ELECTRIC HYBRID CONTROL METHOD OF ASSEMBLY LINE ROBOT BASED ON PROGRAMMABLE LOGIC CONTROLLER

by

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With the development of modern industry, manipulators have become a kind of mechanical equipment widely used in assembly lines, which not only can improve production efficiency and product quality, but also improve working conditions. Taking the polar co-ordinate manipulator in the automated assembly line as the research object, the programmable logic contoller (PLC) based assembly line manipulator electrical hybrid control method is analyzed. The assembly line robot includes the base, the stepping motor to drive the rotation of the waist, the cylinder controlled arm and the gripper, based on the polar co-ordinate manipulator action requirements, FX2N series programmable logic contoller is selected to analyze programmable logic contoller based stepper motor, pneumatic servo positioning device, pitch cylinder and gripper control method in detail. The components of the assembly line manipulator are organically combined by programmable logic contoller to realize the electrical mixing control of the assembly line manipulator. The experimental results show that the assembly success rate and breakage rate of the assembly line robot controlled by the proposed method are 99.25% and 0.85%, respectively. The transmission performance and anti-noise performance are better than the comparison method, compared with the traditional method, this method has significant performance advantages in control accuracy, cost, practicability and so on and it has a good application prospect.

Key words: *programmable logic contoller, assembly line, robot, electrical mixing, control method, stepper motor, pneumatic servo positioning*

Introduction

Machine equipment is an indispensable part of modern industry [1]. With the continuous improvement of economic level and the continuous development of information technology, automation technology has emerged. In modern industry, it not only drives the rapid development of industrialization, but also reflects the benefits brought by technological innovation and the improvement of China's comprehensive national strength and modern industrial level [2]. Manipulators have become a kind of mechanical equipment widely used in assembly lines, which not only can improve production efficiency and product quality, but also improve working conditions. With the maturity of computer control technology [3], the application of robots is more and more extensive. The electric hybrid drive manipulator with electric servo control, pneumatic proportional servo control, and simple linear cylinder control is the typical equipment for machine and electric integration. Its structure can be assembled in the modular

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way, with high comprehensive ability and expandable performance, which can make full use of current resources [4, 5]. Therefore, it has been widely used in the assembly line and has a good application prospect. The PLC is based on the previous sequential controller, using new computer technology, automatic control technology, microelectronics technology, and other processes to form a new industrial control device.

Materials and methods

The composition of the robot

Taking the polar co-ordinate manipulator with three degrees of freedom in the automated assembly line as the research object, this type of manipulator is widely used in assembly lines due to its small size, light weight, simple and compact structure, and good co-operation with other machines [6-8]. The linear motion stretching in the direction of the arm, the counter-clockwise rotation about the central axis, and the pitch rotation about the horizontal axis together constitute the arm movement of the polar co-ordinate type robot. Through this linear motion and two rotations, the manipulator can realize three degrees of freedom of movement of telescopic, pitching and twirling [9, 10], and its structural diagram is depicted in fig. 1. According to the signal PLC control program, it is determined whether the arm movement position is accurate, and a control signal is sent to the solenoid valve to control whether the cylinder continues to move, and the precise positioning of the assembly line robot is completed.

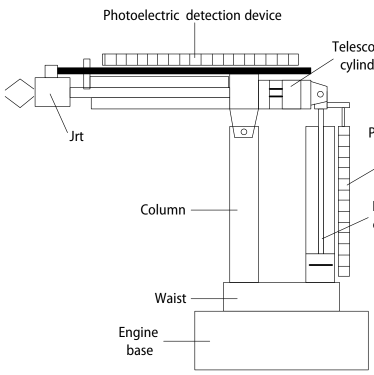

Figure 1. Schematic diagram of the polar co-ordinate robot

Assembly line manipulator control principle

Depicted in fig. 2 is the assembly line manipulator pneumatic principle. It can be seen that the air source, the pneumatic triplex, the pneumatic system control valve and the cylinder

