

Stability Optimization Simulation of Industrial Robot in ROS Environment

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Abstract. This paper studies the end actuator motion state of an RRR industrial robot, and gives a bottom up decision-making scheme based on PID algorithm. Under the background of complex industrial control, any environmental factors will have a deep effect on the accuracy. The physical representation of the accuracy of the end effector is the electrical signal. Focused on the signal difference from joint to joint, based on the ROS and gazebo, the simulation of the RRR mechanical arm model can theoretically and intuitively reflect the differences. To minimize the error, proportional–integral–derivative controller will be used in this model and then Adjust PID parameters of each controller. Assume that the external interference is a linear superposition of impulse signals. The impulse response which the model makes should return to normal as soon as possible. In this way, the purpose of anti-interference is achieved. At the same time, it focuses on solving the motion state of industrial manipulator. For general industrial robots, its actuator, a gripper, should have the function of reaching any position and taking any direction in a certain space area. In other words, if a reference frame o' is fixed on the center of the hand claw, the robot can send o' to any direction at any position in the space area. The position and direction of the gripper are determined by the amount of motion from the base to the gripper pairs. In addition, with the rapid development of the Internet, image has become a common form of information. This paper will use image recognition technology to provide the required detection data and reference values for the PID controller. Thus, the workspace of the industrial robot can be reflected more completely.

Keywords: PID, ROS, Industrial robot.

1. Introduction

The course of industrial robots has been carried out in colleges and universities around the world, aiming at improving the structural level of industrial robots, theoretically developing industrial people in the direction of intelligence, so as to adapt to the rapid development of the Internet [1,2]. In addition, researchers of industrial robots operating under uncertain environmental factors have been exposed to the core technology and gradually understand its importance in the overall structure of industrial robots. As industrial robots continue to progress and develop rapidly in the industry 4.0 environment, the industrial robots should be more intelligent and should have the self-learning ability or just the ability to reset after facing the greatly interfere disturb. So that the robot can not only just replace people the people in the boring harsh and repetitive work in the normal situation but also can still work in the abnormal state. For the use of mechanical arm, the adaptive control should also be considered. Each joint has unique transfer function [3]. What's more each joint will be thought as a whole, to set up the proportional–integral–derivative controller [4]. As a result, the anti-interference can be partly achieved.

2. Robot Simulation in ROS Environment

2.1. Model building

According to the official website of gazebo, we can use two methods to import the URDF robot model into Gazebo: The first method is to generate files based on calling ROS's own services [5]. This method is mainly characterized by the convenience of transmission between the computer and the repository. As long as the relative path of the ROS data package remains unchanged, it needs to

call the python script to call the ROS service. The second method is to use the model database. In this way, the robot model can be included in the World file. However, the premise of using this method is that a series of parameters of the robot model need to be manually added to the Gazebo model database by setting environment variables. Compare and analyze the two methods. In general, the method of using the first method to generate files based on ROS's own service calls is more concise and efficient. Next, it can simulate joints by moving groups [6]. The corresponding Python interface is shown in Figure 1.

