Summary of Research on Robotic Compliance Control

Yunxiang Wang [1, a], Hu Li [1, b], Kunpeng He [1, c]

[1]Shandong University of Science and Technology, Qingdao, Shandong 266590, China.

[a]wyx30890868@126.com, [b]30890868@qq.com, [c]513609375@qq.com

Abstract

Position control can be employed when the operating arm tracks the trajectory movement in space. However, when the end effector and the operating arm work in a collision, only the position-controlled robot will not meet the requirements. In order for the robot to do the correct action, the robot should adjust its action in response to changes in external conditions. In order to enable the robot to respond to changes in the outside world, springs, damping, etc. can be used to form a mechanism that can absorb or store energy to comply with changes in the external environment. Visual sensors, force sensors, etc. can also be used to sense changes in the outside world, and then feed back information to the control system to control the movement of the robot based on changes in the outside world. This requires the robotic compliance control.

Keywords

Robot, position control, compliance control.

1. Introduction

The compliant control of the robot means that the end effector of the robot can respond to changes in external force, showing low stiffness. Position control can be employed when the operating arm tracks the trajectory movement in space. However, when the end effector and the operating arm work in a collision, only the position-controlled robot will not meet the requirements. In order for the robot to do the correct action, the robot should adjust its action in response to changes in external conditions.

In order to enable the robot to respond to changes in the outside world, springs, damping, etc. can be used to form a mechanism that can absorb or store energy to comply with changes in the external environment. Visual sensors, force sensors, etc. can also be used to sense changes in the outside world, and then feed back information to the control system to control the movement of the robot based on changes in the outside world.

Studying the compliance control can increase the life of the robot, enabling the robot to achieve reliable and accurate assembly work and enhance the safety performance of the robot. Applying compliance control to the robot control system takes the robot one step further.

According to whether the compliance is obtained by the control method, the compliance can be divided into passive compliance and active compliance.

Passive compliance: refers to the flexibility that does not require special control of the robot. Features: The compliant ability is provided by mechanical devices and can only be used for specific tasks, with poor applicability; fast response and low cost.

Active compliance: refers to the use of force feedback information, through the special control of the robot to obtain the flexibility. In general, active compliance results in the required flexibility by controlling the stiffness of the various joints of the robot.

2. Development of Compliant Control Research

In the 1980s, Makino first proposed a passive compliant device and designed it as a compliant robotic arm. It is called SCARA (Selective Compliance Assembly Robot Arm). Its mechanical flexibility is in the upper and lower directions, suitable for up and down. In the work task assembled in the direction.

The RCC(Remote Compliance Center), designed by the MIT Draper laboratory, is used for robot assembly operations to follow any compliant Center. RCC is a composed of six spring can be obedient space of compliant wrists, six degrees of freedom which is installed between the wrist and the end of the manipulator actuator, by adjusting the six spring stiffness, can get different sizes of flexibility.

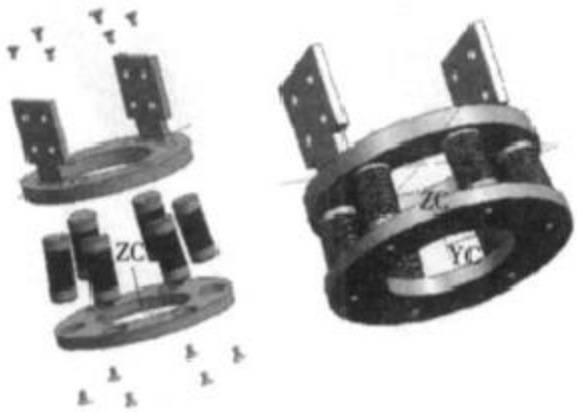


Figure 1. RCC flexible wrist

On the basis of RCC, RH Sturges et al. designed a SRCC (Space Remote Center Compliance) flexible wrist, also known as space RCC, which adjusts the azimuth error by means of a parallel connection with a screw system. When performing shaft hole assembly work, if there is motion error, its auger will produce a certain displacement to allow the workpiece to reach the optimal assembly position, thus effectively preventing jamming and wedge-tightening.