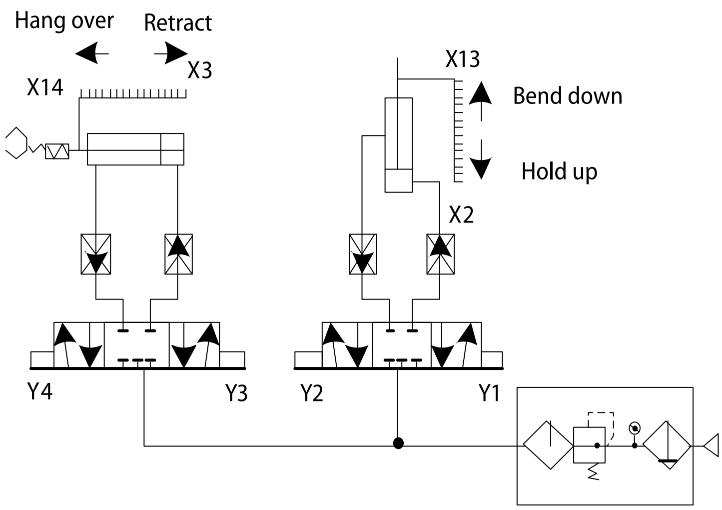

Figure 2. Pneumatic schematic of the manipulator

together constitute the manipulator pneumatic system. The system needs to complete four actions, namely, tilting, lifting, extending and retracting. The air source of the pneumatic system is obtained by the air compressor, and the dry and clean air is obtained through the pneumatic triple piece. The conversion of the motion is completed by the electromagnetic valve, wherein Y1-Y4 is controlled by the PLC. The home position marks X2 and X3 on the scale and the limit marks X13 and X14 provide the home position signal and the limit signal of the pitch and telescopic cylinders, respectively [11-13].

The PLC selection and address planning

Based on the motion requirements of a three-degree-of-freedom polar-co-ordinate robot, two robotic sensors for position limiting and five magnetic proximity switches, seven solenoid valves for driving cylinder movements, and various buttons and the indicator light are used to set the start [14], reset and clear during the entire control process. Taking into account the stability, reliability and convenience of the robot during operation, the robot control device uses FX2N series PLC, and its input and output are 24 points and 16 points, respectively, which not only meet the control requirements, but also have the margin for the expansion. The I/O port of the PLC is connected to the robot and the control box.

Pneumatic servo positioning device control

The displacement sensor of the HMP telescopic cylinder adopts an infrared photoelectric sensor. The piston position of the HMP telescopic cylinder is converted into an electrical signal of 0-10 V continuously fluctuating via the infrared photoelectric sensor, and the SPC200 processes the electrical signal. The algorithm control parameters of SPC200 determine the positioning accuracy and dynamic characteristics of the pneumatic servo positioning device. The main function of the pneumatic servo valve is signal conversion. The continuous gas control signal replaces the output signal processed by SPC200, and finally realizes the servo positioning control of the HMP telescopic cylinder. The structure of pneumatic servo positioning system is shown in fig. 3.

The SPC200-PWR-AIF power module, SPC200--MMI-DIAG diagnostic and communication module and SPC200-DIO digital I/O module together form the SPC200 servo positioning controller. The SPC200-DIO digital I/O module is connected to the PLC. Through the output terminals Y0-Y3, the PLC can control the positioning command record number determination of the SPC200, and start the servo positioning by Y7. At the same time, the signal is completed by the positioning task, and the SPC can transmit the positioning completion status to the input end of the PLC, which is beneficial to the PLC program control.

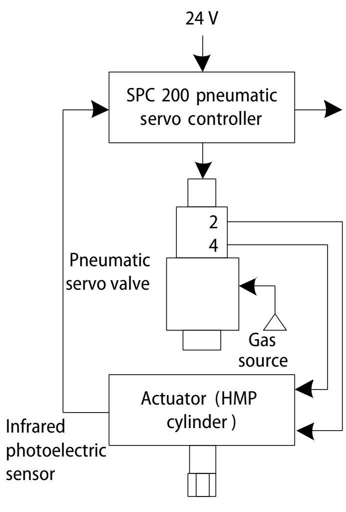

Figure 3. Pneumatic servo positioning system

Pitch cylinder and gripper control

The magnetic switch sensor is placed on the pitch cylinder and the air gripper to detect the position of the cylinder piston. The position detection signal is combined with the start-stop signal of the stepping motor and the pneumatic servo positioning device, and the solenoid valve corresponding to the pitch cylinder and the air gripper is controlled based on the PLC to complete the action control of the cylinder.

Results

In the PLC-based assembly line robot electrical hybrid control method proposed in this paper, the main function of the PLC controller is to receive and issue control commands, *etc.*, in order to complete the automated assembly process. During the implementation of the assembly operation experiment, the assembly success rate and assembly damage rate of the manipulator under the control of the method are mainly tested. The results are shown in tab. 1.