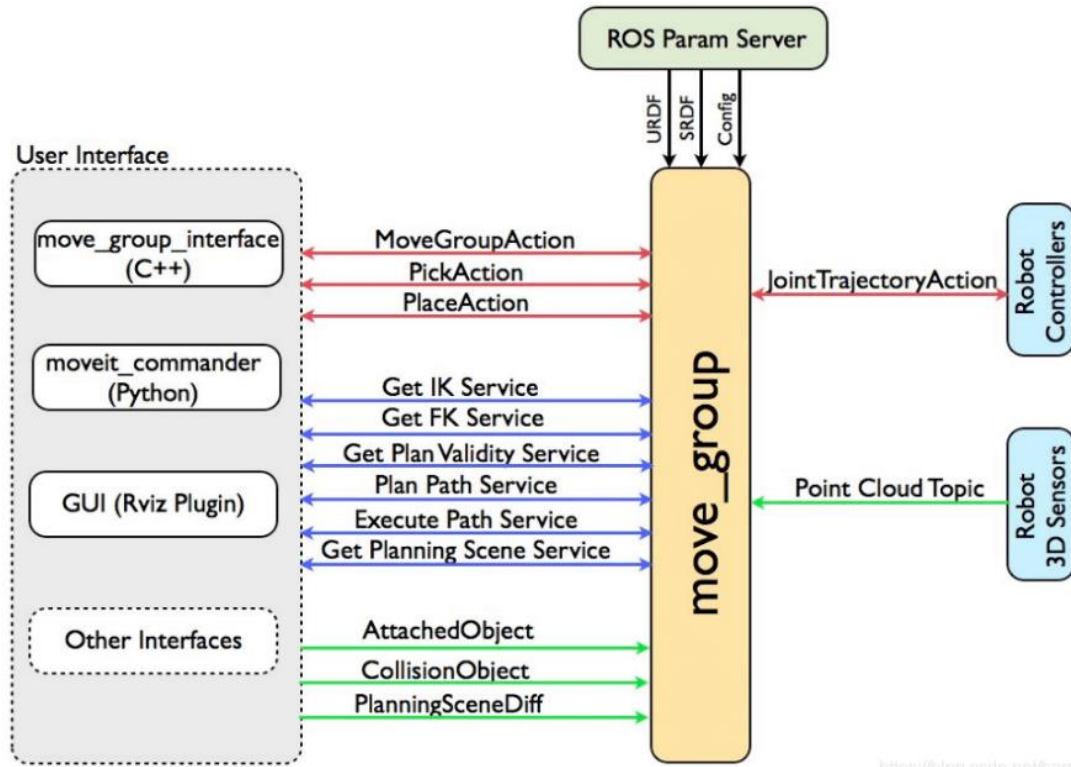


Figure 1. The schematic diagram of python interface

2.2. proportional–integral–derivative controller and the transfer function

If any Laplace transformation of the continuous function $f(t)$ is $F(s)$ and all its poles p_i are known, then the Z transformation $F(z)$ of $f(t)$ is the following equation.

$$F(z) = \sum_{i=1}^n \text{Res}[F(p_i) \frac{z}{z-e^{p_i T}}] = Z[f^*(t)] \quad (1)$$