In the 1950s, Goertzs installed a force feedback device on the electro-hydraulic master-slave arm for the harsh environment of the radioactive experimental workshop. When the operator operated on the main manipulator, he could feel the contact force from the manipulator and the environment. The essence is the force remote sensing.

In the 1960s, Mann hosted the development of an artificial elbow with force feedback. The joint motor is driven by a "muscle" electrode signal and a joint strain gauge signal so that the current will exert a muscle effect.

Since the 1970s, with the rapid development of computers, robotic sensors and control technology, the force control of robots has undergone fundamental changes, and it has become a major direction of robot research: robots are actively and compliant.

3. Active Compliance Control

Active compliance control is also force control. Force control of the robot manipulator is to control the interaction between the robot and the environment. This control measures and controls the contact force applied to the arm, thereby greatly improving the effective working accuracy of the robot.

With the increasing use of robots in various fields, many occasions require robots to have the ability to sense and control contact forces. For welding, handling, and painting, the robot only needs position control, and for cutting, polishing, and assembly operations, active compliance control is required. For example, in the precise assembly of the robot, the surface of the workpiece, the grinding and scrubbing, etc., it is required to keep the end effector in contact with the environment. Therefore, the robot must have such active force feedback based on the completion of these tasks. The ability to control softly.

3.1 Method of Achieving Compliant Control

Impedance Control: Impedance control does not directly control the desired force and position, but rather achieves compliance by controlling the dynamic relationship between force and position. If only static is considered, the force and positional relationships can be described by a rigid matrix. If you consider the relationship between force and speed, you can use a viscous damping matrix to describe. Therefore, the so-called impedance control is to achieve the required rigidity and damping by the appropriate control method to make the end of the manipulator.

Force/position hybrid control: respectively constitutes a position control loop and a force control loop, and realizes compliance control through the synthesis of the control law.

Dynamic Hybrid Control: Decomposes tasks into positional controls of some degrees of freedom and force control of other degrees of freedom in a compliant coordinate space, and then combines the results in joint space into uniform joint moments.

3.2 Development Prospects of Compliance Control

The research on the supple control of robots is one of the basic functions of intelligent robots - the study of force perception. The combination of active and passive has a decisive role in avoiding the collision impact of the robot and the environment from the non-contact to the natural transition of the contact. This is an inevitable trend of robotic compliance control.

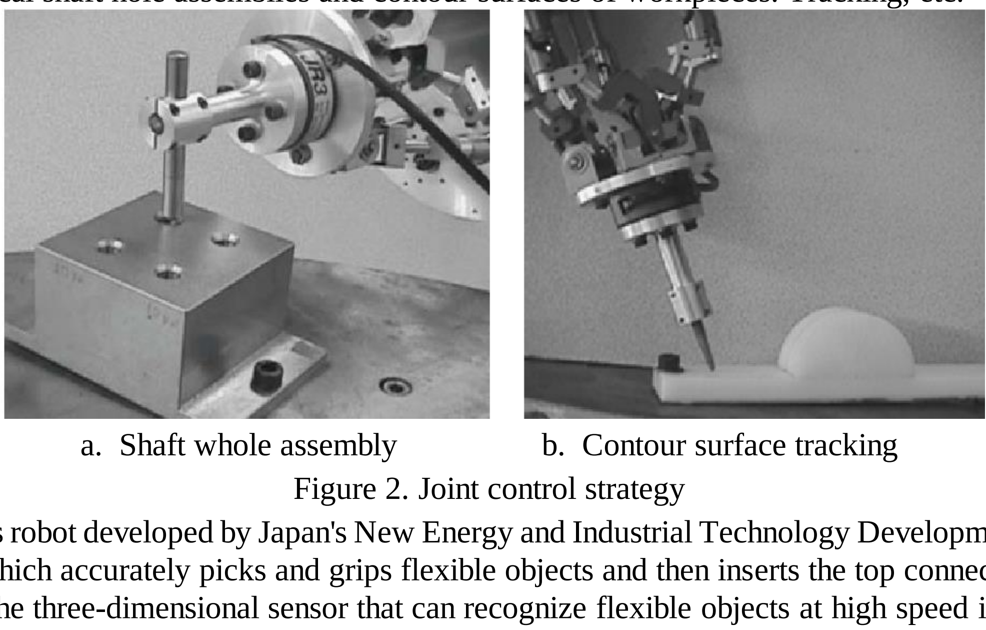
1. Typical operation of assembly operation. Including the bolt into the hole, screwing the screw, cranking the crank, handling heavy loads and so on. The evaluation indicators of the control effect are generally the assembly gap, the force condition and the operation time.