Table 1. Robot assembly success rate and assembly breakage rate of the control method in this paper

Number	Assembly success rate [%]	Assembly breakage rate [%]
1	99.3	1.11
2	99.4	1.24
3	98.6	0.78
4	98.9	0.51
5	99.6	1.01
6	99.7	0.71
7	99.2	1.07
8	98.9	0.83
9	99.5	0.62
10	99.5	0.59

In terms of assembly success rate and assembly damage rate of the manipulator, the method is compared with the robot control method based on high speed and light parallel and the manipulator control method based on dynamic model to verify the control precision advantage of the method. The result is shown in fig. 4.

Analysis tab. 2 and fig. 4 show that the assembly success rate of the assembly line manipulator under the control of this method is as high as 99.25%, which is higher than the other two control methods by 1.93% and 1.89%, respectively. The average assembly damage rate under the control of this method is 0.85%, which is 1.08% and 0.67% lower than the other two control methods. The experimental results show that the control accuracy of this method is high, which can meet the high precision assembly requirements of assembly line manipulators.

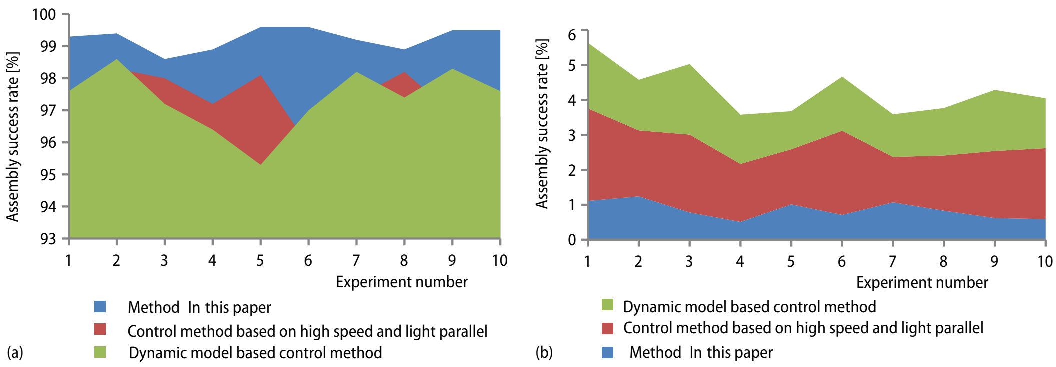

Figure 4. Comparison of experimental results of different methods; (a) assembly success rate, (b) assembly damage rate (*for color image see journal web site*)

Under the three different control methods, the assembly line manipulator stepper motor control, pneumatic servo positioning device control and the average delay, packet loss rate and average peak signal-to-noise ratio in the pitch cylinder and gripper control process are compared to verify the transmission performance of the method. The results are shown in tab. 2.

Table 2. Comparison of transmission performance of different methods

Component		The proposed method	The control method based on high speed and light parallel	The control method based on dynamic model
Stepper motor	Average delay [s]	0.075	0.108	0.086
	Packet loss rate [%]	2.1	4.9	3.0
	Average peak signal to noise ratio [dB]	33.70	32.38	32.44
Pneumatic servo positioning device	Average delay [s]	0.073	0.102	0.086
	Packet loss rate [%]	2.8	5.1	3.7
	Average peak signal to noise ratio [dB]	34.09	33.45	33.70
Pitch cylinder, gripper control	Average delay [s]	0.136	0.159	0.142
	Packet loss rate [%]	1.5	3.8	2.2
	Average peak signal to noise ratio [dB]	33.83	31.80	30.44

Table 3 gives the comparison results of the average delay, packet loss rate, and average peak signal-to-noise ratio of the transmission components of the assembly line manipulators under the control of three different control methods including the method. It can be seen that the average delay and packet loss rate of the assembly line manipulator under the control of this method are lower than the other two methods, and the average peak signal-to-noise ratio is higher than the other two methods. The experimental results show that the proposed method has better transmission performance than the comparison method.