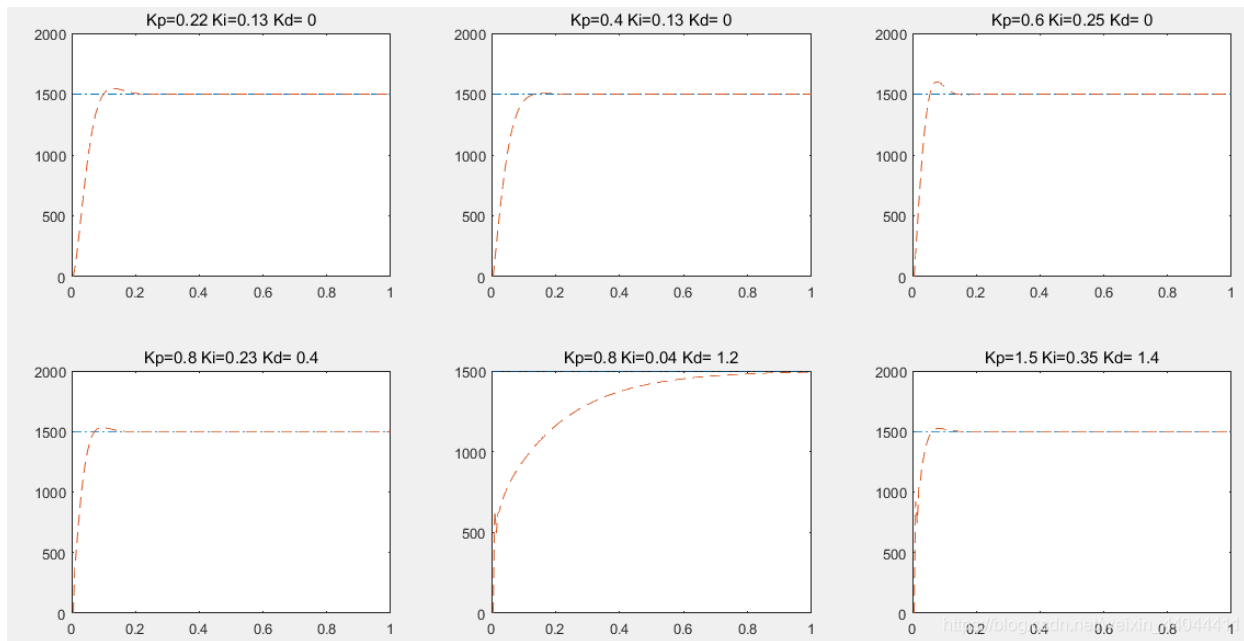


Figure 2. The impulse response function image

And This simulation set the input signal is Impulse signal. The Laplace transform equation of known impulse signal is $H(Z) = 1$. So, the output that the impulse response function is $F(Z)$. So that the relation between the input signal and output signal can be shown by the $F(Z)$. Inverse Laplace transformation of $F(Z)$ function. The transfer function under time sequence is $f(t)$. Discretizing and sampling $f(t)$, The function image is the Figure 2. In addition, the variable at the input end of the PID actuator is the position of the target object. Therefore, image processing is required before adding the PID controller. This simulation uses color features to identify the location of the object, and then sets the location to the actuator as the target value. The input value is the projection point of the end effector on the object grasping plane. In the first step, the color of the standard image needs to be calibrated, that is, the color components of the standard image need to be analyzed. The results are shown in Figure 3. The results show that the experimental data preprocessing process is more accurate, and the next step of simulation can be carried out.

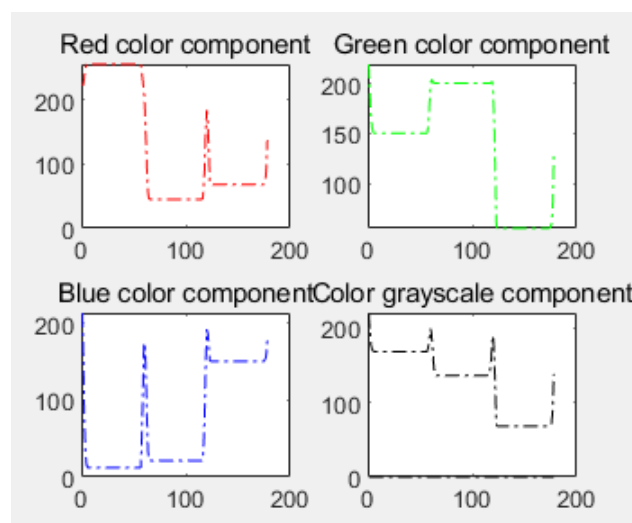


Figure 3. Color components

In this simulation, the image recognition part is composed of the following steps: 1. First convert rgb image to hsv image [7]. RGB color model space, also known as three primary colors (red, green, blue) color model space, in which all colors and their brightness are mixed by R, G, and B primary color components in different proportions, and the three components at a color point are all in 255 gray scale. In case of one-to-one fusion, the color point is white, and in case of one-to-one fusion at

0 gray level, the color point is black. The experimental results show that the overall brightness of the low illumination image is dark because the overall distribution of the gray level of the image is mainly concentrated at the low gray level [8]. Taking the "Satellite" image as an example, the image and its gray level image before the enhancement processing are shown in Figure 3. Low illumination. Because the overall gray level of the image is low, the distribution characteristics of R, G, B components are similar to the overall gray level distribution characteristics of low illumination images, which are distributed at the lower gray level. HSV color model space is a color space evolved from the normalization of RGB three primary color model space. It describes color images through three color components: hue H component, saturation S component and brightness V component. It is oriented to human nonlinear visual perception. Compared with RGB color model space, the image processed by HSV color model space has richer colors and fuller tones. The next step is to convert RGB image to HSV image. The value of h is usually normalized to be between 0 and 360 °. When h=0 is used for max=min (i.e., gray), it is not left undefined. HSL and HSV have the same hue definition, but other components are different. The values of s and v of the HSV color are defined as follows:

$$s = \begin{cases} 0, & \text{if } \max = 0 \\ \frac{\max - \min}{\max} & \text{otherwise} \end{cases} \quad (2)$$

Finally, after the above formula is coded, the experimental results of the test image are shown in Figure 4. The green area is extracted and displayed separately, and its position in the grasping plane is calculated through size conversion, which can be used as the input of the PID controller [9]. In this way, the reference value and input value of the PID controller can be determined, and finally, the median filter is used to reduce the error on the input data.