2. Surface tracking typical operations. This includes scrubbing aircraft, including glass cleaning, repairing workpiece surfaces (deburring, grinding or polishing, etc.), tracking welds, and development of intelligent CNC machine tools.

3. Coordinate with both hands. Two or more robotic arms can work in coordination under mutually constrained conditions. Usually one arm takes the initiative and the other arm follows the force control. Hands coordination is the basis for future multi-arm robot research.

4. Dexterous hand multi-finger coordination. Control the size of the force of grasping objects (such as eggs, table tennis, etc.).

In 2008, Antonio Lopes and Fernando Almeida proposed a strategy for joint control of RCIDs and industrial robots, and applied them to various typical tasks in contact with uncertain environments, such as typical shaft hole assemblies and contour surfaces of workpieces. Tracking, etc.



a. Shaft whole assembly b. Contour surface tracking

Figure 2. Joint control strategy

A multi-axis robot developed by Japan's New Energy and Industrial Technology Development Agency (NEDO), which accurately picks and grips flexible objects and then inserts the top connector into the substrate. The three-dimensional sensor that can recognize flexible objects at high speed is combined with two six-axis robots to accurately identify workpieces such as joints and screws.

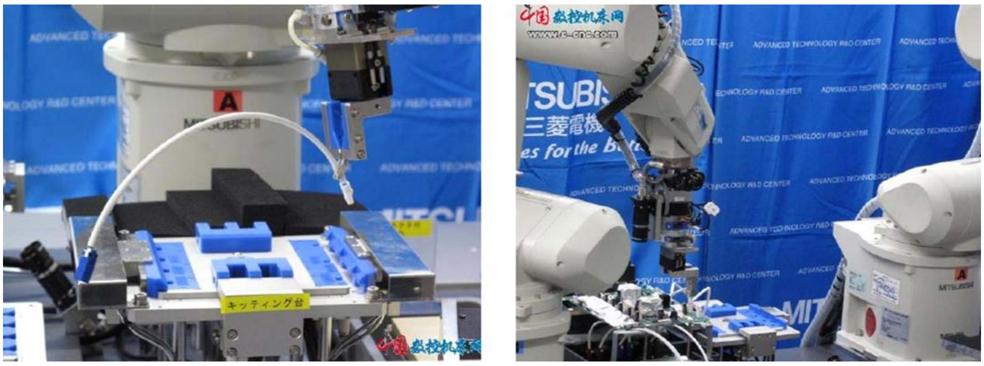


Figure 3. Actively compliant control assembly robot

4. Summary

At present, true force control is not widely used in industrial robots. Because there are still many problems in practical applications, such as the need to carry out a large number of calculations, the lack of precise parameters of the dynamic model, the lack of reliable and durable force sensors.

Current industrial robot control methods have passive compliance (such as RCC), flexibility by reducing position gain (by adjusting the gain of the position control system to change the overall stiffness of the arm), and force sense (force sense enables the arm to detect Contact with the surface and use force detection to perform certain actions).

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