration characteristics of appetizing robot. Considering the constraints of vibration suppression, polynomial fitting method is used to calculate the discrete trajectory data. At the same time, Fourier series function is used to fit the discrete trajectory points. On this basis, the trajectory of the robot is determined, that is, the rectangle is used to fill the area [2]. In addition, some experts also studied the explosion-proof design and trajectory planning of the detonator grabbing robot, discussed the general method of trajectory planning of the robot, deeply deduced the basic principle of polynomial and spline interpolation trajectory to meet the operation requirements, designed the operation trajectory of the detonator box grabbing, and obtained the advantages and disadvantages of various trajectories through the analysis of simulation data. In order to ensure the stability of grasping detonator, the quintic B-spline interpolation trajectory is proposed and simulated in MATLAB, using the Aramco module to detect tags. It allows identification of the Ar Tag tag and its position and orientation relative to the camera. The first step of the algorithm is to calibrate the camera using the grouch table (which is part of the Aramco module) and read the calibration parameters. A time optimal trajectory planning method for industrial robot based on piecewise cubic polynomial is studied. In order to get the optimal trajectory, the acceleration curve here is continuous, and the kinematic constraints of the robot motion are considered. The main advantage of piecewise cubic polynomials is that the maximum absolute values of speed and jerk are equal to their upper bounds respectively, thus minimizing the total execution time. The optimal trajectory of quintic B-spline time acceleration based on particle swarm optimization is proposed [3]. Although the research results of industrial robots are quite abundant, there are still some deficiencies in the trajectory planning of industrial robots.

In order to study the trajectory planning of industrial robot, the monocular vision measurement model is established through the research of industrial robot. The results show that the establishment of monocular vision measurement model is conducive to the trajectory planning of industrial robot.

2. Method

2.1. Industrial Robot

(1) Industrial robot

Through off-line programming technology, industrial robots can repeatedly set their motion in harsh environment, the main body of the machine is the frame and the actuator, including the arm, wrist and hand; the drive system includes the power device and the transmission mechanism, which is responsible for providing the power output and transmission for the main body of the machine; the control system is responsible for sending signals to the drive system and the actuator according to the input instructions and procedures, and controlling them. The effective working range, repeated positioning accuracy, load and allowable torque of industrial robot are important parameters to evaluate the working ability of robot[4].

(2) Robot Trajectory

The motion planning of industrial robot consists of trajectory planning and path planning. Path planning only needs to plan a path that is most suitable for robot motion, and does not need to consider the change of time[5]. According to the needs of the task, based on the path planning, the curves of displacement, velocity and acceleration with time are given[6]. Trajectory planning is to study the trajectory of robot in the corresponding space from the initial position to the end position[7]. Sometimes it is necessary to specify the path points at the starting point and the end point, and even consider the time allocation between the path points[8]. The amount of time between the path points is given, and the velocity and acceleration need to be set when passing through the path points.
Trajectory planning obtains the motion parameters of each output by giving the input parameters[9]. The input values are generally the constraint values of trajectory points, kinematics and dynamics, and the output values are the position, velocity and acceleration of the robot joint or end at the interpolation points[10]. In order to make the robot run stably without vibration and impact, the planned trajectory must be continuous, and the first and second derivatives of the trajectory function, that is, the velocity and acceleration in motion, must also be continuous. The output effect of robot trajectory is verified by experiments, and the accuracy of robot trajectory is improved. This paper studies the improved ant colony algorithm of robot path planning, establishes the robot working simulation environment, improves it by using ant colony algorithm, gives the optimization steps of robot path planning, and verifies the effect of robot path planning through simulation, so as to search the global optimal path. Although the motion accuracy of the industrial robot studied in the past has been greatly improved, the angular acceleration peak value generated by the motion is larger, which leads to the larger vibration amplitude of the robot.

2.2. Monocular Vision Measurement Model

Usually, the pixel coordinate system is based on this matrix. Suppose that the coordinates of a point in space are \((X_C, Y_C, Z_C)\) in the camera coordinate system and \((X_W, Y_W, Z_W)\) in the world coordinate system, then the relationship between them can be expressed by formula (1):

\[
\begin{bmatrix}
X_C \\
Y_C \\
Z_C 
\end{bmatrix} = \begin{bmatrix}
X_w \\
Y_w \\
Z_w
\end{bmatrix}
\]

\[
( T_C ) = R( T_w ) + t 
\]

In other words, the trace of the product of transpose matrix and covariance matrix of rotation matrix should be the largest, while the translation matrix is obtained from the best rotation matrix. Combined with the results of SVD, the following formula (2) can be obtained:

\[
R = U V^T 
\]

The surface feature is composed of a series of control points, and the trajectory optimization problem can be simplified as the pose optimization problem of a single control point. Generally speaking, the optimization problem can be expressed by equation (3):

\[
\min F(x) = (f_1(x), f_2(x),..., f_m(x)) \]

According to the position of the pixel \((U, V)\) and the actual distance \(D\) represented by the pixel, the position of the pixel in the plane coordinate system of the workbench \((x_\omega, y_\omega, Z_\omega)\) can be calculated, as shown in equation (4):

\[
x_w = x_m + u \cdot d \\
y_w = y_m + v \cdot d \\
z_w = 0
\]

Among them, \(D\) can be obtained by Zhang Zhengyou camera calibration; \(Z_\omega = 0\) is because the weld is located on the surface of the workbench.