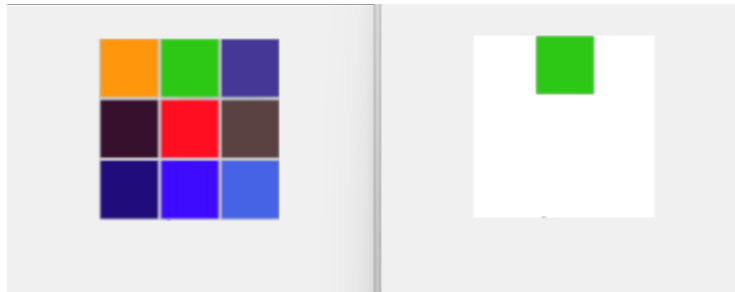


Figure 4. Image recognition results

2.3. Robot state space computation

Workspace is an important performance index of robot, which represents the position set and attitude set that can be reached by the origin of the end coordinate system when all joints of the robot perform all possible motions. At the same time, the workspace of the robot is also an important basis for the following simulation. The premise to solve the workspace is to correctly calculate the forward kinematics of the robot. This paper selects a 6-DOF serial robot, Stanford robot [10]. The overall structure of the industrial manipulator is shown in Figure 5.

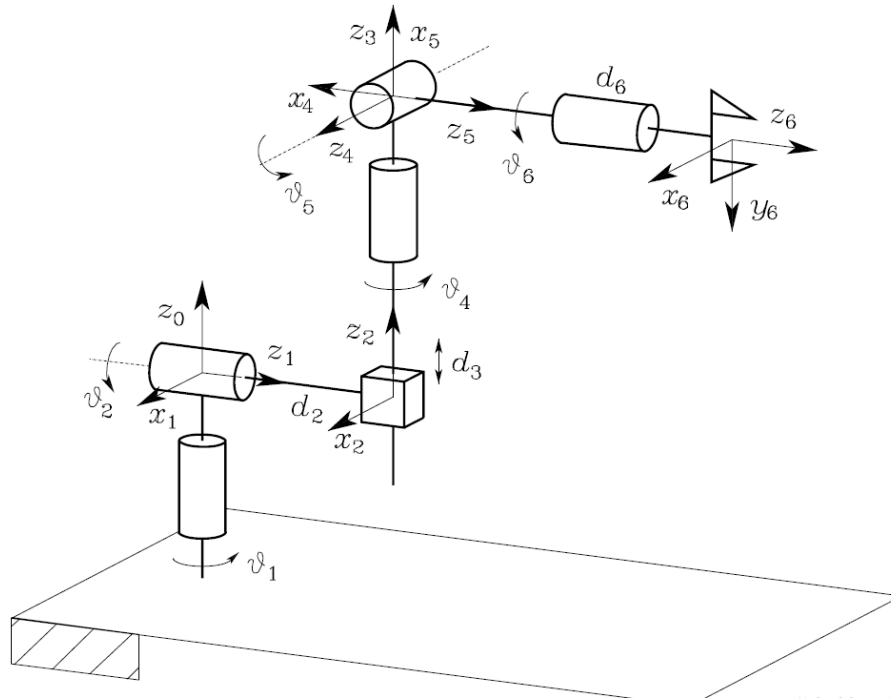


Figure 5. Overall Structure

There are three main methods to solve robot workspace: graphical method, analytical method and numerical method. The graphical method refers to drawing the robot workspace according to the robot motion process. This method has poor accuracy and is easy to be limited by complex structures. It is mainly used for scheme comparison at the initial stage of design. The analytic method is to obtain the mathematical analytic expression of the position and pose of the robot end coordinate system with respect to each joint variable by mathematical derivation according to the kinematic constraint relationship of the robot. Although this method is rigorous, it is not intuitive, and the solution process for robots with a large number of joints is cumbersome. The numerical method refers to solving the position and pose of the robot terminal coordinate system corresponding to these joint variables by using the forward or inverse kinematics equations given a certain number of joint variable values according to a specific method. Typical numerical methods include grid method, Monte Carlo method, etc. Although this method sacrifices some precision, it has high computational efficiency and is easy to be expressed graphically [11]. It is the main workspace solution method at present. In this paper, this simulation chooses Monte Carlo method, which is essentially a random ergodic method. The result of workspace solution is shown in Figure 6(a) and (b).