Table 3. Performance comparison results of different control methods

Control method	The proposed method	The control method based on high speed and light parallel	The control method based on dynamic model
Control precision	Error less than 1%	The error is between 1.9% and 2.0%.	The error is between 1.5% and 1.6%.
Cost	general	Very expensive	expensive
Real time	high	high	high
Practicality	Suitable for different fields of robots	Suitable for underwater robots	Suitable for picking robots
Stability	strong	poor	strong
Control complexity	simple	complex	complex
Anti-noise performance	high	low	low
Effectiveness	high	low	high

In order to verify the anti-noise performance of the proposed method, the peak signal-to-noise ratio of different methods is compared under Gaussian noise interference and salt and pepper noise interference. The result is shown in fig. 5.

It is obtained from fig. 5(a) that the peak signal-to-noise ratio of the three control methods increases with the increase of the signal-to-noise ratio under Gaussian noise interference. The peak signal-to-noise ratio of the proposed method is up to 34.09 dB, and the peak signal-to-noise ratio of the proposed method is always higher than the other two methods. This shows that the proposed method has better anti-noise performance for Gaussian noise than the other two control methods. It is obtained from fig. 5(b) that the peak signal-to-noise ratio of

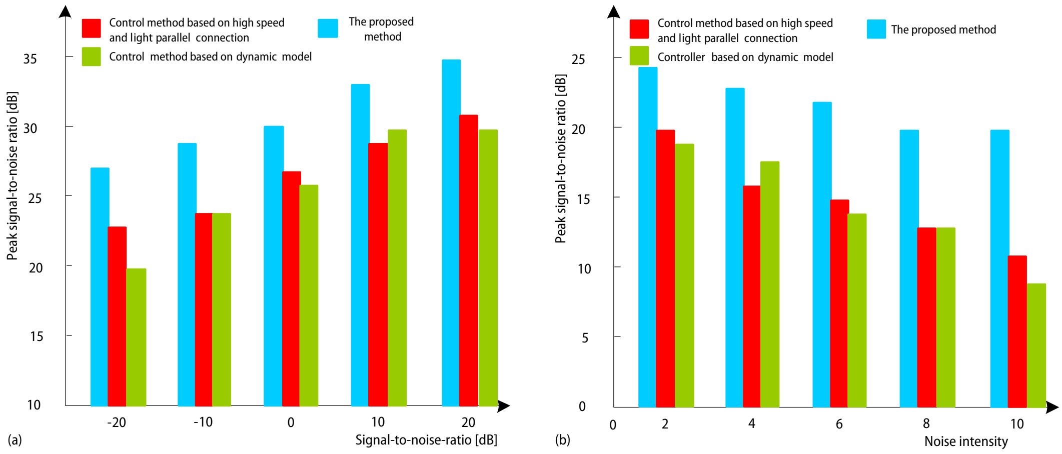

Figure 5. Comparison of noise immunity performance of different methods under noise interference; (a) Gaussian noise interference, (b) salt and pepper noise interference
(*for color image see journal web site*)

the three control methods decreases with the increase of noise intensity under the interference of salt and pepper noise. When the noise intensity is 10, the peak signal-to-noise ratio of the proposed method reaches the lowest, only 19.96 dB. However, it is still significantly higher than the other two methods, and the downward trend is more gradual, which indicates that the method has better anti-noise performance against salt and pepper noise than the other two methods. Based on the experimental results of figs. 5(a) and 5(b), the method has higher anti-noise performance than the other two control methods.

The experiment compares the control precision, cost, real-time, stability and control complexity of three different control methods to verify the performance advantages of the method. The comparison results are described in tab. 3.

It can be obtained from tab. 3 that compared with the other two control methods, the proposed method has significant performance advantages in terms of control accuracy, cost, practicability, control complexity and anti-noise performance. It is real-time and efficiency are the same as the other two control methods. Comprehensive comparison of the performance of different control methods is available. The assembly line manipulator controlled by this method has strong performance advantages and has a good application prospect.

Conclusion

The rapid development of industrialization and the maturity of mechanical technology have made the application of robotic technology more and more extensive. The automated production assembly line manipulator with separate controller, flexible action and high positioning accuracy has developed rapidly. Therefore, it is of great significance to analyze the assembly line manipulator control method in depth. This paper proposes an electrical hybrid control method based on PLC for assembly line manipulators. Based on the advantages of stepper motor servo control and pneumatic servo control, PLC is used to fully combine the two to ensure the compact electrical structure of the assembly line manipulator, high control precision, transmission performance and noise immunity. It has good performance and has a good application prospect. However, there is still room for improvement in assembly success rate, which is also the direction of my future research.

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