3. Experience

3.1. Experimental Object Extraction

In object detection, background modeling is very important for moving object detection based on background model difference. For the problem of fixed camera and fixed object detection, because the background is fixed, optical flow method is used in most cases. For example, when it is applied to road vehicle detection, the set point can be obtained. When the camera is fixed, the optical flow method can be considered. However, the production line is fast and the real-time requirement of target detection is high. Therefore, the optical flow method can not meet the requirements of target detection.
performance of parallel robot in the sorting operation of the production line.

3.2. Experimental Analysis

From the steps of r-cnn algorithm and its advantages and disadvantages, the real-time performance of r-cnn algorithm is low. Because there are many candidate boxes extracted in the steps of the algorithm, most of the target detection tasks do not contain detection targets, which reduces the real-time performance of the target detection algorithm. Among them, candidate box extraction is to randomly obtain a certain size of candidate box from the collected image, and send the pixel information contained in these candidate boxes to the trained neural network for comparison, to obtain the candidate box containing the detection target and output the coordinates. According to the principle of the algorithm, a difference method is proposed to obtain the background of the target detection, which is combined with the situation that the background of the production line changes little. In the actual target detection, the difference method is used to obtain the detection target, and then it is sent to the trained neural network for recognition. Image difference method is to get the detection target by subtracting the original image and the extracted background image, which can be completed one step before the neural network recognition, so as to improve the real-time problem of r-cnn series algorithm and the real-time performance of target detection. Based on the background difference method, an automatic image annotation method is proposed. The process of this method is as follows: (1) get the pure background image as the initial background image $BT$; (2) subtract the current target image $I_t(x, y)$ from the background image by binary subtraction $I_t(x, y) - BT(x, y)$; (3) for the current frame pixel $(x, y)$, use pixel 1 to detect the connected area, get the minimum bounding box, and filter the smaller area; (4) get the target image according to the bounding box, and make it into a certain size. According to the name of the folder, the label of each image is automatically obtained to realize automatic annotation. These data sets can be directly sent to r-cnn series and self built neural network for model training.

4. Discussion

4.1. Angular Displacement Range of Motion

In order to compare the trajectories of the parallel robot designed by cubic polynomial and composite polynomial, the angular displacement, angular velocity and angular acceleration of the parallel robot are simulated and verified by MATLAB software, and the two design methods are compared and analyzed, as shown in Table 1.

| Parameter variable | minimum value | Maximum |
|--------------------|---------------|---------|
| X1                 | 34            | 53      |
| X2                 | 24            | 78      |
| X3                 | 56            | 89      |

It can be seen from the above that the minimum value of angular displacement, angular velocity and angular acceleration of X1 parallel robot is 34 and the maximum value is 53; the minimum value of angular displacement, angular velocity and angular acceleration of X2 parallel robot is 24 and the maximum value is 78; the minimum value of angular displacement, angular velocity and angular acceleration of X3 parallel robot is 56 and the maximum value is 89. The specific results are shown in Figure 1.
It can be seen from the above that the maximum value of angular displacement, angular velocity and angular acceleration of X3 parallel robot is 56, the maximum value of angular displacement, angular velocity and angular acceleration of X3 parallel robot is 89, the minimum value of angular displacement, angular velocity and angular acceleration of x2 parallel robot is 24, and the minimum value of angular displacement, angular velocity and angular acceleration of X1 parallel robot is 53.

4.2. Experimental Methods
The robot scanning system scans standard plane parts with different scanning depth, out of plane angle and out of plane angle, and studies the influence of three parameters on the measurement error. In each scan test, the T-scan was partially moved parallel to the standard plane to keep the posture unchanged during the scan, as shown in Table 2.

| experiment            | Value range | increment |
|-----------------------|-------------|-----------|
| Modeling experiment   | 30-50       | 30        |
|                       | -40-50°     | 73        |
|                       | -30-60°     | 58        |
| Evaluation experiment | 30-50       | 35        |
|                       | -40-50°     | 53        |
|                       | -30-60°     | 74        |

It can be seen from the above that the increment of scanning depth between 30-50 in modeling experiment is 30; the increment of outer angle of -40-50° in modeling experiment is 73; the increment of outer angle of -30-60° in modeling experiment is 58. The increment of scanning depth between 30-50° is 35; the increment of out of plane angle between -40-50° is 53; the increment of out of plane angle between -30-60° is 74. The results are shown in Figure 2.
It can be seen from the above that the maximum increment of scanning depth between 30-50 ° is 35; the maximum increment of outside angle of modeling experiment plane is 73; the maximum increment of outside angle of modeling experiment plane is 74.

5. Conclusion
Modern industrial production puts forward higher requirements for the stability and efficiency of robot motion. Reasonable and effective trajectory planning can improve the motion performance of industrial robot and the automation level of industrial production. The control system of industrial robot is closed and independent, so it is difficult to realize the movement of complex trajectory through teaching programming. Thus, the waiting path is planned in the pieceworker surface image. In order to improve the high-precision machining level of industrial robot, a Trajectory Accuracy Prediction Model Based on ADAMS is explored. The main factors affecting the trajectory accuracy are the structure parameters, nominal value and joint angle deviation of industrial robot. A structural parameter identification scheme is proposed and verified by a laser tracker. The relationship between the joint angle deviation and the working state is analyzed. In this paper, a trajectory control method for serial robot without redundancy is proposed, which is suitable for general singularity of co dimension and non general singularity of any co dimension.

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