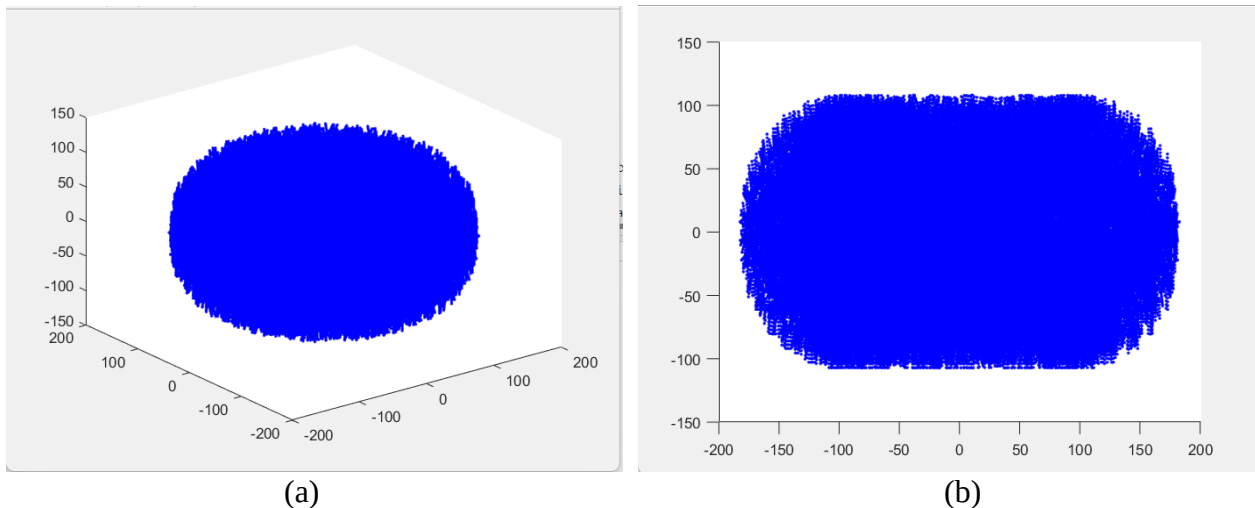


Figure 6. 3D view of the workspace

Preliminary simulation of RRR manipulator based on the workspace above. The simulation process is shown in Figure 7. By changing the value of q_1 q_2 q_3 q_4 to simulate the preliminarily visualized manipulator, the current state is calculated according to the state array and compared with the model.

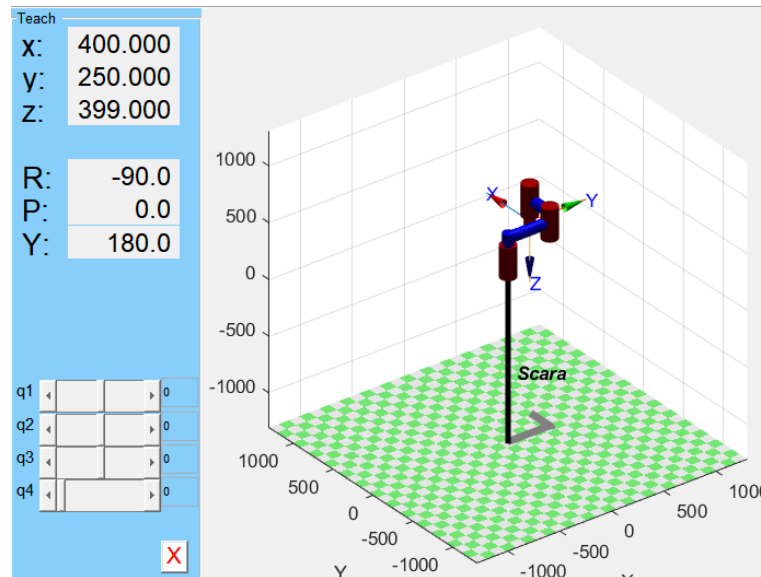


Figure 7. Simulation process

3. Conclusion

Industry 4.0 is the only industrial revolution in which manufacturing can participate. It is a new manufacturing method and concept based on history and current situation. Change is an eternal truth in time and space. Everything is changing all the time. Industry 4.0 poses more difficult challenges to industrial robots in this environment [6] The development of industrial robot simulation technology can not only greatly promote the development of industrial robots, but also ensure the personal safety of operators and save a lot of human, material and financial resources. In addition, it is also helpful to improve the structural design of industrial robots. The new industrial revolution requires industrial robots to change from automation to intelligence. Industry 4.0 integrates big data into management forecasting and management decisions, making big data a part of management, improving the accuracy of management decisions, and making management more scientific [7, 8]. In addition, it is an irreversible trend to change the data from the original digital data to the popular image data. Therefore, when developing Industry 4.0, it is necessary to optimize the control of the terminal controller. Stability is a necessary condition for studying the system

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